GSNZ 2021

Annual Conference 2021

Geoscience Society of New Zealand

30 Nov–2 Dec

Massey University, Palmerston North

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

A Whole New World - From Local to Global

www.confer.nz/gsnz2021

Programme and Abstracts

Geoscience Society of New Zealand
Miscellaneous Publication 158

ISBN (online): 978-0-473-62463-7
ISSN (online): 2230-4495

GEOSCIENCES 2021, Palmerston North

Due to the uncertainty caused by the COVID-19 Delta outbreak, the organising committee decided to postpone the GSNZ 2021 Annual Conference to 2022.
This made our conference theme, "A Whole New World - From Local to Global" even more relevant.
With over 350 delegates registered, 341 abstracts and 12 industry sponsors wishing to connect, a survey indicated that there was little appetite for holding a virtual meeting at the end of a very long year. This abstract volume holds a record of the fully developed conference programme and peer-reviewed abstracts.

BIBLIOGRAPHIC REFERENCE FOR ABSTRACTS VOLUME

Author A., Author B., 2021. Title. In: Zernack A. V., Palmer, J. eds. Geoscience Society of New Zealand Annual Conference 2021: Programme & Abstracts Volume. Geoscience Society of New Zealand Miscellaneous Publication 158. Geoscience Society of New Zealand, Wellington, pp. 123.

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Due to the postponement of the conference, the Field Trip Guides were not published.

GEOSCIENCE SOCIETY OF NEW ZEALAND

Annual Conference
30 November – 2 December 2021
Massey University
Palmerston North

PROGRAMME AND ABSTRACTS

Local Organising Committee

Anke Zernack (Lead convenor)
Julie Palmer (Co-convenor)

Anke Zernack, Julie Palmer, Jon Procter, Gert Lube, Georg Zellmer, Melody Whitehead, Stuart Mead, Gabor Kereszturi, Karoly Nemeth (Science programme)
Sam McColl, Nicki Sayers (Sponsorship)
Gabor Kereszturi (Field trip coordinator)
Shannen Mills, Sarah Tapscott & Stuart Mead (Social programme)
Sarah Tapscott & Shannen Mills (Social media)
Matt Irwin (IT)

Conference logo created by Sarah Tapscott

Conference Organisers

conferences & events

www.confer.co.nz
Ph: +64 (0)4 384 1511

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SESSION CONVENORS

We would like to thank the session convenors for their time and effort in developing the scientific programme and reviewing the abstract submissions.

Peter Almond (Lincoln University)
David Barrell (GNS Science)
Mark Bebbington (Massey University)
Mac Beggs (University of Canterbury)
Kyle Bland (GNS Science)
James Crampton (VUW)
David Dempsey (University of Canterbury)
Russ Van Dissen
Miko Fohrmann (OMV)
Michael Gazley (AusIMM; RSC Mining & Mineral Exploration)
Matt Gerstenberger
Ilmars Gravis (Geoconservation Trust Aotearoa)
Ian Hamling (GNS Science)
Jess Hillman (GNS Science)
David Johnston (Massey University)
Lucy Kaiser (GNS Science; Massey University)
Ben Keet (Geo & Hydro - K8 Ltd)
Christine Kenney (Massey University)
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Jenny Stein (GSNZ)
Dominic Strogen (GNS Science)
Olivia Truax (GNS Science)
Chris Twemlow (Geoconservation Trust Aotearoa; DoC)
Phaedra Upton (GNS Science)
Saskia de Vilder (GNS Science)
Sally Watson (NIWA)
Alana Weir (University of Canterbury)
Melody Whitehead (Massey University)
James Williams (University of Canterbury)
Tom Wilson (University of Canterbury)
Andrea Wolter (GNS Science)
Georg Zellmer (Massey University)
Anke Zernack (Massey University)

FIELD TRIP LEADERS

A big thank you also to the field trip leaders for offering such a great selection of field trips for the conference.

Alastair Clement (Massey University)
Ben Dixon (Te Ahu A Turanga Alliance)
Ian Fuller (Massey University)
Ilmars Gravis (The Geoconservation Trust Aotearoa)
Gabor Kereszturi (Massey University)
Stuart Mead (Massey University)
Anja Moebis (Massey University)
Boglarka Nemeth (Massey; Forest Enterprises)
Karoly Nemeth (Massey; The Geoconservation Trust Aotearoa)
Alan Palmer (Massey University)
Jon Procter (Massey University; Rangitāne o Manawatu)
Callum Rees (Massey University; Horizons Regional Council)

CONFERENCE OVERVIEW

Date		Day Event	Evening Event
Monday 29 November	***Pre-Conference***	Pre-Conference Workshops Student Career Fair	Icebreaker Function ECR Mixer
Tuesday 30 November	***Day 1***	First Day of Scientific Programme	Public Lecture Fun Games & BBQ Night
Wednesday 01 December	***Day 2***	Second Day of Scientific Programme	GSNZ AGM Conference Gala Dinner
Thursday 02 December	***Day 3***	Last Day of Scientific Programme	
Friday 03 December/ Saturday 04 December	***Post-Conference***	Post-Conference Field Trips	

LUNCHTIME MEETINGS AND EVENTS

DAY 1 – 30 November

LAVA NZ SIG Updates
Led by Adrian Pittari

IODP and ICDP - Developing a New Zealand Drilling SIG
Led by Georgia Grant

GeOID SIG Updates
Led by Jenny Stein

STUDENT WORKSHOP: Road To Publication
NZJGG

DAY 2 – 01 December

Sedimentology SIG IAS Updates
Led by Mark Lawrence and Karoly Nemeth

Geochemistry SIG Updates
Led by Sebastian Naeher

WOMEESA - Women in Earth and Environmental Sciences in Australasia
Led by Jess Hillman

DAY 3 – 02 December

GEONET 20th ANNIVERSARY LECTURE

Social Programme

Icebreaker Function

Date: Monday 29 November
Location: Wharerata, Massey University
Time: 5.00pm - 7.00pm

Icebreaker sponsored by

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Fun Games and BBQ Night

Date: Tuesday 30 November
Location: Sports & Rugby Institute, Massey University
Time: 7.00pm – late

Local brews sponsored by

VOLCANIC RISK SOLUTIONS

Conference Gala Dinner

Date: Wednesday 1 December
Location: Awapuni Function Centre and Racecourse
Time: 7.00pm - late

Band sponsored by

VOLCANIC RISK SOLUTIONS

Student and ECR Events

Career Fair

Date: Monday 29 November
Location: AgHort Lecture Block, Massey University
Time: Full Day
Organiser: *Shannen Mills & Sarah Tapscott*

Early Career Researchers (ECR) Mixer

Date: Monday 29 November
Location: BrewUnion
Time: After the Icebreaker
Organiser: *Jenni Hopkins*

FIELD TRIP OFFERS

FIELD TRIP 1

Te Ahu a Turanga:
Manawatū Tararua Highway and Cultural Sites of importance

Leaders:	Ben Dixon (Te Ahu A Turanga Alliance)
	Jon Procter (Massey University, Rangitāne o Manawatu)
Date:	1-Day trip, 3 December 2021
Cost:	$60/person

The new 11.2 km long Manawatū Tararua Highway is being constructed across the Ruahine Ranges from Ashurst to Woodville to replace the existing Manawatū Gorge Road which closed in 2017. Currently under construction by the Te Ahu A Turanga Alliance, this project has facilitated extensive borehole investigation, geological and landslide mapping and groundwater monitoring to further the geological understanding of the area.

Te Ao Māori is actively integrated into the design and construction of the project in a way that celebrates this unique area and its rich cultural heritage. You can expect to see Māori culture expressed in many places on this project, from plant species selection to the design of highway structures and celebration of areas with specific cultural significance.

This field trip will start at the site office with a welcome and introduction to the project from the Alliance, then we will review the project geological model and some of core recovered from the boreholes. Following this, we will travel to key sites along the highway to look at geological outcrops that informed the design, large exposures in 70 m high cuts currently under construction, the construction of the 300 m long bridges crossing the Manawatū River and QEII area, and areas of cultural significance including the recent discovery of moa bones.

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Photo credit to, and in memory of, Stefanie von Bueren

FIELD TRIP 2

Land use and stratigraphy within the eastern Whanganui Basin, lower North Island, New Zealand

Leaders:	Callum Rees (Massey University; Horizons Regional Council) Alan Palmer (Massey University)
Date:	1-Day trip, 3 December 2021
Cost:	$60/person

Keen to explore one of the best records of Quaternary climate change exposed onland anywhere in the world? Say no more, our journey will begin at the Manawatu Saddle, eastern Whanganui Basin, where construction of the new c. $620 million Manawatū Tararua Highway (Te Ahu a Turanga) is underway. Context will be provided by local geological mapping, highlighting faults and erosion prone sediments that present construction challenges. As we move west, towards the Rangitīkei, we will pause on the Pohangina Anticline to explore c. 1.2 –1 Ma basin fill that is exposed by some of the most severe gully erosion within the region, presenting questions around land use management and sustainability. The journey will end with stunning exposures through cylothemic strata (c. 0.9 Ma) at Waitapu Stream and evidence of past volcanism. Lunch and good fossil picking may be enjoyed during a leisurely stroll up the deeply incised stream valley.

Additional Information: Transport will be supplied via minibuses departing from outside the conference venue at Massey University by 8:00 am. Please bring tramping boots, rain jacket, backpack, water and sunscreen.

Moderate level of fitness required.

In association with

TODD ENERGY

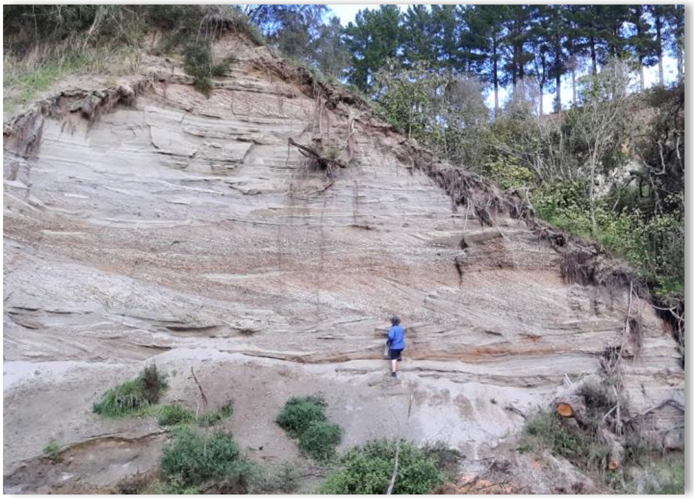

Photo credit: Callum Rees

FIELD TRIP 3

Geomorphology of the lower Manawatu valley

Leaders:	Alastair Clement (Massey University)
	Ian Fuller (Massey University)
Date:	1-Day trip, 3 December 2021
Cost:	$60/person

The geomorphology of the lower Manawatu valley has been strongly conditioned by the controls of climate change, tectonics, sea-level change, and sediment supply. This fieldtrip will explore the geomorphology of the Manawatu valley from the Manawatu Gorge downstream to the Manawatu River mouth at Foxton Beach. Key environments include: fluvial and marine terraces preserved in the valley; the Pohangina anticline; the Manawatu floodplain; the Manawatu dunefield; and the contemporary coastal environment. The fieldtrip will draw on recent research on the Holocene infilling history of the Manawatu estuary and flood histories of the Manawatu River, as well as taking a fresh perspective on established research on the Manawatu dune field.

Additional Information: Waterproof and warm clothing, and study footwear required.

Low to moderate level of fitness required.

Photo credit: Ian Fuller

FIELD TRIP 4

Mt Ruapehu –
Tephra stratigraphy, mass flow deposits & volcanic hazards

Leaders:	Gabor Kereszturi (Massey University) Anja Moebis (Massey University) Jonathan Procter (Massey University) Stuart Mead (Massey University)
Date:	2-Day trip, 3-4 December 2021
Cost:	$220/person

Mt Ruapehu is an andesitic composite volcano, located in the Central Volcanic Plateau. Besides producing many small to large scale hydrothermal, magmatic, and phreatomagmatic eruptions, Mt Ruapehu has produced many small to large-scale flank collapses, and crater rim collapses that have resulted in debris avalanches, landslides, and lahars. Mt. Ruapehu is therefore an excellent natural laboratory to study stratigraphy and sedimentology of tephra and mass flow deposits. The 2-day field trip showcases some of the sedimentary and volcanic processes by visiting key outcrops on the ring-plan and lower flank of Mt Ruapehu. The field trip will introduce new research findings on the tephra stratigraphy, mass flow hazards and landscape evolution response to major tephra forming eruption and mass flow events. This field excursion will also showcase ways of integrating field-based data into numerical modelling and hazards assessment.

Additional Information: Minivan transport and overnight accommodation in Ohakune will be provided.

Easy to moderate hikes.

Photo credit: Anke Zernack

FIELD TRIP 5

Geoheritage, geodiversity and geotourism potential of the Wairarapa region (Lower North Island's East Coast)

Leaders:	Karoly Nemeth (Massey; The Geoconservation Trust Aotearoa) Julie Palmer (Massey) Ilmars Gravis (The Geoconservation Trust Aotearoa) Boglarka Nemeth (Massey; Forest Enterprises)
Date:	2-Day trip, 3-4 December 2021
Cost:	$220/person

In recent years geoheritage and associated concepts such as geoconservation, geotourism, and geodiversity, have gained increasing visibility in New Zealand Geosciences. The field trip visits locations that are iconic in geological research but remain underutilised in the context of geotourism and are virtually unknown as high value geoconservation sites. We will explore complex geological aspects of a region in the Wairarapa that has been shaped by the nearby convergent plate boundary and is not subject to high visitor numbers, in contrast to other well-known, highly promoted tourist destinations. We aim to open a discussion focusing on the geoheritage values of the visited sites against a broader backdrop of global geoheritage research and ventures, particularly in the Southwest Pacific.

This excursion provides a valuable opportunity not only for geoscience specialists but also for schoolteachers, tourism operators, and land managers, or laypeople wishing to broaden their horizons and explore this area in greater depth.

Additional Information: Hiking shoes advisable. Transportation, 1-night accommodation, 2-lunches, 1-breakfast and 1-dinner will be provided.

Light to moderate level of fitness required.

Photo credit: Karoly Nemeth

PUBLIC LECTURE SPEAKERS

Dr Sally Potter

Biography

Sally has been researching how to best communicate forecasts and warnings for natural hazards for over 10 years.

She has helped write GeoNet's earthquake forecasts and eruption forecasts following the Whakaari/White Island 2019 eruption, as well as emergency mobile alerts. She reviewed New Zealand's volcanic alert level system and investigated how often Taupo supervolcano has had unrest. She co-leads international and domestic research programmes on severe weather, looking at how to improve warnings.

Talk: **Warning! Natural hazard forecasts and why people respond in different ways**

Can anyone forecast earthquakes? How active is Taupo supervolcano? Where can you find out more about the natural hazards that might affect you? What makes a warning effective?

This interactive presentation will show you how we can use the best science available to support our decisions and get ourselves ready for impending natural hazards.

Dr Kate Clark

Biography

Dr Kate Clark has been researching past large earthquakes and tsunamis in Aotearoa/New Zealand for over 15 years. Kate's studies started at Massey University where she used tiny microfossils to look at changes in ocean temperature, and she ended up captivated by how fossils record sudden changes in sea level caused by large earthquakes. Her research has made major contributions to understanding the hazard posed to Aotearoa/New Zealand by our largest fault lines: the Alpine fault and the Hikurangi Subduction Zone.

Talk: **Past coastal earthquakes and tsunamis of Aotearoa/New Zealand, and preparing for our shaky future**

Much of the Aotearoa/New Zealand coastline has been shaped by past earthquakes. The coastal landscape bears the imprint of dramatic uplift, sudden subsidence, and tsunami impact. Earthquake geologists use these landscape clues to piece together the history of earthquakes and tsunamis over thousands of years. Kate will explore how the coastal landscape of the lower North Island and upper South Island contains the story of past earthquakes, and how this information helps us prepare for future seismic events.

PLENARY LECTURES

PLENARY 1 – 30 November

Dr Charlotte Severne

Once a Geologist, always a Geologist - 25 years on

What happens when you leave University armed with a Doctorate in Geology and no place to go? There are number of routes open to science graduates other than post-doctoral paths and academic roles but these are obvious and graduates are prepared. Dr Severne will discuss her journey, the opportunities and near misses that colour her career. She will also take a glance at what the workforce of the future will offer for science graduates.

Biography

Dr Charlotte Severne is the Māori Trustee and leads Te Tumu Paeroa - the Office of the Māori Trustee.

Charlotte holds a PhD in Geology from the University of Auckland. In 2016, she was made an Officer of the New Zealand Order of Merit, in recognition of her contribution as an advocate and mentor for Māori Development and Science.

Charlotte also has a wealth of experience in working with Māori business as a science advisor and in governance roles in energy, fisheries and farming entities. Prior to being appointed the Māori Trustee in September 2018, her governance leadership roles were primary and energy sector based.

Dr Kim Martelli

**A Career in the Geosciences:
A world of opportunities from exploration to engineering!**

Kim has led an interesting and varied career since graduating with a BSc in earth science from Massey University including standing on active volcanoes, riding in helicopters, blowing up rocks, avoiding terrorist attacks and land mines, hoping not to need her kidnapping insurance, and developing the liquefaction hazard map for Tauranga City.

She will talk about what led her to study earth science, what pathways she took and how she has ended up back in the Bay of Plenty. Kim will discuss the importance of taking opportunities and creating your own, and how she navigated Geoscience professions where women are a minority.

Biography

Dr Kim Martelli is a Chartered Geologist with a PhD from the University Clermont Auvergne (France) and has over 12 years' experience in field geology conducting geological, geomorphological and hazard mapping in challenging terrain both in New Zealand and around the world (Peru, Turkey, Armenia, Georgia...). She is now a Lead Engineering Geologist and Natural Hazards Specialist with the Engineering Consultancy Aurecon.

Kim has a deep passion for STEM education and development, volunteering in Engineering New Zealand's The Wonder Project and Tauranga's STEM festival. She has completed leadership programmes for high potential women and future leaders, is member of Aurecon's Committee for Diversity, Equity & Inclusion, and the chair for GSNZ Bay of Plenty Branch.

Hollei Gabrielsen

Herenga tangata, hononga ki te whenua.

Mai i te pae tapu o Tongariro
Ko Matua te Toa
Tae iho ki Pīhanga te uwha whakaaroha
Ko Matua te Hine
E ruku ana ahau i tōku wai kōrero
Ko Te Kōpū a Kānapanapa te wai whakahono
E ko Te Arawa!
E ko Tūwharetoa!
E ko Kurauia, Turumakina, Hikairo te mihi atu nei.

Biography

Hollei is of Ngāti Tūwharetoa and Ngāti Whitikaupeka descent and the Technical Advisor Volcanology for Te Papa Atawhai, the Department of Conservation. A māmā to three tamariki, an uri of Te Kāhui Maunga, a mokopuna of te taiao, a student of life and in pursuit of consistent growth.

Much of Hollei's career was dedicated to providing a platform for tangata whenua to assert their rangatiratanga on matters concerning their cultural, spiritual and natural landscape. More recently she made the transition to the public sector to provide technical advice on volcanic matters, unrest, risk and eruptions.

SCIENTIFIC SESSIONS

I. Our Dynamic Planet: Magmatism and Tectonics

a. Maunga Puia - Volcanoes and their eruptive products (LAVA NZ and Sedimentology SIGs endorsed)

*Session Convenors: **Jon Procter**, Gert Lube (Massey University)*

Aotearoa and Zealandia's evolution has been moulded by volcanism. Volcanic products and processes have shaped our landscape and contributed to the development of our indigenous culture. Present-day volcanism threatens the resilience of Aotearoa with many complex potentially hazardous processes impacting communities, infrastructure and economy. This session will be seeking contributions from a wide range of topics that relate to volcanism in Aotearoa, factors driving volcanism, eruptive/effusive products and hazards, past and potential future impacts, simulation of volcanic processes and volcanic geomorphology.

b. Igneous Petrology and Geochemistry (LAVA NZ and Geochemistry SIGs endorsed)

*Session Convenors: **Georg Zellmer**, Carlos Santa Cruz (Massey University)*

This session focusses on magmatism in New Zealand and globally. We welcome petrological (including experimental petrology) and geochemical studies on materials ranging from mantle rocks through plutonic intrusions to volcanic eruption products, to improve our understanding of the petrogenetic processes that govern the different tectonomagmatic systems present on Earth. Further, we are hoping to see a wide range of analytical techniques, from whole-rock to microscopic scale, and from elemental to isotopic investigations, to gain insights into (i) sources and processes of magma genesis; (ii) processes and rates of magma ascent through the crust; (iii) magma-crust interactions; (iv) links between subvolcanic magmatism and volcanic eruptions; (v) syn- and post-eruptive processes as evident from the materials investigated; (vi) intensive parameters such as pressure, temperature, and compositional changes that may be derived; and (vii) the rates and timescales of all of the above, as constrained through a range of both absolute and relative dating methods.

c. Zealandia through space and time

*Session Convenors: **Dominic Strogen** (GNS Science), James Crampton (Victoria University of Wellington)*

All aspects of the evolution of Zealandia, including, but not limited to:

- basement terrane evolution in eastern Gondwana
- the 'basement to cover' transition - from Gondwana subduction to Zealandia rifting
- tectonic evolution and reconstructions of Zealandia and surrounding regions
- paleogeography, paleoenvironments and paleobiology
- rifting and evolution of Zealandia basins
- Paleogene–Neogene plate boundary development through Zealandia
- provenance and uplift studies
- Cretaceous and younger magmatism across Zealandia

II. Lessons from Active Earth Systems: Messages from the Past for the Future

a. Natural hazards – from the geological record to forecasting

*Session Convenors: **Melody Whitehead**, Stuart Mead, Mark Bebbington (Massey University)*

This session aims to present a comprehensive overview of current research surrounding the what, how, when, where, and why of natural hazards in New Zealand, based primarily (but not exclusively) on previous activity, models and current observations. Topics may include:

1. Geological interpretations: what does the geological record tell us about current and future hazardous events
2. System dynamics: what can physical or chemical models tell us about system evolution and event triggers, precursors, and hazard parameters.
3. Physical hazard: from modelling phenomena to observations that improve understanding of hazard dynamics, cascades, zonation and communication
4. Statistical/uncertainty forecasts: from hazard forecasting to data uncertainties including where the geological record may, and may not, be valid and the limits of what the past may tell us about the future

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Kia manawaroa – Ngā Ākina o Te Ao Tūroa

b. Our changing landscapes; surface process dynamics, evolution, and hazards (Sedimentology SIG endorsed)

*Session Convenors: **Karoly Nemeth** (Massey University), Sam McColl (Massey University), David Barrell (GNS Science), Kevin Norton (VUW)*

This session brings together contributions that broaden the understanding of surface processes and their dynamics, evolution, and hazards as relevant to Earth and beyond. In particular, we welcome contributions that address topical issues in geomorphology and surface process sciences using innovative, cross-disciplinary approaches and technologies including remote-sensing, quantitative terrain analysis, numerical modelling, and geochronology. Timescales of interest may extend from that of landscape evolution over millions of years, through to the dynamics of Quaternary climate cycles, or contemporary observations and forward-looking future scenarios. Priority will be given to those contributions whose cross-disciplinary approaches enhance and draw linkages to other branches of the geosciences.

c. Understanding climate and environmental change (Friends of the Pleistocene SIG endorsed)

Session Convenors: Peter Almond (Lincoln University), Lynda Petherick (VUW), Olivia Truax, David Barrell (GNS Science)

Global climate and environmental changes present significant challenges for current and future generations. In this session we encourage submissions from the full spectrum of climate and environmental research, with presentations having a key focus on (but not limited to): (i) analyses of present climate trends/impacts; (ii) climate/environmental reconstruction from geological archives (recent to deep time); (iii) interactions between humans, climate and environment; and iv) computer modelling of past/present climate and environmental change.

d. Integrated Coastal Dynamics: Our Changing Coastline

*Session Convenors: **Kyle Bland** (GNS Science), Andrew La Croix (University of Waikato), Phaedra Upton (GNS Science)*

Coastal environments are complex and dynamic with morphodynamics that are influenced by autogenic processes, natural external forcings, climate change, and direct anthropogenic interactions. These processes act on and are recorded in the landscape and the sedimentary record over a wide range of spatial and temporal scales, from long-term and broad-scale to short-term and fine-scale processes and deposits.How will changing climate and sea level impact New Zealand’s natural and built environments, and how can the nation adapt to these changes socially, economically, and environmentally? In this session we invite presentations that address all aspects of coastal dynamics. We are particularly interested in studies that cross disciplinary boundaries, address the integration of social science and Mātauranga Māori into research programmes, and use modelling to explore the impacts of changing coastal environments on people, society, and infrastructure.

e. The marine environment of Aotearoa/New Zealand: surface and subsurface processes and anthropogenic impact

*Session Convenors: **Jess Hillman** (GNS Science), Sally Watson (NIWA), Karsten Kroeger (GNS Science), Sarah Seabrook (NIWA)*

With the majority of Te Riu-a-Māui/Zealandia lying underwater, marine geology is an essential field of research in Aotearoa/New Zealand. Advances in technology and the growing volume of marine data mean that we are poised on the threshold of a digital ocean. Recent and ongoing research including seafloor sampling surveys, sub-bottom surveys, seafloor mapping programmes, ROV and AUV dives have acquired a wealth of new data, allowing us to further explore offshore geology and active processes beneath the seafloor. Furthermore, we are increasingly aware of anthropogenic impacts from the coastal waters to the abyssal plains. This session seeks contributions from studies across the disciplines of marine geology and biogeosciences, ranging from the depths of the continental slopes to the shallow coasts.

III. Living in A Dynamic GeoCultural Landscape: Geosciences and Society

a. Advances in Disaster Risk Science: systemic risks and co-production of knowledge (merged with session 3b.)

*Session Convenors: **Alana Weir** (University of Canterbury), Tom Robinson (University of Canterbury), James Williams (University of Canterbury), Tom Wilson (University of Canterbury), David Johnston (Massey University)*

Global efforts to reduce the impacts of disasters over the last decade have failed to keep up with growing exposure of people and assets to hazards, which is generating new risks and a steady rise in disaster-related losses. The UN member state-ratified Sendai Framework for Disaster Risk Reduction (2015) aims to reverse this trend, by calling for a more holistic, people-centric approach to disaster risk reduction, in which communities, government, private sectors and research institutions work together to build resilience and develop collaborative disaster risk reduction (DRR) practices. The geosciences are an essential discipline within the DRR mission, particularly through multi- and inter-disciplinary studies. Increasing acknowledgement of systemic risk factors has necessitated the investigation of the dynamic, cascading properties of disaster risk. In tandem, there is mounting evidence that best-practice for DRR involves collaboration and co-production of knowledge across the science-policy-practice interface. When coupled, these two eminent DRR principles present a unique challenge and an exciting opportunity in risk management and resilience-building initiatives. With this in mind, we warmly invite contributions on topics relating to geological risk and resilience studies and initiatives. We especially welcome contributions from practitioner and policy expert and early-career scientists.

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Kōmihana Rūwhenua

b. Connecting and Communicating about Geohazards

Session Convenors: ***Sally Potter*** *(GNS Science)*

This session will explore recent, current, and planned initiatives relating to communicating about geohazards. We encourage updates and activities from major research programmes, engagement methods and user needs assessments, forecasts, visualisation tools and maps, crowdsource or citizen science activities, outreach, and education programmes. Social science research on risk perceptions, behavioural response, and communication are welcome. Presentations can be on original research, reviews, or practical/applied, and about any geohazard, impacts or risks. We welcome contributions to describe the aim(s) of their project, methods/processes, challenges they experienced, wins and successes, outputs, and any impacts.

Merged with 3a. into:
3b. Connecting & Communicating about Geohazards and Risks
Session Convenors: ***Sally Potter (GNS Science) and Alana Weir*** *(University of Canterbury)*

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EARTHQUAKE COMMISSION
Kōmihana Rūwhenua

c. Geoheritage of Aotearoa and the SW Pacific

Session Convenors: ***Karoly Nemeth*** *(Massey University; Geoconservation Trust Aotearoa), Ilmars Gravis (Geoconservation Trust Aotearoa), Chris Twemlow (Geoconservation Trust Aotearoa; Department of Conservation)*

Geoheritage research continues to develop as a transdisciplinary science, where classical geological knowledge and physical geography research often occurs in parallel with biogeography, and tourism research. In turn these may be heavily influenced by social sciences such as pedagogy and cultural histories. New advances in geoeheritage research on the global stage demonstrate the dynamic nature of this science arena, with New Zealand and the SW Pacific providing the perfect canvas for researching and engaging with this field.We invite participants to demonstrate the diversity of geoheritage research within the New Zealand and SW Pacific context. In particular, we seek previously unpublished research, and new descriptive works outlining development of methodologies and projects for building geoheritage inventories; exploring the place of geotourism and geoconservation within diverse communities; and integration of advanced technologies within these research fields such as: advanced GIS, data mining techniques, remote sensing, and virtual technologies. We also seek submissions exploring global developments in these fields, that would place our regional geoheritage ventures in a wider global context and developments in internationally recognised best practices. This session is supported by Geoconservation Research and presenters are encouraged to develop a full length paper that can be submitted to this peer-reviewed, zero-fees open access magazine.

conservation

Session participants are encouraged to submit their conference paper on geoheritage, geoconservation, geoeducation and geotourism to the new peer-reviewed scientific journal Conservation (MDPI). More information can be found here: https://www.mdpi.com/journal/conservation. Questions can be directed to Prof Karoly Nemeth (Editor) at k.nemeth@massey.ac.nz.

d. Manawa whenua, hōkikitanga kawenga: Tangata whenua, Geo-scapes and Geoscience (cancelled)

Session Convenors: ***Christine Kenney*** *(Massey University), Lucy Kaiser (GNS Science and Massey University), Anke Zernack (Massey University)*

Tangata whenua have a unique eco genealogical relationship with the land of Aotearoa; personified as Papatūānuku the earth mother. Boundaries between humanity and the land are rendered non-existent as evidenced in the Māori cultural proverb: "Ko au te whenua, te whenua ko au" I am the land and the land is me. Geoscientists who are tangata whenua and/or have conducted research with tangata whenua that relates to the five key conference themes, are invited to present their research. Joint presentations with Māori research partners are also welcome. All presenters are encouraged to consider and where appropriate, comment on how their research has:

- Fostered science engagement with tangata whenua
- Been co-created in partnership with tangata whenua
- Addressed the geological/science concerns of tangata whenua
- Contributed to building science, technological and research capability of tangata whenua Acknowledged Mātauranga Māori
- Responded to Māori ethical concerns about researching the whenua

e. GeoEducation and Outreach

Session Convenors: Jenny Stein (GSNZ)

This session is a chance for all those involved in geoscience education and outreach to showcase what they have learned through their interactions with aspiring geoscientists and geologists, schoolteachers, students, community groups and the general public. By sharing our knowledge and experiences, we will find out what works, what doesn't, and what else we can do to help create meaningful experiences for non-earth science professionals.

IV. Facing the Future: Innovative Applications and Technologies in Geosciences

a. Computational advances in Geosciences

*Session Convenors: **Stuart Mead** (Massey University), David Dempsey (University of Canterbury)*

The increasing availability of computational power, numerical platforms and machine learning techniques has created significant opportunities for geoscience. This session aims to showcase the development, use and application of computational techniques in geosciences. We invite contributions from all aspects of geoscience utilising these computational advances including, but not limited to:

- model development, improvement, application, and validation
- machine learning techniques applied to geosciences
- database development and data analysis
- techniques leveraging high performance computing (HPC)
- geoscientific data visualisation

b. Remote Sensing and Earth Observation for Geological Applications

*Session Convenors: **Gabor Kereszturi** (Massey University), Ian Hamling (GNS Science)*

This session highlights new research using remote sensing to probe geological processes. The topics can cover from the lab- and field-based to satellite remote sensing with optical, thermal, RADAR, LiDAR sensors, or combinations. The session aims to present a good blend of research from both methodology and application aspects. The methodological contributions can include validation/calibration, sensor fusion, image classification and regression, and sensitivity analysis. Contributions exploring geological applications are welcome from any part of geoscience, including but not limited to digital terrain analysis, landslides, suspended sediment mapping, surface deformation, mineral exploration, natural hazards, geothermal and volcano research, geological mapping, among others.

c. Engineering Geology/Geomorphology: Advances and Applications in a Dynamic World

*Session Convenors: **Sam McColl** (Massey University), Saskia de Vilder (GNS Science), Andrea Wolter (GNS Science), Kerry Leith (GNS Science)*

This session aims to highlight innovation and advances in the field of Engineering Geology/Geomorphology and the practical application of this knowledge to inform decision makers and increase resilience to natural hazards. We welcome a broad range of abstracts including advances in our understanding of slope stability mechanics and processes, the properties and behaviour soil and rock, engineering geological ground models, and innovative technologies used for monitoring and modelling ground conditions and unstable slopes.

d. Geoscience for Future Energy Systems

Session Convenors: ***Mac Beggs*** *(University of Canterbury), Miko Fohrmann (OMV)*

This session will canvass papers showcasing the roles of geoscience in enabling a sustainable, reliable and affordable future energy system for New Zealand. This may include new applications of expertise and technology from existing energy industries to the evaluation and development of new possibilities including more challenging classes of geothermal energy, offshore wind and marine energy, and geostorage for hydrogen, CO2 sequestration. Potential mineral resources for battery technology may also be addressed.

e. Geochemical tools and applications to reconstruct environmental and climate change, human impact and Earth history in New Zealand, Australia and Antarctica (Geochemistry SIG endorsed)

Session Convenors: ***Sebastian Naeher*** *(GNS Science), James Scott (University of Otago)*

This session highlights innovative research of the New Zealand and overseas geochemistry community about environmental and climate change. It discusses technological developments and applications of new indicators on topics such as reconstructing productivity, nutrient cycling and water quality in aquatic environments, and metal tracers and non-traditional isotope systems to quantify processes on land and at sea. Selected topics discuss pollution and human impact or new research into global geochemical cycles across time that link the earth, ocean and atmosphere. Multiproxy reconstructions of life evolution and bioheritage, high-resolution paleorecords and dating of environmental archives are also presented.

f. Mineral Deposits: Geology, Exploration and Resources

Session Convenors: ***Michael Gazley*** *(AusIMM and RSC Mining and Mineral Exploration)*

This session is intended to be broad to capture all aspects of research on mineral deposits, exploration for mineral deposits, and examination of mineral systems and their resources, both in New Zealand and globally. This session welcomes papers that examine the structural controls on the location, architecture, depositional processes, and post-mineralisation modification of mineral deposits, through the implementation of traditional and innovative techniques at micro- to crustal-scale; through papers that examine exploration techniques or approaches to find mineral deposits; and papers that explore resource modelling, responsible development of resources and post-mining processes like mine-closure, remediation and acid-mine drainage.

New Zealand is well-endowed with mineral wealth that ranges from iron sands on the west coast of the North Island, and garnet sands of the West Coast of the South Island to hard-rock and alluvial gold of the Otago region and Coromandel Volcanic Zone. These minerals and more novel elements besides (such as REE placer deposits and Li in geothermal systems) could be extracted to support New Zealand' transition to a low-carbon economy. Minerals play a key role in this transition and New Zealand must understand its own resources, where they are and how to utilise them in an efficient and responsible manner to support this transition.

V. General Geosciences Not Covered Under Specific Conference Themes

a. The Anthropogenic – The influence of contaminants in land and groundwater (cancelled)

Session Convenors: ***Ben Keet*** *(Geo & Hydro – K8 Ltd)*

The session aims to highlight the need for input of geosciences into the contaminated land discipline. Although most contaminated land projects focus on relative small areas (1–100 ha), regional contaminated land issues require geospatial and geoscience inputs. In NZ geothermal and volcanic regions have their own set of background concentrations that affect all contaminated site reports made in that region. Therefore, Geoscience input is important.

b. Geoscience Horizons - Manawatu-Whanganui where the past experiences herald decisions for the future (cancelled)

Session Convenors: ***Szabolcs Kosik*** *(Horizons Regional Council), Callum Rees (Horizons Regional Council), Julie Palmer (Massey University)*

Manawatu – Whanganui is under the jurisdiction of the Horizons Regional Council. It covers more than 22,000 km^2 of North Island, NZ a region with diverse geology and geomorphology including the Hikurangi subduction and associated accretionary prism, active volcanoes of Tongariro National Park and uplifted Neogene sedimentary basins. The landscape is characterised by strongly dissected hill country and alluvial plains flanked to the west by a coastal-marine setting. The region is geologically active with mass movements and fluvial erosion two of the most recognised processes operating. Less frequent and less predictable geological events, such as volcanic activity, earthquakes and sea level fluctuation in response to climate change, are too often overlooked yet all three have played an integral role in the development of regions unique landscape and cover beds. The Horizons' landscape is one of the best records of late Neogene -Quaternary deposits in NZ and perhaps the world. The geoheritage values of the region need to be incorporated into regional planning and used to steer local economic development in the future.

	CONFERENCE PROGRAMME for TUESDAY, 30 November		
07.00	**REGISTRATION**		
08.00	**OPENING CEREMONY SSLB1** Mihi Whakatau (Terry Hapi) Conference opening address (Ray Geor) Conference Opening Welcome (convenors) Turitea Kapa Haka Roopu *Bus transport for Kapa Haka Roopu sponsored by* tranzit coachlines		
08.45	**PLENARY 1 SSLB1** **Charlotte Severne *"Once a Geologist, always a Geologist - 25 years on"***		
	SSLB1	***SSLB2***	***SSLB3***
09.15-10.30	**1a. Maunga Puia** *Jon Procter; Gert Lube (Massey University)*	**2d. Integrated coastal dynamics** *Kyle Bland (GNS Science); Andrew La Croix (University of Waikato); Phaedra Upton (GNS Science)*	**3e. GeoEducation & Outreach** *Jenny Stein (GSNZ)*
09.15-09.30	**Procter J** & Sciascia A **-** Taranaki Mounga - The interface of Mātauranga ā Iwi and Science ***(keynote)***	**King D** et al. - A Foraminiferal Sea-Level Reconstruction from Aramoana Salt Marsh, Dunedin	**Thomson J** - Who are you talking to - and why are you doing it? ***(keynote)***
09.30-09.45	**Massiot C** et al. - CALDERA - Connections Among Life, geo-Dynamics and Eruptions in a Rifting Arc: a Scientific Drilling Idea	**Roche B** et al. - Linking processes to deposits: fluid muds in the lower Waihou River, New Zealand	**Kennedy B** et al. - Virtual Fieldtrips To Volcanoes- 10 Year Perspective
09.45-10.00	**Brenna M** et al. - Post-caldera volcanism reveals shallow priming of an intra-ocean arc andesitic caldera: Hunga volcano, Tonga, SW Pacific	**Patton NR** et al. - Using surface roughness to determine coastal dune ages of at K'gari (Fraser Island) and the Cooloola Sand Mass, Australia	**Saha S** et al. - Towards a bicultural approach to designing educational resources in Aotearoa New Zealand: Recommendations from reflections at the interface ***(keynote)***
10.00-10.15	**Bann G** et al. - Newly identified mafic and felsic tuffs from the Early - Mid Permian, southern Sydney Basin: explosive volcanism derived from northwest Zealandia.	**Keller E** et al. - Modelling the probability of inundation with Bayesian Networks: A pilot study in the Hauraki Plains	**Bull S** et al. - Who's using Geotrips.org.nz? A user-based approach to optimizing online geoscience communication
10.15-10.30	**Kereszturi G** et al. - Towards a global spectral-geomechanical database of volcanic rocks using VNIR-SWIR spectroscopy	**Bland KJ** et al. - Co-designing research for environmental, social, and cultural benefit: Tātaihia te Parataiao o Te Wahapū – Hokianga Harbour sedimentation project	**Boyes A** et al. - A portal for geoscience webmaps and information on the Te Riu-a-Māui / Zealandia region
10.30-11.00	**Morning Tea**		

	SSLB1	*SSLB2*	*SSLB3*
11.00-13.00	**1a. Maunga Puia** *Jon Procter; Gert Lube (Massey University)*	**2c. Climate & environmental change** *Peter Almond (Lincoln University); Lynda Petherick (VUW); Olivia Truax; David Barrell (GNS Science)*	**4d. Geoscience for Future Energy Systems and Mineral Resources** *Michael Gazley (AusIMM and RSC Mining and Mineral Exploration); Mac Beggs (University of Canterbury); Miko Fohrmann (OMV)*
11.00-11.15	**Hopkins J** et al. - Efficient Identification of Cryptotephra in Marine Sediment cores; a non-destructive approach	**Hollis CJ** et al. - Making Sense of Paleocene Zealandia	**Chambefort I** et al. - Geothermal: The Next Generation - Advancing the Understanding of New Zealand's Supercritical Resources ***(keynote)***
11.15-11.30	**Garova E** et al. - Extending (Crypto) Tephro-chronology to Northern Finland and Russia	**Sutherland R** et al. - Neogene mass accumulation rate of carbonate sediment across northern Zealandia, Tasman Sea, southwest Pacific	**Yang J** et al. - CO2 Emissions of the Tauhara Geothermal Systems, Taupo Volcanic Zone, New Zealand
11.30-11.45	**Zernack AV** et al. - The Origin and Geoarchaeological Significance of Ocean-rafted Pumice Found in Mesolithic to Medieval Contexts in Norway	**Duncan B** et al. - The response of Antarctic vegetation to major glaciation during the Oligocene/Miocene Transition	**La Croix A** et al. - How notional injection sites for carbon geosequestration are identified: the Surat Basin, Australia
11.45-12.00	**Mills S** et al. - Using Tephra Records to Understand Stratovolcano Response to Edifice Collapse	**Grant GR** et al. - Reduced magnitude of the onset of Northern Hemisphere Glaciation during the Early Pleistocene	**Beggs M** et al. - Hikurangi Margin Gas Hydrate Deposits: Might they ever have been developed as an energy resource?
12.00-12.15	**Prentice M** et al. - Advances towards a comprehensive ignimbrite stratigraphy of the Tauranga Volcanic Centre, North Island, New Zealand	**Ryan M** et al. - Source-to-sink archives of vegetation change since the Last Glacial Maximum, Waipaoa Sedimentary System, New Zealand	**Christie T** - Copper in onshore New Zealand: mineral deposit types, occurrences and potential for this critical metal
12.15-12.30	**Stern S** et al. - Stratigraphic insights into the ~AD1450 caldera-forming Kuwae eruption sequence, central Vanuatu, South Pacific	Moore EMM, **Eaves SR** et al. - Climate reconstructions for the Last Glacial Maximum from a simple cirque glacier in Fiordland, New Zealand	**Palmer M** et al. - Distinct scheelite REE geochemistry and $^{87}Sr/^{86}Sr$ isotopes in proximally- and distally-sourced metamorphogenic hydrothermal systems, Otago Schist, New Zealand
12.30-12.45	**McLeod O** et al. - Stratigraphy of Karioi stratovolcano, Raglan	**Tielidze L** et al. - Climate change during the last glacial termination in the Southern Alps - evidence from new glacier chronologies and snowline reconstructions	**Gazley M** et al. - Soil-sample geochemistry normalised by class membership from machine-learnt clusters of satellite and geophysics data
12.45-13.00	**Thrasher G** et al. - Pleistocene–Recent Volcanism within the Cape Egmont Fault Zone	**Piva S** et al. - Using ultrahigh resolution pollen analysis to understand regional vegetation responses to the Ōruanui supereruption	**Vearncombe J** - Legacy Data and Data Upcycling
13.00-14.30	**Lunch, meetings, poster viewing**		

13.30-14.30	LAVANZ SIG *Adrian Pittari*	IODP and ICDP SIG *Georgia Grant*	GeOID SIG *Jenny Stein*	Student Workshop: Road to publication - *NZJGG*
	SSLB1	*SSLB2*	*SSLB3*	

14.30-16.00	**1a. Maunga Puia** *Jon Procter; Gert Lube (Massey University)*	**2c. Climate & environmental change** *Peter Almond (Lincoln University); Lynda Petherick (VUW); Olivia Truax; David Barrell (GNS Science)*	**4c. Engineering Geology/Geomorphology** *Sam McColl (Massey University); Saskia de Vilder; Andrea Wolter; Kerry Leith (GNS Science)*
14.30-14.45	**Lipiejko N** et al. - Experimental modelling of tsunami generation by the entrance of pyroclastic density currents into water	**Prebble M -** Palaeoclimate Research and the Archaeological Record in Aotearoa and Oceania ***(keynote)***	**Steele C** et al. - Hazard Classification System for Roxburgh Gorge Landslides
14.45-15.00	**Corna L** et al. - Blocking or Topping - Simulating Pyroclastic Currents Across Obstacles	**Truax O** et al. - Modern freshening of Ross Sea surface waters outside the range of natural variability during the last 5,000 years	**Singeisen C** et al. - Coseismic rock slope failure mechanisms – insights from landslides triggered by the 2016 Mw 7.8 Kaikōura earthquake
15.00-15.15	**Brosch E** et al. - The role of turbulent fluctuations on the destructive force of dilute pyroclastic density currents	**MacClure Z** et al. - Microstructural responses to shear localisation in the lateral margin of the Haupapa/Tasman Glacier	**Milne C** & Tunnicliffe J - High-resolution, Multivariate 2D and 3D Compositional Method for Assessment of Grain-size & Facies Organisation in a Landslide-impacted River System
15.15-15.30	**Murch AP** et al. - Submarine volcanic eruptions are implosive	**Perrett B** et al. - Climatic and tectonic controls on the trace element chemistry of rivers in the South Island of New Zealand	**de Vilder A** et al. - Disaggregating landslide risk: What drives Landslide Risk in Franz Josef and Fox Glacier Valleys?
15.30-15.45	**Hughes E** et al. - SO2 emissions from explosive basaltic eruptions at Okataina	Dietrich Z, **Reid C** et al. - Geochemical fingerprinting of sediment sources infilling Whakaraupō | Lyttelton Harbour, New Zealand	**Wolter A** et al. - A national landslide dam database for New Zealand
15.45-16.00	**Ching C** et al. - Observations of the Mount Ruapehu Crater Lake (Te Wai ā-moe) and implications for volcano monitoring	**Griffin A** et al. - GNS Science's journey to be carbon neutral by 2025	Brink G & **Brook M** - Engineering characteristics and behavior of tropical red soils: an example from Republic of the Congo
16.00-17.30	**Poster session/afternoon tea: SSLB Upper Foyer**		
	1a. Maunga Puia: A1-30 1b. Igneous Petrology: A31-46 2c. Climate & environmental change: A47-61	2d. Coastal dynamics: A62-67 3c. Geoheritage: A68 3e. GeoEducation: A69-75	4c. Engineering Geology: A76-79 4d. Geoscience for Future Energy Systems and Mineral Resources: A80-83

17.30-19.00	**PUBLIC LECTURE SSLB1** **Sally Potter *"Warning! Natural hazard forecasts and why people respond in different ways"*** **Kate Clark *"Past coastal earthquakes and tsunamis of Aotearoa/New Zealand, and preparing for our shaky future"***
19.00-late	**FUN AND GAMES BBQ DINNER Sports and Rugby Institute**

POSTERS (TUESDAY, 30 NOVEMBER)

1a. Maunga Puia

A1	**Caldwell AJ** et al.	Seismic Investigation of the West Ngatatura Volcanic Field, New Zealand: Implications for monogenetic volcanic architecture and plumbing.
A2	**Li B** et al.	Monogenetic volcanism in a dynamic fluvio-lacustrine setting - Tongxin Volcano, Arxan-Chaihe Volcanic Field, NE China
A3	**Tsang S.**	Lava flow inundation hazard in the Auckland Volcanic Field
A4	**Doll P** et al.	Towards a better understanding of effusive activity of Ruapehu in the last 20 ka
A5	**Jacobs K**	Using seismic ambient noise to understand Ruapehu Crater Lake heating cycles
A6	**Mazumdar A** & Turner G	Palaeomagnetic records of the Laschamp and Mono Lake geomagnetic excursions from Tongariro, New Zealand
A7	**Kilgour G** et al.	Cryptic magmatic processes in the lead up to a phreatic eruption: a composite modelling approach at Te Maari, Tongariro
A8	**Hamling I** & Kilgour G	Dynamic vent area changes at Whakaari White Island derived from staring spotlight satellite data
A9	**Morgan M** & Procter J	The landscape evolution within a confined active distal ring plain environment, Central North Island
A10	**Miller C** et al.	The integrated history of repeated caldera formation and infill at the Okataina Volcanic Centre: Insights from 3d gravity and magnetic models
A11	**Ellis S** et al.	TaupōInflate: Illustrating the detection of magmatic inflation below Lake Taupō
A12	**Mestel ERH** et al.	Using seismology to probe the modern magma reservoir at Taupō volcano
A13	**Illsley-Kemp** F et al.	Reoccurring earthquake swarms reveal the deep roots of the Hipaua-Waihī-Tokaanu geothermal system
A14	**Hall A** & Cronin S	Geological Insights into the Eruptive History of the World's Largest "Dirty" Geyser: Waimangu Geyser 1900-1904, Waimangu Volcanic Valley, New Zealand
A15	**Rooyakkers SM** et al.	Oxygen isotope perspectives on silicic magmatism and hydrothermal circulation in the modern Central Taupō Volcanic Zone
A16	**Seelig L** et al.	Plutonic insights into shallow magma systems beneath the Central Taupō Volcanic Zone (New Zealand) and their relationship to the magma-hydrothermal interface
A17	**Farsky D** et al.	Subduction, mantle and crustal influences of the Taupo Volcanic Zone: Insights from helium isotopes
A18	**Kinley T** et al.	Volcanic geology of the Pukunui Rhyolite Dome, Tauranga Volcanic Centre.
A19	**Stenning A** et al.	Refining the Early Geochronological Record for the Dunedin Volcano, New Zealand
A20	Gorny C, **White J** et al.	Melting ice with a large subglacial eruption, Snæbýlisheiði, Iceland
A21	Moore EMM, **Eaves SR** et al.	Fire and ice: the IAVCEI/IACS joint commission on volcano–ice interactions
A22	**Jarvis PA** et al.	Interaction between vortices and settling-drive gravitational instabilities at the base of volcanic clouds
A23	**Watson LM** et al.	Infrasound radiation from impulsive volcanic eruptions: Nonlinear aeroacoustic 2d simulations

A24	**Baxter RJM** et al.	Fishing for answers from artificial volcanic fissures
A25	**Lube G** & Brosch E	PDC models based on fluvial analogies strongly underestimate hazard magnitudes
A26	**Suresh S** et al.	Speleovolcanology in New Zealand
A27	**Clarke M** et al.	Hide and seek: Cryptotephra studies applied to a deep marine core
A28	**Moore HC** et al.	High-temperature oxidation of the pyroclasts in the proximal 1886 Tarawera deposits, New Zealand
A29	**Tapscott S** et al.	A detailed, quantitative investigation into the physical properties of tephra in the stratigraphical sequence of the Y5 phase of the Taupo 232 CE eruption
A30	**Zernack AV** et al.	Pungapunga – working with iwi to explore traditional use of pumice and its future potential for sustainable Māori business solutions

1b. Igneous Petrology and Geochemistry

A31	**Wilson LJE** et al.	Characterisation of the anomalous sub-alkaline Maniototo Basalts in the alkaline Dunedin Volcanic Group; Sources and
A32	**Ukstins** I et al.	Volatiles in nominally anhydrous mantle olivine from the Auckland Volcanic Field.
A33	**Coulthard Jr. D** et al.	Taranaki and Taupo titanomagnetite contain trace concentrations of structurally bound H2O
A34	**Swann J** et al.	To what extend does magmatic CO2 and H2O drive eruption style in the Kokowai 4 and 7 eruptions, Mt. Taranaki, New Zealand?
A35	**Davidson A** et al.	Insights into magmatic source properties for large-scale eruptions at Mt Taranaki – An isotope investigation
A36	**Ray L** et al.	Is Panitahi the new Mt Taranaki summit, or a transient magma leak?
A37	**D'Mello N**	Remobilization of cool mafic mushes by hot felsic melts: diverse primary melt compositions at Taranaki volcano, New Zealand
A38	**Elms HC** et al.	Timescales of Magmatic Processes at Ōkataina from Fe-Mg Diffusion in Orthopyroxene
A39	**Zellmer G** et al.	Origin of crystals in mafic to intermediate magmas from circum-pacific continental arcs: implications for the composition and origin of parental melts
A40	**Hughes E** et al.	Using a multi-volatile thermodynamic model to understand the effects of sulphur on silicate magmas
A41	**Georgatou A** & de Ronde C	Magma fertility in Brothers submarine volcano
A42	**Gruender K** et al.	Deep magma sources feeding eruptions from Red Crater (Tongariro, New Zealand): Geochemical insights from mineral chemistry and olivine-hosted melt inclusions
A43	**Cocker K** etal.	The magmatic history of Ngauruhoe Volcano from phenocryst records
A44	**Corella Santa Cruz CR** et al.	New comprehensive Pb isotopic data elucidate novel petrogenetic processes across the Taupo Volcanic Zone
A45	**Mauriohooho K** et al.	Sr-isotopic patterns in the north Taupo area: Persistent source influences on long-lived rhyolitic volcanism
A46	**Chatterjee A** & Daczko N	Hydrous shear zones in the lower arc crust are sites of melt transfer – A case study from George Sound shear zone

2c. Understanding climate & environmental change

A47	**Penafiel Bermudez S** & Cooper T	Re-defining the J hyperthermal event via paleoenvironmental analysis of early Eocene marl and limestone alternations from Mead Stream, New Zealand
A48	**Powell NG**	Is the Plenus Cold Event 'cooling greenhouse' transition an analogue for future global cooling geoengineered via ocean fertilisation and CO2 drawdown?
A49	**Wilsher C** et al.	A Magnetostratigraphy of the Eocene to Oligocene Orepuki-1 Core
A50	**Clement AJH** & Whitehouse PL	Working towards a model of the deglaciation of the Southern Alps icefield for investigating local GIA effects on Holocene relative sea-level changes
A51	**Stuthridge G** et al.	The glacial history of Lake Tennyson, North Canterbury, New Zealand
A52	**McDonald L** et al.	Understanding the causes of drought in New Zealand: The Skeleton Lake record of Holocene hydroclimate in southern New Zealand
A53	**Lalor M** et al.	Late Holocene records of climate change from Southern New Zealand
A54	**Hanson JM** et al.	A preliminary study of Late Holocene sedimentary records from Whakaraupō (Lyttelton Harbour)
A55	**Barker S** et al.	The climatic and environmental impacts of New Zealand supereruptions
A56	**Muir R** et al.	Paleotemperatures in Patagonia during the Antarctic cold reversal determined by glacial modeling
A57	**Reyes L** et al.	Using sediment cores to understand the environmental history of Aotearoa's lakes
A58	**Burns J** et al.	Paleomagnetism of Sediment Cores from Coulman High, Antarctica
A59	**Lutz F** et al.	How well can seismology measure ice anisotropy? A calibration experiment at the Priestley Glacier
A60	**Doyle I** et al.	Developing a flood-rich alluvial sediment archive to understand environmental change in the Whanganui catchment
A61	**Hilton TW** et al.	Hestia-AKL: An Inventory of Fossil Fuel CO2 Emissions for Auckland, New Zealand

2d. Integrated Coastal Dynamics

A62	**Denys P** & Pearson C	Coastal subsidence and uplift in New Zealand - Implications of vertical land motion on the coast
A63	**Clark K** et al.	Improving the marine reservoir age database for Aotearoa New Zealand to enable better chronologies of Holocene coastal change
A64	**Hamling I** et al.	A snapshot of New Zealand's dynamic deformation field derived from InSAR and GNSS observations and its influence on coastal vertical land movement
A65	**Lawrence MJF** et al.	Sedimentation patterns in a small modern anthropogenically-influenced estuary; Otuwhero Inlet, Abel Tasman
A66	**Ryan M** et al.	New insights into the sedimentation of the Wellington Basin (CBD) over the Last Glacial Cycle
A67	**Thomas M** & Gorman A	Seismic imaging of Quaternary sedimentary wedge at the mouth of the Clutha River

3c. Geoheritage of Aotearoa and the SW Pacific

A68	**Poojary S** et al.	Using palaeomagnetic techniques to uncover the history of an archaeological site in Napier, Hawkes Bay

3e. GeoEducation and Outreach

A69	**Dobson MJ** et al.	A Virtual Field Trip Teaching Model for Transdisciplinary Learning
A70	**Dreyer A** et al.	Educational role-playing simulation for volcanic crisis at Taupō Volcano for GSNZ2021 (Palmerston North)
A71	**Nahona S** et al.	The collaboration of mātauranga māori and geoeducation: an example from Tātaihia te Parataiao o Te Wahapū – Hokianga Harbour sedimentation project
A72	**Banerjee D** et al.	Student surveys inform digital device practices in field teaching
A73	**Tsang S** et al.	Primary school lessons for increased community resilience
A74	**Watson A** et al.	Insights from a volcanology virtual field trip to Iceland
A75	**Pee A** & Martin M	Development of a Virtual Reality Application for Gamified Environmental Education in Aotearoa New Zealand

4c. Engineering Geology/Geomorphology

A76	**Spiekermann R** et al.	Statistical landslide susceptibility modelling for pastoral hill country
A77	**Gnesko L** et al.	Understanding shallow instability in the Kaikoura Canyon using differential bathymetry and dynamic shear testing
A78	**Rozmus K** et al.	Coastal Cliff Retreat of the East Coast Bays Formation, Auckland with Sea-Level-Rise, New Zealand
A79	**Vaknin I** & Nicol A	What can we learn about fault geometries and growth mechanisms from a CT scan of a faulted rock?

4d. Geoscience for Future Energy Systems and Mineral Resources

A80	**Hameed A** et al.	Investigation of a large fill failure at an open-cast mine in the Waikato coal region
A81	**Hill MP**	Aggregate Opportunity Modelling for New Zealand
A82	**Hudson S** et al.	Vein textures and geochemistry of the Wharekirauponga (WKP) epithermal Au-Ag deposit, Hauraki Goldfield, Coromandel
A83	**Nersezova EE** et al.	Determining Mechanical and Textural Properties of Digitate Sinter from the Taupō Volcanic Zone.

	CONFERENCE PROGRAMME for WEDNESDAY, 01 December		
07.00	**REGISTRATION**		
08.00	**PLENARY 2 SSLB1** **Kim Martelli *"A Career in the Geosciences: A world of opportunities from exploration to engineering!"***		
	SSLB1	***SSLB2***	***SSLB3***
08.30-10.00	**2a. Natural Hazards** *Melody Whitehead; Stuart Mead; Mark Bebbington (Massey University)*	**4e. Geochemical Tools & Applications** *Sebastian Naeher (GNS Science); James Scott (University of Otago)*	**4c. Engineering Geology/Geomorphology** *Sam McColl (Massey University); Saskia de Vilder; Andrea Wolter; Kerry Leith (GNS Science)*
08.30-08.45	**Ardid A** et al. - Whakaari 2016, blue-sky eruption? New insights from tremor's feature correlations	**Bird M** - Abundance and isotope (^{13}C, ^{14}C) composition of Pyrogenic carbon ***(keynote)***	**Barrell D** & Lee J - Urban Geological Mapping at GNS Science
08.45-09.00	**Brooks-Clarke I** et al. - Mineralogical insights into hydrothermal eruption conditions at Rotokawa Geothermal Field, New Zealand		**Hill M** et al. - Scaled 3D geological modelling of Wellington to assist with engineering geology and understanding natural hazards.
09.00-09.15	**Dempsey D** et al. - Evaluation of a real-time automated system for probabilistic forecasts of phreatic eruptions	**Webster-Brown J** et al. - Wild Fire Geochemistry: Lessons for managing future impacts on water systems	**Stronach A** & Stern T - A New Basin-Depth Map of the Fault-Bound Wellington CBD Based on Residual Gravity Anomalies
09.15-09.30	**Fitzgerald R** et al. - Using pneumatic cannon experiments to understand volcanic ballistic hazard footprints	**O'Sullivan-Moffat H** et al. - Urban Methane Emissions in Auckland, New Zealand	**Leith K** et al. - Moving Beyond Pore Pressure: New Insights Into the Impact of Wetting on Fractured Rock
09.30-09.45	**Wild A** et al. - Short-term eruption forecasting for the Auckland Volcanic Field using a Bayesian Event Tree	**Anderson Johnson P** et al. - The Paleoceanography of the Tasman Sea during past Interglacials	**Kirk P** et al. - An evolving story of the geology of the Manawatū Saddle: Evidence from the Manawatū -Tararua Highway
09.45-10.00	**Bebbington M** & Jenkins S - Intra-eruption Forecasting Using Analogue Volcano and Eruption Sets	**Naeher S** et al. - Calibration of organic biomarkers as paleoenvironmental indicators in New Zealand lakes	**Taylor-Silva B** & Mackay S - Characterising South Auckland Geology
10.00-10.30	**Morning Tea**		

	SSLB1	*SSLB2*	*SSLB3*
10.30-12.30	**2a. Natural Hazards** *Melody Whitehead; Stuart Mead; Mark Bebbington (Massey University)*	**4e. Geochemical Tools & Applications** *Sebastian Naeher (GNS Science); James Scott (University of Otago)*	**4a. Computational Advances** *Stuart Mead (Massey University); David Dempsey (University of Canterbury)*
10.30-10.45	**Taylor-Offord S** & McDougal T- Stories of Expansion; 20 years of evolution and environmental change in the geonet sensor network	**Stirling C** - Biogeochemical Cycling of Trace Metals and their Isotopes: Links to Past and Present Climate Change ***(keynote)***	**Fry B** et al. - Physics to Resilience: Next Generation Earthquake and Tsunami Response ***(keynote)***
10.45-11.00	**Watson L** et al. - Infrasound Radiation from Impulsive Volcanic Eruptions: Nonlinear Aeroacoustic 2D Simulations		
11.00-11.15	**Bloom C** et al. - Evaluating Regional Earthquake Induced Landslide Susceptibility Parameters for New Zealand using a Machine Learning Approach	**Gangl S** et al. - Cd isotopes in carbonates deposited during 'OAE 2': Assessment of a novel palaeo-productivity tracer	**Wang X** et al. - COMCOT simulation model, its features and recent applications
11.15-11.30	**Boulton C** et al. - The upper crustal strength and stability of greywacke fault rocks: implications for earthquake rupture nucleation and propagation	**Rowe M** et al. - Strontium isotope ratios of New Zealand Kauri: An indicator of climate conditions?	**Holden C** - Seismic structural monitoring in Wellington using advanced seismological techniques
11.30-11.45	**Langridge R** et al. - The fault in our horizon: Regional active fault mapping updates 2018-2021	**Dobson MJ** et al. - Earth's oldest extraterrestrial impact? Evidence for a large impactor 3.48 billion-years-ago (Dresser Formation, Pilbara Craton, Australia)	**Huijser D** et al. - BIROC-H20: A new way to process FTIR spectra of olivine hosted basaltic melt inclusions
11.45-12.00	**Warren-Smith E** et al. - Heterogeneity in microseismicity and stress near repeated rupture terminations along the late interseismic Alpine Fault	**Höpker S** et al. - Organic controls on transition metals in cave waters and speleothems - insights from kinetic experiments	**Duran E** et al. - 3D Magnetic inversions constrained by Euler deconvolution solutions using simpeg
12.00-12.15	**Kissling W** et al. - Inter-caldera crustal permeability and thermal processes in the Taupō Volcanic Zone, New Zealand.	**Isson T** - Silica secreting organisms regulate climate on Earth	**Duncan N** et al. - Visualising Geological Samples Using MARS Spectral CT
12.15-12.30	**Howarth J** et al. - Quantitative lacustrine paleoseismology may reveal the rupture direction of the 1717 CE Alpine Fault earthquake	**Martin AP** et al. - A biochemical surface of New Zealand	**Mavroeidi M** & Rattenbury M - FAIR Principles applied to high-value geoscience datasets
12.30-14.00	**Lunch, meetings, poster viewing**		
13.00-14.00	Sedimentology SIG *Mark Lawrence/Karoly Nemeth*	Geochemistry SIG *Sebastian Naeher*	WOMEESA SIG *Jess Hillman*

	SSLB1	*SSLB2*	*SSLB3*
14.00-15.30	**2a. Natural Hazards** *Melody Whitehead; Stuart Mead; Mark Bebbington (Massey University)*	**2b. Our Changing landscapes** *Karoly Nemeth; Sam McColl (Massey University); David Barrell (GNS Science); Kevin Norton (VUW)*	**4b. Remote Sensing & Earth Observation** *Gabor Kereszturi (Massey University); Ian Hamling (GNS Science)*
14.00-14.15	**Kluger MO** et al. - Liquefied Tephra Layers In Lakes: A New Paleoseismometer ***(keynote)***	**Davidson D** et al. - Proximal Tsunami Sources Associated with Subducting Seamounts Along the Hikurangi Margin, New Zealand: Potential Drivers, Mechanics, and Hazard Implications	**D'Anastasio E** et al. - GeoNet huritau: 20 years of continuous GNSS Data in Aotearoa
14.15-14.30		**Fieman D** et al. - Quantifying the Influence of the M7.8 Kaikoura Earthquake-Induced Landslides on Cosmogenic Radionuclide Concentrations	**Johns B** & Cave M - New Zealand National Lidar and Regional Applications
14.30-14.45	**Chaneva J** et al. - Liquefaction Susceptibility Analyses of Lacustrine Tephra Soil Materials	**Kosik S** et al. - Landscape evolution and quantification of long-term erosion rates in the Hautapu River catchment, New Zealand	**Ilanko T** et al. - The versatility of low-cost, lightweight, Raspberry Pi-based tools for volcano monitoring
14.45-15.00	**McQuillan GR** et al. - The first search for seismic deformation of the Hinuera Surface, Hamilton Basin	**Rees C** et al. - Waitapu Shell Conglomerate (c. 0.9 Ma), Whanganui Basin	**Chakraborty R** et al. - Arsenic Zonation for Mineral Prospecting at Rise and Shine Shear Zone, New Zealand, using Hyperspectral Remote Sensing
15.00-15.15	**Pizer C** et al. - The Waimihia Eruption as an isochron for paleoseismology	**James Shulmeister** - Too low and too long: The problem of older glaciations in the Southern Alps	**Cao Y** et al. - Phase gradient based InSAR time-series analysis: hunting slow moving landslides triggered by the 2016 Kaikoura Earthquake
15.15-15.30	**Humphrey J** et al. - Earthquake Timings and Fault Interactions in Central New Zealand	**Prior D** et al. - Ice mechanics: what do we still need to know to model ice sheets?	**Williams F** et al. - InSAR for Landslide Monitoring: Combined Approaches Lead to Better Results
15.30-17.00	**Poster session/afternoon tea: SSLB Upper Foyer**		
	1c. Zealandia: B1-14 2a. Natural Hazards: B15-45 NSHM Special Symposium: B46-48	2b. Changing landscapes: B49-52 2e. Marine Environment: B53-63 3b. Hazard Communication: B64-67	4a. Computational Advances: B68-76 4b. Remote sensing: B77-81 4e. Geochemical tools: B82-88
17.00-18.00	**GSNZ AGM**		
18.30 19.00-late	*Busses depart Massey University* **Conference Gala Dinner Awapuni Racecourse**		

POSTERS (WEDNESDAY, 01 DECEMBER)

1c. Zealandia through space and time

B1	**Eberhart-Phillips D**	The influence of basement terranes on tectonic deformation: joint earthquake travel-time and ambient noise tomography of the southern South Island, New Zealand
B2	**Cooper N** et al.	Ultra-refractory mantle under the Southern Alps, and implications for modern and ancient continental lithosphere construction
B3	**Martin AP** et al.	The New Geological Map of the Hyde-Macraes Shear Zone and Waihemo Fault Zone area, northeastern Otago 1:50 000
B4	**Stratford W** et al.	The geometry of the Fiordland-Puysegur subduction zone
B5	**Parker M** et al.	Provenance of Miocene–early Pleistocene conglomerates in the northern Canterbury Basin
B6	**Collins NA** et al.	Once-in-a-Lifetime: Pliocene fossils of the Central Interceptor project, Auckland, New Zealand [Part A]
B7	**Stolberger T** et al.	Once-in-a-Lifetime: Pliocene fossils of the Central Interceptor project, Auckland, New Zealand [Part B]
B8	**Young G** et al.	Trace fossils on the St Bathans fauna: Using skeletal marks and pathologies to make palaeontological interpretations
B9	**Glowacki TM**	Forces changing the Lithosphere’s layout
B10	**Tateiwa K** et al.	The characteristics of source parameters of interplate earthquakes occurring in and around the Raukumara Peninsula in the North Island, New Zealand (2)
B11	**Lang J** et al.	Palaeoseismological investigations in regions of low strain using cave damage: A case study from central–western North Island (Waitomo caves), New Zealand
B12	**Macnaughtan M** et al.	Preliminary results of an avo analysis in the southern HSM: Insights into fluid and pressure regimes
B13	**McGregor R** et al.	Investigating the 2001 Taupō Fault Belt Seismic Swarm
B14	**Tagami A** et al.	Stress field in the Tohoku region, Japan and its relationship with faults of recent earthquakes (4)

2a. Natural hazards

B15	**Stanley A** et al.	Reconstructing the hydrothermal eruptive history and mechanisms of the Te Kopia geothermal field
B16	**Werner C** et al.	Is Taranaki Exhaling? Detecting Volatile Emissions from a Dormant Volcano
B17	**Scott E** et al.	Development of a Bayesian event tree for short-term eruption onset forecasting at Taupō Volcano
B18	**Asher C**	A low cost semi-autonomous aquatic rover for low pH, high temperature geothermal and volcanic waterways
B19	**Bakkar H** et al.	Temporal stress variations and volcano dynamics at Taupō Volcano measured by seismic anisotropy monitoring of volcanic activities in NZ
B20	**Alves LFN**	A compiled historical volcanic hazards database for Tongariro National Park, New Zealand
B21	**Sork A**	Short-Term Eruption Forecasting in New Zealand
B22	**Whitehead M** et al.	Stratigraphy and age of volcano-fluvial and tephra deposits associated with Te Puninga Fault, Morrinsville, Hauraki Basin

B23	**Hughes JW** et al.	Towards an updated paleoseismicity in Hamilton lowlands using liquefied tephra layers in lakes
B24	**Kluger MO** et al.	Comparison of visual approaches for determining pumice content of tephras for geotechnical investigation
B25	**Melchert RA** et al.	Cataloguing and promoting the national earthquake information database
B26	**Viskovic P** et al.	A Repeating Earthquake Catalogue for New Zealand
B27	**Chamberlain CJ** et al.	Hot takes on earthquake temperature rise and frictional energy
B28	**Coffey G** et al.	Periodic pore fluid pressure as a viable mechanism for the generation of slow slip events in velocity-strengthening faults
B29	**Perez A** et al.	Revising the magnitudes in the New Zealand earthquake catalogue to be consistent with moment magnitude
B30	**Christophersen A** et al.	Reconstructing landslide-generated lacustrine tsunami resulting from major Alpine Fault earthquakes
B31	**Hughes KE** et al.	The history of earthquake and tsunami monitoring on Rēkohu-Wharekauri-Chatham Islands from 1932 to 2021
B32	**Johnston D** & Gledhill K	Mapping Stress Drop Variations Along the Alpine Fault to Investigate Conditional Rupture Segmentation
B33	**Juarez-Garfias IdC** et al.	A Paleoseismic Investigation of the Long Valley Fault, Central Otago
B34	**Meyer F** et al.	WELLVEL: WELLington Region Water WELLbore Levels And Seismic VELocity Changes
B35	**Savage M** et al.	Recent surface rupturing earthquakes along the south flank of the Greater Caucasus near Tbilisi, Georgia
B36	**Stahl T** et al.	Earthquakes and seismic hazard in southern New Caledonia, southwest Pacific
B37	**Chin S-J** et al.	The Southern Alps Long Skinny Array (SALSA): Virtual Earthquake Analysis of the Alpine Fault between Milford Sound and Maruia
B38	**Townend J** et al.	An Empirical Approach to Modelling Multi-Fault Earthquakes
B39	**Walsh E** et al.	Reconstructing Seismic Shaking and Storm Events in Lake Gunn
B40	**Wilson-Harding I** et al.	Fault ruptures triggered by large rhyolitic eruptions at the boundary between tectonic and magmatic rift segments: The Manawahe Fault, Taupō Rift, New Zealand
B41	**Villamor P** et al.	How do fault surface ruptures influence flooding hazards?
B42	**Murray E** et al.	Investigating and modelling fault-rupture induced river avulsions (f.i.r.a)
B43	**Roger J** et al.	The Pacific-wide tsunami triggered by the Mw 8.1 Raoul Island earthquake in the 5 March 2021 triplet of tsunamis
B44	Schacherer L, **Leith K** et al.	A Landscape-Age-Aware Model of Potential Rock Slope Instability in Kaikoura, NZ
B45	**Salichon J** et al.	GeoNet 20th Anniversary: A walk-through the GeoNet earthquake catalogue and its evolution

SPECIAL SYMPOSIUM NSHM Revision Project

B46	**Coffey G** et al.	Derivation of paleoearthquake recurrence intervals as inversion constraints in NZ NSHM 2022
B47	Rastin SJ, …, **Rollins C** et al.	Distributed seismicity modelling for the New Zealand National Seismic Hazard Model 2022
B48	**Thingbaijam KKS** et al.	Shape of average coseismic slip profiles

2b. Our changing landscapes

B49	**Coursey S** et al.	Post-glacial geomorphic evolution of the Lake Wakatipu delta
B50	**Nisbet E** et al.	Developing a palaeo-reconstruction of deep-seated, slow moving landslides in the Whanganui Basin
B51	**Österle J** etal.	Using cosmogenic radionuclides and fission-track thermochronometry to benchmark human-enhanced erosion in a time of rapid climate change
B52	**Ross C** et al.	The influence of clay mineral properties on expansion in Southland soils, New Zealand

2e. The marine environment of Aotearoa

B53	**Boettger L** et al.	The Slow Meltdown of Gas Hydrates
B54	**Oluwunmi PA** et al.	Numerical simulation of methane production from an interbedded gas hydrate reservoir in the southern end of the Hikurangi Margin of New Zealand.
B55	**Warnke F** et al.	Geologic Champagne: Enigmatic Seafloor Pockmarks On The Chatham Rise
B56	**Ribó M** et al.	Repeat seabed mapping: Understanding complex morphological changes in seafloor bedforms
B57	**Watson SJ** et al.	Regional-scale mapping of landslide deposits in marine seismic reflection data
B58	**Spain E** et al.	Geomorphic time series reveals the constructive and destructive history of Havre Caldera, Kermadec Arc
B59	**Shorrock A** et al.	Gravity flow pathways towards IODP Site U1520 in the northern Hikurangi Margin
B60	**Seabrook S** et al.	Microbial Markers of Human Disturbance: Current knowledge and future potential
B61	**Hillman J** et al.	The human footprint on the seabed: Case studies from the Southern Hikurangi
B62	**Doyle O** & Reid C	Local variation of Foraminiferal abundance in Lyttelton Harbour/Whakaraupō
B63	**Kortink M** et al.	The NZ DART deep ocean tsunameter network and the many ways to trigger it

3b. Connecting & Communicating about Geohazards and risks

B64	**Garlick E** & Horne S	Twenty years of GeoNet public information
B65	**Hornblow S**	Communicating findings of South Dunedin geological drilling and aquifer testing to stakeholders and the public
B66	**Naguit M** et al.	GeoNet's Strong Motion Network: 20 Years of Seismic Data, Products and Service
B67	**Patel J** et al.	Erionite in New Zealand: geological occurrence, mineralogical character and a preliminary risk assessment

4a. Computational advances in Geosciences

B68	**Burton C** & Planka M	2001: A Data Packets Odyssey; 20 Years of Evolution and Technological Advancements in the GeoNet Communications Network
B69	**Williams C** et al.	A 10-year catalogue of slow slip events at the Hikurangi Subduction Margin (2006-2016)
B70	**Steinke B** et al.	Identification of Seismo-volcanic Regimes at Whakaari (New Zealand) via Systematic Tuning of an Unsupervised Classifier
B71	**Holden C** et al.	Testing Earthquake Early Warning Systems for New Zealand
B72	**Howell A** et al.	Towards an automated workflow for the creation of 3D models of fault networks
B73	**Hansen K** et al.	The visualization of geological and geophysical data in a 3D virtual reality environment
B74	**Chambers C** et al.	Material and structural investigation of fossils using MARS spectral CT
B75	**Contla Hernandez B** et al.	Geochemistry: What can it tell us about the next eruption?
B76	**Mead S** & Kereszturi G	Generative adversarial networks to forecast debris avalanche hazard

4b. Remote Sensing and Earth Observation for Geological Applications

B77	**Simpson I**	GeoNet now - part of the fabric of New Zealand
B78	**Ma Y**	Automated detection of slow slip events in GPS time series with a novel change-point detection method
B79	**Rodriguez-Gomez C** et al.	Remote sensing techniques to map plant behaviour at Waiotapu Geothermal Field
B80	**Stevenson T** et al.	A synthesis of shield volcano evolution based on a 3D lithological reconstruction of Heyward Promontory, Dunedin, NZ
B81	**Zhang R** et al.	The volume relationship between monogenetic volcanic cone and its associated lava flow: Digital Elevation Model-based analysis

4e. Geochemical tools and applications

B82	**Ginnane CE** et al.	Refining the Bulk: Ongoing Developments in Ramped Pyrolysis Radiocarbon Measurements and Complementary Analyses
B83	**Turnbull JC** et al.	70 years of radiocarbon and greenhouse gas measurements in New Zealand
B84	**Scott JM** et al.	Buried swamps reveal rapid post-LGM Holocene sea-level rise in Westland, South Island
B85	**Brodnax R** etal.	Spatial and Temporal Variations in Metal-Ligand Complexation, Reconstructed from Speleothems
B86	**Kaith R** et al.	Factors Affecting Fate of Erionite in Soils
B87	**Turnbull R** et al.	Dunedin city’s legacy of lead
B88	**Lowe D** et al.	Who Discovered The Cause of “Bush Sickness”, The Animal-wasting Disease Associated Mainly With Pumice Soils and Some Other Soils in New Zealand?

	CONFERENCE PROGRAMME for THURSDAY, 02 December		
07.00	**REGISTRATION**		
08.45	**PLENARY 3 SSLB1** **Hollei Gabrielsen *"Herenga tangata, hononga ki te whenua."***		
	SSLB1	***SSLB2***	***SSLB3***
08.30-10.00	**2a. Natural Hazards** *Melody Whitehead; Stuart Mead; Mark Bebbington (Massey University)*	**2e. Marine Environment of Aotearoa** *Jess Hillman (GNS Science); Sally Watson (NIWA)*	**1b. Igneous Petrology & Geochemistry** *Georg Zellmer; Carlos Santa Cruz (Massey University)*
08.30-08.45	**Delano J** et al. - Exhuming interest in the 1987 Egdecumbe earthquake	**Crutchley G** et al. - Structural traps and local tectonic stress fields controlling fluid flow, gas hydrate formation and methane seepage: New Zealand's southern Hikurangi margin	**Burgin D** et al. - Deciphering the Martian mantle from in-situ 87Sr/86Sr measurements on shock melted plagioclase in Martian meteorites
08.45-09.00	**Pita-Sllim O** et al. - Spatiotemporal analysis of repeating earthquakes near Porangahau, Hikurangi Margin, New Zealand	**Hillman JIT** et al. - Defining the southern end of the Hikurangi Margin gas hydrate province	**Rattenbury M** et al. - Pluton Map characterisation of New Zealand's intrusive rocks
09.00-09.15	**Power W** et al. - The 2021 update to the National Tsunami Hazard Model	**Davy B** et al. - Sub-bottom Profiler Dating of Glacial Horizons and the Timing of Carbonate Mound Formation on the Southern Hikurangi Margin ***(keynote)***	**Wu J** et al. - Magmatic processes inferred from olivine xenocrysts from the Auckland Volcanic Field, New Zealand
09.15-09.30	**Seebeck H** et al. - Geologic Earthquake and Tsunami Modelling of the Active Cape Egmont Fault Zone		**Baxter RJM** et al. - Final depth of magma residence under Iceland regulated by magma flux.
09.30-09.45	**Kaiser A** et al. - Capturing Local Ground Motions in Seismic Hazard: The Wellington Basin Case Study	**Kroeger KF** et al. - Sub-seafloor gas generation and migration and gas hydrate formation mechanisms at the Hikurangi Margin, New Zealand	**Brahm Scott R** et al. - Progressive dehydration reaction of the slab tracked by across-arc variations in olivine-hosted melt inclusions
09.45-10.00	**Hughes L** et al. - Assessing tsunami hazard in New Zealand using a long time scale synthetic earthquake catalogue	**Seabrook S** & Torres M - Marine Seeps in Changing Environments	**Rebecchi M** et al. - Diffusive re-equilibration of mafic elements in the lead-up to the world's youngest basaltic Plinian eruption: the 2019 eruptive sequence at Ulawun volcano, Papua New Guinea
10.00-10.15	**Gusman A** et al. - Tsunami source model and forecasting of the 2021 Loyalty Island earthquake	**Nodder SD** et al. - Importance of near-bed lateral processes in biogenic fluxes to the seafloor in Aotearoa New Zealand deep-water environments	**Seropian G** et al. - A century of ongoing silicic volcanism at Cordón Caulle, Chile: new constraints on the magmatic system's depth
10.15-10.30	**Griffin J** et al. - Slip rates for the Hyde and Dunstan Faults, southern New Zealand, revealed by cosmogenic radionuclide dating	**Hill TA** et al. - Determining the preconditioning and triggering mechanisms of submarine landslides on anticlinal thrust ridges, offshore of the Southern Wairarapa coast.	**Smithies S** et al. - Following magma: the pathway of silicic magmas during an ignimbrite flare-up, Taupō Volcanic Zone

10.30-11.00	**Morning Tea**		
	SSLB1	***SSLB2***	***SSLB3***
11.00-13.00	**Special Symposium NZNSHM 2022** *Matt Gerstenberger; Russ Van Dissen (GNS Science)*	**2e. Marine Environment of Aotearoa** *Karsten Kroeger (GNS Science); Sarah Seabrook (NIWA)*	**1c. Zealandia through space & time** *Dominic Strogen (GNS Science); James Crampton (VUW)*
11.00-11.15	**Gerstenberger M** et al. - An update on the 2022 NSHM Revision Project	**Whitten C** et al. - Nature vs Nurture - Quantifying Evolutionary Rate and Ecophenotypic Variation in Pelicaria vermis	**Scott JM** - What lies beneath? Zealandia's lower lithosphere ***(keynote)***
11.15-11.30	**Seebeck H** et al. - New Zealand Community Fault Model v1.0	**Hayward BW** et al. - Foraminiferal insights into the 2016 Kaikōura turbidity currents	
11.30-11.45	**Nichols A** et al. - What do large earthquakes look like in New Zealand and how should they be incorporated into our National Seismic Hazard Model?	**Orpin A** et al. - Using the 2016 Kaikōura earthquake to test hypotheses that underpin turbidite paleoseismology	**Stern T** et al. - Seismic properties of the lithospheric mantle under New Zealand: some tectonic implications
11.45-12.00	**Wallace L** et al. - Geodetic deformation model for the 2022 New Zealand National Seismic Hazard Model	**Shorrock A** et al. - Stratigraphic evolution of a northern Hikurangi Margin trench-fill sequence during the late Quaternary	**Sagar M** - Zircon fertility and yield of plutonic suites and implications for provenance studies, Te Riu-a-Māui/Zealandia
12.00-12.15	**Rattenbury M** & van Dissen R - Fault orientation and length analysis for informing regional distributed seismicity potential and ground motion	**Carey J** et al. - Laboratory simulations of slip behaviour in Hikurangi Subduction Zone sediments in response to earthquakes and elevated pore-fluid pressures	**Crampton J** & Tulloch A - Pointing the Finger at Mesozoic Subduction Termination in Marlborough
12.15-12.30	**Rollins C** et al. - Constraining the rates of large, moderate and small earthquakes in New Zealand for the 2022 National Seismic Hazard Model	Mackay M, **Roperez J** et al. - Seafloor Mapping in New Zealand and the Rest of the World	**Sahoo T** et al. - Evolution of Cretaceous normal faulting in the Great South Basin
12.3012.45	**Thingbaijam K** et al. - Development of a seismogenic slab model for New Zealand	**Ribo M** et al. - Microplastics in Marine Sediments: Findings from the First Study around Aotearoa / New Zealand	**Shalla Y** et al. - Evidence of Volcanic-Tectonic Interactions on a Newly Identified Fault in the Reporoa Basin, Taupō Volcanic Zone, New Zealand
12.45-13.00	**Kaiser A** et al. - Capturing local ground motions in seismic hazard: the Wellington basin case study	**Watson SJ** et al. - Anchoring by high-tonnage vessels: a global driver of seabed damage	**Strogen D** et al. - Paleogeographic evolution of Zealandia: mid-Cretaceous to present
13-14.30	**Lunch**		
13.30-14.00	**GEONET 20th ANNIVERSARY LECTURE (*SSLB1)***		

	SSLB1	*SSLB2*	*SSLB3*
14.00-15.30	**3b. Connecting & Communicating about Geohazards and Risks** *Sally Potter (GNS Science); Alana Weir (University of Canterbury)*	**3c. Geoheritage** *Karoly Nemeth (Massey University; Geoconservation Trust Aotearoa); Ilmars Gravis (Geoconservation Trust Aotearoa); Chris Twemlow (Geoconservation Trust Aotearoa; Department of Conservation)*	**1c. Zealandia through space & time** *Dominic Strogen (GNS Science); James Crampton (VUW)*
14.30-14.45	**Charlton D** et al. - Co creating a volcanic hazard mapping framework for Aotearoa New Zealand	**Zakharovskyi V** & Nemeth K - The quick method to identify the most valuable geosites	**Hirschberg H** & Sutherland R - Kinematic Model of New Zealand from Fault Slip Rates
14.45-15.00	**Calderon R** et al. - Disaster Risk Management Scenarios for caldera volcanoes in Taupō Volcanic Zone	**Gravis I** et al. - The Geoconservation Trust Aotearoa. Integrating geosciences, conservation, education, tourism, sociology, and art in New Zealand and the South Pacific	**Upton P** et al. - Marlborough Fault System: a complex 4D transition zone in central New Zealand illuminated by topographic fabric
15.00-15.15	**Potter SH** et al. - Connecting real-time hazard and impact data with users: Exploring user needs	**Nemeth K** - Volcanic geoheritage in the light of volcano geology	**van Wijk** K - Seismic methods to present the crust of the Auckland Volcanic Field in three dimensions
15.15-15.30	**Lake-Hammond A** & Orchiston C - Sharing the Science Beneath Our Feet: Preparing for the next Alpine Fault earthquake	**Williams S** et al. - Building the case for geoheritage as a tool for tsunami hazards risk resilience in a southwest Pacific Islands context	**Xavier-Conceicao FA** et al. - Geophysical Characterization and Modeling of Metamorphic and Sedimentary Units in East Timor: Insight into Tectonic and Basin Evolution
15.30-16.30	**CLOSING CEREMONY SSLB1** Conference Convenors, 2021 Committee and GSNZ NZJGG speech and Best Student Talks Best Student Posters presented by VRS		

ABSTRACTS

IN ALPHABETIC ORDER BY FIRST AUTHOR

THE PALEOCEANOGRAPHY OF THE TASMAN SEA DURING THE LAST INTERGLACIALS

Patty Anderson[1], Gavin Dunbar[1] and Sebastian Naeher[2]

[1]Victoria University of Wellington, Antarctic Research Centre, Wellington, New Zealand
[2]GNS Science, Lower Hutt, New Zealand

patty.andersonjohnson@vuw.ac.nz

Ninety-eight percent of the past million years has been colder than today. Although not perfect future analogues, two short windows of warmer-than-modern conditions exist in Marine Isotope Stage 5e (MIS5e~125ka) and MIS11 (405ka). Analysis of sea surface temperature (SST) in the southern East Australian Current (EAC), shows MIS5E and 11 have different SST responses to warming, suggesting more than one warming 'pathway' is possible in the SW Pacific. These past analogues may help us better understand future climate changes in New Zealand (NZ).

Using samples from MIS5e and 11 from DSDP/ODP sites in the Tasman Sea that lie under different sectors of the EAC and the Tasman Front, we look to reconstruct ocean heat transport in these interglacials. We aim to compare the results with selected NZ terrestrial sites that cover the same time period in order to reconstruct, and then compare and contrast the oceanography and NZ climatology of these super-warm interglacial periods with each other and numerical simulations.

Our analytical approach is based on foraminiferal $\delta_{18}O$ combined with biomarker-based ocean temperature proxies (e.g. alkenone unsaturation, GDGTs) and a similar biomarker process for terrestrial lake sediments. We will present our preliminary findings at the conference.

ORAL
Session 4e.

WHAKAARI 2016, BLUE-SKY ERUPTION?
NEW INSIGHTS FROM TREMOR'S FEATURE CORRELATIONS

<u>Alberto Ardid</u>[1], Shane Cronin[2] and David Dempsey[1]

[1] *Department of Civil and Natural Resources Engineering, University of Canterbury, New Zealand*
[2] *School of Environment, University of Auckland, New Zealand*

alberto.ardid@canterbury.ac.nz

Seismic tremor on volcanoes offers the greatest potential to rapidly identify precursors heralding imminent eruptions. New Zealand's Whakaari volcano is monitored by the GeoNet seismic network. Of seven eruptions recorded during the last decade, precursors for most were identified by a recently developed, automated pattern-recognition routine (Dempsey et al., 2020). However, a shallow-vent, hydrothermal eruption in 2016 could not be forecasted, likely due to a lack of magmatic priming. This event was sudden, explosive and generated a significant pyroclastic surge. Identifying such 'blue-sky' eruptions is of prime importance for effective risk management perspective.

To explore precursory activity in a different way than previous methods, we developed a correlation analysis between time-series features calculated from seismic records one month before five Whakaari eruptions as well as a total of 18 eruptions from other New Zealand, Alaskan and Kamchatkan volcanoes. The time series features are calculated by subdividing tremor data into sliding 48-h windows and computing for each window 706 statistical parameter named 'features' (e.g., mean, variation, Fourier coefficients, etc.). This creates a new time series that can be tested between volcanoes. If similar patterns are discovered, these may point to a common underlying pre-eruptive process.

Our results reveal several new precursors for the 2016 Whakaari eruption through strong correlations between feature behavior at different eruptions. The 2016 Whakaari eruption not only shares similarities with other Whakaari eruptions, but also with eruptions at Ruapehu and Veniaminof in Alaska.

The next step is to expand our eruption catalogue to strengthen eruption correlations from a wider range of international volcano observations. This research set the scene for a generalizable volcano forecasting approach, with models trained on time series features of pre-eruptive signals across multiple eruption styles and settings.

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ORAL
Session 2a.

A LOW COST SEMI-AUTONOMOUS AQUATIC ROVER FOR LOW PH, HIGH TEMPERATURE GEOTHERMAL AND VOLCANIC WATERWAYS

Cameron Asher[1]

[1] *GNS Science, Taupo, New Zealand*

c.asher@gns.cri.nz

With increasing focus on risk mitigation in volcanic and geothermal monitoring, innovative techniques and equipment to change the way we conduct field work are strongly desired. One aspect that has ample room for improvement is work on and around volcanic and geothermal lakes These pose a risk due to their high temperatures, acidic waters, and potential for eruptive activity. Typical field activities around these bodies of water are conducted in-person and focused at the water-edge or, in some cases, in small occupied boats.

This study develops a semi-autonomous aquatic rover, primarily designed for bathymetry mapping, but scalable for other scientific monitoring equipment, such as water sampling and gas measurements. The rover is required to be low cost, rapidly and remotely deployable, easily replaceable, and ultimately reduce risk to field staff by reducing exposure. Case studies of field applications are presented, showing reproducibility of results, simplicity of surveys, and quantification of risk reduction to field staff.

POSTER
Session 2a.

TEMPORAL STRESS VARIATIONS AND VOLCANO DYNAMICS AT TAUPŌ VOLCANO MEASURED BY SEISMIC ANISOTROPY

Henriette Bakkar[1], **Martha Savage**[1] **and Finnigan Illsley-Kemp**[1]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand*

bakkahenr@myvuw.ac.nz

Taupō volcano is responsible for Earth's youngest super-eruption 25.5 ka ago and is still considered an active volcano with the last eruptive event ~1800 years ago. In recent years, volcanic unrest periods have been observed by seismic swarms and crustal deformation in the caldera (Illsley-Kemp et al., 2021). The high rates of magma production combined with the historically active behavior of the volcano and the rising local population requires an improved knowledge of volcanic unrest. The existence of areas of dense fractures, hot and highly pressurized fluids, and melt-bodies is typical of volcanic regions in the upper crust. These features and their temporal changes can be detected by the passage of seismic waves through the media and the continuous background seismic noise. Drastic changes in the preferential orientation of the fast polarized waves have been identified prior to eruption or dike emplacements in several volcanoes (Gerst & Savage, 2004; Roman & Gardine, 2013; Savage et al., 2015). Previous research in the Taupō Volcanic Zone have determined a preferential orientation of the fast polarized wave parallel to the rifting structures (Audoine et al., 2004; Illsley-Kemp et al., 2019) and the maximum horizontal stress determined with focal mechanisms (Townend et al., 2012; Johnson et al., 2010). However, in the Central TVZ, seismic anisotropy does not correspond with the regional tectonic stresses and has been related to a local magmatic stress source (Illsley-Kemp et al., 2019). Therefore, temporal variations in the fast polarized shear-wave will be measured using 20 Geonet stations around Taupō volcano using MFAST software (Savage et al., 2010) for a 10-year earthquake catalogue. These temporal variations will be correlated with low frequency time series using Real-Time Seismic Energy-Measurement (RSEM) and Seismic-Spectral Amplitude-Measurement (SSAM) from continuous data recorded at station RATZ. Temporal analysis of principal stress correlated with volcano dynamics could provide clues of the nature of the stress behavior in the Central Taupō Volcanic Zone.

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POSTER
Session 2a.

STUDENT SURVEYS INFORM DIGITAL DEVICE PRACTICES IN FIELD TEACHING

Dona Banerjee[1], Tim Stahl[1], Heather Purdie[1], Sam Hampton[1,3,4], Kate Pedley[1], Ben Kennedy[1], Jonathan Davidson[1], Erik Brogt[2]

[1] *School of Earth and Environment, University of Canterbury, New Zealand*
[2]*Academic Development, University of Canterbury, New Zealand*
[3]*Frontiers Abroad, Christchurch, New Zealand*
[4]*VolcanicKED, Christchurch, New Zealand*

A substantial rise in the use of digital devices has been observed over the past two decades across all disciplines in tertiary education. Relatively few studies have documented the many variables that influence student experience and perceptions of learning in field settings. We surveyed c. 100 students and staff using devices in one-day, multi-day, and research-based field trip courses at the University of Canterbury over two years. Pre- and post-trip questionnaires, as well as thematic analysis of open-ended responses, were evaluated to determine (i) differences between trip setting and duration, (ii) advantages and disadvantages of Bring-Your-Own-Device (BYOD) vs. We-Bring-A-Device (WeBAD), and (iii) how students perceived the devices assisted their navigation and communication skills. In general, students on multi-day and research trips found devices more useful than on one-day trips, particularly when the use of the device was specific and its role clearly distinguished from that of traditional methods for navigation and data collection. Students variably preferred BYOD (for familiarity and ownership of data) or WeBAD (for memory, durability, and overall performance). Based on our data, digital device use in the field can be best adapted to two end-member scenarios: basic GPS and geotagged photos as a supplement to traditional field mapping, and custom data collection (e.g., for research projects). We developed a teaching framework that outlines best practices when incorporating devices in field-based geoscience courses and provide a case study of how we used the framework to facilitate a self-guided field trip during COVID restrictions in Christchurch. The work adds to a growing body of evidence that technology can be useful in education so long as educators carefully consider pedagogy and put evidence-informed practice ahead of novelty (e.g., Sutcliffe, 2021).

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POSTER
Session 3e.

NEWLY IDENTIFIED MAFIC AND FELSIC TUFFS FROM THE EARLY - MID PERMIAN, SOUTHERN SYDNEY BASIN: EXPLOSIVE VOLCANISM DERIVED FROM NORTHWEST ZEALANDIA.

Glen Bann[1], Brian Jones[1] and Ian Graham[2]

[1]School of Earth, Atmospheric and Life Sciences, University of Wollongong, Wollongong, NSW, 2522, Australia
[2]School of Biology, Earth and Environmental Sciences, University of NSW, Kensington, NSW, Australia

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The Sydney Basin forms the most southern exposed area of the Permo-Triassic East Australian Rift System which extended along the eastern margin of Gondwana. A suite of newly identified mafic and felsic tuffs are described from the Early – Mid Permian Shoalhaven and Talaterang Groups of the southern Sydney Basin. This includes the Clyde Coal Measures, Wasp Head, Pebbley Beach and Snapper Point Formations, Wandrawandian Siltstone, Nowra Sandstone, Berry Siltstone and the lower Broughton Formation.

The mafic tuffs commonly comprise abundant biotite and muscovite grains, which are often deformed, K feldspar, plagioclase, volcanic quartz, with embayments, quartz shards, and rare euhedral zircons. The felsic tuffs contain abundant volcanic and metamorphic quartz, plagioclase, more common pumiceous material, less micas, and very rare or absent, shards. Trachytic microclasts are common with rare rhyolitic material, in both tuff types. All tuffs contain various amounts of carbonaceous material and are commonly reworked, although a lack of abrasion on the phenocrysts in the mafic tuffs suggests a proximal source. Many tuffs are associated with bioturbation and body fossils, including death assemblages. Numerous dropstones of the same tuff material are common throughout the sequence, with volcanic clasts usually dominating in the east and metamorphic cratonic clasts in the west. The presence of *Cruziana* ichnogenera and glendonites throughout the succession, in addition to wavy contact surfaces beneath coarser sands and clasts suggest deposition was dominated by episodic storm activity in cold climate marine conditions with periodic coastal ice sheets depositing the clasts, or dropstones. Crossbedding in the sandstone units indicate a predominantly northerly palaeocurrent direction.

The felsic tuffs represent small or distal components of much larger volcaniclastic aprons surrounding vents to the southeast, within the northwest Zealandia craton, possibly associated with the Western Eastern Province Terranes, such as the Brook Street Terrane, or the more felsic Median Batholith and associated volcanism, or, is yet to be discovered. The source for the mafic tuffs is more proximal, from island volcanoes to the south and southeast of the exposed Sydney Basin. Detritus from these volcanoes periodically inundated the cratonic sediments, that were predominantly derived from the west.

Volcanism was therefore influencing the earliest stages of the evolution of the southern Sydney Basin, much earlier than previously recognized.

ORAL
Session 1a.

THE CLIMATIC AND ENVIRONMENTAL IMPACTS OF NEW ZEALAND SUPERERUPTIONS

Simon Barker[1], Stephen Piva[1], Holly Winton[1], Colin Wilson[1], Rewi Newnham[1], Lionel Carter[1], Nels Iverson[2], Alexa Van Eaton[3], Larry Mastin[3], Michael Sigl[4]

[1] *Victoria University of Wellington, Wellington, New Zealand*
[2] *Mew Mexico Institute of Mining and Technology, Socorro, New Mexico, USA*
[3] *Cascades Volcano Observatory, United States Geological Survey, Vancouver, Washington, USA*
[4] *University of Bern, Bern, Switzerland*

simon.barker@vuw.ac.nz

Rapid changes in Earth's climate have been documented after historic explosive volcanic eruptions. However, the magnitude of explosive eruptions in the geological record far exceeds those witnessed in modern history, by up to one hundred times. Through simply scaling the measured impacts of historic volcanic eruptions, it has been proposed that high-magnitude volcanic "supereruptions" may have caused major shifts in Earth's past climate and severely impacted the environment. We are investigating three NZ supereruptions that spread ash across most of NZ and are exceptionally well preserved in several high-resolution palaeoenvironmental records including marine cores, terrestrial sediment and lake records and Antarctic ice cores: the 25.5 ka Oruanui (1150 km^3 ash), 350 ka Whakamaru (~3000 km^3 ash) and ~1 Ma Kidnappers (~2000 km^3 ash) supereruptions. Using multiple climate and environmental proxies in these records we will assess the impact of past NZ supereruptions across a range of climate conditions and geographical scales. First, we will model ash plumes and deposition from past supereruptions to assess eruptive conditions and the total release of volatiles. Second, we will investigate regional impacts on NZ vegetation and landscapes by looking at mm-scale changes in pollen records from NZ lakes and bogs. Third, we will assess multiple Antarctic ice cores records that preserve vital insights into the climactic impacts of a supereruption over short, medium and long time intervals. In this presentation we will highlight our preliminary findings and discuss our methodologies and future research opportunities.

POSTER
Session 2c.

URBAN GEOLOGICAL MAPPING AT GNS SCIENCE

David Barrell[1] **and Julie Lee**[2]

[1] *GNS Science, Dunedin, New Zealand.*
[2] *GNS Science, Lower Hutt, New Zealand.*

d.barrell@gns.cri.nz

GNS Science's Urban Geological Mapping project, supported through the Government's Strategic Science Investment Fund, is compiling geoscientific datasets for selected New Zealand urban centres. These datasets provide foundational information on the geological materials and structure of the target areas, geared towards practitioners in geotechnics, hazard assessment and risk reduction, and sustainable resource utilization, development and planning. Various factors are considered for selecting target areas. These include where there is a need for improved geological maps, where there are notable geological or geotechnical issues or where significant urban expansion is in progress or planned. Current target areas are Dunedin, Napier-Hastings, Auckland, and Queenstown.

The urban geology data products are tailored to the nature of each urban area, for example Queenstown's setting in a glacier-scoured basin in schist terrain compared to Auckland's highly varied Mesozoic-Cenozoic geology with capping Quaternary volcanics. Typical component datasets are a geological map, a geomorphological map, and representations of the subsurface geology in the form of cross sections, structural contours and/or digital 3D geological models. Available borehole data are compiled to assist in geological interpretation and subsurface modelling. Explanatory texts accompany these datasets. The data products are published as part of the GNS Science Geological Map series in digital-only formats that can be accessed from GNS Science servers or downloaded from the GNS Science website,

The data products will be completed and issued for each urban area, and any future updates will be done as a date-versioned new edition.

Rather than focusing on detailed geological maps at a specific scale, the project aims to provide a geological, stratigraphic and geomorphological framework for each urban area and convey 2D, 3D and 4D understanding of the geology. This is intended to give the products greater utility, and we hope longevity, in providing bigger-picture geological context for more detailed, site-specific, investigations.

ORAL
Session 4c.

FISHING FOR ANSWERS FROM ARTIFICIAL VOLCANIC FISSURES.

R.J.M. Baxter[1,2], R.P. Cole[1,3], J.D.L. White[1], M.H. Bowman[1], T. Dürig[3], B. Pooley[1], Farra Engineering[4], S.J. Cronin[5], M.T. Guðmundsson[3], G.S. Leonard[6], G.A. Valentine[7]

[1] *Department of Geology, University of Otago, Dunedin, New Zealand*
[2] *Department of Earth Sciences, University of Cambridge, Cambridge, UK*
[3] *Institute of Earth Sciences, University of Iceland, Reykjavik, Iceland*
[4] *Farra Engineering, 43 Cresswell Street, Dunedin, New Zealand*
[5] *School of Environment, University of Auckland, Auckland, New Zealand*
[6] *GNS Science, Lower Hutt, New Zealand*
[7] *Department of Geology and Centre for Geohazard, University at Buffalo, Buffalo, USA*

r.j.m.baxter@gmail.com

Potentially rapid and unpredictable evolution of volcanic fissure eruptions complicates hazard management. Initial fissures erupt magma through cracks that can be many kilometres long until discrete vents form, hours to months later. Magma localisation is influenced initially by fissure geometry, then physical and thermal feedbacks including wall rock removal and magma solidification. We built the first lab-scale model volcanic fissure able to investigate the influence of fissure shape and wall rock temperature on thermal focusing and flow localisation. We can conduct long-running experiments to test feedback mechanisms and sensitivity of the system to variations in these parameters. The Artificial Fissure (ArtFish) is 2 m long, 1.5 m tall, with variable slot width of 0-20 mm. One wall of the fissure comprises 70 independent plates each with adjustable temperature and position, facilitating numerous potential experiments. We use as the analogue fluid molten polyethylene glycol (PEG 600), with temperature-dependent viscosity, and solidifying at ~ 22 °C.

Initial ArtFish experiments tested its function as an analogue model for natural fissures. Importantly, we show that our key variables, fissure shape, wall temperature and fluid flow rate, can be controlled. Simple to complex configurations exemplify the range of experiments possible with the device. Additional key features, such as a stable and planar fluid feeding system, fluid recycling, and use of particle tracers for flow monitoring, are also proven. Spatial and temporal thermal evolution of the fissure is measured by thermal sensors in each wall unit. Solidification and flow localisation progress is recorded on video, with tracers successfully illustrating diverging and converging flow patterns around obstructions and decreasing flow rates at the fluid-wall interface as solidification progresses. ArtFish can model a wide range of natural scenarios and will assist hazard planners with forecasting loci where eruptions can focus and how fissures may evolve.

POSTER
Session 1a.

FINAL DEPTH OF MAGMA RESIDENCE UNDER ICELAND REGULATED BY MAGMA FLUX

R.J.M. Baxter[1,2], J.C. Maclennan[1], D. Neave[3], Þ. Þórðarson[4].

[1] Department of Earth Sciences, University of Cambridge, Cambridge, UK,
[2] Department of Geology, University of Otago, Dunedin, New Zealand,
[3] Department of Earth Sciences, University of Manchester, Manchester, UK,
[4] Institute of Earth Sciences, University of Iceland, Reykjavik, Iceland

rjmb3@cam.ac.uk

An essential component of continuing to advance volcano-monitoring efforts, is continuing to improve understanding of volcanic system processes, architecture, and timescales for magma storage, extraction, and ascent. One important variable is constraining magma storage depths prior to imminent eruption. While some individual volcanoes have been scrutinised in detail, there is no well-consolidated understanding of magma storage-depth distribution across volcanic systems. There is some speculation of a relationship between plumbing architecture and magma-flux, but no focused effort to investigate the extent of this relationship. We investigate final magma storage depths across Iceland, for which suspected controls on magma-flux (spreading rates, mantle potential temperature) and resulting magma productivity are well constrained.

We created PyOPAM, an open-source software that runs in Python, to estimate final storage depths of basaltic melt. This streamlined, reinvigorated Olivine-Plagioclase-Augite-Melt barometer estimates the position of the eutectic of the melt, the depth where basaltic melt was three-phase-saturated. Using 366 experimental glass compositions compiled from literature, we calibrate this barometer and constrain 1 σ to 1.26 kbar. We apply PyOPAM to a dataset of ~13,400 compositional analyses compiled from Iceland. Of these, 3809 analyses generate robust pressure estimates, elucidating final storage depths for 23 of the 30 volcanic systems across Iceland.

Modal magma storage pressure increases with decreasing crustal thickness and spreading rates, then decreases with increasing crust thickness and spreading rates, indicators of increasing magma flux. The thermal structure of the crust adds a secondary control on the depth of storage for basaltic magmas. High magma flux in cold crust results in deep storage of basaltic magma, while high magma-flux in warm crust results in shallow magma storage. This demonstrates that magma flux is the primary control of the final storage depths for basaltic magma, with some modulation by crust thermal structure.

ORAL
Session 1b.

Intra-eruption Forecasting Using Analogue Volcano and Eruption Sets

Mark Bebbington[1] **and Susanna Jenkins**[2]

[1] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*
[2] *Earth Observatory of Singapore, Nanyang Technological University, Singapore*

m.bebbington@massey.ac.nz

Pre-eruption forecasting, particularly at poorly studied or awakening volcanoes, relies heavily on formal or informal use of information from other better observed (analogue) volcanoes. Equally as important as onset forecasting is the ability to forecast the future of an eruption currently in progress. In an earlier paper (Bebbington and Jenkins, 2019), we developed a methodology for intra-eruption forecasting, based on a semi-Markov chain model of transitions among multiple types of eruptive phases. Having further expanded the data base to now include 2670 eruptions from 353 volcanoes, we are able to examine what selection basis for analogue volcanoes provides the most accurate forecasting of eruption sequences. In particular, we consider subsetting the data according to the type (e.g., stratovolcano, shield, …) and/or dominant composition (andesite, basalt, …) of the source volcano. These were compared against the accuracy when using the entire dataset, or just the record of the target volcano itself. We found that any subset performed better than the entire dataset … apart from the up to 40% of the eruptions which could not be forecast at all(!) by the subset as they contained features that were not in the analogue set. After extending the models to cope with this problem, we find that shields are well forecast by limiting the analogue set, in contrast to domes where the entire dataset works best. Interestingly, stratovolcanoes are relatively poor predictors of their own behaviour or, in other words, are good candidates for analogue modelling. Apart from this, limiting the analogues set to the target volcano itself is a viable strategy when it has at least 20 eruptions in the dataset.

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ORAL
Session 2a.

HIKURANGI MARGIN GAS HYDRATE DEPOSITS: MIGHT THEY EVER HAVE BEEN DEVELOPED AS AN ENERGY RESOURCE?

Mac Beggs[1], Brett Rogers[1], Gareth Crutchley[2], Francesco Turco[3]

[1] Elemental Group, [2]Geomar, [3]University of Otago.

mac@beggs.nz

The widespread occurrence of gas hydrate in the Hikurangi margin was first recognized in seismic reflection data 40 years ago (Katz, 1981), and the possibility that development of those resources might eventually be of economic significance has been a significant driver for subsequent research.

Early provisional estimates of gas volumes in place in Hikurangi margin deposits (eg Pecher and Henrys, 2003), although sometimes characterized as “conservative”, were very large in comparison to eg discovered gas reserves in Taranaki Basin. It was however recognized that most of the Hikurangi margin gas hydrate province would probably host very low hydrate saturations, while concentrated accumulations would more likely occur in regions of focused fluid flow.

Interpretation of both high resolution (TAN1808) and industry seismic data over structures containing hydrate deposits offshore Wairarapa (Turco et al, 2021; Crutchley et al, in review) has revealed important details of the occurrence of both gas hydrate and free gas, allowing for more refined, but still very provisional, assessment of gas volumes in place. Notably, it appears that concentrated hydrate domains are mainly coincident within dipping strata beneath anticlines and, in some cases, vertical conduits that link sub-hydrate gas accumulations to sites of seabed gas seepage.

The scope for commercial production of gas from hydrate remains under investigation internationally, but numerical simulations of production through depressurization indicate low flow rates, therefore requiring unrealistically large numbers of wells to produce commercially meaningful daily volumes. However, where concentrated hydrate deposits are associated with sizeable underlying (and possibly laterally adjacent) free gas volumes, dissociation of gas hydrate could contribute to ultimate resource recovery. The work outlines the assessment of free gas, undersaturated hydrates and saturated hydrates across selected Hikurangi margin sites.

Any possibility of gas development from the Hikurangi margin province was foreclosed by the exploration ban in 2018 and the relinquishment of petroleum exploration permits then in place.

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ORAL
Session 4d.

ABUNDANCE AND ISOTOPE (^{13}C, ^{14}C) COMPOSITION OF PYROGENIC CARBON

Michael Bird[1,2]

[1] *College of Science and Engineering, James Cook University, Cairns Qld, Australia*
[2] *Australian Research Council Centre of Excellence for Australian Biodiversity and Heritage*

michael.bird@jcu.edu.au

Pyrogenic carbon (PyC) is produced during the incomplete combustion of organic matter. It is pervasive in the environment, distributed throughout the atmosphere as well as soils, sediments and water in both the marine and terrestrial environment. PyC in the form of biochar has been suggested as a tool for terrestrial carbon sequestration and soil amelioration because a variable component of PyC is highly recalcitrant and persists for millennia. PyC is derived ultimately from plant material and therefore retains information on the vegetation that was burnt, encoded in its stable carbon isotope composition. PyC preserves well in sedimentary archives because it is relatively resistant to degradation, and microcharcoal particle counting has long been used to generate proxy records of fire incidence in the past. In some circumstances, PyC is relatively easy to isolate but in many others, PyC is very small, ancient, and dispersed in a matrix. Hydrogen pyrolysis (HyPy) is a technique that we have optimized for the quantification and isolation of PyC from a variety of matrices for determination of abundance, stable isotope composition and radiocarbon age.

Ecosystem $\delta^{13}C$ values vary widely across the tropics as a result of changes in the balance of vegetation using C_4 versus C_3 photosynthesis and information on changes in ecosystem C_3:C_4 balance can be obtained from the development of $\delta^{13}C$ time series from PyC in sedimentary archives. Stable isotope analysis of PyC in sedimentary archives by HyPy therefore enables the development a more nuanced understanding of the interplay between fire regime and vegetation structure/function (and climate) in the tropics, in the past. This talk will provide an introduction to HyPy as an analytical tool, present results from modern ground-truthing studies and fromcase studies where the technique has been used to develop proxy records of biomass burning, fire intensity and vegetation dynamics.

KEYNOTE
Session 4e.

CO-DESIGNING RESEARCH FOR ENVIRONMENTAL, SOCIAL, AND CULTURAL BENEFIT: TĀTAIHIA TE PARATAIAO O TE WAHAPŪ – HOKIANGA HARBOUR SEDIMENTATION PROJECT

Kyle J. Bland[1], Wendy Henwood[2], Georgia R. Grant[1], Christopher D. Clowes[1], Shontelle Nahona[1,3], Callum Whitten[3], Marcus J. Vandergoes[1]

[1] *GNS Science, PO Box 30368, Lower Hutt 5040, New Zealand*
[2] *Te Rarawa Anga Mua, PO Box 361, Kaitaia 0441, New Zealand*
[3] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, PO Box 600, Wellington 6140, New Zealand*

k.bland@gns.cri.nz

Hokianga-Nui-a-Kupe is an extensive natural harbour of great significance to Te Rarawa and other iwi with whakapapa connections to the area. Land-use changes are believed by many to have resulted in reduced species diversity and abundance, poor water quality, and increased siltation. Hokianga communities want to restore the mauri of their waterways utilising culturally connected, transdisciplinary science that engages with mātauranga Māori and local histories.

In partnership, GNS Science and Te Rarawa collected > 20 sedimentary cores from the harbour between Rangi Point and The Narrows. Analyses included hyperspectral scanning, grainsize, mollusc, foraminifera, and pollen diversity and abundance, XRF, stable isotope, and C-14 dating. Interviews with locals involved with the harbour throughout their lives provided a rich social history that complemented the coring aspects. They shared experiences and observations of developments and practices that had likely contributed to the current state of the harbour, including reclamations, plantation forestry, erosion, roading and causeways, and changing weather patterns. Fishermen also noted changes in fish stocks, species (including invasive species), and their distribution.

Palynology has provided a detailed record of past flora surrounding Hokianga Harbour, including the presence of tree species not (presently) widely distributed in the surrounding ngahere. *Pinus radiata* pollen spikes, typically ~30–40 cm below seabed, indicate a stratigraphic position of post-early 1970s. The Lowest Occurrence of a non-native invasive bivalve species, *Theo lubrica*, which arrived in Northland waters in the early to mid-1970s, provides further chronological constraints. Changes in sediment composition, stable isotopes, and diversity/abundances of mud-sensitive molluscan species reflect changes in sediment input. Study of benthic foraminifera reveals two primary faunal associations (*Ammonia* and *Ammonia-Haynesina*), representing intertidal and subtidal environments, respectively.

The project has assisted the project team and other partners in growing and implementing marae-based environmental education kaupapa to the next generation of kaitiaki, across Te Hiku.

ORAL
Session 2d.

EVALUATING REGIONAL EARTHQUAKE INDUCED LANDSLIDE SUSCEPTIBILITY PARAMETERS FOR NEW ZEALAND USING A MACHINE LEARNING APPROACH

Colin Bloom[1], Chris Massey[2], Tim Stahl[1], Andy Howell[1,2], and Corinne Singeisen[1]

[1] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*
[2] *GNS Science, Lower Hutt, New Zealand.*

colin.bloom@pg.canterbury.ac.nz

Earthquake induced landslides are some of the most extensive and impactful hazards resulting from large earthquakes. As a result, significant effort has gone into improving regional earthquake induced landslide susceptibility models for hazard planning and emergency response. Global observations have shown that some landslide susceptibility factors have variable influence on statistical model performance depending on region and underlying lithology. Using a detailed landslide inventory from the 2016 Mw 7.8 Kaikōura earthquake we trained logistic regression and random forest models to evaluate the influence of more than 20 potential landslide susceptibility parameters in a New Zealand specific context. Model parameters include a mix of common susceptibility factors (e.g. topographic slope, aspect, vegetation density, and hillslope position) and novel factors (e.g. distributed fault deformation, pre-existing landslides, and coastal influences). Results indicate that the most important earthquake induced landslide susceptibility parameters for the Kaikōura earthquake were geology, slope, and distance to a surface fault rupture. Models trained on the topographic slope parameter alone were c. 75% accurate when predicting landslides generated from the Kaikōura earthquake. Several important susceptibility parameters from other landslide inventories, for example topographic aspect, had very little influence on model performance. Removing some novel model parameters, for example proximity to the coast, decreased model performance by up to 3%. This modeling effort will both pave the way for an improved national earthquake induced landslide susceptibility modeling tool and introduce several new earthquake induced landslide susceptibility parameters that could improve modeling globally.

ORAL
Session 2a.

THE SLOW MELTDOWN OF GAS HYDRATES

Laurenz Boettger[1], Paul Oluwunmi[1], Rosalind Archer[2], George Moridis[3,4], Matthew Reagan[4], Ingo Pecher[1]

[1] *School of Environment, The University of Auckland, Auckland, New Zealand*
[2] *Faculty of Engineering, The University of Auckland, Auckland, New Zealand.*
[3] *Harold Vance Department of Petroleum Engineering, Texas A&M University, College Station, USA.*
[4] *Energy Geoscience Division, Lawrence Berkeley National Laboratory, Berkeley, USA.*

bboe633@aucklanduni.ac.nz

Gas hydrates can be found beneath large areas of New Zealand's seafloor (Pecher and Henrys, 2003). The occurrence of gas hydrates in marine sediments is determined by the thermodynamic conditions of high-pressure and low temperatures (Sloan and Koh, 2007). Responses of the gas hydrate system to changes in those conditions arising from geologic processes have been previously studied with a focus on ocean warming. These studies suggest that a significant amount of time is required for re-adjustment, following a pressure decrease or temperature increase, during which gas hydrates could be present between the previous level of the base of gas hydrate stability (BGHS) and its level after adjustment (e.g. Kretschmer *et al.*, 2015; Ruppel and Kessler, 2017). Besides ocean warming and sea-level fluctuations, rapid sedimentation can be another factor controlling the position of gas hydrates in marine sediments. Fast sedimentation rates can lead to an upward migration of the BGHS resulting from an upwards shift of the isotherm. To investigate the effects of rapid sedimentation and changing ocean conditions on the gas hydrate system, this study uses a 2D TOUGH+HYDRATE model based on the IODP Site U1517 located in the Tuaheni Landslide Complex (TLC) along the Hikurangi Margin. A combined approach of logging-while-drilling (LWD) data, three-dimensional (3D) seismic data and physical properties of sediment core measurements was used to reconstruct the environmental and geological conditions throughout the modelled time interval. Emphasis was given to the permeability reconstruction based on NMR data applying the empirical Schlumberger-Doll Research (SDR) equation with a lithology-dependent A coefficient (Daigle & Dugan, 2009). This method yielded a 15 cm resolution over the entire core length of 172 m, advancing the model and bringing it closer to in situ conditions. Combining these complementary datasets, we strive to reconstruct the development of the gas hydrate system beneath the TLC over geologic timescales and look at the possible contribution of gas hydrates to slope instability.

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POSTER
Session 2e.

THE UPPER CRUSTAL STRENGTH AND STABILITY OF GREYWACKE FAULT ROCKS: IMPLICATIONS FOR EARTHQUAKE RUPTURE NUCLEATION AND PROPAGATION

Carolyn Boulton[1], André Niemeijer[2], Andy Nicol[3], and Susan Ellis[4]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand*
[2] *HPT Laboratory, Department of Earth Sciences, Utrecht University, The Netherlands*
[3] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*
[4] *GNS Science, Lower Hutt, New Zealand.*

carolyn.boulton@vuw.ac.nz

Across New Zealand, multiple large-magnitude earthquakes have ruptured faults within Torlesse Supergroup greywacke historically. Yet the strength and stability of greywacke fault rocks have never been investigated systematically. In this research, hydrothermal friction experiments were conducted on greywacke psammite and argillite across a wide range of crustal conditions (v=0.01 μm/s to 100 μm/s, T=50°C to 600°C, and □n’=75 MPa). Samples of psammite and argillite were collected from the fault core and footwall of the sinistral-reverse Leader Fault. Results reveal that at T=250°C to 450°C (10 to 18 km depth for a 25°C/km geothermal gradient), all argillite and psammite samples exhibit velocity-weakening behaviour and have Byerlee (m=0.6-0.8) values of sliding friction. That is, greywacke argillite and psammite are frictionally strong and unstable at conditions corresponding to the hypocentral depths of the 2010 Mw 7.1 Darfield (~10 km depth) or 2016 Mw 7.8 Kaikōura (~13 km depth) earthquakes.

At temperatures ≤200°C, the argillite samples have similar friction coefficients (m=0.32-0.53), are weaker than the psammites (m=0.55-0.65), and are velocity strengthening. We hypothesise that the low friction coefficients of footwall and fault core argillite promote distributed slip at shallow depths where faults are oriented parallel to bedding and/or where bedding is optimally oriented. Experimental results also show that the velocity-weakening to velocity-strengthening transition temperature, interpreted to represent the seismic-aseismic transition, is both lithology- and velocity-dependent. At the lowest velocities imposed, the transition temperature is 450°C in the psammite and 350°C in the argillite; at the highest velocities imposed, the transition temperature increases to over 600°C in the psammite and 500°C in the argillite. Because the seismic-aseismic transition in greywacke occurs across a range of temperatures, greywacke fault zones should exhibit microseismicity and seismic moment release at depths below the 350°C isotherm typically taken to correspond to the onset of quartz plasticity and aseismic behaviour.

ORAL
Session 2a.

A PORTAL FOR GEOSCIENCE WEBMAPS AND INFORMATION ON THE TE RIU-A-MĀUI / ZEALANDIA REGION

Andrew Boyes[1], **Jenny Black**[1] **and Phil Scadden**[1]

[1] *Geospatial Data & Analysis, GNS Science, Lower Hutt, New Zealand*

a.boyes@gns.cri.nz

E Tūhura - Explore Zealandia (TEZ) is a web portal which gives geoscientists and the public access to maps, graphics, and other information on Te Riu-a-Māui / Zealandia - the 5 million square kilometre continent on which New Zealand sits.

In June 2020 GNS Science launched two new map posters that provided fresh insights into Te Riu-a-Māui / Zealandia. The maps cover the bathymetry (Mortimer et al. 2020a), and the tectonic (Mortimer et al. 2020b) origins of Earth's eighth continent.

These maps are available on TEZ (https://data.gns.cri.nz/tez) as digital, zoomable, & interrogatable webmaps, incorporating the information sources from Mortimer 2020. Also available is a webmap of Geoscience data incorporating with a rich library of spatial data from GNS Science, NIWA, DOC & LINZ. New layers are added regularly as datasets become available.

The site contains web pages summarizing in plain language the discovery of the Earth's 8th continent Zealandia, an explanation on its Te Reo name Te Riu-a-Māui, & an outline of the major themes of the GNS research programme Understanding Te Riu-a-Māui / Zealandia.

We present an overview of the information & data available, and how to utilize the features of the web portal to access them. These can be applied to a wide variety of research and will be of use to anyone with an interest in Te Riu-a-Māui / Zealandia.

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Mortimer N, Smith Lyttle B, Black J. 2020. Bathymetric map of Te Riu-a-Māui / Zealandia. Lower Hutt (NZ): GNS Science. 1 poster, scale 1:8,500,000. (GNS Science poster; 7).

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ORAL
Session 3e.

PROGRESSIVE DEHYDRATION REACTION OF THE SLAB TRACKED BY ACROSS-ARC VARIATIONS IN OLIVINE-HOSTED MELT INCLUSIONS

Raimundo Brahm[1], Daniel Coulthard Jr.[1], Georg F. Zellmer[2], Takeshi Kuritani[2], Naoya Sakamoto[3], Haijme Taniuchi[4], Hisayoshi Yurimoto[3]

[1]School of Agriculture and Environment, Massey University, Palmerston North, New Zealand.
[2]Graduate School of Science, Hokkaido University, Sapporo, Japan.
[3]Isotope Imaging Laboratory, Creative Research Institution, Hokkaido University, Sapporo, Japan.
[4]Department of Geoscience, Shizuoka University, Shizuoka, Japan

r.brahm@massey.ac.nz

The stability and breakdown of major and trace mineral phases in subducting slabs control the cycling of trace elements through subduction zones. High pressure-temperature experiments on peridotitic, basaltic and sedimentary rocks (representing the different layers of the subducted slab) and the analysis of natural metamorphic rocks have been used to characterize the stability of the involved minerals and the partitioning behavior of trace components between these minerals and the liquids of interests (melts, fluids, and supercritical liquids). However, while experimental data is commonly employed in the interpretation of the processes that govern trace elements and their ratios in arc magmas, their applicability has never been tested on natural arc melts. Using data from olivine-hosted melt inclusions sampled along and across the northern Japan and southern Kurile arcs, we show here for the first time that experimentally and thermodynamically constrained phase stabilities in subducted materials indeed systematically control the variation in large ion lithophile, high field strength and rare earth elements as predicted by these models and experiments. This work elucidates subduction zone elemental cycling in a well-characterized petrogenetic setting and provides important constraints on the interpretation of trace element ratios in arc magmas in terms of the prograde metamorphic reactions within the subducting slab from arc-front to the far back-arc. Our data thereby also shed light on potential caveats in the interpretation of trace element signatures in arc magmas, particularly in across-arc sample sets.

ORAL
Session 1b.

POST-CALDERA VOLCANISM REVEALS SHALLOW PRIMING OF AN INTRA-OCEAN ARC ANDESITIC CALDERA: HUNGA VOLCANO, TONGA, SW PACIFIC

Marco Brenna[1], Shane J. Cronin[2], Ian E.M. Smith[2], Alessio Pontesilli[3], Manuela Tost[4], Simon Barker[5], Sisi Tonga'onevai[6], Taaniela Kula[6], and Rennie Vaiomounga[6]

[1]Department of Geology, University of Otago, Dunedin, New Zealand
[2]School of Environment, University of Auckland, Auckland, New Zealand
[3]Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy
[4]Land Development and Engineering Ltd, Gisborne, New Zealand
[5]School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand
[6]Geology Unit, Natural Resources Division, Ministry of Lands and Natural Resources, Nuku'alofa, Tonga

Marco.brenna@otago.ac.nz

Intra-oceanic arcs are typically associated with intermediate (andesitic) cone volcanoes. However, caldera volcanoes may also form in these settings from very large eruptions, resulting in sudden changes to the magma reservoir. These reservoirs can then produce either semi-continuous or intermittent low-intensity volcanism between major caldera-producing or caldera-deepening eruptions, providing insights into the post-caldera evolution of the system. Hunga volcano (Kingdom of Tonga, Southwest Pacific) is a large mainly submarine edifice that produced a series of caldera-forming eruptions ~900 years ago. Since then, numerous smaller-scale subaerial and submarine eruptions occurred, the most recent forming new islands in 2009 and 2014/15. Pyroclastic deposits associated with these latest eruptions have identical (range ~0.1 wt.% of all major oxides) andesitic composition that overlap with the primitive end of the slightly wider compositional range of the caldera-forming episodes. Texturally simple plagioclase, clinopyroxene and orthopyroxene phenocrysts in pre-, syn- and post-caldera pyroclasts point to a single shallow storage reservoir at 5–8 km depth. Lack of complex zonation indicates that this reservoir is constantly resupplied by low-flux inputs of basaltic andesite magma and is large enough that convective mixing rapidly homogenises new inputs. The reservoir feeds intermittent, low-intensity, post-caldera volcanism with constant andesite composition, driven possibly by magmatic overpressure and "leakage" of gas-rich magma pockets around the edges of the caldera. More primitive and compositionally variable basaltic andesites formed a lava-dominated edifice prior to the caldera-forming event. This suggests a causal link between magma supply dynamics and caldera priming relating to the maturing of the plumbing system and formation of a sustained subvolcanic andesite magma reservoir.

ORAL
Session 1a.

Engineering characteristics and behavior of tropical red soils: an example from Republic of the Congo

George Brink[1] and Martin Brook[2]

[1] Tonkin and Taylor, 105 Carlton Gore Rd, Newmarket, Auckland 1023, New Zealand.
[2] School of Environment, The University of Auckland, Auckland 1010, New Zealand.

m.brook@auckland.ac.nz

Tropical soils have unique characteristics due to the compositions and micro-structures of material developed under hot, humid, soil-forming conditions. Such soils can give rise to challenging conditions for the development of infrastructure in tropical regions, where residual soils, rather than transported soils, are usually the focus for attention. The engineering behavior of these materials in-situ, are often dissimilar to the engineering behavior predicted from laboratory testing regimes (Brink and Brook, 2020). Indeed, conventional engineering classification tests (e.g., to British and ASTM standards) are largely concerned with the determination of the index properties of soils based on temperate climates. Here, we report geochemical, geotechnical and index properties of tropical transported soils from test pits on the slopes of Mt Lekoumou in the Mayoko region of the Republic of the Congo. Mt Lekoumou represents an area of Banded Iron Formation (BIF) bedrock, overlain by loose, unconsolidated Fe-rich clayey gravel (transported ore) and a hematite cap. Aside from the upper-most slopes, the entire area is overlain by colluvium of varying thickness, which is the focus of this study. X-ray diffraction (XRD) of the colluvium indicates that goethite, kaolinite and hematite are the dominant minerals in the soils. The colluvium is characterized by moderately high liquid limits (LL), but comparatively low plasticity index (PI) values, so plots close to the A-line on a Casagrande Chart. Triaxial tests recorded effective cohesion (c') of 0 and 31 kPa and effective friction angles (ϕ') of 26°-39°, and shear box tests recorded comparable results. Considerable variation in matric suction pressure values for different samples of the same colluvium material, at the same moisture content, occurs. Therefore, as with tropical residual soils, systematic site investigations should be conducted on tropical transported soils prior to construction and development, in order to minimize the effects resulting from ground failure.

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ORAL
Session 4c.

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SPATIAL AND TEMPORAL VARIATIONS IN METAL-LIGAND COMPLEXATION, RECONSTRUCTED FROM SPELEOTHEMS

Robert Brodnax[1], **Sebastian Höpker**[1] **and Adam Hartland**[1]

[1] *Environmental Research Institute, School of Science, University of Waikato, New Zealand.*

adam.hartland@waikato.ac.nz

Speleothems are important sources of paleoclimate information which is largely encoded in geochemical properties such as stable isotope ratios (e.g., $^{18}O/^{16}O$) and trace elements. Recent research has demonstrated that the transfer of transition metal (M) cations (Cu^{2+}, Zn^{2+}, Ni^{2+} and Co^{2+}) into the speleothem $Ca(M)CO_3$ solid solution is controlled primarily by complexation processes with binding ligands (L). A consequence of this is that the abundance of these ions in secondary cave precipitates (like stalagmites) is mainly dependent on ligand dissociation kinetics, and hence the residence time of dripwater on the speleothem surface during precipitation. This makes transition metal ion abundance a potentially useful proxy for dripwater flow rate, and by extension regional rainfall. This study tests the temporal and spatial stationarity of ligand transition metal binding to further support the development of this proxy. This study will use diffusive gradients in thin films (DGT) to determine the lability (i.e., binding strength) of M-L complexes extracted from speleothems across a range of ages and origins. The ultimate goal of this research is to determine whether the effect of ligands on metal speciation is generally constant over time and space. If this were true, then transition metal abundance in speleothems could be used as a proxy for cave drip rate, providing the first direct hydrological proxy in paleoclimate reconstructions.

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POSTER
Session 4e.

MINERALOGICAL INSIGHTS INTO HYDROTHERMAL ERUPTION CONDITIONS AT ROTOKAWA GEOTHERMAL FIELD, NEW ZEALAND

Isabelle Brooks-Clarke[1], Shane Cronin[1], Mark Simpson[2]

[1] *School of Environment, Faculty of Science, University of Auckland, New Zealand*
[2] *GNS Science, Wairakei, New Zealand*

ibro315@aucklanduni.ac.nz

Located ~20 km northeast of Taupo within the central North Island, the Rotokawa Geothermal Field produced multiple hydrothermal eruptions between ~25,000 to 3,500 years ago. These prehistoric eruptions at Rotokawa were much larger than historical examples elsewhere within the Taupo Volcanic Zone, ejecting breccia several kilometers from multiple vent locations (Browne and Lawless, 2001; McNamara et. al. 2016). Understanding how such large hydrothermal eruptions occur is an important factor for hazard management in active New Zealand geothermal areas, especially those managed for electricity generation such as Rotokawa.

This study analyzed hydrothermal eruption breccia blocks and matrix material sampled from the Rotokawa Field using petrographic and scanning-electron microscopy, electron microprobe, and visible-near-Infrared spectroscopy. Four distinct source lithologies were identified, comprising Oruanui Ignimbrite, pre- and post-Oruanui volcaniclastic lacustrine sediments, and lithified, 'recycled' hydrothermal breccia. These units lie within ~50 m of the surface. We show that hydrothermal mineralization led to permeability reduction, potentially inducing overpressures within the shallow Rotokawa Field (c.f., Mick et. al. 2021).

Alteration mineral assemblages and indicator mineral species broadly constrain eruption sources to between the near-surface vadose zone and up to ~1 km depth. The mineralogy indicates subsurface temperatures between 140 to 380°C. Complexity of overprinting alteration assemblages suggests repeated changes in shallow subsurface conditions over time and 'recycling' of breccia deposits. Textural characteristics of void-filling mineralization suggest multiple depositional phases from fluids that experienced cyclic changes in temperature and chemistry. We interpret these to represent re-organization of fluid flow through the shallow field following each eruption, focused within or surrounding diatremes produced by previous eruptions.

The predominantly low temperature alteration mineral assemblage rules out magmatic eruption triggers. The common inclusion of lacustrine sediments within breccia deposits suggests rapid lake drainage (e.g., Huka Lake, post-Oruanui Lake Taupo), causing initial depressurization of the hydrothermal system, triggering the eruption series.

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ORAL
Session 2a.

THE ROLE OF TURBULENT FLUCTUATIONS ON THE DESTRUCTIVE FORCE OF DILUTE PYROCLASTIC DENSITY CURRENTS

Ermanno Brosch[1], Gert Lube[1], Matteo Cerminara[2], Tomaso Esposti-Ongaro[2], Eric C.P. Breard[3], Josef Dufek[3], Betty Sovilla[4] and Luke Fullard[5]

[1]Volcanic Risk Solutions, Massey University, Palmerston North, New Zealand
[2]Istituto Nazionale di Geofisica e Vulcanologia – Sezione di Pisa, Pisa, Italy
[3]Department of Earth Sciences, University of Oregon, Eugene, United States of America
[4]WSL Institute for Snow and Avalanche Research SLF, Davos, Switzerland
[5]Horizons Regional Council, Palmerston North, New Zealand

e.brosch@massey.ac.nz

Dilute pyroclastic density currents are one of the most destructive volcanic phenomena occurring during explosive activity. They exhibit destructive potential through dynamic pressures in the range of 10^0–10^2 kPa, capable to destroy concrete buildings. Because these flows are characterized by high velocities, temperatures, and dynamic pressures, they cannot be directly probed, and their internal flow dynamics remain largely unknown. Currently, limited direct observations and depositional record provide means to infer their internal workings.

Here we present results from PELE eruption simulator large-scale experiments and direct field measurements of dilute pyroclastic density currents. Measured fluctuations in flow velocity and density generate a train of dynamic pressure pulses that travel inside the flow during propagation. These pulses exhibit pressures up to 1 kPa in the experiments, which translate to tens to hundreds of kPa in nature. We show that the largest dynamic pressures are concentrated into large coherent turbulent structures and gravity waves. Furthermore, measured dynamic pressure fluctuations exceed mean values by up to a factor of three, showing that currently applied estimates for hazard modelling are underestimating the destructive flow force. Experimental and field measurements reveal that the frequencies of the largest coherent structures, are controlled by a Strouhal number of c. 0.3. This allows to quantify the number of pressure pulses which for real-world flows amount to c. 1–20 pulses per minute. The combined processes of coherent turbulent structures and gravity waves reveal how destructive flow energy and hazard potential, in specific dynamic pressure, is carried inside dilute pyroclastic density currents during propagation.

These findings are also applicable to other types of fully turbulent particle-laden gravity currents, such as powder snow avalanches. The presented results have implications for current hazard and risk models and call for a re-evaluation of volcanic hazard mitigation plans.

ORAL
Session 1a.

WHO'S USING GEOTRIPS.ORG.NZ? A USER-BASED APPROACH TO OPTIMIZING ONLINE GEOSCIENCE COMMUNICATION

Suzanne Bull[1], Jenny Black[1], Jeremy Houltham[1], Ben Sloboda[1] and Julian Thompson[2],

[1] *GNS Science, Lower Hutt, New Zealand*
[2] *Out There Learning, Lower Hutt, New Zealand.*

s.bull@gns.cri.nz

This talk presents the results of a user-based study of the people and groups using GeoTrips.org.nz. GeoTrips is an award-winning, web-based catalogue of self-guided fieldtrips designed to lead the public on journeys of discovery around our beautiful landscapes and geology. Since being set up in 2015 over 400 trips have been contributed by geoscientists from all around Aotearoa-New Zealand.

Despite scientifically excellent content, the site performs relatively poorly. Google analytics show that in the 12 months prior to April 2021, GeoTrips had 22,000 visitors, and a bounce rate (i.e. user lands on the site and leaves without any actions or clicks) of 75%. Most visitors stayed on the site for less than 10 seconds and there was very little information available relating to who the key users are, and their needs, expectations, concerns, and motivations.

To understand how we can grow GeoTrips and ensure longevity of the site we undertook a user needs assessment via a user survey. The survey results along with site metrics were used to create user personas - archetypical users whose goals and characteristics represent the needs of a larger group of users. In turn the personas helped us to better understand the requirements of target users and design solutions to best satisfy users' needs.

In this talk, we present our findings: who is using GeoTrips? What does GeoTrips do well? And what does it not do so well - where are the opportunities? We explain how these results have been fed into a user-guided 'product roadmap' aimed at upscaling the usership, reach and impact of GeoTrips.

ORAL
Session 3e.

DECIPHERING THE MARTIAN MANTLE FROM IN-SITU ^{87}SR/^{86}SR MEASUREMENTS ON SHOCK MELTED PLAGIOCLASE IN MARTIAN METEORITES

Daniel Burgin[1], James M. Scott[1], Marshall C. Palmer[1] Petrus J. le Roux[2], Malcolm R. Reid[1,3], and Claudine H. Stirling[1,3]

[1] Department of Geology, University of Otago, Dunedin, New Zealand
[2] Department of Geological Sciences, University of Cape Town, South Africa
[3] Centre for Trace Element Analysis, University of Otago, Dunedin, New Zealand

danielburgin123@gmail.com

Martian rocks occur on Earth despite the lack of any return missions from Mars. These Martian rocks are meteorites that have been ejected from the red planet during asteroid collisions. We have analysed the composition of 15 shergottite (igneous) Martian meteorites, focusing on the chemical and isotopic compositions of shock melted plagioclase glass known as maskelynite. This glass, which forms when the plagioclase composition collapses when the rock was subject to the extreme high pressures during a meteorite collision with Mars's surface, is ideal for in-situ ^{87}Sr/^{86}Sr analysis because it has very low Rb and low REE and, therefore, minimal interferences on ^{87}Sr/^{86}Sr. Our sample suite shows three distinct Sr isotope groups that correspond to depleted (~0.702), intermediate (~0.712), and enriched (~0.722) compositions. The high Sr (> 130 ppm) but lack of Rb (< 3 ppm) in maskelynite (^{87}Rb/^{86}Sr ratio of < 0.1) mean that the ^{87}Sr/^{86}Sr ratios must represent the mantle sources. However, the Sr isotope range is vastly wider than Earth's convecting mantle (~0.703-0.705) and confirms that the Martian mantle is poorly isotopically mixed. This implies that Mars has not had plate tectonics and significant mantle convection, which both processes on Earth have promoted efficient mantle mixing. Most of our samples analysed for conventional bulk rock Sr, Nd and Pb isotopes by solution geochemistry show contamination by a terrestrially-derived component, and evidence for this can be seen in the infiltration of trace elements along grain boundaries. Therefore, the in-situ laser ablation Sr isotope acquisition technique is extremely powerful because it is more rapid that solution geochemistry, avoids the issue of terrestrial contamination, and provides high quality information on the Martian mantle.

ORAL
Session 1b.

PALEOMAGNETISM OF SEDIMENT CORES FROM COULMAN HIGH, ANTARCTICA

Julianne Burns[1], Christian Ohneiser[1], Gavin Dunbar[2], Richard Levy[2,3,], and Robert McKay[2]

[1]*Department of Geology, University of Otago, Dunedin, New Zealand.*
[2]*Antarctic Research Centre, University of Victoria, Wellington, New Zealand.*
[3]*GNS Science, Lower Hutt, New Zealand*

burju709@student.otago.ac.nz

During the ANDRILL 2010-2011 Coulman high site survey season a collection of short sediment cores were recovered from beneath the Ross Ice Shelf c. 60 km east of Ross Island near the modern-day ice calving zone. McKay et al (2015) demonstrated from these cores that the glacial retreat and open-marine conditions became established at this site before 8.6 kyr and that the ice sheet retreat was trigged by ocean forcing. Here we present results of a paleo and environmental magnetic study of two Coulman High cores from the McKay et al (2015) study. Our goal was to reconstruct the evolution of the Holocene geomagnetic field at this site (the declination, inclination and field strength) which can form the basis for a regional secular variation reference record and an environmental magnetic record.

Discrete and continuous paleomagnetic samples were measured at the Otago Paleomagnetic Research facility at the University of Otago on the 2G Enterprises Superconducting magnetometer. Samples were stepwise demagnetized in alternating fields of up to 100 mT and subsequently an Anhysteretic Remanent Magnetization was applied to the demagnetized samples to allow development of a relative paleo intensity record. After demagnetization the Anisotropy of Magnetic Susceptibility (AMS) was measured on the AGICO Kappabridge fitted with a 3D rotator.

Initial results indicate the sediments carry a stable detrital magnetization which has faithfully recorded the evolution of the Holocene geomagnetic field with steeper inclinations in younger sediments. Overall the inclinations are shallower than expected at this high latitude which may indicate that a degree of inclination shallowing has occurred. AMS fabrics have a less well developed fabric in younger sediments and a tilted fabric which may indicate gently dipping bedforms in this region.

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POSTER
Session 2c.

2001: A DATA PACKETS ODYSSEY; 20 YEARS OF EVOLUTION AND TECHNOLOGICAL ADVANCEMENTS IN THE GEONET COMMUNICATIONS NETWORK

<u>Conrad Burton</u>[1] and Michal Planka[1]

[1] *GNS Science, Avalon, Lower Hutt, New Zealand*

c.burton@gns.cri.nz

Since the inception of GeoNet there has been a silent worker powering away in the background to robustly deliver the high-quality scientific data we are so familiar with from GeoNet sites. A private wide area network (WAN) has been set up to provide secure data telemetry between sites and to direct data out to our datacentres where its collected, processed and published to GeoNet webpages and made available in a scalable way.

Over the last 20 years this private WAN or communications network has evolved greatly with a shift in serial communications to an ethernet/IP based system. Enhancements include moving the bridged network to a routed network, increases in the coverage and capabilities of cellular networks, and the availability of satellite technology, all working in unison to allow for faster, more reliable, and more flexible data transmission.

We'll first take a journey through the lifecycle of a data packet; from its beginnings as a rumble in the earth to a perfectly digitised waveform displayed on your laptop, we run through the key stages underpinning its transformation. Next, we focus in and elaborate on the central stage of that journey, the GeoNet Communications Network, presenting a timeline from 2001 until 2021 showing the major milestones in the network and a description of the technological advancements that made them a possibility. Finally, we'll present what it's future may look like and what game-changers could be lurking on the horizon.

POSTER
Session 4a.

DISASTER RISK MANAGEMENT SCENARIOS FOR CALDERA VOLCANOES IN TAUPŌ VOLCANIC ZONE

Rodrigo Calderon[1], Thomas Wilson[1], Graham Leonard[2], Sarah Beaven[1], Luis Lara[3]

[1] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*
[2] *GNS Science, Lower Hutt, New Zealand.*
[3] *SERNAGEOMIN, Santiago, Chile.*

rodrigo.calderon@pg.canterbury.ac.nz

Disaster Risk Management (DRM) for caldera volcanoes is particularly challenging because it includes several sources of hazards at different spatial and temporal scales. Caldera volcanoes, especially silicic ones, are usually linked to explosive eruptions with high destructive potential but, fortunately, low recurrence. However, large caldera volcanic systems can also produce relatively frequent unrest episodes, which may not lead to an eruption, but can produce societal impacts and may require precautionary risk management actions (Johnston, 2002). Given this complexity, it is important that credible and relevant volcanic risk knowledge is used to inform DRM strategies.

This research is focused on the use of engagement to co-design DRM Scenarios for caldera volcanic activity in Taupō Volcanic Zone (TVZ). TVZ is considered one of the most active caldera volcanic systems on Earth and includes two well-established calderas: The Taupō Volcanic Centre (TVC) and Okataina Volcanic Centre (OVC). Scenarios are prospective stories about how a phenomenon may evolve. In this case, those scenarios are constructed in terms of potential impacts on society from eruptions and caldera unrest episodes. The engagement process used to construct these scenarios has been developed within the ECLIPSE Programme with Caldera Advisory Group members, iwi, and industry representatives, bringing together a range of perspectives regarding the form and function of the DRM scenarios.

Five primary considerations and requirements from the different participants in the development process are identified. These include a detailed description of physical phenomena, physical impacts, intangible impacts, timeline analysis (short-term and long-term impacts or disruptions), and appropriate risk communication products. This presentation will provide an overview of the scenario co-production process to date, DRM scenario framework, and selected example scenarios.

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ORAL
Session 3a.

SEISMIC INVESTIGATION OF THE WEST NGATATURA VOLCANIC FIELD, NEW ZEALAND: IMPLICATIONS FOR MONOGENETIC VOLCANIC ARCHITECTURE AND PLUMBING

Alex J. Caldwell[1], Jennifer D. Eccles[1], Alan Bischoff[2], and Lorna J. Strachan[1]

1. School of Environment, University of Auckland, Auckland, New Zealand
2. School of Earth and Environment, University of Canterbury, Christchurch, New Zealand

acal410@aucklanduni.ac.nz

Monogenetic volcanic fields are known to occur beneath urban areas and while these are of high hazard interest, subsurface geophysical imaging is a challenge in these settings. The West Ngatatura Volcanic Field is an intraplate, deep marine, Pliocene monogenetic volcanic field, buried under several hundred metres of sediments, located in the northern Taranaki Basin, New Zealand (Bischoff et al., 2020). The field is slightly older and spatially close to varied intraplate monogenetic fields in northern New Zealand, yet, it has not been established how West Ngatatura relates to these. Legacy 2D seismic reflection data provides a special opportunity to study monogenetic processes in New Zealand. This project aims to use this data to interpret architecture and morphologies of the volcanic cones and intrusions to investigate plumbing structures and structural controls on the volcanic field relating to the northern Taranaki Graben.

Initial interpretation of the data reveals multiple cone-like structures that match the criteria for volcanoes (Bischoff et al., 2019a and b). The cones have continuous inclined reflectors with higher apparent amplitude discontinuous reflectors along its flanks that have previously been interpreted as heterogeneous horizons such as pillow lavas or pyroclastic material. Saucer sills have been inferred by their high amplitude reflections and upwards, inclined, narrowing flanks. Possible geophysical artefacts have also been identified in the migrated industry data that could mislead interpretation such as velocity pull-up of reflectors beneath the relatively high velocity cone, automatic gain control and attenuation artefacts. Intrabed multiples of saucer sills have also been identified, having closely mimicked the geometry and depth to a reflector above. Further work is being conducted to differentiate structures into pre-, syn- & post-eruptive sequences and surfaces to better refine the morphology and architecture of the West Ngatatura Volcanic Field.

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POSTER
Session 1a.

PHASE GRADIENT BASED InSAR TIME-SERIES ANALYSIS: HUNTING SLOW MOVING LANDSLIDES TRIGGERED BY THE 2016 KAIKOURA EARTHQUAKE

Yunmeng Cao[1], Ian Hamling[1], Chris Massey[1], Phaedra Upton[1]

[1] *GNS Science, Lower Hutt, New Zealand*

y.cao@gns.cri.nz

It is challenging to use regular InSAR techniques to detect slow-moving landslides, particularly when triggered by large earthquakes. Locally distributed landslides deformation signals could be easily polluted by other background signals (e.g., atmospheric delays, strong post-seismic deformations), and unwrapping errors caused by spatio-temporal decorrelation noises could lead to large biases (even wrong values) in regular InSAR time-series results, especially when the area of interest is located in the vegetated regions or far from the reference point. To overcome the above limitations of regular InSAR, here we developed a new InSAR phase gradient based time-series analysis method, for hunting possible slow-moving landslides triggered by the 2016 earthquake. Using the ascending and descending Sentinel-1 data over Kaikoura region, from 2014 to 2021, we estimate the time-series evolutions of the InSAR phase gradient and their uncertainties, and we also validate the advantages of our new method against the standard SBAS InSAR technique. Based on the phase gradient results, we analyse their differences before and after the earthquake to identify those landslides initiated by the earthquake and which continued to move after the earthquake.

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ORAL
Session 4b.

LABORATORY SIMULATIONS OF SLIP BEHAVIOUR IN HIKURANGI SUBDUCTION ZONE SEDIMENTS IN RESPONSE TO EARTHQUAKES AND ELEVATED PORE FLUID PRESSURES

Jon Carey[1], Laura Wallace[1], Yoshihiro Kaneko[2], Demian Saffer[3] and Dave Petely[4]

[1]GNS Science, Lower Hutt, New Zealand
[2]Kyoto University, Kyoto, Japan
[3]University of Texas, Texas, USA
[4]University of Sheffield, Sheffield, UK.

j.carey@gns.cri.nz

Understanding mechanisms controlling the range of slip behaviors observed on subduction zone faults is a critical step toward assessing hazards from the world's largest earthquakes and associated tsunamis. Slow slip events (SSEs) release energy slowly but may increase stress in areas of a subduction zone and may trigger damaging rapid-slip earthquakes. Similarly, although SSEs are typically observed without a discernible trigger, evidence that they could be initiated by dynamic stress changes due to passing seismic waves from regional or distant earthquakes is increasing. Unprecedented, widespread shallow SSEs were triggered on the Hikurangi subduction zone offshore the North Island's East Coast during the weeks following the M7.8 Kaikoura earthquake and similar triggering of SSEs has been observed on a smaller scale at other subduction zones. This suggests that fault zones hosting SSEs are highly sensitive to small stress perturbations, and thus are very weak and/or close to failure.

We are conducting a range of laboratory experiments in a dynamic shear box on sediment samples recovered from the Hikurangi subduction zone during the International Ocean Discovery Program (IODP) Expedition 375 to explore how earthquake shaking and changes in pore-fluid pressure influence slip behavior in shallow subduction zones.

Our experiments suggest that whilst some silty-clay rich materials within the fault zone may display slow-slip-style movement in response to dynamic loading associated with regional seismicity and as a result of the accompanying transient development of excess pore fluid pressures, others, such as the pelagic incoming plate sediments, are less likely to slow-slip. Instead, under certain loading conditions, these materials stiffen which, whilst making them stronger, may make them more susceptible to rapid slip events. Our results, to date, provide new insights into the complex mechanical behavior of the shallow subduction zone sediments and how this influences slip behavior after transient loading from earthquakes and changes in pore-fluid pressure.

ORAL
Session 2e.

ARSENIC ZONATION FOR MINERAL PROSPECTING AT RISE AND SHINE SHEAR ZONE, NEW ZEALAND, USING HYPERSPECTRAL REMOTE SENSING

Rupsa Chakraborty[1], **Gabor Kereszturi**[1], **Reddy Pullanagari**[2], **Dave Craw**[3], **Salman Ashraf**[4] **and Patricia Durance**[5]

[1]*Geosciences, School of Agriculture & Environment, Massey University, Palmerston North, NZ*
[2]*MAF Digital Lab, School of Food & Advanced Technology, Massey University, NZ*
[3]*Geology Department, University of Otago, Dunedin, NZ.*
[4]*GNS Science, Avalon, Lower Hutt, NZ*
[5] *BHP Billiton, Perth, Western Australia, Australia*

r.chakraborty@massey.zc.nz

Hyperspectral imaging (HSI) provides rich spectral information at a regional scale. Hyperspectral remote sensing measures reflected light from the Earth's surface discretized into hundreds of narrow and contiguous spectral bands. Each material has a unique reflectance profile. HSI can be used for quantitative analysis of surface composition and for classification. However, complexities such as mixed pixels, light scattering mechanisms, multi dimensionality can pose major challenges in processing and analyzing the data.

Here, we present a novel method for mapping and screening for arsenic anomalies in soils along the Rise and Shine Shear Zone (RSSZ), South Island, NZ. The study is situated within the Otago Schist, hosting mesothermal gold mineralization within the upper green schist facies. The upper and lower green schist facies are separated by the Thomson Gorge normal fault. The study area consists of rugged terrain with sparse soil outcrops (5-70% exposure fraction), with grass/tussock vegetation cover. The study utilizes soil geochemistry data procured using pXRF for arsenic concentration of the ground training samples, along with 2m spatial resolution HSI data captured by the AisaFENIX airborne sensor. Initially we have used band selection algorithm to filter bands important to the model and relevant to geology of the area. A selection of 85 bands were then further put through Orthogonal Total Variation Component Analysis (OTVCA) to concise the information in 10 bands. OTVCA output was then classified using Random Forest (RF) classifier to map three levels of arsenic concentration in the area (<20 ppm, between 20 to 100 ppm and >100 ppm). The high arsenic concentration zones were interpreted to be related to the gold mineralization (leached from arsenopyrite). The underlying geology correlates with soil exposure, which is captured by our classification. This makes the classification analysis challenging but also shows an apparent increase in model accuracy and validates known ground points.

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ORAL
Session 4b.

GEOTHERMAL: THE NEXT GENERATION - ADVANCING THE UNDERSTANDING OF NEW ZEALAND'S SUPERCRITICAL RESOURCES

Isabelle Chambefort[1] and the Geothermal: The Next generation's Team[1,2,3,4,5, 6, 7]

[1] *GNS Science, New Zealand*
[2] *Victoria University of Wellington, New Zealand*
[3] *ETH Zurich, Switzerland*
[4] *University of Auckland, New Zealand*
[5] *Upflow, New Zealand*
[6] *Bridger Limited, New Zealand*
[7] *Traverse Environmental, New Zealand*

i.chambefort@gns.cri.nz, geothermalnextgeneration@gns.cri.nz

New Zealand is endowed with generous geothermal resources. Currently untapped, NZ's deeper, supercritical geothermal resources have the potential to provide a near- unlimited source of renewable energy, with ten times more energy than conventional geothermal. New Zealand's unique tectonic setting with its active rifting arc produces voluminous magma and outstanding heat flow. It delivers exceptional opportunities for geothermal development and has placed New Zealand among the leaders in geothermal energy technology for the past 60 years. Our present level of scientific understanding, however, is insufficient to offer industry-ready solutions for NZ. Our multidisciplinary programme aims to resolve the critical, underpinning geological, geochemical and technological challenges – unknown in conventional geothermal – to enable future NZ generations to sustainably use supercritical resources for electricity generation and high-temperature industrial applications, while minimising carbon emissions.

This research programme – building on over a decade of research – aims to minimise exploration and technological risks by detailing heat transfer at significant depth; interactions between New Zealand rocks and fluids at supercritical conditions; modelling system sustainability; and delineating the potential of these resources.

We assembled New Zealand and overseas geophysicists, geologists, experimental geochemists, modellers, as well as economic and Māori strategic investment advisors. Here we present the main objectives, relevance, future linkages and the first results of this challenging new scientific endeavour. New Zealand's supercritical journey is underway and on display through www.geothermalnextgeneration.com and associated social media connections.

KEYNOTE
Session 4d.

A REPEATING EARTHQUAKE CATALOGUE FOR NEW ZEALAND

Calum J Chamberlain[1], Laura Hughes[1], Olivia D. Pita Sllim[1], John Townend[1] and Amanda M. Thomas[2]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, New Zealand.*
[2] *Department of Earth Sciences, University of Oregon, Eugene, OR, USA.*

calum.chamberlain@vuw.ac.nz

Repeating earthquakes provide a novel tool to both locate and monitor regions of faults that host creep. Because repeating earthquakes are thought to represent the repeating loading and failure of frictionally strong asperities within an otherwise creeping zone of a fault, they can be used to identify these transitional zones, and potentially monitor temporal variability in creep at high spatial resolution. The repetitive nature of repeating earthquake sources yields highly correlated waveforms over time, providing an effective means to identify repeating earthquakes. Nevertheless, accurate characterisation of whether a well-correlated event is truly repeating requires careful analysis.

In this presentation we outline the methods used to develop a repeating earthquake catalogue for New Zealand, and highlight some of the first order observations of where repeating earthquakes, and hence transitional frictional fault properties, occur in New Zealand. Initial results show high densities of repeating sources near the Southern Alpine Fault and Puysegur subduction zone, and the Taupō volcanic zone, as well as at two previously studied regions of the Hikurangi subduction margin. Detailed analysis of repeating earthquakes offshore Raukumara has highlighted repeating earthquakes concentrated at the edge of known slow-slip patches. Further focused analysis of the repeating earthquakes around Pōrangahau is presented in a related presentation by Olivia D. Pita-Sllim.

POSTER
Session 2a.

MATERIAL AND STRUCTURAL INVESTIGATION OF FOSSILS USING MARS SPECTRAL CT

Claire Chambers[1, 2], Marzi Anjomrouz[2], Neryda Duncan[1, 2], Jereena, Sheeja[2, 3], Anthony Butler[2,3], Phil Butler[1,2] and the MARS Collaboration[2]

[1] *School of Physical and Chemical Sciences, University of Canterbury, Christchurch, New Zealand*
[2] *MARS Bioimaging Ltd, Christchurch, New Zealand*
[3] *Division of Health Sciences, University of Otago, Dunedin, New Zealand*

Cch140@uclive.ac.nz

I present the first images of fossils scanned using MARS spectral photon CT. This new imaging modality uses an energy-resolving, photon-counting detector developed at CERN to investigate the energy-dependent attenuation properties of objects. Technology and techniques developed for in-clinic imaging have been extended to the materials and structures commonly found in fossils. The results of spectral CT imaging of fossils are presented demonstrating the ways in which this technology may be useful to future non-destructive investigation of fossils.

POSTER
Session 4a.

LIQUEFACTION SUSCEPTIBILITY ANALYSES OF LACUSTRINE TEPHRA SOIL MATERIALS

Jordanka Chaneva[1], **Vicki G Moon**[1], **Max O Kluger**[1], **David J Lowe**[1], **Rolando P Orense**[2], **and Richard A Melchert**[1]

[1] *School of Science/Te Aka Mātuatua, University of Waikato, Hamilton, New Zealand*
[2] *Department of Civil and Environmental Engineering, University of Auckland, Auckland, New Zealand.*

jc409@students.waikato.ac.nz

Numerous hidden faults have recently been discovered in the Hamilton lowlands, along with newly-identified paleoliquefaction features recorded in layers of pumiceous volcanic ash (tephra) layers in lake sediments. Around 30 lakes in total, each ~20,000 years old, lie scattered amidst the faults in the lowlands. We have begun a multidisciplinary investigation of the potential earthquake-related hazard of the faults to Hamilton and adjacent areas by mapping the spatial and temporal distribution of liquefaction features preserved in those lakes (see presentations by Kluger and others). Our primary hypothesis is that these tephra layers have liquefied, forming tephra-seismites, as a result of strong seismic shaking on proximal faults. Here, we performed geotechnical (i.e., Atterberg limits, grain size, particle density) and mineralogical (i.e., grain shape, pumice content) analyses in order to assess the liquefaction susceptibility of previously liquefied tephra layers. The layers comprise mainly coarse silts to medium sands dominated by volcanic glass shards, glassy pumice fragments, and minor amounts of felsic and mafic crystals. Geotechnical studies of glass-rich, pumiceous tephra deposits are limited compared with those obtained on hard-grained quartzofeldspathic materials and moreover, previous studies have largely dealt with sand-sized materials rather than silts. Therefore the analyses we performed are also of a broader importance when it comes to geotechnical properties of pumiceous soils/materials. The key tephra layers are able to be categorized into two groups: (i) liquefaction susceptible sands, silty sands, and silts with no clay minerals; and (ii) samples with a potential but unconfirmed liquefaction susceptibility: silts that contain more than 5% clay-sized particles in the form of clay minerals.

ORAL
Session 2a.

CO CREATING A VOLCANIC HAZARD MAPPING FRAMEWORK FOR AOTEAROA NEW ZEALAND

Danielle Charlton[1,2], Mary Anne Clive[1], Jan Lindsay[2] and Graham Leonard[1]

[1] *GNS Science, 1 Fairway Drive, Avalon 5010, PO Box 30-368, Lower Hutt 5040, New Zealand*
[2] *School of Environment, The University of Auckland, Private Bag 92019, Auckland 1142, New Zealand.*

d.charlton@gns.cri.nz

Volcanic hazard maps are critical tools for communicating hazard information and when developed, communicated, and used appropriately they can represent a central point for communication and mitigation of volcanic hazards and discussions about risk.

There is no consistent approach to volcanic hazard mapping in Aotearoa New Zealand. Mapping has to-date been ad hoc with differing degrees collaboration between map makers, stakeholders and with map users. Existing maps have been produced by different scientists using a variety of approaches and designs. This diversity stems from differences in map purpose; the methodology used; prevailing scientific and cartographic practices at the time; and local standards or policy requirements.

Since 2019, we have been combining communications research, expert experiences, and user needs in order to co-develop and test a new operational framework for volcanic hazard map development in Aotearoa. The framework includes workflows and guidelines for the development of different types of map that are commonly used (e.g. long-term preparedness and event specific maps).

We will present the current status of this framework, how it has been co-developed to date and next steps. In addition, we have used this approach to assist in the development new long-term maps for Tongariro National Park, event specific risk to life maps for Whakaari, and for a new map-based communication product for Taranaki Maunga. These case studies have led to iterative and reflexive enhancements in the framework in order to better capture the range of unique volcanic environments in Aotearoa. For example, in the recreational Ruapehu setting, we found that hazard information should supplement a more comprehensive communication product that also addresses risk.

ORAL
Session 3b.

HYDROUS SHEAR ZONES IN THE LOWER ARC CRUST ARE SITES OF MELT TRANSFER – A CASE STUDY FROM GEORGE SOUND SHEAR ZONE

Aditi Chatterjee[1] and Nathan Daczko[1]

[1] *School of Earth and Environmental Sciences, Macquarie University, Sydney, Australia*

aditi.chatterjee@students.mq.edu.au

Recent studies of the lower arc crust exposed in Fiordland, New Zealand, conclude that shear zones are sites of melt migration and mass transfer through the deep crust. The 4-10 km-wide George Sound Shear Zone (GSSZ) in central Fiordland comprises two main rock-types, relatively dry two-pyroxene gneisses and hornblende-bearing gneisses. Petrographic analysis of samples collected in a transect across the shear zone shows a range of hydration reaction textures from rims of hornblende + quartz around pyroxene grains to complete replacement of pyroxene grains. Plagioclase is recrystallised and partially replaced by clinozoisite. Additionally, biotite mode increases from outside the shear zone towards higher strain rocks, well foliated hornblende-biotite-clinozoisite gneisses.

Analysis of BSE images and polarised light microscopy, identifies the microstructures indicative of the former presence of melt as: (a) interconnected mineral films of K-feldspar along grain boundaries inferred to have pseudomorphed former melt, (b) grains that terminate with low dihedral angles, and (c) interstitial grains. Further, undulose extinction in quartz, serrated grain boundaries, and bent plagioclase twins suggest internal strain and grain boundary migration recrystallisation of solid grains accompanied melt-present deformation. Geochemical analysis of whole-rock data shows a positive correlation for Zr (ppm), K_2O (wt%), Rb/Sr vs SiO_2 (wt%) for hornblende-rich gneisses; Cr+Ni (ppm) are comparatively higher for two pyroxene gneisses.

From the above observations, it is inferred that a felsic to intermediate hydrous melt migrated along the GSSZ through two-pyroxene gneiss host rocks. The melt migrated along grain boundaries by deformation-assisted pervasive melt flow. Syn-deformational melt-rock interaction hydrated pyroxenes to hornblende + quartz, plagioclase to clinozoisite, and introduced high proportions of biotite into the assemblage. Crystallisation of melt precipitated K-feldspar and quartz in small pockets and films along grain boundaries. Further, EBSD analysis and Thermocalc calculations provide deeper insight into the interconnectivity of the melt and associated mass transfer.

POSTER
Session 1b.

EARTHQUAKES AND SEISMIC HAZARD IN SOUTHERN NEW CALEDONIA, SOUTHWEST PACIFIC

Shao-Jinn Chin[1], Rupert Sutherland[1], Martha Savage[1], John Townend[1], Julien Collot[2], Camille Clerc[3], Samuel Etienne[2], Bernard Pelletier[4], Pierre Lebellegard[4], Adrija Mazumdar[1], Finnigan Illsley-Kemp[1]

[1]Victoria University of Wellington, Wellington, New Zealand
[2]Service Géologique de Nouvelle-Calédonie, Nouméa, New Caledonia
[3]University of New Caledonia, Nouméa, New Caledonia
4 Géoazur (UMR 6526), IRD, Nouméa, New Caledonia

shaojinn.chin@vuw.ac.nz

We use a network of 12 temporary and 9 permanent broadband seismometers to generate 14 months (2018–2019) earthquake catalogue and local magnitude function for southern New Caledonia. Local magnitudes are calibrated to moment and body wave magnitudes in the USGS catalogue using records of 107 earthquakes in the New Hebrides–Vanuatu subduction zone over a magnitude range of 4.0 to 7.0. Earthquakes in southern New Caledonia are mostly shallower than 20 km. In contrast, hypocentres in the subduction zone are shallower than 30 km west of the trench and deepen eastward to a maximum of 100 km, generally following the subduction geometry even though station coverage in this region is poor. While there are only three events with a magnitude (M) ≥ 4.0 in southern New Caledonia, more than 300 earthquakes with M ≥ 4.0 are located in the subduction zone. In other word, earthquakes occur about 100 times more frequently at the plate boundary than in southern New Caledonia. We evaluate probabilistic seismic shaking hazard by extrapolation of our local magnitude–frequency relation. Inclusion of a more complete local earthquake catalogue increases the seismic hazard for southern New Caledonia relative to the recent regional estimates of Johnson et al. (2021).

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POSTER
Session 3b.

OBSERVATIONS OF THE MOUNT RUAPEHU CRATER LAKE (TE WAI Ā-MOE) AND IMPLICATIONS FOR VOLCANO MONITORING

Charles Ching[1], Ben Kennedy[1], Jim Cole[1], Alex Nichols[1], Brad Scott[2], Bruce Christenson[3], Harry Keys[4], Hollei Gabrielsen[5,6] and Jon Procter[7]

[1] School of Earth and Environment, University of Canterbury, Christchurch, New Zealand
[2] Wairakei Research Centre, GNS Science, Taupo, New Zealand
[3] National Isotope Centre, GNS Science, Lower Hutt, New Zealand
[4] Former Department of Conservation Scientist, Taupo, New Zealand
[5] Department of Conservation, Tongariro District, New Zealand
[6] Te Kāhui o Paerangi – Ngā Waihua o Paerangi Trust, Ohakune, New Zealand
[7] School of Agriculture and Environment, Massey University, Palmerston North, New Zealand

ctc35@uclive.ac.nz

All historical eruptions at Mount Ruapehu have occurred from its Crater Lake, Te Wai ā-moe. This study aims to better understand the Crater Lake dynamics by utilising visible light, thermal, and multispectral images of the Crater Lake captured by GNS Science, Ngati Rangi, DOC, and this study. Visible light observations reveal colour changes on the entire Crater Lake surface from blue to green to grey, and localised grey, yellow, and black discolourations, which correlate with surface temperature anomalies on thermal and multispectral images. The current hypothesis is that Crater Lake colour changes are controlled by seasonal glacial meltwater input, and volcanic fluids that convect sediment and sulphur in the Crater Lake. The grey, yellow, and black discolourations are interpreted as localised upwelling of lake-floor sediment or vent-hosted sulphur that is transported by volcanic fluids from subaqueous vents to the surface. The locations of these sediment and sulphur upwellings have been used to identify three more vent locations beneath the Crater Lake, in addition to the two vents previously recognised. These upwellings are much more dynamic than previously understood, with some upwellings appearing and disappearing in <10 minutes. Crater Lake surface observations have been previously suggested to correlate with volcano monitoring data (e.g., lake temperature and chemistry, seismicity, gas flux), however, as yet time series plots display no strong correlation, implying that processes occurring within the Crater Lake are not fully understood. Thermal and multispectral cameras identified upwellings that were not seen with visible light cameras, indicating their importance as research tools with volcano monitoring potential. This suggests that an array of cameras would be useful additions to the current volcano monitoring network at Mount Ruapehu, however the equipment would require its own power supply, telemetry, and ability to withstand alpine weather conditions comprising high winds, ice, and -10 $^{\circ}$C temperatures.

ORAL
Session 1a.

COPPER IN ONSHORE NEW ZEALAND: MINERAL DEPOSIT TYPES, OCCURRENCES AND POTENTIAL FOR THIS CRITICAL METAL

Tony Christie[1]

[1] *GNS Science, Lower Hutt, New Zealand.*

t.christie@gns.cri.nz

Copper was mined at several locations in New Zealand soon after European settlement, e.g. Kawau Island (1846), Dun Mountain (1855) and Great Barrier Island (1857), with later production at D'Urville Island (1879), Maharahara (1881), Pupuke (1892), Moke Creek (1917), Pakotai (1947) and Parakao (1961). These operations were short-lived because of their small size and the poor economics of shipping ore overseas for processing. The requirement for substantial quantities of copper in electricity generation equipment and its transmission has made copper a critical element/metal/material for the low carbon future and therefore it is timely to review New Zealand's copper deposits for their potential resources.

Most of New Zealand's known onshore deposits can be classified into four main types:

1.) Porphyry Cu deposits that consist of stockwork quartz veins deposited from hydrothermal fluids generated by stocks and dikes of diorite to granodiorite composition, e.g. Coppermine Island, Miners Head, Great Barrier Island, Paritu and Ohio Creek deposits.

2.) Volcanogenic massive sulphide deposits that formed on the sea floor by hydrothermal systems generated by submarine volcanic activity, e.g. Pupuke, Parakao and Lottin Point deposits. A variety of this deposit type associated with chert and pillow lava in Mesozoic greywacke includes Kawau Island, Te Kumi, Maharahara, Moke Creek and Waitahuna.

3.) Serpentine-hosted Fe-Cu deposits that are shear-controlled lenses of mineralisation in serpentinised ultramafic rocks of the Dun Mountain Ophiolite Belt, e.g. deposits on D'Urville Island and Red Mountain, Otago.

4.) Gabbroid-associated Cu-Ni deposits formed by magmatic crystallisation of Cu and Ni minerals in magma chambers or conduits, e.g. deposits associated with igneous complexes at Riwaka (Graham Valley), Blue Mountain, Tapuaenuku, and Otama.

Porphyry Cu deposits probably represent the best exploration target in terms of potential for large resources, but higher Cu grades of the other deposit types may enable production from smaller deposits.

ORAL
Session 4f.

REVISING THE MAGNITUDES IN THE NEW ZEALAND EARTHQUAKE CATALOGUE TO BE CONSISTENT WITH MOMENT MAGNITUDE

Annemarie Christophersen [1], Sandra Bourguignon[1], David A. Rhoades[1], Trevor Allen[2], Chris Rollins[1], Jerome Salichon[1], John Ristau[1], Matt C. Gerstenberger[1]

[1] *GNS Science, Avalon, Lower Hutt, New Zealand*
[2] *Geoscience Australia, Canberra, Australia.*

a.christophersen@gns.cri.nz

The revision of the New Zealand National Seismic Hazard Model (NSHM) relies on the earthquake catalogue for the development of seismicity rate models. For consistency with the ground motion models that are calibrated to use moment magnitude M_W, the magnitudes in the catalogue are ideally expressed as M_W. The most commonly available magnitude in the catalogue is a New Zealand specific local magnitude M_{LNZ77} that was derived in 1977 [*Haines*, 1981]. M_{LNZ77} – reports have been back-calculated until as early as 1931 and were routinely calculated until the introduction of the seismic processing software SeisComP3 (SC3) in 2012. Since 2012, the most prevalent magnitude is also a local magnitude-type, M_{LSC3}. Regular moment tensor calculations and its derived magnitude M_{WNZ} were introduced in 2009 [*Ristau*, 2008] and back calculated for some earthquakes as early as 2003, when an adequate network of broadband stations became available. For earthquakes in the magnitude range 4 – 6, M_{LNZ77} and M_{LSC3} overestimate earthquake size compared to M_{WNZ} [*Ristau*, 2009; *Ristau et al*., 2016]. Previous studies have used the earthquakes with M_{WNZ} reports to derive new attenuation relations for local magnitudes, resulting in M_{LNZ16} and M_{LNZ20}, the latter including a depth term [*Rhoades et al.*, 2021; *Ristau et al.*, 2016]. Here, we calculate M_{LNZ20} for around 178,000 earthquakes, from around 1 million vertical amplitude readings in the period from 2000-2011, and for around 100,000 earthquakes and again around 1 million vertical amplitude readings in the period from 2012-2020. We restricted both these datasets to ensure good quality of the derived regression relationships for these earthquake pairs. We applied those to the catalogue and defined a preferred magnitude. The resulting data are available as a stand-alone dataset, which is described in a GNS Science report . Here we discuss the method and summarise the key features of the dataset.

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POSTER
Session 2a.

IMPROVING THE MARINE RESERVOIR AGE DATABASE FOR AOTEAROA NEW ZEALAND TO ENABLE BETTER CHRONOLOGIES OF HOLOCENE COASTAL CHANGE

Kate Clark[1], Jocelyn Turnbull[1], Bruce Marshall[2], Taylor Ferrick[1], Jamie Howarth[3]

[1] *GNS Science, Lower Hutt*
[2] *Museum of New Zealand Te Papa Tongarewa*
[3] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington*

k.clark@gns.cri.nz

Chronologies of Holocene coastal change are often based on radiocarbon ages derived from marine shells. For example, the timing of earthquake-driven marine terrace uplift along the Hikurangi subduction zone is typically dated using shell material found within the terrace coverbeds. Calibrated radiocarbon ages derived from marine shells have a ~500 year marine reservoir age correction applied to account for the offset between ^{14}C in the atmosphere and in the ocean. The ~500 yr correction is a global average for the past 11.6 ka but there are local deviations, quantified by ΔR. The existing global marine reservoir database has 45 ΔR values for the Aotearoa New Zealand coastline. The weighted mean of all these values is -63 ± 85 yrs, but there are strong hints of regional variations. For example, the weighted mean of the 7 west coast samples is -160 ± 40 yrs, and the weighted mean of 21 North Island east coast samples is -46 ± 76 years. However, the geographic spread of samples in the database is uneven meaning the spatial relationships between ΔR and ocean circulation or latitude is difficult to assess. In this project we have calculated an additional 156 ΔR values, these data come from thirty locations around the Aotearoa New Zealand mainland islands and are based on dating shells of known pre-1950 CE age from the National Collection at the Museum of New Zealand Te Papa Tongarewa. These data will allow us to better quantify local marine reservoir effects around the coastline, and ultimately this will lead to more accurate chronologies of coastal change based on marine radiocarbon ages.

POSTER
Session 2d.

HIDE AND SEEK: CRYPTOTEPHRA STUDIES APPLIED TO A DEEP MARINE CORE

Madison Clarke*[1], **Jenni Hopkins[1], Richard Wysoczanski[2], Valerie van den Bos[1], Lorna Strachan[3]**

[1] *School of Geography Environment and Earth Science, Victoria University of Wellington, Wellington, New Zealand.*
[2] *NIWA, Wellington, New Zealand.*
[3]*School of Environment, University of Auckland, Auckland, New Zealand*

*clarke.madison.21@gmail.com

The aim of the project is to reconstruct the volcanic record for the upper 500 m of the IODP U1520D core drilled during Research Cruise 375. The project will focus on developing methods of using XRF, magnetic susceptibility and density data to identify cryptotephra within the deep marine sediment core. This identification will then be run through machine learning and statistical techniques to pin point sites of interest within long cores to target for sampling for cryptotephra. Once the cryptotephra are identified we will extract the samples and, where appropriate, analyse the glass shards for major and trace element compositions. This information will be combined with the existing macroscopic tephra framework to reconstruct a more detailed record of the volcanic eruptions from the TVZ during the past 800 ka.

Here we present the initial findings from the method development portion of this study. We have tested and developed the correct density separation techniques using 2.0 g/cm^3 sodium polytungstate (SPT) to concentrate the glass shards, then 2.5 g/cm^3 SPT to extract the glass shards. We have also determined the accuracy of our method by testing a range of glass shard concentrations and monitoring the recovery of the glass shards from these samples by our method. These methods have been applied to whole cores (traditional method) and to targeted core sections (new method) to test our machine learning and statistical techniques.

POSTER
Session 1a.

WORKING TOWARDS A MODEL OF THE DEGLACIATION OF THE SOUTHERN ALPS ICEFIELD FOR INVESTIGATING LOCAL GIA EFFECTS ON HOLOCENE RELATIVE SEA-LEVEL CHANGES

Alastair J.H. Clement[1], Pippa L. Whitehouse[2]

[1] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*
[2] *Department of Geography, Durham University, Durham, UK*

a.clement@massey.ac.nz

During the Last Glacial Maximum (LGM; c. 30-18 ka) the Southern Alps were covered by an extensive mountain icefield with an estimated volume of approximately 6,800-6,900 km^3. The LGM icefield was characterised by a valley-constrained style of glaciation, with outlet glaciers extending 70-100 km onto the adjacent forelands. Large-scale glacial retreat commenced c. 17 ka—today, only mountain glaciers remain, with the icefield having lost 99.25 percent of its LGM mass.

Glacial isostatic adjustment (GIA) of the South Island in response to the growth and deglaciation of the icefield has previously been hypothesised but has not been substantively investigated. The LGM mass of the icefield may have produced a glacial forebulge around the icefield margin that collapsed as the mass of the icefield decreased. The collapse of forebulge may have influenced Holocene relative sea-level changes around the South Island's coastline that may be unravelled by GIA modelling.

The ice history of the Southern Alps icefield is a key input for GIA modelling. However, the icefield is a minor component of existing global ice histories. Models have been produced of the LGM mass of the icefield (Golledge et al., 2012; James et al., 2019), but these models are only for a single point in time.

To address this gap these models of the LGM mass of the Southern Alps icefield will be scaled to produce a time-series of the deglaciation of the icefield from the LGM to c. 6 ka (when the minimum extent of the icefield was reached). The scaling uses modelled temperature data to drive shifts in equilibrium line altitudes, with glacier mass reduced based on accumulation area ratios. Ultimately this local ice history will be merged with components of the global ice history to correctly model the GIA process. This poster presents interim results from the scaling process.

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POSTER
Session 2c.

THE MAGMATIC HISTORY OF NGAURUHOE VOLCANO FROM PHENOCRYST RECORDS

Kate Cocker [1], **Phil Shane** [1], **Claudine H. Stirling** [2,3], **Malcolm R. Reid** [2,3], **Shane Cronin**[1]

[1] School of Environment, University of Auckland, Auckland 1142, New Zealand
[2] Department of Chemistry, University of Otago, Dunedin 9054, New Zealand
[3] Centre for Trace Element Analysis, University of Otago, Dunedin 9054, New Zealand

kcoc785@aucklanduni.ac.nz

Sub-crystal scale $^{87}Sr/^{86}Sr$ analysis of plagioclase and groundmass in Ngauruhoe andesite's highlight isotopic signatures consistent with disequilibrium processes, not seen using bulk-rock studies, thus furthering our understanding of magma assembly. An open magmatic system is evident from heterogeneous phenocryst populations of various cognate and non-cognate origins and magma mingling observed in the groundmass. The studied samples span an age range of 2 ka through to the most recent 1975 eruption, collected from various sectors of the edifice. Much of the plagioclase consist of a relic core, surrounded by one or several mantling overgrowths, thought to be linked to multi-stage growth during transport through the crust. Overall, the total compositional range across all samples is wide (An_{54-91}). The inter-crystal $^{87}Sr/^{86}Sr$ diversity is considerable, with differences up to 0.7039 to 0.7060. Isotopic zoning within phenocrysts is evident with rim-core differences up to 0.0017 and contrasting isotopic zonation can occur in phenocrysts of the same sample. Non-cognate plagioclase includes, calcic relic cores ($>An_{80}$) exhibiting low $^{87}Sr/^{86}Sr$ ratios (<0.7050), likely to be sourced from deep cumulates or mafic magma. These cores are overgrown by more sodic rims ($\sim An_{55}$) with higher $^{87}Sr/^{86}Sr$ ratios (~0.7055) and are likely the result of growth in an upper crustal system. Phenocrysts which are most likely cognate because of their concordant composition and isotopic ratio with the groundmass, consist of oscillatory zoning and lack relic cores, others display decompression-induced replacement of calcic plagioclase with more sodic compositions. These textures reflect the dynamic processes of magmatic ascent and temporary storage.

Overall historic magmas have more radiogenic plagioclase and groundmass relative to the pre-historic magmas. Also, there is a decreasing abundance of plagioclase in the lavas with time. The degree of crustal assimilation appears to have increased as the system evolved.

POSTER
Session 1b.

HOT TAKES ON EARTHQUAKE TEMPERATURE RISE AND FRICTIONAL ENERGY

Genevieve Coffey[1], Heather Savage[2] and Pratigya Polissar[2]

[1] *Earth Surface Processes, GNS Science, Lower Hutt, New Zealand*
[2] *Earth and Planetary Science, University of California Santa Cruz, USA.*

g.coffey@gns.cri.nz

Earthquakes dissipate some energy as frictional heat leading to dramatic increases in temperature along fault zones. This temperature rise can have profound effects on fault zone behavior, for example it can lead to large reductions in fault strength from the onset of thermally-activated dynamic-weakening mechanisms. As a result, constraining the temperature rise that occurred during past earthquakes provides a window into frictional strength and the processes controlling strength that occur during coseismic slip. It also allows us to place constraints on the earthquake energy budget, a key component in understanding what controls a ruptures ability to grow or lead to its arrest.

With the development of paleotemperature proxies and borehole temperature observatories, an increasing number of coseismic temperature and frictional energy estimates for different faults have been constrained. Here, we present a compilation of these estimates and the first broad constraints on the earthquake energy budget as a whole for numerous faults. We see that temperature rise increases with depth of faulting and that frictional energy increases somewhat with displacement but is similar across different types of faults. Our results demonstrate a fundamental difference in the way energy is partitioned between small and large earthquakes. In smaller earthquakes the energy budget is dominated by frictional heating, while for larger events it is more evenly divided between frictional, radiated, and fracture energy.

We suggest that as earthquakes get large and, due to dynamic weakening, more of the slip distance is spent sliding at lower friction, more energy can go towards radiating seismic waves and fracture energy. These results provide a first look into the earthquake energy budget as a whole and are an important advancement in understanding the energy required for earthquake rupture.

POSTER
Session 2a.

ONCE-IN-A-LIFETIME: PLIOCENE FOSSILS OF THE CENTRAL INTERCEPTOR PROJECT, AUCKLAND, NEW ZEALAND [PART A]

Nathan Collins[1], Thomas Stolberger[1] Bruce Hayward[2], and Alan Beu[3]

[1] Natural Sciences department, Tāmaki Paenga Hira Auckland War Memorial Museum, Auckland, New Zealand
[2] Geomarine Research, Auckland, New Zealand
[3] GNS Science (emeritus, palaeontology), Lower Hutt, New Zealand

ncollins@aucklandmuseum.com

In early 2020, construction on Watercare's Central Interceptor wastewater tunnel in Māngere, Auckland, uncovered thousands of fossil specimens 35 m below the surface within the Pliocene "Kaawa Shell Bed". Although widespread beneath southern Auckland, the "Kaawa Shell Bed" is rarely encountered at the surface, with current knowledge based on scattered outcrops (e.g. Kaawa Creek), borehole data, and fortuitous excavations (e.g. Waitematā Brewery). This rich find therefore represents a unique opportunity to characterise the previously poorly represented Pliocene molluscan fauna of northern New Zealand.

Preliminary investigations of the assemblage have revealed at least 180 taxa including 10 new species, of probable Waipipian age (3.7–3.0 Ma). The dominant components (*Glycymerita, Tawera, Maoricrypta*) suggest that deposition occurred in a shallow nearshore setting (<20 m) such as a subtidal channel. These components are supplemented by taxa from rocky shore (e.g. *Turbo*, *Crassostrea*, *Cellana*) and sandy beach environments (e.g. struthiolariids, *Paphies*). The remarkable discovery of several flax snails (Placostylinae) within the deposit represent the oldest fossil evidence for this group and significantly predates previous sub-fossil specimens (~100 kya). Other notable specimens include the first record of Conidae from Pliocene New Zealand and a baleen whale vertebra.

POSTER
Session 1c.

GEOCHEMISTRY: WHAT CAN IT TELL US ABOUT THE NEXT ERUPTION?

Brenda Contla Hernandez[1], Melody Whitehead[2], Mark Bebbington[1,2], Michael C. Rowe[3]

[1] *School of Fundamental Sciences, Massey University, Palmerston North, New Zealand*
[2] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*
[3]*School of Environment, University of Auckland, Auckland, New Zealand*

b.hernandez@massey.ac.nz

Volcanic eruptions can cause great loss of life, as well as damage to infrastructure and the environment. Worldwide efforts have been made to monitor volcanoes and to try and forecast the possible style and size of eruptions, as well as changes occurring during volcanic activity. However, volcano-monitoring techniques have yet to reach this goal, and formal linkages between monitoring and geochemical data remain unresolved.

Machine learning (ML) methods have been widely used to investigate possible hidden patterns or relationships in volcanic data. For instance, ML methods have been applied to automatically detect ground deformation from InSAR images[1], and to link infrasound to changes in eruption activity at Etna[2]. ML methods have also been used to identify links between geochemical data from erupted material with subsurface dynamics and properties[3]. This research aims to explore the use of a variety of ML methods and statistical methods (including k-means, Support Vector Machine and Principal Component Analysis) as applied to a complex multivariate data set of whole-rock geochemical samples, pre-eruption monitoring signals and eruption data (as described initially by VEI and start and end date of activity). This presentation provides an overview of the information available from nearly 250 volcanoes around the world that have erupted since 1970. Particularly, the available whole-rock geochemistry samples of erupted products and monitoring data from eruptions that have occurred since the implementation of wide-spread monitoring (c.1930) and recording (c.1970). This work will consider the use of geochemical data to identify possible links with monitoring data and key properties in them that could help to develop statistically robust eruption scenarios.

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POSTER
Session 4a.

ULTRA-REFRACTORY MANTLE UNDER THE SOUTHERN ALPS, AND IMPLICATIONS FOR MODERN AND ANCIENT CONTINENTAL LITHOSPHERE CONSTRUCTION

Nadine Cooper[1], James M. Scott[1], Marshall C. Palmer[1], Malcolm R. Reid[1,2]

[1] Department of Geology, University of Otago, Dunedin, New Zealand
[2] Centre for Trace Element Analysis, University of Otago, Dunedin, New Zealand

coona484@student.otago.ac.nz

Ultra-refractory spinel-bearing ultramafic peridotite xenoliths occur in Cretaceous and Cenozoic alkaline basalts in the Southern Alps and Westland, New Zealand. Two new suites of peridotite xenoliths, collected from the Southern Alps in late 2020-early 2021, are dominantly harzburgitic with minor dunite and lherzolite. These suites have olivine and spinel mineral compositions as well as low bulk rock Al_2O_3 and CaO that indicate they underwent extensive (> 30%) partial melting. Spinel chemical compositions indicate that this was likely via hydrous melting, and therefore most likely in a sub-arc environment. Since the overlying crust of one of these suites is fore-arc material, some of the buoyant refractory mantle peridotite must have been translated under the Southern Alps since Early Cretaceous subduction along the Gondwana margin ceased. Orthopyroxene trace elements and the occurrence of apatite-bearing assemblages indicate that the peridotite suites have been modified by minor mantle metasomatism after depletion. The global significance of these ultra-refractory rocks is that their bulk compositions and minerals are chemically similar to the mantle lithosphere associated with Earth's ancient continents –Archean cratons, which form the nucelli to continents. However, our to-date Re-Os isotope data coupled with PGE and other bulk rock data are consistent with rhenium-depletion and assembly of Zealandia's ultra-refractory domains in the Cenozoic, with some older embedded components within the lithosphere inherited from the convecting mantle. The modern process of generating refractory peridotite in a supra-subduction zone environment may therefore be a partial analogue for the formation of the very refractory portions of Archean mantle lithospheric material and would suggest that subduction has begun before the end of the Archean.

POSTER
Session 1c.

NEW COMPREHENSIVE PB ISOTOPIC DATA ELUCIDATE NOVEL PETROGENETIC PROCESSES ACROSS THE TAUPO VOLCANIC ZONE

Corella Santa Cruz, Carlos R.[1]; Stirling, Claudine H.[2,4]; Zellmer, Georg F.[1]; Straub, Susanne M.[3]; Brenna, Marco[4]; Nemeth, Karoly[1]

[1] Volcanic Risk Solutions, Massey University, Private Bag 11222, Palmerston North 4442, NZ
[2] Centre for Trace Element Analysis, University of Otago, Po Box 56, Dunedin 9054, NZ
[3] Lamont-Doherty Earth Observatory of Columbia University, 61 Route 9W, Palisades, NY 10964, USA
[4] Department of Geology, University of Otago, Po Box 56, Dunedin 9054, NZ

c.santacruz@massey.ac.nz

The Taupo Volcanic Zone (TVZ) is an area of subduction zone volcanism in a rifted arc, active since 2 Ma, dominated by high-volume high-silica eruptions from large caldera-systems, and has one of the highest present-day magma production rates on Earth. Fractional crystallisation (FC) and assimilation-fractional crystallisation (AFC) have typically been modelled to account for the TVZ compositional range, utilizing the Torlesse - composite terrain greywacke crust as the main assimilant. Previous studies typically focussed on specific areas within the TVZ and only considered either basic, or intermediate, or acid magmatism. Here, we present a new and comprehensive lead isotopic dataset of the entire TVZ. The results presented here represent a spatiotemporally and compositionally comprehensive sample suite. They cover old and new volcanic products (2 Ma – Present), are distributed across the east-west and north-south extension of the TVZ and are basic through intermediate to acid in chemical composition, showing a linear lead isotopic trend. These lead isotopic compositions (based on ^{208}Pb/^{204}Pb, ^{207}Pb/^{204}Pb and ^{206}Pb/^{204}Pb ratios) are integrated with MELTS and Magma Chamber Simulator models. Together with the strontium isotopic signatures (^{87}Sr/^{86}Sr ratio), major oxide contents and trace elements concentrations at different pressures (100 MPa - 900 MPa) and low initial water contents consistent with published data (0.5 - 1.5 wt% H_2O), our findings show that FC or AFC with Torlesse greywacke crust as the assimilant cannot reasonably reproduce the observed data. Here, we will explore alternative processes, including subduction melange diapirism as one potential process to produce the intermediate to acid magmas in the TVZ.

POSTER
Session 1b.

Blocking or Topping - Simulating Pyroclastic Currents Across Obstacles

Lucas Corna[1], Ermanno Brosch[1], Daniel Uhle[1], James Ardo[1] and Gert Lube[1]

[1] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*

l.corna@massey.ac.nz

The interaction of Pyroclastic Density Currents (PDCs) with topography remains an enduring uncertainty in volcanic hazard models. To bridge this gap, we simulated the propagation of dilute PDCs over hill-shaped obstacles in dynamically and kinematically scaled large-scale experiments and measured the spatiotemporal variation in flow velocity, density, temperature and deposition across flow runout lengths of up to 35 m. We systematically varied the size of obstacles relative to the boundary layer thickness of the PDCs, while keeping their form as well as the PDC starting conditions unchanged.

We observe four phases of interaction whose local effects increase with obstacle height. 1. upstream partial flow blocking, which reduces the bulk flow density by up to 70%; 2. flow compression and acceleration on the stoss-side; 3. flow detachment, expansion and deceleration on the crest and lee-side; and 4. flow re-attachment and separation into a slow, relatively cold, dilute backflow in a vortex underneath the detachment zone and a fast, hot, more concentrated downstream flow above. These processes are accommodated by orders of magnitude decreases in deposition rate with local changes from deposition of thick, stratified, dune-bedded and massive deposits upstream to thinly laminated deposits across and behind the obstacle, and changes in flow and deposit grainsizes.

However, after the obstacles, flow velocity and density (hence dynamic pressure), final runout length, flow duration, and deposition are remarkably similar for each obstacle. This implies that topography and blocking have little consequences on downstream hazard impacts and necessitate processes in dilute PDCs that counter these effects. We show that the strong perturbation of the vertical flow density stratification with maxima migrating from the flow base to mid-flow levels drives this counterbalancing process. This results in sudden increases in the flow-driving density contrast of the largest coherent turbulence structures and formation of fast-moving internal gravity waves.

ORAL
Session 1a.

TARANAKI AND TAUPO TITANOMAGNETITES CONTAIN TRACE CONCENTRATIONS OF STRUCTURALLY BOUND H_2O

Daniel A. Coulthard Jr.[1], Georg F. Zellmer[1], Naoya Sakamoto[2], Morihisa Hamada[3], Sébastien Jégo[4], Takeshi Kuritani[5], Akihiko Tomiya[6], Hisayoshi Yurimoto[2,5]

[1]*School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*
[2]*Creative Research Institution (CRIS), Hokkaido University, Sapporo, Japan*
[3]*Research Institute for Marine Geodynamics, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Yokosuka, Japan*
[4]*Institut des Sciences de la Terre d'Orléans UMR 7327, CNRS/INSU-Université d'Orléans-BRGM, Orléans, France*
[5]*Department of Earth and Planetary Sciences, Graduate School of Science, Hokkaido University, Sapporo, Japan*
[6]*Research Institute of Earthquake and Volcano Geology, Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology, Tsukuba-shi, Japan*

d.a.coulthard@massey.ac.nz

Novel ion microprobe experiments have revealed that hydrogen partitions into spinel-structured oxides. Iron-rich spinels, hereafter referred to as titanomagnetites, sourced from Fantham's Peak (Taranaki Volcano) and Lake Taupo (Taupo Volcano) typically exhibit small but significant $^{16}O^{1}H$ signal intensities that cannot be attributed to either secondary mineral / melt inclusions or background OH formation under high vacuum. Using recently obtained relative sensitivity factors, we estimate that these titanomagnetites contain as much as c. 30 µg/g H_2O.

Similar ion microprobe experiments were conducted on synthetic basalt samples produced using Fantham's Peak scoria and internally heated pressure vessels. Using a Stacked CMOS Active Pixel Sensor, images representing the two-dimensional distribution of OH signal intensity suggests that titanomagnetite may contain as much as c. 200 µg/g H_2O under conditions analogous to those within arc crust.

POSTER
Session 1b.

POST-GLACIAL GEOMORPHIC EVOLUTION OF THE LAKE WAKATIPU DELTA

Steph Coursey[1], Samuel McColl[1], Joshu Mountjoy[2], Sean Fitzsimons[3], and Ian Fuller[1]

[1] *School of Agriculture and Environment, Massey University, Palmerston North, NZ*
[2] *Ocean Geology Group, National institute of Water and Atmospheric Research, Wellington, NZ*
[3] *Te Iho Whenua, School of Geography, University of Otago, Dunedin, NZ*

s.coursey@massey.ac.nz

Sub-lacustrine mass-movement processes have received little attention, particularly in Aotearoa, and their causes are poorly understood. Investigation of the post-glacial development of lake basins allows for the evaluation of landslide-related hazards associated with these dynamic environments. All the major natural lakes in Aotearoa's Southern Alps are associated with deep glacial trough valleys, where typically rapid sedimentation and infilling by active river deltas produces highly dynamic systems. Recent acquisition by NIWA of high-resolution bathymetric data of Lake Wakatipu provides an opportunity to study the sub-lacustrine geomorphology, in order to assess the dynamics and hazards, of this iconic and culturally significant lake.

We have used the bathymetric data to map features along the lake floor, producing a geomorphic map of the entire lake. The mapping has revealed a dynamic environment, including a subaqueous canyon and channel in the upper end of the lake beginning at the Rees-Dart delta. Crescentic-shaped bedforms dominate the subaqueous delta and canyon, with wavelengths of up to 150 m. There is evidence for episodes of erosion along the channel represented by terrace-like features and knickpoints, and for channel avulsions. While similar features have been identified in the marine environment (e.g. fjords and off the continental shelf (Chen et al., 2021), such features are relatively unknown in lake settings and may be symptomatic of the rapid uplift and erosion of the adjacent mountains. In other locations along the canyon, there is evidence of lake-floor landsliding, suggesting potential hazard and a mechanism of sediment reworking within the lake. It is likely that extensive sediment deposition is obscuring some depositional features related to subaqueous landsliding. We plan to use seismic refraction and repeat bathymetric surveys in selected locations to support our landform interpretations and further develop an understanding of the dynamics and hazards of this lake basin.

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POSTER
Session 2b.

POINTING THE FINGER AT MESOZOIC SUBDUCTION TERMINATION IN MARLBOROUGH

James Crampton[1] **and Andy Tulloch**[2]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington Te Herenga Waka, Wellington, New Zealand.*
[2] *GNS Science, Dunedin, New Zealand.*

james.crampton@vuw.ac.nz

There is continued debate about when long-lived Mesozoic subduction terminated along the Zealandian margin, with estimates lying in the range of 105 Ma to 70 Ma. Debate may, in part, reflect true variations in timing along the ~ 2000 km of margin between the eastern end of the Chatham Rise and Raukumara Peninsula. Notwithstanding this, even at specific points on the margin, local observations and data continue to be offered in support of very different interpretations. This is true in southeastern Marlborough, where “the great Coverham section” (McKay 1886, p. 71) represents the longest-studied and one of the most complete stratigraphic sections spanning the tectonic transition from Cretaceous subduction to passive margin. Despite the long history of geological exploration, however, many details of the geology at Coverham and in nearby areas have remained poorly understood.

Detailed geological mapping at Coverham and in the Wharekiri and Kekerengu valleys has revealed the presence of two mid-Cretaceous, apparently low-angle normal faults that were active between ~105 Ma and ~95 Ma. Thick (up to 500 m) submarine mass-transport complexes accumulated against these fault scarps and perhaps within associated submarine canyons. Mass-transport complexes are overlain by a thick, fining-upwards succession of marine sandstone and mudstone with very widespread and spectacular evidence of ongoing slope instability and mass-wasting. Highly variable paleocurrent and paleoslope indicators demonstrate sediment accumulation within confined, topographically complex settings. The presence of low-angle normal faults is inferred to mark extension that was related to local onset of rifting between East Antarctica, Australia and Zealandia. Speculatively, extension and spectacular mass-transport and -wasting deposits may also record impact and disruptive passage of the buoyant, high-relief Hikurangi Plateau salient (“finger”) beneath the Marlborough accretionary wedge in the final stages of Mesozoic subduction.

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ORAL
Session 1c.

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STRUCTURAL TRAPS AND LOCAL TECTONIC STRESS FIELDS CONTROLLING FLUID FLOW, GAS HYDRATE FORMATION AND METHANE SEEPAGE: NEW ZEALAND'S SOUTHERN HIKURANGI MARGIN

Gareth Crutchley[1], Jess Hillman[2], Joshu Mountjoy[3], Sally Watson[3], Francesco Turco[4], Karsten Kroeger[2], Bryan Davy[2]

[1] GEOMAR Helmholtz Centre for Ocean Research, Kiel, Germany
[2] GNS Science, Avalon, Lower Hutt, Aotearoa New Zealand
[3] NIWA, Hataitai, Wellington, Aotearoa New Zealand
[4] University of Otago, Dunedin, Aotearoa New Zealand

gcrutchley@geomar.de

Sub-seabed fluid flow, gas hydrate formation and seafloor methane seepage are tightly interwoven processes with implications for marine biodiversity, ocean chemistry and energy. We combine long-offset seismic reflection data with new high-resolution seismic data to investigate shallow folding, faulting and fracturing, and relationships to focused gas migration and hydrate formation. Anticlines, effective structural traps for focusing free gas, are characterised by normal fault systems within the hydrate stability zone. The normal faults presumably form as a result of sediment layer folding and gravitational collapse of the ridges during uplift. The orientations of normal faults and elongated vertical gas conduits give important insight into local stress fields that control fluid flow. We observe a distinct change in the orientation (a ~70° rotation) of gas conduits from ridge parallel within an anticline near the deformation front to oblique to the deformation front within anticlines further inboard. This rotation points to a switching of the least and intermediate principal stresses that we interpret as a tendency for anticlines further inboard (those more structurally mature) to accommodate a greater degree of ridge-parallel shortening. These observations suggest that variable shallow strain partitioning is an important process during anticline development within this obliquely convergent margin, and perhaps other similar settings globally, with fundamental implications for gas migration, hydrate formation and methane seepage.

ORAL
Session 2e.

GEONET HURITAU: 20 YEARS OF CONTINUOUS GNSS DATA IN AOTEAROA

E. D'Anastasio[1], M. Kortink[1], S. Hreinsdottir[1], L. Wallace[1], D. Whitaker[1], R. Winefield[2]

[1] *GNS Science Te Pu Ao, Lower Hutt, New Zealand*
[2] *Toitū Te Whenua Land Information New Zealand, Wellington, New Zealand.*

e.danastasio@gns.cri.nz

Global Navigation Satellite System (GNSS) data are used to precisely determine the position of an object on the earth's surface. In geophysics, the ability to measure ground deformation with an accuracy of a few millimeters revolutionized the understanding of plate boundary deformation processes. 20 years ago, when the GeoNet project started, GNS, EQC, and LINZ established a partnership to instate a national continuous GNSS network. The network has now grown to almost 200 stations. 37 stations form the LINZ's PositioNZ core network and are evenly distributed across the country. The remaining are GeoNet stations, installed in target areas to monitor New Zealand's ground deformation. GeoNet ensures that data are continuously received, properly archived, curated, and generates several products that are made accessible to the community. These products are used for a wide range of geodetic applications, from long term monitoring of plate tectonics to real-time positioning and surveying. Data are used by LINZ to support the New Zealand Reference Datum and real-time positioning applications. GNSS data from the GeoNet and PositioNZ networks have enabled the discovery of slow slip events at the Hikurangi subduction zone, detected displacements caused by major earthquakes, and helped researchers to monitor landslides, volcanoes, and a range of deformation processes throughout New Zealand's plate boundary zone.

Acknowledgments:
Numerous technicians, scientists and geodesists have contributed in the years to the development of the GeoNet and PositioNZ networks. We would like to acknowledge the contribution of J. Beavan, M. Amos, N. Balfour, L. Bland, G. Blick, C. Burton, D. Collett, H. Cowan, P. Denys, A. Douglas, S. Edwards, K. Fenaughty, N. Fournier, P. Gentle, K. Gledhill, J. Hanson, B. Hodge, A. Jordan, D. Matheson, C. Miller, N. Palmer, S. Taylor-Offord, H. Woodard, and all the operational teams that worked for the GeoNet Project since 2001.

ORAL
Session 4b.

INSIGHTS INTO MAGMATIC SOURCE PROPERTIES FOR LARGE-SCALE ERUPTIONS AT MT TARANAKI – AN ISOTOPE INVESTIGATION

Alex Davidson[1], Simon Turner[1], John Creech[1]

[1] *Earth and Environmental Science, Macquarie University, Sydney, Australia*

alexandra.davidson@hdr.mq.edu.au

While the tectonic context of Mt Taranaki remains partially unresolved, it is widely considered the western-most expression of the subduction-related volcanism of the Hikurangi arc-trench system. Alternative models invoke delamination of the lithosphere and resulting mantle inflow for the source of magmatism, which may be supported by similarities between Uranium-series disequilibria data from global analogues. The magnitude of ^{238}U-^{230}Th disequilibria in volcanic rocks is primarily controlled by melt generation and magma transport events, and thus is useful for extracting information about these processes. U-series data has been collected for a range of high-K andesitic eruptives aged between 0.35 to 22 ka from Mt Taranaki, New Zealand, placing constraints on the magma origin and timescales of source processes. Preliminary data indicates potentially two magmatic sources that yielded magmas with ^{230}Th and ^{238}U excesses respectively. Subduction-related volcanics are typified by ^{238}U excesses relative to ^{230}Th, attributed to the addition of slab-derived fluid to the mantle wedge beneath the arc, however several eruptions analysed display unusually large ^{230}Th excesses for a typical arc volcanic system ((^{230}Th)/(^{238}U) = 1.063 – 1.4), positioning them within the average field for OIB samples. Parallels between U-series values for trachyandesite Ashikule Basin (AKB) samples in northwestern Tibet and Mt Taranaki eruptives are apparent, the former of which are derived from melts generated by the convective removal of lower lithosphere. Eruptions recording ^{230}Th excesses form a coherent flat linear array, uncharacteristic of melts generated by fluid addition to a mantle wedge. Such arrays indicate rapid source processes, occurring on timescales of less than 10 kyr and indicating short residence times and rapid magma ascent. These source to surface processes are intrinsically linked to styles of future activity, and incorporating this knowledge into hazard modelling assists in minimizing impact and improving resilience of affected communities from future eruptions.

POSTER
Session 1b.

PROXIMAL TSUNAMI SOURCES ASSOCIATED WITH SUBDUCTING SEAMOUNTS ALONG THE HIKURANGI MARGIN, NEW ZEALAND: POTENTIAL DRIVERS, MECHANICS, AND HAZARD IMPLICATIONS

Sam Davidson[1], Philip Barnes[2], Bill Fry[3], Shaun Williams[4], Jarg Pettinga[1], Andy Nicol[1], Cyprien Bosserelle[4], Rebecca Welsh[2]

[1]School of Earth and Environment, University of Canterbury, Private Bag 4800, Christchurch, NZ
[2]National Institute of Water and Atmospheric Research, Private Bag 14901, Wellington, New Zealand
[3]GNS Science, PO Box 30-368, Lower Hutt, New Zealand
[4]National Institute of Water and Atmospheric Research, PO Box 8602, Christchurch, New Zealand

sam.davidson@pg.canterbury.ac.nz

Subducting seamounts can have a profound impact on the morphostructure, seismicity, and overall tectonic stability of convergent margins. Along the central and northern sections of the Hikurangi Margin offshore of eastern New Zealand, subducting seamounts are associated with anomalous topographic uplift and large slope failures, some of which may produce damaging tsunami. Further, a presently subducting seamount imaged beneath the outer wedge offshore of Gisborne has previously been identified as a potential earthquake source mechanism for the 1947 Gisborne tsunamis. Consequently, the role subducting seamounts play in the formation of damaging earthquake or landslide tsunami is of high importance for understanding potential tsunami hazards to coastal communities. As several urban centres and communities are located along New Zealand's east coast, coupled with short warning lead times for proximal tsunami sources, it is important to constrain both the mechanics and impact of likely tsunami which may be generated by subducting seamounts.

Two key regions along the Hikurangi Margin are identified as potentially tsunamigenic where subducting seamounts have resulted in morphostructural modification of the upper plate. The southern of these tsunami sources, across Rock Garden and Ritchie Ridge/Banks, is responding to the subduction of Ritchie Seamount through an increase in outer wedge slope taper and complex upper plate fracturing. Such deformation favours gravitational relaxation and slope failure. Further north, earlier seamount subduction and the formation of the Ruatoria Re-entrant reflects an end-member catastrophic failure wherein a large volume of the outer wedge failed simultaneously. Although largely collapsed, continued seamount subduction, coupled with pervasive normal faulting and several regions of increased slope taper provide potential source regions for tsunami. Furthermore, deep-seated wedge collapse may be triggered by only moderately large earthquakes that in themselves may not invoke substantial threat or necessarily be strongly felt. These findings suggest further tsunami modelling efforts are needed.

ORAL
Session 2b.

SUB-BOTTOM PROFILER DATING OF GLACIAL HORIZONS AND THE TIMING OF CARBONATE MOUND FORMATION ON THE SOUTHERN HIKURANGI MARGIN

Bryan Davy[1], Gareth Crutchley[2], Jess Hillman[1], Joshu Mountjoy[3], Ingo Pecher[4,]

[1]GNS Science, Avalon, Lower Hutt New Zealand
[2]GEOMAR Helmholtz Centre for Ocean Research, Kiel, Germany
[3] NIWA, Hataitai, Wellington, New Zealand
[4]University of Auckland, Auckland, Aotearoa New Zealand

b.davy@gns.cri.nz

Modern interferometric sub-bottom profilers can record vertical horizon resolution to 40 cm and achieve penetration up to 100 m sub-seafloor, in favourable conditions. The high-resolution data enable the recognition of reflectors corresponding to past glacial-interglacial intervals, as well as intervening reflectors corresponding to stadial low-stands. The technique has been previously applied using the “Atlas Parasound” sub-bottom profiler in investigating the timing of pockmark formation on the Southwestern Chatham Rise (Davy et al. 2010, Stott et al. 2019). We apply this technique to two selected sites on ridgetops of the Southern Hikurangi Margin, beyond the influence of current erosion, mass transport deposits, and recent deformation, and surveyed using the “Kongsberg TOPAS PS-18” sub-bottom profiler, onboard R/V Tangaroa during cruise TAN1808.

Examined sites are on Kekerengu Bank and West Uruti Ridge. The Kekerengu Bank is the southernmost accretionary ridge of the Hikurangi Margin. Highly oblique convergence has meant the Kekerengu Ridge is highly faulted, with slow convergent accretion but prolific seafloor methane venting and widespread seafloor carbonate mounds. The Uruti Ridge region, off the Wairarapa Coast, is a mature accretionary ridge with a prominent bottom simulating reflection (BSR), fault-controlled fluid migration pathways, seafloor carbonate mounds and methane venting. It has been well studied by seismic reflection analysis (e.g., Crutchley et al. 2015) as well as carbonate distribution and seep epifaunal communities (e.g., Liebetrau et al., 2010, Bowden et al. 2013).

Coincident TOPAS and seismic reflection profiles at both sites reveal a correlation between the Last Glacial Maximum/end of ice age reflectors and the occurrence of carbonate mound formation. This presentation will discuss these findings and their implications for the timing of seafloor methane venting at the Southern Hikurangi Margin.

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KEYNOTE
Session 2e.

DISAGGREGATING LANDSLIDE RISK: WHAT DRIVES LANDSLIDE RISK IN FRANZ JOSEF AND FOX GLACIER VALLEYS?

Saskia de Vilder[1], Chris Massey[1], Biljana Lukovic[1], Tony Taig[2], and Regine Morgenstern[1]

[1]*GNS Science, Lower Hutt, Wellington, New Zealand*
[2]*TTAC Ltd, Marston, Chesire, UK.*

s.devilder@gns.cri.nz

Franz Josef and Fox Glacier Valleys are popular tourist destinations that experience landslide hazards in response to earthquakes, high rainfall and de-glaciation. To understand the life-safety risk to visitors we undertook a quantitative risk analysis (QRA) of debris avalanches, debris flows and rockfalls along roads and tracks in both valleys. We considered earthquake induced landslides, given the proximal location to the Alpine Fault, and 'non-earthquake' induced landslides, as we could not establish a relationship between rainfall and snowmelt with landslide occurrence.

For each trigger type, we collated landslide inventories, created landslide susceptibility maps, determined landslide frequency – magnitude relationships and undertook detailed numerical runout modelling. Given the lack of inventory data for earthquake induced landslides on the West Coast, we used relationships from the 2016 M_W 7.8 Kaikoura, 1968 M_W 7.1 Inangahua and 1929 M_W 7.8 Murchison earthquake events to inform potential earthquake induced landsliding in the valleys for different levels of ground shaking, categorized into peak ground acceleration (PGA) bands. We combined the hazard information for earthquake and non-earthquake induced landslides with the spatio-temporal probability of an individual and their vulnerability, to generate four risk metrices, which include the local personal risk (LPR), the risk per trip for visitors, the annual individual fatality risk (AIFR), and societal risk.

Our analysis reveals that the main drivers of risk in both valleys are non-earthquake induced landslides, when using time-independent seismic hazard inputs. In particular, landslides volume classes of 10,000 m^3 and 50,000m^3 dominate the risk profile of each valley, with these volume classes representing the mid-range of landslide sizes that can occur in each valley. While the contribution to risk from non-earthquake induced landslides is high, societal risk is dominated by earthquake events with PGA > 0.6 g. This detailed understanding of landslide risk holds implications for risk management practices.

ORAL
Session 4c.

EXHUMING INTEREST IN THE 1987 EDGECUMBE EARTHQUAKE

Jaime Delano[1], Tim Stahl[1], Andy Howell[1,2], Kate Clark[2]

[1] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*
[2] *GNS Science, Lower Hutt, New Zealand.*

jaime.delano@pg.canterbury.ac.nz

Characterizing seismic hazard relies on information about the expected size, slip type, and frequency of earthquake rupture, but deriving these characteristics from paleoearthquakes is complicated by inadequate pre-earthquake topographic data and post-earthquake surface modification. The 1987 Mw6.6 Edgecumbe earthquake in New Zealand produced widespread, complicated surface deformation from discrete surface rupture, hanging wall subsidence, liquefaction, and sediment compaction. Post-earthquake reconnaissance efforts measured scarp displacements and regional coseismic deformation, but were hindered by incomplete pre-earthquake topographic data, such as the location and size of pre-existing scarps. Similarly, more recent lidar-based studies had difficulty distinguishing between cumulative and single-event scarps, and lack individual event rupture distribution information. We use historical aerial photos to build the first pre- and post-earthquake digital surface models and orthophoto mosaics of the Edgecumbe earthquake to characterize coseismic slip. By differencing the pre- and post-earthquake surface models, we more definitively measure discrete and distributed deformation and compare the effectiveness of the technique to more traditional field- and lidar-based studies. We identified most fault traces recognized in 1987, mapped new traces not recorded in the field, and take denser, detailed remote slip measurements with a vertical separation resolution of ~0.25–0.5 m. Our maximum and average vertical separation measurements on the Edgecumbe fault trace (2.5 ± 0.3 m and 1.4 m, respectively), are similar to field-based maximum and recalculated averages of 2.4 m and 1.1 m. The resulting horizontal and vertical slip data are used to refine the estimated subsurface fault geometry and slip distribution at depth. Refined paleoearthquake slip behavior can be integrated into future seismic hazard models and enable better forecasting of fault surface displacement.

ORAL
Session 2a.

EVALUATION OF A REAL-TIME AUTOMATED SYSTEM FOR PROBABILISTIC FORECASTS OF PHREATIC ERUPTIONS

David Dempsey[1], **Shane Cronin**[2] **and Andreas Kempa-Liehr**[2]

[1] *University of Canterbury, Christchurch, New Zealand*
[2] *University of Auckland, Auckland, New Zealand.*

david.dempsey@canterbury.ac.nz

Phreatic explosions at tourist-visited volcanoes are difficult to predict, as illustrated by the deadly 2019 Whakaari (New Zealand) and 2014 Mt Ontake (Japan) eruptions. Quantifying eruption risk is essential for allowing safe access to such sites and for planning emergency response and evacuation. In this study, we evaluated three methods for producing short-term (48 hour) probabilistic estimates of phreatic eruptions. Two methods are derived from a numerical forecasting model and the third method is expert elicitation.

The numerical model was developed from a pseudopropsective analysis of seven Whakaari eruptions using time-series feature engineering to identify precursors in tremor data. This forecasting system was evaluated for a real-time operation period of 17 months and was subsequently improved to filter out regional earthquakes and to attempt to identify non-eruptive volcanic unrest. We used the model's eruption potential score as input to a trigger-based eruption alarm.

When optimized in hindsight, this system anticipates six out of past seven eruptions, with alarms over 3.8% of the study period. For this method, the estimated 48-hour probability of eruption is 8.1% inside an alarm and 0.05% outside, i.e., a 148-fold elevated risk during an alarm. The second method used isotonic calibration to transform the forecasting model output directly to a probability, which resulted in estimated risks 31 and 142 times higher than normal in the hours and days before eruptions.

Finally, we compared these results to repeated rounds of expert elicitation that followed the 2019 Whakaari eruption. We show that, under such unprecedented and atypical circumstances, elicitation likely overestimated the eruption probabilities. This suggests that retrospective assessment of past elicitations could be a fruitful exercise to identify and correct biases in the continued use of this method.

ORAL
Session 2a.

COASTAL SUBSIDENCE AND UPLIFT IN NEW ZEALAND IMPLICATIONS OF VERTICAL LAND MOTION ON THE COAST

Paul Denys[1] and Chris Pearson[1]

[1] *School of Surveying, Otago University, Dunedin, New Zealand, New Zealand*

pdenys@surveying.otago.ac.nz

Vertical land motion (VLM) has been measured using continuous Global Navigation Systems (GPS/GNSS) at various locations around New Zealand's coastline. Some of the observed VLM is caused by the long term (geological time scales) plate boundary processes e.g. the east coast of the North Island's subduction zone More recently, the earthquake sequences in Christchurch (2010-11), Cook Strait (2013) and Kaikoura (2016) have had a significant effect on the coast both at the time and after the earthquakes.

We present two case studies that demonstrate how VLM is changing the coastal environments. Firstly, the impact of the M_w 7.8 Kaikoura 2016 earthquake that initially caused subsidence (coseimsic displacement) of the lower North Island and upper South Island at the centimetre level. However, the ongoing post-seismic relaxation is resulting in uplift for which much of the coastline is now higher than immediately before the earthquake. Secondly how the 2010-11 Christchurch earthquakes have induced ongoing post-seismic subsidence of the Heathcote-Avon estuary that will cause significant issues in light of sea level rise.

POSTER
Session 2d.

GEOCHEMICAL FINGERPRINTING OF SEDIMENT SOURCES INFILLING WHAKARAUPŌ | LYTTELTON HARBOUR, NEW ZEALAND

Zoë Dietrich[1,2,3] Catherine Reid[3], Darren Gravley[2,3], Sam Hampton[2,3,4]

[1] Bowdoin College, Brunswick, Maine, USA.
[2]Frontiers Abroad, frontiersabroad.com
[3]University of Canterbury, Christchurch, New Zealand
[4]VolcanicKED, Christchurch, New Zealand

catherine.reid@canterbury.ac.nz

Intertidal beaches and mudflats are ecologically important habitats, and the Whakaraupō | Lyttelton Harbour mudflats have been identified as an area of Significant Natural Value by Environment Canterbury. Sedimentation is a key process impacting the health of near-shore environments and is a pressing ecological issue for Whakaraupō | Lyttelton Harbour. However, while the potential sources of sediment are known, they have not yet been quantified in the accumulated harbour sediments. We sampled surface sediments around the perimeter of the harbour and applied geochemical (pXRF), grainsize, and componentry analyses to determine modern surface sediment sources. These analyses were repeated with a sediment core to investigate historical sediment sources over the last ~300 years.

Predictably, volcanic-derived materials dominate modern Whakaraupō | Lyttelton Harbour accumulated sediments, shed via streams from the surrounding volcanic hills. Sediments also include eroded loess with inputs notable in Head of the Bay east to Diamond Harbour from the adjacent Barrys Bay loess. Marine sediments from Pegasus Bay are likely transported not only into the outer harbour, but into the central and upper harbour regions as well.

Core sediments, interpreted to have been deposited prior to European settlement, reveal mud-sized marine sediments were transported into Head of the Bay from Pegasus Bay and/or Waimakariri longshore drift and constituted a main sediment source, in addition to volcanic-derived materials. Around the time of European settlement and land clearing, Head of the Bay sediment sources shifted from primarily marine and volcanic-derived to Barrys Bay loess. Further anthropogenic activities in the 1980s-90s likely resulted in increased hillslope erosion and subsequent mudflat deposition of Barrys Bay loess. Foraminifera decrease in abundance following the switch to loess dominated sediments, and cockle shells disappear from the record.

ORAL
Session 2c.

REMOBILIZATION OF COOL MAFIC MUSHES BY HOT FELSIC MELTS: DIVERSE PRIMARY MELT COMPOSITIONS AT TARANAKI VOLCANO, NEW ZEALAND

Nessa D'Mello

Massey University, Palmerston North

n.dmello@massey.ac.nz

The prevalence of antecrysts carried in porphyritic lava domes extruded from arc volcanoes is widely accepted, but less is known about the origins of crystals in more fluid lava flows. The crystal cargo of Holocene lava flows from Taranaki volcano, New Zealand, is dominated by plagioclase, clinopyroxene, and amphibole, in chemical disequilibrium with the melt they are entrained in. Major element chemistry also reveals a compositional overlap of mineral data between phenocrysts and xenoliths from Taranaki. The suite of xenoliths includes ultramafic rocks, gabbros, and amphibolite. Further, the ratio of mafic crystals entrained in the lavas, ranging between 40 and 55 vol.%, exerts a strong control on the whole rock composition of the lavas, reducing magmatic silica contents by 5–11 wt%. Our data are inconsistent with commonly invoked processes of fractional crystallization and concomitant evolution to more felsic compositions. We propose that high-temperature, aphyric to sparsely phyric parental melt compositions (55–68 SiO_2 wt%) ascend through a colder, more mafic mush zone that contributes the crystal cargo. The data indicate that some of the back-arc primary melts from the Hikurangi mantle wedge are significantly more felsic than typical arc basalts that are commonly invoked as parental magmas. Thermometric and hygrometric constraints also preclude a deep crustal hot zone model for the origin of these felsic melts.

POSTER
Session 1b.

EARTH'S OLDEST EXTRATERRESTRIAL IMPACT? EVIDENCE FOR A LARGE IMPACTOR 3.48 BILLION-YEARS-AGO (DRESSER FORMATION, PILBARA CRATON, AUSTRALIA)

Michaela Dobson[1], Kathleen Campbell[1], Michael Rowe[1], Martin Van Kranendonk[2], Jeff Havig[3], Diego Guido[4], Frances Westall[5], Frédéric Foucher[5], Trinity Hamilton[3], Ayrton Hamilton[1], Bonnie Teece[2], Bruce Charlier[6], David Adams[1], Frans Gerber[6], Jeffery Lang[1], and Stuart Morrow[1]

[1] *School of Environment, The University of Auckland, Auckland, New Zealand*
[2] *School of Biological, Earth and Environmental Sciences, University of New South Wales, Sydney, Australia.*
[3] *College of Biological Sciences, University of Minnesota, USA.*
[4]*CONICET and Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata, Instituto de Recursos Minerales (INREMI), Argentina*
[5]*CNRS, Centre de Biophysique Moléculaire Orléans Cedex 2, France*
[6]*School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand*

Mdob102@aucklanduni.ac.nz

The site(s) for the origin of life, and the environmental inputs that affected the evolution of early life, are debated. Compared to today, ancient Earth was a hostile environment, with an anoxic, CO2/CH4 rich atmosphere; Fe2+ (aq) anoxic oceans; and an interval of impactors called the Late Heavy Bombardment (LHB). These impactors could have hindered early life by boiling oceans and surface waters, superheating the atmosphere, and causing global cooling. However, these impactors also could have provided the nutrients needed for life to develop.

The LHB is proposed to have extended from 4.1 to 3.8 Ga, with planets and moons of the inner Solar System enduring frequent large impactor bombardments. After this period, the bombardment rate rapidly decreased between 3.6- 3.0 Ga to modern-day impact rates. Recent research suggests the LHB did not decrease as rapidly as first. Thus, a multitude of large bolide impacts may have occurred during the Archean, which (1) have not been preserved in the geologic record due to billions of years of erosion or (2) have not been discovered yet.

Here we present recently discovered spherule rich layers, within drillcore samples from the 3.48 Ga Dresser Formation, Pilbara Craton in Western Australia, whose textures suggest an impact origin. Samples show petrographic textures (spherical shapes, quenched features, radial crystal splays, and off-centered vesicles) similar to younger impact spherule beds. We discuss recently obtained geochemical data- EMPA, LA-ICP-MS, solution ICP-MS (PGE & REEs), RAMAN- that suggest an impact origin, and proposed future geochemical research. Currently, there are 14 widely accepted impact spherule layers in Archean rocks, with the oldest identified in the geologic record dating to 3.47 Ga. If these samples are impactor in origin, they could represent the oldest evidence of a bolide impact in the geologic record of Earth.

ORAL
Session 4e.

A VIRTUAL FIELD TRIP TEACHING MODEL FOR TRANSDISCIPLINARY LEARNING

Michaela Dobson[1,2], **Haritina Mogoșanu**[2], **Kathleen Campbell**[1,2], **Ayrton Hamilton**[1], **and Gina Swanney**[1]

[1] *The School of Environment, The University of Auckland, Auckland, New Zealand*
[2] *New Zealand Astrobiology Network, New Zealand.*

Mdob102@aucklanduni.ac.nz

The University of Auckland new Astrobiology General Education (GE) Undergraduate Course has over 200 students enrolled from 19 disciplines. This course has a strong Earth Science component, using hot spring deposits from the Taupō Volcanic Zone as analogues for possible past life on Mars. Astrobiology field trips are often undertaken in environments that are not easily accessible, logistically challenging, dangerous, and exhibit delicate features that require protection. The risk is exacerbated with large class sizes (>150 students), while GE courses create issues around student's schedule availability. Research indicates that student learning is enhanced through doing and engaging with the medium that they are studying. Astrobiology, provides a means to take 'Big Questions' - e.g What is life?– and present these in a tangible and easily understandable way.

Here we present a model for Virtual Field Trip (VFT) teaching that is designed for students from broad academic backgrounds. Created as a collaboration between the University of Auckland's Earth Science programme and the New Zealand Astrobiology Network (NZAN), this VFT enables students to become planetary scientists, following protocols and approaches used in real missions. Students engage with field sites via Google Earth/Mars fly-bys, drone videos, 3D models, hand sample and thin section analysis, and orbital and rover data. Students virtually interact with their environment (Rotorua and Mars), critically assess the data, and drawn their own conclusions around the validity of a Mars sample return mission. This has real-world application, as there are currently several active Mars missions. This is an effective approach not only for COVID-19 lockdowns but also for learning how to operate in remote locations such as Mars. Finally, as this VFT model has specifically been designed around a transdisciplinary cohort, it can also be easily adapted and implemented for other groups, such as school students.

POSTER
Session 3e.

TOWARDS A BETTER UNDERSTANDING OF EFFUSIVE ACTIVITY OF RUAPEHU IN THE LAST 20 KA

Pedro Doll[1], Ben Kennedy[1], Alex Nichols[1], Shaun Eaves[2, 3], Jim Cole[1], Graham Leonard[4], Dougal Townsend[4], Gillian Turner[5, 6] and Geoff Kilgour[7]

[1] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand* [2]*Antarctic Research Centre, Victoria University of Wellington* [3]*School of Geography, Environment and Earth Sciences, Victoria University of Wellington* [4]*GNS Science, Lower Hutt* [5]*Institute of Geophysics, Victoria University of Wellington* [6]*School of Chemical and Physical Sciences, Victoria University of Wellington* [7]*GNS Science, Wairakei*

pedro.doll@pg.canterbury.ac.nz

Detailed knowledge of past volcanic eruptions is the key to producing accurate volcanic hazard assessments. In New Zealand and particularly at Mt Ruapehu, most studies of eruptions occurring since the last glacial maximum have focused on the chronology of explosive events. However, there have been several dozens of lava flows erupted since the glaciers started retreating, but studies have so far not been able to determine whether their emplacement was concentrated in few large effusive events or spread out over the last 20 ka. This difference is critical to understanding lava flow hazard, and to achieve this we will apply new dating techniques to obtain a detailed history of the eruptive activity.

The main aim of this project is to improve Ruapehu's postglacial effusive chronology using paleomagnetism and surface exposure dating with in situ terrestrial cosmogenic ^{3}He. These techniques have been shown to yield eruption ages with a relative error of 5%, more accurate than the $^{40}Ar/^{39}Ar$ ages currently used to frame the Pleistocene/Holocene lava flows of Ruapehu. Published and new geochemistry data (major and trace elements) will be used to fingerprint eruption products and test hypotheses regarding temporal links between lava-forming eruptions and pyroclastic sequences in the volcano's ring plain and flanks. Additionally, a new high-resolution (30 ppsm) Digital Surface Model based on LiDAR data will be used to assist lava mapping and classification, and to estimate erupted volumes more accurately.

Combining these new data, the lava eruption rate variation for the last 20 ka will be calculated, ultimately improving our understanding of lava flow hazard at Ruapehu and contribute to the understanding of volcanic hazards in the southern section of the Taupō Volcanic Zone.

POSTER
Session 1a.

Developing a flood-rich alluvial sediment archive to understand environmental change in the Whanganui catchment

Imogen Doyle[1], Sean Fitzsimons[2], Ian Fuller[1], Mark Macklin[3] and Sam McColl[1]

[1] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*
[2] *School of Geography, University of Otago, Dunedin, New Zealand.*
[3] *School of Geography, University of Lincoln, Lincoln, United Kingdom.*

Immy.doyle@gmail.com

Understanding the pathways and patterns of erosion and sediment mobilisation are essential to the successful development and application of erosion control and mitigation schemes. Past records of environmental change provide insight into the drivers of sediment mobilisation and transport, including the influence of human induced landscape change.

Investigation of a high-resolution sediment archive from Atene, a valley meander cut-off in the lower reaches of the Whanganui Gorge has revealed a flood-rich record reflecting late Holocene paleoenvironmental and climatological change (Fuller et al., 2019). Here, a further three cores collected from Atene as part of the Smarter Targeting of Erosion Control (STEC) program are presented to extend sedimentological, chronological, and geochemical information from the site.

Organic material sampled from the cores will establish age depth models constraining the timing and magnitude of floods and records of erosional events recorded within the bend. Particle size analysis (PSA) and geochemical analysis (ITRAX) of sedimentological units facilitate the identification of flood units and the evaluation of flood magnitude providing insight into temporal patterns of event magnitude and frequency. A facies model utilising PSA and geochemical data is developed to help identify and evaluate processes controlling sediment delivery to Atene bend. The derived facies model reflects the erosion and flood history of the catchment and the response of the system to environmental change. The archive spans approximately ~2000 years, tracking the impacts of both late Holocene climate change and human arrival and settlement within the catchment.

References.

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POSTER
Session 2c.

LOCAL VARIATION OF FORAMINIFERAL ABUNDANCE IN LYTTELTON HARBOUR/WHAKARAUPŌ

Olivia Doyle[1] and Catherine Reid[1]

[1] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand.*

ord15@uclive.ac.nz

Modern foraminiferal distributions are often used to aid in reconstruction of historical fluctuations in climate. My research is focused on benthic foraminiferal assemblages in Lyttelton Harbour/Whakaraupō, attempting to infer life cycles, and mapping them against sediment types and tidal elevation to inform fossil assemblage usage for tracking of sea level change and interpreting marginal marine environments. I have looked both at mapping foraminiferal distribution in Lyttelton Harbour/Whakaraupō, and the change in selected communities over time. I have been doing monthly sampling at fixed sites from mid 2020-2022 to answer seasonality and life cycle length questions. This sampling has involved four repeats in a small (~15cm^2) area, along with a sediment sample.

Whilst my research was originally looking for life span data on *Ammonia aoteana* and *Trochammina inflata*, it has also shown significant abundance variation within the sample sites at each sampling interval (repeats taken ~10cm apart have total counts being twice the amount of the other), whilst the ratios between species remain approximately the same. The changes in populations (both as a whole and for individual species) have varied similarly over several months of sampling, with ratios remaining similar, but with total species counts occasionally varying by more than 500% between months.

The dataset being built should aid in local paleoenvironmental reconstructions with understanding the variability in local assemblages and the range of species' preferred environment. The species ratios not changing significantly is an important finding from my study, as well as understanding how much total foraminiferal abundance differs in both location and through time, particularly with respect to understanding dissolution and seasonal changes in populations.

POSTER
Session 2e.

Educational Role-playing Simulation For Volcanic Crisis At Taupō Volcano For GSNZ2021 (Palmerston North)

Amy Dreyer[1], **Ben Kennedy**[1], **Thomas Wilson**[1], **and Simon Barker**[2]

[1] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*
[2] *School of Geography, Environment, and Earth Science, Victoria University of Wellington, Wellington, New Zealand.*

Adr71@uclive.ac.nz

Educational role-playing simulations have proved successful in enhancing the learning of natural hazards. Participants improve transferable skills such as communication, team-work, decision making, and problem solving whilst also learning content knowledge on volcanoes. The simulation discussed here is situated at Taupō Caldera, a silicic volcano that has produced destructive explosive eruptions and undergone extensive periods of volcanic unrest without eruption. Any future eruption, or even period of sustained and/or severe volcanic unrest, could have considerable societal impacts locally and across New Zealand.

This research project has produced two simplified scenarios for Taupō Volcano, based on historic behaviour of Taupō volcano, analogous global silicic eruptions, and an expert elicitation exercise (Scott et al. 2021). One scenario describes volcanic unrest leading to an eruption, and the other presents a scenario of volcanic unrest leading to emplacement of magma without eruption. Volcanic unrest activity includes increased seismicity, low frequency earthquakes, and migration of earthquake hypocenters, ground deformation, increased geothermal activity, hydrothermal eruptions, and development of new fumaroles. The eruption sequence includes dome formation followed by a Plinian phreatomagmatic eruption.

The educational role-playing simulation is designed for, but not limited to, students entering the industry. Participants are divided into groups and assigned roles that reflect a simplified version of New Zealand's key stakeholder team structures: Geonet, Civil Defense Emergency Management, and Iwi (Campbell, 2020). The game runs for 5 hours and simulated data reporting on the behaviour of the volcano and the community is streamed to participants. The participants work together with the goal of successfully monitoring and managing the volcanic crisis.

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POSTER
Session 3e.

THE RESPONSE OF ANTARCTIC VEGETATION TO MAJOR GLACIATION DURING THE OLIGOCENE/MIOCENE TRANSITION

Bella Duncan[1], Rob McKay[1], Richard Levy[1,2], Tim Naish[1] , Joe Prebble[2], Osamu Seki[3], Christoph Kraus[1], Heiko Moossen[4,5], G. Todd Ventura[2,6], Denise Kulhanek[7,8], James Bendle[4]

[1] *Antarctic Research Centre, Victoria University of Wellington, Wellington, 6140, New Zealand*
[2] *Geological and Nuclear Sciences, P.O. Box 30-368, Lower Hutt 5040, New Zealand*
[3] *Institute of Low Temperature Science, Hokkaido University, N19W8, Kita-ku, Sapporo, Hokkaido 060-0819, Japan*
[4]*School of Geography, Earth and Environmental Sciences, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK*
[5] *Present address: Max Planck Institute for Biogeochemistry, P.O. Box 10 01 64, 07701 Jena, Germany*
[6] *Present address: Department of Geology, Saint Mary's University, 923 Robie Street, Halifax, Nova Scotia, B3H 3C3, Canada*
[7] *International Ocean Discovery Program, Texas A&M University, College Station, TX, USA*
[8] *Present address: Institute of Geosciences, Christian-Albrechts-University of Kiel, 24118, Kiel, Germany*

Bella.Duncan@vuw.ac.nz

The Mi-1 glaciation during the Oligocene/Miocene Transition (OMT) is one of the largest transient glaciations of the Cenozoic, and marks a key step in Antarctic ice sheet history from the relative warmth of the Oligocene to large temperature and ice volume fluctuations in the early Miocene. Antarctic vegetation subsisted through this glacial period, before eventually disappearing from the continent as climate conditions became increasingly polar in the late Neogene. We use plant wax compound specific isotope trends ($\delta^{13}C$ and $\delta^{2}H$) in an Antarctic proximal sediment core (Deep Sea Drilling Project 270) to investigate the response and survival mechanisms of Antarctic vegetation to this extreme climate event. A marked negative *n*-alkane $\delta^{13}C$ excursion, coupled with a shift to more positive *n*-alkane $\delta^{2}H$ is interpreted to be the result of Antarctic plants sacrificing water use efficiency to maintain photosynthesis and carbon uptake during glacial conditions. This is driven by an orbital configuration which would have resulted in short, cold growing seasons with low light intensity. Further drivers of these isotopic trends are inferred to be more arid conditions, and a shift to a restricted low altitude, coastal vegetation with more stunted growth forms.

ORAL
Session 2b.

VISUALISING GEOLOGICAL SAMPLES USING MARS SPECTRAL CT

Neryda Duncan[1,2], Marzieh Anjomrouz[1], Ben Kennedy[2], Jereena Sreedharan Sheeja[1,3], Rayhan Uddin[2], Claire Chambers[1,2], Jacob Darby[2], Mitchell Chambers[2], Phil Butler[1,2,3,4], Sikiru A Adebileje[3,5], Steven D Alexander[1], Maya R Amma[1], Fatemeh Asghariomabad[1], Ali Atharifard[1], James Atlas[1,2], Kenzie Baer[3], Stephen T Bell[1], Anthony P H Butler[1,2,3,4,5], Pierre Carbonez[3,4], Krishna M Chapagain[3], Alexander I Chernoglazov[1,5], Jennifer A Clark[3,6], Frances Colgan[3], Jonathan S Crighton[3], Shishir Dahal[3,9,10], Jérôme Damet[3,4,11], Theodorus Dapamede[3], Niels J A de Ruiter[1,2,3,5], Devyani Dixit[2], Robert M N Doesburg[1], Karen Dombroski[1], Steven P Gieseg[2,3,4], Anish Gopinathan[1], Brian P Goulter[1], Joseph L Healy[1], Luke Holmes[12], Tracy Kirkbride[6], Chiara Lowe[1], V B H Mandalika[1,2,5], Aysouda Matanaghi[1], Mahdieh Moghiseh[1,3], David Palmer[7], Raj K Panta[1,3,4], Peter Renaud[2,3], Yann Sayous[2], Nanette Schleich[8], Emily Searle[2],Lieza Vanden Broeke[1], Vivek V S[1], E Peter Walker[3], Michael F Walsh[1], Manoj Wijesooriya[1] and W Ross Younger[1]

[1]MARS Bioimaging Ltd, [2] University of Canterbury, Christchurch, New Zealand, [3]University of Otago, Christchurch, New Zealand,[4]European Organisation for Nuclear Research (CERN), Geneva, Switzerland,[5]Human Interface Technology Laboratory New Zealand, University of Canterbury, Christchurch, New Zealand, [6]Ara Institute of Canterbury, Christchurch, New Zealand, [7]Lincoln University, Lincoln, New Zealand, [8]University of Otago Wellington, Wellington, New Zealand, [9]Ministry of Health, Nepal, [10]National Academy of Medical Sciences, Kathmandu, Nepal, [11]Institute of Radiation Physics, Lausanne University Hospital, Lausanne, Switzerland, [12]Canterbury District Health Board

neryda.duncan@marsbioimaging.com

This research describes a capability study of the MARS spectral CT scanner to visualise and provide information on geological samples. This imaging technique is non-destructive and has the ability to replace the restrictive 2-D data geologists currently use with useful 3-D geological data. To examine this capability, igneous rock samples from the University of Canterbury Department of Geology, were imaged for the investigation of underlying geological events.

Material identification and quantification of MARS images has been successfully proven in preclinical and clinical fields. However, applying this technology to geological samples required a feasibility study. Using the MARS spectral CT scanner, a set of scan parameters such as x-ray tube current, exposure time and filtration were optimised to achieve images with high spatial, spectral and material resolution. The chemical compositions of the rock samples were studied, and the separate composition attenuation curves were examined to set energy bins to enhance spectral analysis. As the structural information is also important to determine the crystal alignment and pore size, a geometric calibration method was developed and implemented, resulting in better spatial resolution of the system and producing clear and artefact-free images.

The features of interest examined in this study included crystal alignment, fault plane geometry and void size and connectivity. This information enables geologists to enhance their understanding of earth systems and events. The preliminary results indicate that the current MARS technology is capable of providing useful geological information.

ORAL
Session 4a.

3D MAGNETIC INVERSIONS CONSTRAINED BY EULER DECONVOLUTION SOLUTIONS USING SIMPEG

Evert Durán[1], Julie Rowland[1] and Jennifer Eccles[1]

[1] *School of Environment, The University of Auckland, Auckland, New Zealand*

e.duran@auckland.ac.nz

One of the main challenges of geophysical inversion is its non-uniqueness problem, that is, multiple models within the discretization of the subsurface replicate the observed data. Even though the model space is mathematically vast, the geologically plausible models are not. By carefully adding information on depth and extent of possible physical boundaries or subsurface structures, the discretization of the space of solutions can be constrained and help promote better models. This available information is mostly sparse, like borehole data. Since borehole data is not usually available, we will use the source locations obtained in Euler Deconvolution estimations to set bounds to the under-determined problem posed by geophysical inversion. With the advent of l1-norms to solve optimization problems (e.g compressive sensing) and geophysical open-source tools with methods for lp-regularization norms like SimPEG (Simulation and Parameter Estimation in Geophysics) (Cockett et al., 2009; Fournier and Oldenburg, 2019), we can promote models that produce sharp boundaries while respecting the prior information, as opposed to smoothing out the physical properties. Using a simple magnetic model and the Hikurangi dacite dome in Northland as examples, we will illustrate the basic inversion framework and how adding information into a reference model, while judiciously choosing the regularization parameters, can improve the quality of the 3D models retrieved in magnetic and magnetic vector inversions.

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ORAL
Session 4a.

THE INFLUENCE OF BASEMENT TERRANES ON TECTONIC DEFORMATION: JOINT EARTHQUAKE TRAVEL-TIME AND AMBIENT NOISE TOMOGRAPHY OF THE SOUTHERN SOUTH ISLAND, NEW ZEALAND

Donna Eberhart-Phillips

GNS Science Dunedin North

eberhartphillips@ucdavis.edu

The South Island lithosphere, consisting of multiple amalgamated terranes, currently undergoes oblique collision with major faulting, crustal thickening and subduction along the plate boundary. We examine crustal properties of the relatively low-strain region east of the lithospheric plate boundary, combining earthquake travel-time tomography with surface wave observations. This enhances spatial resolution in low seismicity areas, improves shallow resolution and sharpens velocity gradients between terranes. Southern Alps results indicate high Vp schist upper crust. Similarly, Central Otago ranges exhibit high Vp with northeast trending structure, and distinct northwest trending ranges characterize the northern margin. The Otago schist shows thick lower crust, while contrasting higher Vp below 15-km depth characterizes the Matai terrane and Median batholith, backstops during accretion and deformation. Comparison of sparse seismicity, structural domains and geodynamic modelling shows how Cenozoic structures relate to deeper properties. Seismicity within the schist tends to be distributed within key transition regions rather than along specific faults, and these zones tend to show low Vp and low Qp. The most prominent seismicity zone is along the Southern Alps transition to northern Otago ranges. Faulting and brittle deformation along the Southern Alps margin corresponds to the eastern edge of ductile crustal thickening above the bending of strong oceanic lower crust. The thick weak crust rheology of Otago, relative to Canterbury, enables broad deformation, with numerous active faults that may not persist to depth. Along the southern stronger plutonic terranes, there is a band of sparse deeper (15-30 km) seismicity, consistent with strong elastic brittle crust.

POSTER
Session 1c.

TAUPŌINFLATE: ILLUSTRATING THE DETECTION OF MAGMATIC INFLATION BELOW LAKE TAUPŌ

Susan Ellis[1], Simon J. Barker[2], Colin J.N. Wilson[2], I. Hamling[1], Sigrun Hreinsdottir[1], Finnigan Illsley-Kemp[2], El R.H. Mestel[2], James Muirhead[3], Bubs Smith[4], Martha K. Savage[2], Pilar Villamor[1], Peter Otway[5], Warwick Kissling[1], Kristian Hansen[2], and Muriel Gerbault[6]

[1] *GNS Science, Lower Hutt, New Zealand*
[2] *SGEES, Victoria University of Wellington, Wellington, New Zealand*
[3] *University of Auckland, Auckland, New Zealand*
[4] *Ngāti Tūwharetoa, Turangi, New Zealand*
[5]*23 Holyoake Tce, Omokoroa 3114*
[6]*GET (IRD, CNRS, UPS), Toulouse, France.*

s.ellis@gns.cri.nz

Lake Taupō (Taupō-nui-a-Tia) infills and conceals the composite caldera of an active rhyolitic magmatic system in the central Taupō Volcanic Zone (TVZ). Ground deformation (from GPS, InSAR and lake levelling) is a key unrest indicator at calderas and one of the main volcanic monitoring tools at Taupō. In particular, the rate and location of deformation is crucial when considering the origins and significance of past and future unrest events, though the distribution of the geodetic monitoring network, size of the lake and numerous potential sources of unrest make monitoring challenging. We have developed a spreadsheet tool, TaupōInflate, to easily calculate and plot ground deformation from inflation of magma at depth beneath Taupō caldera. While the tool has some limitations, e.g., omission of the response of crystal-rich partial melt around inflating melt-dominant bodies, it can be used to quickly evaluate potential sources of inflation during unrest events and to highlight detection limits for the current network under different conditions- i.e., to explore the likelihood of detecting inflating magma bodies beneath Lake Taupō. We show examples which estimate the minimum size of an inflating body that is detectable at each recording station, constrained by estimated magma properties, depths and temperatures prior to eruption from the geological record. These examples highlight locations below Lake Taupō where it is challenging to detect even substantial volumes of inflating magma (up to 20 km3), owing to restricted station placement, although any rise of silicic magma in a dike from storage towards the surface is likely to be detectable. The sizes of inflating bodies detectable by the present monitoring system are larger than many past eruptions, illustrating the need to link deformation with patterns of seismicity to better track the growth of magma bodies beneath the lake.

POSTER
Session 1a.

TIMESCALES OF MAGMATIC PROCESSES AT ŌKATAINA FROM FE-MG DIFFUSION IN ORTHOPYROXENE

Hannah C. Elms[1], Daniel J. Morgan[2], Simon J. Barker[1], Colin J. N. Wilson[1] and Bruce L. A. Charlier[1]

[1] School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand
[2] School of Earth and Environment, University of Leeds, Leeds, United Kingdom

hannah.elms@vuw.ac.nz

One of the main challenges in assessing the risk posed by an active volcano is determining the likely timescales over which its magmatic processes operate. Constraining pre-eruptive timescales is important for understanding the likely range of signals and warning times a volcano may give prior to an eruption. Here we present the results of a study into the timescales of pre-eruptive magmatic processes operating at Ōkataina volcano, in the northern part of the central Taupō Volcanic Zone. We use Fe-Mg diffusion across initially sharp compositional boundaries in orthopyroxene from three rhyolitic eruptive episodes covering the three main vent regions of the young Ōkataina system (the 15.6 ka Rotorua episode from the Ōkareka Embayment, the 14 ka Waiohau episode from Mt Tarawera, and the 5.5 ka Whakatāne episode from the Haroharo Massif). Coupled with melt chemistry data and evidence from physical volcanology, this study shows how rapidly the magmatic systems involved can recharge from dormancy into an eruption-ready state. A Monte Carlo model was used to ensure full consideration of the (often large) uncertainties associated with diffusion timescales such as these.

Our findings suggest that recharging (or priming) of the magmatic system at Ōkataina occupied times on the order of decades up to a few centuries prior to eruption, with residence times for individual, eruptible melt-dominant magma bodies being on the order of years to decades. Processes which can potentially trigger the primed system into eruption (or significant unrest), for example heating processes associated with the injection of mafic magma, only take a few months to a year to take effect. These results highlight the importance of present-day geophysical monitoring in detecting changes in the volcano over yearly to decadal timescales, which are relevant to the possible assembly of eruptible magma bodies.

POSTER
Session 1b.

SUBDUCTION, MANTLE AND CRUSTAL INFLUENCES OF THE TAUPO VOLCANIC ZONE: INSIGHTS FROM HELIUM ISOTOPES

<u>David Farsky[1]</u>, Michael Rowe[1], Isabelle Chambefort[2], Simon Barker[3] and David Graham[4]

[1] School of Environment, University of Auckland, Auckland, New Zealand
[2] GNS Science, Wairakei Research Centre, Taupo, New Zealand.
[3] School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand
[4]College of Earth, Ocean and Atmospheric Sciences, Oregon State University, Corvallis, USA

david.farsky@auckland.ac.nz

Subduction zones produce melt in the mantle by lowering the mantle solidus through addition of fluids generally derived from the subducting slab. Due to buoyancy the mafic melt rises through the crustal column to the surface, and during its ascent it can interact with the surrounding crust by mixing or assimilation. The analysis of helium isotopes in mafic hosts presents an opportunity to track and define these processes to great depths and determine the relative input from Earth's mantle. We analyzed the elemental and isotopic composition of helium in phenocrystic olivine and pyroxene in basaltic tephras from the Central Taupo Volcanic Zone (CTVZ) and in basaltic andesites from the Southern Taupo Volcanic Zone (STVZ), New Zealand. Measured helium isotopic ratios are typical for a subduction zone setting, ranging from 5.27-6.61 R/R_A in CTVZ olivine and from 5.01-6.23 R/R_A in STVZ olivine. Pyroxenes yield a range from 4.66-5.97 R/R_A in CTVZ and 2.85-4.85 R/R_A in STVZ, indicating a greater distinction between the two regions for pyroxenes than observed in olivine.

The helium isotope ratios can be interpreted to be the result of two endmember processes: (1) Mixing and/or assimilation of primordial ^{3}He-rich melts derived from MORB-like mantle with R/R_A around 8 with crustal material on its ascent to the surface and during storage in upper crustal reservoirs; or (2) The shift from MORB-like values may be an attribute of the source after influx of slab fluids (R/R_A of +3±1)[1] implying little crustal assimilation during ascent. We compared our results to melt generation models[2,3] to identify key processes that can explain the helium isotope ratios observed for the TVZ and other volcano-tectonic settings worldwide.

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POSTER
Session 1a.

QUANTIFYING THE INFLUENCE OF THE M7.8 KAIKŌURA EARTHQUAKE-INDUCED LANDSLIDES ON COSMOGENIC RADIONUCLIDE CONCENTRATIONS

Dina Fieman[1], Kevin Norton[1], Claire Lukens[2], and Jamie Howarth[1]

[1] *School of Geology, Environment, and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand*
[2] *School of Natural Sciences, University of California Merced, Merced, California, USA*

dina.fieman@vuw.ac.nz

The concentration of in situ produced cosmogenic radionuclides such as ^{10}Be in detrital quartz from river sediments is now widely used to calculate catchment-wide denudation rates. Although useful for quantifying long-term catchment denudation rates, the catchment-average approach does not capture erosional processes driven by landsliding. Major landslide events can input large amounts of low-concentration ^{10}Be into the river system, biasing the concentration distribution and increasing the average denudation rate. A better understanding of how earthquake-induced landslides can influence the ^{10}Be signal is necessary before reliably inferring denudation rates. There are existing numerical models that consider landslide events on the ^{10}Be concentration, however these models either do not track the concentrations with depth, can only model steady state background processes, or do not use realistic topography. We developed a new cosmogenic nuclide production model that calibrates the ^{10}Be concentration at depth on a cell by cell basis based on various erosional processes. Erosional scenarios including steady-state erosion, hillslope diffusion, as well as landslide events can be inputted into the model. To test how major landslide events influence the ^{10}Be concentration, we use the landsliding that occurred in the Hapuku and Kowhai catchments from the 2016 Kaikōura, New Zealand M_w7.8 earthquake. Major landslides occurred in both catchments, however the landslides in each catchment have contrasting volumes, depths, and river connectivity. The modelled concentration distributions for the Hapuku and Kowhai catchments are compared to quantify how landslide volume, depth, and river connectivity can influence the overall ^{10}Be signal in the river. The model results not only quantify the earthquake-induced landslide events that occurred in the Kaikōura, but reiterate the need to consider the size and spatial distribution of mass wasting events when inferring long-term landscape evolution using cosmogenic radionuclides.

ORAL
Session 2b.

Using Pneumatic Cannon Experiments to Understand Volcanic Ballistic Hazard Footprints

Rebecca Fitzgerald[1,2], Ben Kennedy[1], Tom Wilson[1] and Graham Leonard[2]

[1] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*
[2]*GNS Science, Avalon, New Zealand.*

r.fitzgerald@gns.cri.nz

Volcanic ballistic projectiles (VBP) ejected from explosive eruptions can have sufficient kinetic energy to cause injury or death to exposed people. An increasing number of visitors to volcanoes and an increasing global population has driven the need for a more complete understanding of volcanic ballistics, the hazard they pose, human vulnerability, and risk management strategies. An important knowledge gap is the hazard footprint from an individual VBP impact. What aspects contribute to it and its size, and how does the intensity of the hazard (kinetic energy) change across the footprint?

Pneumatic cannon experiments firing volcanic rocks at a range of substrates were used to quantify the contribution that shrapnel/debris from impacting VBPs has on the hazard footprint. We found that more porous VBPs were more likely to produce ejecta from fragmentation upon impact than higher density ballistics and harder, more cohesive substrates produced higher kinetic energy ejecta than looser substrates. Applying the range of ejecta kinetic energies recorded in these experiments to human fragility models (based on recorded casualty data) shows that VBP impacts can produce ejecta upon impact with enough kinetic energy to injure, implying hazard footprint estimates should be substantially larger than ballistic diameter.

These experiments improve our understanding of the hazard to people on volcanoes from ballistics and provide important data to inform risk assessments and mitigation measures in areas exposed to volcanic ballistic hazard.

ORAL
Session 2a.

ORAL

Session 2a.

PHYSICS TO RESILIENCE: NEXT GENERATION EARTHQUAKE AND TSUNAMI RESPONSE

Bill Fry[1], Andy Nicol[2], Anna Kaiser[1], Aditya Gusman[1], William Power[1], SJ McCurrach[3], Ken Gledhill[4], Andy Howell[1], Jose Borerro[5], Bruce Shaw[6], Matt Gerstenberger[1], Mark Stirling[7], David Burbidge[1], David Dempsey[2], Caroline Holden[8], Sophia Tsang[1], Richard Smith[1]

[1] *Te Pu Ao, GNS Science, Lower Hutt, New Zealand*
[2] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*
[3] *Earthquake Commission, Wellington, New Zealand*
[4] *National Emergency Management Agency, Wellington, New Zealand*
[5] *ECoast, Raglan, New Zealand*
[6] *Columbia University, NY, USA*
[7] *Department of Geology, University of Otago, Dunedin, New Zealand*
[8] *SeismoCity.org.nz, Wellington, New Zealand*

b.fry@gns.cri.nz

Public funding of science is increasingly leveraged to provide direct benefit to society. This evolution of government priorities encourages the mutually beneficial alignment of research programmes to deliver improved outcomes, many of which would not have been possible through isolated research. In this talk, we present one such case.

We will first give an update of the Resilience to Nature's Challenges (RNC) national science challenge Earthquake and Tsunami Programme. This programme has implemented NZ's first national-scale earthquake simulator. Our V1.0 national earthquake model represents over 300,000 years of possible earthquakes in New Zealand. Ongoing efforts are aimed at evaluating the usefulness of the model for application to some of NZ's biggest earthquake challenges. The scope of application includes 1) next generation seismic and earthquake tsunami hazard and risk modelling and 2) providing input scenarios to improve large local and regional earthquake and tsunami response tools.

We will then show how the RNC synthetic seismicity catalogue has been used to test regional tsunami early warning algorithms under the Rapid Characterisation of Earthquakes and Tsunamis (R-CET) programme. R-CET is implementing tools to rapidly use seismic shaking and direct tsunami measurements to improve coastal forecasting of tsunamis.

The 5 March earthquakes and tsunamis were a (painfully early!) bellwether of our tsunami forecasting efforts in R-CET. While not yet fully operational, we successfully used direct tsunami observations recorded on the NZ DART network to help underpin advice that led to an improved tsunami response. Tangible response gains were realized in improved estimation of likely tsunami threat duration leading to more rapid and informed de-escalation and cancellation of a national warning than would have likely occurred without the NZ DART network data and R-CET response tools.

KEYNOTE
Session 4a.

CD ISOTOPES IN CARBONATES DEPOSITED DURING 'OAE 2': ASSESSMENT OF A NOVEL PALAEO-PRODUCTIVITY TRACER

Sophie K. Gangl[1], **Claudine H. Stirling**[1], **Matthew O. Clarkson**[2] **and Hugh C. Jenkyns**[3]

[1] *Department of Geology, University of Otago, PO Box 56, Dunedin, 9054, New Zealand*
[2] *Department of Earth Sciences, ETH Zürich, Clausiusstrasse 25, 9092 Zürich, Switzerland*
[3] *Department of Earth Sciences, University of Oxford, South Parks Road, Oxford OX1 3AN, UK*

sophie.gangl@otago.ac.nz

Cadmium (Cd) displays nutrient-type behaviour in the oceans and offers increasing potential as a tracer of the efficiency of the ocean's 'biological pump' and its ability to transport CO_2 from the atmosphere to the deep ocean during major disturbances of the ocean–atmosphere system. This marine geochemical profile arises because phytoplankton preferentially incorporate lighter Cd isotopes under many oceanic conditions, leaving surface waters enriched in heavier isotopes. As a consequence of this fractionation, Cd-isotope ratios have been shown to track nutrient availability and the intensity of primary productivity in the modern oceans. In addition, Cd isotopes can also be fractionated by sulfide formation under anoxic/euxinic conditions, complicating the interpretation of geochemical records. Cadium isotopes have been applied to ancient sediments in a limited number of cases, and may offer insights into past ocean biogeochemistry.

Oceanic Anoxic Event 2 (OAE 2) represents a period of widespread environmental degradation and ocean de-oxygenation, likely the result of increased volcanism, intensified weathering, elevated nutrient input to the ocean and augmented primary productivity. However, direct evidence for the availability of bio-limiting nutrients in the oceans and the role of primary productivity as a feedback mechanism to eventually re-stabilise climate is limited. Here we present the first carbonate Cd-isotope record for OAE 2, from the well-constrained and stratigraphically-expanded pelagic chalk section of Eastbourne (UK). In so doing, we combine records of global weathering changes (Li isotopes) and ocean deoxygenation (U isotopes), in the same section, to deconvolve the biogeochemical feedbacks that operated during development and recovery of OAE 2. Furthermore, we make a comparison with published Zn-isotope data (Sweere et al., 2018) that, like Cd, offers the potential to trace past globally significant productivity changes and/or sulfide precipitation.

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ORAL
Session 4e.

TWENTY YEARS OF GEONET PUBLIC INFORMATION

Elizabeth Garlick[1], Sara Horne[1]

[1] *GNS Science, Lower Hutt, New Zealand*

e.garlick@gns.cri.nz

Twenty years ago, when GeoNet was founded, we couldn't have imagined what our public information journey would look like. The growth of social media has had a profound effect on our public information, allowing us to build relationships and educate our users to share a common geohazard language with us.

GeoNet's public information evolved organically during the Canterbury earthquakes and then stepped up following Kaikōura. The need for information was changing rapidly and GeoNet was able to step up and take on that role.

Elizabeth Garlick takes us through the first two decades to celebrate how far we've come, and the relationships that are integral to GeoNet's public information success.

POSTER
Session 3b.

EXTENDING (CRYPTO)TEPHROCHRONOLOGY TO NORTHERN FINLAND AND RUSSIA

Elena Garova[1,2], Maarit Kalliokoski[3], Esther Gudmundsdottir[4], Evgeny Konstantinov[1]

[1] *Institute of Geography, Russian Academy of Sciences, Moscow, Russia*
[2] *School of Science-Te Aka Mātuatua, University of Waikato, Hamilton, New Zealand*
[3] *NordVulk, University of Iceland, Reykjavik, Iceland*
[4] *Institute of Earth Sciences, University of Iceland, Reykjavik, Iceland*

garova.el@igras.ru

Tephrochronology is a powerful method that uses geochemically fingerprinted volcanic ash layers (tephra) for correlating and dating geological and archaeological archives. Tephra arising from Icelandic eruptions is often dispersed to Europe and by analysing sparse concentrations of fine-grained volcanic glass, cryptotephra, it is possible to link sequences located thousands of kilometres away from volcanic source.

The European Arctic is a key area for studying Holocene environmental evolution due to its sensitivity to climate change. It is important to date climatic changes precisely and gain knowledge on their frequency. Tephrochronology is one of the best tools to reach that goal because deposits at different sites, uniquely, can be linked to precisely the same time (the date of eruption that generated the cryptotephra). So far, little research on cryptotephrochronology has been performed in the region, thus the aims of the project were to (1) improve knowledge of the extent of spatial distribution of tephra fall-out by discovering cryptotephra deposits, and (2) to use the newly discovered cryptotephras as isochrons to date postglacial development of the Arctic. Three peat cores from Kola peninsula, Russia, and one lake core from Finnish Lapland, were examined for the presence of volcanic glass concentrations. In our study we found cryptotephra deposits derived from six Icelandic volcanic systems: Hekla, Veiðivötn-Bárðarbunga, Grímsvötn, Öræfajökull, Askja, and Katla. We tentatively correlated these to dated tephra marker-layers including Glen Garry/A-2000 tephra, CLA-L1 tephra, Öræfajökull 1362, and SILK YN using major element composition and stratigraphic superpositioning of volcanic glass deposits. However, additional dating methods such as radiocarbon are required to confirm these correlations. Our discovery of at least four basaltic cryptotephras emphasizes that basaltic shards can travel farther than previously thought – in this case, up to 2000 km. Our study demonstrates a great potential for tephrochronology in the European Arctic.

ORAL
Session 1a.

SOIL-SAMPLE GEOCHEMISTRY NORMALISED BY CLASS MEMBERSHIP FROM MACHINE-LEARNT CLUSTERS OF SATELLITE AND GEOPHYSICS DATA

Michael Gazley[1], Shawn B. Hood[2] and Matthew J. Cracknell[3]

[1] *RSC Mining and Mineral Exploration, 93 The Terrace, Wellington, New Zealand.*
[2] *GoldSpot Discoveries Corp., 69 Yonge Street, Suite 1010, Toronto, Ontario, Canada.*
[3] *ARC Industrial Transformation Research Hub for Transforming the Mining Value Chain, University of Tasmania, Hobart, Australia*

m.gazley@rscmme.com

The primary aim of mineral exploration is to focus the search space from regional scale (1000s km^2) to prospect scale (1–10 km^2), identify areas that warrant further investigation, and ultimately drill a target. Mineral deposits typically display geochemical anomalism related to the conditions of their formation, or the weathering and mass transport of sediment away from a mineral deposit. However, this anomalism can be obscured in soil-sample surveys due to background variations in host bedrock chemistry and the transformation and redistribution of original minerals during surface weathering, regolith development, and supergene processes.

This contribution uses machine-learnt map products to aid in the interpretation of a regional-scale soil-sample dataset. ASTER (satellite spectral) data were combined with airborne radiometric data using Self-Organising Maps (SOM) to generate a map of regolith type. A map of bedrock geology was previously derived by the authors from airborne geophysical data using Random Forests. These two products are used to classify soil samples with an objective bedrock-geology and regolith-type classification. A z-score normalisation was implemented on the soil-sample geochemical data, using two different matrices (regolith type and bedrock geology) to remove the bias of bedrock geology and regolith type from the soil sample chemistry. The signal that remains likely reflects metasomatic processes, and associated elemental anomalism, potentially linked to mineralisation. These data can then be plotted to provide maps of (pathfinder) element anomalies, thus identifying potential exploration targets.

We explore this approach to normalise geochemical data in a dataset of 9,924 soil samples collected over an area of 1,028 km^2, from Kerkasha, Eritrea (Nubian Shield). The Kerkasha project is an early-stage exploration project, with a limited understanding of the local geology and mineral deposit types; however, it contains many Au and Cu prospects that have received minimal exploration work.

ORAL
Session 4f.

Magma fertility in Brothers submarine volcano

Ariadni Georgatou[1], Cornel de Ronde[1]

[1] *GNS Science,1 Fairway Drive, Lower Hutt 5040, New Zealand*

a.georgatou@gns.cri.nz

Submarine arc hydrothermal systems present many similarities in terms of geochemistry and mineralisation to shallow parts of porphyry-Cu and epithermal-Au deposits on land while they are also considered to be modern analogues of fossilised volcanic hosted massive sulfide (VHMS) deposits on land. Although, there are numerous studies, on arc magmas in subaerial systems[1], that have investigated the potential of a magma to form an economic deposit, also known as "magma fertility", there is limited related information on submarine systems[2]. Brothers active submarine volcano situated along the Kermadec arc is one of the most well-studied systems known for expelling huge amounts of volcanic gas and forming blacksmoker chimneys rich in Cu-Zn-Au on the seafloor (up to Cu=36 wt.%)[3]. Recent studies suggested that Brothers represents a high sulfidation deposit on the seafloor with evidence for a magmatic input possibly due to an underlaying porphyry-Cu deposit providing a fertile source for metals and magmatic volatiles[4,5].

Here we investigate the source and transport of Cu and Au as well as the magma efficiently to concentrate these metals in order to produce the known VHMS deposit at Brothers. A focus is shown in newly acquired fresh samples collected from the NE side of the caldera wall by an ROV. Preliminary results on whole rock geochemistry indicates that dacitic magmas are depleted in Cu (med=15 ppm) while petrography and in situ chemistry of magmatic sulfides indicate that sulfide blebs can reach up to 500 μm and are composed of mainly pyrrhotite plus minor chalcopyrite (Cu<24 wt.%). This evidence suggests that although sulfides are expected to sequestrate substantial amounts of Cu in depth, rendering the residual magma Cu-poor, sulfide dissolution in shallower levels, confirmed by sulfide-oxide breakdown textures, lead to Cu release back to the system resulting in a later Cu enrichment of the exsolving fluids.

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POSTER
Session 1b.

REFINING THE BULK: ONGOING DEVELOPMENTS IN RAMPED PYROLYSIS RADIOCARBON MEASUREMENTS AND COMPLEMENTARY ANALYSES

C.E. Ginnane[1], J.C. Turnbull[1,2], A. Phillips[1], A. Zondervan[1], S.D. Nodder[3], K. Maier[3], S. Naeher[1]

[1] *GNS Science, National Isotope Centre, 30 Gracefield Road, Gracefield, Lower Hutt, 5010*
[2] *CIRES, University of Colorado at Boulder, USA*
[3] *National Institute of Water & Atmospheric Research Ltd (NIWA), Private Bag 14-901, Kilbirnie, Wellington 6241*

c.ginnane@gns.cri.nz

Ramped pyrolysis oxidation accelerator mass spectrometry (RPO-AMS) has been recently established at Rafter Radiocarbon Laboratory (RRL). This technique improves on bulk radiocarbon measurements by disentangling distinct carbon pools in a sample by exploiting the thermochemical stability of specific groups of organic compounds. This allows more labile carbon to be separately analysed from refractory carbon that often precludes accurate dating of detrital sediment.

Ongoing methodology refinement for quality assurance is paramount to obtain accurate and precise results. For RPO-AMS, both modern and dead carbon contamination must be considered and corrected for both time-dependent and independent sample preparation and measurement processes. Using secondary materials with known radiocarbon content to assess our blank corrections and measurement performance over time, we have improved lab processes and resultant data quality. A specific challenge for RPO-AMS is complete graphitisation of small CO_2 samples. RRL has designed a new low-volume reactor to improve efficiency and promote complete graphitisation. A new low-volume graphitisation line will be constructed in early 2022.

In addition to building accurate sediment chronologies, RPO-AMS can also be used in tracing sediment transport processes. Both applications are enhanced by supplementary corroborating analyses. We have pioneered the novel application of pyrolysis-gas chromatography-mass spectrometry (Py-GC-MS) configured to mimic conditions of the RPO-AMS system to identify the chemical composition of each aliquot taken at equivalent temperatures. This chemical fingerprint informs the source of carbon in each RPO split, distinguishing depositional carbon from transported allochthonous carbon. Another complimentary traditional method of carbon source identification is employing bulk stable carbon isotopes to distinguish marine from terrestrial carbon sources. We have begun investigations to augment RPO-AMS measurements with stable carbon isotope analysis of RPO aliquots to analyse for $\delta^{13}C$ as well as radiocarbon content for the thermally differentiated carbon groups, providing a step-change from bulk towards compound specific stable isotope analyses.

POSTER
Session 4e.

FORCES CHANGING THE LITHOSPHERE'S LAYOUT

Tomasz M. Glowacki

Independent researcher, no affiliation

tomek@tegassociates.co.nz

Voices on the internet call for revision of past and present Earth processes: "…I think it is time to question and discuss this theory to understand more precisely the nature of the Earth". "… it is time to understand some disadvantages of plate tectonics such as subduction, plumes and hot spots and building mountains" – extracts from the discussion on (Research Gate, 2018). All theories regarding changing the lithospheric layout expose a lack of understanding of the mechanism responsible for plate tectonics. At least, almost every article on this subject starts with an honest statement like this: "the driving mechanism of plate tectonics remains elusive" (D. Zaccagnino et al., 2020). Scientists well understand the need of getting to the crux of this matter: "Understanding global plate motions is one of the central problems of geodynamics…" (Lithgow-Bertelloni et al., 1995). Forces shifting continents are not visible; but the consequences of their actions are. To describe the plate tectonics mechanism, it is sufficient to recognize six (6) primary motions which produce Earth's accelerations and decelerations that create tangential forces to Earth's surface, which are responsible for plate tectonics: 1. Rotation, 2. Oscillation, 3. Wobbling and axial tilting, 4. Rotation around Barycenter 5. Change of spin and 6. Orbiting the Sun.

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POSTER
Session 4c.

UNDERSTANDING SHALLOW INSTABILITY IN THE KAIKOURA CANYON USING DIFFERENTIAL BATHYMETRY AND DYNAMIC SHEAR TESTING

Laura Gnesko[1], **Tim Stahl**[1], **Joshu Mountjoy**[2] **and Jon Carey**[3]

[1] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*
[2] *National Institute of Water & Atmospheric Research (NIWA), Wellington, New Zealand*
[3] *GNS Science, Lower Hutt, New Zealand*

laura.gnesko@pg.canterbury.ac.nz

Submarine landslides are ubiquitous along continental slopes and display a range of failure styles but their mechanisms, size and distribution during earthquakes remain poorly understood. Submarine failures can pose significant risk to coastal communities and associated infrastructure. The 2016 Kaikōura earthquake triggered submarine landslides that initiated an 850-megaton sediment flow that travelled >680 km along the ocean floor. Here, we used high-resolution bathymetry and dynamic shear testing of shallow sediment cores near the Kaikoura canyon head to investigate the failure mechanisms, sizes, and distributions of coseismic landslides.

Preliminary morphological mapping of the canyon and pre- and post-earthquake bathymetry differencing show failures occurring predominantly within soft Quaternary sediments overlying bedrock along the canyon rim. The post-earthquake landscape is characterized by steepened scarps along the rim, retrogressive erosion of existing gullies, and evacuation of up to 30 m of material down incised gullies. The pelagic sediments recovered from shallow cores sampled within the rim (1-3 m) are a clayey silt with a liquid limit of 28.7%, and a plasticity index above the A-line (11.9%) classifying the material as a lean clay (CL) with low to medium plasticity and slow dilatancy. Dynamic shear testing of the sediments using modelled maximum ground acceleration from the Kaikōura Canyon indicates possible liquefaction behaviour during shaking. The combination of these results suggests a non-negligible portion of the turbidity current triggered in 2016, and subsequent modification to the canyon, was caused by failure within the soft sediments overlying bedrock.

POSTER
Session 4c.

MELTING ICE WITH A LARGE SUBGLACIAL ERUPTION, SNÆBÝLISHEIÐI, ICELAND

Carolyn Gorny, James DL White, Magnús T Guðmundsson

[1] *Department of Geology, University of Otago, Dunedin, New Zealand*
[2] *Institute of Earth Sciences, University of Iceland, Reykjavik, Iceland*

james.white@otago.ac.nz

Volcanism in Iceland produces volcanic landforms that record waxing and waning of ice sheets, and recent subglacial eruptions of Grimsvötn volcano reveal glaciers' important role in shaping volcanic edifice morphology and eruption style. For an older but much larger (Laki-scale) subglacial eruption, we have modelled the syn-eruptive ice sheet and eruptive melting using geological, glaciological, and thermodynamic principles. The Snæbýlisheiði volcanic deposit is a NNW-SSE elongate, sinuous, flat-topped ridge in south central Iceland with a source area in the Eastern Volcanic Zone. The ridge's volume is 26 km^3, its height 100-300 m, width ~3-7 km, and length ~34 km, and it is inferred to have formed in one eruption. The first 1-3 km of the ridge comprises the source area, which has subaerially deposited spatter and accretionary lapilli-bearing ash beds exposed high on the edifice. Further down-ridge additional accretionary lapilli tuff crops out at 6 km, and variably welded scoriaceous coarse lapilli tuff breccia/spatter at 7.6 and 9 km. These observations provide key constraints for estimating ice-sheet size at the time of eruption. We infer that most energy released during the eruption was expended in melting overlying ice. A first-order approximation is that the thickness of ice melted scales with eruptive-deposit thickness when ice is thick and bedrock and ice surfaces have gentle slopes. We model a parabolic ice sheet, and show that melt-through of the ice sheet for the thickest part of the deposit (out to 7-9 km from the vents) can be reconciled with ice sheets extending 20-40 km S/SE beyond the tip of Snæbýlisheiði, effectively reaching the present coast. This ice sheet, modelled with the subaerial-deposit constraints, is more similar to the Younger Dryas or Preboreal ice sheets than to those in current models for the last glacial maximum in Iceland.

POSTER
Session 1a.

Reduced magnitude of the onset of Northern Hemisphere Glaciation during the Early Pleistocene

Georgia Grant[1], Tim Naish[2], Peter Kamp[3], Molly Patterson[4], Benjamin Keisling[5], Stephen Meyers[6], Rich Levy[1,2], Rob McKay[2]

[1] Te Pū Ao *GNS Science, Te Whanganui-a-Tara, Aotearoa,*
[2] *Te Puna Pātiotio Antarctic Research Centre, Te Herenga Waka, Te Whanganui-a-Tara, Aotearoa*
[3] *Te Whare Wānanga o Waikato, Kirikiriroa, Aotearoa*
[4] *Binghamton University SUNY, New York, USA*
[5] *Lamont-Doherty Earth Observatory, New York, USA*
[6] *University of Wisconsin-Madison, Wisconsin, USA*

g.grant@gns.cri.nz

Intensification of the Northern Hemisphere glaciation to continental scale began about 2.7 million years ago (Ma), as indicated by the geographic distribution of ice-berg rafted debris in deep ocean sediment cores and increasing amplitude of variability in the benthic oxygen isotope (δ18O) proxy global ice volume record, beyond what Antarctica could reasonably contribute. However, the location, extent, and thickness of these ice sheets is poorly constrained by proximal geologic evidence, and the interpretation of ice volume from proxy δ18O record is uncertain due to the additional influence of bottom-water temperature on δ18O composition.

A new direct and continuous sea-level record (PlioSeaNZ) has been recently developed from Pliocene shallow-marine sedimentary deposits in Whanganui Basin, New Zealand, using the relationships between sediment transport, water depth, and grain size on a wave-graded continental shelf (Grant et al., 2019). Here we present an extension of the PlioSeaNZ sea-level record using the early Pleistocene sedimentary sequences from Whanganui Basin (e.g. Naish & Kamp, 1996), and reconstruct the amplitude and frequency of glacial-interglacial, global sea-level fluctuations between 3.3-1.7 Ma.

Early Pleistocene (~2.6-1.7 Ma) fluctuations in global mean sea-level were between 5-45 m, with an average of 20 m, significantly lower amplitude than those reconstructed from benthic δ18O records (17-60 m; Miller et al., 2020) during the intensification of the Northern Hemisphere Ice Sheets (NHIS). We suggest that while NHIS reached an extent whereby they were calving ice bergs at the coast by 2.7 Ma, their volume is overestimated in reconstructions based on the benthic δ18O proxy.

This has significant implications for the wide use of δ18O as an ice volume proxy, the assumptions of NHIS distribution, and the relative contribution of Antarctic and NHIS to global sea-level at this time.

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ORAL
Session 2c.

THE GEOCONSERVATION TRUST AOTEAROA. INTEGRATING GEOSCIENCES, CONSERVATION, EDUCATION, TOURISM, SOCIOLOGY, AND ART IN NEW ZEALAND AND THE SOUTH PACIFIC

Ilmars Gravis[1]; **Chris Twemlow**[1]; **Karoly Nemeth**[1,2]

[1] *The Geoconservation Trust Aotearoa, Ōpōtiki, New Zealand*
2 School of Agriculture and Environment, Massey University, Palmerston North, New Zealand

secretary@geocoservation.org

Geoconservation globally is becoming one of the most recognised terms around the conservation of special places integrating the fields of geoheritage; conservation; enviromentalism; archaeology; and cultural history. In the academic field a significant body of work explores conceptual theories behind geoconservation, in addition to establishing frameworks and methodologies for assessment of geoconservation values and promotion of geoconservation ventures. Geoconservation as a discipline supports community awareness of geoheritage; the importance of geodiversity as an intrinsic landscape value; and the value of cultural landscapes shaped by their geology and history. Applying a transdisciplinary approach to complex problems currently facing humanity and our environment allows the application of urgently needed multi-faceted solutions. Interdisciplinary science can respond to environmental factors that may shape sustainable development, nature conservation, and geoeducation. Geosystem services offer alternative ways to build a resilient society able to live with abiotic nature rather than threaten and degrade it. Using a co-design framework at the community-based level can identify geoheritage values and result in long-lasting and sustainable outcomes in community development; land management; and governmental policy. The Geoconservation Trust Aotearoa aims to act as a facilitator and expert provider; empowering communities; and co-producing methods to understand, protect and engage with abiotic nature.

ORAL
Session 3c.

GNS SCIENCE'S JOURNEY TO BE CARBON NEUTRAL BY 2025

Angela G Griffin[1], **Gary Wilson**[1] **and GNS Science Carbonreduce project team**[1]

[1] *GNS Science, PO Box 30368, Lower Hutt 5010, New Zealand*

a.griffin@gns.cri.nz

GNS Science has been tracking its carbon emissions from some of its largest emitting activities for more than a decade, before joining the Toitū Envirocare carbonreduce programme (previously known as CEMARS) in 2020. By joining the programme, GNS Science can now accurately measure the carbon emissions related to our science and to our organisation, and put strategies in place to manage and reduce impacts.

We have used the 2018-2019 financial year as a baseline, from which our emissions reduction targets will be measured against. Compilation of data from various sources related to our operational and organisational activities, including fieldwork and the staff commute, took place prior to joining the programme. Working with suppliers and vendors to acquire data for reporting has been a learning experience, and not always successful.

By reporting on Scope 1, 2 & 3 emissions, GNS Science's carbon emission total is 3218.44 tonnes CO_2e for 2018-2019. Our top 10 emission sources equate to ~90% of our total emissions, with some of the biggest emitters being international air travel (874 t CO_2e), the staff commute (852 t CO_2e), domestic air travel (355 t CO_2e), electricity (317.62 t CO_2e), natural gas use (229 t CO_2e), and diesel vehicle use (70 t CO_2e).

We have set targets to reduce (rather than offset) the total net emissions by 20% by 2025. Subtargets relating to the biggest emissions are ambitious, however by engaging all of GNS (including the Board), we are confident that we can meet them. Data from our 2019-2020 and 2020-2021 financial years provides an indication of what can be achieved, when forced to reduce carbon-emitting activities and provide some guidance as to how to manage our emissions while maintaining our business.

ORAL
Session 2c.

SLIP RATES FOR THE HYDE AND DUNSTAN FAULTS, SOUTHERN NEW ZEALAND, REVEALED BY COSMOGENIC RADIONUCLIDE DATING

Jonathan D. Griffin[1, 2], Mark W. Stirling[1], Klaus Wilcken[3], David J.A. Barrell[4], Krista Simon[3]

[1]Department of Geology, University of Otago
[2]Community Safety Branch, Geoscience Australia
[3]Australian Nuclear Science & Technology Organisation (ANSTO
[4]GNS Science

jonathan.griffin@postgrad.otago.ac.nz

Reverse faulting in Otago, southern New Zealand, accommodates distributed tectonic convergence on the eastern side of the Australia-Pacific plate boundary. Paleoearthquake records from some of these reverse faults show highly variable earthquake recurrence times, with some interpretations suggesting long (~100 kyr) periods of seismic quiescence on individual faults. In this study we give longer term context to the paleoearthquake record by constraining late Quaternary slip rates on two significant faults within the system, the Hyde and Dunstan faults. Slip rates are constrained using cosmogenic radionuclide dating of faulted alluvial fan surfaces and interpretation of lidar digital elevation models. We determine an average fault slip rate of about 0.27 mm/yr (0.24 – 0.37 mm/yr at 95% confidence) for the Hyde Fault since 115 ka and a slip rate of about 0.16 mm/yr (0.13 – 0.23 mm/yr) for the Dunstan fault since 320 ka. Both faults show deviations from a constant linear slip rate through time, with slip rates varying by a factor of 2 – 4 over timescales of 15 – 80 kyr. Increases in slip rate are out of phase on the two faults, supporting a hypothesis that strain is shared within the fault system over timescales on the order of 10s – 100s kyr; however, neither fault shows evidence for long periods of seismic quiescence. These results have implications for characterising the seismic hazard posed by these faults.

ORAL
Session 2a.

Deep magma sources feeding eruptions from Red Crater (Tongariro, New Zealand): Geochemical insights from mineral chemistry and olivine-hosted melt inclusions

Kerstin Gruender[1], **Simon J Barker**[1], **Michael C Rowe**[2]

[1] *Victoria University of Wellington, Wellington, New Zealand*
[2] *School of Environment, University of Auckland, Auckland, New Zealand*

kerstin.gruender@vuw.ac.nz

Andesite volcanoes are characteristic features of subduction zones. Their eruptive behaviour and associated hazards can be challenging to understand and predict because they erupt both explosively and effusively, often without much warning. Their magmatic systems are complex, ultimately driven and sustained by magma recharge from the mantle. However, primitive magma compositions are mostly overprinted by interactions with the overlying crust before eruption, obscuring signatures of deeper crustal levels and the mantle. Geochemical analysis of crystal cargoes of erupted magmas, especially early crystallized minerals (e.g. olivine), can provide insights into deep magmatic processes that whole-rock geochemistry can't resolve. Tongariro is a large composite andesite volcano located in one of New Zealand's most volcanically active areas at the southern end of the Taupo Volcanic Zone (TVZ). This study investigates the magmatic driving force behind young (<1.8 ka) eruptions from Red Crater. Basaltic andesite scoria (53-54 wt.% SiO_2) contains rapidly quenched primitive olivine ($Fo_{85\text{-}90}$) with glassy melt inclusions. We present results from the study of mafic mineral and melt inclusion geochemistry aiming to capture and characterize primitive magma compositions. We identify at least three olivine and two melt inclusion populations. Primitive melt inclusions contain 49-53 wt.% SiO_2, ~7 wt.% MgO, up to 3500 ppm S and 3000 ppm Cl and are amongst the most primitive melts reported in the TVZ. More evolved melt inclusions have 54-57 wt.% SiO_2, 4-6 wt.% MgO and much lower volatile concentrations. Our initial interpretation supports the rapid ascent of a primitive Mg-rich magma interacting with crustal magma reservoirs, recorded by multiple crystal and melt inclusion populations, mineral textures and zoning. This research provides insights into Tongariro's deeper volcanic magma system and will help to improve our knowledge about magma sources feeding eruptions in this area and contribute to our general understanding of andesite petrogenesis in continental subduction zones.

POSTER
Session 1b.

TSUNAMI SOURCE MODEL AND FORECASTING OF THE 2021 LOYALTY ISLAND EARTHQUAKE

<u>Aditya R. Gusman</u>[1], William Power[1], Jean Roger[1], Bill Fry[1], Yoshihiro Kaneko[2]

[1] *Earth Structures and Processes, GNS Science, Lower Hutt, New Zealand*
[2] *Department of Geophysics, Graduate School of Science, Kyoto University, Kyoto, Japan.*

a.gusman@gns.cri.nz

A tsunamigenic M_w 7.7 earthquake occurred in the Southern New Hebrides subduction zone on the 10th of February 2021. The tsunami was observed at coastal gauges in the islands around the source area, and at a new DART buoys network that was designed to enhance the tsunami forecasting capability of the Southwestern Pacific. We used the tsunami waveforms in an inversion to estimate the fault slip distribution. The estimated major slip region is located near the trench with maximum slip amount of 4 m. Observed seismic body and surface waves can be reproduced from the tsunami source model with an assumed rupture velocity of 1 km/s. While the computed seismic moment for the source model of 3.39×10^{20} Nm (Mw 7.65) is slightly smaller than the GCMT solution (4.01×10^{20} Nm).

The source model was then used as reference model to evaluate our tsunami forecasting methods. Tsunami heights in the warning regions can be obtained by interpolating results of pre-computed scenarios around the earthquake location. The pre-computed waveforms can also be interpolated and then compared with the observation to verify the tsunami forecast. We found that the interpolated tsunami waveforms at the DART stations match the observations better than the waveforms from the pre-computed scenarios.

We can also obtain a tsunami forecast using a tsunami magnitude approach. The tsunami magnitude Mt=7.72 was obtained from the tsunami peak amplitudes recorded at DARTs along the Hikurangi-Kermadec-Tonga subduction zone. The tsunami magnitude was then used to predict tsunami height in the warning regions. The predicted tsunami threat levels from both interpolation and tsunami magnitude methods match those from the reference map in most of the warning regions.

ORAL
Session 2a.

GEOLOGICAL INSIGHTS INTO THE ERUPTIVE HISTORY OF THE WORLD'S LARGEST "DIRTY" GEYSER: WAIMANGU GEYSER 1900-1904, WAIMANGU VOLCANIC VALLEY, NEW ZEALAND

Annahlise Hall and **Shane Cronin**

School of Environment, University of Auckland, Auckland, New Zealand.

ahal294@aucklanduni.ac.nz

The Waimangu ("Black Water") Geyser was a brief yet spectacular geothermal phenomenon triggered following the destructive events of the 1886 Tarawera rift eruption[1,2]. Although no surface hydrothermal activity existed in the southwestern rift section pre-1886, this area now marks the world's youngest geothermal system, named Waimangu Valley after the geyser[1,2]. The Waimangu Geyser is the largest geyser recorded on Earth. During its active period from 1900-1904, it blasted black mud, sand, and water into the air at perceived heights of around 450 m, lasting ~6 hours in 36-hour cycles[1-3]. Eruption deposits are a good analogue of past eruption processes that can reconstruct unknown eruptive histories. Thus, we investigated the previously unstudied but now extinct Waimangu Geyser through its deposits to ground-truth historical observations, infer eruptive history, and determine what likely drove its unusually "dirty" and vigorous behaviour and if there was a volcanic component?

Twenty-one samples of mud and sand were examined through a 2.5 m-thick sequence of postulated geyser deposits, stratigraphically above the 1886 Rotomahana mud. Grain-size distributions were determined by sieving and lithological distributions and particle shape were analysed via microscopy. Our results suggest that the geyser began with its most vigorous activity, ejecting a larger portion of coarser particles (>16 mm). These particles were mainly recycled 1886 basaltic scoria and Rotomahana mud. By contrast, later geyser activity involved ejection of a greater proportion of finer (<64 μm) material and a larger proportion of rhyolitic particles, including pumice correlated to the ~AD 1305[4] Kaharoa pumice and rhyolitic lava fragments. This fining and deepening source-material sequence suggests an excavation and possible waning-energy sequence through the life of the geyser. We found no evidence of fresh magma/glass. The geyser likely represents a series of small hydrothermal-like eruptions, driven by repeated trapping and explosive release of heated meteoric waters. Fluid traps/plugs were formed by ejecta fall-back and collapse of unstable conduit walls formed in mainly unconsolidated deposits. Our ongoing studies include analysis of hydrothermal alteration in the geyser via clay mineral analysis and re-evaluating energy output via combining historical imagery with deposit geometry.

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POSTER
Session 1a.

INVESTIGATION OF A LARGE FILL FAILURE AT AN OPEN CAST MINE IN THE WAIKATO COAL REGION

Adil Hameed[1], Martin Brook[1] and Julie Rowland[1]

[1]School of Environment, The University of Auckland, Auckland 1010, New Zealand

aham699@aucklanduni.ac.nz

Failure of ‘made ground’, land surfaces that have been constructed from fill, are common throughout New Zealand, and are a primary cause of land instability in urban areas such as Wellington and Auckland. In urban areas, fill is created by excavation of soil and/or rock from ‘footprints’ of ground ahead of construction, with the fill then placed and compacted in gullies and depressions, often creating additional areas for further building, or recreation. In recent years, some of the fill in ‘made ground’ has failed spectacularly in residential suburbs of both Auckland and Wellington, often due to pore water pressure increases following heavy rainfall. In addition to these urban fill failures, the extractives industry also has to deal with large volumes of fill. This is overburden that is removed in the process of targeting and extracting ore, aggregate, or coal seams. This can also lead to fill failures within the quarry or mine site that can interrupt production until the failure is stabilized and remediated. Here, we outline a large fill failure -possibly one of New Zealand’s largest- at an open-cast coal mine in the Waikato Coal Region of the North Island. Slope failures at open-cast mines in the Waikato Coal Region are an accepted consequence of economic coal extraction, on account of the low strength (typically <10 MPa), and slake-prone nature of some of the Te Kuiti Group sedimentary units (Lindsay et al., 2001), overburden that is removed during stripping. Indeed, mining operations over the decades have meant that large volumes of overburden have been placed as engineered fill around the mine site. In this case study, the interplay of variable compaction, permeability and strength contrasts, activity of clay minerals within the fill, and rainfall, are all factors that have promoted fill instability at the site.

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POSTER
Session 4f.

A SNAPSHOT OF NEW ZEALAND'S DYNAMIC DEFORMATION FIELD DERIVED FROM INSAR AND GNSS OBSERVATIONS AND ITS INFLUENCE ON COASTAL VERTICAL LAND MOVEMENT

<u>Ian Hamling</u>[1], Sigrun Hreinsdóttir[1], Richard Levy[1]

[1] GNS Science, 1 Fairway Drive, Avalon, Lower Hutt, New Zealand
[2] GNS Science, Wairakei Research Centre, Taupo, New Zealand.

i.hamling@gns.cri.nz

Measuring the deformation at the Earth's surface over a range of spatial and temporal scales is vital for understanding seismic hazard, detecting volcanic unrest and assessing the effects of vertical land movements on sea level rise. Here, we combine ~10 years of InSAR observations from Envisat with interseismic campaign and continuous GNSS velocities to build a high-resolution velocity field of New Zealand. Exploiting the horizontal GNSS observations, we estimate the vertical component of the deformation to provide the vertical land movement (VLM) for the entire 15,000 km-long coastline of New Zealand. The estimated vertical rates show large variability around the country as a result of volcanic, tectonic and anthropogenic sources. Largest interseismic subsidence rates are observed along the North Islands east coast extending across the Cook Strait into the Kaikōura region supporting models of at least partial locking of the southern Hikurangi subduction interface. A major challenge for estimating the long term VLM for New Zealand is its dynamic setting. While the Envisat data presented here spans a time period where New Zealand was relatively unaffected by earthquakes, areas of coastline are not stable through time. In the future, full resolution processing of new satellite data combined with GNSS will allow for almost real time monitoring of New Zealand's evolving deformation field.

POSTER
Session 2d.

DYNAMIC VENT AREA CHANGES AT WHAKAARI WHITE ISLAND DERIVED FROM STARING SPOTLIGHT SATELLITE DATA

Ian Hamling[1], **Geoff Kilgour**[2]

[1] *GNS Science, 1 Fairway Drive, Avalon, Lower Hutt, New Zealand*
[2] *GNS Science, Wairakei Research Centre, Taupo, New Zealand.*

i.hamling@gns.cri.nz

The driving mechanisms behind phreatic eruptions make them challenging to forecast. Typically, pressurization occurs over a range of timescales, due to the injection of hydrothermal fluids or by the release and ascent of magmatic gas into a sealed hydrothermal system. In either scenario, the area of deformation is often restricted to an area of 10's of m^2, making direct measurements difficult. Furthermore, the presence of hydrothermal features such as crater lakes and high temperature fumaroles often prevent clear views of the vent area. In addition, standard satellite radar measurements return data from pixels that have an area of ~10 m^2, making it near-impossible to identify fine-scale topographic changes. Here we present analysis from new high-resolution (0.25-1 m) Synthetic Aperture Radar data acquired over Whakaari White Island since 2020. By using these radar data, it is possible to see through cloud and steam, enabling us to track small-scale changes in and around the vent area. Our results show the highly dynamic nature of the vent area, including the formation of new sub-vents and fine-scale fluctuations in the lake level. In addition, deformation timeseries allow us track subtle displacements associated with changes in the shallow hydrothermal and magmatic systems, and active landslide. Following the eruption 2019, deformation around the vent area has largely been dominated by subsidence with small scale changes in displacement rates often correlated to other observable changes. We also observed renewed downslope motion of the SW crater wall with ~300 mm of subsidence along its head scarp. Together, these data provide a case study for utilizing new satellite measurement to assess fine-scale changes at hazardous and remote volcanic systems helping to supplement the array of monitoring tools available to volcanologists.

POSTER
Session 1a.

THE VISUALIZATION OF GEOLOGICAL AND GEOPHYSICAL DATA IN A 3D VIRTUAL REALITY ENVIRONMENT

Kristian Hansen[1], Simon Barker[1], Finnigan Illsley-Kemp[1], Craig Anslow[1], Christof Mueller[2], Graham Leonard[2]

[1] *School of Geography, Environment, and Earth Sciences. Victoria University of Wellington*
[2] *GNS Science*

kris91268@gmail.com

Advances in technology provides us with ever-increasingly detailed and interactive means for displaying and analysing scientific data. Geological data is often visually complex but somewhat limited when displayed in 2D, particularly for large complex maps and subsurface models. Virtual reality (VR) technology has become highly accessible over the past few years and has the capability to greatly improve the way we display and interpret geological and geophysical data. Here, we explore the viability of using VR to monitor, study, and teach about geological and geophysical data from the Taupō Volcanic Zone (TVZ). The TVZ is the most productive and frequently active rhyolitic volcanic zone on Earth, and this region is the focus of ongoing research through the ECLIPSE Programme. Currently, the area is being actively monitored by GeoNet/GNS for signs of unrest (e.g. earthquakes, ground deformation, gas flux) and this data is made publicly available. Our research uses VR and 3D video game rendering technology to visualise a user-selected geographic region. Satellite imagery is overlain on a digital elevation model, with the option to display other static geographic data. The TVZ VR program can then pull monitoring data such as ground deformation, gas chemistry, and earthquake locations, directly from the GeoNet server. This data can be near-real-time or for a selected time period, and is then visualised in 3D. We invite conference attendees to experience VR and will provide a live demonstration during the presentation. The TVZ VR program is designed to be user-tested amongst scientists for use in research and monitoring as well as university students of varying levels and high school students to determine its effectiveness and usability for outreach and education. User testing will start in October, and a PC version will also be made available for other applications and website use. We envisage that VR will form a core-component of a future volcano-monitoring dashboard for the TVZ and New Zealand volcanoes in general.

POSTER
Session 4a.

A PRELIMINARY STUDY OF LATE HOLOCENE SEDIMENTARY RECORDS FROM WHAKARAUPŌ (LYTTELTON HARBOUR)

Johanna M. Hanson[1], Catherine M. Reid[1], Matiu Prebble[1] and James Shulmeister[1]

[1] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*

johanna.hanson@pg.canterbury.ac.nz

Limited research has been conducted on Holocene records from Horomaka (Banks Peninsula). Changes in past environmental conditions (e.g., relative sea levels, vegetation) and how the landscape has changed over the Holocene (particularly human landscape alteration), is not well understood in this area. Our research will provide insight into the links between marine and terrestrial proxies to investigate past climate and vegetation variability around Banks Peninsula. Sediment cores from Lyttelton Harbour (Te Whakaraupō), Okains Bay (Kawatea) and Lake Forsyth (Te Wairewa) will underpin palaeoecological, sedimentological and geochemical research. Further, due to the active nature of New Zealand, a sea level curve unaffected by tectonism has been difficult to achieve, with the Gibb (1986) sea level curve having been the most commonly utilised. However, the relative tectonic stability of Horomaka provides an opportunity to better inform eastern South Island sea-level curves.

From this poster presentation we will present preliminary results from a shallow-marine sediment core and surface samples collected from Head of Bay, Lyttelton Harbour. Sediment and foraminiferal analysis were conducted to examine past environmental conditions (e.g., salinity and changes in sea level) over the Holocene.

Future analyses on this core will include pollen and micro-charcoal analyses (past vegetation and fire regime changes), grain size and Itrax analyses (palaeo-tsunamis) and radiometric dating. This research will present important information on a previously understudied area regarding past climate and sea level variability, changes in landscape and also external factors affecting these sites (e.g., palaeo-tsunamis).

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POSTER
Session 2c.

FORAMINIFERAL INSIGHTS INTO THE 2016 KAIKŌURA TURBIDITY CURRENTS

<u>Bruce W. Hayward</u>[1], Ashwaq T. Sabaa[1], Jamie D. Howarth[2], Alan R. Orpin[3], Lorna J. Strachan[4]

[1]Geomarine Research, 19 Debron Ave, Remuera, Auckland
[2]School of Geography, Environment and Earth Sciences, Victoria University, Wellington
[3]NIWA, Private Bag 14901, Kilbirnie, Wellington
[4]School of the Environment, University of Auckland, Auckland

b.hayward@geomarine.org.nz

The 2016 Kaikōura Earthquake (Mw7.8) triggered simultaneous turbidity currents down ten submarine canyons along a 200 km stretch of the continental slope. Many of these smaller canyons possibly discharged into the abyssal Hikurangi Channel that flows northwards along the foot of the slope. 136 foraminiferal samples from the 2016 turbidite and pre-turbidite sediment were taken from 25 canyon and channel cores (1000-4000 m water depth) and these provide insights into flow behaviours and provenance of the turbidity currents.

All turbidite and pre-turbidite faunas have signatures of downslope displacement (shallow-water benthics, size-sorted test distributions, low planktic %). Pre-turbidite faunas were displaced by turbidity currents >150 years before 2016. They can be distinguished from the recent turbidite faunas by the presence of tests of deep-water benthics and planktic rain, which have been added into the pre-turbidite sediment since emplacement. There are no consistent changes in foraminiferal parameters in the 2016 turbidite with distance displaced (10-650 km). Intra-turbidite faunal variability in a single core is attributed to incorporation of deep-seafloor tests by early turbidity current pulses, different source canyons, and test-size sorting during transport and deposition.

Although no tributary canyon has taxonomically-distinct faunas, analyses suggest that they could be distinguishable using a combination of the relative abundance of key benthic genera, fragmentation index, absolute test abundance and planktic %. Two ordinations based on these faunal parameters form a template for inferring the provenance and constructing hypotheses about the potential flow history of the 2016 turbidite in the Hikurangi Channel. The lowermost portions of the turbidite show affinities to a mixed Opouawe-Cook canyons source, suggesting it was an early turbidity current down the central region of the channel. Upper portions of the turbidite deposited 350-650 km down channel predominantly show a Kaikōura Canyon provenance, inferring that this more southerly sourced material arrived slightly later.

ORAL
Session 2e.

AGGREGATE OPPORTUNITY MODELLING FOR NEW ZEALAND

Matthew P. Hill[1]

[1] *GNS Science, 1 Fairway Drive, Avalon, Lower Hutt, New Zealand.*

m.hill@gns.cri.nz

Efficient utilisation of New Zealand's aggregate resources is critical to supporting infrastructure development as well as reducing operational and transport costs related to extraction of the raw materials. To achieve this, aggregate sources and the quality of those resources needs to be identified, they must be reserved from competing land interests wherever possible, they should be extracted close to their markets and the requirements and concerns of all stakeholders should be understood.

A mineral potential modelling approach has been used to identify places with opportunity for future hard rock and gravel extraction across New Zealand. Geographic information system (GIS) software has been used to build a spatial model of the critical components of aggregate opportunity using digital geological, land-use, statistical and geographic data. Model components include source rocks, land use, future demand, supporting infrastructure and cultural sensitivity that use 23 mappable criteria layers. These are combined using the fuzzy logic expert-weighted spatial modelling technique to qualitatively rank aggregate resource opportunities at a national scale.

The resulting maps and their GIS-based equivalent datasets of gravel and hard rock aggregate opportunity can be used to manage aggregate resources, generate targets for exploration activities and provide insight into future resources.

POSTER
Session 4f.

Scaled 3D geological modelling of Wellington to assist with engineering geology and understanding natural hazards

Matthew Hill[1], Anna Kaiser[1], Liam Wotherspoon[2], Jenny Black[1], Sandra Bourguignon[1], Brendon Bradley[3], Robin Lee[3], Scott Nodder[4], Aasha Pancha[5], Vaughan Stagpoole[1], Wanda Stratford[1], Brook Tozer[1], Susi Woelz[4]

[1] *GNS Science, Lower Hutt, New Zealand*
[2]*University of Auckland, New Zealand*
[3] *University of Canterbury, Christchurch, New Zealand*
[4]*NIWA, Private Bag 14-901, Kilbirnie, Wellington*
[5]*Aurecon, Wellington, New Zealand*

m.hill@gns.cri.nz

Modelling in three-dimensions (3D) is challenging when the results need to be used for analysis at different scales and resolutions. It is also challenging when data varies in spatial density, quality and availability. We present four geological models at different scales for the Wellington area and consider the variations required for their use in understanding natural hazards and practical applications of engineering geology in the region. The 3D geological models have been created to understand the regional thickness of Quaternary sediments, forward model fundamental site period and Vs30, and to determine basement geometry in relation to active faulting.

The regional geological model of the Wellington Quaternary sedimentary sequence needed a reduction in the amount of geological and borehole data for efficient computation, but it was important that enough data were retained to ensure that key features were not lost. This contrasts with the higher resolution geological models used for: (1) forward modelling of site period in the Wellington City area where a major challenge is uneven data density; (2) the velocity model for the Wellington CBD where there is a high density of data but large variations in quality and interpretation; and, (3) the Rongotai Isthmus, a data-poor area modelled to support new urban geophysical research, where unlike the other smaller-scale studies that defined engineering units, lithologic units were modelled from well-described geology and previous detailed stratigraphic research.

To resolve some of these problems, key data that constrain the models, such as geological mapping and borehole records, are retained in databases external to the 3D modelling software so they can be resampled for each project, type or scale. It was also critical that end users were consulted at the beginning of projects so that resulting 3D volumes, surfaces or interpolations were suitable for the studies that would utilise the results.

ORAL
Session 4c.

DETERMINING THE PRECONDITIONING AND TRIGGERING MECHANISMS OF SUBMARINE LANDSLIDES ON ANTICLINAL THRUST RIDGES, OFFSHORE OF THE SOUTHERN WAIRARAPA COAST.

T.A. Hill[1], A.R. Gorman[1], S.J. Watson[2], J.J. Mountjoy[2], J.I.T. Hillman[3], S. Woelz[2]

[1]Department of Geology, University of Otago, Dunedin,
[2]National Institute of Water and Atmospheric Science (NIWA), Wellington,
[3]Institute of Geologic and Nuclear Sciences (GNS), Wellington.

tayla.hill@postgrad.otago.ac.nz

Submarine landslides are documented on active margins globally, where they tend to be concentrated along the frontal thrust of an accretionary prism (Riedel et al., 2019). Historical evidence suggests that submarine landslides on active margins could be preconditioned by oversteepening, long-term tectonics, and climate change. While documented triggering mechanisms can include seismic ground shaking, excess pore pressure within the sediment, gas hydrates, tidal-loading, and erosion (Watson et al., 2019). This study will focus on determining these mechanisms on anticlinal thrust ridges located on the southern Hikurangi margin. Repeat surveying fails to detect large landslide events, suggesting a need to investigate other critical processes and factors contributing to these events other than earthquakes (Barnes et al., 2010; Mountjoy et al., 2014).

This study uses 2-D seismic data collected aboard the TAN1808 voyage along the Hikurangi Margin to map preserved mass-transport deposits (MTDs) off the southern Wairarapa coast. Three sites have been used in the characterisation of MTDs as they occur on anticlinal thrust ridges, are located closest to the deformation front, and have contrasting subsurface environments. In total, 16 MTDs have been mapped on Mungaroa Ridge, 4 on Pahaua Ridge, and 7 on Glendhu and Honeycomb Ridges. In order to determine whether the MTDs were deposited before or post ridge growth, kinematic indicators and broad-scale geomorphic features associated with slope instability were identified.

Conducting a geophysical investigation of these complex events is fundamental to our understanding of historical landslide frequency and their potential to generate tsunamigenic hazards (Masson et al., 2006). The results of this study will provide a detailed characterisation of submarine landslides occurring along active margins will contain unique features identified in seismic data and identification techniques that can be applied globally. These data contribute to New Zealand's first margin wide MTD database.

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ORAL
Session 2e.

DEFINING THE SOUTHERN END OF THE HIKURANGI MARGIN GAS HYDRATE PROVINCE

Jess IT Hillman[1], Gareth Crutchley[2], Bryan Davy[1], Sally Watson[3] and Joshu Mountjoy[3]

[1] *GNS Science, Avalon, Lower Hutt, Aotearoa New Zealand*
[2] *GEOMAR Helmholtz Centre for Ocean Research, Kiel, Germany*
[3] *NIWA, Hataitai, Wellington, Aotearoa New Zealand*

j.hillman@gns.cri.nz

The Hikurangi Margin hosts Aotearoa New Zealand's largest gas hydrate province. The southern limit of the gas hydrate province may well coincide with the southern termination of tectonic-derived folding. Prior to the acquisition of new seismic data in 2018, little was known about the southern extent of the Hikurangi Margin gas hydrate province offshore Kaikōura. Using high resolution seismic, and sub-bottom profiler data we investigated the extent and character of gas hydrates in this region. In addition, water column imaging data revealed the location of several active gas seeps.

These data and subsequent analyses allow us to determine the relationship between gas hydrate occurrence and deformation associated with the Hikurangi Subduction zone. Sediments in the southern Hikurangi Margin have experienced pronounced compaction and horizontal compression due to impingement of the Chatham Rise on the deformation front (Crutchley et al. 2020). We investigate whether there is a connection between fluid migration, gas hydrate formation and enhanced deformation in this area of the margin. At present, no evidence indicating the presence of gas hydrates has been observed south of Kaikōura along the east coast of Te Waipounamu South Island. Furthermore, we use newly acquired subsurface data to investigate the relationship between fluid flow processes and the dynamic seafloor topography of the submarine canyons in this region.

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ORAL
Session 2e.

THE HUMAN FOOTPRINT ON THE SEABED: CASE STUDIES FROM THE SOUTHERN HIKURANGI

Jess IT Hillman[1], **Sally Watson**[2] **and Sarah Seabrook**[2,3]

[1] *GNS Science, Avalon, Lower Hutt, Aotearoa New Zealand*
[2] *NIWA, Hataitai, Wellington, Aotearoa New Zealand*
[3] *University of Auckland, Aotearoa New Zealand*

j.hillman@gns.cri.nz

Humans have considerable, widespread, and ever-increasing impact on the health of oceans worldwide. Most seabed habitats globally have been impacted by human stressors in some form (Halpern et al., 2019), from the coast to the deepest parts of the oceans. In Aotearoa/New Zealand the offshore exclusive economic zone is ~15 times the land area and supports a range of industries and as a result hosts numerous human pressures including fisheries, pollution, and resource extraction. Seafloor seeps are abundant along the Hikurangi Margin (Watson et al. 2019), and support dynamic, highly productive local ecosystems. These seeps are predominantly located along the crest of thrust ridges that have formed due to subduction related deformation. The structural complexity and localised sources of production provided by seep systems have been shown to support commercially important fisheries species, such as those targeted by benthic trawlers (Bowden et al. 2013, Seabrook et al. 2019).

Benthic trawling around Aotearoa New Zealand is constrained to water depths of <1500 m. Recent video data, acquired using remotely operated vehicles (ROVs), has highlighted contrasts in seabed morphology and species abundance between active seep sites within, and outside of, the designated trawling zone. At some sites the direct impact of trawling, such as trawl marks on the seafloor, is clear, whilst at others the effect is marked by the lack of seep fauna. ROV video footage of the seabed also reveals the presence of rubbish at numerous locations.

We document observations from recent voyages along the southern Hikurangi, highlighting locations where humans have impacted the seabed. We contrast sites across different depth ranges and localities along the margin to emphasise the impact of different human activities on seabed habitats. Results presented are critical for marine environmental planning to ensure the sustainability of human activities in the oceans around Aotearoa New Zealand.

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POSTER
Session 2e.

HESTIA-AKL: AN INVENTORY OF FOSSIL FUEL CO_2 EMISSIONS FOR AUCKLAND, NEW ZEALAND

Timothy W. Hilton[1], Elizabeth D. Keller[1], Sapthala Karalliyadda[2], Adrian Benson[1], Lucas Domingues[1], Kevin Gurney[3], and Jocelyn C. Turnbull[1]

[1] GNS Science Te Pū Ao, Lower Hutt, New Zealand
[2] Victoria University of Wellington, Wellington, New Zealand
[3] Northern Arizona University, Flagstaff, Arizona, USA

t.hilton@gns.cri.nz

The largest city in New Zealand, Auckland is home to roughly 1.5 million people — one third of New Zealand's population. Here we assemble a bottom-up inventory of Auckland's fossil fuel carbon dioxide emissions from a variety of data sources. We use these emissions estimates in combination with the UrbanVPRM land surface model to estimate the net carbon balance of the region. This work is part of the larger CarbonWatch NZ project, which aims to produce estimates of New Zealand's net carbon balance quickly enough to assess and refine ongoing national efforts to reach carbon neutrality.

POSTER
Session 2c.

KINEMATIC MODEL OF NEW ZEALAND FROM FAULT SLIP RATES

Hamish Hirschberg[1] and Rupert Sutherland[1]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand*

hamish.hirschberg@vuw.ac.nz

We use fault slip rates to construct a kinematic model of the New Zealand plate boundary zone that represents deformation averaged over several seismic cycles. We additionally create a model of strain rate style from fault slip rates. We use a non-linear regression method to solve for a velocity field with embedded faults that is consistent with slip rate observations, our strain rate style model and plate motions. The resulting kinematic velocity model provides a good fit to observations, balances on-fault and off-fault deformation and shows the major features of the plate boundary. The model provides estimates of subduction zone slip rates and highlights areas where published slip rates are not consistent, which notably includes the Hikurangi-Marlborough transition.

ORAL
Session 1c.

Seismic structural monitoring in Wellington using advanced seismological techniques

Caroline Holden[1]

[1] *SeismoCity Ltd*

Caroline.Holden@seismocity.co.nz

Sklodowska et al. (2021) employed advanced seismological techniques usually applied to Earth studies to the Te Puni building (instrumented as part of the GeoNet building instrumentation programme) for the 2009-2017 time-period. Focusing on two techniques (Interferometry and transfer function), we were able to track transient changes in the building dynamic response from various level of earthquake loadings and over time despite the absence of structural damage.

Learning from this project, we apply the above techniques to buildings from the GeoNet building instrumentation programme with a different service function, or different typology than the Te Puni steel structure.

MBIE Stout street is an interesting example of a 1920s concrete structure with heavy steel reinforcing and of government level importance. Instrumentation of the building started in 2014. We selected a total of over 3,000 earthquakes from 2014 to 2021. Early results already show a clear decrease in the fondamental frequency of the structure in a step change trend related to the Kaikoura earthquake. We are working with the engineering team who designed the strenghening phase of this structure in 2014 to discuss the interpretation of these results and interest in expanding this reseach to other parts of the building.

The Wellington hospital, a modern base-isolated structure is also an ideal candidate showcasing damage avoidance system and with a high importance level. Instrumentation of the building started in 2009. We selected a total of 903 earthquakes from 2009 to 2021. Early results already show a clear decrease in the fondamental frequency of the structure in a step change trend, occuring following the 2013 Cook Strait sequence and the 2016 M7.8 Kaikoura earthquake. This analysis is specifically related to one direction of the building and more detailed analysis is currently being done.

ORAL
Session 4a.

TESTING EARTHQUAKE EARLY WARNING SYSTEMS FOR NEW ZEALAND

<u>Caroline Holden</u>[1], Rasika Nandana[2], Martha Savage[2] and Sarah-Jayne McCurrach[3]

[1] *SeismoCity Ltd*
School of Geography, Environment and Earth Sciences, Victoria University of Wellington[2]
[3] *Earthquake Commission, Wellington, New Zealand*

Caroline.Holden@seismocity.co.nz

Straddling an active boundary of two major tectonic plates, Aotearoa New Zealand is vulnerable to earthquakes as well as local and regional tsunamis. Although earthquakes are not predictable, it is possible to issue shaking alerts at locations away from the epicentre by rapidly analysing seismic waveforms. Early warning systems are key in reducing the impact of earthquake and tsunami disasters. Currently, earthquake early warning (EEW) systems are implemented in several countries including Japan, Taiwan, South Korea, and Mexico. However, there is no public earthquake early warning system in New Zealand.

The aim of this research is to test earthquake early warning algorithms for Aotearoa New Zealand considering the national seismic and geodetic networks, ocean pressure, and tide monitoring stations as well as needs and requirements from our key national response agencies and stakeholders. We will present an overview of the research project, preliminary work regarding data latency of the current seismic network and initial simulation results for an EEW algorithm using New Zealand sensor data for recent large earthquakes.

POSTER
Session 4a.

Making Sense of Paleocene Zealandia

Christopher J. Hollis[1], Sebastian Naeher[2] Chris Clowes[2], David Naafs[3], Richard Pancost[3], Richard Sykes[2], Molly M. Range[4], Brian K. Arbic[4], Brandon C. Johnson[5], Vasily Titov[6], and Ted. C. Moore[4],

[1] *Victoria University of Wellington, Wellington, New Zealand*
[2] *GNS Science, Lower Hutt, New Zealand.*
[3] *Organic Geochemistry Unit, School of Chemistry, School of Earth Sciences, and Cabot Institute for the Environment, University of Bristol, Bristol, UK.*
[4] *Department of Earth and Environmental Sciences, University of Michigan, Ann Arbor, USA.*
[5] *Department of Earth, Atmospheric, and Planetary Science, Purdue University, West Lafayette, USA*
[6] *National Oceanic and Atmospheric Administration, Pacific Marine Environmental Lab, Seattle, USA*

Chris.hollis@vuw.ac.nz

Recent research helps to resolve two long-standing mysteries in local Paleocene stratigraphy and in turn demonstrate the pronounced impact of past global changes on Zealandia's environment. The first mystery relates to the Cretaceous/Paleogene boundary (KPB). Why does Zealandia have such a patchy record of this event, especially in North Island's East Coast Basin, where the boundary coincides with deposition of glauconitic sands and in some places olistostromes? Even in the most complete sections in northeastern South Island, the boundary is marked by short hiatuses and evidence of erosion. It turns out the eastern margin of Zealandia may have felt the full force of the KPB megatsunami. Modelling predicts that the impact of a 14 km-diameter asteroid in Mexico generated a 1.5 km high wave. Primary trajectories modelled for the tsunami lay to the northeast and southwest of the impact site. Eastern Zealandia is predicted to have experienced waves of over 10 m high and flow velocities >1 m/s (Range et al, in review).

The second mystery relates to the deposition of the Waipawa Formation, an organic-rich mid-Paleocene mudstone. Why does this potential petroleum source rock occur in some settings but not in others, and what caused the apparent regressive episode that led to its deposition? We find that organic matter in Waipawa Formation is mainly degraded terrestrial plant material, which was swept into the offshore sedimentary basins during short-lived climatic cooling that is linked to a drawdown of CO_2 (Naeher et al, 2019; Hollis et al., in review). This cooling event marks a significant perturbation in the long-term Paleocene–Eocene warming trend, perhaps caused by a brief cessation in volcanic outgassing of CO_2. Base-level fall, linked to cooling and expansion of ephemeral ice sheets, flushed terrestrial biomass into offshore depocentres in some settings and caused erosion and condensed successions in others.

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ORAL
Session 2c.

ORGANIC CONTROLS ON TRANSITION METALS IN CAVE WATERS AND SPELEOTHEMS – INSIGHTS FROM KINETIC EXPERIMENTS

Sebastian N. Höpker[1], Bedartha Goswami[2], Megan Grainger[3], Sebastian F. M. Breitenbach[4] and Adam Hartland[1]

[1] *Environmental Research Institute, School of Science, University of Waikato, Hamilton, New Zealand*
[2] *Cluster of Excellence "Machine Learning", University of Tübingen, Tübingen, Germany*
[3] *Chemistry, School of Science, University of Waikato, Hamilton, New Zealand*
[4] *Department of Geography and Environmental Sciences, Northumbria University, Newcastle upon Tyne, United Kingdom.*

seb.hoepker@gmail.com

Speleothems (secondary cave carbonate deposits) present excellent archives for the reconstruction of past climates over various temporal and spatial scales, given their continuous growth and exceptional viability for radiometric dating. The concentrations of many trace elements that are incorporated into the crystal fabric during carbonate precipitation vary in response to processes in the karst system, and may serve as proxies of past environments and climate. However, current interpretations of trace elements in speleothems are often limited to alkaline earth metals (primarily Mg and Sr) due to their relatively well-understood controls and comparably predictable partitioning between the aqueous and crystal phase.

In this study, we assess the kinetic behaviour of a suite of first-row transition metals (Ni, Cu, Co) in dripwater with view to developing a novel hydrological proxy in stalagmites. These elements are primarily transported through the karst system bound in complexes with natural organic matter (NOM). The rate of dissociation of such metal-NOM complexes at the dripwater-stalagmite interface is understood to control the availability of these elements for the incorporation into precipitates (Hartland & Zitoun, 2018). The link between NOM-complex dissociation and metal availability for deposition offers an opportunity to quantitatively relate respective carbonate metal concentrations to the time available for complexes to dissociate and release metals within the thin water films on stalagmite surfaces. We present results from Competitive Ligand Exchange (CLE) experiments carried out on dripwaters from various caves in New Zealand to characterise metal-NOM complex kinetics in different environmental settings. Our findings from CLE and cave-analogue experiments demonstrate the contrasting controls on different elements in speleothems, and emphasise the potential for kinetically-limited elements in stalagmites to enable quantitative estimations of past hydrological variability.

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ORAL
Session 4e.

EFFICIENT IDENTIFICATION OF CRYPTOTEPHRA IN MARINE SEDIMENT CORES; A NON-DESTRUCTIVE APPROACH

Jenni Hopkins[1], Madison Clarke[1], Janine Bidmead[1], Shaun Eaves[1], Jamie Howarth[1], Charlotte Pizer[1], Alan Orpin[2], Grace Frontin-Rollet[2], and Richard Wysoczanski[2]

[1] *School of Geography Environment and Earth Science, Wellington, New Zealand*
[2] *National Institute of Water and Atmospheric Research, Wellington, New Zealand.*

jenni.hopkins@vuw.ac.nz

Volcanic eruptions have punctuated New Zealand's geologic history for millions of years. Evidence of many of these eruptions occur as distal macroscopic (visible) tephra deposits found in deep marine sediment cores, often many hundreds of kilometres from source. As such, these macroscopic tephras likely provide evidence of only the largest eruptions, potentially introducing a preservation bias in the record. The recent development of cryptotephra (invisible tephra) identification, concentration, and quantification methods are allowing an increasingly detailed picture of volcanic activity to be uncovered.

Here we present a new method for identifying cryptotephra using non-destructive techniques (XRF, magnetic susceptibility, density). Data collected from down-core scans are modelled to quantitatively discriminate and characterise the macroscopic tephra then, unsupervised machine learning (e.g. Principle Component Analysis) and statistical techniques are used to identify potential cryptotephra within the dataset. New results generated during this period of method development have been applied to both targeted core sections, and full cores. Previously unidentified (crypto)tephra deposits have been isolated, characterised and used to further refine the code (developed in R statistical language) and unsupervised machine learning approach. With the addition of detailed chronology for the cores (through radiocarbon dating), we comment on the timing of the volcanic events identified, and the longevity of elevated tephra inputs (volcanic activity) into the marine sedimentary environment.

ORAL
Session 1a.

COMMUNICATING FINDINGS OF SOUTH DUNEDIN GEOLOGICAL DRILLING AND AQUIFER TESTING TO STAKEHOLDERS AND THE PUBLIC

Sharon Hornblow[1]

[1] *Natural Hazards, Otago Regional Council, Dunedin, New Zealand*

Sharon.hornblow@orc.govt.nz

In 2021 the Otago Regional Council (ORC) installed groundwater monitoring equipment and extracted geological core samples to develop understanding of the geology and hydrogeology beneath residential South Dunedin and reclaimed coastal parts of Dunedin city.

New piezometer installations brought the number of groundwater monitoring (level, temperature, and conductivity at 15-minute intervals) sites within the Dunedin CBD to 36, up from four in 2018. Existing bores had provided good data on the nature of the ground and water table below Dunedin, an important aspect of Dunedin's hazard-scape. The greater density of monitoring sites has improved the understanding of influence from tides and rainfall on shallow groundwater levels across the city (Cox et al., 2020). These findings are important for hydraulic modelling and infrastructural improvements, but also play a part in public understanding of the natural environment and exposure to climate change hazards. Core samples from each site, up to 60 m below MSL, have aided ongoing research into Dunedin's geology and past vertical land movements, and their implications for future relative sea level change, e.g., work by NZSeaRise and Glassey et al., (2021).

Communicating environmental change in the past, at different sea levels, and projecting what future higher sea levels could look like for the city is an important aspect of stakeholder communication, an ongoing process at events such as South Dunedin Future community hui. This stakeholder engagement on issues of the changing environment and flood protection needs of greater South Dunedin forms a key part of the Dynamic Adaptive Pathways approach to investigating possible climate change mitigation, and planning solutions.

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POSTER
Session 3b.

QUANTITATIVE LACUSTRINE PALEOSEISMOLOGY MAY REVEAL THE RUPTURE DIRECTION OF THE 1717 CE ALPINE FAULT EARTHQUAKE.

Jamie Howarth[1], Adelaine Moody[1], Sean Fitzsimons[2], Russ Van Dissen[3], Tim Little[1], Jesse Kearse[1] and Marcus Vandergoes[3]

[1] *School of Geography, Earth and Environmental Science, Te Herenga Waka/Victoria University of Wellington, Wellington, New Zealand*
[2] *School of Geography, University of Otago, Dunedin, New Zealand.*
[3] *GNS Science, Lower Hutt, New Zealand*

jamie.howarth@vuw.ac.nz

The spatial distribution of earthquake ground shaking is controlled by the location, magnitude and rupture direction of an earthquake. Paleoseismic investigation can provide invaluable information on the location and magnitude of prehistoric large earthquakes but reconstruction of rupture direction has proved challenging. Recent work comparing the spatial distribution of ground motions to turbidite emplacement associated with the 2016 M_w7.8 Kaikōura earthquake has shown that turbidite paleoseismology may provide a tool for reconstructing rupture direction (Howarth et al., 2021). Here we use a network of seven lakes throughout the northern South Island of New Zealand to constrain the spatial distribution of ground motions and rupture direction of the most recent M_w>8.0 earthquake on the Alpine Fault that occurred in ~1717 CE. Precise chronologies developed from a combination of ^{210}Pb, biostratigraphic and ^{14}C dating were used to identify the sedimentary signatures (ranging from in-situ deformation structures to deposits resulting from subaqueous mass-wasting, and earthquake-related processes in the lake catchments) of historic earthquakes in the lakes to constrain the relationship between ground motions and the observed earthquake signatures. These calibrations were used to reconstruct the spatial distribution of ground motions associated with the 1717 CE Alpine Fault earthquake by identifying deposits formed by this earthquake using the precise chronologies and assigning ground motions based on the type of sedimentary signature associated with the earthquake. Preliminary comparison of the reconstructed spatial distribution of ground motions and physics-based ground motion simulations that account for rupture direction show that the 1717 CE rupture most likely had a south to north rupture direction. Ongoing work aims to establish whether the Alpine Fault has a preferential rupture direction by examining the shaking distributions of preceding earthquakes. Our work shows the potential of lacustrine paleoseismology for reconstructing the location, magnitude and now rupture direction of past earthquakes.

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ORAL
Session 2a.

TOWARDS AN AUTOMATED WORKFLOW FOR THE CREATION OF 3D MODELS OF FAULT NETWORKS

Andy Howell[1,2], Tim McLennan[3], Laura King[3], David Wojtas[3], Andy Nicol[1], Hannu Seebeck[2] and Russ Van Dissen[2]

[1]School of Earth and Environment, University of Canterbury, Private Bag 4800, Christchurch, New Zealand
[2]GNS Science, PO Box 30-368, Lower Hutt, New Zealand
[3]Seequent Ltd, Christchurch, New Zealand

a.howell@gns.cri.nz

Fault geometry and the connectivity between faults at depth are both important controls on earthquake behaviour, so modelling these parameters accurately is essential to models of the earthquake cycle. However, the effects of uncertainties in fault geometry and connectivity are often not fully explored, partly because using current techniques building a fault model is difficult and time consuming. For example, the current 3D Community Fault Model — which results from several hundred person hours of work — represents only one of many hypothetical fault networks that would be consistent with available constraints.

We present a preliminary automated workflow for the creation of 3D models of New Zealand's faults, using python and the mesh-cutting capabilities of Leapfrog Software. This workflow creates a 3D fault model from: (1) GIS fault traces; (2) dip estimates; and (3) a text file containing information on which faults are thought to terminate against each other. Our approach is faster, more internally consistent and much less labour intensive than previous (mainly manual) methods of fault model creation; it will allow a thorough exploration of the sensitivity of models to fault geometry and will therefore be of use in several diverse areas of earthquake science.

POSTER
Session 4a.

VEIN TEXTURES AND GEOCHEMISTRY OF THE WHAREKIRAUPONGA (WKP) EPITHERMAL AU-AG DEPOSIT, HAURAKI GOLDFIELD, COROMANDEL

Samuel Hudson[1], Dr. Julie Rowland[1], Dr. Michael Rowe[1], Thomas Gardner[2], & Lorrance Torckler[2]

[1]*School of Environment, The University of Auckland, Auckland, New Zealand*
[2]*OceanaGold Limited, Waihi, New Zealand.*

Shud878@aucklanduni.ac.nz

Epithermal Au-Ag deposits are a significant host of gold, with 17% of all known gold resources contained in these systems (Frimmell, 2008). One such deposit is the Wharekirauponga (WKP) low sulfidation deposit, located in the Hauraki Goldfield within the Coromandel Volcanic Zone. Originally prospected in the late 1800s before being abandoned, modern exploration has discovered three large subsurface mineralised structures (Masangcay, 2017). The most significant of these, the East Graben (EG) vein system, has shown significant gold intercepts, including one at 22.8 g/t over a 48.9 m interval (OceanaGold, 2021). A distinct anomaly identified in this structure is the presence of highly varied vein textures between the hanging wall and footwall (Masangcay, 2017). The hanging wall of this system is comprised primarily of veins hosting crustiform-colloform and lattice quartz textures, transitioning into veins dominated by sulfide hosted quartz breccias on the footwall side of the system.

This study aims to understand geochemical variations across this EG vein system, focusing specifically on the distinctly varied vein textures located across the footwall and hanging wall sides of this system. Deposit scale mapping of geochemical data and vein textures in the systems using Leapfrog Geo and ioGAS shows clear variations in alteration products, elemental concentrations, and vein textures associated with the EG system. Analysis indicates the presence of a large adularia enriched alteration halo, where most altered rocks have experienced a penetrative wash of sulfide enrichment. Further microscale work investigating the geochemistry, including petrographic, EPMA, and SEM analysis of altered rocks associated with different vein textures will aid in developing a model regarding the genesis of this mineralizing system. Additionally, fluid inclusion analysis will aid in constraining a model of mineralisation for the EG system, by providing indications as to the pressures, temperatures, and salinities of fluids involved.

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POSTER
Session 4f.

SO_2 EMISSIONS FROM EXPLOSIVE BASALTIC ERUPTIONS AT OKATAINA

Ery Hughes[1], **Geoff Kilgour**[1], **and Jon Blundy**[2]

[1] *Volcanology Team, Te Pū Ao | GNS Science, Aotearoa New Zealand*
[2] *Department of Earth Sciences, University of Oxford, UK*

e.hughes@gns.cri.nz

Volcanic SO_2 emissions can lead to global impacts on climate and health, depending on the magnitude and injection height into the atmosphere. Global impacts are caused by the conversion of SO_2 into sulphate aerosols, which can lead to significant solar screening for weeks to months after an eruption. The effects of basaltic volcanism are typically associated with long-lived fissure eruptions, which have local to global impacts (e.g., Kīlauea 2018, Laki 1783–1784, flood basalts). However, short-lived explosive basaltic volcanism can also inject significant SO_2 into the upper atmosphere affecting the local (and potentially even global) climate, environment, and health outcomes (e.g., Ambae 2018–2019, Sunset Crater 1085 CE). The Okataina Volcanic Centre (OVC) is the source of voluminous rhyolitic volcanism but also explosive basaltic eruptions. In this work, we focus on the SO_2 released from these basaltic explosive eruptions using the petrologic method.

We quantify the minimum SO_2 released from OVC basalts (Okareka 23.5 ka, Rotokawau 3.4 ka, Kaharoa 0.6 ka, and Tarawera 1886 CE) by combining sulfur concentrations in melt inclusions[1,2] (2000–3500 ppm S_T) with erupted volumes derived from existing isopach maps[3–6]. The basaltic Plinian eruption of Tarawera released ~5 Tg SO_2 over ~5 hours; the smaller eruption of Rotokawau potentially released ~7 Tg SO_2 over a much longer time period; and Okareka and Kaharoa released much less SO_2 due to their small erupted volumes (for comparison, Krakatau 1883 CE released 5.6 Tg SO_2). Rotokawau likely had significant local impacts due to the large SO_2 release and low plume heights (5–7 km[4]). The significant SO_2 emissions from Tarawera, combined with the high injection heights (~28 km[7]), supports recent work showing southern hemisphere cooling 1–2 years after the eruption[8,9]. This highlights the potential impacts of eruptions of these sulphur-rich magmas from the OVC.

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ORAL
Session 1a.

USING A MULTI-VOLATILE THERMODYNAMIC MODEL TO UNDERSTAND THE EFFECTS OF SULPHUR ON SILICATE MAGMAS

Ery Hughes[1,2], **Lee Saper**[2,3], **Philippa Liggins**[4] **and Edward Stolper**[2]

[1] *Volcanology Team, Te Pū Ao | GNS Science, Aotearoa New Zealand*
[2] *Division of Geological and Planetary Sciences, Caltech, California USA*
[3] *School of GeoSciences, University of Edinburgh, UK*
[4] *Department of Earth Sciences, University of Cambridge, UK*

e.hughes@gns.cri.nz

Basaltic magmas in the Okataina Volcanic Centre (OVC) are sulphur rich, containing 2000–3500 ppm S. More generally, sulphur is the third most abundant volatile element in silicate magmas after hydrogen and carbon. It is present in several phases (e.g., silicate melt, vapor, FeS-rich melt, solid and liquid sulfates) and multiple species and oxidation states in silicate melt (e.g., S^{2-} and SO_4^{2-}) and vapor (e.g., S_2, SO_2, H_2S, and OCS). Despite the resulting complex behavior of sulfur in magmatic systems with changing intensive variables (e.g., temperature, pressure, and oxygen fugacity), there has been considerable progress recently in the development of thermodynamic models of these systems that provide a framework for understanding these complexities.

We present a multi-volatile (COHS) thermodynamic model of silicate melt ± vapor ± sulphide melt ± anhydrite to understand how sulphur behaves in basaltic magmas in the crust. We use this model to understand the cause of the sulphur solubility minimum and maximum in silicate melts that have been observed experimentally. The sulphur solubility minimum can have important consequences, including that calculations of the pressure of vapor-saturation using the volatile concentration measured in glass melt inclusions and submarine glasses require the inclusion of S along with H_2O and CO_2. Otherwise, these calculations can significantly underestimate the actual entrapment or eruption pressure, especially for relatively oxidised systems such as arc and hotspot magmas. The sulphur solubility maximum for silicate melts (± vapor) coexisting with sulfide liquid and anhydrite can be used to set limits of magmatic f_{O2} and on the sulphur-carrying capacity of a silicate magma. The latter is important during mantle melting, ore deposit formation, and SO_2 emissions during explosive volcanism. We also explore how sulphur degassing influences oxygen fugacity during depressurization, and in particular that the sign of the effect changes at the sulfur solubility minimum.

POSTER
Session 1b.

STRATIGRAPHY AND AGE OF VOLCANO-FLUVIAL AND TEPHRA DEPOSITS ASSOCIATED WITH TE PUNINGA FAULT, MORRINSVILLE, HAURAKI BASIN

Joshua W. Hughes[1], David J. Lowe[1], Pilar Villamor[2], Vicki G. Moon[1], Kate J. Clark[2], Philippa Morris[2], George R. McQuillan[1], Alicia Medialdea[3], Genevieve Coffey[2], Kelvin Berryman[4], Robert Langridge[2], Alan G. Hogg[1], Brent V. Alloway[5], Yaasameen Shalla[6], Olivia Mark[6]

[1]*School of Science/Te Aka Mātuatua, University of Waikato, Hamilton, New Zealand*
[2]*GNS Science, Lower Hutt, New Zealand*
[3]*National Research Centre on Human Evolution (CENIEH), Burgos, Spain*
[4]*Berryman Research and Consulting, 18 Cluny Road, Plimmerton, Porirua 5026, New Zealand*
[5]*Geohazard Assessment Services, Auckland, New Zealand*
[6]*School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand*

jh354@students.waikato.ac.nz

The newly-recognised Te Puninga Fault has the potential to produce earthquakes of magnitude Mw 6.7, and hence poses a hazard to the adjacent community of Morrinsville and surrounding region[1]. To study the fault's paleoseismic history, two trenches (named Arnold and Rylands) were excavated across two traces in February 2021 as part of a joint EQC/Marsden-funded project led by GNS Science with support from Waikato University. Two main lithologic units were exposed: the lower comprises volcano-fluvial sediments of the Hinuera Formation (HFm) (mainly bedded sands with occasional peaty lenses) deposited by the ancestral Waikato River, and the upper comprises a composite mantle of post-Hinuera tephra deposits ~0.7 m in thickness, the basal tephra possibly being 23.5-cal-ka Okareka tephra. In both trenches, the scarp was sufficiently high (~4 m) for different soils to form as a result of varying ground-water conditions upon represented lithologies across the fault scarp: Gley Soils are associated with lower HFm deposits, whereas Allophanic Soils[2] are prevalent within upper HFm deposits capped by tephras. Radiocarbon (^{14}C) dating and tephrochronology were used to determine a chronology of the deposits (OSL sampling was also undertaken: results pending). A laterally-continuous peat lens, including leaf material, in the lowermost part of HFm within Arnolds trench yielded ^{14}C-ages ranging from 23.5 to 24.9 cal ka, consistent with HFm deposition by the Waikato River prior to its avulsion at Piarere[3] into Hamilton Basin after ~23.5 cal ka. Within lowermost Rylands trench, another peat layer was dated at 11.5 cal ka, suggesting ~1.5 m of post-Hinuera alluvium had been deposited at this site – most likely from nearby Piako River. Two visible tephra layers, represented by laterally discontinuous pumiceous lapilli and fine ash lenses occurring close to the ground surface were identified as Taupo (AD 232 ± 10) and Kaharoa (AD 1314 ± 12) tephras, respectively.

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POSTER
Session 2a.

RECONSTRUCTING LANDSLIDE-GENERATED LACUSTRINE TSUNAMI RESULTING FROM MAJOR ALPINE FAULT EARTHQUAKES

Katie E. Hughes[1], Jamie Howarth [1] and Sean Fitzsimons[2]

[1] *School of Geography, Earth and Environmental Science, Te Herenga Waka - Victoria University of Wellington, Wellington, New Zealand*
[2] *School of Geography, University of Otago, Dunedin, New Zealand.*

katie.hughes@vuw.ac.nz

New research indicates there is a 75% probability of a rupture on the Central Section of the Alpine Fault within the next 50 years**,** with an 82% probability the earthquake exceeds magnitude 8. These new finds emphasize the critical need to understand the secondary hazards associated with the major Alpine Fault rupture expected within our lifetime. The secondary hazard of co-seismic subaerial and subaqueous landslides poses a significant hazard as they can generate tsunamis with wave heights exceeding 100 m (Lituya Bay Alaska, 1958; Lake Geneva Switzerland, South-central Chile, 1960; Lake Lucerne Switzerland, 1601). Despite the speculated susceptibility of South Island lakes to Alpine Fault triggered lacustrine tsunamis, the past occurrence of and future susceptibility to this hazard remains unquantified.

This research addresses this knowledge gap through reconstructing tsunamigenic failures associated with the 1717 CE, $M_w > 8.1$ Alpine Fault earthquake for three lakes that exhibit different physiography and intensities of ground motion during this earthquake (Lake Rotoiti, Lake Brunner, Lake Wānaka). Multibeam sonar and geophysical instrumentation will be used to map the lakebed and subsurface in high resolution for sedimentological and geomorphological interpretation of mass-wasting deposits. Sediment coring will enable high-resolution chronology to be produced allowing direct links between tsunamigenic mass-wasting and the 1717 CE Alpine Fault earthquake to be established for the first time. The sediment record and characteristics of the deposits will inform models of the resultant wave propagation and inundation. This research marks a novel development in the quantitative understanding of the response of South Island lakes to major Alpine Fault earthquakes and furthers the field of study of this hazard in lacustrine environments.

POSTER
Session 2a.

ASSESSING TSUNAMI HAZARD IN NEW ZEALAND USING A LONG TIME SCALE SYNTHETIC EARTHQUAKE CATALOGUE

Laura Hughes[1], Martha Savage[1], Richard Arnold[1], William Power[2], Emily Lane[3], Andy Howell[2,4], Bruce Shaw[5], Bill Fry[2]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand*
[2] *GNS Science, Lower Hutt, New Zealand*
[3] *National Institute of Water and Atmospheric Research (NIWA), Christchurch, New Zealand*
[4] *University of Canterbury, Christchurch, New Zealand*
[5] *Lamont Doherty Earth Observatory, Columbia University, Palisades NY 10964*

laura.hughes@vuw.ac.nz

A tsunami with devastating, wide-reaching consequences affecting New Zealand is a significant hazard that needs to be analyzed and quantified. The Puysegur Subduction Zone to the south, the Hikurangi Margin to the east, and the Tonga-Kermadec Subduction Zone to the north, all have the potential to generate catastrophic tsunamis, like those that were observed in Sumatra–Andaman in 2004 and Japan in 2011. Additionally, there are numerous crustal faults that have tsunamigenic potential. Previous tsunami hazard studies have begun to examine this infrequent but potentially deadly hazard, using models of past tsunamis, as well as possible future events assuming the estimated magnitude ranges of the faults concerned. Here, we use a 10,000-year subset of a one-million-year synthetic earthquake catalogue created using RSQSim (Rate and State Earthquake Simulator). From the RSQSim output, earthquake deformation models were produced and fed into COMCOT (Cornell Multi-grid Coupled Tsunami model) to model the resulting tsunamis. Preliminary results, excluding the Tonga-Kermadec Subduction Zone, allow us to begin to assess the local and regional tsunami hazard to the coast for the whole of New Zealand, regional councils, and forecast warning zones. Wave height distributions and the return period of maximum wave heights were initially investigated. These preliminary results show that, in the Hawke's Bay and Wellington regions, maximum wave heights of ~20m and ~30m, respectively, were observed and for 2,500-year return periods wave heights of ~8m and ~13m, respectively, were observed. In addition, due to the vast number of earthquakes in the overall synthetic earthquake catalogue, it is not possible to run tsunami simulations for every earthquake. Instead of using traditional location/magnitude metrics to determine earthquakes to run tsunami models for, we use the earthquake's tsunami energy. We model earthquakes which have a tsunami energy greater than 1×10^{10}J, as all these events contribute significantly to the hazard.

ORAL
Session 2a.

BIROC-H20: A NEW WAY TO PROCESS FTIR SPECTRA OF OLIVINE HOSTED BASALTIC MELT INCLUSIONS

David Huijser[1], Elaine Smid[2], Michael Rowe[2] and Jan M Lindsay[2]

[1] *Department of Statistics, The University of Auckland, Auckland, New Zealand*
[2] *School of Environment, The University of Auckland, Auckland, New Zealand*

d.huijser@auckland.ac.nz

Fourier Transform Infrared Spectrometry (FTIR) analysis is a popular technique used to estimate pre-eruptive H_2O and CO_2 concentrations in mineral-hosted pockets of silicate melts (melt inclusions and embayments; MI and ME, respectively). As technology and volcanological knowledge advances, there is an increasing interest in using high-resolution FTIR techniques to assess volatile heterogeneity within silicate glasses. However, many challenges exist when processing large amounts of spectral data, and these currently cannot be resolved using existing software. To address these issues, we are creating a new, open-access Python software package, BIROC-H2O (basaltic IR analysis of carbon dioxide and water in host olivine), designed to batch-process high-resolution spectral 2D FTIR map files collected on olivine-hosted, basaltic MI and ME. The software is currently being tested using data collected from samples from the Auckland Volcanic Field, New Zealand, analysed on the infrared (IR) beamline at the Australian Synchrotron.

BIROC-H2O requires simple inputs: 1) the raw spectral data file, 2) additional details (map dimensions and errors), 3) major element chemistry of the olivine host and glass, 4) average thickness (optional). Some of the novel features that this code offers are the ability to batch process a large number of spectra in a consistent manner; thickness calculations from interference fringes and their subsequent removal from the spectra, and an automated olivine contamination correction method. The software provides users with several output files: a table summarising the results from each spectral analysis point; 'heat maps' of H2O concentrations, CO2 concentrations, and thicknesses across the sample; and a robust estimation of errors on these values. Preliminary results are promising and indicate that this new code will allow for easier, more robust processing of olivine hosted basaltic glass FTIR spectra.

ORAL
Session 4a.

EARTHQUAKE TIMINGS AND FAULT INTERACTIONS IN CENTRAL NEW ZEALAND

Jade Humphrey[1], **Andy Nicol**[1], **Andy Howell**[1,2], **Nicola Litchfield**[2], **Russ Van Dissen**[2], **Rob Langridge**[2]

[1] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*
[2] *GNS Science, Lower Hutt, New Zealand.*

jade.humphrey@pg.canterbury.ac.nz

Forecasting the probability and magnitude of future large earthquakes on active faults is typically dependent on information collected from paleoearthquakes. These paleorecords are often incomplete and timing of earthquakes are imprecisely dated, which impacts our ability to estimate their slip and recurrence intervals. Historical events demonstrate that many large earthquakes rupture multiple faults with complex rupture patterns.

To improve understanding of the importance and controlling factors of multi-fault earthquakes, we compare the timing of earthquakes between active faults in central New Zealand. We use a compilation of more than 150 existing radiocarbon dates recalibrated using OxCal (Bronk Ramsey, 2007) to determine the timing of earthquakes on faults within the region. We use Bayesian statistics to test and quantify the probability of earthquake synchroneity between different faults and segments of the same fault.

The refined data provides improvements for the timing of paleoearthquakes for the faults studied. These new ages indicate that in some cases, the timings of surface-rupturing earthquakes differ between faults. In other cases, inferred paleoearthquakes on different faults are approximately the same age, suggesting interactions across fault systems. These “synchronous” earthquakes occurred during time windows of up to 150 years, with the most striking event recorded on the Wellington, Wairarapa and subduction thrust faults at approximately 700-850 cal. yrs BP. The apparent synchroneity of earthquakes could indicate the occurrence of large multi-fault ruptures and/or earthquake clusters, both of which may suggest stress transfer and interactions between faults on timescales of seconds to hundreds of years. These fault interactions have important implications for seismic hazard in central New Zealand and will be used to inform physics-based earthquake modelling.

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ORAL
Session 2a.

THE VERSATILITY OF LOW-COST, LIGHTWEIGHT, RASPBERRY PI-BASED TOOLS FOR VOLCANO MONITORING

Tehnuka Ilanko[1], Tom D. Pering[2], Thomas Wilkes[2], Andrew McGonigle[2,3,4], Alejandro Díaz Moreno[5], Silvio De Angelis[6], and Armando Pineda[7]

[1] School of Science, University of Waikato, Hamilton, New Zealand
[2] Department of Geography, The University of Sheffield, United Kingdom
[3] School of Geosciences, The University of Sydney, Australia
[4]Faculty of Health, Engineering, and Sciences, University of Southern Queensland, Australia
[5]Reynolds International Ltd., Broncoed Business Park, Wrexham Road, Mold, United Kingdom
[6]Earth, Ocean, and Ecological Sciences, University of Liverpool, United Kingdom
[7]Pineda Consulting and Services, Finca Xejuyu, Chimaltenango, Guatemala

tehnuka.ilanko@waikato.ac.nz

Over the past decade, ultraviolet (UV) cameras have become a widely used tool for campaign-style measurements of volcanic sulphur dioxide (SO_2) emissions, which in turn are valuable for understanding and forecasting volcanic activity. Recently developed UV cameras (PiCams) based on Raspberry Pi computers and smartphone sensors (Wilkes et al. 2016, 2017) offer additional versatility thanks to their low cost, low power requirements, and portability. Here, we discuss the value of such camera deployments using examples from the field.

This includes using multiple PiCams, including those with solar recharge capability, to better understand plume dynamics and more accurate quantify SO_2 fluxes. The cameras can also be used in conjunction with other portable, low power, instrumentation such as Raspberry Shake & Boom seismic and infrasound sensors to develop a more complete model of eruption dynamics in a combined low-cost approach to volcano monitoring.

We discuss fieldwork case studies from Sabancaya, Peru (Ilanko et al. 2019); Yasur, Vanuatu (Ilanko et al. 2020); and Pacaya, Guatemala, to demonstrate how field configurations and modelling procedures can be adapted according to environmental conditions, availability of wind velocity data, access, and distance to plume, to obtain information on SO_2 emissions, plume speeds, and eruption dynamics. In addition to being a practical tool for field campaigns, therefore, UV cameras such as the PiCam present a strong option for permanent volcano monitoring installations.

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ORAL
Session 4b.

REOCCURRING EARTHQUAKE SWARMS REVEAL THE DEEP ROOTS OF THE HIPAUA-WAIHĪ-TOKAANU GEOTHERMAL SYSTEM

Finnigan Illsley-Kemp[1], Olivia Pita-Sllim[1], Calum J. Chamberlain[1], Simon J. Barker[1], Colin J.N. Wilson[1], Martha K. Savage[1]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, New Zealand*

finnigan.illsleykemp@vuw.ac.nz

Through detailed earthquake detection, location, and waveform analysis of a decade of seismic activity, we image the deep fluid pathways that feed the Hipaua-Waihī-Tokaanu geothermal field (HWT). The HWT is located at the southern end of Lake Taupō, on the northeastern slopes of the extinct andesite volcano Kākaramea. Resistivity surveys indicate an extensive geothermal system, which is expressed at the surface in hot springs, fumaroles, and the Hipaua steaming cliffs (Severne, 1999; Risk et al., 2002). Geochemistry studies suggest that the geothermal fluids are sourced from deep beneath Kākaramea, and the locations of the surface expressions suggest an interaction between the fluids and regional faults (Severne, 1999). The locations of Reoccurring earthquake swarms imply that fluids are migrating from at least 7 km depth, potentially from a deeper magmatic source, although surface volcanism at Kākaramea ceased around 220 ka (Stipp, 1968). The **SPATIAL ELONGATION, MAGNITUDE DISTRIBUTION,** and temporal evolution of the earthquake swarms suggest **THEY ARE CAUSED BY FLUID MIGRATION, RATHER THAN FAULT-SLIP OR MAGMATIC INTRUSION. WE SUGGEST THAT T**hese fluids migrate along zones of high permeability caused by intersecting fault planes. Our results give insights into the origin of the HWT geothermal field and the physical mechanisms behind geothermal seismicity. These swarms are highly likely to **REOCCUR** in the future and further work is needed to constrain the seismic and consequent landslide hazards they pose to communities at the southern end of Lake Taupō.

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POSTER
Session 1a.

SILICA SECRETING ORGANISMS REGULATE CLIMATE ON EARTH

<u>Terry Isson</u>

University Of Waikato

tisson@waikato.ac.nz

The coupled cycling of carbon and silica regulates climate on Earth. In particular, we propose that baseline CO_2 levels on Earth are determined by the balance of silicate weathering (a CO_2 sink) and reverse weathering (a CO_2 source). Here, we present a 3 billion year record of Li isotopes as recorded in marine carbonates, that supports the view that silica secreting organisms play a critical role in regulating rates of reverse weathering on Earth. This refined view of the carbon-silica cycle highlights that the ecological success of siliceous organisms exerts a potentially significant influence on Earth's climate regime. This promotes the need to better quantify the synergistic effects of environmental change (warming, deoxygenation and acidification) on siliceous organisms and vice versa, so as to develop a more complete understanding of how marine ecosystems respond to and shape hyperthermal events—such as the one we are currently navigating.

ORAL
Session 4e.

USING SEISMIC AMBIENT NOISE TO UNDERSTAND RUAPEHU CRATER LAKE HEATING CYCLES

Katie Jacobs[1]

[1] *GNS Science, Lower Hutt, New Zealand*

k.jacobs@gns.cri.nz

Heating of Ruapehu crater lake has been observed for decades, with crater lake temperature measurements available as early as 1950, and regular hourly temperature data available from April 2009. The lake temperature varies over periods of months and since 2009, temperatures at the peaks of these cycles are regularly between 30 and 45 degrees C.

A previous study by Mordret et al (2010) analyzed ambient noise velocity and decorrelation over several months around both the 2006 and 2007 phreatic eruptions. They showed very small changes in both velocity and decorrelation value for the 2006 but not the 2007 eruption. In this study we compare some of recent heating cycles from the last two years to ambient noise velocity and decorrelations (measure of similarity between a reference stack and a shorter moving stack of 10 days) at local seismic stations. During 2020 autocorrelations for station FWVZ, one of the stations on the flanks of Ruapehu used by Mordret, shows a significant negative correlation between the ambient noise decorrelation values and peaks in the lake temperature data. Relatively velocity changes are not seen at these times indicating, as previous studies have suggested, that decorrelation values may be more sensitive to variations in noise source and local heterogenous changes. Although tremor sometimes accompany the heating cycles average daily RSAM measurements over the same frequencies (.1-1 hz) have no significant correlation to the lake temperature data.

Changes in lake temperature alone are unlikely to affect the correlation values and detectable mechanical properties, thus these decorrelations during higher recorded lake temperatures may be imaging a physical mechanism driving or accompanying the heating cycles. Classifying and understanding the relationships between heating and decorrelation may be able to inform future monitoring efforts in identifying whether increased lake temperatures represent typical heating cycle or more drastic changes.

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POSTER
Session 1a.

INTERACTION BETWEEN VORTICES AND SETTLING-DRIVEN GRAVITATIONAL INSTABILITIES AT THE BASE OF VOLCANIC CLOUDS

Paul A. Jarvis[1], Allan Fries[1], Jonathan Lemus[1], Costanza Bonadonna[1], Amanda Clarke[2], Jeremy Phillips[3] and Irene Manzella[4]

[1] *Department of Earth Sciences, University of Geneva, Geneva, Switzerland*
[2] *School of Earth and Space Exploration, Arizona State University, Tempe, Arizona, USA*
[3] *School of Earth Sciences, University of Bristol, Bristol, UK*
[4] *School of Geography, Earth and Environmental Sciences, University of Plymouth, Plymouth, UK*

paul.jarvis@unige.ch

Ash sedimentation from volcanic clouds often occurs through downward-propagating columns, called fingers, which have velocities exceeding the terminal settling velocities of fine ash, e.g., Ruapehu 1996, New Zealand; Eyjafjallajökull 2010, Iceland. Subsequently, fine ash sediments closer to the vent than would otherwise be expected, impacting both deposit interpretations and dispersal forecasts. Whilst previous studies have shown that ash fingers can form from a settling-driven gravitational instability (SDGI), these investigations typically consider simplified scenarios where there is no ambient motion. Here, we extend these studies by using analogue experiments to consider the effect of volcanic cloud spreading on the formation and evolution of ash fingers.

In our experiments, a turbulent suspension of glass beads in fresh water (the analogue volcanic cloud) spreads as a gravity current over a denser, sugar solution (the analogue atmosphere). By varying the particle volume fraction in the suspension, we control the density difference between the current and the ambient and, consequently, the spreading rate. At low spreading rates, fingers resulting from the SDGI are observed to form with a wavelength on the order of centimeters, comparable to those observed in static experiments and simulations. Conversely, at high spreading rates, turbulent vortices, generated by the Kelvin-Helmholtz instability (KHI) and with a wavelength of 10s of centimeters, occur at the current base and are sufficiently strong to re-entrain particles into the current, inhibiting sedimentation. However, at intermediate spreading rates, the SDGI fingers become modulated by the Kelvin-Helmholtz vortices to generate larger, downwelling plumes at the Kelvin-Helmholtz wavelength.

Our results suggest that shear at the base of volcanic clouds can increase the wavelength of fingers by an order of magnitude. Since the downward velocity of fingers depends on their size, this therefore needs to be taken into account when developing parameterisations of the effect of SDGIs on ash dispersal.

POSTER
Session 1a.

NEW ZEALAND NATIONAL LIDAR AND REGIONAL APPLICATIONS

Bjorn Johns[1] **and Murry Cave**[2]

[1] *Toitū Te Whenua Land Information New Zealand, Wellington, New Zealand*
[2] *Gisborne District Council, Gisborne, New Zealand.*

bjohns@linz.govt.nz

Airborne lidar data will be available for 80% of New Zealand by 2024. The Toitū Te Whenua Land Information New Zealand (LINZ) National Elevation Programme is working with councils in this ambitious endeavour that is resulting in new lidar datasets from across most of New Zealand over the next few years. The data is made available in a consistent format and under open license (data.linz.govt.nz), and it includes a large amount of coverage of unpopulated terrain where lidar has not been captured before. It is of value to the geosciences in its ability to accurately map the land in three dimensions leading to change detection, geomorphological mapping, identification of natural hazards, etc. The Elevation Aotearoa (elevationaotearoa.co.nz) initiative complements the data and provides user guides, examples, and other information to facilitate uptake and highlight use cases.

The Gisborne/Tairawhiti District was one of the first to achieve full coverage and the data is in active use. Geoscience applications underway include differencing of the Waipaoa River, gravel fluxes in the Waiapu, urban landslide mapping, enhanced land use capability mapping and active fault mapping.

ORAL
Session 4b.

THE HISTORY OF EARTHQUAKE AND TSUNAMI MONITORING ON RĒKOHU-WHAREKAURI-CHATHAM ISLANDS FROM 1932 TO 2021

David Johnston [1] **and Ken Gledhill** [2]

[1] *School of Psychology, Massey University, Wellington, New Zealand*
[2] *GNS Science, Lower Hutt, New Zealand.*

d.m.johnston@massey.ac.nz

Earthquake monitoring on Rēkohu-Wharekauri-Chatham Islands dates from the early 1930s, with the installation of the first seismograph in 1932 and running until 1941. In December 1966 the station was re-established, running until April 1994. It was again re-established as part of the new GeoNet Programme in December 2007. An enhanced network, including GPS continues to operate from number of locations on the island. As part of the Pacific Tsunami Warning Center (PTWC) a Tsunami Sea Level Monitoring was first installed in Waitangi in November 1989 and moved to Owenga Wharf in December 2007. An education "seismometers in schools" programme has been running since 2018, with new equipment installed in Te One and Kaingaroa Schools in 2021. Further developments and upgrades are planned across the entire network.

POSTER
Session 2a.

MAPPING STRESS DROP VARIATIONS ALONG THE ALPINE FAULT TO INVESTIGATE CONDITIONAL RUPTURE SEGMENTATION

Ilma del Carmen Juarez-Garfias[1], Emily Warren-Smith[2], John Townend[1] and Rachel Abercrombie[3]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington*
[2] *GNS Science*
[3] *Department of Earth and Environment, Boston University*

Ilmadelcarmen.juarezgarfias@vuw.ac.nz

The Alpine Fault (AF) is an active transform fault that is late in its cycle of large earthquakes. Paleoseismic results reveal that places along the fault, which coincide with along-strike changes in geometry, kinematics and slip rates, act as conditional barriers to rupture. The geometry, seismicity rates and geology of the AF differ between three segments; North Westland (NW), Central (C) and South Westland (SW) but it is unclear whether earthquake source properties also vary between those segments.

We use an Empirical Green's Function (EGF) approach to calculate stress drops of moderate-magnitude (M_L2-4.4) earthquakes occurring on or near the AF. We use data from the permanent GeoNet network and temporary networks including the Dense Westland Arrays Researching Fault Segmentation (DWARFS) network installed in early 2019.

We make separate P- and S-wave measurements of stress drop for 95 earthquakes occurring within 5 km of the AF. The stress drops range between 1 and 352 MPa and show good agreement with stress drops measured in studies elsewhere in New Zealand and worldwide. We see no dependence of stress drop values on depth, magnitude or focal mechanism, but do see variation in average stress drop values along strike. We obtain median values of 8 and 9 MPa for P- and S-waves, respectively, for the SW/C segment boundary zone; of 17 and 39 MPa for the C segment; and of 15 and 19 MPa for the NW/C segment boundary zone. We observe no systematic differences in stress drop along either the NW or C segments, but median values are slightly higher than those of the SW segment. This may indicate that the differences in fault geometry, slip, and seismicity of the SW segment may have a bigger effect on stress drops there than for other segments, or that the SW segment is weaker overall.

POSTER
Session 2a.

RAPID CHARACTERISATION OF EARTHQUAKES & TSUNAMI (R-CET PROGRAMME) – THE LOCAL EARTHQUAKE CHALLENGE

Anna Kaiser[1], Bill Fry[1], Yannik Behr[1], Elisabetta D'Anastasio[1], Emily Warren-Smith[1], Calum Chamberlain[2], Nick Horspool[1], Chris Zweck[1], Paul Teal[2]

[1] *GNS Science, Lower Hutt, New Zealand.*
[2] *Victoria University of Wellington, New Zealand*

a.kaiser@gns.cri.nz

The recently launched R-CET Endeavour programme aims to advance and test modern methods to rapidly characterise earthquakes and tsunami and provide critical early information for earthquake response. R-CET's three working groups focus on (i) local earthquakes, (ii) SW Pacific and Kermadec earthquakes, and (iii) science to practice and community engagement. Here, we present an overview of early research underway in the Local Earthquake Group.

Rapid characterisation of local earthquakes is necessary not just to understand how the ground has ruptured, but to provide rapid robust forecasts of an earthquake's likely impacts, e.g. tsunami, shaking, loss/damage, ground deformation, landslides, liquefaction and aftershock distribution/likelihood. Over the last decade of large earthquakes to impact New Zealand, robust 3D or '4D' models of the earthquake have typically taken days to weeks to develop, such that the initial response relies on a 'point source' model (epicentre and magnitude; see figure). The increasing availability and density of real-time seismic and geodetic (GNSS) data from the GeoNet network have opened up new possibilities to apply modern characterisation algorithms, including machine learning, in near real-time.

Our first critical steps are the determination of a rapid earthquake centroid, magnitude (Mww) and finite fault extent. We have begun testing the FinDer software, showing that applied to the Darfield earthquake, the method can identify fault orientation and rupture direction/extent within 90 seconds of the earthquake's first strong motion record. We are also prototyping real time processing of GNSS data and testing the ability of G-FAST algorithms to generate rapid finite fault estimates using an extensive NZ synthetic earthquake catalogue developed under the Resilience Science Challenge. Research is also underway to advance the ability of template-matching algorithms to identify and map aftershocks in near real-time. These methods coupled with results from w-phase inversion provide a theoretic pathway to generate first rapid finite fault models and robust shakemaps for large New Zealand earthquakes.

ORAL
Session 2a.

FACTORS AFFECTING THE FATE OF ERIONITE IN SOIL

Ranjana Kaith[1], Melanie Kah[1] and Martin Brook[2]

School of Environment, The University of Auckland, New Zealand.

rkai241@aucklanduni.ac.nz

Erionite is a naturally occurring fibrous zeolite mineral formed by hydrothermal alteration of silica-rich volcanic rocks, tuff and volcanic ash. International studies have linked human exposure to erionite with the occurrence of malignant mesothelioma, which is a form of lung cancer commonly associated with asbestos inhalation. Weathering and human activities such as construction and mining, have the potential to disturb naturally occurring Erionite bearing rocks, which can release mineral fibres into the air and may pose a risk of human exposure by inhalation.

Erionite was first identified in Durkee, Oregon, USA in 1898 and since then erionite has been detected in various other parts of the globe. Currently there is a lack of comprehensive studies on the occurrence, transportation, and weathering of erionite in soils (Farcas et al., 2017). This is a crucial knowledge gap and thus, opens up a large possibility of further research on the pathway of erionite from rock, into soil and air.

This study will compile our current knowledge about the occurrence of erionite in soil, along with influencing factors such as climatic conditions, weathering and geomorphology. A critical aspect to consider when working with erionite in soils is the sampling and analytical approaches. For instance, Fluidized Bed Asbestos Segregator (FBAS) is a sample preparation instrument utilised to quantify fibrous minerals present in soil. The detection limits achieved by FBAS are in the range of 0.002% to 0.005% by weight, which is up to 100 times lower than the detection limits achieved by other techniques. The analytical approach ideally typically combines Transmission Electron microscopy (TEM), Scanning electron Microscopy (SEM), Electron Dispersive Spectroscopy (EDS), Inductively Coupled Plasma mass spectrometry (ICP-MS), and X-Ray Diffraction (XRD).

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POSTER
Session 4e.

MODELLING THE PROBABILITY OF INUNDATION WITH BAYESIAN NETWORKS: A PILOT STUDY IN THE HAURAKI PLAINS

Liz Keller[1,2], Georgia Grant,[1] Annemarie Christophersen[1], Phil Mourot[3] and Lara Clarke[1]

[1] *GNS Science, Lower Hutt, New Zealand*
[2] *Antarctic Research Centre, Victoria University of Wellington, Wellington, New Zealand*
[3] *Waikato Regional Council, Hamilton, New Zealand.*

l.keller@gns.cri.nz

We describe a pilot study to develop and test the application of Bayesian Networks (BNs) to estimate current and future probability of coastal inundation due to climate change, focusing on issues faced by the Hauraki District in Waikato. BNs offer a complementary and efficient alternative to the use of multiple, computationally-intensive process-based models to assess the likelihood of inundation and/or flooding, with the added benefit of explicitly including uncertainties. This pilot study was stakeholder-driven and developed in consultation with the Waikato Regional Council, who identified the operation of the Kauaeranga Spillway as a significant risk in the region. The operation of the spillway requires closure of State Highway 25, restricting access to Thames and interrupting essential services. We present a prototype model describing the likelihood of the operation of the Kauaeranga Spillway, given the intensity and amount of rain received over the last 120 hours and ensuing river height and flow rate. The information derived from the model is intended to assist stakeholders in planning infrastructure development and maintenance, earlier warning systems and better communication of imminent road closures.

ORAL
Session 2d.

VIRTUAL FIELDTRIPS TO VOLCANOES- 10 YEAR PERSPECTIVE

Ben Kennedy[1], Jonathan Davidson[1], Timothy Martin[1], Alexander Watson[1], and Alison Jolley[2]

[1] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*
[2]*Te Puna Ako – Centre for Tertiary Teaching & Learning, University of Waikato, Hamilton, New Zealand*

Ben.kennedy@canterbury.ac.nz

Over 10 years we have been creating virtual fieldtrips with the goal to give students a genuine experience and feeling of what it would be like on in-person fieldtrips. To deliver virtual fieldtrips we have trialed fully immersive worlds, 360 videos, 3D visualizations, bicultural content and a Massive Open Online Course (MOOC) with automated feedback. We have used virtual fieldtrips to take students to places they would otherwise not be able to go, to familiarize students with field skills and content before going into the field in order to maximize learning. Our research results from student interviews, focus groups and pre-post measures of learning show that students enjoy and engage well with the digital content, although we are still far from an immersive in-person field experience.

In this presentation we will focus on general recommendations developed from literature review, instructor experience, and student feedback. (1) The digital approach of the virtual fieldtrip should be guided by content, skills, and attitude-based learning goals. (2) Build a mutually beneficial interdisciplinary team from your university (including educational research graduate students) - this lessens workload and provides longevity. (3) In-field videos (instructional and 360) with interviews (starring course instructor and highlighting diverse role-models) allow for a good connection between students, staff and the place. (4) Keep technology as simple as possible (e.g., tools students are familiar with like Google Earth); however, an interactive, 3D perspective can add new learning opportunities to a in person fieldtrips.

Looking to the future, we hope to use artificial intelligence generated nudges to teach interactive engagement with video watching and notetaking. Such interactive virtual fieldtrips could be a suitable replacement for lecture content in a flipped classroom or as preparatory exercises for in-person fieldtrips, and only as in-person fieldtrip replacements when appropriate.

ORAL
Session 3e.

TOWARDS A GLOBAL SPECTRAL-GEOMECHANICAL DATABASE OF VOLCANIC ROCKS USING VNIR-SWIR SPECTROSCOPY

Gabor Kereszturi[1], Michael Heap[2,3], Lauren Schaefer[4], Herlan Darmawan[5], Frances Deegan[6], Ben Kennedy[7], Jean-Christophe Komorowski[8], Marina Rosas-Carbajal[8], Amy Ryan[9], Valentin Troll[5], Marlène Villeneuve[10] and Thomas Walter[11]

[1] Volcanic Risk Solutions, School of Agriculture and Environment, Massey University, Palmerston North, New Zealand
[2] Université de Strasbourg, CNRS, Institut Terre et Environnement de Strasbourg, UMR 7063, 5 rue Descartes, Strasbourg F-67084, France
[3] Institut Universitaire de France (IUF), Paris, France
[4] U.S. Geological Survey, Boulder, Colorado, USA
[5] Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Gadjah Mada, Yogyakarta, Indonesia
[6] Department of Earth Sciences, Natural Resources and Sustainable Development, Uppsala University, Sweden
[7] Geological Sciences, University of Canterbury, Christchurch, New Zealand
[8] Université de Paris, Institut de Physique du Globe de Paris, CNRS, Paris, France
[9] Department of Earth and Environmental Sciences, University of Minnesota, MN 55455, USA
[10] Chair of Subsurface Engineering, Montanuniversität Leoben, Leoben, Austria
[11] GeoForschungsZentrum Potsdam, Potsdam, Germany

G.Kereszturi@massey.ac.nz

Volcanoes are subject to intense fluid circulation, altering primary rock properties. The rock alteration can be due to “cold” water-driven weathering or “hot” hydrothermal fluids. Such alteration is facilitated by the efficient circulation of fluids through fractures and the connected pore-network. Fluid-driven alteration can manifest as mineral dissolution and precipitation, ultimately changing the host rock’s properties, such as strength and elasticity. Alteration-induced geomechanical changes are complex due to the large range of protolith porosity (e.g. 0.01-0.8) and permeability (e.g. 10^{-10} to $\leq 10^{-18}$ m^2). For example, fresh pyroclastic rocks can initially have low strength, which can be ‘reinforced’ by mineral precipitation. In contrast, dense lava rocks can decrease their strength due to pore space enlargement and development of secondary clays, oxides, sulfides and sulfates.

This study analysed lab-tested samples from Ruapehu, Merapi, Whakaari, Chaos Crags, Ohakuri, Styrian Basin and La Soufrière de Guadeloupe, to provide new insights into the controls on geomechanical properties due to weathering and hydrothermal alteration. The volcaniclastic and lava rocks from basaltic to rhyolitic compositions encompass surface weathering, intermediate and advanced argillic alteration styles. The physical and geomechanical properties [e.g. porosity range of 0.02-0.67, P-wave velocity range of 88-5800 m/s and uniaxial compressive strength range of 0.1-312 MPa] were measured on rock core samples, and compared with Visible-Near Infrared (VNIR; 350-1000 nm) and Shortwave Infrared data (SWIR; 1000-2500 nm). Partial Least Squares Regression (PLSR) was employed to successfully predict physical and mechanical properties using VNIR-SWIR spectroscopy data. The PLSR-based prediction models highlighted a handful of spectral bands around 400-600 nm, 1400 nm and 2200-2300 nm, indicating the hydrated secondary minerals behind the observed geomechanical changes. The proposed method using VNIR-SWIR spectroscopy can lead to a new way of mapping physical and geomechanical properties at outcrop-scale using field spectrometers, and volcano-scale using airborne and satellite remote sensing.

ORAL
Session 1a.

CRYPTIC MAGMATIC PROCESSES IN THE LEAD UP TO A PHREATIC ERUPTION: A COMPOSITE MODELLING APPROACH AT TE MAARI, TONGARIRO

Geoff Kilgour[1], Ian Hamling[2], Bruce Christenson[3], Agnes Mazot[1], Sigrún Hreinsdóttir[2]

[1] *Wairakei Research Centre, GNS Science, Taupō, New Zealand*
[3] *GNS Science, Lower Hutt, New Zealand*
[2] *National isotope Centre, GNS Science, Wellington, New Zealand*

g.kilgour@gns.cri.nz

Magma ascent, degassing, and the pressurisation imparted on hydrothermal systems are some of the potential drivers of phreatic eruptions. However, the lack of juvenile ejecta in phreatic eruption deposits precludes in-depth analyses of these potential drivers. To overcome this lack of direct information, we can use a combination of disparate modelling tools to explore the size, state, and depth of magma in the lead up to a phreatic eruption.

The first Te Maari eruption in a century occurred on 6th August 2012, preceded by a fortnight of seismic swarms that began on 13th July. The unusual seismicity prompted further gas analyses of the main fumaroles on Tongariro, and these samples clearly indicated that magma had ascended into the shallow crust beneath Te Maari. Results pointed to a CO_2-rich pulse of gas discharging from Lower Te Maari at that time, with CO_2/CH_4 values orders of magnitude above baseline. A re-analysis of InSAR data indicates that low-amplitude, vent-proximal deformation occurred days before the seismic swarms began. Here we attempt to calculate the dimensions of the pre-eruption magma intrusion and assess the lower bounds of our detection capability to inform future monitoring efforts.

We take the temperature data obtained from the main Te Maari fumaroles and fit a series of conductive cooling models. This thermal model accounts for a typical Tongariro andesite magma and provides constraints on the potential dimensions of the intrusion. Our modelling approach results in non-unique solutions, which we then test using forward models to assess the minimum intrusion dimensions that could be hidden from detection. This is achieved through a series of iterative models that explore the expected deformation pattern. Finally, we provide some context for the pre-eruption seismicity based on our broader magmatic understanding obtained through this analysis.

POSTER
Session 1a.

A FORAMINIFERAL SEA-LEVEL RECONSTRUCTION FROM ARAMOANA SALT MARSH, DUNEDIN

Daniel King[1], Rewi Newnham[1], Andrew Rees[1], Kate Clark[2], Roland Gehrels[3], Ed Garrett[3], William Henriquez Gonzalez[1], and Valerie van den Bos[1]

[1] *School of Geography, Environment, and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand.*
[2] *GNS Science Ltd., Avalon, Lower Hutt, New Zealand.*
[3]*Environment and Geography Department, University of York, York, United Kingdom.*

daniel.king@vuw.ac.nz

The threat posed by sea-level rise around New Zealand's cities is known to be either exacerbated or ameliorated by centennial-scale vertical land motion. To contextualise the possible influence of this process on sea-level rise around the city of Dunedin, we use foraminiferal assemblages from the salt marsh at Aramoana (at the mouth of the Otago Harbour), alongside regional data from Pounawea and Mokomoko salt marshes, to generate a transfer function for use in reconstructing historical relative sea-level changes. A 17-19 cm-thick sandy peat sequence was found to be consistently present across the northern part of the marsh by test-coring, and the foraminiferal assemblages of two sediment cores from the upper marsh were counted and identified. Applying locally-weighted weighted averaging transfer functions, and dating the sediments using 210Pb (modelled using the Bayesian age-depth modelling package rPlum), foraminiferal assemblages for two sediment cores indicate 1.75±0.87 and 2.08 ±0.87 mm/yr relative sea-level rise since 1900, and our data series shows excellent agreement with the nearby tide gauge record. From the interval of ~1881 (tentatively dated via a distinct charcoal horizon) until 1900, a possible subsidence phase is recorded from both cores prior to the installation of the Dunedin tide gauge, though the relatively low precision of our models precludes a detailed assessment of this interval. Below the salt marsh peat sequence (i.e. prior to ~1880), the sedimentary record comprises dune sands, and is not considered trustworthy in the generation of a sea-level reconstruction. This Dunedin study is part of a broader study involving sites in Auckland and Wellington that aims to quantify the contribution on vertical land motion to relative sea-level change in Aotearoa/New Zealand's major urban centres.

ORAL
Session 2d.

VOLCANIC GEOLOGY OF THE PUKUNUI RHYOLITE DOME, TAURANGA VOLCANIC CENTRE.

Taya Kinley[1], Adrian Pittari[1] and Marlena Prentice[1]

[1]School of Science, University of Waikato, Hamilton, New Zealand

tayak99@hotmail.com

The Mount Misery volcanic dome complex, ~10 km southwest of Tauranga, comprises three named rhyolite domes (Mount Misery, Greenpark and Pukunui). Mount Misery dome has been $^{40}Ar/^{39}Ar$ dated to 2.69 Ma, which makes it one of the older domes of the Minden Rhyolite Group in the Tauranga Volcanic Centre. The dome complex is geochemically distinct from other TgVC domes, particularly having the highest Zr content. The focus of this presentation is on the volcanic geology of the Pukunui dome which is exposed in a quarry in the Pyes Pā area, with a view to understanding the aspects of the history of rhyolite dome growth and explosive activity in the TgVC.

The Pukunui dome at the quarry lies above extensive andesite of the contemporaneous Otawa Volcanics. The upper part of the rhyolite exposed in the quarry has visible flow folding and jointing patterns, and alternating thin and thick flow banding. Flow folding occurs on multiple scales. Unstable faces are due to frequent jointing, and variations between fresh hard rhyolite and softer altered rhyolite. A subvertical few metre-wide zone is particular altered and crumbly. Petrographically, the rhyolite typically has alternating thickness in flow banding from 1 mm - 30 mm with mostly crystalline banding. Two areas in the quarry had different compositions, the rhyolite samples were either thin banded at 1 mm – 4 mm, or coarse banded at 5 mm – 30 mm. It appears the rhyolite was emplaced as a single dome. A pyroclastic succession on laps onto the dome approximately 320m to the northwest and comprises an ignimbrite with a lower lithic concentration zone of large andesite clasts, overlain by bedded tuffs and lapilli tuffs. The stratigraphic relationship between the Otawa andesite, Pukunui rhyolite and the pyroclastic succession helps to understand the relative timing of different eruption styles in the TgVC.

POSTER
Session 1a.

AN EVOLVING STORY OF THE GEOLOGY OF THE MANAWATŪ SADDLE: EVIDENCE FROM THE MANAWATŪ -TARARUA HIGHWAY.

Philip Kirk[1], Grace O'Sullivan[2] and Ben Dixon[1]

[1] Aurecon New Zealand Ltd
[2] Seequent Ltd, New Zealand.

philip.kirk@aurecongroup.com

Construction has started on the new Te Ahu a Turanga Alliance Manawatū–Tararua Highway, which traverses the southern Ruahine Range between Saddle Road and the Manawatū Gorge.

The Highway is formed predominantly on the extremely-weak marine sedimentary rocks of the Plio-Pleistocene Manawatū seaway, but the underlying greywacke basement rock will be encountered locally in the central and eastern portions of the project.

Geotechnical investigations and early construction works have suggested some refinements to the present lithostratigraphy of the area, and these are incorporated into the engineering geological model for the project. In general, we have grouped lithological units based on shared geotechnical properties, however for the conglomerates and interbedded sandstones and where specific geotechnical design risks require it, we developed a more detailed geological model. The investigations have also enabled a better understanding of the structural geological history of the project area, with several new faults identified, and previously known structures better constrained geographically and by timing of their activity.

ORAL
Session 4c.

INTER-CALDERA CRUSTAL PERMEABILITY AND THERMAL PROCESSES IN THE TAUPŌ VOLCANIC ZONE, NEW ZEALAND.

W. Kissling, S. Ellis, S. Barker, K. Hansen

We construct numerical models of bulk heat and water transport from the base of the crust to the surface beneath the Ngākuru Graben, an inter-caldera region in the Taupō Volcanic Zone (TVZ), New Zealand. The models use a conventional heat and fluid mass transport code, modified to include a multi-component crust with fully coupled thermal processes including melting and latent heat. Temperature dependent melting curves for crustal components from shallow silicic rocks (greywacke and rhyolite) to dacite, andesite and basalt are derived from Rhyolite-MELTS. Equivalent thermal properties at any depth are calculated by mixing rules according to both composition and melt fraction.

The model represents a 2-D NW-SE across-rift section 50 km wide and 15 km deep. A 20 km-wide 'hot-plate' represents the heat and fluid flux from extensive intrusion of ~1 m^3s^{-1} of primitive basalt into the base of the TVZ, with temperatures of ca.1000°C and heat flux of 700 mWm^{-2}. A key feature of the models is the decrease of basement permeability with depth. Basement permeabilities vary from ~10^{-14} m^2 at 1.5 km depth to ~10^{-17} m^2 at 15 km, with a 'shape-parameter' used to match temperature proxies for several geophysical constraints.

Our models reproduce expected basal temperatures, a brittle-ductile transition at 8 ± 1 km and a zone of partial melt below approximately 10 km depth. The models predict that transient high-temperature geothermal systems exist for 10-20% of the time, interspersed by quiescent periods where surface heat and fluid flow are significantly lower. The transient nature of the geothermal systems ultimately results from the depth variation of basement permeability, with shallow permeabilities being high enough to support a large-scale unsteady convective system. Lifetimes of the geothermal systems are ~ 100 ky and, in common with present-day geothermal systems, temperatures can reach ~300ºC at < 1 km depth.

ORAL
Session 2a.

LIQUEFIED TEPHRA LAYERS IN LAKES: A NEW PALEOSEISMOMETER

Max O Kluger[1], David J Lowe[1], Vicki G Moon[1], Jordanka Chaneva[1], Tehnuka Ilanko[1], Pilar Villamor[2], Rolando P Orense[3], Richard Johnston[4] and Nic Ross[5]

[1] *School of Science/Te Aka Mātuatua, University of Waikato, Hamilton, New Zealand*
[2] *GNS Science, Lower Hutt, New Zealand*
[4] *Department of Civil and Environmental Engineering, University of Auckland, Auckland, New Zealand.*
[4] *Faculty of Science and Engineering, Swansea University, Swansea, United Kingdom.*
[5] *Hamilton Radiology Imaging Centre, Hamilton, New Zealand*

max.kluger@waikato.ac.nz

Calamitous earthquakes in regions of low to moderate seismicity, such as Christchurch (New Zealand) and New Madrid (central United States), are associated with ruptures on unmapped, hidden faults that hamper paleoseismicity evaluation. We present a new paleoseismic method using liquefied tephra layers (tephra-seismites) in lakes to identify and date the activity of such hidden faults in the Hamilton lowlands, North Island. Around 30 closed-basin Late Pleistocene lakes, scattered amidst newly-discovered hidden faults in the Hamilton lowlands, contain numerous distal tephra (volcanic-ash) layers of known age. The tephra layers, 2–8 cm in thickness and with internal bedding comprising glass-dominated sand and silt, exhibit remarkable seismogenic injectites directed downward into host organic sediments in some of the lakes, but not in others. Downward-directed injectites have never been reported in lakes. We analysed tephra-bearing sediments in multiple cores taken from ten lakes to (i) characterise the tephra-seismites, (ii) derive a mechanism for their downward injection, and (iii) reconstruct the basin's paleoearthquake history since ~15.6 calendar (cal) ka by examining the spatial and temporal extent of the tephra-seismites associated with five key tephra layers. We hypothesise that during paleoearthquakes (which likely occurred within several hundred years of tephra deposition), sand-rich beds within tephra layers were liquefied and forced downward, primarily because of the high inverse density contrast between the tephra and organic lake sediments above and below, and also because silt-rich beds capping the tephras prevented upward-directed injection. From our current data, we infer that at least three episodes of paleoseismic activity of regional faults in proximity to the Hamilton Basin took place soon after ~15.6, ~14.0, and ~7.6 cal ka, and with an average recurrence interval of ~5 kyr. Our novel methodology is potentially globally applicable in seismic and volcanic regions including those with low to moderate seismicity and hidden faults.

KEYNOTE
Session 2a.

TOWARDS AN UPDATED PALEOSEISMICITY IN HAMILTON LOWLANDS USING LIQUEFIED TEPHRA LAYERS IN LAKES

Max O Kluger[1], Jose Moratalla[2], David J Lowe[1], Vicki G Moon[1], Jordanka Chaneva[1], Tehnuka Ilanko[1], Pilar Villamor[2], Rolando P Orense[3] and Richard Johnston[4]

[1] *School of Science/Te Aka Mātuatua, University of Waikato, Hamilton, New Zealand*
[2] *GNS Science, Lower Hutt, New Zealand*
[3] *Department of Civil and Environmental Engineering, University of Auckland, Auckland, New Zealand.*
[4] *Faculty of Science and Engineering, Swansea University, Swansea, United Kingdom.*

max.kluger@waikato.ac.nz

The Hamilton lowlands have been considered an area of low- to moderate seismic risk based on the limited record of historical activity and lack of known active faults. Recent discoveries of hidden faults in and around Hamilton, and paleoseismic studies on Te Puninga and Kerepehi faults in the Hauraki Plains, indicate a potentially higher risk for future earthquakes than previously anticipated. Around 30 closed-basin, ~20 cal-ka-aged lakes scattered amidst newly-discovered hidden faults in the Hamilton lowlands contain numerous distal tephra layers of known age. The tephras, 2–8 cm in thickness and with internal bedding comprising glass-dominated sand and silt, display seismogenic injectites directed downward (i.e., tephra-seismites) into host organic sediments in some of the lakes, but not in others (see oral paper by Kluger and others). In order to better estimate the seismic risk in the Hamilton lowlands we present a new paleoseismic method using the liquefied tephra layers in lakes to identify and date the activity of hidden faults in the Hamilton lowlands. We analysed sediment cores taken from ten lakes to reconstruct the basin's paleoearthquake history since ~15.6 cal ka by examining the spatial and temporal extent of the tephra-seismites associated with five key tephra layers. From our current data, which are limited in that there are no thick tephra layers capable of being liquefied since ~7.6-cal-ka Tuhua tephra, and with spatial coverage from only ten lakes, we infer that at least three episodes of paleoseismic activity of regional faults in proximity to the Hamilton lowlands took place soon after ~15.6, ~14.0, and ~7.6 cal ka, and with an average recurrence interval of ~5 kyr. An uncertainty analysis of the expected ground motion intensities from possible rupture scenarios at the Kerepehi and Te Puninga faults was carried out. Results provided us with sufficient confidence to conclude that these paleoearthquakes caused peak ground accelerations strong enough to liquefy tephras in the lakes around the Hamilton lowlands.

POSTER
Session 2a.

THE NZ DART DEEP OCEAN TSUNAMETER NETWORK AND THE MANY WAYS TO TRIGGER IT

Megan Kortink[1], Jean Roger[1], Jonathan Hanson[1], David Burbidge[1], Connor Rapley[1], Jerome Salichon[1] and Mark Chadwick[1]

[1] *GNS Science, Lower Hutt, New Zealand*

m.kortink@gns.cri.nz

In 2019, New Zealand implemented a deep ocean network to monitor ocean heights around its shores and the Southwestern Pacific Ocean. This is a collaborative effort between multiple scientific institutes and government emergency management agencies. The array consists of 12 DART tsunameters with a focus on monitoring tsunamis from the Hikurangi, Kermadec, Tonga, and Vanuatu subduction zones. Regular observations reported by the recorders are the current deep sea tides and any abnormal sea-level fluctuations which match certain criteria, known as an auto-trigger. Currently when a DART is auto-triggered, the National Geohazard Monitoring Centre (NGMC) along with the Tsunami Expert Panel (TEP) assess the threat to New Zealand, evaluating if the auto-trigger is linked to any tsunami waves that could threaten the coast.

To avoid numerous parasitic activations that could be related to non-tsunami waves like sensor subsidence, internal waves, atmospheric pressure jumps, etc., we are currently working on generating an auto-trigger catalogue. This catalogue will allow the NGMC to quickly assess all auto-triggers and then decide if the TEP should be activated. At present, this catalogue consists of six different auto-trigger categories: Earthquakes, Positive and Negative Spikes, Tsunamis, Subsidence and “sharks teeth”, or multiple spikes. These categories are likely to evolve as we develop a better understanding on their origins (instrumental, natural phenomenon or human induced).

Improvements in deep ocean sea level data provision and displays are also occurring in parallel to ease the access to DART data for event response teams, the public and scientists. These include a multi data set tool for searching, downloading and plotting DART data: TILDE. This is a common time-series API that currently includes raw water height data, and has short-term plans to include de-tided data, calculated from the New Zealand DART Network.

POSTER
Session 2e.

LANDSCAPE EVOLUTION AND QUANTIFICATION OF LONG-TERM EROSION RATES IN THE HAUTAPU RIVER CATCHMENT, NEW ZEALAND

Szabolcs Kósik[1], Callum Rees[1], Malcolm Todd[1], Alan S. Palmer[2], Manuela Tost[3], William McKay[1]

[1]Horizons Regional Council, Palmerston North, New Zealand
[2]School of Agriculture and Environment, Massey University, Palmerston North, New Zealand
[3] Land Development and Engineering Ltd, Gisborne, New Zealand

szabolcs.kosik@horizons.govt.nz

Quantifying erosion is fundamental to understanding the significance of surface processes and protecting our natural soil resources. Here, we focus on the spatio-temporal patterns of river incision and landscape formation along the Hautapu River, with the aim of informing soil conservation measures.

The study area contains deeply incised landscapes formed in Late Miocene to Pliocene, weakly consolidated sedimentary strata. A suite of Late Pleistocene river terraces has been superimposed over this older marine succession. Cover beds of loess and tephra overlie the river terraces, providing a chronostratigraphic framework. Channelized mass-flow deposits of the Mataroa Formation (125-150 ka), derived from collapse of Mt Ruapehu andesite stratovolcano (Tost et al., 2015), overlie the Greatford Terrace.

The topographic position of these mass-flow deposits is used to reconstruct the paleogeomorphology of a 180-km^2 area of the Hautapu catchment. The depth of incision and total erosion are obtained by comparing the reconstructed surface with present day topography.

The landscape within the upper Hautapu River catchment provides evidence of channel abandonment. The most recent channel avulsion event likely occurred during the late Pleistocene (c. <15 ka) and is associated with the abandonment of the Mangoiwa Stream valley and establishment of the current Hautapu River channel. This event is thought to have occurred as a result of uplift and associated faulting along the Snowgrass Dome.

Total erosion and average sediment yields calculated for the past c. 150 ka indicate approximately 7-8 times higher long-term sediment yields than modelled values calculated for present day conditions (Dymond et al., 2016). Accelerated erosion during glacial and stadial periods, evidenced by fluvial aggradation, is considered to have effectively stripped topsoil from deforested highlands leading to greatly increased sediment yields. Subsequent landscape stabilisation and soil formation during the Holocene is associated with a reduction in sediment supply and enhanced fluvial incision.

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ORAL
Session 2b.

SUB-SEAFLOOR GAS GENERATION AND MIGRATION AND GAS HYDRATE FORMATION MECHANISMS AT THE HIKURANGI MARGIN, NEW ZEALAND

Karsten F. Kroeger[1], Jess I.T. Hillman[1], Gareth J. Crutchley[2], Francesco Turco[3] and Philip M. Barnes[4]

[1] GNS Science, 1 Fairway Drive, Lower Hutt 5010, New Zealand
[2] GEOMAR Helmholtz Centre for Ocean Research Kiel, Wischhofstr. 1-3, 24148 Kiel, Germany
[3] University of Otago, 362 Leith Street, Dunedin 9016, New Zealand
[4] National Institute of Water and Atmospheric Research (NIWA), 301 Evans Bay Parade, Wellington 6021, New Zealand

k.kroeger@gns.cri.nz

The widespread occurrence of gas hydrates along the southern Hikurangi Margin is documented by bottom simulating reflections (BSRs) in seismic data, caused by the impedance contrast between gas hydrate and free gas at the base of the hydrate stability zone (HSZ). High-amplitude reflections within the HSZ indicate the presence of concentrated gas hydrates. Such zones of high reflectivity occur beneath structures associated with plate boundary deformation and in buried channel sands beneath the Hikurangi Channel. Interestingly, high-amplitude reflections beneath thrust ridges are often layer-parallel, and likely associated with sandy turbidite deposits. With increasing age of thrust ridges these high-amplitude reflections shift to the landward side.

To better understand controls on gas hydrate formation and distribution we have constructed basin models at different scales. These models are designed to predict gas generation, both through thermal cracking deep in the basin and through shallower microbial generation of methane. By forward modelling burial and deformation and changes in physical properties, we reconstruct migration of gas, formation of gas hydrate, and the role of faults and sedimentary architecture in these processes.

These models reproduce the distribution of gas hydrates as indicated by high amplitude reflections within the HSZ and the strength of the BSR. Whilst concentrated gas hydrate seaward of the deformation front is predicted to have dominantly formed from thermogenic gas, gas hydrate beneath thrust ridges is predicted to consist predominantly of biogenic methane. The distribution of gas hydrate and the landward enrichment with increasing thrust ridge age is predicted to be the result of microbial gas generated beneath the HSZ migrating along permeable strata into the HSZ. This process is enhanced by the presence of prominent back-thrusts diverting gas into the landward limbs of anticlines and by recycling of gas hydrate at the base of the HSZ during ongoing burial.

ORAL
Session 2e.

How Notional Injection Sites for Carbon Sequestration Are Identified: The Surat Basin, Australia

Andrew D. La Croix[1], Jim R. Underschultz[2], Phil Hayes[2], Andrew Garnet[2], and the UQ-SDAAP Project Team[2]

[1] *School of Earth and Environmental Science, University of Waikato, Hamilton, New Zealand*
[2] *Centre for Natural Gas, University of Queensland, Brisbane, Australia*

a.lacroix@waikato.ac.nz

Notwithstanding the effect of greenhouse gases on our climate (IPCC, 2021), the path towards a carbon-neutral global economy will likely require energy from fossil fuels for decades during an energy transition (IEA, 2020). The challenge facing nations, such as Australia, is continuing economic and social development while meeting energy demands and reducing CO2 emissions during this transition; Australia is endowed with coal and petroleum resources and is a major exporter to the Asia-Pacific region. An important method to balance the economy and environment is carbon capture and storage (CCS), which the IPCC predicts will be a key enabler to help the world reach net-zero emissions by mid-century and limit global warming to 1.5º C (Institute, 2020). The Mesozoic Surat Basin in Australia is a candidate for CCS due to its favorable geology and proximity to large emitters, but it is also a strategic groundwater resource. For commercial-scale CCS it is essential to identify the most suitable location for long-term safe storage of CO2 and demonstrate limited adverse impacts on groundwater. How is this done and what implications does this hold for other CCS projects globally?

A multi-disciplinary investigation of CCS in the Surat Basin has recently been completed. Risk-minimizing, multi-criteria decision-making methods and suitability analysis was applied to determine hypothetical injection sites. Analysis of both surface (e.g., environmental and infrastructure) and sub-surface (e.g., geoscience and engineering) criteria were used to build a suitability map within a risk framework and locate the preferred areas of the basin for notional CO2 injection.

We will showcase the major surface and subsurface considerations for CCS in the Surat Basin, focusing primarily on pertinent geo-engineering issues. An overview of hypothetical injection sites, including recently collected pilot data, will demonstrate the efficacy of our characterization strategy that future CCS projects can use as a methodological model.

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ORAL
Session 4d.

SHARING THE SCIENCE BENEATH OUR FEET: PREPARING FOR THE NEXT ALPINE FAULT EARTHQUAKE

Alice Lake-Hammond[1] and Caroline Orchiston[2]

[1] *AF8 [Alpine Fault magnitude 8], South Island, New Zealand*
[2] *Centre for Sustainability, University of Otago, Dunedin, New Zealand.*

alicelh@af8.org.nz, caroline.orchiston@otago.ac.nz

The *AF8 Roadshow: The Science Beneath Our Feet* is a key risk communication and engagement activity led by AF8 [Alpine Fault magnitude 8], a collaborative programme of work between science and emergency management aimed at increasing societal preparedness for the next Alpine Fault earthquake.

Scientific evidence has shown that the Alpine Fault has a history of generating regular, large earthquakes. Newly updated probabilities suggest there is a 75% chance of an Alpine Fault earthquake occurring in the next 50 years, and that there is an 82% chance it will be a magnitude 8+ event (Howarth et al. 2021). Hazard and risk modelling indicates that the impacts of an earthquake this size will have major implications for the entire South Island, and will generate a disaster of national significance (Orchiston et al. 2018). A primary objective of AF8 has been to increase public awareness and preparedness for a future Alpine Fault earthquake. It is vital that the public understand the implications of this science in their local context and are enabled to take action to be better prepared.

The AF8 Roadshow shares Alpine Fault hazard and impact science alongside preparedness information with South Island communities. It is designed to enable conversations, activate local knowledge, and support informed decision-making to increase awareness of, and our preparedness for, a future event. Past events have shown New Zealanders are great at coming together to support each other in an emergency. The Roadshow encourages people to have these conversations in advance, through a combination of school visits and public talks.

This presentation will explain how the AF8 Roadshow communicates the hazard risk and stimulates conversations to support informed decision-making. We include learnings and insights about communicating complex, and potentially scary, science to enable action rather than causing fear and fatalism.

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ORAL
Session 3b.

LATE HOLOCENE RECORDS OF CLIMATE CHANGE FROM SOUTHERN NEW ZEALAND

Mikaeli Lalor[1], **Dr Chris Moy**[1] **and Dr Marcus Vandergoes**[2]

[1] *Department of Geology, University of Otago, Dunedin, New Zealand*
[2] *GNS Science, Lower Hutt, Wellington, New Zealand.*

kaeli.lalor@postgrad.otago.ac.nz

In the Southern Hemisphere, dynamic climate phenomena like the El Niño-Southern Oscillation and the Southern Annular Mode produce precipitation and temperature anomalies that directly influence New Zealand's freshwater ecosystems. Physical and biological processes in alpine lakes are particularly sensitive to regional climate changes and provide opportunity to reconstruct environmental change using sediment cores. However, lack of paleoclimate records spanning the late Holocene hinders our ability to place modern changes in a long perspective. A sediment record of climate and environmental change from a South Island alpine lake, Lake Lockett is presented to evaluate ecosystem response to past temperature and precipitation change during the late Holocene. Hyperspectral imaging (HSI) of pigments and µ-X-ray fluorescence (XRF) scanning of elemental abundance were applied to two lake sediment cores. Sedimentary structures and facies transitions are emulated by elemental profiles, such as lithogenic (Fe, Ti, K), organic (incoherent-coherent scattering ratio, inc./coh.) and biogenic (Si/Ti) proxies. Principal Component Analysis (PCA) was used to group chemical indicators for processes triggered by temperature and/or precipitation. PCA results and HSI data were compared, to trace temporal trends and geochemical patterns in the sediment cores. PCA of the geochemical dataset indicated most variance is associated with lithogenic contribution, corresponding closely with HSI clay proxy R_{570}/R_{630}. The second Principal Component was led by variations in Si/Ti contribution, analogous with HSI primary production proxy $RABD_{660\text{-}670}$. Geochemical and pigment correlations suggest that climate-driven processes affecting physical weathering and catchment run-off heavily control Lake Lockett sedimentation. Using high-resolution non-destructive techniques, isolating productivity changes can tell us about ecosystem response. This study demonstrates first steps in integrating high-resolution scanning data to reconstruct paleoenvironmental change, providing valuable information for future lake ecosystem management. We present these results, along with radiocarbon and ^{210}Pb chronologies, drawing comparisons between lakes and evaluating significant climate change during the late Holocene.

POSTER
Session 2c.

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PALAEOSEISMOLOGICAL INVESTIGATIONS IN REGIONS OF LOW STRAIN USING CAVE DAMAGE: A CASE STUDY FROM CENTRAL–WESTERN NORTH ISLAND (WAITOMO CAVES), NEW ZEALAND

Jeffrey Lang[1], Joel Baker[1], Paul Williams[1], Julie Rowland[1], Kate Clark[2], Jamie Howarth[3], John Hellstrom[4], Travis Cross[1], Tatiana Goded[2]

[1] *School of Environment, The University of Auckland, Private Bag 92019, Auckland 1142, New Zealand*
[2]*GNS Science, PO Box 30368, Lower Hutt, New Zealand*
[3]*School of Geography, Environment and Earth Sciences, Victoria University of Wellington, PO Box 600, Wellington, New Zealand*
[4]*School of Earth Sciences, University of Melbourne, Victoria 3010, Australia.*

jlan103@aucklanduni.ac.nz

Speleoseismology reconstructs paleo-earthquake records from evidence of damage preserved in caves. Cave damage features (e.g., rockfall, broken and deformed speleothems) are uranium-series dated by analysis of pre- and post-damage speleothem calcite. However, in regions of low strain and infrequent damaging earthquakes, cave features can fail spontaneously without a triggering event, leading to potential misinterpretation of the damage record. We present a scheme for assessing diverse types of cave damage based on their potential for having been seismically induced, by considering the site-, cave- and region-specific processes likely to have influenced the stability of each feature prior to damage. This scheme is applied to a suite of 69 damage features (0.5–225 ka) sampled from caves in the seismically quiet Waitomo district, western North Island, New Zealand. Application of the criteria to each damage feature (i.e., potential earthquake evidence) resulted in an amplified signal relative to the noise, which enabled us to interpret damage 'events' with more confidence. In the 225-kyr record, 13–16 damage events were identified, with three defined levels of confidence (Tier 1 damage event = low confidence to Tier 3 = moderate confidence). Events of Tier ≥ 2 were shown to exceed the noise–signal threshold established for this dataset. With a focus on the younger part of the record, 4–5 damage events of Tier ≥ 2 were identified since 16 ka, yielding recurrence intervals for this period of 3.2–4.0 kyr (Tier 2 and 3 events) or 5.3–16.0 kyr (Tier 3 events only). Based on a probabilistic seismic hazard assessment, and an estimated Modified Mercalli intensity threshold of MM VII–VIII for generating the observed damage, the likely sources of seismically induced cave damage at Waitomo are the distal Hikurangi subduction margin or a hidden, proximal fault.

POSTER
Session 1c.

THE FAULT IN OUR HORIZONS: REGIONAL ACTIVE FAULT MAPPING UPDATES 2018-2021

Rob Langridge[1], Regine Morgenstern[1], Dougal Townsend[1], Nicola Litchfield[1], Genevieve Coffey[1] and Ian Lowe[2]

[1]*Paleoseismology Team, GNS Science, P O Box 30-368, Lower Hutt 5040, New Zealand*
[2]*Horizons Regional Council, Private Bag 11025, Palmerston North 4442, New Zealand.*

r.langridge@gns.cri nz

GNS Science has partnered with Horizons Regional Council to update active fault data across Horizons' seven districts. The major goals of this program were to: i) provide detailed mapping of active fault locations using airborne LiDAR and a new photogrammetry-derived region-wide 1-m pixel resolution digital surface model (DSM); ii) use this data to develop Fault Avoidance Zones (FAZ) according to the MfE Guidelines for building on or near active faults; and (iii) update ; recurrence interval (RI) data for faults that can be used with FAZs, or where appropriate with Fault Awareness Areas (FAAs).

The districts were generally tackled from south to north, from Horowhenua, to Palmerston North, Manawatū, Rangitikei, Whanganui, Ruapehu and lastly Tararua District. Several new faults were located as part of this study, e.g. the Tokomaru Fault in Horowhenua, and in some cases known active folds were found to have active faults associated with them, e.g., the Feilding Anticline/Rauoterangi Fault in Manawatū.

Fault activity is variable across the region. Tararua and Ruapehu districts have the largest number of named active faults and also those with shorter recurrence intervals falling into RI Class I (≤2000 yr) and II (>2000 to ≤3500 yr), as they are associated with the Hikurangi Subduction forearc and Taupō Rift, respectively. This work resulted in a follow-up paleoseismic study undertaken for the Rauoterangi Fault, which extends through the town of Feilding beneath numerous pre-existing infrastructure and residences. Trenching this fault has confirmed past ruptures on the eastern of two active reverse fault strands mapped through the town.

FAZs or FAAs have now been generated for all mapped active faults across the region and can be used as a decision-making tool at cadastral scale. Results of this work are being used by the individual District Councils for planning and building decisions.

ORAL
Session 2a.

SEDIMENTATION PATTERNS IN A SMALL MODERN ANTHROPOGENICALLY-INFLUENCED ESTUARY; OTUWHERO INLET, ABEL TASMAN

Mark JF Lawrence[1], Salman Asraf[1] and Henry Gard[1]

[1] *GNS Science, 1 Fairway Drive, Lower Hutt, New Zealand*

m.lawrence@gns.cri.nz

Otuwhero Inlet is located just south of Abel Tasman National Park and about 2.5 km north of Kaiterteri, and flows into Tasman Bay. Anecdotally, inlet characteristics have changed significantly in recent years due to land-use factors such as forestry, tourism, and built infrastructure. As a first step in understanding the resultant changes in sedimentation patterns a methodology has been developed, aimed at comparing the modern system with that of the recent past (<100 years).

The modern system was characterised by identifying a range of estuarine sub-environments using a combination of modern satellite imagery and ground mapping of geomorphic features and associated sedimentary structures. The distribution of flora and fauna was also documented. To augment the mapping and feature identification, 57 shallow surface samples (≤5 cm depth) were obtained from a series of transverse and longitudinal transects representing the fluvially dominated to fully marine dominated parts of the estuary. In addition, nine shallow (<1.0 m long) cores were acquired. The samples were obtained for grain size analysis, to provide additional information on sediment entrainment, transport and deposition, further refining the estuarine sub-environment classification. This methodology is analogous to that of Simon et al (2021), published while this project was being undertaken. The modern sub-environment classification was then used as a guide for mapping features on a series of historical air photographs that were georeferenced to the modern satellite imagery.

Identified sub-environments range from fluvial channels to offshore bars. The air photographs showed significant changes in major estuary features since 1944. For example, the main channel has moved southwards and has been confined by stop banks. Significant aggradation has occurred probably as a result of Cyclone Gita and upstream logging operations. Overall, there has been noticeable shifting of sub-environments over a relatively short time.

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POSTER
Session 2d.

MOVING BEYOND PORE PRESSURE: NEW INSIGHTS INTO THE IMPACT OF WETTING ON FRACTURED ROCK

Kerry Leith[1,2], Ying Li[1], Paul Selvadurai[1], Rui Wu[1], Matthew Perras[3], Simon Loew[1]

[1] Department of Earth Sciences, ETH Zurich, Zurich, Switzerland
[2] Surface Geosciences, GNS Science, Lower Hutt, New Zealand
[3]Department of Civil Engineering, York University, 4700 Keele St, Toronto, Canada

k.leith@gns.cri.nz

The absorption of water into intact, or fractured rock has been shown to simultaneously increase strain, decrease elastic stiffness, and reduce the strength of the material. The elastic effects are evident throughout the wetting process, though are particularly strong as the material transitions from ~75% to 100% saturation, where induced volumetric extensional strains can reach 10^-4, Young's modulus can decrease by as much as 13%, and induced stresses can exceed 20 MPa. While the reduction of fracture toughness is difficult to constrain, wetting typically reduces the unconfined compressive strength of a wet rock by as much as 30%, while sub-critical fracture velocities can increase by several orders of magnitude.

The aforementioned effects are not trivial. To put things in context:

- induced stresses are equivalent to pore pressures more typically observed at depths of ~2 km,
- induced strains exceed thermo-elastic strains associated with temperature changes of 100℃, and,
- the associated strength reduction is roughly equivalent to a two-order-of-magnitude decrease in characteristic rock mass block volume (derived from GSI)

Here, we present examples of the response of a fine-grained granite to both increasing humidity, and the introduction of standing water, under loaded, and free-standing conditions. We highlight the mechanisms driving each observation, and draw particular attention to implications for critical geomorphological or geotechnical settings (e.g. landslides, underground excavations, or wells created for geothermal energy production) subjected to the effects of a changing climate (e.g. increasing atmospheric water vapour content, or melting of permafrost).

ORAL
Session 4c.

MONOGENETIC VOLCANISM IN A DYNAMIC FLUVIO-LACUSTRINE SETTING TONGXIN VOLCANO, ARXAN-CHAIHE VOLCANIC FIELD, NE CHINA

Bo-xin Li[1], Károly Németh[1], Julie Palmer[1], Alan Palmer[1] and Jonathan Procter[1]

[1] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*

doomlee1216@hotmail.com

Tongxin Lake locates on the NE of the Arxan-Chaihe Volcanic Field (ACVF) southwest of the Great Xing'an Range, Inner Mongolia, NE China. The lake occupies today about 1.5 km^2. After two field seasons (2018, 2019), this lake is considered as a complex maar formed by phreatomagmatic explosive eruptions. With the well-constructed stratigraphy columns, the signals of sedimentary parameters show that shortly after the onset of the first magmatic explosive eruptions an active fissure have experienced violent explosive eruption forming thick pile of pyroclastic density current-dominated ash and lapilli blanketing the faulted basement ranges. Successions of the pyroclastic deposits indicate large volumes of juvenile and accidental ejecta accumulated together following the old terrain rugged topography.

The mapped pyroclastic deposit distribution suggests that the regional fluvial system reworked and significantly redistributed the volcanic materials at the catchmant areas of the Chaoer River. Utilising terrain analysis through QGIS indicates that the present day lake floor is well below the current center line of the Chaoer River. The paleo-Chaoer River valley was filled with lava flows, the modern river cut into. Position of the elevated basement blocks around Tongxin Lake suggests that where the first vents opened must have been occupied by a predecestor lake fed by a small catchment of ~10 km^2. The volcanic eruption likely occurred in the northern end of this wet region started by lava fountaining, followed by paroxysmal phreatomagmatic explosive eruption that enlarged the basin and blocked its southern areas by fresh tephra. This southern tephra blanket were washed away by the Chaoer River and giving way for a small outflow channel that gradually drained the Tongxin Lake. Tongxin Volcano is a fine example to demonstrate the interplay between internal and external controlling parameters of monogenetic volcanism in a rapidly changing fluvio-lacustrine system in cold temperate climate.

POSTER
Session 1a.

EXPERIMENTAL MODELLING OF TSUNAMI GENERATION BY THE ENTRANCE OF PYROCLASTIC DENSITY CURRENTS INTO WATER

Natalia Lipiejko[1], Colin N. Whittaker[1], Emily M. Lane[2], William L. Power[3], James D.L. White[4]

[1] *Department of Civil and Environmental Engineering, University of Auckland, Auckland, New Zealand*
[2]*National Institute of Water and Atmospheric Research (NIWA), Christchurch, New Zealand*
[3]*GNS Science, Wellington, New Zealand*
[4]*Department of Geology, University of Otago, Dunedin, New Zealand*

natalia.lipiejko@auckland.ac.nz

Volcanic tsunamis can expand the radius of hazards posed by a volcano well beyond the reach of the eruption itself. Pyroclastic density currents produced by the 1883 eruption of Krakatau caused large tsunamis and claimed over 36,000 lives up to 800 kilometres from the volcano (Latter, 1981). Around 20% of all deaths directly associated with volcanic eruptions have been caused by volcanic tsunamis (Latter 1981, Paris 2015), however; the source mechanisms are poorly understood.

This project involves experimental modelling of tsunami generation by the entrance of pyroclastic density currents into the sea. A fluidised granular column of glass beads is released from a reservoir into a water-filled flume. We explore the effect of particle size distribution on the flow-water interactions and the wave generation process.

As the ratio of large to small beads increases, the velocity profile of the flow before entering the water becomes more uniform and its average velocity decreases. Upon entry, the flow separates into the main part of the flow that pushes the water away generating waves and the part that mixes with water at the surface. The entrance of the flow into the water generates a solitary-like leading wave followed by a much smaller trough and trailing waves. The overall wave profile does not depend on the particle size distribution of the flow. There is a weak correlation between the wave amplitudes and the particle size.

Assuming equipartition of energy, the energy transfer between the flow and water, and hence the efficiency of the wave generation, was found to be between 14-32%. A further Particle Tracking Velocimetry (PTV) analysis will be performed to calculate the velocity field generated by the flow and corresponding kinetic energy of the waves. Our results provide insight into the generation mechanism and can be further used in volcanic tsunamis hazard numerical modelling and assessment.

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ORAL
Session 1a.

WHO DISCOVERED THE CAUSE OF "BUSH SICKNESS", THE ANIMAL-WASTING DISEASE ASSOCIATED MAINLY WITH PUMICE SOILS AND SOME OTHER SOILS IN NEW ZEALAND?

David J. Lowe[1], Megan R. Balks[1] and Tehnuka Ilanko[1]

[1] *School of Science-Te Aka Mātuatua, University of Waikato, Hamilton, New Zealand*

david.lowe@waikato.ac.nz

"Bush sickness" refers to an ill-thrift or 'wasting' disease of sheep and cattle now known to be caused by cobalt deficiency, cobalt being a key element in vitamin B_{12} (cobalamin). Before its cause was identified, stock became thin and anaemic, young offspring could not be reared, and many animals died[1]. The most extensive occurrences were on silica-rich Pumice Soils developed mainly on Taupo (AD 232 ± 10) and Kaharoa (AD 1314 ± 12) tephras, a relationship recognized by Leslie Grange and Norman Taylor (1932)[2]. The condition was also recognised in the King Country ('Mairoa dopiness'), Nelson ('Glenhope ailment'), and Southland ('Morton Mains disease'). By the 1920s, the condition was widely believed to result from iron deficiency. The positive responses of affected animals to iron-oxide licks ('ores'), as observed in the early 1930s, appeared to support this hypothesis[1]. Later, Dick Grimmett and Brian Shorland (1934) identified traces of cobalt in some ores but (unfortunately) concluded that this and other trace elements would be "totally inadequate" to account for responses observed. Meanwhile, Australians were investigating an equivalent condition known as 'coast disease', 'Denmark disease', and 'enzootic marasmus' (literally 'animal disease of under-nourishment'). In Perth, John Filmer and Eric Underwood, after trials with iron-free ore extracts, concluded in 1934 that "enzootic marasmus is not due to deficiency of iron in the food". They systematically examined various trace elements (cobalt being the last studied), and wrote in June 1935 that "cobalt must be regarded as an essential element in animal nutrition". Independently, geologist Dick Thomas in Adelaide suggested that 'coast disease' might be due to a lack of red blood cells because of inadequate cobalt, and colleague Ted Lines confirmed this suggestion from a cobalt-related study on sheep, publishing his findings in May 1935. Thus, Lines, Thomas, Underwood, and Filmer deserve credit for discovery[1].

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POSTER
Session 4e.

PDC MODELS BASED ON FLUVIAL ANALOGIES STRONGLY UNDERESTIMATE HAZARD MAGNITUDES

Gert Lube[1], Ermanno Brosch[1],

[1] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*

g.lube@massey.ac.nz

The study of the sedimentary characteristics of dilute pyroclastic density current deposits is a key approach to better understand and characterise PDC dynamics, frequency, and hazards in the geological record of volcanoes. Current approaches use sediment transport principles developed for fluvial systems. How well these analogies capture the sediment transport behaviour of dilute PDCs remains poorly understood.

To bridge this gap in understanding, we simulated the transport and sedimentation processes inside these hot flows in large-scale experiments and reproduce the spatiotemporal deposit facies variations of natural deposits. We demonstrate that the evolving flow structure can be subdivided from the aggrading deposit upwards into a dynamic bedload region with particle concentrations of c. 0.5 to several vol%, a transient region with particle concentrations of c. 0.1–1.5 vol%, a dilute, fully turbulent region with formation of mesoscale clusters, and an upper dilute turbulent region absent of mesoscale clusters.

The particle feeding mechanisms of the transient region is related to the occurrence of mesoscale clusters. This process has a key role in modifying the sediment transport modes inside the bedload region. These modifications cause a variation of the dynamics of the lower flow boundary, including erosion/deposition events, and variations of the deposition rate over at least three orders of magnitude. They lead to the formation of shifting sandwaves, rolling and saltation of particles inside the experimental dilute PDC depositing massive, stratified and laminated deposit structures, while traditionally assumed direct tractional bedload deposition plays a minor role. Due to the occurrence of turbulent gas-particle feedbacks and high solid-fluid density ratios, the vertical flow density structure varies by orders of magnitude from the Roussian profiles seen in fluvial systems. We show that frequently used PDC hazard models that are based on fluvial transport analogies underestimate the values of destruction-causing dynamic pressure by about two-thirds.

POSTER
Session 1a.

HOW WELL CAN SEISMOLOGY MEASURE ICE ANISOTROPY? A CALIBRATION EXPERIMENT AT THE PRIESTLEY GLACIER

Franz Lutz[1], David Prior[1], Rilee Thomas[1], Sheng Fan[1]

[1] *Department of Geology, University of Otago, Dunedin, New Zealand*

franz.lutz@otago.ac.nz

Shear margins of glaciers and ice streams play an important role controlling the flow of these ice bodies. Crystallographic preferred orientation (CPO) patterns of ice in the shear margins have been found to exhibit highly aligned crystal orientations and therefore result in strongly anisotropic behaviour of ice deformation. A characterisation of anisotropy in shear margins is therefore needed to better assess their influence on ice flow, ultimately providing better constraints on the discharge of grounded ice masses and sea level rise. Deep ice cores, drilled at locations chosen for paleoclimate reconstruction, are the main information source about natural ice CPO, resulting in a sampling bias towards settings with little flow. Geophysical methods are proposed as alternative to constrain CPO in settings that are not usually sampled by ice coring, such as shear margins.

The presented study investigates crystallographic alignment of ice in a lateral shear margin of the Priestley Glacier, Antarctica by characterising seismic anisotropy. Findings from seismic experiments covering different scales are presented: Ultrasonic P- and S-wave velocity measurements made in ice core samples taken at the location provide a constraint on azimuthally varying seismic velocities. A vertical seismic profile dataset that was recorded using a hammer-and-plate seismic source is analysed to constrain seismic anisotropy in the scale of several tens of meters. Finally, explosive sources enable the study of seismic waves propagating along pathlengths in the kilometer-scale. Forward models of ice CPO are informed by the seismic and ultrasonic velocities and shown to provide an excellent match to the microstructure observed in core samples.

POSTER
Session 2c.

AUTOMATED DETECTION OF SLOW SLIP EVENTS IN GPS TIME SERIES WITH A NOVEL CHANGE-POINT DETECTION METHOD

Yiming Ma

Department *of Mathematics and Statistics, University of Otago, Dunedin, New Zealand*

maym@maths.otago.ac.nz

A slow slip event (SSE) is a type of recurring slow earthquakes, part of which plays an important role in releasing strain in subduction zones and has been found to precede large natural earthquakes. Over the past few decades, a wealth of GPS stations (over 15,000) have been deployed to detect SSEs worldwide. The huge amount of daily GPS time series makes it increasingly challenging to detect SSEs manually from visual inspection of noisy time series, therefore demanding a robust automatic detection method. In this talk, we present a new method to automatically estimate the start and end times of SSEs in noisy GPS data. Our method recasts the problem of identifying SSEs as that of estimating change-points in a piecewise-linear signal, as SSE data have a piecewise structure which is nearly piecewise-linear. A novel approach based on spectral decomposition and adding noise is proposed to obscure the deviation from the piecewise linearity in the underlying SSE signal. We firstly validate our method's detection performance for a range of noisy simulated SSE data, and then apply it to detect SSEs in real data from the Cascadia subduction zone. We compare our method with a commonly-used detection method, which is based on Akaike's Information Criterion. Results obtained on both simulated and real SSE data demonstrate that our method works well for detecting change-points in SSE data, outperforming the commonly-used detection methods.

POSTER
Session 4b.

MICROSTRUCTURAL RESPONSES TO SHEAR LOCALISATION IN THE LATERAL MARGIN OF THE HAUPAPA/TASMAN GLACIER.

Zoe MacClure[1], David Prior[1], Sheng Fan[1], Heather Purdie[2] & Lisa Craw[3]

[1] Department of Geology, University of Otago, Dunedin, New Zealand
[2]Department of Geography, University of Canterbury, Christchurch, New Zealand
[3]Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, TAS, Australia

maczo861@student.otago.ac.nz

Alignment of ice crystals c-axes develop during the deformation of natural ice and are responsible for mechanical anisotropy. Quantifying the effects of anisotropy will have a large impact on the robustness of predictions of ice sheet response to climate change. We have very few measurements of ice c-axis patterns at locations where the larger scale deformation kinematics are constrained. The Haupapa/Tasman Glacier presents an accessible location to study the microstructural response to strain in a temperate valley glacier. We have identified a lateral shear margin on the true left of the glacier that allows us to examine structures and microstructures within an ice shear zone.

Large-scale observations and structural measurements provided a framework to select large, oriented samples for microstructural analysis. The samples were cut into parallel 5mm slabs of ~A4 size. The 3D ice microstructure (grain shapes and sizes) was built from polarized light images of each slice. Selected slices were analysed further using a fabric analyser (measures c-axis orientation) and cryo-electron backscattered diffraction (cryo-EBSD, measures full crystallographic orientation).

The samples comprise mainly coarse (~20mm) ice grains with lobate irregular boundaries and internal low angle boundaries and lattice distortion. Aggregates of finer (~1mm) sub-polygonal ice grains form in localised blobs and planar layers up to 10mm thick. The layers of coarse and fine grains are folded. The coarse grains have c-axes strongly aligned sub-perpendicular to the dominant layering. The fine grains have much weaker c-axes alignments, some almost random.

The c-axis maxima in coarse grains lies perpendicular to the shear plane and matches expectation from laboratory experiments. The randomly oriented aggregates of fine grains have never before been observed in naturally deformed ice. These may represent the result of rapid localized shear in the margin, with implications for shear margin mechanics.

ORAL
Session 2c.

SEAFLOOR MAPPING IN NEW ZEALAND AND THE REST OF THE WORLD

Kevin Mackay[1], Jaya Roperez[1], Helen Neil[1], Arne Pallentin[1], Tilmann Steinmetz[1], Vaughan Stagpoole[2], Jenny Black[2], Adam Greenland[3], Glen Rowe[3]

[1] NIWA – South and West Pacific Regional Data Center of The Nippon Foundation – GEBCO Seabed 2030 Project;
[2] Institute of Geological and Nuclear Sciences;
[3] Land Information New Zealand

The ocean being at least 70% of the earth does not just provide resources to sustain human life but also drives earth's processes geologically and climate-wise. With climate change, sea-level rise and tsunami threats; seamless land and underwater elevation is essential for risk mitigation. Even though most marine science studies use seafloor topographic data as base information needed for creating ocean process models, analysis and interpretation, ~80% of the world's ocean is still unmapped. Hence, increasing the uncertainty of the accuracy of global models. This is what drives The Nippon Foundation – GEBCO Seabed 2030 Project to pursue gathering and compiling existing data and promote ocean mapping so that humanity will have free data access of a fully-mapped ocean floor by year 2030.

There are four (4) regional data centers to facilitate and realize the goals of the project, with one being located and hosted by the National Institute of Water and Atmospheric Research Ltd (NIWA).

The presentation will highlight the earthquake in March 2021 where the government managed to send tsunami advisories to the public in such short period of time and how accurate it was, and relating this to the aims and background of the Seabed 2030 Project.

ORAL
Session 2e.

PRELIMINARY RESULTS OF AN AVO ANALYSIS IN THE SOUTHERN HSM: INSIGHTS INTO FLUID AND PRESSURE REGIMES

Michael Macnaughtan[1], Ingo Pecher[1] and Lorna Strachan[1]

[1] *School of Environment, The University of Auckland, Auckland, New Zealand.*

mmac731@aucklanduni.ac.nz

Characterising an active subduction margin's deeply-buried fluid and pressure regime is imperative when addressing seismogenic potential. Deep, compaction-related expulsion of fluids (e.g. H_2O and CH_4) may fundamentally influence plate coupling by locally modifying the interface's frictional regime. Seismogenesis and slip patterns at a plate interface are often directly controlled by the occurrence accumulated fluids at normal and high pressures. As part of a wider study into the seismogenic potential of the southern Hikurangi Subduction Margin (HSM), we have embarked on an amplitude versus offset (AVO) analysis with the aim of delineating the occurrence of fluids and estimate their pressure regime at the plate interface. Carbon-bearing fluids are hypothesized to be stratigraphically trapped by impermeable strata which may result in a widespread fluid overpressure regime. We present results from an initial AVO effect analysis that shows the existence of AVO signatures in the southern HSM. Definition of AVO signatures and interpretation of fluid escape structures (FES) provides the conceptual framework for a wider AVO inversion study that aims to characterise fluid type at the subduction interface.

We interpret AVO signatures present in current two-dimensional seismic data and interpret anomalous seismic structures potentially related to fluid-escape at the subduction interface. Stratal sequences of interest previously summarized by Davy et al. (2008) and Plaza-Faverola et al. (2012) are: The Mesozoic Sequence (MES) (70-100 Ma) composed of redeposited, low-energy clastic sediments and Sequence Y, composed of mudstones and nannofossil chalks aged 70-32 Ma. Brightening and dimming effects such as those defined by Rutherford and Williams (1989) are interpreted in MES-Sequence Y strata on the Chatham Rise and parallel with the subduction interface under the Hikurangi Trough. Geologically, these reflectivity variations could be the product of contrasting lithologies or pore fluid type (Chopra and Castagna, 2014).

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POSTER
Session 1c.

THE NEW GEOLOGICAL MAP OF THE HYDE-MACRAES SHEAR ZONE AND WAIHEMO FAULT ZONE AREA, NORTHEASTERN OTAGO 1:50 000

Adam P. Martin[1], Belinda Smith Lyttle[1], Andrew H. Allibone[2], Hamish Blakemore[3], Simon C. Cox[1], Dave Craw[4], Sean Doyle[3], Richard L. Kellett[5], Doug J. MacKenzie[4], Nick Mortimer[1], Tom Ritchie[6], Tusar R. Sahoo[5], Sam Stephens[7]

[1] GNS Science, Dunedin, New Zealand
[2] Rodinian (NZ) Ltd., Wanaka, New Zealand.
[3] Oceana Gold, Dunedin, New Zealand
[4] Department of Geology, University of Otago, Dunedin, New Zealand
[5] GNS Science, Lower Hutt, New Zealand
[6] Hardie Pacific, Dunedin, New Zealand
[7] Prospect Solutions, Queenstown, New Zealand

a.martin@gns.cri.nz

A new 1:50 000 scale geological map of northeastern Otago has been published by GNS Science and partners (Martin et al. 2021). The >3000 km^2 map area includes the trans-crustal Waihemo Fault Zone, the economically significant Hyde-Macraes Shear Zone in the Otago Schist and the western edge of the Canterbury Basin. The map area is two-thirds onshore and one-third offshore, amalgamated into a seamless geological map (sheet 1) with legend and cross-sections (sheet 2). With knowledge of these important structures and areas at an all-time high and still a strong focus amongst researchers and explorers, it was an opportune time to compile available information, both for future workers, and to aid the search for comparable structures elsewhere in Otago. The map illustrates the complexity of a small chunk of our local 'frozen' Mesozoic accretionary wedge and will be a useful analogue for those researching the active Hikurangi subduction margin.

Major findings are as follows. The Waihemo Fault Zone can be traced offshore in the interpreted seismic data for at least 10 km. The Hyde-Macraes Shear Zone cannot be traced offshore and structural data suggests it may pinch out close to where the Austral Superprovince cover sequence overlies the Rakaia Terrane near the coast (east). Magnetically distinct greenschist units can be traced as continuous layers in the Otago Schist rocks for up to 10 km.

Dataset features include the following: unpublished structural data and mapping; re-processed offshore data from seismic; nomenclature is Litho2014; a complete GIS using GeoSciML; geological interpretation of geophysical data onshore and offshore; up to date structural and historical resources data; up to date mining data and; structure contour data. This product will be available as downloadable .pdf files of the 2 map sheets, plus a downloadable data package of the GIS as well as downloadable layer files.

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POSTER
Session 1c.

A BIOCHEMICAL SURFACE OF NEW ZEALAND

Adam P. Martin[1], **Rose E. Turnbull**[1], **Karyne M. Rogers**[2] **and Giovanni Pradel**[2]

[1] *GNS Science, Dunedin, New Zealand*
[2] *GNS Science, Lower Hutt, New Zealand.*

a.martin@gns.cri.nz

A biochemical surface for New Zealand has been constructed using near-surface, topsoil samples covering both the North and South Island. Soil samples have been analysed by *aqua regia* inductively coupled plasma mass spectrometry on the sub-2mm portion for 65 minor and trace elements. The results are > 75,000 data points from > 800 sites showing the distribution of analytes across New Zealand. An additional 20% of samples were analysed for quality assurance and quality control which quantitatively demonstrate the survey design and analysis methodology chosen were appropriate to understand regional-scale variations.

Initial results indicate a geogenic control on element distribution based on Austral Superprovince geology, with additional influence from Zealandia Megasequence sedimentary geology, the distribution of Rūaumoko Volcanic Region rocks and loess. In select areas, additional natural controls include Australian dust, redistribution along flood plains and mass wasting processes. Superimposed on the background signal are anthropogenic impacts from sources that may include urban development, fertilizer application and lead polluting activities such as vehicle exhausts and paint application. The completion of this survey brings New Zealand in line with global efforts to complete national-scale geochemical baseline surveys.

This is part of a multi-year project undertaken by GNS Science, in partnership with Manaaki Whenua - Landcare Research, universities and MBIE to better understand the distribution of elements, isotopes and minerals in New Zealand's active environments. It is supplemented by regional studies of strontium, carbon, nitrogen and sulfur isotopes, magnetic mineralogy and urban studies, with application to human health, mass wasting, ground water quality, environmental health, mineral exploration, carbon sequestration, anthropology, statistics and societal impacts to name a few.

ORAL
Session 4e.

CALDERA - CONNECTIONS AMONG LIFE, GEO-DYNAMICS AND ERUPTIONS IN A RIFTING ARC: A SCIENTIFIC DRILLING IDEA

Cécile Massiot[1], Ludmila Adam[2], Edward Bertrand[1], Craig Cary[3], Geoff Kilgour[4], Sarah D. Milicich[1], Craig Miller[4], Alex Nichols[5], Shane Rooyakkers[1], Matthew Stott[5] and Pilar Villamor[1]

[1]GNS Science, Lower Hutt, New Zealand
[2]University of Auckland, Auckland, New Zealand
[3]University of Waikato, Hamilton, New Zealand
[4]GNS Science, Wairakei, New Zealand
[5]University of Canterbury, Christchurch, New Zealand

c.massiot@gns.cri.nz

Calderas are major volcanic features that pose large volcanic and seismic hazards. They also host heat, energy and minerals that offer economic benefits and support abundant microbiota. However, interactions between volcanism, tectonism, fluid circulation and the deep biosphere in calderas are not fully understood because subsurface observations are sparse. We propose the CALDERA (Connections Among Life, geo-Dynamics and Eruptions in a Rifting Arc) scientific drilling and downhole observatory project in the Ōkataina Volcanic Centre (OVC), to support the development of an integrated 4-dimensional model of hydrology and microbiology at the OVC/Taupō Rift intersection in the context of magmatic and tectonic activity on various timescales (days to decades to tens of thousands of years). The site is ideal because it combines high eruption frequencies, caldera unrest events, commonly occurring earthquake swarms, a densely faulted rapidly extending rift, diverse fluid circulation and a large variety of surface mibrobiota. We propose these hypotheses to test by drilling:

1. Baseline behaviour: The interplay between tectonic and magmatic processes across the OVC/Taupō Rift intersection can explain differences in hydrological and biological processes inside, outside and at the margins of the caldera.
2. Changes in tectonic and volcanic states: these can be detected early in boreholes by changes in fluid temperature, pressure, chemistry, and potentially using microbes as biosensors.

The project design has input from local Māori, regulatory authorities and emergency managers. The programme will underpin 1) resilience to volcanic and seismic hazards; 2) sustainable management of groundwater and geothermal resources, and 3) understanding of subsurface microbial diversity, function and geobiological interactions. At these early stages of planning and in preparation for an ICDP workshop proposal, we invite the scientific community to contribute to the project design and strengthen linkages with other research projects.

ORAL
Session 1a.

SR-ISOTOPIC PATTERNS IN THE NORTH TAUPO AREA: PERSISTENT SOURCE INFLUENCES ON LONG-LIVED RHYOLITIC VOLCANISM

Kate Mauriohooho[1], Bruce L.A. Charlier[1], Colin J.N. Wilson[1], Isabelle Chambefort[2], Graham Leonard[3]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand*
[2]*GNS Science Wairakei Research Centre, Taupō, New Zealand*
[3]*GNS Science Avalon Research Centre, Wellington, New Zealand*

kate.mauriohooho@vuw.ac.nz

$^{87}Sr/^{86}Sr$ ratios have long been used as signatures of the origins of magmas because of isotopic contrasts between mantle and crustal contributions. In the context of the central Taupō Volcanic Zone, initial, deep crustal processes (>10 km) of assimilation are inferred to generate intermediate compositions from interaction between mantle melts and greywacke crust (McCulloch et al., 1994; Graham et al., 1995). In the north Taupō area, previous geochemical studies have generated major- and some trace-element suites, including some Sr isotopic data. Here we present a fuller data set of Sr isotopic analysis spanning a wide geographic area from southern Taupō to the Northern Taupō area (Northwestern dome complex, Western Dome Belt, Maroa dome complex). These data are linked to existing and new $^{40}Ar/^{39}Ar$ geochronological data to provide a picture of time-space variations in Sr-isotopic values. Whole rock samples of rhyolite lava and pumice lapilli were analysed for Sr isotopes on the Triton thermal ionization mass spectrometer (TIMS) instrument at Victoria University of Wellington. The results illustrate a bimodality to the isotope signatures in the Taupō area with two long lived magma systems active over ~400 kyr. These patterns imply the presence of a spatial control with a lower $^{87}Sr/^{86}Sr$ ratios in central-north Taupō (<0.7054) and higher $^{87}Sr/^{86}Sr$ ratios (>0.7056) further south. We infer that these patterns reflect the composition of two distinct basement domains, linked to surficial recognised basement terranes (Torlesse, Waipapa), and also reflect a consistency of deep crustal magmatic processes despite the diversity of volumes and compositions erupted. However, the patterns break down to some extent into the younger (post-50 ka) eruptives as the intensity of activity ramped up into the Oruanui. This younger activity may reflect a fundamental change in the style of magmatism in the area.

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POSTER
Session 1b.

FAIR PRINCIPLES APPLIED TO HIGH-VALUE GEOSCIENCE DATASETS

Maria Mavroeidi[1] and Mark Rattenbury[1]

[1] *GNS Science, PO Box 30368, Lower Hutt.*

m.mavroeidi@gns.cri.nz

The FAIR Principles (Wilkinson et al. 2016) were developed to increase the Reuse of digital data both by people and machines. To achieve Reuse, data should be Findable, Accessible and Interoperable. GNS Science is committed to making its data FAIR. We have assessed the FAIR compliance for datasets associated with GNS Science's eight Nationally Significant Collections and Databases (NSCD) as well as numerous high-value natural hazards datasets (NHDs), documented the process and created a roadmap to increase FAIR compliance.

The Findable dimension is largely met by GNS Science's Dataset Catalogue that links metadata to datasets. The metadata registered in the catalogue are harvested by other catalogues, registries and search engines. Findability has been further improved with the use of Digital Object Identifiers (DOIs).

The Accessible dimension requires data can be retrieved with commonly-used open and free protocols (http, ftp) employed by GNS Science.

The Interoperable dimension requires data to be open standard formats rather than proprietary formats. Where resources allow, GNS Science uses machine-readable formats and community accepted vocabularies.

The Reusable dimension requires data are richly described with metadata. GNS Science uses the ISO19115 metadata standard and requires metadata around provenance and licensing to be captured. For sensitive and restricted data, the conditions around access and reuse are clearly articulated through GNS Science metadata.

Available FAIR assessment tools have been adapted and used to evaluate FAIR compliance of these high-value geoscience datasets. In terms of average scores, the eight NSCDs are 92% Findable, 83% Accessible, 64% Interoperable and 70% Reusable, whereas the four NHDs are 77% Findable, 59% Accessible, 32% Interoperable and 48% Reusable. The differences between the dataset groups reflect a disparity in levels of funding support. There is potential for further improvement in FAIR compliance for all datasets.

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ORAL
Session 4a.

Palaeomagnetic records of the Laschamp and Mono Lake geomagnetic excursions from Tongariro, New Zealand

Adrija Mazumdar[1] and Gillian Turner[2]

[1] School of Geography, Environmental and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand
[2]School of Chemical and Physical Sciences, Victoria University of Wellington, Wellington, New Zealand

adrija.mazumdar@vuw.ac.nz

Palaeomagnetic records of the Mono Lake (MLE, ~33 ka) and Laschamp (LE, ~41 ka) geomagnetic excursions have been discovered in volcanic and sedimentary records globally, however records from the southern hemisphere are rare. This research aims to estimate the direction and intensity of characteristic remanent magnetization from 45 - 28 ka lavas from the Tongariro Volcanic Centre (TgVC) in the central North Island, addressing controversies regarding the age, duration, and global structure of the field, to understand features of excursions and the underlying geodynamo mechanism. This study combines existing data from the TgVC and the Auckland Volcanic Field (Cassata et al., 2008; Ingham et al., 2017) with data from two new sites on Mt Tongariro, dated by $^{40}Ar/^{39}Ar$ methods (Pure et al., 2020). New samples collected in December 2020 have been taken through progressive thermal demagnetization, with remanent magnetization and magnetic susceptibility measured at each step. The estimated palaeodirections are both of normal polarity, possibly indicating a recovered field post-MLE: Site LP151 (28.3±5.2 ka) has a direction with declination (D) = 7.2°, inclination (I) = -66.1° and α_{95} = 2.7° from 18 specimens. Site LP147 (30.1±6 ka) has a direction with D = 340.7°, I = -65.1° and α_{95} = 4.9° from 14 specimens. The direction vectors both differ significantly from the present-day field (D = 21.5°, I = -64.5°) and the field expected for a geocentric axial dipole (D = 0, I = -58.4°), indicating distinct, primary palaeodirections. Future work will analyse results from palaeointensity experiments to estimate the changes in field strength over the same period. Mapping of virtual geomagnetic pole positions for the MLE and LE suggests that the field evolved through complex non-dipole field configurations during both events, which will be further investigated with the addition of palaeointensity information.

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POSTER
Session 1a.

UNDERSTANDING THE CAUSES OF DROUGHT IN NEW ZEALAND: THE SKELETON LAKE RECORD OF HOLOCENE HYDROCLIMATE IN SOUTHERN NEW ZEALAND

<u>Laura McDonald</u>[1], Christopher M. Moy[1], Marcus Vandergoes[2], Bob Dagg[1] and the Lakes380 science team.

[1] *Geology Department, University of Otago*
[2] *GNS Science, Wellington*

lamcdonald89@gmail.com

Precipitation in southern New Zealand (NZ) is strongly modulated by the strength and latitudinal position of the Southern Hemisphere westerly winds (SWW). The instrumental record indicates that southward displacements of the winds are important in driving hydrologic deficit in southern NZ, but the magnitude and timing of Holocene variations are poorly constrained. We present a record from Skeleton Lake (SL) in Southland to investigate the climate drivers and history of late Holocene drought. Hyperspectral imaging, μ-XRF, physical property measurements, loss-on-ignition and pollen concentration data were used to identify downcore changes in sedimentary facies in littoral and depocenter cores. Principle component analysis was used to reduce the size of the data set and identify dominant trends. The combined data define facies related to shoreline proximity and are defined by lithogenic, aquatic-macrophyte and diatom abundance. The littoral core shows evidence of a lake level reduction from an interval with high lithogenic material and low organic material indicating close proximity to the shoreline. Two reductions in lake level are interpreted in the depocenter core from high aquatic-macrophyte abundances, indicating that the lake level dropped sufficiently that the depocenter was in the photic zone. The low-stands identified in SL broadly correspond with the timing of the Late Holocene Warm Dry Period (LHWDP) identified in southern Patagonian lakes from ~4000-2700 cal yr BP and also observed in Central Otago. The LHWDP is associated with a southward shift of the SWW and storm tracks that provide precipitation to southern NZ and Patagonia. The results from SL indicate a period of late Holocene hydrologic deficit is likely to have occurred across the southern mid-latitudes and the record provides important context for understanding instrumental records.

POSTER
Session 2c.

INVESTIGATING THE 2001 TAUPŌ FAULT BELT SEISMIC SWARM

Ross McGregor, Finnigan Illsley-Kemp and John Townend

School of Geography, Environment and Earth Science, Victoria University of Wellington, Wellington, New Zealand

ross.mcgregor@vuw.ac.nz

At Taupō volcano, the active magma reservoir and nearby Taupō Fault Belt (TFB) are both associated with high rates of microseismicity. In general, determining whether this seismicity is of magmatic or tectonic origin is challenging. However, one distinctive swarm of earthquakes, which occurred between January and June 2001, is spatially distinct from others in the instrumented area (Barker et al, 2020). This swarm occurred within the TFB and was originally attributed to motion on the Kaiapo fault, although no surface ruptures were identified (Peltier et al, 2009; Barker et al, 2020).

The 2001 swarm provides an opportunity to study tectonic faulting without the influence of a magmatic seismic signal and, fortuitously occurred while temporary seismic arrays were operating. Our results should help constrain the risk these faults pose to the nearby townships of Taupō and Kinloch as well as to the numerous geothermal and hydrothermal power plants in the vicinity.

We manually picked 529 earthquakes, occurring between January and June 2001, including all earthquakes larger than magnitude 1 reported by GeoNet. Using these events in template matched-filtering (Chamberlain et al, 2018), many other events were identified via cross-correlation. Focal mechanisms have also been constructed for some larger magnitude events, primarily yielding strike-slip solutions at this stage.

Our analysis of the temporary network data reveals substantially more earthquakes occurred than originally identified by GeoNet. Double-difference relocation of the events indicates they did not solely occur on the Kaiapo Fault and represent slip on multiple faults. Our results also display temporal variation, with increased activity at the end of February and April. These periods show swarm like characteristics, with events occurring within seconds of each other and no visible aftershock pattern. Possible interaction between the TFB and the magma reservoir on a local scale will be resolved through these results.

POSTER
Session 1c.

STRATIGRAPHY OF KARIOI STRATOVOLCANO, RAGLAN

<u>Oliver McLeod</u>[1], Roger Briggs[2] and Diane Bradshaw[3]

[1] *The MacDiarmid Institute, Victoria University of Wellington, Wellington, New Zealand*
[2] *School of Science, University of Waikato, Hamilton, New Zealand*
[3] *Stakeholder Relations Partner Iwi, GNS Science, Wairakei, New Zealand*

oliver.mcleod@vuw.ac.nz

Karioi maunga is the eroded remnant of a basaltic stratovolcano near the town of Raglan, on the North Island's west coast. The maunga is recognised by the Tainui people as the forlorn wife of Pirongia, another prominent volcano in the Alexandra Volcanic Group[1], who cast away the island of Karewa (an offshore tuff ring), and then lay down eternally as the *wahine moe* (sleeping woman).

The volcanic landscape of Karioi has been somewhat explored geologically[2,3] but never mapped beyond the formation level[4]. Due to severe coastal erosion, Karioi contains arguably the most complete cross section through a stratovolcano in Aotearoa, from pre-volcanic sediments to early phreatomagmatic deposits, sub-aerial shield lavas and later-stage pyroclastic stratocone(s) with exposed radial dykes. Karioi is also the largest *(intact)* intraplate volcano in the North Island, and one of only a handful of volcanoes globally to have erupted both intraplate and arc basalts concurrently from the same vent system. The volcano is therefore an insightful subject for detailed geological mapping.

The author presents the latest findings from a mapping campaign which encompasses 200 km^2 of the volcanic edifice, piedmont and surrounding (Okete) monogenetic volcanic field. An integrated stratigraphy is proposed to distinguish the various phases of shield, stratocone and monogenetic vent growth. The new map illustrates the fine-scale intercalation of intraplate and arc basalts throughout the volcanic succession, raising complications for the existing models of basalt petrogenesis in subduction environments. Furthermore, the map provides insights into the style, scale, timing, and tectonic influences of intraplate volcanism in the western North Island, which has migrated northward from Raglan to Auckland during the last 3 Myr.

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ORAL
Session 1a.

THE FIRST SEARCH FOR SEISMIC DEFORMATION OF THE HINUERA SURFACE, HAMILTON BASIN

George R. McQuillan[1], **Francesca Spinardi[1]**, **Vicki G. Moon[1]**, **Willem P. de Lange[1]**

[1]*School of Science/Te Aka Mātuatua, The University of Waikato, Hamilton, New Zealand*

gm32@students.waikato.ac.nz

Te Tātua o Wairere Fault Zone is a newly-recognised active fault zone of the Hamilton lowlands, with an approximately north-south strike that extends across south-eastern Hamilton City [1]. Fault deformation is recognised in stratigraphic units of the Hamilton Hills, where youngest offset has been observed in c. 50 ka tephra of the Hamilton Ash Formation. A key aspect in establishing most recent activity within the fault zone involves analysis of the geomorphically lower and stratigraphically younger Hinuera Surface, a c. 20–15 ka alluvial plain adjoining the hills [2]. The low-relief Hinuera Surface has been subject to intensive post-European settlement landscape modification, making the already difficult task of recognising seismic deformation even more problematic. We used extensive desktop study, including digital elevation models and historic aerial imagery, in conjunction with field reconnaissance and walkover surveys, to identify extremely subtle topographic indications of possible seismic influence in the Ruakura area, such as elevation breaks and paleochannel offsets. A number of electrical resistivity tomography (ERT) arrays were subsequently conducted across identified sites of interest, in order to establish a location in which to excavate a trench for paleoseismic analysis. Geomorphic indicators and ERT anomalies strongly suggest the presence of faulting in the Ruakura area but sediments underlying the Hinuera Surface are unconsolidated silts, sands, and gravels of the Hinuera Formation, which do not support development of a distinct, recognisable fault plane. A c. 30 m long x 3m deep trench opened on the AgResearch Ruakura Farm, c. 60m east of the Waikato Innovation Park campus, did not unearth direct evidence of a fault but did expose shallow paleoliquefaction and deformation structures which are interpreted as near-fault deformation, related to seismic activity within Te Tātua o Wairere Fault Zone <c. 15 ka.

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ORAL
Session 2a.

GENERATIVE ADVERSARIAL NETWORKS TO FORECAST DEBRIS AVALANCHE HAZARD

Stuart Mead[1], **Gabor Kereszturi**[1]

[1] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*

s.mead@massey.ac.nz

Numerical models of hazardous environmental flows are tools frequently applied to hazard and risk assessment, scenario modelling and understanding of the underlying processes. The complexity and level of detail in numerical models have increased as computational power has become more available as parallelism and new computational techniques have reduced the computational burden of numerical modelling. However simulations through these numerical models still pose a large computational challenge. This can limit the applicability of numerical models to probabilistic hazard assessment, where a large number of simulations are required to adequately sample the probability space, and for rapid hazard/crisis assessment where simulation results need to be generated at short lead times.

One approach to alleviating these limitations is through construction of a surrogate model. A surrogate (or metamodel) is a model of the simulation results within a defined parameter space. Surrogate models typically learn from simulation results to create a fast approximation to the numerical model. Here, we explore the use of neural networks as a surrogate model to generate debris avalanche footprints from Ruapehu volcano, New Zealand. Neural networks have shown promise for approximating Partial Differential Equations and may therefore produce a suitable trained surrogate model. A generative adversarial network (GAN) architecture is used as the surrogate, trained using depth-averaged debris avalanche simulation outputs.

Our trials of GANs as a surrogate highlight a few key points: (1) well-trained GAN surrogates have high accuracy in reproducing model footprints, (2) the surrogate GANs show better accuracy when constrained to groups with similar simulation inputs (i.e. it is not generalizable), and (3) different loss functions (mean-square error vs. mean absolute error) affect trainability and accuracy.

These results, and future perspectives on the use of GANs for hazard assessment will be highlighted.

POSTER
Session 4a.

COMPARISON OF VISUAL APPROACHES FOR DETERMINING PUMICE CONTENT OF TEPHRAS FOR GEOTECHNICAL INVESTIGATION

Richard A. Melchert[1], Jordanka Chaneva[1], Max O. Kluger[1], Vicki G. Moon[1] and David J. Lowe[1]

[1] *School of Science/Te Aka Mātuatua, University of Waikato, Hamilton, New Zealand*

ram49@students.waikato.ac.nz

Pumice content greatly impacts geotechnical properties of soil. Pumice particles have high void ratios in comparison to most hard-grained soils as a result of internal vesicles. The presence of pumiceous particles affects the crushability and compression characteristics of soil, which may impact their strength characteristics and liquefaction resistance. Geotechnical studies of glass-rich, pumiceous tephra soils are limited compared with those that investigated hard-grained quartzofeldspathic materials. A better understanding of how pumice content affects the geotechnical behaviour of pumiceous tephra is important in New Zealand because extensive infrastructure and dense population areas are located on pumiceous tephra soils. The focus of our study was to improve accuracy in determining pumice content in tephra layers that have been deposited in lake sediments in the Hamilton lowlands. Some of the tephra layers showed signs of paleoliquefaction and are composed of silts and well- and poorly sorted sands (see presentations by Chaneva et al. and Kluger et al.). Of the various methods for ascertaining pumice content, we focused on visual inspection methods examining SEM images. We looked at grain counting, point counting, and polygonization (total area of particles). The grain counting method uses the number of grains as a surrogate for the volume of the particles. This method is relatively fast but may produce unrepresentative estimates of the pumice content in poorly graded samples. Time and accuracy of the point counting method were both proportional to the resolution of the grid used, with higher grid resolutions producing estimates tending towards the actual (true) percentage of pumice in the image. The polygonization method produced accurate percentages of pumice particles for the images but is a time-consuming approach. We adopted the point counting method for our study and have plans to improve its efficacy.

POSTER
Session 3a.

USING SEISMOLOGY TO PROBE THE MODERN MAGMA RESERVOIR AT TAUPŌ VOLCANO

<u>Eleanor R.H. Mestel</u>[1], Finnigan Illsley-Kemp[1], Martha K. Savage[1], Colin J.N. Wilson[1] and Bubs Smith[2]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand*
[2] *Ngāti Tūwharetoa.*

eleanor.mestel@vuw.ac.nz

Taupō is an active rhyolitic caldera volcano that displays background seismicity and surface deformation, with periods of elevated unrest on roughly decadal timescales. Any resumption of eruptive activity at the volcano poses a major source of hazard, and interactions between the magma reservoir and the regional tectonics that lead to unrest and possible eruption are not well understood. The likely location of the modern reservoir has been constrained by study of past eruptive products and some geophysical imaging (gravity, broad-scale tomography). Earthquake patterns during the 2019 unrest episode have also been used to infer the location and size (>~250 km^3) of the modern-day magma reservoir, but its location and extent have not been directly imaged. As part of the ECLIPSE project, seismological methods are being used to investigate the Taupō reservoir, combining GeoNet data with records from the 13 broadband seismometer ECLISPE network. Development of the ECLIPSE network approximately doubles the number of seismic stations within 10 km of the lake shore.

We present here initial results on the characterisation of the seismicity in the Taupō region. These results include the improvement of earthquake locations with the addition of picks from the ECLIPSE stations and the use of automated machine learning phase picking and association techniques. We highlight results from the 3rd June 2021 M4.8 earthquake and its aftershocks. This earthquake was relatively large for the region and occurred southeast of the lake in an area where earthquakes have not often been observed. We also present initial results from the cross correlation of ambient noise between stations in the ECLIPSE network, with many of the station pairs crossing the region most likely to contain the modern-day magma reservoir. We observe clear changes in the seismic signals across this region, with strong attenuation in local earthquakes and cross-correlations across the caldera.

POSTER
Session 1a.

A PALEOSEISMIC INVESTIGATION OF THE LONG VALLEY FAULT, CENTRAL OTAGO

Fox Meyer[1] , Mark Stirling[1], Jonathan Griffin[1] and Ningsheng Wang[2]

[1] Department of Geology, University of Otago, Dunedin, New Zealand
[2] School of Geography, Environment and Earth Sciences, Victoria University, Wellington, New Zealand

meyai385@student.otago.ac.nz

This study represents the first paleoseismic survey of the Long Valley Fault, a 21 km reverse fault[1] located between Poolburn and Manorburn reservoirs in the Central Otago Range and Basin province. The prominent surface trace of the fault implies Holocene activity, and while Central Otago is defined as a low seismicity region, that does not mean that it is low risk [2.] An understanding of this fault is imperative for planning the Lake Onslow hydro-battery project, which is planned to lay atop the southern section of this fault. Long Valley Fault is 33 km northeast of Roxburgh and 27 km southeast of Alexandra. While this area is sparsely populated, the fault represents a hazard to several hydroelectric power stations built on the Clutha River. This study, the first of its kind on the Long Valley Fault, determined rupture characteristics by constructing a paleoseismic trench and applying Optically Stimulated Luminescence (OSL) dating to the exposed geometry. The trench exposed fractured schist thrust atop quaternary sediments. The geometry of this exposed fault indicated a single event displacement of between 1-2 meters, characteristic of other Central Otago reverse faults[2]. A slip rate of 0.06 mm/yr was calculated based on the oldest sediments in the trench, and OSL dating between colluvial wedges indicated a recurrence interval of 23.4 kyr. The rupture intensity of previous events, based on fault geometry, is approximately M_W 7.14. Three events were evidenced in the trench. Using OSL dating age constraints and OxCal analysis, the dates of these past ruptures were approximated to be 74.9, 33.4 and 14.5 kyr BP. However, Central Otago faults are prone to aperiodic behaviour[3]. These conclusions will enable seismic risk management of the Lake Onslow scheme and proximate hydroelectric stations.

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POSTER
Session 2a.

THE INTEGRATED HISTORY OF REPEATED CALDERA FORMATION AND INFILL AT THE OKATAINA VOLCANIC CENTRE: INSIGHTS FROM 3D GRAVITY AND MAGNETIC MODELS

Craig Miller, Jenny Barretto[2], Vaughan Stagpoole[2], Fabio Caratori-Tontini[3], Thomas Brakenrig[1] and Edward Bertrand[2]

[1] *GNS Science Wairakei Research Centre, Private Bag 2000, Taupo, New Zealand*
[2] *GNS Science, PO Box 30-368, Lower Hutt, New Zealand.*
[3] *University of Genoa, Department of Earth Sciences, Environment and Life (DISTAV), viale Benedetto XV 5, 16132, Genova, Italy*

c.miller@gns.cri.nz

Multistage collapse caldera create complex geological structures that are often buried by kilometers of infill, making study of their origins difficult from outcrop alone. Here we present new gravity and aeromagnetic data compilations derived from terrestrial, lake and airborne surveys to investigate the buried internal structure of the Okataina Volcanic Centre (OVC) and interpret its stages of development. Magnetic highs (1300 nT) are caused by a combination of thick lava flows and domes that infill the collapse structures, as well as deeper feeder structures/dyke complexes that extend below the basement to at least 6 km depth. Several large rhyolite flows are conspicuously non-magnetic and create negative residual anomalies that we interpret to relate to their magnetic mineral deficient nature, rather than hydrothermal alteration. Hydrothermal alteration is limited to topographically low areas near the topographic collapse margins suggesting fluid circulation within the caldera exploits shallow structures.

The gravity data show a -62 mGal residual gravity low associated with the OVC, with the steepest gradients occurring inside the topographic margins. The gradient of the gravity low is stepped towards its lowest point near the outlet of Lake Tarawera. Each step is interpreted as relating to the buried structural collapse margins of the Utu, Matahina and Rotoiti catastrophic caldera forming eruptions, creating a nested caldera structure. Buried caldera margins associated with oldest Utu/Matahina eruptions may play a role in the location of the youngest Tarawera eruptions. We propose smaller amplitude gravity lows that extend outside the topographic margins of the caldera are related to lateral magma migration to the south-west, towards eruption vents within the caldera. 3D gravity inversion, including models numerically constrained by a 3D magnetotelluric model, suggest a caldera depth of 5000±500 m that accumulated over at least 3 collapse episodes along with rifting induced subsidence in the past 550 ka.

POSTER
Session 1a.

USING TEPHRA RECORDS TO UNDERSTAND STRATOVOLCANO RESPONSE TO EDIFICE COLLAPSE

Shannen Mills[1], Jonathan Procter[1], Anke Zernack[1], Gabor Kereszturi[1], Stuart Mead[1], Georg Zellmer[1], Shane Cronin[2] and Ian Schipper[3]

[1] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*
[2] *School of Environment, University of Auckland, 23 Symonds Street, Auckland Central*
[3] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington*

s.mills@massey.ac.nz

Edifice failures are common phenomena at stratovolcanoes around the world and represent a major hazard with the resulting debris-avalanche deposits (DAD) burying the surrounding landscape. These large collapse events also dramatically modify the morphology of the edifice, thus influencing the shallow volcanic plumbing system and characteristics of the conduit. Changes of the edifice morphology are reflected in different eruption styles, and variations in textural, sedimentological, and lithological characteristics of deposits produced before and after collapse.

Mount Taranaki has experienced at least 14 major edifice failures throughout its eruptive history, providing a unique opportunity to study pre- and post-collapse changes in volcanic activity. This study is focused on the record from 20-30,000 years ago which includes two DADs, the 27.3 ka Ngaere (5.85 km^3) and the 24.8 ka Pungarehu Formation (7.5 km^3). This period was also characterised by increased explosive activity that emplaced multiple tephra layers in the southeastern to southwestern sector of the ring plain, forming the Poto and Paetahi tephra formations.

Field work across the ring plain has identified 28 tephra layers within these two formations with variations in grainsize, thickness and componentry reflecting changes in eruption style and revealing several large explosive events. Variably thick interbedded soil layers represent time breaks between eruptions. Observed variations in pumice density and bubble textures derived from initial density and synchrotron analysis of clasts from the different layers furthermore suggest changes in conduit process, and column stability throughout the sequence.

So far, this study has shown that Mt. Taranaki experienced an increase in explosive activity during the regrowth phase between and following major collapse events. Together with ongoing geochemical work focused on characterising the magmatic response of the shallow plumbing system, this study will improve our understanding of how the hazards at Mt. Taranaki change in relation to edifice growth and collapse.

ORAL
Session 1a.

HIGH-RESOLUTION, MULTIVARIATE 2D AND 3D COMPOSITIONAL METHOD FOR ASSESSMENT OF GRAIN-SIZE & FACIES ORGANISATION IN A LANDSLIDE-IMPACTED RIVER SYSTEM

Charlotte Milne[1], Jon Tunnicliffe[1]

[1] *School of Environment, The University of Auckland, Auckland, New Zealand*

cmil137@aucklanduni.ac.nz

Effective measurement of gravel-bed surface grain-size and facies organisation is important when understanding river systems undergoing disturbance such as pulsed sediment delivery from disturbance upstream. In recent years the use of high-resolution unmanned aerial vehicle (UAV)-based imagery for assessing grain-distribution of gravel surfaces has grown in popularity. Similarly, the use of Structure from Motion (SfM) 3D modelling for creating elevation models and capturing roughness information has allowed further extraction of textural information. Here we present a novel combination of photogrammetry and tool-assisted methods that provide improved estimation of grain-size and surface facies mapping. Three repeat surveys were made between July and September of 2019 in the Hapuku River, assessing the rapidly changing gravel-bed texture in the course of an aggradation sequence, due to the propagation of a sediment wave through the system following the 7.8 Mw 2016 Kaikōura earthquake.

UAVs were used to capture high resolution images of a 500m by 100m site of active aggradation. SfM 3D modelling was then employed to create high resolution (<4mm) orthomosaics of the riverbed. Purinton & Bookhagen's (2019) edge-detection tool, PebbleCountsAuto was used to semi-automatically detect the *b*-axis size of individual clasts exposed on the stream bed, while roughness was extracted using CloudCompare's roughness tool. A high-resolution timeseries of change was collected, consisting of SfM 3D model outputs, grainsize tools and roughness mapping. On average approximately 30'000 grains were counted per survey, far more than could be sampled using traditional surface sampling methods. Results showed grain-size estimation findings matched ground-truth validation data at the 95% confidence interval. Final grain-size results showed that D_{50} and D_{84} percentiles decreased by 6.7% and 10.1% respectively between July and September 2019, as the proportion of new wave material increased. Similarly high-resolution facies mapping allowed the analysis of process-form relationships and revealed a surface proportional increase of 17% of the aggrading unit representing wave material arrival.

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ORAL
Session 4c.

CLIMATE RECONSTRUCTIONS FOR THE LAST GLACIAL MAXIMUM FROM A SIMPLE CIRQUE GLACIER IN FIORDLAND, NEW ZEALAND

Emily M.M. Moore[1,2], Shaun R. Eaves[1,2], Kevin P. Norton[2], Andrew N. Mackintosh[3], Brian M. Anderson[1], Lisa H. Dowling[4], Alan J. Hidy[5]

[1]Antarctic Research Centre, Victoria University of Wellington, New Zealand
[2]School of Geography Environment and Earth Sciences, Victoria University of Wellington, New Zealand
[3]School of Earth, Atmosphere and Environment, Monash University, Clayton, Australia
[4]GNS Science, National Isotope Centre, Lower Hutt, Wellington, New Zealand
[5]Lawrence-Livermore National Laboratory, California, USA.

shaun.eaves@vuw.ac.nz

Mountain glacier records offer important constraints on the timing and magnitude of climate variability during the last glacial cycle. Existing moraine chronologies from the central Southern Alps indicate maximum ice extent was achieved during marine isotope stage 3-4, followed by repeated advances of similar, but gradually declining extent during marine isotope stage 2, until onset of the glacial termination. Questions remain over the precise role of climate in driving these changes, as most existing moraine chronologies come from large, complex former valley glacier systems, where non-climatic influences such as changing bed topography and proglacial lake formation may have influenced glacier length changes. Here we address this problem via a new cosmogenic ^{10}Be chronology and equilibrium line altitude reconstruction from a cirque glacier situated in Fiordland, New Zealand. Our chronology shows moraine deposition at 32 ± 11 ka, 18.7 ± 0.3 ka, 18.1 ± 0.2 ka, and c. 17.2 ± 0.3 ka. The simple geometry of the former glacier supports the role of climate in driving a net decline of regional ice volume during marine isotope stages 3-2. Close spacing and good preservation of the 19-17 ka moraines permits 2D glacier reconstruction which suggests the equilibrium line altitude remained depressed by c.1130 m (equivalent to 5.8 ± 0.6°C colder than present) during this interval. Onset of warming after 17.2 ± 0.3 ka is consistent with climate proxy evidence for a sustained southward shift in the southern westerly winds, which may have promoted deglaciation via shifting ocean currents and promoting increases in atmospheric carbon dioxide.

ORAL
Session 2c.

HIGH-TEMPERATURE OXIDATION OF THE PYROCLASTS IN THE PROXIMAL 1886 TARAWERA DEPOSITS, NEW ZEALAND

Hannah C Moore[1], Rebecca J Carey[1], Bruce F Houghton[2], Martin Jutzeler[1] and James D L White[3]

[1] *Centre for Ore Deposit and Earth Sciences, School of Natural Sciences, University of Tasmania, Hobart, Australia*
[2] *Department of Geology and Geophysics, University of Hawai'i, Honolulu, United States*
[3] *Geology Department, University of Otago, Dunedin, 9054, New Zealand*

Hannah.Moore@utas.edu.au

Microlite crystallization in pyroclasts can occur in the conduit, in flight, or in situ after deposition. Distinguishing products of primary vs. post-depositional crystallization can be challenging in near-vent environments. Here we examine pyroclasts from the 1886 basaltic Plinian eruption of Tarawera volcano, New Zealand, to assess how heat in the ultraproximal deposits affected microlite growth and subsolidus mineral transformations. Scoria and ash pyroclasts were selected from (a) an ultraproximal section (T47), <100 m from vent, dominated by clasts from the jet and Plinian column margin, and (b) a medial fall deposit section (T43), 2.5 km from the fissure. Groundmass crystallinities contrast between sections, from high (94–100 % void-free corrected; VFC) in T47 pyroclasts to intermediate (75–84 % VFC) in T43 pyroclasts. We infer that extensive crystallization, particularly of Fe–Ti oxide microlites, and subsolidus modification of olivine occurred after deposition. Short pyroclast transport times, relatively coarse ejecta, high accumulation rates, intense vent-derived heat, and the movement of hot gases through the deposits favored post-deposition modification of primary eruptive textures. We recommend against use of (ultra)proximal pyroclasts microtextures to infer conduit conditions, unless no medial and/or distal pyroclasts are available.

POSTER
Session 1a.

THE LANDSCAPE EVOLUTION WITHIN A CONFINED ACTIVE DISTAL RING PLAIN ENVIRONMENT, CENTRAL NORTH ISLAND

Michael Morgan[1], Jonathan Procter[1]

[1] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*

michaelateamorgan@gmail.com

The Upper Whanganui River catchment between Aukopae and the Central Plateau contains a ~340 ka record of volcanism within an fluvially active, evolving catchment. A combination of volcanism, tectonism and changing climate have caused significant change within the system. From previous studies, both the Whakapapa and Whanganui Rivers have had periods of mass flow activity, sourced from the Tongariro Volcanic Centre (TgVC), however the influence on this system by external factors such as climate and tectonism have not been explored. In addition to this, the region has been subjected to several large rhyolitic eruptions by the proximal Taupo Volcanic Zone (TVZ), of which the larger events are known to be landscape altering events. The full extent of the influence of the rhyolitic products was unknown, along with the respective deposit's spatial distribution and preservation. Extensive mapping shows that volcanic activity and faulting are the major contributors to the morphology and sediment production in the catchment. Movement along the National Park and Raurimu Fault systems has resulted in the abandonment of the oldest observed volcaniclastic surfaces, with the lower surface controlled by a combination of volcaniclastic sediment influx and climactic influence on the volcanic edifices, thus the resulting are formed as a result of combined volcaniclastic and epiclastic deposits. Ruapehu Volcano is the most productive volcano with regards to sediment into the system, with Tongariro observed to contributing minimally. The TVZ caldera forming events have caused significant system resets; the Whakamaru ignimbrite is preserved as inverted valleys, with the modern fluvial systems incising into the softer country rock. The Oruanui ignimbrite caused significant valley infill via reworked ignimbrite and tephra deposits occurring within the active channels immediately after the event. The 232 AD Taupo event again caused a significant disturbance to the system, infilling and resetting the channel levels within the current bounds of the modern river valley and causing rerouting of entire systems. Significant rapid, reworking and remobilization of the deposits occurred resulting a range of complex sedimentary structures.

POSTER
Session 1a.

PALEOTEMPERATURES IN PATAGONIA DURING THE ANTARCTIC COLD REVERSAL DETERMINED BY GLACIAL MODELING

Ruby Muir[1], Shaun Eaves[1], Lauren Vargo[1], Brian Anderson[1]

[1] *Antarctic Research Centre, Victoria University Wellington, New Zealand*

ruby.muir@vuw.ac.nz

Reconstructing paleoclimate is the key to understanding Earth's climate system and future climate change. Here, we apply a coupled glacier mass balance–ice flow model to reconstruct paleoclimate in Patagonia during the Antarctic Cold Reversal (14.6–12.8 ka). The ACR was a period of rapid, non-linear climate change hypothesised to have been driven by interconnected climate processes which parallel those associated with anthropogenic climate change.

Applying climate driven glacier models to recreate past ice extents as delineated by dated moraines is powerful tool to reconstruct quantitative, localised paleotemperatures. Improvements in gridded global climate datasets combined with recent developments in remote sensing of the world's glaciers has opened the opportunity for extensive paleo-reconstruction not limited by access for climate or glacier monitoring. However, there remains an outstanding question as to how accurate and reliable reconstructions using only distally developed datasets can be.

Using a positive degree day mass balance model coupled with a 2D ice flow model, gridded precipitation and temperature datasets and model parameters are tuned to recreate glacier thickness, extent, and 21st century thickness change as described in recent global remote sensing derived datasets (Farinotti et al., 2019; Hugonnet et al., 2021). We then alter temperature and precipitation to provide quantitative constraint of the envelopes of past climate change during the ACR; our results show significant cooling in South America during this period that aligns with New Zealand glacier-based reconstructions. Finally, we assess how error and uncertainty in all the above parameters impact the paleotemperature reconstructions. Thus, we establish and evaluate a methodology to produce consistent paleoclimate reconstructions using globally distributed mountain glaciers in the absence of local data.

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POSTER
Session 2c.

SUBMARINE VOLCANIC ERUPTIONS ARE IMPLOSIVE

Arran P. Murch[1,2], Ryan Portner[1], Ken Rubin[3], and David Clague[4]

[1] Geology Department, San Jose State University, San Jose, California 95192, USA
[2] Department of Geology and Paleontology, National Museum of Nature and Science, Tsukuba, Japan
[3] Department of Earth Sciences, University of Hawai'i at Mānoa, Honolulu, HI, United States
[4] Monterey Bay Aquarium Research Institute, Moss Landing, California 95039, USA

Arranmurch@googlemail.com

Compared to their subaerial counterparts, submarine eruptions remain enigmatic and poorly understood, a result of the lack of direct observations and difficulty recreating ambient conditions in the lab. Here we use video from eruptive activity at 1200 m water depth at West Mata seamount in 2009, one of two deep subaqueous eruptions to have ever been observed, to investigate a distinct eruptive style termed *bubble escape activity*, characterized by the ascent and implosion of 0.5 to 1 m vapor bubbles.

Bubble escape activity occurs in three stages defined by changing volatile and lava behavior. In Stage 1 the vapor bubble ascends through a magma filled conduit driving ductile deformation of the lava at the vent. The high ambient pressure at West Mata seamount means the vapor bubble undergoes negligible expansion during conduit ascent. In Stage 2 ductile fragmentation of lava overlying the vapor bubble occurs, driven by the bubble's buoyant ascent. This brings the vapor bubble into direct contact with the ambient water. In Stage 3 rapid heat transfer from the vapor to ambient water drives bubble implosion through condensation and contraction of the volatile phase.

Implosions during bubble escape activity are a key but heretofore overlooked component of subaqueous eruptions. Vapor implosion is driven by rapid heat transfer to the ambient environment and is therefore pressure independent suggesting implosions are an important part of both pyroclastic and effusive eruptions across the entire ocean depth range. The implications of this study are of fundamental importance for how we think about, and monitor subaqueous eruptions in the future.

ORAL
Session 1a.

HOW DO FAULT SURFACE RUPTURES INFLUENCE FLOODING HAZARDS? INVESTIGATING AND MODELLING FAULT-RUPTURE INDUCED RIVER AVULSIONS (F.I.R.A)

Erin Murray[1], Timothy Stahl[1] and Andrew Howell[1,2]

[1]School of Earth and Environment, University of Canterbury, Christchurch, New Zealand
[2] GNS Science, Wellington, New Zealand

erin.murray@pg.canterbury.ac.nz

The surface rupture of the Papatea fault in the 2016 Kaikōura earthquake caused near-instant avulsion of the Waiau Toa / Clarence River into a new course. Here, we used pre-and-post event lidar and aerial imagery, 2D hydrodynamic modelling in HEC-RAS, and a newly developed synthetic fault scarp generator to investigate the sensitivity of the coseismic flooding to different hydraulic and tectonic inputs. In our calibration model, we used flow rates measured one hour prior to the 2016 earthquake and a post-event, natural fault scarp Digital Elevation Model (DEM) upon which hydraulic calculations were performed. The calibration model produced a >90% spatial accuracy of flooding when compared to aerial imagery taken the day following the avulsion. We ran subsequent models using a pre-event DEM manipulated with a synthetic fault scarp bearing the same general characteristics as the Papatea fault. The synthetic scarp model responded in a remarkably similar manner to the post-event calibration model, confirming that with some knowledge regarding the flow regime, fault kinematics, and single event displacements, the extent of flooding could have been forecast prior to the event. The accuracy of the preliminary synthetic scarp model opens the door for future hazard and risk assessments to be completed in the over 400 locations where faults and rivers intersect in New Zealand. We present preliminary findings of applying this workflow to future fault-rupture induced avulsions (FIRA), including where the Wellington Fault and the Te Awa Kairangi / Hutt River intersect multiple times in densely populated areas.

POSTER
Session 2a.

Calibration Of Organic Biomarkers As Paleoenvironmental Indicators In New Zealand Lakes

Sebastian Naeher[1], David Naafs[2], Marcus Vandergoes[1], Susie Wood[3], Jonathan Puddick[3], John Pearman[3], Christopher Moy[4], Andrew Rees[5], Lizette Reyes[1] and the Lakes380 team

[1] *GNS Science, Lower Hutt, New Zealand*
[2] *University of Bristol, Bristol, United Kingdom*
[3] *Cawthron Institute, Nelson, New Zealand*
[4] *University of Otago, Dunedin, New Zealand*
[5] *Victoria University of Wellington, Wellington, New Zealand*

s.naeher@gns.cri.nz

Lipid biomarkers (molecular fossils) are biomolecules originating from specific source organisms. They are preserved in soils, sediments, sedimentary rocks, and petroleum, where they can be used for environmental and climatic reconstructions.

One of the most common applications is their use as paleotemperature indicators in aquatic and terrestrial environments. Glycerol dialkyl glycerol tetraethers (GDGTs), which originate from archaea and bacteria, are widely used as indicators of air and water temperature. Based on the observed relation between GDGT composition in lake sediments and monitoring data, global and regional transfer functions to reconstruct mean air and water temperatures have been developed and widely applied to reconstruct climate across the Cenozoic. However, many challenges remain, including a general absence of samples from New Zealand in global calibration studies.

The MBIE Endeavour funded “Lakes380 - Our lakes' health: past, present, future” research programme provides the unique opportunity to:

1) establish an improved Aotearoa specific temperature calibration of GDGTs and other temperature indicators from lake sediments representative of all regions of Aotearoa;
2) to determine environmental factors that may limit the widespread application of the new temperature calibrations, which may result from particular lake conditions or characteristics;
3) to apply existing and develop new biomarker tracers of water quality and ecosystem changes for our lakes.

In this presentation we highlight the new insights that biomarkers preserved in lake sediments can provide to better understand past, present and future changes of our lakes and Aotearoa’s environment.

ORAL
Session 4e.

GEONET'S STRONG MOTION NETWORK: 20 YEARS OF SEISMIC DATA, PRODUCTS AND SERVICE

Muriel Naguit[1], John Young[1] and Jerome Salichon[1]

[1] *GNS Science, 1 Fairway Drive, Avalon, Lower Hutt, New Zealand*

m.naguit@gns.cri.nz,
j.young@gns.cri.nz
j.salichon@gns.cri.nz

Seismic strong motion data is a core component in fields of Seismology and Earthquake Engineering. Since GeoNet came into being on July 2001, this non-profit project improved the strong motion data as one of its base products and service for end-users including engineers, seismologists, seismic risk & hazard specialists and urban planners.

GeoNet operates under the Natural Hazards Division of GNS Science and is primarily funded by the New Zealand Earthquake Commission (EQC). With highly-integrated system, GeoNet offers data collection and processing, real-time monitoring, rapid response and event analysis for various natural hazards –earthquake being the main item. GeoNet's network of over 315 strong motion stations situated strategically in New Zealand generates an ensemble of data products available within minutes of an earthquake – thanks to the real-time transmission of continuous data streams and near-real time data processing and accessibility.

Over the span of 20 years, the strong motion data grows dramatically along with denser networks, upgraded data transmission and better instrumentation. The advent of new technology makes large databases more dynamic and accessible, even supported by webservices to access seismic waveforms, metadata and catalogues in a robust and rapid fashion. The GeoNet strong motion network supports free-field and the NZ widespread locality, where strong motion instruments complement the weak motion instruments for rapid ground motion assessment and near-event source information. There are also 20 structural array sites in selected buildings and bridges that support earthquake engineering initiatives in improving NZ seismic design and in the upgrade of structural mitigation measures. At present, the GeoNet project along with teams of specialists, continuously cater to the requirements of its end-users to offer quality products and support services.

POSTER
Session 3b.

THE COLLABORATION OF MĀTAURANGA MĀORI AND GEOEDUCATION: AN EXAMPLE FROM TĀTAIHIA TE PARATAIAO O TE WAHAPŪ – HOKIANGA HARBOUR SEDIMENTATION PROJECT

Shontelle Nahona[1,2], Chris J. Hollis[2], Kyle J. Bland[1], Kate J. Clark[1],

[1] GNS Science, PO Box 30368, Lower Hutt 5040, New Zealand
[2] Victoria University of Wellington, Wellington, New Zealand

nahonash@outlook.com

Mātauranga Māori, being a large system of knowledge collected through generations of Māori tūpuna (ancestors), provides a rich and valuable kete of observations that can be applied to many geoscience and environmental issues. However, low numbers of Māori actively play a role in the Earth Sciences and paleontology research. This raises an important question of how can we connect rangatahi with the geosciences and better foster the integration of Mātauranga Māori and participation with Earth science?

In partnership with Te Rarawa iwi, GNS has begun characterizing the drivers of environmental change within Hokianga-Nui-a-Kupe (Hokianga Harbour) using a suite of sediment cores. As part of the project, we have developed creative "game-playing" resources to help communicate the scientific process. We aim to show that 'science' really isn't that hard, especially to those students who dismiss science because it is difficult to understand in its conventional delivery format.

Using the salinity and water-depth preferences of benthic foraminifera as a basis, a 'battle-card' game was developed. This battle occurs in the setting of Hokianga Harbour; as the game plays out there are 5 different salinity and water-depth sites placed along the harbour. Rangatahi are armed with 5 randomly drawn foraminifera species cards and must pick the best foraminifera card from their hand that would win at each given site. The groups with the most cards at the end wins!

This resource was first tested on >60 high school-aged Māori rangatahi at a marae-based Noho Taiao in Pawarenga (Northland), and then subsequently played with two other groups. Feedback from participants has shown that innovative, hands-on, fun and competitive approaches such as Battle of the Forams, can help players understand complex scientific concepts, whilst learning in a Te Ao Māori-centric environment. We are currently developing an "Amazing Race"-based game to continue this initiative.

POSTER
Session 3e.

VOLCANIC GEOHERITAGE IN THE LIGHT OF VOLCANO GEOLOGY

Károly Németh[1]

[1] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*

k.nemeth@massey.ac.nz

Volcanic geoheritage relates to the geological features of a region that are associated with the formation of a volcanic terrain in diverse geoenvironmental conditions. These features include the volcanic processes, volcanic landforms and/or the eruptive products of volcanism that form the geological architecture of that region. Volcanic geoheritage is expressed through the landscape and how it forms and evolves through volcanic processes on various spatio-temporal scales. In this sense it is directly linked to the processes of how magma released, transported to the surface and fragmented, the styles of eruption and accumulation of the eruptive products. Volcanic geoheritage is directly linked to the natural processes that generated them. Geocultural aspects are treated separately through volcanic geosite identification and their valorization stages. Identification of volcanic geosites, based on various valorization techniques, have been applied successfully in the past decades to many geological heritage elements. Volcanism directly impacts societal, cultural, and traditional development of communities, hence the "living with volcanoes" concept and indigenous aspects and knowledge about volcanism can and should play important roles in these valorization methods through co-development, transdisciplinary approaches by including interconnected scientists in discussions with local communities. Elements of volcanism and volcanic geoheritage benefit of the geoculture of society so volcanic geoheritage sites are ideal locations for community geoeducation where resilience toward volcanic hazard could be explored and applied more effectively than it is done today. Geoparks within volcanic terrains or volcanism-influenced regions should be the flagship conservation, education and tourism sites for this message. Volcanism can be an integral part of processes operating in sedimentary basins. Here volcanic eruptive products and volcanic processes contribute to the sediment fill and geological features that characterize the geoheritage of that region.

ORAL
Session 3c.

DETERMINING MECHANICAL AND TEXTURAL PROPERTIES OF DIGITATE SINTER FROM THE TAUPŌ VOLCANIC ZONE

<u>Ema E Nersezova</u>[1], Michael C Rowe[1] and Kathleen A Campbell[1]

[1]School of Environment, University of Auckland, Auckland, New Zealand.

ener055@aucklanduni.ac.nz

In 2007, Mars rover Spirit detected opaline silica deposits near sulphate-rich soils, adjacent to volcanic feature Home Plate, on Mars[1]. Deposition of opaline silica, interpreted as siliceous sinter, in a volcanic setting is strong evidence for an ancient hydrothermal system in this area, implying the existence of past aqueous and potentially habitable environments on Mars[2]. The deposits found on Mars are remarkably texturally similar to digitate sinter structures found in the Taupō Volcanic Zone (TVZ), New Zealand. As biogenic activity is a requirement for producing textures seen in modern sinters[3], this suggests that microbial life may be involved in the formation of the Mars deposits and still be fossilised within. Potential sample return from Mars thus justifies the study of terrestrial analogues, like the TVZ.

Within the context of sample return logistics, it is important we have a firm understanding of mechanical properties of the materials we target. Thus, we investigate the relationship between hardness and porosity of sinters from 6 hot springs in the TVZ. We selected sinters for analysis that represent different textures, hot spring fluid chemistries, and hardness properties so as to have a wide range of results to compare. Micro-computed tomography (micro-CT) scans were taken of a micro-stromatolite from each sinter deposit, recreating a virtual 3D model of the sample which will be further analysed to determine porosity. This will be correlated with hardness, as determined from nanoindentation hardness testing of samples from each sinter. Results from micro-CT indicate a range of textures and porosities within the sinter deposits, and early nanoindentation results show variation in hardness that can be attributed to mineralogical heterogeneity. We hope to produce a mechanical characterisation of modern TVZ sinter deposits such that the results would be relevant to designing sampling mechanisms in future Mars explorations.

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POSTER
Session 4d.

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DEVELOPING A PALAEO-RECONSTRUCTION OF DEEP-SEATED, SLOW MOVING LANDSLIDES IN THE WHANGANUI BASIN

Ella Nisbet[1], Sam McColl[1], Forrest Williams[1], Kat Holt[1], Ian Fuller[1], Andrew Neverman[2], Alan Palmer[1]

[1] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*
[2] *Manaaki Whenua - Landcare Research, Palmerston North, New Zealand*

e.e.nisbet@massey.ac.nz

Landslides are a major hazard and a key agent of hillslope erosion and sediment generation in Aotearoa New Zealand (Crozier, 2010, Dymond et al., 2016, Eyles, 1983, Smith et al., 2021). Large, deep-seated landslides are a common landscape feature in the Neogene soft-rock hill country of the Whanganui Basin in the North Island, Aotearoa. These landslides are typically slow-moving, however, cumulative displacement means that they can still cause extensive damage to infrastructure, and they can also fail rapidly and catastrophically.

To date, the palaeo-landslide activity and controls are poorly understood. This research seeks to assess how the frequency and movement patterns of landslides in the Whanganui Basin have changed over time, and determine the responsible processes (e.g. can the palaeo-landslide activity be attributed to climate forcing of fluvial incision, major earthquakes, or forest clearance)? Evaluating long-term patterns of landslide activity will contextualize modern day movement rates and activity, and allow for the development of improved hazard mitigation and response plans.

We present an innovative morphometric landslide dating approach, that combines absolute age data with high-resolution DSM data will be developed to create a landslide age map. Absolute age dating data from radiocarbon analysis will be achieved by taking sediment cores from lakes on selected landslides. Preliminary results from two sediment cores taken from the Torere landslide (on the western bank of the Moawhango River) place the age of the landslide around the late Holocene. These data will be used to calibrate relative landslide ages assessed from morphometric indices. Morphometric indices, to be calculated from 1-m DSM data, will include surface roughness, slope angle, curvature, and drainage network development. We can use this data to identify spatio-temporal patterns in landslide activity and assess landslide causes.

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POSTER
Session 2b.

IMPORTANCE OF NEAR-BED LATERAL PROCESSES IN BIOGENIC FLUXES TO THE SEAFLOOR IN AOTEAROA NEW ZEALAND DEEP-WATER ENVIRONMENTS

Scott D. Nodder[1], Matt Pinkerton[1], Malcolm R. Clark[1], Kate L. Maier[1], Jessica V. Wilks[2], Andrés S. Rigual-Hernández[3] and Gerard C. A. Duineveld[4]

[1] National Institute of Water & Atmospheric Research (NIWA), Wellington, Aotearoa New Zealand.
[2] Department of Biological Sciences, Macquarie University, North Ryde, NSW, Australia.
[3] Department of Geology, Universidad de Salamanca, Salamanca 37008, Spain.
[4] Royal Netherlands Institute for Sea Research (NIOZ), Texel, The Netherlands.

scott.nodder@niwa.co.nz

Vertical fluxes of biogenic carbon, nitrogen, silica and carbonate are key components of elemental and biogeochemical cycles in the ocean. Global models of vertical particle flux generally assume a power law relationship whereby organic fluxes reduce exponentially with increasing depth. In many deep-sea environments, however, where fluxes have been measured simultaneously in the water column and near-seabed, it is apparent that such simplistic models do not always hold, with deeper fluxes often higher than or asynchronous with near-surface fluxes. The main causes of increasing flux with water depth are inferred to be the wider particle source area of deeper traps, mid-water particle scavenging and repackaging, especially by zooplankton, and lateral inputs of advected material.

In the Aotearoa New Zealand region, particle flux experiments in subtropical (STW), subantarctic (SAW) and Subtropical Frontal Zone (STFZ) waters commonly display such features. Higher near-bed fluxes at upper to lower bathyal depths are observed in STW and SAW, east of New Zealand, with the organic carbon flux contributions from deeper traps effectively alleviating postulated deficits in the annual energy demands of deep-sea benthic communities. Coastal benthic diatoms, conspicuous in fluxes within northern STFZ waters on the Chatham Rise, indicate that biogenic materials can be transported as much as 400 km away from their original loci. On the crest of the rise and in Kaikōura Canyon, fluxes measured at 15 m above the seafloor can be up to an order of magnitude lower than those measured at 2 m above the seafloor due to localised anthropogenic seabed disturbances, highlighting the importance of near-bed fluxes in elemental cycling and benthic remineralisation processes.

These observations raise doubts about the robustness of globally applied flux models to the region, especially if these are not locally validated with sediment trap field data, and also have implications for regional paleoenvironmental reconstructions.

ORAL
Session 2e.

MONITORING OF VOLCANIC ACTIVITIES IN NZ

Luana F.N. Alves[1]

[1] GNS science, GeoNet, Wellington, New Zealand

l.alves@gns.cri.nz

GeoNet is a collaboration between the Earthquake Commission and **GNS** Science. It is funded by the New Zealand Government to provide national coverage for hazard detection, emergency response, and to increase the quality, applicability and confidence limits of hazard research. There are currently 12 active volcanic areas in New Zealand. The probability of an eruption affecting a large area is relatively low, although New Zealand needs to be prepared for a range of volcanic eruption styles. GeoNet maintains permanent surveillance (24/7) at active and potentially active volcanoes, monitoring natural hazards and delivering rapid response to events.

GeoNet produces New Zealand's volcanic alert bulletins with information about the volcanic alert levels and monitors for signs of volcanic unrest such as earthquake activity and gas release. They are constantly designing systems for volcano surveillance using techniques in seismology, geodesy, chemistry and remote sensing and conducting eruption monitoring to provide vital information on local and regional dangers and impacts.

Monitoring is currently being undertaken at active volcanoes including Raoul Island, White Island, Tongariro, Ngauruhoe, and Ruapehu. Geothermal sites with volcanic signatures are also monitored, including, Rotorua, Tiketere, Waiotapu, Rotoma, Rotomahana, Tokaanu, Kawerau, Broadlands, Ngatamariki, Tauhara, Wairakei, and Rotokawa.

At the GNS volcanic gas lab, we monitor volcanic activities through gas and water chemistry by utilising several analytical methodologies such as:

• **Gas Chromatography analysis** (He, H_2, Ar, O_2, N_2, CH_4, CO, CH_4, Hydrocarbons),

• **Classical chemical analysis** (NH_3, H_2S, CO_2, I_2, $BaSO_4$),

• **Ion Chromatography analysis** (Anions and Cations).

Gas and water chemistry directly relate to the amount and location of magma inside a volcano. The analytical results are reported to the Volcanology Team and GEONET. This contributes to identifying the state of volcanic activity (alongside seismic, geodetic data, remote sensing, and visual observations).

POSTER
Session 2a.

NUMERICAL SIMULATION OF METHANE PRODUCTION FROM AN INTERBEDDED GAS HYDRATE RESERVOIR IN THE SOUTHERN END OF THE HIKURANGI MARGIN OF NEW ZEALAND.

P.A Oluwunmi[1]*, I.Pecher[1], R.Archer[2], M.Reagan[3], G.Moridis[3], Gareth Crutchley[4], Mac Beggs[5], Brett Rogers[5].

1 School of Environment, University of Auckland, New Zealand;
2 Department of Engineering Science, University of Auckland, New Zealand;
3 Earth Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, California, USA;
4 GEOMAR Helmholtz Centre for Ocean Research, Germany;
5 Elemental Group, New Zealand.

paul.oluwunmi@auckland.ac.nz

The southern end of New Zealand's Hikurangi Margin is reported to contain significant gas hydrate deposits. With New Zealand's conventional gas supplies being rapidly depleted, gas hydrates on the margin have attracted much attention as a possible unconventional energy source. Our study area is where the Pacific Plate has been subducting beneath the Australian Plate for about 24-30 Myr. Convergence in this region is highly oblique, resulting in a tectonically complex transition zone between subduction and strike-slip motion. This gas hydrate system is beneath a four-way closure anticlinal ridge with its longest axis trending northeast-southwest. This ridge lies close to the deformation front of the wedge, in water depths of ~2100-2300 metres below sea level (mbsl), where gas has accumulated to a thickness of up to ~240 m beneath the base of gas hydrate stability.

In our studies, we used pTOUGH+HYDRATE (pT+H) to construct a 2-D axisymmetric cylindrical gas production model of the margin based on geophysical and geochemical survey data. pT+H is a simulator capable of simulating all flows, non-isothermal states, coupled mass and energy transport in a porous or fractured hydrate-bearing geologic medium. Furthermore, it can effectively account for all heat exchange caused by hydrate dissociation or formation, gas dissolution, and inhibitor dissolution. The production of gas from an interbedded system of hydrate-bearing sands and mud is the focus of our studies. We used a vertical well to perform flow simulations of stepwise constant-pressure production of 1Mpa/hr. The results for the basic scenario will be presented, along with a comparison to the case without interbeds.

POSTER
Session 2e.

USING THE 2016 KAIKŌURA EARTHQUAKE TO TEST HYPOTHESES THAT UNDERPIN TURBIDITE PALEOSEISMOLOGY

Alan Orpin[1], Jamie Howarth[2], Stephanie Tickle[2], Scott Nodder[1], Katherine Maier[1], Lorna Strachan[3] and TAN2109 science team

[1]*National Institute of Water and Atmospheric Research (NIWA), Greta Point, Wellington 6021.*
[2]*School of Geography, Environmental and Earth Sciences, Victoria University of Wellington 6140.*
[3]*School of Environment, University of Auckland, Auckland 1142.*

alan.orpin@niwa.co.nz

Paleo-earthquake records generated from turbidites have been used to produce arguably the longest and most complete records of subduction zone earthquakes around the globe. Such records provide potentially vital information for earthquake forecasting but the basis for them has been vigorously debated by earthquake geoscientists. Debate about the rigour of turbidite-earthquake records exists because there are few examples where the relationships between the fault(s) that rupture in an earthquake, the spatial extent of strong ground-shaking, and the deposition of co-seismic turbidites have been observed. Our presentation will summarise provisional highlights gleaned from a RV *Tangaroa* voyage in October 2021 that will use the unique opportunity provided by the 2016 Kaikōura earthquake – one of the best measured earthquakes in history – to test hypotheses that underpin turbidite paleoseismology. We will collect new high-quality short cores from closely spaced sites within selected submarine canyons on the southern Hikurangi margin, building on the success of three previous RV *Tangaroa* coring campaigns (TAN1613, TAN1705 and TAN1906) that show turbidites are reliable 'natural seismometers' (Howarth et al., 2021). The science objectives for our new voyage to the Hikurangi subduction margin are to recover additional high-quality cores that will be amenable to high-resolution geological characterisation (CT and micro-XRF scanning) to allow critical appraisal of the following: (1)"the confluence test"; (2) variability in longitudinal and thalweg-to-levee turbidite deposition within the Hikurangi Channel depositional system; (3) potential influence of turbidite source areas; (4) spatial sampling representativeness of coring methods and the possible influences of short-wavelength bedforms on core recovery and sedimentological features; and, (5) biological modification by bioturbation and its impact on event preservation in the sedimentary record.

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ORAL
Session 2e.

Using cosmogenic radionuclides and fission-track thermochronometry to benchmark human-enhanced erosion in a time of rapid climate change

Jürgen Österle[1], Kevin P. Norton[1], Claire E. Lukens[2], Fritz Schlunegger[3], Matthew W. Sagar[4], Klaus Wilcken[5]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand.*
[2] *Department of Life and Environmental Sciences, University of California, Merced, USA.*
[3] *Institute of Geological Sciences, University of Bern, Bern, Switzerland.*
[4] *GNS Science, Lower Hutt, New Zealand.*
[5] *Centre for Accelerator Science, Australian Nuclear Science and Technology Organisation, Sydney, Australia.*

juergen.oesterle@email.com

Human activities can have profound direct impacts on landscape evolution, including increases in soil erosion rates and landslide susceptibility; changes in river morpho-dynamics, floodplain environments, and sediment storage; and increased coastal erosion. These problems are compounded by the effects of anthropogenic climate change on the frequency and magnitude of extreme weather events, which also increase erosion. However, to put human-enhanced erosion into context, it is important to understand how erosion responds to changes in natural systems, including climate, that operate over geological timescales. The dearth of erosion data integrated over thousands to millions of years in New Zealand poses a significant barrier in this regard. Lake sediments have been the prime targets for paleo-environmental reconstructions and, while they provide high-resolution archives of climate and erosion, most New Zealand lake successions only span the last ~18,000 years, when climate has generally been cooler than today. To provide unprecedented insight into rates and patterns of erosion on geological timescales in New Zealand, we will quantify erosion using cosmogenic radionuclides and fission-track thermochronometry on fluvial sedimentary deposits in the Canterbury region — the Plio-Pleistocene Kowai Formation and Pleistocene-Holocene river deposits — derived from the erosion of the Southern Alps. Comparing the erosion record of the Southern Alps against published New Zealand and global paleo-climate proxy data, we will assess if and how climatic perturbations over the last ~5 Myr resulted in concomitant modifications of erosion. This time window includes the mid-Pliocene (3.3-3.0 Ma) warm period — the last time climate was similar to the present — and the mid-Pleistocene (1.2-0.8 Ma) transition, recording the shift to the prevailing 100,000-year glacial cycles. The results arising from this research will further our understanding of the natural background rate of erosion in New Zealand and will be essential to forecasting the impact of anthropogenic climate change on erosion.

POSTER
Session 2b.

URBAN METHANE EMISSIONS IN AUCKLAND, NEW ZEALAND

Harrison O'Sullivan-Moffat[1,2], Jocelyn Turnbull[1], David O'Sullivan[2] and Lucas Gatti Domingues[1]

[1] National Isotope Centre, GNS Science, Lower Hutt 5010, New Zealand
[2] Te Herenga Waka - Victoria University of Wellington, Kelburn 6012, New Zealand.

osulliharr@myvuw.ac.nz

Methane is the second most important greenhouse gas and methane emissions from urban areas make up about 10% of New Zealand's total methane emissions. Urban methane emissions can be more more easily mitigated in New Zealand than agriculture methane emissions, however, urban emissions are currently poorly constrained.

Using a car equipped with a cavity ring-down spectrometer for atmospheric methane concentration measurement, we mapped urban methane emissions in Auckland, New Zealand. The results confirm there is a significant contribution to the methane budget from all of the known sources from landfills, wastewater treatment plants, and natural gas infrastructure (which is >80% methane in New Zealand). The observations suggest that domestic methane emissions could be a significant, but poorly constrained, contribution.

During the mobile survey campaign, several suburbs (Stonefields, Meadowbank, Point Chevalier, and Point England) were repeatedly sampled for methane concentrations. All suburbs except Point England (which has no natural gas infrastructure) had numerous, small, methane sources present throughout the day, the number of small methane sources increases during the evening. Constant leaks throughout the day are likely from persistent leaks in the natural gas infrastructure, the larger number of transient leaks are associated with the "behind the meter" emissions. These emissions are from leaking pipes/gas appliances within the house, on/off pulses and emission of un-combusted methane from gas appliances. This research contributes to understanding of the Auckland city carbon budget as part of CarbonWatchNZ.

ORAL
Session 4e.

DISTINCT SCHEELITE REE GEOCHEMISTRY AND $^{87}Sr/^{86}Sr$ ISOTOPES IN PROXIMALLY- AND DISTALLY-SOURCED METAMORPHOGENIC HYDROTHERMAL SYSTEMS, OTAGO SCHIST, NEW ZEALAND

Marshall Palmer[1], Emma J. Scanlan[1], James M. Scott[1], Lauren Farmer[1], Daniel Pickering[1], Victoria J. Wilson[1], Marcus Oelze[2], D. Craw[1], Petrus J. le Roux[3], Yan Luo[4], D. Graham Pearson[4], Malcolm R. Reid[1,5], Claudine H. Stirling[1,5]

[1] Department of Geology, University of Otago, Dunedin, New Zealand
[2] GFZ German Research Centre for Geosciences, Potsdam, Germany
[3] Department of Geological Sciences, University of Cape Town, South Africa
[4] Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, Canada

Marshall.palmer487@gmail.com

The Otago Schist hosts orogenic tungsten (W) mineralization in two deposit types. Proximally-sourced ("proximal") deposits in sub- to lower-greenschist facies Mesozoic metasedimentary rocks through the central Southern Alps comprise quartz-carbonate veins with minor scheelite and few sulphides. Distally-sourced ("distal") deposits are hosted in crustal discontinuities within Mesozoic sub-greenschist to upper-greenschist facies metasedimentary rocks and are associated with abundant sulfides ± Au. In-situ trace element and in-situ $^{87}Sr/^{86}Sr$ compositions of scheelite show geochemical distinctions in these different deposit types. Proximal deposits are characterised by scheelite with both heterogenous trace element and Sr isotope compositions that display variations that can be linked to different veins, host rock types and scheelite generations. In contrast, scheelite within distal scheelite deposits tends to have homogenous trace element and Sr isotopic ratios at the deposit to grain scale. The heterogenous compositions of proximal deposits represent local derivation of components from the sub-millimetre to meter scales and small extents of fluid flow, which resulted in a high sensitivity to sources and local rock compositions and limited large-scale equilibration of elemental and isotopic systematics. On the other hand, the larger distal deposits formed by regional leaching by metamorphic fluids, probably at the greenschist-amphibolite facies boundary, followed by homogenisation of these fluids as they ascended through the crust, leading to the deposition of scheelites with rather uniform chemical characteristics. Our data re-enforce the model that the tungsten evolution in the Otago Schist involved local-scale mobilisation of W in the shallow crust by breakdown of detrital rutile and scheelite at low metamorphic grade. Burial of these veined scheelite-bearing rocks to temperatures of ~500ºC enabled remobilisation of W by metamorphic fluids, concurrent with scavenging of Au, As and S, followed by return of the metal-bearing fluids towards mid to upper crustal levels, where they precipitated scheelite.

ORAL
Session 4f.

PROVENANCE OF MIOCENE–EARLY PLEISTOCENE CONGLOMERATES IN THE NORTHERN CANTERBURY BASIN

Matt Parker[1], **Kari Bassett**[1], **Matt Sagar**[2], **Greg Browne**[2,3] **and Alex Nichols**[1]

[1] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*
[2] *GNS Science, Lower Hutt, New Zealand*
[3] *MotuekaGeo Ltd, Nelson, New Zealand*

matt.parker@pg.canterbury.ac.nz

The northern Canterbury Basin currently lies within the wider deformation zone of the Pacific–Australian plate boundary, with oblique plate motion resulting in the exhumation of the Southern Alps, Kaikoura Ranges, and the North Canterbury Fold and Thrust Belt. The transition from fine- to coarse-grained siliciclastic sediments in the early to middle Miocene provides indirect evidence for this exhumation. This research aims to better understand the provenance of Miocene to early Pleistocene conglomerates by sampling along a NE–SW transect perpendicular to distinctive basement terranes. Mineralogy, geochemistry, and geochronology of clasts and interbedded sandstones will be used to reconstruct drainage pathways and topographic evolution in northern Canterbury.

The conglomerates are generally dominated by greywacke clasts from the Torlesse Composite Terrane (Pahau, Kaweka and Rakaia terranes). In the northern section of the transect (Kaikoura–Cheviot), other clast types include micritic limestone, well-indurated sandstone, and amygdaloidal volcanics. Probable sources are the Amuri Limestone, Cretaceous sandstones, and Cookson Volcanics Group, respectively. Towards the central to southern section of the transect (Culverden–inland Canterbury), greywacke clasts dominate, with rarer volcanic, well-indurated mudstone and soft sandstone/mudstone clasts. To the southeast near Amberley, porphyritic basalt clasts may be derived from the Banks Peninsula volcanics ~60 km to the south. Interbedded sandstones often contain glauconite, potentially derived from older sediment as indicated by rare greensand clasts.

Further point-counting and geochemical analyses will aid in differentiating between Pahau Terrane and Rakaia Terrane sources for greywacke clasts, and sources of volcanic clasts. These data will be combined with forthcoming detrital zircon U–Pb ages of interbedded sandstones to allow Rakaia, Kaweka, and Pahau (or other) terranes to be differentiated based on unique age distributions. These results will ultimately provide constraints on when and where terranes were being exhumed near the developing Pacific–Australian plate boundary.

POSTER
Session 1c.

ERIONITE IN NEW ZEALAND: GEOLOGICAL OCCURRENCE, MINERALOGICAL CHARACTER AND A PRELIMINARY RISK ASSESSMENT

Janki Patel[1], Martin Brook[1], Dario Di Giuseppe[2], Valentina Scognamiglio[2], Alessandro F. Gualtieri[2], Melanie Kah[1] and Ayrton Hamilton[1]

[1] *School of Environment, University of Auckland, Auckland, New Zealand*
[2] *Department of Chemical and Geological Sciences, University of Modena and Reggio Emilia, Modena, Italy*

Jpat924@aucklanduni.ac.nz

Erionite is a naturally occurring zeolite mineral originating from diagenesis or hydrothermal alteration of volcanic rocks. The two main types of rock that erionite is present in include tuff and basalt. Erionite can have a fibrous morphology, and as with asbestos fibre exposure, when it is aerosolized and inhaled, fibrous erionite has been linked to cases of malignant mesothelioma, a rapidly fatal and aggressive tumour. Importantly, fibrous erionite appears to be one or two orders of magnitude more carcinogenic than the six regulated asbestos minerals. The first health issues regarding erionite exposure and mesothelioma were noted in Cappadocia (Turkey), and more recently, in the USA. The International Agency for Research on Cancer (IARC) has classified erionite as a Group 1 carcinogen. Nevertheless, when erionite fibres remain undisturbed in rock, they are not thought to pose a risk to human health. In New Zealand, erionite has been found at numerous locations throughout both the North and South Islands, including (from north to south) Kaipara, Auckland, Taupo Volcanic Zone, and Moeraki. During an investigation at Riverhead, Auckland, Miocene tuffaceous rocks were studied using various analytical techniques, including SEM, TEM, Raman Spectroscopy, pXRD and FT-IR Spectroscopy. The investigation found that Erionite-K was present within the rocks and exhibited a fibrous morphology (Patel & Brook, 2021). Dimensional analysis conducted using TEM found that 45.6% of fibrous minerals satisfied the requirements for a respirable airborne fibre (length, $L \geqslant 5$ μm, a diameter, $w \leqslant 3$ μm, and L/w value $\geqslant$3:1). Nevertheless, there is a considerable time lag between exposure to erionite and the development of mesothelioma (~20-40 years). Coupled with non-linear dose concentration-duration-risk relationships, this compounds the difficulty in understanding mineral exposure and developing risk management strategies. Research is ongoing into erionite distribution and transport pathways in rock, soil, and air, in addition to other fibrous zeolites.

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POSTER
Session 3b.

Using surface roughness to determine coastal dune ages at K'gari (Fraser Island) and the Cooloola Sand Mass, Australia

Nicholas R. Patton[1,2], James Shulmeister[1,2], Tammy Rittenour[3], Daniel Ellerton[2,4], and Peter Almond[5]

[1]School of Earth and Environment, University of Canterbury, Christchurch 8041, NZ
[2]School of Earth and Environmental Sciences, The University of Queensland, Brisbane 4072, AUS
[3]Department of Geology, Utah State Luminescence Laboratory, Logan, UT 84322, USA
[4]Department of Geological Sciences, Stockholm University, SE 10961 Stockholm, SE
[5]Department of Soil and Physical Sciences, Lincoln University, Christchurch 7647 New Zealand

Nicholas.Patton@pg.canterbury.ac.nz

The Southeast Queensland dune field, Australia hosts thousands of onlapping parabolic dunes providing a globally important record of environmental and geomorphological processes. Although some dunes are dated, acquiring numerical ages of all dunes is impractical owing to the scale of the dunefield. Yet, a more complete understanding of dune chronology is important for deciphering environmental change. We estimate the age of Holocene dunes at Fraser Island and the Cooloola Sand Mass by calibrating a roughness-age model (n=24). We demonstrate a robust exponential relationship ($r^2 = 0.91$, RMSE = 1.032 ka) between surface roughness and timing of dune emplacement. Landscape smoothing arising from the dominance of hillslope and lack of advective processes underpins the relationship. By applying the model, we estimate the ages of 827 Holocene dunes in both dune fields. Cumulative probability density functions of dune ages suggest similar trends of major dune emplacement phases in both dune fields resulting from sea-level variability. Fraser Island had two major phases of dune emplacement at ~1 and ~4.5 ka, whereas the Cooloola Sand Mass included a third at ~8 ka. We highlight that the additional dune ages generated by the roughness-dune age model does not generate major new dune emplacement events and adds significance to the 4.5 ka and 1 ka events. The two events correspond to minor sea-level rise and the onset of ENSO at 4.5 ka and to changes in wave directions tied to ENSO and PDO mode changes at 1 ka. We contend that surface roughness age modelling employing high resolution elevation data is a rapid and accurate approach to filling in chronological gaps in dune fields globally

ORAL
Session 2d.

DEVELOPMENT OF A VIRTUAL REALITY APPLICATION FOR GAMIFIED ENVIRONMENTAL EDUCATION IN AOTEAROA NEW ZEALAND

Amber Peek[1] and Michael Martin[1]

[1] *School of Environment, University of Auckland, Auckland, New Zealand*

apee461@aucklanduni.ac.nz

Environmental education is critical in a unique environment such as Aotearoa's, however there are many access barriers. Factors such as disability, proximity to nature, and socioeconomic status all impact New Zealanders' capacity to access the natural environment and learn about it.

Virtual reality is an increasingly accessible technology with the power to transport people to any space, real or imagined, instantly. This has the power to bring environmental education to communities and individuals that may not otherwise have access to such resources.

Through the development of a virtual reality software that teaches people about an environmental issue, and tests their knowledge in a gamified manner, people's environmental education experience will also be used to generate geospatial data. The specific environmental issue chosen will be determined following consultation with Department of Conservation staff and other knowledgeable individuals, and will likely be an invasive weed species such as *Araujia hortorum*, commonly known as 'moth weed' (Foxcroft et al. 2014).

The virtual reality application will be developed using the Unity video game engine for the Oculus Quest 2 hardware in a manner similar to the *Locative Reality* software in development at the University of Auckland's Spatial Innovation Lab (Peek, Martin, & Kolston, 2021). The software operates in three stages. The first stage involves an interactive lesson on the chosen environmental issue, covering topics such as how to identify it as well as what to do to manage the issue.

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POSTER
Session 3e.

RE-DEFINING THE J HYPERTHERMAL EVENT VIA PALEOENVIRONMENTAL ANALYSIS OF EARLY EOCENE MARL AND LIMESTONE ALTERATIONS FROM MEAD STREAM, NEW ZEALAND

Sonja Penafiel Bermudez[1, 2], **Thomas Cooper** [2]

[1] *GNS Science, Wellington, New Zealand*
[2] *School of Geography, Environment and Earth Sciences, Victoria University, Wellington, New Zealand.*

s.bermudez@gns.cri.nz

Abstracts This study integrates paleonotology and geochemistry to provide a paleoclimatic analysis of cyclic sedimentation in the Lower Marl at Mead Stream in Marlborough, Aotearoa/New Zealand. Analysis of marine palynomorph, radiolarian and foraminifera assemblages from the alternating marls and limestones improves biostratigraphic resolution and further defines events during the Early Eocene Climatic Optimum (EECO; ~53–49 Ma) — a period characterised by the highest temperatures of the Paleogene.

The resulting paleontological assessment of microfossils from the Lower Marl coupled with stable isotope analysis at the initiation of the EECO, indicates an earlier onset of the J hyperthermal event than previously recorded. Additionally, acmes of the foraminifera genus Morozovella and dinoflagellate cyst Homotryblium tasmaniense within these events suggest that the J carbon isotopic excursion (CIE) may have occurred as a two-stage event. The presence of these (sub) tropical foraminifera and high abundances of warm water, extreme salinity marine palynomorphs infers the southern expansion of warm waters.

POSTER
Session 2c.

PERIODIC PORE FLUID PRESSURE AS A VIABLE MECHANISM FOR THE GENERATION OF SLOW SLIP EVENTS IN VELOCITY-STRENGTHENING FAULTS

Andrea Perez[1], Yoshihiro Kaneko[2] and Martha Savage[1]

[1]Victoria University of Wellington, School of Geography, Environment and Earth Sciences, New Zealand [2]Kyoto University, Graduate School of Science, Japan.

perezan@staff.vuw.ac.nz

Geophysical observations have inferred temporal pore pressure changes that correlate with the occurrence of slow slip events (SSEs) in Hikurangi, Cascadia and central Japan subduction zones (Warren-Smith et al. 2019, Gosselin et al. 2020, Nakajima et al. 2018). These fluctuations in pore fluid pressure are interpreted as due to fluid migration during and between SSE cycles, which could be promoted by permeability changes during SSE's slip. To examine the role of temporal variations in pore pressure on SSEs, here we investigate the effect of periodic perturbations of pore fluid pressure on a velocity-strengthening (VS) fault, using 3D numerical modeling that accounts for rate-and-state friction. We consider static perturbations, where the location of the perturbation is constant over time, and migrating perturbations, where a pore fluid pressure pulse is set to migrate along dip. SSEs can be triggered by both types of perturbations under a wide range of VS conditions and background effective normal stress (1-10 MPa). The properties of the triggered SSEs depend on the magnitude, duration, periodicity and size of the perturbation, as well as on the migration speed of the pore fluid pressure pulse. We also constrain the parameter space that reproduces the properties (i.e. duration, slip, recurrence interval) of shallow SSEs observed along the central portion of the Hikurangi margin for both static and migrating pore fluid pressure perturbations. Our results indicate that these SSEs could be distinguished from spontaneous SSEs of comparable characteristics on VW faults by the temporal evolution of SSE's slip, as slip accumulates faster for the triggered SSEs. Our results suggest that a VS fault with periodic perturbations of pore fluid pressure is a viable mechanism for the generation of SSEs, which implies that the conditions that lead to SSEs within the rate-and-state framework are broader than previously thought.

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POSTER
Session 2a.

CLIMATIC AND TECTONIC CONTROLS ON THE TRACE ELEMENT CHEMISTRY OF RIVERS IN THE SOUTH ISLAND OF NEW ZEALAND

<u>Ben Perrett</u>[1,2], Claudine H. Stirling[1,2], Matt Druce[1,2], Markus Dengg[1,2], Malcolm R. Reid[1,2]

1 Department of Geology, University of Otago, PO Box 56, Dunedin, NZ.
2 Centre for Trace Element Analysis, University of Otago, PO Box 56, Dunedin, NZ.

Perbe034@student.otago.ac.nz

The distributions and biogeochemical properties of many trace elements in the environment are intimately connected to Earth's carbon, sulphur and climate cycles. When the drivers of these properties are accurately constrained, it is possible to reconstruct robust time-series records of trace element cycling from sedimentary archives, and in turn generate a wealth of information on the processes driving and modulating past climate events, providing crucial boundary conditions for modelling future-climate scenarios. Changes in Earth's climate modify the rate and style of continental weathering, and the relative importance of chemical versus physical weathering, thereby influencing the release of dissolved trace elements into rivers and ultimately the oceans. However, for many trace elements, the impact of weathering processes and subsequent biogeochemical transformations within rivers are poorly constrained, which leads to large uncertainties in past climate reconstruction efforts.

This study investigates a suite of waters from 15 rivers with catchments draining the Southern Alps of New Zealand, to characterise the relative importance of chemical versus physical weathering on the trace element inventory entering riverine systems. This investigation is facilitated by low levels of anthropogenic pollution, which allow for the effect of changes in climatic and tectonic conditions on the distributions of a series of major elements, trace elements, and trace element isotope systems, to be elucidated. Through the use of source contribution and statistical modelling, as well as strontium ($^{87}Sr/^{86}Sr$) isotope tracer analysis to constrain primary mineral sources, trace elements are differentiated based on the relationships between their concentrations and environmental drivers of chemical and physical weathering. This provides new constraints for the linkages between climate and trace element cycling, and in turn, informs reconstructions of past environmental change through key climate events.

ORAL
Session 2c.

SPATIOTEMPORAL ANALYSIS OF REPEATING EARTHQUAKES NEAR PORANGAHAU, HIKURANGI MARGIN, NEW ZEALAND

Olivia Pita-Sllim[1], Calum J. Chamberlain[1] and John Townend[1]

[1] School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand.

olivia.pitasllim@vuw.ac.nz

Repeating earthquakes are thought to re-rupture the same fault-patch at different times, and thus have nearly identical waveforms, locations and magnitudes. Because repeating earthquakes represent cyclic loading, they can be used to detect temporal and spatial changes of slip-rate at depth and hence monitor how stress is transferred to seismogenic zones.

The Hikurangi subduction zone exhibits a variety of fault-slip related phenomena from large megathrust earthquakes to slow-slip. The northern Hikurangi margin hosts shallow slow-slip and is weakly coupled to shallow depths. In contrast, the southern Hikurangi margin is strongly coupled, with predominantly deep slow-slip events. The transition in coupling occurs beneath the township of Porangahau, making the surrounding area an exemplary focus region for studying how this along-strike change in behaviour is accommodated.

To examine slip processes near Porangahau, we have constructed and analysed a catalogue of repeating earthquakes that occurred since 2004. To build our catalogue, we first clustered GeoNet's extensive earthquake catalogue using a cross-correlation threshold of at least 0.95 normalised cross-correlation on two or more stations to identify repeating earthquakes. We then used a matched-filter to identify additional repeating events missing in the GeoNet earthquake catalogue.

Using precise locations and well-constrained focal mechanisms, we determined that the majority of the repeating earthquake families on the subduction interface are located at the transition from strong- to weak-coupling of the subduction interface. The majority of the repeating earthquakes we identify are located up-dip or down-dip of modeled slow slip patches, with few families correlating spatially with slow slip events. We infer that the spatial anti-correlation between repeating earthquakes and slow slip is the result of different frictional properties between these regions. The insights gained from this study lay the groundwork for future work constraining processes of strain accumulation at the creeping-to-locked transition zone near Porangahau.

ORAL
Session 2a.

USING ULTRAHIGH RESOLUTION POLLEN ANALYSIS TO UNDERSTAND REGIONAL VEGETATION RESPONSES TO THE ŌRUANUI SUPERERUPTION

Stephen Piva[1], Simon Barker[1], Rewi Newnham[1], Andrew Rees[1], Colin Wilson[1], Lionel Carter[2] and Paul Augustinus[3]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, New Zealand.*
[2] *Antarctic Research Centre, Victoria University of Wellington, New Zealand.*
[3] *School of Environment, University of Auckland, New Zealand.*

stephen.piva@vuw.ac.nz

The 25.5 ka Ōruanui supereruption from Taupō volcano is the youngest known supereruption on Earth that ejected >1100 km^3 of pyroclastic material. However, the impacts of this event on global climate and the NZ environment remains speculative. We address this through a ultrahigh resolution investigation of pollen from Onepoto maar lake, Auckland. Sediment was sampled at contiguous 1 mm intervals, directly above and below the Ōruanui tephra to assess pre- and post-eruption pollen records ~240 km from source. Our results show a minor and short-lived vegetation response. The composition of the regionally-extensive beech forest changed post-eruption, with a decline in the dominant arboreal species *Fuscospora* potentially related to direct damage. This is suggested to have led to an opening of the canopy, allowing opportunistic species of grasses (Poaceae), herbs (Asteraceae), ferns and shrubs (*Coprosma*) to colonise. However, after ~8–12 years the vegetation recovered, with *Fuscospora* and other species of tall trees recuperating and subsequently shading out plants that had flourished following the volcanic disturbance. Alongside compositional changes, a significant decrease in the concentration of all palynomorphs is observed for ~50-70 years, which may reflect a combination of sedimentation rate and reduced vegetation productivity due to volcanogenic cooling. With ultrahigh ecological-scale resolution, our results are transferable for forecasting the potential impacts of future explosive eruptions.

ORAL
Session 2c.

THE WAIMIHIA ERUPTION AS AN ISOCHRON FOR PALEOSEISMOLOGY

Charlotte Pizer[1], **Jamie Howarth**[1], **Kate Clark**[2], **Andy Howell**[2,3], **Jaime Delano**[3]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand*
[2] *GNS Science, Lower Hutt, New Zealand*
[3] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*

charlotte.pizer@vuw.ac.nz

Understanding the location and magnitude of past earthquakes is essential for constraining seismic hazard and better informing community preparedness for future large earthquakes. At subduction zones, this requires the temporal correlation of earthquake records across large spatial extents because rupture patches of subduction earthquakes can be variable and may exceed hundreds of kilometers. Identifying primary airfall tephra provides a chronostratigraphic tiepoint that can be used to synchronize widely spaced on - and offshore earthquake records, with precision that exceeds that of radiocarbon-dating alone.

Tephrochronology is a particularly important tool for the Hawke's Bay region on the central Hikurangi Subduction Margin, where the low resolution of earthquake chronologies means it is difficult to confidently correlate the complex evidence of both coseismic uplift and subsidence between sites. The Waimihia eruption has a currently accepted age of 3401 ± 108 cal BP (Lowe et al., 2013) and provides a key marker tephra for Holocene events, with many studies indicating evidence of closely-timed earthquakes.

Here, we summarize evidence for coseismic coastal deformation occurring prior to or co-temporal with the Waimihia eruption and present a new chronology for this sequence from high density radiocarbon dating and Bayesian age-depth modelling on on- and offshore sediment. Applying this to our emerging earthquake record from Hawke's Bay, we demonstrate the value of tephrochronology for the correlation of onshore and offshore paleoseismology – an essential step of constraining the location and magnitude of past subduction earthquakes.

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ORAL
Session 2a.

Using Palaeomagnetic Techniques To Uncover The History Of An Archaeological Site In Napier, Hawkes Bay

Shefali Poojary[1], Gillian Turner[1] and Gaylynne Carter[2]

[1] School Chemical and Physical Sciences, Victoria University of Wellington, Wellington, New Zealand
[2] Archaeology Hawkes Bay Ltd., New Zealand.

shefali.poojary@vuw.ac.nz

Archaeomagnetic dating is a powerful technique in an archaeologist's toolbox. Over the past millennium, the direction of the geomagnetic field over New Zealand has shifted from ca. 15° W to 20° E of N, gradually steepening at the same time. This characteristic palaeosecular variation is captured in the regional record NZPSV1k[1], providing a reference against which the direction and/or intensity of magnetization of test features can be compared and hence dated. During the redevelopment of a mid-twentieth century residential site in central Napier, archaeological evidence for earlier occupation was found some 600-700 cm below the modern surface. Features such as well-preserved hangi, shallow fire-scoops, and stone-lined fireplaces were found on a surface covered in shells and pumice. Six features: two hangi, two fire-scoops, the baked floor of a hearth and a pumice hearthstone, were sampled for palaeomagnetic study. Detailed analysis of the thermoremanent magnetization (TRM) of the baked hearth floor yields a palaeodirection with declination (D) = 12.3°, inclination = -63.5° and α_{95} = 8.1° from eight samples. Comparison of this direction with the NZPSV1k reference curve gives an age between 1700 and 1900 A.D., most likely around 1800 A.D.

Preliminary results on the TRMs of stones from the hangi and firescoops indicate that these may belong to an earlier time period. Our results, therefore, suggest an extended period of occupation, when, before mid-nineteenth century reclamation, the area was predominantly wetland, and the site was surrounded by swamps and shallow tidal lagoons. The surface covering of pumice and its use as hearth-lining stones suggest that the fire-cracked volcanic stones, evidently recycled multiple times in the hangi, were locally rare. It is hoped that rock magnetic studies will help establish the source of these stones, a further facet of the application of archaeomagnetism in deciphering the cultural history of the region.

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POSTER
Session 3c.

CONNECTING REAL-TIME HAZARD AND IMPACT DATA WITH USERS: EXPLORING USER NEEDS

Sally H Potter[1], **Sara Harrison**[1,2], **Graham S Leonard**[1], **Kristie-Lee Thomas**[3], **Moka Apiti**[4], **Sue Harvey**[1], **and Geoff Kilgour**[1]

[1] *GNS Science, Lower Hutt, New Zealand*
[2] *Massey University, Wellington, New Zealand*
[3] *University of Canterbury, Christchurch, New Zealand*
[4] *Digital Navigators Ltd, Wellington, New Zealand*

s.potter@gns.cri.nz

There is a need to better connect stakeholders and other users with real-time hazard and impact data during and immediately after a hazardous event to enable a faster and more informed response. Currently, communications are prepared and response decisions are made based on a vacuum of information in the early stages of an event. Monitoring networks have gaps reducing spatial-temporal visibility, there are very few automated real-time hazard to impact models available, and there is limited capacity for officials to visit every site to assess the damage quickly. These gaps result in delays in decisions to respond to and reduce further impacts, a reliance on media for situational awareness, and a lack of timely information to inform public messaging. There are also gaps in risk modelling input data which inform impact forecasting systems.

We conducted 16 interviews with stakeholder agencies in 2020 to understand their chalalice

Zakharovskyilenges in accessing real-time hazard and impact information. We aligned with other projects which collected data on the public's willingness to submit observations (N=4725 through an online survey) and engaged with stakeholders to understand user needs for risk modelling software (six workshops and a survey, N=145). We scoped out the development of a visualisation tool for New Zealand as a potential solution to better connect real-time information to users.

We found that there is a need to connect existing hazard and impact data from multiple agencies (Potter et al., 2020). More information connectivity is desired with forecasts and warnings, monitoring data, crowdsourced observations, and real-time risk model outputs. A co-developed online viewer application and increased data availability to incorporate these data into agencies' existing dashboards may address these needs.

Next steps include investigating increasing crowdsourced data collection and associated data management, co-developing a visualisation application, and improving connectivity between stakeholders and data through existing services.

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ORAL
Session 3b.

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IS THE PLENUS COLD EVENT 'COOLING GREENHOUSE' TRANSITION AN ANALOGUE FOR FUTURE GLOBAL COOLING GEOENGINEERED VIA OCEAN FERTILISATION AND CO_2 DRAWDOWN?

Nicholas G. Powell[1]

[1] *Forensic & Industrial Science Ltd, PO Box 67-087, Mt Eden, Auckland 1349, New Zealand*

research@forensicscience.co.nz

Ocean fertilisation has been proposed as a way to reduce atmospheric concentrations of CO_2, a long-lived greenhouse gas, by enhancing marine uptake of carbon via long-term sequestration into anoxic sediments in the form of biogenic high molecular weight organic compounds.

While considerable attention has been focussed on 'warming icehouse' climate transitions because of their relevance to global warming, 'cooling greenhouse' transitions also warrant careful study because of their potential utility as paleoanalogues for future geoengineered efforts implemented to counteract climate forcing by anthropogenic emissions.

A 'cooling greenhouse' transition is evident near the Cenomanian-Turonian boundary (*ca.* 94 Ma), where Ocean Anoxic Event 2 is discernible as isotopic excursions and accumulations of organic-rich sediments. Ocean anoxia may be a biogeochemical response to fertilisation by large igneous province (LIP) basaltic volcanism. The concomitant Plenus Cold Event, which punctuated an otherwise-very-warm mid Cretaceous, is interpreted as a global climatic response to CO_2 drawdown.

The Waipounamu Erosion Surface, New Zealand, and the correlative West Antarctic Erosion Surface developed penecontemporaneously with Plenus cooling. While an origin involving marine erosion has been proposed by LeMasurier and Landis (1996), these enigmatic planar destructional surfaces can alternatively and preferably be interpreted as subglacial floors formed beneath extensive (>10^6 km^2) ephemeral continental interior ice sheets that nucleated during the Plenus Cold Event.

In principle, inferences about the extent and timing of Cretaceous glaciation could be integrated into models that interrogate the interplay of LIP ocean fertilisation, pCO_2, global temperature, eustasy and ice volumes. Such models could conceivably also be used to calibrate the ocean fertilisation required to geoengineer CO_2 drawdown.

The syn-Plenus 'cooling greenhouse' transition may constitute an informative paleoanalogue for any geoengineered initiatives involving ocean fertilisation and marine sequestration of CO_2 that might be needed to mitigate the climatic effects of anthropogenic emissions and to stabilise future Earth climates.

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POSTER
Session 2c.

The 2021 Update to the National Tsunami Hazard Model

William Power[1], **David Burbidge[1] and Aditya Gusman[1]**

[1] *Department of Earth Structure and Processes, GNS Science, Lower Hutt, New Zealand*

w.power@gns.cri.nz

The National Tsunami Hazard Model (NTHM) is a key science product for reducing the impact of tsunamis in New Zealand by providing estimates of tsunami heights at the shoreline for return periods of up to 2,500 years. It underpins a variety of other products such as the evacuation zones used when a tsunami threatens New Zealand, probabilistic tsunami inundation assessments used in land-use planning, and probabilistic tsunami risk assessments. The original NTHM was completed in 2013 (Power, 2013), since then knowledge of tsunami sources and how to model the resulting tsunamis has improved significantly. We have recently completed an update to the NTHM and will use this presentation to outline the nature of the updates that have been made.

Some of the significant changes include:

- Updates to the subduction source earthquake recurrence estimates using the parameters from latest Global Earthquake Model (GEM) global subduction zone model.
- Updates to the scenario database used to estimate the offshore wave heights of regional and distant source tsunamis, to make use of the most recent modelling used for producing tsunami threat maps following a large earthquake.
- Revision of the method used to estimate wave heights from local crustal tsunami sources, replacing a very simple empirical modelling approach with scaled hydrodynamical modelling.

The results of these and other changes on estimates of shoreline tsunami hazard around New Zealand will be presented and discussed.

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ORAL
Session 2a.

PALAEOCLIMATE RESEARCH AND THE ARCHAEOLOGICAL RECORD IN AOTEAROA AND OCEANIA

Matiu Prebble[1],

[1] *Te Kura Aronukuraki, Te Whare Wānaka o Waitaha, Ōtautahi, Aotearoa: School of Earth & Environment, College of Science, University of Canterbury, Christchurch New Zealand*

matiu.prebble@canterbury.ac.nz

The recent characterizing of the distal effects of the Initial Burn Period (IBP) in Aotearoa by Māori, from black carbon recorded in ice cores from Antarctica (McConnell et al. 2021), is representative of the broader scientific enterprise of understanding the links between palaeoclimate and indigenous societal changes. There is an embedded but contestable assumption that the near-time human settlement of Aotearoa and Oceania, coupled with the greater resolution of both archaeological and palaeoclimate data can better frame causal relationships between these historical datasets. The correlation between the IBP and ice core black carbon clearly demonstrates Southern Hemisphere teleconnections, but why is this so impactful to the scientific community, and how does or will this drive future research? Here, I explore the relationship between the palaeoclimatology of the Little Ice Age (LIA) and the archaeological record of Aotearoa and Oceania. In Aotearoa, this continues to drive hypotheses of culture change between the 'Moa Hunter' hunter-gatherer and the 'Classic Period' horticulturalist economy as a function of LIA climate cooling in the 16th Century (e.g. Waters et al 2017; Prebble et al. 2019). In the tropical Pacific Islands, increasingly reliable measures of palaeohydroclimate (e.g. Ladd et al. 2021; Sachs et al. 2021) are being used to examine settlement or abandonment histories of islands in the face of climatic extremes (Sachs et al 2018; Sear et al. 2020). In such a vast region as Oceania, substantial problems lie in generating proximate datasets necessary to test casual hypotheses. Examining a number of case studies in Aotearoa and Oceania, I look at the spatial disjunction between highly resolved palaeoclimate proxies and archaeological/palaeoecological records, and show that even where close proximity exists 'correlation limitations' are prevalent. Following Kintigh & Ingram (2018), I highlight cases where causal arguments rely on multiple lines of evidence that support links between climatic and cultural events, but also examine high magnitude climatic episodes and their associated cultural contexts, that appear not to have resulted in change.

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KEYNOTE
Session 2c.

ADVANCES TOWARDS A COMPREHENSIVE IGNIMBRITE STRATIGRAPHY OF THE TAURANGA VOLCANIC CENTRE, NORTH ISLAND, NEW ZEALAND

Marlena Prentice[1], **Miriam Namaliu**[1], **Adrian Pittari**[1], **David J. Lowe**[1], **Peter Kamp**[1] **and Geoff Kilgour**[2]

[1] *School of Science/Te Aka Mātuatua, University of Waikato, Hamilton, New Zealand*
[2] *GNS Science, Taupo, New Zealand*

prenticelm@gmail.com

The Tauranga Volcanic Centre (TgaVC), in western Bay of Plenty, was active from 2.95 to 1.90 Ma. Volcanic products of TgaVC comprise an eroded andesitic stratovolcano (Otawa Formation), numerous rhyolite-dacite lava dome/dome complexes (Minden Rhyolite Subgroup), minor exposures of basalt near Matakana Island within Tauranga Harbour, and a pyroclastic succession comprising multiple ignimbrites that was conventionally split into a package of multiple, related ignimbrite and fall deposits of the older Papamoa Formation and the climactic ignimbrite of the Waiteariki Formation.

We have revised the stratigraphy of the pyroclastic succession of the Papamoa Formation which is confined to the northern and western foothills of the Papamoa Range, overlying the Otawa Formation. Five ignimbrites have been identified and four locally widespread units are named as follows: non-welded Welcome Bay and welded Wharo ignimbrites (together formerly Lower Papamoa Ignimbrite); non-welded Otawera Ignimbrite; and non-welded Arateka Ignimbrite (formerly Upper Papamoa Ignimbrite). These ignimbrites can be distinguished on the basis of proportion of pumice types, textural properties, and geochemical composition. Radiometric dating indicates they were erupted between ~2.4 and ~2.2 Ma. The ~2.1 Ma voluminous, welded, crystal-rich Waiteariki Ignimbrite is proximally-exposed over a wide area west of the Papamoa Range.

By combining this revised proximal stratigraphy of the TgaVC and distal tephra records identified in contemporaneous sediments of northern Hawke's Bay, we identify eight explosive rhyolitic eruptions that took place between ~2.4 and 2.0 Ma, giving an average repose period between explosive eruptions for the TgaVC of ~50 kyrs. This is a maximum value as local dome eruptions have been excluded due to uncertain links between them and known tephra-fall deposits. The eruption tempo indicates that the period 2.4–2.0 Ma was a time of frequent rhyolitic activity centered within the TgaVC throughout the contiguous Tauranga and Kaimai regions which culminated with the eruption of the Waiteariki Ignimbrite.

ORAL
Session 1a.

ICE MECHANICS: WHAT DO WE STILL NEED TO KNOW TO MODEL ICE SHEETS?

David Prior[1], Sheng Fan[1], Rilee Thomas[1] and Ting Wang[2]

[1] *Department of Geology, University of Otago, Dunedin, New Zealand.*
[2] *Department of Statistics, University of Otago, Dunedin, New Zealand.*

david.prior@otago.ac.nz

Ice sheet models are a key tool for predicting future climate change impacts on New Zealand, most particularly sea level. Marine ice shelves, locations where the climate driven changes are most dramatic, are a focus of Antarctic research. Ice shelf evolution changes the driving force for the flow of inland ice making its way to the sea. Estimating the effect that the change in driving force has on the rate of ice flow requires a good empirical understanding of ice mechanics. Robust ice flow laws are essential for predictions on the decadal timescale relevant to planners. Ice deformation is an important component of ice flow and the deformation flow law used in most ice sheet models has problems: some can be fixed now and others need further research work.

1. ***Things we know are wrong:*** The stress exponent (n) relates the strain-rate response to driving stress (strain-rate $\propto$ stress^n). The value of n = 3, that is commonly used, is wrong. The correct value should be 4, the value measured when ice is deformed to significant strains (>10%) and microstructures and deformation mechanisms are at a steady state. The n value has a very significant effect on models (Bons et al., 2018). We will show a new best-fit empirical flow law from existing laboratory data.
2. ***Things we still need to know:*** There remain key unknowns, some more important. Preliminary work on ice chemistry suggest that this does not have a significant effect for polar ice sheets. Mechanical anisotropy of ice is real, but is not yet properly parameterized. Whether anisotropy is important to ice sheet models depends on the time resolution of the model. For models that resolve short period stress changes, for example tidal flexure, anisotropy is very important. Anisotropy may be less important for modelling longer term evolution.

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ORAL
Session 2b.

TARANAKI MOUNGA –
THE INTERFACE OF MĀTAURANGA Ā IWI AND SCIENCE

Jon Procter (Muaupoko),
Acushla Sciascia (Ngāti Ruanui, Ngāruahinerangi, Te Ati Awa)

School of Agriculture and Environment, Massey University, Palmerston North, New Zealand

j.procter@massey.ac.nz

A handful of papers exist that attempt to bridge Māori knowledge or mātauranga Māori (Hikuroa, 2017; King et al., 2007) and apply that knowledge through a western science lenses for mutually beneficial outcome such as resilience. This is usually achieved in a context where Māori accounts of an event were also witnessed alongside European experiences or recordings of that event. Only rarely has there been attempts to bridge the temporal and cultural divide to correlate oral traditions to scientific records or hazardscape change (King et al., 2018). This is usually undertaken within a strict methodological framework that satisfies scientific rigour but also tikanga.

Taranaki poses a unique case study in that the tikanga applied to explore and essentially use mātauranga-a-iwi is very specific to individual iwi and hapu but also the sharing and use of that knowledge occurs within a very strict set of conventions possibly due to the results of colonisation. Exploring volcanism in Taranaki from a mātauranga Māori context also presents additional significant challenges in that volcanism has not been observed by Europeans or (post-colonial) Taranaki iwi/hapu and explaining those volcanic phenomena and their reactions to those phenomena from a cultural perspective has not occurred or been recorded when compared to other New Zealand examples such as Tarawera (Cashman and Cronin, 2008) and Ruapehu (Gabrielsen et al., 2017). Simply, Taranaki has not erupted for a number of generations and from an anthropological sense the memory of those events have been buried or forgotten over time.

However, we know that narratives and historic accounts exist in the language, songs, carving styles, genealogies and stories of whānau, hapū and iwi around the mountain. Much of which are tightly kept to specific whānau members and leaders and not widely known or shared. In some instances, this is deliberately protected and therefore hidden and in others, it is simply due to knowledge being lost over time. In this presentation, we will explore and discuss the tensions and opportunities for interfacing mātauranga ā iwi and science through the context of Taranaki mounga in the hopes to support whānau, hapū and iwi to unearth the hidden memories of past eruptions and the cultural significance of such events.

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KEYNOTE
Session 1a.

PLUTON MAP CHARACTERISATION OF NEW ZEALAND'S INTRUSIVE ROCKS

Mark Rattenbury[1], Rose Turnbull[2], Andy Tulloch[2], Matt Sagar[1] and Kevin Faure[1]

[1] *GNS Science, Lower Hutt, New Zealand*
[2] *GNS Science, Dunedin, New Zealand.*

m.rattenbury@gns.cri.nz

The Pluton Map (PMAP) research project aims to characterise New Zealand's plutons in terms of diverse geochemical and physical properties and other defining features within an improved geological map context. The pluton extents from geological map data are being linked to analysed and measured property data from representative samples across each pluton. Additional characteristic attributes are also being compiled for every pluton, for example, petrogenetic suite affiliation, U-Pb intrusion age, emplacement depth, classifying element ratios and calculations such as Sr/Y and Zr+Ce+Y+Nb, and O-, Sr-Nd and Lu-Hf isotopes. Each pluton will have a key sample identified whose chemistry, age and other properties is representative of the pluton. Many of these key samples are not yet identified and will require field sampling and use of hand specimens in existing collections for further geochemical analysis and dating.

PMAP draws from two Nationally Significant Collections and Databases; the Regional Geological Map Archive and Datafile (RGMAD) and the National Petrology Reference Collection (NPRC) and Petlab Database. The Petlab analytical data will be accessed live and displayed in a web-enabled GIS-based application and can thus accommodate future data acquisition. In turn, the project will add to the NPRC through new samples, Petlab through new analytical data and thorough QA/QC of existing data, and to RGMAD with improved geological map rendering of pluton geology.

The pluton geology of Rakiura/Stewart Island has been the testbed for PMAP. Key samples have been identified, Petlab data improved and validated and summary attributes compiled. These data have been linked to the island's digital geological map enabling portrayal of colour-symbolised plutons based on different properties and defining features. Focus is now shifting to the pluton geology of Fiordland, West Coast and Northwest Nelson with the latter two areas needing pluton-level differentiation of the existing suite-based geological map units.

ORAL
Session 1b.

IS PANITAHI THE NEW MT TARANAKI SUMMIT, OR A TRANSIENT MAGMA LEAK?

Lena Ray, Shane Cronin, Phil Shane, Ingrid Ukstins

School of Environment, The University of Auckland, Auckland, New Zealand

lena.ray@auckland.ac.nz

Panitahi (Fanthams Peak) is a secondary volcanic cone on Mount Taranaki that has been active within the last ~3000 years. It produced both explosive Plinian eruptions and extensive lava flows, within a short time window. Its eruptions are out of synchrony with (Turner et al., 2011) and have differing compositions to the summit vent. Future eruption potential means that Panitahi is a significant factor in hazard assessments. As Panitahi lies close to the general axis of younging along the Taranaki Volcanic Lineament, it could represent a migration of volcanic activity. In this study, we examine Panitahi magma sources and stratigraphy to understand its future threat. We examined whole-rock and mineral compositions of a new suite of 24 Panitahi and 5 summit lavas, and deposits from the short-lived ~1.8 ka BP Curtis Ridge Vent between Panitahi and the summit cone (Turner et al., 2008). Panitahi lavas and pyroclastics are more mafic than those of the summit vent in whole rock compositions (49-54% vs. 53-60% SiO_2 and 1.5-2.2% vs 2.3-3.5% K_2O). Their mineralogy is also dominated by high volume%, coarse (0.5-10 mm) mafic pyroxenes. Despite this, Panitahi lavas show more radiogenic $^{87}Sr/^{86}Sr$ ratios than older summit-sourced eruptives with similar SiO_2 concentrations. Clinopyroxene compositions are generally homogenous, although several samples show a range of distinct amphibole compositions. Titanomagnetite compositions, which differentiate eruptive groups at Taranaki, show generally more mafic compositions than summit lavas, while Curtis Ridge samples show even more mafic and lower-TiO_2 compositions. The crystal-scale heterogeneity of the lavas suggests assembly from multiple magmas, or mobilization of mafic crystals by a radiogenic melt. Re-analysis of paleomagnetic and tephra ages suggest that Panitahi mainly erupted over a ~3-2.8 ka BP. This, along with a narrow compositional range, suggests that Panitahi is more similar to other flank domes than a long-lived eruptive centre.

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POSTER
Session 1b.

DIFFUSIVE RE-EQUILIBRATION OF MAFIC ELEMENTS IN THE LEAD-UP TO THE WORLD'S YOUNGEST BASALTIC PLINIAN ERUPTION: THE 2019 ERUPTIVE SEQUENCE AT ULAWUN VOLCANO, PAPUA NEW GUINEA

Marco Rebecchi[1], **Dr. Ian Schipper**[1], **Dr. Cynthia Werner**[1] **and Dr. Bruce Charlier**[1]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, New Zealand*

marcomariarebecchi@vuw.ac.nz

The 2019 eruptive sequence at Ulawun volcano (5.05°S, 151.33°E, 2334m), which consisted of a Plinian eruption on June 26th and August 3rd and a Strombolian flank eruption on October 1st, includes the world's youngest Plinian eruptions of basaltic composition and represents the strongest and most mafic eruptions ever witnessed at Ulawun volcano since the start of monitoring. All three eruptions are characterised by only small seismic precursors and very quick eruptive onsets and cessations (< 24h). Textural and crystal-melt equilibria analyses of samples from all three eruptions reveal eruption triggering by abrupt magma decompression leading to fast magma ascent and a large viscosity increase by disequilibrium crystallization of microlites (plagioclase >> olivine > clinopyroxene). Compositional zoning of plagioclase antecrysts further indicates a very mafic (An>90) and volatile rich (>4 wt.% H2O) initial magmatic intrusion with a rim-ward negative correlation between decreasing An-content and increasing mafic element concentrations (Mg, Fe, Ti) that perfectly mirror each other. The anorthite curve is interpreted as growth curve showing an initial slow ascent and dehydration of this new intrusion while the mafic element curves indicate re-equilibration by diffusion after disruption through a last-stage mafic recharge. Increased magma decompression is assumed to have been triggered by volatile exsolution after last-stage mafic recharge leading to a rapid, buoyant ascent of the magma and large undercooling of the magma causing disequilibrium microlite crystallization. Due to their Plinian intensity, average degassed CO_2 outputs of around 460 kT for the June and around 595 kT for the August eruption have further been calculated with the help of respective satellite based TROPOMI SO_2 and previously published global, in-situ measured volcanic gas data. It is therefore assumed that the subducting slab at the New Britain trench is carbonate-rich introducing volatile-rich magmas into volcanic systems and volatiles as high as the Stratosphere.

ORAL
Session 1b.

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WAITAPU SHELL CONGLOMERATE (C. 0.9 MA), WHANGANUI BASIN

<u>Callum Rees</u>[1,2], Julie Palmer[1] and Alan Palmer[1]

[1] Department of Earth and Soil Science, *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*
[2] *Horizons Regional Council, Palmerston North, New Zealand*

callumjrees@gmail.com

The Whanganui Basin in the lower North Island of New Zealand contains one of the most comprehensive marine Quaternary successions exposed onland anywhere in the world (Pillans 2017). The succession is spectacularly exposed in the Rangitikei River valley, where ongoing regional uplift and deep fluvial incision has formed cliffs and steep valley sides.

The basins Castlecliffian succession (1.63 – 0.34 Ma) contains primary and reworked volcaniclastic products from the Taupo Volcanic Zone. Geochemical 'fingerprinting' of tephra and volcaniclastic beds allows for the identification of chronostratigraphic horizons, facilitating basin wide correlation. The units are often richly fossiliferous with fossil assemblages forming the basis for stratigraphic subdivision and contemporary counterparts persisting around modern-day New Zealand waters providing paleo-environmental analogues.

The Waitapu Shell Conglomerate is an important marker horizon that contains the first influx of Kaukatea Pumice (c. 0.9 Ma). The conglomerates fossil assemblage contains a mixture of estuarine to offshore species. Deposition is thought to have taken place seaward of a transgressive shoreline on a storm-dominated, muddy, innermost shelf, characterised by migrating gravel dunes interfingering with deeper water heterolithic facies.

We follow the Waitapu Shell Conglomerate and its lateral equivalents across the Whanganui Basin, exploring differences in lithology, sedimentary structures and faunal content. A reduction in bioclastic material occurs towards the basins eastern margin together with an increase in coarse greywacke detritus and preservation of lignite deposits.

Sedimentary response to ignimbrite emplacement appears to have involved inundation of river and coastal settings, causing valley aggradation, river avulsion, infilling and loading of the Whanganui coastal embayment and formation of a hydraulically active seafloor. Lateral changes in depositional style toward the basins eastern margin are considered to be related to relative position on the paleo-shelf, reduction of accommodation space, intermittent preservation of low stand deposits and proximity to the uplifting paleo-axial range.

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ORAL
Session 2b.

USING SEDIMENT CORES TO UNDERSTAND THE ENVIRONMENTAL HISTORY OF AOTEAROA'S LAKES

Lizette Reyes[1], Claire Shepherd[1], Marcus Vandergoes[1], Susie Wood[2], The Lakes380 Team[3]

[1] *GNS Science, Lower Hutt 5040, New Zealand.*
[2] *Cawthron Institute, Nelson 7042, New Zealand.*
[3] *https://lakes380.com/about-the-project/the-team/*

l.reyes@gns.cri.nz

The health of Aotearoa's lakes is central to our environmental, economic and cultural wellbeing. However, the knowledge we have about their health is very limited because less than 5% of them are monitored nationwide. Additionally, we know nothing about what most lakes were like prior to human disturbances in the landscape. This makes modelling national scale water quality and setting informed restoration targets challenging. The 'Our lakes' health; past, present, future' programme, also known as Lakes380 (www.lakes380.com), is using a comprehensive suite of techniques to assess current health and reconstruct the environmental history of Aotearoa's lakes. The team has been collecting surface water and sediment samples and sediment cores from across Aotearoa. With the sediment cores the aim is to collect 1000 years of lake history, capturing change from before human settlement until the present day. This will assist in understanding what factors have impacted these ecosystems over time. To date the team has sampled 305 lakes ranging from alpine, coastal, lowland and highland sites. A suite of environmental indicators from lake sediments, such as pollen, hyperspectral data and environmental DNA, are used to reconstruct vegetation change, lake productivity, algal abundance and shifts in lake health. Here we present details of the workflow associated with this ambitious national scale project, including core preparation and storage, curation and tracking of samples, sampling methods and analytical techniques and description of specialised equipment that are used in the teams' laboratories.

References.
https://lakes380.com/

POSTER
Session 2c.

REPEAT SEABED MAPPING: UNDERSTANDING COMPLEX MORPHOLOGICAL CHANGES IN SEAFLOOR BEDFORMS

Marta Ribó[1], Sally J Watson[2], Helen Macdonald[2], Lorna J Strachan[1], Arnaud Valcarcel[2], Craig Stevens[2], David Plew[2], Kevin Mackay[2]

[1] *School of Environment, Faculty of Science, The University of Auckland, New Zealand*
[2] *National Institute of Water and Atmospheric Research (NIWA), New Zealand.*

m.ribo@auckland.ac.nz

Repeat, high-resolution, multibeam surveys are crucial to identify geomorphological changes on the seafloor, especially in the extremely dynamic shallow waters (< 200 m water depth). Timeseries bathymetric datasets allow us to measure and monitor spatial- and temporal changes in submarine bedforms and determine their evolution patterns. This is important for a better understanding of the sediment transport processes and the related hydrodynamics, but also to determine the settings for benthic ecosystems and identify changes in seafloor geomorphology to prevent potential damage of offshore infrastructure and maritime pathways.

We present three multibeam data sets acquired in 2017, 2020 and 2021 over a field of gravel-sand bedforms located in the high-energy Cook Strait / Te Moana-o-Raukawa, between Cape Koamaru and The Brothers / Ngāwhatu-kai-ponu. In this study we combine timeseries bathymetric data, ground-truth data (video footage and sediment samples) and oceanographic data (i.e., combining hydrodynamic modelling (RiCOM and ROMS) with in-situ observations from an Acoustic Doppler Current Profiler) to understand the sediment dynamics in the area. Results show that coarse sand and gravel field of dunes with superimposed megaripples have undergone intricate morphological changes. The ~100-m length and ~15-m height submarine dune crests bifurcate, becoming more complex between 2017-2020, followed by the reforming of dune crests between 2020-2021. Hydrodynamic data and modelling suggests there is an interaction between the tidal near-bottom currents and the sediment transport, creating a morphological positive feedback, which might be leading the complex bedform morphological changes observed in the repeated mapping surveys.

This study reveals the dynamic nature of the seabed over short time-scales (years) in highly dynamic areas, such as the tidally vigorous Cook Strait region. Our findings demonstrate the importance of repeat multibeam mapping in understanding of the rate and scale of changes on the seafloor.

POSTER
Session 2e.

MICROPLASTICS IN MARINE SEDIMENTS: FINDINGS FROM THE FIRST STUDY AROUND AOTEAROA / NEW ZEALAND

Marta Ribó[1], Sally J Watson[2], Sarah Seabrook[1,2], Lorna J Strachan[1], Nina I Novikova[1] and Rachel Hale[2]

[1] *School of Environment, Faculty of Science, The University of Auckland, New Zealand*
[2] *National Institute of Water and Atmospheric Research (NIWA), New Zealand.*

m.ribo@auckland.ac.nz

Plastic pollution in the marine environment is a growing concern worldwide. However, little is known about the distribution and accumulation of microplastic particles (< 5mm) on the seafloor or the impact on benthic communities. Once in the ocean, microplastics behave like any other sediment particle and can become highly concentrated in specific environments with negative impacts on marine species and microbes.

In Aotearoa/New Zealand microplastics have been identified in sediments on land, in rivers, and in coastal zones; but the presence of microplastic particles in offshore marine sediments is less well-understood. Here we present the findings of the first study that have successfully identified plastic particles in offshore marine sediments around Aotearoa/New Zealand. We quantified the microplastic content in sediments collected from the Queen Charlotte Sound/Tōtaranui (QCS), using sediment cores from two sites: 1) high-human impact area, near the Picton coastal township; and 2) a low-human impact area, near the Kokomohua Marine Reserve (~30 km from the Picton township).

Results show different types of microplastic particles (e.g., fibres, fragments and foam), in several colours (e.g., blue, red, white and black), with different chemical composition, indicating a myriad of plastic pollution sources. We found an alarmingly widespread spatial distribution of plastic particles all over the QCS area. Microplastics were identified throughout the sediment cores, reaching depths of ~45 cm below the seabed. However, we observed variations in the abundance of microplastics across the sediment depth profiles across the two sites, suggesting there may be changes in the temporal distribution, sources and/or transport of microplastics within QCS.

This study provides crucial information for regional authorities to mitigate the source of plastic pollution in QCS. This research represents a proof of concept that can be used in future studies to identify the full extent of plastic pollution in Aotearoa/New Zealand's marine sediments.

ORAL
Session 2e.

LINKING PROCESSES TO DEPOSITS: FLUID MUDS IN THE LOWER WAIHOU RIVER, NEW ZEALAND

Ben Roche[1], Andrew D. La Croix[1] and Julia C. Mullarney[1]

[1] *Earth and Environmental Sciences, University of Waikato, Hamilton, New Zealand*

benr@waikato.ac.nz

Traditionally mud deposition has been considered to occur in low energy depositional settings, such as lakes or the deep sea. However, more recently, laboratory studies have shown that flocculation of mud particles can result in mud deposition at high flow velocities (Schieber, Southard & Thaisen, 2007); these deposits are known as dynamic muds and have been interpreted from shallow marine strata in the rock record (Mackay & Dalrymple, 2011). This study aims to determine how variations in physico-chemical conditions, forced primarily by river flow and tides, affect the depositional style and characteristics of mud beds within a modern fluvial to marine (FMT) system.

At five sites along the lower Waihou River, oceanographic instruments were deployed through a neap-spring cycle to quantify near bed flow parameters such as suspended sediment concentration, flow velocity and salinity. Co-located vibracores were collected following instrument deployment and were analysed using SEM, thin sections, and x-radiography to identify the dominant mud bed types. Results showed that three main styles of mud were deposited: 1) structureless muds, 2) low angle cross-laminated muds, and 3) graded muds. The types of mud beds observed indicate that, at least some of them were deposited under turbulent flow to quasi-laminar plug flow, as appose to gravitational settling; the process data supports this contention. In addition to variations in mud beds within individual cores, there was systematic variation across the FMT.

The results of this study are exciting because they show that under natural flow conditions: 1) mud is deposited at the same (fast) flow velocities as sand; and 2) the position of deposits along the FMT can be predicted based on the depositional style of muds. Together these findings will help improve paleoenvironmental reconstructions by providing process-response linkages that can be used by sedimentologists studying the ancient sedimentary record.

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ORAL
Session 2d.

REMOTE SENSING TECHNIQUES TO MAP PLANT BEHAVIOUR AT WAIOTAPU GEOTHERMAL FIELD

Cecilia Rodriguez-Gomez[1], Gabor Kereszturi[1], Reddy Pullanagari[2], Paramsothy Jeyakumar[1], Robert Reeves[3], Andrew Rae[3] and Jonathan N. Procter[1]

[1] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*
[2] *MAF digital Lab, School of Food and Advanced Technology, Massey University, Palmerston North, New Zealand*
[3] *GNS Science, Wairakei Research Centre, Taupo, New Zealand*

c.gomez@massey.ac.nz

Active geothermal areas can form over high heat flux due to shallow magma bodies or increased geothermal gradient. The exploration and monitoring of geothermal areas including geological, geophysical, and geochemical techniques, can be time and cost consuming. Optical remote sensing is an example of a cost and time-efficient geophysical method; although, it is challenged if geothermal areas are densely covered by vegetation. We hypothesise that vegetation can be used as a proxy to map underlying geothermal activity and heat-flux due to its capability for uptaking and translocating metals and metalloids from geothermal fluids and host rock/soil.

Here, we study the Waiotapu Geothermal Field (WGF), New Zealand, to evaluate the capacity of vegetation as a proxy for subsurface activity in geothermal areas. We focused on kunzea ericoides var. microflora – or colloquially Kanuka plants. Kanuka is an endemic shrub known for its thermotolerance, and its ability to live in acidic and nitrogen-depleted soils. Airborne hyperspectral remote sensing data was complemented with 77 Kanuka field samples, adjacent soil and rock samples for ground truth. These samples have been analysed using Visible Near Infrared (VNIR) and Shortwave Infrared (SWIR) spectroscopy and Inductively Coupled Plasma Mass Spectrometry (ICP-MS) for their chemical concentrations. The chemical concentrations were analysed using Principal Component Analysis to group indicator elements (e.g. Ag, As, Ba, Cd, Sb) for further analysis. Both spectral measurements were then used to detect high element concentrations typical for increased geothermal activity. Image regression using Kernel Partial Least Squares Regression and classification using Random Forest models were employed to map approximate element concentrations within the WGF. The results show good agreement with independent airborne thermal infrared survey and calculated vegetation height from Light Detection and Ranging survey data. These study shows the potential of vegetation to be used as a proxy for subsurface activity in densely vegetated geothermal areas.

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POSTER
Session 4b.

THE PACIFIC-WIDE TSUNAMI TRIGGERED BY THE M_W 8.1 RAOUL ISLAND EARTHQUAKE IN THE 5 MARCH 2021 TRIPLET OF TSUNAMIS

Jean Roger[1], Aditya Gusman[1], William Power[1] and David Burbidge[1]

[1] *Earth Structures and Processes, GNS Science, Lower Hutt, New Zealand*

j.roger@gns.cri.nz

At 2.27am New Zealand time on 5 March 2021 (13:27:34 UTC), a magnitude Mw7.3 earthquake occurred about 170km NE off Gisborne in the Hikurangi subduction zone (37.479°S/179.458°E). This earthquake woke up the North Island of New Zealand with a strong and long shaking and was the first of a triplet of events which triggered tsunami alerts later the same day.

At 6.41am, it was followed by a Mw7.4 earthquake on the Kermadec subduction zone (29.677°S/177.840°W). This turned out to be a foreshock of the following Raoul Island Mw8.1 megathrust earthquake that occurred at 8.28am (29.723°S/177.279°W).

Although the tsunami from the first earthquake was relatively small, mostly focused on the east and north coasts of the New Zealand North Island, and the second being mostly hidden in between the two others, the third one had a widespread propagation. It showed up on several New Zealand coastal gauges with maximum amplitudes of typically less than 30cm and globally maximum values of 65cm and 48cm were recorded at Norfolk Island and Galapagos respectively. A systematic analysis of 145 coastal gauge records located around the azimuth of the source epicenter classifies this tsunami as transoceanic, with a clear signal for example in Antarctica, California and even Japan.

The use of numerical simulation of tsunami source inversion models and filtering of available datasets confirms its widespread propagation and demonstrates that the first wave arrival is hidden in the ambient noise (e.g. storm) for ~1/3 of the stations and that, for most of them, the first wave does not correspond to the maximum amplitude which is about 3 times higher (median value). In addition, the main peak often occurred ~3 hours after the first arrival with longer delay of 10 hours and more observed in a few places. This is likely due to local effects.

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POSTER
Session 2a.

OXYGEN ISOTOPE PERSPECTIVES ON SILICIC MAGMATISM AND HYDROTHERMAL CIRCULATION IN THE MODERN CENTRAL TAUPŌ VOLCANIC ZONE

Shane M. Rooyakkers[1], Kevin Faure[1], Isabelle Chambefort[2], Colin J. N. Wilson[3], Simon J. Barker[3] and Hannah C. Elms[3]

[1] National Isotope Centre, GNS Science, Lower Hutt, New Zealand
[2]Wairakei Research Centre, GNS Science, Wairakei, New Zealand
[3]School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand.

s.rooyakkers@gns.cri.nz

New Zealand's central Taupō Volcanic Zone (TVZ) is among the most intensive regions of silicic magmatism, crustal heat flow and hydrothermal circulation on Earth. However, despite recent advances in understanding TVZ magmatic-hydrothermal systems, the origin of silicic magmas in the TVZ remains poorly constrained and the depths of hydrothermal fluid circulation are uncertain. Oxygen isotopes have potential for resolving these issues because the strong isotopic contrasts between mantle-derived magmas, greywacke basement and meteoric water allow mass exchanges to be traced through the crust. We present new laser fluorination oxygen isotope analyses of plagioclase ± quartz ± hornblende ± groundmass from juvenile products of silicic eruptions from the modern TVZ (i.e. events including, and after, the ca. 53 ka Rotoiti eruption). Crystals in the post-Rotoiti products of magmatic systems centred beneath Lake Taupō and the adjacent NE dome system, plus post-25 ka products of Ōkataina, have O-isotopic ratios appropriate for equilibrium with melt δ^{18}O values of ~+7-8.5‰ (VSMOW), consistent with measured groundmass values. This range excludes rare plagioclase and quartz grains with δ^{18}O >+10‰ that are inherited from (or crystallised from melts of) the greywacke basement. In contrast, plagioclase grains from the ca. 31-45 ka Mangaone Subgroup eruptions of Ōkataina show pronounced isotopic disequilibrium within individual units and higher δ^{18}O values, commonly ~+10-14‰, reflecting an abundance of material strongly influenced by or derived from greywacke. The melt δ^{18}O values of most modern TVZ silicic magmas are consistent with modest (<~30%) greywacke assimilation, in good agreement with radiogenic isotope data. Evidence for significant assimilation of low-δ^{18}O hydrothermally-altered crust is lacking, suggesting that most TVZ magmas reside below the zone of hydrothermal circulation, although a short-lived trend of decreasing δ^{18}O and increasing ^{87}Sr/^{86}Sr in Taupō magmas shortly after the caldera-forming Ōruanui eruption may reflect minor cannibalisation of altered roof rock following caldera collapse.

POSTER
Session 1a.

The influence of clay mineral properties on expansion in Southland soils, New Zealand

Clarissa Ross[1], **Dr Candace Martin**[1] **and Lawrence Kees**[2]

[1] *Department of Geology, University of Otago, New Zealand*
[2] *Environment Southland Regional Council, New Zealand*

clarissa.ross@postgrad.otago.ac.nz

Agriculture in New Zealand's Southland region constitutes a vital portion of the economy, reliant on soil health for sustainable farming practices and management of the region's freshwater resources. Some Southland soils expand in wet conditions, and are prone to macropore development, or "cracking" in dry conditions. This is primarily caused by a high proportion of clay minerals present with water content dependent particle sizes. This results in porosity that provides a passageway for water, pesticide, and fertilizer infiltration through the soil into the water table. The introduction of toxic agricultural chemicals into the soil and groundwater has adverse consequences for stock and human health, as groundwater is a major source of potable water in Southland. This project aims to relate clay mineralogy to both soil porosity and swelling, in respectively wet and dry conditions, by analysing the types and proportions of clay minerals in Southland soils.

Ten different Southland soil types have been sampled, primarily within the Central Plains area. The sites selected allow for variations in climate, relief, and parent material. Clay mineralogy analysis by X-ray diffraction to identify and quantify clay mineralogy is ongoing. Analysis of geochemical properties, including elemental composition, cation exchange capacity, pH, and carbon/nitrogen content illustrate how clay mineralogy relates to chemical and textural features. Clay mineralogy and radiometric data are compared to identify potential correlation of expansive soil with widespread spatial datasets. The data produced by this project will contribute to Environment Southland's soils database and improve the understanding of the role of clay minerals in soil expansion and soil drainage processes. These databases supply information to nutrient management programs like Overseer to provide soil drainage parameters that model nutrient leaching. Ultimately, this research will relate geochemical soil properties to hydropedological processes that have a significant impact on freshwater quality and water management.

POSTER
Session 2b.

STRONTIUM ISOTOPE RATIOS OF NEW ZEALAND KAURI: AN INDICATOR OF CLIMATE CONDITIONS?

Michael Rowe[1], Erik Mass[1], Bruce Charlier[2], Gretel Boswijk[1], Luitgard Schwendenmann[1]

[1] *School of Environment, University of Auckland, Auckland, New Zealand*
[2] *School of Geography, Environmental and Earth Science, Victoria University of Wellington, Wellington, New Zealand.*

Michael.rowe@auckland.ac.nz

Dendrochronology in New Zealand provides an important source of climate data. Recent research on kauri (*Agathis australis*) has shown that ring width variability contains a signal of the El Nino-Southern Oscillation (ENSO). However, the chemical signal contained within tree growth rings is also a potentially useful source of environmental data. Here, we present investigative research on the dendrochemistry of kauri tree-rings, utilising archived kauri cores from Northland, Auckland, and Coromandel. Trace elements and strontium isotopes from individual tree rings were analyzed to look for correlations to indices such as age (dendrochronology), tree ring width, rainfall, or El Nino-La Nina cycles.

Tree ring strontium isotopic compositions ($^{87}Sr/^{86}Sr$) of core from kauri in Northland and Auckland regions indicate systematic variations through the lifespan of the trees with isotopic ratios becoming less radiogenic as the trees age. Although both cores show the same temporal trend, the absolute magnitude of isotopic variability is quite different, with a Northland kauri tree recording a large $^{87}Sr/^{86}Sr$ range from >0.7103 to <0.7092, while a contemporary core from an Auckland kauri is all < 0.7092. Interestingly, carbon-normalized Sr count rates show no significant change in composition despite the changing isotopic compositions, while Mg/C, Rb/C and Ba/C are all positively correlated to $^{87}Sr/^{86}Sr$ in the Northland kauri core.

Isotopic compositions in this study broadly correlate to long-term rainfall records. However, there are no obvious correlations between isotopic or trace element compositions and El Nino – La Nina years, despite clear temporal trends in dendrochemical results. Lack of obvious correlation between geochemical results and climate conditions may result from averaging of chemical components across rings in the outer sapwood, or from biological processing-buffering of chemical components.

ORAL
Session 4e.

COASTAL CLIFF RETREAT OF THE EAST COAST BAYS FORMATION, AUCKLAND WITH SEA-LEVEL-RISE, NEW ZEALAND

Kuba Rozmus[1], David Bell[1] and Romy Ridl[1]

[1] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*

kuba.rozmus@pg.canterbury.ac.nz

Auckland has the highest population density to coastline ratio in New Zealand. The eastern bays are predominantly made up of the East Coast Bays Formation, which forms steep coastal cliffs that are prone to instability. Numerous cases of cliff failures have been documented, affecting recreational areas and residential developments. The cliff exposures show flat-lying closely interbedded sequences of sandstone and mudstone, although the sandstone consists of finer grained particles including clays. The thin mudstone (100-200 mm thick) preferentially erodes from wetting and drying, displaying slaking characteristics, resulting in rock block toppling of the sandstone units. Where bedding steepens due to soft-sediment slumping, the steeply inclined beds permit translational sliding.

Cliff retreat along the eastern bays, due to slope degradation from weathering and coastal erosion marine processes, is estimated to be between 3.5-180 mm/year (de Lange and Moon, 2005). This is expected to be exacerbated with increasing sea levels driven by climate change. Current projections of sea level rise across the Auckland coastline are ~1.1 m within the next 100 years (Bell et al., 2017). To evaluate the influence of sea-level-rise on cliff retreat and instability, local structures, and geotechnical properties of coastal cliffs should be characterized.

This research involves detailed mapping of the cliff face structures along the coastal cliffs between Stanmore Bay and Cockle Bay to (a) characterize the dominant failure mechanisms associated with geological structure; (b) identify geotechnical zones with similar geological structure and failure mechanisms; and (c) carry out a hazard assessment for each geotechnical zone. While investigations are ongoing, it is anticipated that this study will result in a geo-hazard map displaying areas with increases susceptibility to failure due to sea-level-rise.

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POSTER
Session 4c.

NEW INSIGHTS INTO THE SEDIMENTATION OF THE WELLINGTON BASIN (CBD) OVER THE LAST GLACIAL CYCLE

Matt Ryan[1], **Connor Chisnall**[1], **Ayoub Riman**[1],

[1]*ENGEO Ltd, Wellington, New Zealand.*

mtryan@engeo.co.nz

The engineering and design of seismically resilient constructions requires extensive ground investigations. Here we present sediment core and borehole data retrieved from the lower Thorndon Basin and the Te Aro Basin from the Wellington CBD, and outline their recent and geological history.

Several ~55m cores from the Thorndon Basin are dated to beyond 25 ka, and suggests average sedimentation rates were ~2 m/kyr. These sedimentation rates are up to 4 times higher than that of the Te Aro Basin. Both sites showed distinct changes in sediment ranging from alternations in gravel, sand, silt, shell rich mud, organic muds, and peat. Extensive investigation of these cores will help to provide new insights into the tectonic, sea level and vegetation histories on the landscape over the Late Pleistocene in the Wellington Region.

POSTER
Session 2d.

Source-to-sink archives of vegetation change since the Last Glacial Maximum, Waipaoa Sedimentary System, New Zealand.

Matt Ryan[1], Kat Holt[2], Gavin Dunbar[3], Mike Marden[4], Brent Alloway[5], Dallas Mildenhall[6], Alan Palmer[2], Helen Bostock[7]

[1.] *ENGEO Wellington, 6140, New Zealand;*
[2] *School of Agriculture and Environment, Massey University, Palmerston North, 4410, New Zealand.*
[3] *Victoria University Wellington, Te Herenga Waka, Wellington, New Zealand.*
[4] *48 Hillview Terrace, Gisborne 4010, New Zealand.*
[5] *School of Environment, The University of Auckland, Private Bag 92019, Auckland, New Zealand*
[6] *GNS Science, Lower Hutt, 5040, New Zealand*
[7] *School of Earth and Environmental Sciences, University of Queensland, Brisbane, Queensland, Australia*

Mtryan@engeo.co.nz

Records of terrestrial vegetation change capturing the last deglacial between ~18 and 6.5 ka from the Gisborne/East Coast region of the North Island, have been challenging to obtain. Arid conditions combined with the unstable landscape characteristic of the tectonically and volcanically active region precluded development and persistence of lake and bog sites suitable for preservation of long, continuous pollen records. However, lacustrine sediments preserved in abandoned meander channels on relict fluvial terraces provide a hitherto untapped source of pollen records.

Three such sites in the Waipaoa Sedimentary System (WSS) have been sampled to yield discontinuous pollen records; Redpath (16.3-14.1 ka); Linburn (18.3-8.5 ka); and Manders Rd (14-2 ka). These pollen data are further supported with a 18-7 ka pollen record from marine core MD06-3002, lower Poverty Bay continental slope, and a ~13-0 ka pollen record from the continental shelf (MD06-3006). Ages were constrained by radiocarbon dating and tephrochronology. For the early deglacial, both the onshore and offshore data imply cool climate conditions, with herbs and alpine trees and shrubs, and stands of beech or mixed beech/podocarp forest likely populating the exposed continental shelf. By ~15.5 cal ka BP much of the region was under forest.

At MD06-3006, the highest proportions of mangrove pollen (*Avicennia marina*) and the thermophilous shrub *Ascarina lucida* occur between 11-6.5 ka. This timing is consistent with evidence for a post-glacial rise in sea-level and inundation of the Waipaoa floodplain between 10-7 kyr. The presence of these taxa suggest climate was warm and humid during the early Holocene, with mangroves presently found further north (1°) in the Bay of Plenty. Ferns increase following frequent volcanic disturbances, with a 10x increase in *Pteridium* spores at ~~1312 AD consistent with Polynesian arrival.

ORAL
Session 2c.

ORAL

ZIRCON FERTILITY AND YIELD OF PLUTONIC SUITES AND IMPLICATIONS FOR PROVENANCE STUDIES, TE RIU-A-MĀUI/ZEALANDIA

Matt Sagar[1]

[1] *GNS Science, Avalon, Lower Hutt, New Zealand*

m.sagar@gns.cri.nz

Detrital zircon (DZ) geochronology of sandstones has become the most commonly and widely used method in provenance studies of sedimentary successions. However, the zircon fertility and yield of sediment sources are rarely addressed in a comprehensive manner. Using geological map and whole-rock geochemical data, zircon fertility and relative yield for basement rocks have been investigated. Results for the three most voluminous Devonian–Cretaceous plutonic suites (Karamea, Darran and Separation Point) are presented here.

On a Zr Harker diagram, the Karamea Suite defines a negative trend. In contrast, the Darran and Separation Point suites have convex-up patterns with Zr peaks at ~55 wt% SiO_2. This suggests that Karamea Suite magmas were saturated with respect to zircon, whereas only those Darran and Separation Point suite magmas with ≥55 wt% SiO_2 crystallised zircons. The mean Zr in rocks of these suites with ≥55 wt% SiO_2 is indistinguishable (~140 ± 75 ppm). Therefore, assuming all Zr is contained in zircon, the average zircon *fertility* of the Karamea, Darran and Separation Point suites is comparable.

Zircon *yield* (Spencer et al., 2018) for a given geological unit depends not just on zircon fertility but also on erosion rate and areal extent. Paleo-erosion rates are difficult to quantify. On the other hand, plutonic suite areal extents can be readily estimated using geological map data. The areal extents of the Karamea and Darran suites are ~35% and ~90% that of the Separation Point Suite (>4000 km^2; Ringwood et al., 2021). This partly explains the prominent c. 110–125 Ma peak in the DZ age spectra of many Cretaceous–Cenozoic sandstones. However, it is not the entire extent of the suites that is important rather that of constituent zircon-bearing plutons (i.e., those with ≥55 wt% SiO_2). Work is on-going to quantify this for the Darran and Separation Point suites.

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ORAL
Session 1c.

TOWARDS A BICULTURAL APPROACH TO DESIGNING EDUCATIONAL RESOURCES IN AOTEAROA NEW ZEALAND: RECOMMENDATIONS FROM REFLECTIONS AT THE INTERFACE

Sriparna Saha[1,2], Sylvia Tapuke[3], Kelvin Tapuke[4], Ben Kennedy[2], Sara Tolbert[1] & Angus Macfarlane[1]

[1]College of Education, Health and Human Development, University of Canterbury, Christchurch, New Zealand
[2]School of Earth & Environment, University of Canterbury, Christchurch, New Zealand
[3] Kaiarahi, Partnerships Advisor, SCION, Rotorua, New Zealand
[4]Partnerships Advisor, ECLIPSE Program, New Zealand.

ssa317@uclive.ac.nz

Aotearoa, New Zealand is volcanically active due to its location on the boundary of the Australian and Pacific plates. Māori, the Indigenous people of Aotearoa, have extensive knowledge of their local area and history of past volcanic activity. Braiding of the Indigenous knowledge system of Mātauranga Māori with Western science can lead to increased preparedness and understanding of volcanoes. However, successful collaboration between different knowledge systems are challenging due to the history of colonial extractive research.

Here, we share insights from our work for designing bicultural educational resources. In 2019, the Earthquake Commission (EQC)[1] New Zealand with a vested interest to raise awareness of natural disasters and their impacts commissioned the LEARNZ "our supervolcanoes" virtual field trip to teach about caldera volcanoes in Aotearoa. The involvement of Kaupapa Māori researchers in the project facilitated an authentic opportunity to develop bicultural educational resources.

Interviews with involved iwi representatives, geologists and educators demonstrate that (i) opportunities for multiple engagements (ngā wānanga, ngā hui) to lay groundwork for long term relations; (ii) constructing & reconstructing needs of the project prior to its start and re-affirming them throughout; (iii) communicating, understanding and following tikanga (protocols) and agreed upon norms throughout, to acknowledge and appreciate the support provided by each iwi representative; (iv) budgeting to include provisions for salaried partnerships and culturally appropriate compensations and acknowledgement of mana whenua[2] hosting obligations; (v) following up projects with Māori partners to maintain mutually beneficial long term relationships can foster successful research partnerships. We recommend that these lessons from the co-construction of the LEARNZ VFT inform the engagement process with local iwi representatives for development of future bicultural educational resource thereby supporting the partnership approach to research collaborations in Aotearoa.

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[1] https://www.eqc.govt.nz/
[2] Iwi with ancestral connections to the area

ORAL
Session 3e.

Evolution of Cretaceous normal faulting in the Great South Basin

<u>Tusar R. Sahoo</u>[1, 2], Andy Nicol[1], Greg H. Browne[2] & Dominic P. Strogen[2]

[1] *University of Canterbury, Private Bag 4800, Christchurch, New Zealand*
[2] *GNS Science, P O Box 30368, Lower Hutt, New Zealand.*

t.sahoo@gns.cri.nz

Rift basins form due to extensional tectonics, with the history of growth faulting providing insights into continent-scale processes. Many global examples of rift basins have been uplifted and inverted, and in such cases, it is difficult to study the complete fault growth history. However, the Great South Basin is a continental rift basin which contains a thick Cretaceous rift succession that is largely unaffected by Neogene compressional tectonics and is imaged by good-quality seismic data. Interpretation of these data suggest three distinct stages of Cretaceous normal faulting, referred to here as; fault system initiation, fault system growth and fault system death. Each stage shows development of rift grabens filled with onlapping strata above a basal unconformity. The different stages of fault-system evolution comprise dominant NE-trending faults, and minor NW-trending faults. Fault system initiation (~105–101 Ma) primarily occurred in the central Great South Basin with rift depocentres mostly on, or close to, NW-trending basement terrane boundaries. These pre-existing basement boundaries represent zones of weakness that locally promoted early localisation of NW faults and retarded the propagation of NE faults. The fault system growth stage (~101 to 90 Ma) was characterised by widespread and more intense faulting with NE-trending faults increasing in length, number, displacement and spatial distribution. The influence of basement fabric gradually decreased during this stage. Finally, during the fault system death stage (~90 to 83 Ma) the number, length and displacement of faults decreased. Fault death coincided in time with the onset of Gondwana breakup and reflects the localisation of extension along spreading centres distal to the Great South Basin.

ORAL
Session 1c.

GeoNet 20th Anniversary: A walk-through the GeoNet Earthquake catalogue and its evolution

Jerome Salichon[1], **John Ristau**[1], **Steve Sherburn**[1], **Annemarie Christophersen**[1], **Jonathan Hanson**[1]

[1] *Geological and Nuclear Sciences, GNS*

j.salichon@gns.cri.nz

As part of GeoNets 20th anniversary, we propose a walk-through of one of its most critical outputs and datasets; namely the collected event information data set also known as "earthquake catalogue".

The present GeoNet catalogue has been inherited from previous NZ geological surveys. It contains thousands of events documented or located and informed over decades by the New Zealand Geological Survey (1865) and later by various DSIR and GNS Science initiatives. Over the last twenty years, it exists as a maintained and curated scientific publicly available product generated in near real-time from the GeoNet operated national permanent earthquakes monitoring systems and seismic acquisition networks. Contextually, the earthquake catalogue sits closely alongside a variety of complementary GeoNet and Earthquake Information Database data sets (a Nationally Significant Collection and Database hosted by GNS). These include the paper seismogram collection, digital seismic waveform and metadata repositories and a host of derived earthquake data sets (e.g. strong motion focused data products, regional moment tensors).

The GeoNet event data set is a substantial patchwork of earthquake information combining different methodologies, acquisition processes, science evolution and interests. Here we represent and describe this critical data set over time and space, with some focus on key evolutions such as network development and expansion, changes in earthquake location systems, and key events captured by the network.

We will draw on a range of complementary and contextually related data sets in order to empirically capture an overall summary of the earthquake event information records in held in the catalogue. Taking the opportunity of the 20th GeoNet anniversary, this data set walk-through is a first step into exploring the future of the maintenance, management, and development of a modern digitized and versioned national earthquake catalogue.

POSTER
Session 2a.

WELLVEL: WELLINGTON REGION WATER WELLBORE LEVELS AND SEISMIC VELOCITY CHANGES

Martha Savage[1], Sam Thorpe-Loversuch[1], Hubert Zal[1], Corentin Caudron[2], Megan Kortink[1,3], Katie Jacobs[3], John Townend[1], Simon Lamb[1], Caroline Holden[4], Aaron Laing[5], Konrad Weaver[1]

[1] School of Geography, Environment and Earth Sciences, Victoria University of Wellington, New Zealand
[2] ISTerre, Univ. Grenoble Alpes, Univ. Savoie Mont Blanc, CNRS, IRD, IFSTTAR, 38000 Grenoble, France
. [3] GNS Science, Lower Hutt, New Zealand
[4]SeismoCity Ltd, New Zealand
[5]Greater Wellington Regional Council, Wellington, New Zealand

Martha.savage@vuw.ac.nz

Seismic wave speeds, water bore levels and GNSS station locations all changed at the time of the 2016 Kaikōura earthquake. The WELLVEL project is determining the relation between these types of changes by re-examining data from permanent GeoNet stations and by deploying temporary seismometers at sites of 11 water bores in the Wellington region that were evaluated for changes due to the Kaikōura earthquake.

For the permanent data on the South Island, using the station-to-station noise cross-correlation technique we found drops in velocity at the time of the Kaikōura earthquake up to 0.2%. Cross-component correlations on stations in the Wellington region return velocity drops up to 0.5% on southwestern stations BHW and WEL at the time of the Kaikōura earthquake for the frequency range 0.1-1 Hz. These drops are not as strong on stations located further north, with the largest amplitude drop of about 0.25% on station KIW at Kāpiti Island and OGWZ just northeast of KIW.

The 5th March 2021 M7.3 Te Araroa earthquake about 600 km northeast of Wellington produced the most intense ground shaking response on WELLVEL, with an initial 174 mm drop in water height and a peak ground acceleration of 3.9 cm/s^2. This event and two more distant Kermadec earthquakes (M=8.1 and 7.4) on the same day produced tsunamis that were visible on a wellbore near the shore. However, none of the stations showed any net increase or decrease in water level or in seismic velocity in the hours following the event.

Correlation between water height and seismic velocity is ambiguous over long-term scales. We are checking our processing parameters to see if we can get stronger signals to be sure whether we can distinguish the difference between signal and noise when we compare velocity changes to earthquake occurrence and to water well levels.

POSTER
Session 2a.

A Landscape-Age-Aware Model of Potential Rock Slope Instability in Kaikoura, NZ

Lilith Schacherer[1], Kerry Leith[1,2], Larissa de Palezieux[1] and Simon Loew[1]

[1] *Department of Earth Sciences, ETH Zurich, Zurich, Switzerland*
[2] *Surface Geosciences, GNS Science, Lower Hutt, New Zealand*

k.leith@gns.cri.nz

The susceptibility of rock slopes to external perturbations (e.g. heavy rainfall or earthquakes), may depend on the sensitivity of the host landform. As weathering and internal fracture propagation degrade rock mass strength through time, the sensitivity of rock slopes to external forcing events is likely to be dependent on the age, and erosional setting of landscape elements. Here we present new models to estimate the surface ages and erosional activity of elements with respect to the maturity state of the landscape. This new approach offers the opportunity to highlight geomorphological controls on earthquake-induced landsliding.

We employ geological data, and morphological metrics to classify the landscape into eight separate categories, including soil, and water bodies, and six bedrock landforms (concave surface, convex surface, slope, cliff, cliff top, cliff toe). Our landscape age model is based on an assessment of local uplift, erosion, and drainage-basin relief and attempts to capture the time since landforms within the catchment were at the fluvial baselevel. We separate age intervals by interglacial cycles and regional changes in tectonic activity, assuming these define periods of accelerated landscape change. Based on expert knowledge, we then identify five landslide susceptibility categories designed to highlight landforms undergoing either an increase in driving stress or reduction in internal strength. These include relatively young (<100 ka), weathering-controlled cliffs and hillslopes; older fracture-controlled cliffs and hillslopes (>100 ka), mature (125 - 370 ka) fracturing controlled cliffs and crests in small catchments, mature (125 - 370 ka) slopes and cliffs with high roughness, and transitional regions associated with high normalized channel steepness within relict (> 2 Ma) terrains.

We test our model with a statistical analysis that compares the landslide distribution of the 2016 Kaikoura Mw 7.8 earthquake with randomly seeded points that predict landslide occurrence based on ground motion amplitudes.

ORAL
Session 4c.

DEVELOPMENT OF A BAYESIAN EVENT TREE FOR SHORT-TERM ERUPTION ONSET FORECASTING AT TAUPŌ VOLCANO

Emmy Scott[1], Mark Bebbington[2], Thomas Wilson[1], Ben Kennedy[1] and Graham Leonard[3]

[1] *School of Earth and Environment, University of Canterbury, Christchurch*
[2] *School of Fundamental Sciences, Massey University, Palmerston North*
[3]*GNS Science, Lower Hutt, Wellington.*

emmy.scott@pg.canterbury.ac.nz

Taupō volcano, within the Central Taupō Volcanic Zone, is a silicic caldera volcano that has experienced both relatively small and very large eruptions. It is home to the world's most recent super-eruption, the 26.5ka Oruanui Eruption, and one of the most violent eruptions in the last 5000 years, the 232AD Taupō eruption. There have been at least 27 eruptions of VEI 3-6 at Taupō since 20.5ka, making Taupō volcano one of the most frequently active silicic volcanoes on earth. Considering there are 39,300 people living within 50km of Taupō volcano and 3.4 million within 250km, there is a high volcanic hazard exposure and a clear requirement to manage the volcanic risk. This is complicated by observations that Taupō volcano has experienced 17 recorded periods of unrest in the last 140 years, none which have led to eruption. There is little understanding about volcanic unrest at Taupō, particularly the implications for eruption forecasting.

Therefore, improved eruption forecasting tools would be particularly useful to help inform risk management for a future crisis at Taupō. One possible approach was developed to answer how likely an eruption will occur, given observed unrest – Bayesian Event Tree for Eruption Forecasting (BET_EF) (Marzocchi et al., 2008). Such BETs aid scientists, decision makers, and emergency management in understanding the dynamics of an unrest episode, and hence the potential risk.

BET_EF was developed specifically for Taupō volcano for short-term eruption forecasting. The Taupō volcano BET_EF model was developed from analogue data augmented as necessary through a structured expert elicitation workshop with the majority of Aotearoa-New Zealand's volcanologists and monitoring experts. The resulting BET_EF model was then validated by running though each historic unrest episode at Taupō volcano, which provided an estimated magmatic unrest and eruption probability for each unrest episode.

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POSTER
Session 2a.

WHAT LIES BENEATH? ZEALANDIA'S LOWER LITHOSPHERE

James M. Scott[1]

[1] *Department of Geology, University of Otago, Dunedin, New Zealand*

Aitev257@student.otago.ac.nz

New Zealand has a remarkably large number of exhumed mantle occurrences for a small (exposed) landmass. Since the last regional syntheses of peridotite (1987) and serpentinite (1966), many new locations have been discovered and abundant geochemical and isotopic data have been acquired. Mantle peridotite is now known from nine massifs along the base of the Dun Mountain Ophiolite Belt (DMOB), xenoliths in volcanic fields in at least 77 localities, and as one 15 km-long orogenic body in Fiordland. In these occurrences, spinel peridotite is abundant, plagioclase peridotite is restricted to the DMOB, and garnet peridotite is absent. Geothermobarometry of these rocks indicate a relatively thin Zealandia lithosphere of < ~ 70-80 km. The xenoliths and orogenic peridotites represent exhumed lower portions of Phanerozoic continental lithosphere, largely modified by hydrous melting during Cenozoic subduction whilst Zealandia was still part of the accretionary margin developed onto the East Antarctic Craton. Following the cessation of Early Cretaceous subduction, some of the refractory mantle domains appear to have been laterally translated under the Gondwana forearc during slab rollback and associated heating to granulite facies of the lower crust. This is supported by the occurrence of trapped arc melts that are now converted to garnet pyroxenite and were metamorphosed towards the end of the Early Cretaceous. Hydrated mantle peridotite (serpentinite) is even more widespread than peridotite in Zealandia and is extensively developed in three ophiolites (Dun Mountain, Northland and Pounamu). These ophiolites mark important evidence for the closure of ocean basins with the Zealandia tectonic framework.

ORAL
Session 1c.

BURIED SWAMPS REVEAL RAPID POST-LGM HOLOCENE SEA-LEVEL RISE IN WESTLAND, SOUTH ISLAND

James M. Scott[1], **Aidan Aubert**[1], **Tom Ritchie**[2]

[1] *Department of Geology, University of Otago, Dunedin, New Zealand*
[2] *Hardie Pacific, Dunedin*

James.scott@otago.ac.nz

Examination of sediments in bore holes down to a depth of 75 m below current sea-level on the floodplains of South Westland near the Manakaiaua River, indicates that basal glacial sediments consisting of silts are overlain by terrestrial inter-layered gravel, sand and swamp horizons formed as the rivers meandered over the plains. Offset calculations of valleys and moraines displaced by the Alpine Fault in this area suggest that the moraines must date back to at least 120,000 years. Although the Alpine Fault is nearby, this area has not been significantly tectonically affected in the last 20,000 ka. This means that the sediments record the terrestrial sedimentation as sea level rose. Radiocarbon dating of material near the base of the boreholes yielded dates of ~ 10,000 years BP, whereas dating of wood at only 18 – 19 m depth produced a date of 7,000 years BP. These results suggest that this area preserves evidence for high initial rate of sedimentation (~9.2 mm/yr) between 10,000 – 7,000 years BP and a slower sedimentation rate (~2.7 mm/yr) over the last 7,000 years. This is consistent with initial rapid infilling of the valley as sea-level rose following the Last Glacial Maximum, followed by a slow rise to the current level.

POSTER
Session 4e.

MICROBIAL MARKERS OF HUMAN DISTURBANCE: CURRENT KNOWLEDGE AND FUTURE POTENTIAL

Sarah Seabrook[1,2], Marta Ribo[2] and Sally Watson[1]

[1] *National Institute of Water and Atmospheric Research, Wellington, New Zealand*
[2] *School of Environment, University of Auckland, Auckland, New Zealand.*

sarah.seabrook@niwa.co.nz

Coastal ecosystems are centres of ecologic and economic productivity, yet are among the most threatened by human impacts. These systems face chronic and acute risks from cumulative impacts of pollution, seafloor disturbance, and rapidly changing climate conditions (Thrust et al., 2021). Few tools exist to monitor the synergistic human stressors that plague coastal ecosystems, and current monitoring efforts struggle to keep pace with the rapid changes. Advancements in molecular technologies have led to great successes in environmental monitoring through eDNA approaches such as the marine biosecurity toolbox (Bowers et al., 2021). Similarly, experiments in a range of ecosystem types have found measurable and predictable microbial responses to various pollutants (i.e. De La Rosa-Acosta et al., 2015). Here, we propose that microbial markers may provide a method of holistic environmental assessment, allowing us to monitor and detect a range of cumulative stressors with one tool. Due to the speed at which evolutionary forces act upon most microbial taxa, we also foresee this approach being able to provide rapid assessment of subtle shifts in ecosystems away from stable states, before environmental tipping points are neared or passed. As pollution and climate change impacts continue to increase, we will face many uncertainties in our management of coastal ecosystems. The development of tools to screen environments for microbial markers of pollution may be key to more rapid, effect ecosystem management in this uncertain future.

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POSTER
Session 2e.

Marine Seeps in Changing Environments

Sarah Seabrook[1,2,3], **Marta Torres**[3]

[1] *National Institute of Water and Atmospheric Research, Wellington, New Zealand*
[2] *School of Environment, University of Auckland, Auckland, New Zealand.*
[3] *College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Oregon, United States*

sarah.seabrook@niwa.co.nz

When it comes to seeps, geologists and ecologists would likely agree on one thing – while similarities may be found, no one seep is the same as any other. The product of complex forces, acting across geological to modern time scales, seep communities develop at the interface of Darwinian evolution and plate tectonics. We see these interacting forces on methane seeps that proliferate across continental margins driven by tectonic and environmental drivers, such as those in the Cascadia and Hikurangi Margins, to emergent seeps forming at our poles under a warming climate, such as those observed in the Ross Sea. Using these three environments, we will explore (1) how plate subduction and environmental conditions interact to produce depth delineated seep habitats on the Cascadia Margin, (2) how varied subsurface flow regimes and human impacts together shape seep habitats on the Hikurangi Margin, (3) and how glacial-interglacial cycles couple with a rapidly changing climate to lead to emergent seeps in the Ross Sea of Antarctica. With these examples, we will discuss how geologic forcing factors, natural selection from microbial to macro scales, and human influence may interactively contribute to form these dynamic seep systems. Identifying points of intersection, we will conclude with thoughts of how looking across these drivers can help us better understand unique seep environments across changing environmental conditions.

ORAL
Session 2e.

Geologic, earthquake and tsunami modelling of the active Cape Egmont Fault Zone

Hannu Seebeck[1], Glenn Thrasher[1], Paul Viskovic[1], Suzanne Bull[1], Clarrie Macklin[1], Xiaoming Wang[1], Caroline Holden[1,*], Yoshi Kaneko[1,2]

[1] *GNS Science, PO Box 30368, Lower Hutt 5040, New Zealand*
[2] *Kyoto University, Yoshida-honmachi, Sakyo-ku, Kyoto 606-8501 Japan.*
**now at SeismoCity Ltd., 16 Buckley Road, Wellington 6023, New Zealand*

h.seebeck@gns.cri.nz

The active Cape Egmont Fault Zone in the southern Taranaki Basin, New Zealand, is a complex series of synthetic and antithetic dip-slip normal faults accommodating present-day extension. The fault zone is well imaged on petroleum industry seismic reflection data, with a number of faults exposed and studied onshore. This presentation provides an overview of Seebeck et al. (2021)'s examination of earthquake hazard along the fault zone.

The maximum depth of fault rupture is c. 20 km, above which 90% of recorded earthquakes occur. Earthquake focal mechanisms generally indicate strike-slip to oblique-normal faulting, which contrasts with dip-slip faulting observed in the sedimentary sequence and surface fault traces.

Fault lengths determined from a three-dimensional structural model indicate likely earthquake magnitudes from the fault population sampled are M_W 5.4 ± 0.5. The largest and most mature fault – the Cape Egmont Fault – is at least 53 km long and, dependent on segment rupture, could generate an earthquake up to M_W 7.3.

Ground motions and shaking intensities were examined by numerical simulation for M_W 7.1 Cape Egmont Fault earthquake scenarios. Predicted ground motions (Peak Ground Velocity [PGV] and Peak Ground Acceleration [PGA]) at key locations were estimated using deterministic and stochastic modelling methods.

Stochastic ground motion models result in greater PGVs than deterministic models or Ground Motion Prediction Equations, particularly within 10 km of the source. Stochastic PGAs are comparable to observed PGAs from the Darfield earthquake, despite differences in fault source parameters. Predicted shaking intensities are strong to very strong across the southern Taranaki Peninsula.

A numerical tsunami model generated for a M_W 7.1 Cape Egmont Fault earthquake scenario indicates that a significant east-directed tsunami could sweep the coastlines around the South Taranaki Bight. A focused maximum wave height of up to 2 m is predicted at the coast to the northwest of Whanganui.

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ORAL
Session 2a.

PLUTONIC INSIGHTS INTO SHALLOW MAGMA SYSTEMS BENEATH THE CENTRAL TAUPŌ VOLCANIC ZONE (NEW ZEALAND) AND THEIR RELATIONSHIP TO THE MAGMA-HYDROTHERMAL INTERFACE

Laura K. Seelig[1], Colin J.N. Wilson[1], Isabelle Chambefort [2], Shane M. Rooyakkers[3]

[1 1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand.*
[2] *GNS Science, Wairakei Research Centre, Taupo, New Zealand.*
[3] *GNS Science, National Isotope Centre, Lower Hutt, New Zealand.*

laura.seelig@vuw.ac.nz

The central Taupō Volcanic Zone (TVZ) is an area of vigorous Quaternary silicic volcanism accompanied by an exceptional geothermal heat flux reflected by 23 high-temperature (>240 °C) geothermal systems. It is challenging to observe the processes occurring in modern magmatic systems underlying the central TVZ, and most of what we know about such processes comes from past eruptive products. Geophysical studies can inform on the location, extent and movement of magma in real-time, but cannot provide detailed information on magma or fluid compositions, or processes occurring within the magma chamber(s).

Within the central TVZ, rare plutonic fragments have been ejected as lithic clasts in several silicic and mafic eruptions. These plutonic rocks offer vital insights into young magmatic systems underlying the central TVZ and their relationship to overlying hydrothermal systems. A collection of granitoids from several central TVZ eruptions will be used for petrographic (mineralogical and textural), geochemical and isotopic analysis. These data will be used to constrain the environment of crystallisation of these granitoids, in terms of pressure (depth) and temperature constraints and the magmatic processes contributing to their petrogenesis.

In addition to petrological characterisation, the residual fluids in these granitoids will be assessed through studies of fluid inclusions from quartz phenocrysts and hydrothermal quartz that have grown within vugs. Assessment of the fluids circulating during and after granitoid crystallisation and the formation of miarolitic cavities will help to constrain processes occurring in the enigmatic magmatic-hydrothermal transition zone. These data will provide further insights on the origins of 'deep' hydrothermal fluids and their magmatic components, which are sampled in modern TVZ geothermal wells. This combination of petrological and stable isotope assessment of the granitoids, we will address whether and when meteoric fluids reach the granitoid bodies and hence indicate the presence or absence of significant permeability that can guide future utilisation of supercritical geothermal resources.

POSTER
Session 1a.

A CENTURY OF ONGOING SILICIC VOLCANISM AT CORDÓN CAULLE, CHILE: NEW CONSTRAINTS ON THE MAGMATIC SYSTEM'S DEPTH

Gilles Seropian[1], Ian Schipper[2], Sarah Smithies[1], Lydia Harmon[3], Ben Kennedy[1], Jonathan Castro[4], Brent Alloway[5,6] and Pablo Forte[4,7]

[1]*School of Earth and Environment, University of Canterbury, Christchurch New Zealand*
[2]*School of Geography, Environmental and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand*
[3]*Earth and Environmental Sciences, Vanderbilt University, Nashville, USA*
[4]*Institute of Geosciences, Johannes Gutenberg-Universität Mainz, Mainz, Germany*
[5]*School of Environment, The University of Auckland, Auckland, New Zealand*
[6]*Instituto de Geografía, Pontificia Universidad Católica de Chile, Santiago, Chile*
[7]*Instituto de Estudios Andinos, UBA-CONICET, Buenos Aires, Argentina*

gilles.seropian@pg.canterbury.ac.nz

Cordón Caulle in southern Chile has produced three dacitic to rhyolitic fissure eruptions over the past century (in 1921-1922, 1960 and 2011-2012), and thereby provides an ideal opportunity to examine the architecture of its underlying silicic system. While the 2011-2012 eruption has been extensively studied, comparatively little is known about the 1921-1922 and 1960 events. Major-element matrix glass analyses from the 1960 products (71.5 wt.% SiO_2) are indistinguishable from the 2011-2012 data (72.2 wt.% SiO_2), but the 1921-1922 analyses form a discrete, slightly less evolved sub-population (69.0 wt.% SiO_2). We utilise rhyolite-MELTS geobarometry to estimate both the storage and extraction depths of all three magmas. For all three eruptions, magma was stored in the shallow crust, between 80-150 MPa (3.5-6.6 km). The 2011-2012 magma body spanned this whole depth range but the 1921-1922 and 1960 magma bodies were more confined in pressure, at 90-112 MPa (4.0-5.0 km) and 123-13 MPa (5.4-6.3 km) respectively. Melt extraction from a parental crystal-mush occurred in the range 70-200 MPa (3.1-9.0 km) for all three eruptions, suggesting contiguous melt segregation and storage in the shallow crust. We then discuss whether the deeper magma storage in 1960 reflects the influence of a seismic trigger by events associated with the M9.5 Great Chilean earthquake. Finally, we explore whether bubble textures of the erupted products can be related to the magma storage depths.

ORAL
Session 1b.

EVIDENCE OF VOLCANIC-TECTONIC INTERACTIONS ON A NEWLY IDENTIFIED FAULT IN THE REPOROA BASIN, TAUPŌ VOLCANIC ZONE, NEW ZEALAND

Yaasameen Shalla[1], Pilar Villamor[2], Colin J.N. Wilson[1], Nicola Litchfield[2], Robert Langridge[2], Cecile Massiot[2], James Muirhead[3] and Madisen Snowden[3]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand*
[2] *GNS Science, Lower Hutt, New Zealand*
[3] *School of Environment, The University of Auckland, Auckland, New Zealand*

yaas.shalla@vuw.ac.nz

The Reporoa Basin of the Taupō Volcanic Zone (New Zealand) is often considered less tectonically active than the surrounding Taupō Rift. However, Light Detection and Ranging (LiDAR) sensing acquired between 2011 – 2015 has highlighted features interpreted as potentially active fault traces in the Reporoa Basin. The inferred fault traces have 060° and 045° orientations and are observed between the eastern section of the modern Taupō Rift (TR) and the North Island Fault System (NIFS). Although 060° striking faults are not unknown in the Taupō Rift, they are less common in the modern rift (Villamor et al., 2017). These findings prompted us to focus on the Reporoa Basin's young tectonic activity, its implications for our understanding of TR evolution and possible role as a kinematic link between the rift and the NIFS.

Paleo-seismic trenching was carried out in May 2021 on one of the LiDAR inferred faults with a 060° strike. The trenching confirmed the presence of an active fault, named the Parekarangi Fault, with evidence of several post-25 ka ruptures. All the stratigraphy exposed in the trench is interpreted as being post-25 ka, and the total observable fault slip occurred over several discrete slip events. Younger tephras (post-3.5 ka from Taupō) have been identified, and older units will be identified through analysis of glass chemistries (carbon suitable for dating was not found). Notably, evidence for volcanic–tectonic interactions related to the latest explosive eruption of Taupō (232 CE: Hogg et al. 2012) was also found. This was shown by displacement of the Taupō plinian pumice (unit Y5) along the fault plane, while the overlying ignimbrite (Y7) was undeformed, implying syn-eruptive fault slip. These observations support regional-scale (~40 km) interactions between tectonic and silicic system, and that changing stress states associated with large Plinian eruptions can drive faulting in the TVZ at distances of 40 km from erupting vents.

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ORAL
Session 4e.

ORAL
Session 1c.

GRAVITY FLOW PATHWAYS TOWARDS IODP SITE U1520 IN THE NORTHERN HIKURANGI MARGIN

Anthony Shorrock[1], Lorna Strachan[1], Philip Barnes[2], Helen Bostock[3], Stuart Henrys[4], Robert Harris[5], Anne Trehu[5], Joshu Mountjoy[2], Rebecca Bell[6], Jenni Hopkins[7], Steffen Kutterolf[8], Adam Woodhouse[9], Martin Crundwell[4] and Atsushi Noda[10]

[1] School of Environment, University of Auckland, Auckland, New Zealand
[2] National Institute of Water and Atmospheric Research (NIWA), Wellington, New Zealand.
[3] School of Earth and Environmental Sciences, University of Queensland, Brisbane, Australia
[4] GNS Science, Wellington, New Zealand
[5] Oregon State University, Corvallis, Oregon, USA
[6] Imperial College, London, UK
[7] Victoria University of Wellington, Wellington, New Zealand
[8] Geomar, Kiel, Germany
[9] University of Texas, Austin, Texas, USA
[10] National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Japan

asho465@aucklanduni.ac.nz

Analysis of seismic and bathymetric features of the northern Hikurangi Subduction Margin (HSM) can help reveal how sediment may have been transported from the continental shelf to the Hikurangi Trough during the late Quaternary, and how such flows may interact with the seamount-studded regional topography. This has particular relevance to ongoing studies on sediment from core Site U1520, retrieved during International Ocean Discovery Program (IODP) Expeditions 372B/375, which preserves a ~500m long sediment record that has been dominated by the deposition of an extensive turbidite sequence within the upper ~100m over the past ~40 kyrs.

The results of the seismic and bathymetric analyses indicate that there are two primary flow pathways towards Site U1520. The first is through the Māhia Canyon system that directly incises the edge of the continental shelf and connects to terrestrial and along-shore sediment transport systems during glacial low stands. The second is through the overspill of flows at a ~90° easterly bend in the ~800 km long Hikurangi Channel. The combined influence of gravity flows from these two conduits have resulted in huge volumes of sediment into the Hikurangi Trough, with sediment rates at Site U1520 reaching as high as ~10 m/kyr during the Last Glacial Maximum (LGM). These findings provide new insights into how gravity flows have operated in the HSM and how they have influenced both the geomorphic and stratigraphic character of this region.

POSTER
Session 2e.

STRATIGRAPHIC EVOLUTION OF A NORTHERN HIKURANGI MARGIN TRENCH-FILL SEQUENCE DURING THE LATE QUATERNARY.

Anthony Shorrock[1], Lorna Strachan[1], Philip Barnes[2], Helen Bostock[3], Stuart Henrys[4], Robert Harris[5], Anne Trehu[5], Joshu Mountjoy[2], Rebecca Bell[6], Jenni Hopkins[7], Steffen Kutterolf[8], Adam Woodhouse[9], Martin Crundwell[4] and Atsushi Noda[10]

[1] School of Environment, University of Auckland, Auckland, New Zealand
[2] National Institute of Water and Atmospheric Research (NIWA), Wellington, New Zealand.
[3] School of Earth and Environmental Sciences, University of Queensland, Brisbane, Australia
[4] GNS Science, Wellington, New Zealand
[5] Oregon State University, Corvallis, Oregon, USA
[6] Imperial College, London, UK
[7] Victoria University of Wellington, Wellington, New Zealand
[8] Geomar, Kiel, Germany
[9] University of Texas, Austin, Texas, USA
[10] National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Japan

asho465@aucklanduni.ac.nz

An integrated investigation on the stratigraphic characteristics of a northern Hikurangi Subduction Margin (HSM) trench-fill sequence has been undertaken to assess how this deep marine depocenter has evolved in the late Quaternary. This study has incorporated bathymetric, seismic, and lithologic datasets acquired from the region to define the spatiotemporal distribution of key stratigraphic and geomorphic features that can be related to the nature and timing of depositional processes These analyses integrate with core data acquired from International Ocean Discovery Program (IODP) Site U1520 during Expedition 372B/375 to provide a chronology and a three-dimensional regional context for the sedimentary facies present in the core.

The results of this study show that the northern Hikurangi Trough has undergone significant changes in the past three Marine Isotope Stages (MIS). Gravity flows are interpreted as the primary conduits of sediment delivery to the trough floor and were dominantly sourced from both the Māhia Canyon system and from overspill of flows from the Hikurangi Channel. Such flow processes may have infilled a depression that was blocked by a Mass Transport Deposit (MTD) in MIS3 (57-27 ka). In MIS2 (27-14 ka), there was a substantial increase in sediment supply during the glacial lowstand that facilitated the development of large-scale sediment waves downslope of the mouth of the Māhia Canyon and a weakly-confined channel-belt system above Site U1520. This channel system was subsequently infilled in MIS1 (14 ka – present) as sediment supply decreased, forming the gently-sloping, modern plain.

These findings provide new insights into what sedimentary processes have been active along the northern HSM during the late Quaternary and how they have varied over time in response to changing environmental conditions.

ORAL
Session 2e.

Too low and too long: The problem of older glaciations in the Southern Alps

James Shulmeister

UNIVERSITY OF CANTERBURY *Christchurch*

james.shulmeister@canterbury.ac.nz

In many valleys on the eastern side of the Southern Alps evidence exists for older (pre-Otiran) glaciations that were significantly greater in extent than the Otiran limits. Traditional models for the glaciation sequences suggest that these older glaciations should be preserved at progressively higher elevations, as the mountain ranges rise, while the valleys are continuously incised, leaving very young deposits on the valley floors. Associated with this model is the idea that glacier lengths are gradually shortening through the Middle to Late Pleistocene as accommodation space in the valley reaches increases.

Glacial reconstructions in many of the valleys have highlighted problems with the model. These can be summarised as follows;

1. High elevations sites such as Kakapo Hill in the Hope Valley and the Avoca Plateau in the Waimakariri that should date to older glaciations yield anomalously young glacial ages

2. The floors of several Canterbury valleys demonstrate preservation of penultimate and older glacial and paraglacial sediments at modern river levels. These include the Rakaia, Hope and Rangitata (Potts) valleys.

These observations cast doubts on the uplift and incision model but what remains is the preservation of older glacial and paraglacial sediments in positions far advanced of those of the last glacial cycle. This implies that our understanding of how and why these extensive older glaciations occurred needs reconsideration. This paper is designed to propose a new question about the nature of landscape evolution in the Southern Alps in the Middle to Late Pleistocene.

ORAL
Session 2b.

GEONET NOW – PART OF THE FABRIC OF NEW ZEALAND

Ian Simpson[1]

[1] *GNS Science, Lower Hutt, New Zealand*

i.simpson@gns.cri.nz

Two decades ago, experts from GNS Science, Land Information New Zealand and EQC came together to create GeoNet.

What started as a way to generate data for research has grown into a critical piece of national infrastructure – providing not just real-time monitoring, but backing the science response during emergencies and offering a social platform to inform and reassure New Zealanders.

The next two decades will offer many new opportunities, but how can we ensure a sustainable future for GeoNet? Ian Simpson looks at how GeoNet's grown and adapted – and how people remain at the heart of everything GeoNet does.

POSTER
Session 4b.

COSEISMIC ROCK SLOPE FAILURE MECHANISMS – INSIGHTS FROM LANDSLIDES TRIGGERED BY THE 2016 MW 7.8 KAIKŌURA EARTHQUAKE

Corinne Singeisen[1], Chris Massey[2], Andrea Wolter[2], Richard Kellett[2], Caleb Gasston[3], Colin Bloom[1], Tim Stahl[1], Katie Jones[2,4]

[1]University of Canterbury, Christchurch, New Zealand
[2]GNS Science, Lower Hutt, New Zealand
[3]University of Auckland, Auckland, New Zealand
[4]Victoria University of Wellington, Wellington, New Zealand

corinne.singeisen@pg.canterbury.ac.nz

Landslide failure mechanisms in a rock slope are mainly controlled by topography, lithology, structure and rock mass damage – factors that also control landslide susceptibility. The influence of failure mechanisms on rock slope stability, however, is rarely considered in regional susceptibility analyses. In this study, we use 3D pixel tracking in pre- and post-earthquake aerial imagery, geomorphic mapping, rock mass characterisation, and geophysical ground investigations to develop conceptual models for three earthquake induced landslides triggered by the 2016 Mw 7.8 Kaikōura earthquake on New Zealand's South Island. Analysis of two incipient landslides in Torlesse greywacke illustrate the complex failure stages of a rock mass comprising multiple sets of closely-spaced and low persistence discontinuities. Conversely, analysis of a landslide in massive Neogene siltstones, illustrates the role of high persistence bedding planes on generating large translational 'block' slides. These two distinct failure mechanisms in lithologies with fundamentally different stress histories highlight the link between rock mass damage, failure mechanism, and initiation. In greywacke failures, the rupture plane appears to initiate close to the ridgetop and propagates downslope through multiple failure modes along pre-existing, but low-persistence, joints. This top-down failure initiation suggests that topographic amplification due to shaking may play an important role in landslide triggering. In comparison, the landslide in Neogene siltstone initiated by sliding along a weak, high persistence, bedding plane near the base of the slope where topographic stresses are highest. Our results thus suggest that (1) failure mechanisms and, as a result, coseismic landslide susceptibility factors, may vary fundamentally in different geological settings; and (2) greywacke failures may be particularly prone to earthquake triggering due to the susceptibility of amplification in closely jointed rock masses and multiple degrees of kinematic freedom through which failure could occur.

ORAL
Session 4c.

FOLLOWING MAGMA: THE PATHWAY OF SILICIC MAGMAS DURING AN IGNIMBRITE FLARE-UP, TAUPŌ VOLCANIC ZONE

Sarah Smithies[1], Darren Gravley[1], Guilherme Gualda[2], Lydia Harmon[2], Kari Cooper[3] and Alex Nichols[1]

[1] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*
[2] *Department of Earth and Environmental Sciences, Vanderbilt University, Tennessee, USA.*
[3] *Department of Earth and Planetary Sciences, UC Davis, California, USA.*

sarah.smithies@pg.canterbury.ac.nz

The central Taupō Volcanic Zone (TVZ) had a period of hyperactive silicic volcanism (“ignimbrite flare-up”) between 350 and 240 ka, erupting >3000 km^3 magma in seven caldera-forming eruptions. New petrology data tracks the creation, extraction, and storage of individual magma parcels that erupted during each of these caldera-forming events, to understand the crustal magma systems driving this extraordinary flare-up.

To disentangle the histories of the magma bodies, 10 – 12 pumice samples from each eruption (Whakamaru, Matahina, Kaingaroa, Pokai, Chimp, Ohakuri, Mamaku) were geochemically analysed via (1) whole-rock major and trace elements (2) glass major and trace elements (3) glass Sr, Pb, and Nd isotopic data from a subset of samples. We calculated the pressure of magma storage and extraction from the crystal mush by rhyolite-MELTS geobarometry (Gualda & Ghiorso 2014; Gualda et al. 2019).

The magmas are typically extracted from a reservoir zone in the mid to lower crust (200 – 400 MPa) with some shallow extraction (100 – 150 MPa). The magma systems feeding each eruption are highly heterogeneous. Each eruption contains multiple chemically and isotopically distinct homogeneous magma batches that are stored at different depths and extracted from discrete parts of the reservoir. Some magma batches (Whakamaru, Kaingaroa, Chimp, Ohakuri, Mamaku) are extracted from the deeper reservoir and move to a shallower storage zone in the upper crust (~150 MPa), whilst others are extracted and stored at similar depths (Matahina, Chimp, Pokai). Towards the end of the flare-up, the magma systems are more vertically distributed, the Ohakuri and Mamaku eruptions tap a wide range of depths from 2 km (50 MPa) to 15 km (400 MPa). Our results have implications for how the vertical extent of the crust accommodates extraordinary levels of magmatism during an ignimbrite flare-up event, here in New Zealand and globally.

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ORAL
Session 1b.

A COMPILED HISTORICAL VOLCANIC HAZARDS DATABASE FOR TONGARIRO NATIONAL PARK, NEW ZEALAND

Amilea Sork[1]

[1] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*

ars115@uclive.ac.nz

A record of past volcanic hazards and hazard magnitudes is an essential component of risk management at volcanoes. Tongariro National Park (TgNP) is host to multiple volcanic vents and a popular tourist destination, necessitating risk management.[1,2] Knowledge gaps in TgNP's eruption history have been a focus since the 1995 Ruapehu eruption episode.[2] Few studies of the historical eruption record, and no studies of the associated hazards, have been conducted before now. The objective of this BSc Honours study is to produce a database which quantifies the hazards associated with each known historical eruption at TgNP.

A database was set up in Microsoft Excel and populated with hazard data. Sources used for data included published scientific articles, unpublished theses from New Zealand universities, and volcanic alert bulletins. Verified and estimated hazards have been provided, along with magnitudes wherever possible. Hazards covered are ash, lahars, ballistics, pyroclastic density currents (PDCs), and lava.

169 eruption episodes, comprising 343 individual eruption events, 44 unrest events, and 11 non-eruptive lahars, have been identified. While Ngauruhoe and Ruapehu have had the same number of eruptive episodes (75 versus 76, respectively), Ruapehu has had far more individual eruptive events (232 versus 84). Ash is by far the most common recorded hazard. Ruapehu is the largest producer of all studied hazards.

The historical record for ash, lahars, and ballistics is well-populated based on frequency comparisons before and after modern recording techniques. The database for PDCs is poorly populated. Lava has occurred in record very rarely.

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POSTER
Session 2a.

GEOMORPHIC TIME SERIES REVEALS THE CONSTRUCTIVE AND DESTRUCTIVE HISTORY OF HAVRE CALDERA, KERMADEC ARC

Erica Spain[1,2], Rebecca Carey[1], Jo Whittaker[1], Vanessa Lucieer[1], Jodi Fox[1], Sally Watson[2]

[1] *Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Tasmania, Australia*
[2] *National Institute of Water and Atmospheric Research, Wellington, New Zealand*

Erica.spain@niwa.co.nz

Change detection in the deep ocean is rare due to a paucity of data at appropriate scales. Monitoring of active seafloor processes requires repeat, comparable surveys. Here, we utilise an exceptional suite of bathymetric data across a spatio-temporal range at Havre volcano, Kermadec Arc, Southwest Pacific, over a period of 13 years. Surveyed in 2002 by RV Tangaroa, Havre caldera was resurveyed in 2012 (RV Tangaroa) and 2015 (RV Tangaroa, AUV Sentry, and ROV Jason) following the largest observed deep-marine rhyolitic volcanic eruption.

These unprecedented datasets allow us to compare landforms across spatial and temporal scales and understand the constructive and destructive forces driving the evolution of Havre volcano. Multiple bathymetric datasets are used to parameterise geomorphological features and volcanic products over the caldera. We then interpret the volcanic, tectonic, erosional, and depositional processes behind the caldera's morphology.

Four geomorphic groups of varying scale are interpreted: (i) large-scale tectonic features, e.g. faults, calderas; (ii) coherent volcanic products, e.g. lavas, domes; (iii) clastic volcanic products, e.g. ash, ash-lapili-block, giant pumice; and (iv) mass-wasting features, e.g. debris flows, mega blocks. We use high-resolution AUV bathymetry to develop a fine-scale geomorphic map to reveal additional landforms and processes obscured in coarse-resolution data. We integrate bathymetric data with ROV Jason sampling and video data to refine geomorphic boundaries. We also integrate data from previous geological studies of Havre to inform the geomorphic interpretation.

Our work reveals additional growth on the primary dome emplacement (dome OP) between 2012 and 2015, which was not previously recognised. We also confirm voluminous shedding on the northern caldera wall and smaller scale shedding on the southeastern wall. Our map reveals the variety of geomorphic forms of a range of processes, highlighting the importance of repeat, high-resolution bathymetric surveys

POSTER
Session 2e.

STATISTICAL LANDSLIDE SUSCEPTIBILITY MODELLING FOR PASTORAL HILL COUNTRY

Raphael Spiekermann[1,2], **Hugh G. Smith**[1], **Sam McColl**[2], **Lucy Burkitt**[2], **Ian C. Fuller**[2]

[1] *Manaaki Whenua – Landcare Research, Palmerston North, New Zealand.*
[2] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand.*

spiekermannr@landcareresearch.co.nz

Silvopastoralism in New Zealand's highly erodible hill country is an important form of erosion and sediment-loss control. We present research on quantifying the effect of trees on slope stability at farm scale using statistical landslide susceptibility modelling. First, we mapped and classified trees using Light Detection and Ranging (LiDAR) data in combination with regional orthophotography (2010 – 2017) across an 840 km^2 study area in the Wairarapa (Spiekermann et al. 2021). We then developed a statistical landslide susceptibility model for pastoral hill country, which for the first time includes spatial distribution models to capture the effect of individual trees on slope stability for different vegetation types (poplar/willow, eucalyptus, conifer, mānuka/kānuka). Models were trained and tested using a landslide inventory consisting of 43,000 landslide scars. Model performance was very good, with a median AUROC of 0.95 in the final model, which equates to an accuracy of 88.7% using a cut-off of 0.5.

Using two farms in the study area, we illustrate application of the landslide susceptibility model for quantifying the reduction in shallow landslide erosion due to the presence of trees in the landscape. Landslide erosion was reduced by 16.6% at Site 1 and 42.9% at Site 2 due to all existing vegetation. The effectiveness of individual trees on reducing landslide erosion was shown to be less a function of species than that of targeting highly susceptible areas with adequate tree densities. We found 80% of landslides can be expected to occur in 12.1% and 7.3% of the area of Sites 1 (1,700-ha) and 2 (462-ha), respectively. The high-resolution spatial information provided by the landslide susceptibility maps can be used by decision makers in land management to support the development and targeting of erosion mitigation measures in pastoral hill country.

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POSTER
Session 4c.

RECENT SURFACE RUPTURING EARTHQUAKES ALONG THE SOUTH FLANK OF THE GREATER CAUCASUS NEAR TBILISI, GEORGIA

Stahl, T.[1]; Cowgill, E.[2]; Boichenko, G.[3]; Vasey, D.A.[2]; Godoladze, T.[3]

[1] *School of Earth and Environment, University of Canterbury, New Zealand*
[2]*Department of Earth and Planetary Sciences, University of California, Davis, CA*
[3]*Institute of Earth Sciences, Ilia State University, Tbilisi, Georgia*

Fault source characterization is a critical step towards improving estimates of seismic hazard but remains largely absent from the Georgian Greater Caucasus. Here, a paleoseismic trench near the capital city of Tbilisi revealed evidence for recurring surface rupture on a shallowly dipping thrust fault. The fault has broken through the overturned forelimb of a fault-propagation anticline that folds a sequence of soils and deposits. Stratigraphic relationships and radiocarbon dating of terrestrial gastropod shells corrected for 'old carbon' age anomalies loosely constrain three earthquakes on this fault between ~40 and ~3 ka with variable dip-slip displacements ranging between 0.35 m and ~3 m and a cumulative displacement of 6.5 ± 0.85 m. Single event slips and recurrence intervals (11, 25, and a 3 ka open interval) at this site demonstrate apparent slip rate variations of 3-7x over the last two earthquake cycles on the fault, which we attribute to possible rupture complexity involved in crustal thrust fault earthquakes. To our knowledge, this is the first paleoseismic trench in the Greater Caucasus presented in the international literature. This study thus provides a structural and geochronologic template for future paleoseismic investigations in the Greater Caucasus while highlighting some of the challenges of conducting seismic source characterization in this region.

POSTER
Session 2a.

RECONSTRUCTING THE HYDROTHERMAL ERUPTIVE HISTORY AND MECHANISMS OF THE TE KOPIA GEOTHERMAL FIELD.

Alec Stanley[1], Shane Cronin[1] and Ingrid Ukstins [1]

[1] *School of Environment, University of Auckland, Auckland, New Zealand*

asta055@aucklanduni.ac.nz

The Te Kopia geothermal system straddles a zone of parallel structures along the Paeroa Fault Zone within the Taupo Volcanic Zone (TVZ) and is a good example of how geological structures create zones of permeable fractured rocks that guide geothermal fluids. Te Kopia has a series of distinctive surface geothermal features, including mudpools, fumaroles, sinter deposits, and hydrothermal eruption craters. Since access to Te Kopia is via a short walking path from roadside parking, there is the potential for significant exposure of the public to numerous geothermal hazards. Numerous landslides are noted in this area (Bignall and Browne 1994; Clark and Browne 2000).

Field investigations along a 1.5 km stretch of scarp identify three eruption craters, 150 m, 250 m, and 300 m in diameter. Up to 7 distinct breccia deposits between 0.2 to >1.4 m-thick are found in crater walls of the largest crater, comprising a variety of clast lithologies embedded in a firm, poorly sorted ash matrix. These are interbedded by 3 distinct tephra units (Holocene units - identification underway). Polymict breccia clasts include sinter, ignimbrite, pumice-rich breccias, and silicified fine muds. The largest distal breccia identified lies >200 m from the crater edge and is >0.4 m thick. Eruptions of this scale could certainly endanger the road, farms and powerlines nearby.

Priming and triggering mechanisms for hydrothermal eruptions in this area could include landslide deposits capping the geothermal aquifer, fracturing and cap-sealing by fault motion, or changes in hydrology induced by a combination of these processes. Several recent landslides have been mapped along this scarp, covering 4-6 km^2, some of which partially encroach on active geothermal areas. We will investigate the permeability, textural, and mineralogical properties of landslide deposits and breccias to understand possible inter-relationships and hydrothermal eruption source depths by comparing breccia lithology with nearby geology.

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POSTER
Session 2a.

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HAZARD CLASSIFICATION SYSTEM FOR ROXBURGH GORGE LANDSLIDES

Charlotte Steele[1], Don Macfarlane[1] and Peter Silvester[2]

[1] *AECOM New Zealand Ltd, Christchurch*
[2] *Contact Energy Ltd, Clyde, Otago.*

Charlotte.Steele@aecom.com

Ancient landslides form approximately 50% of the Roxburgh Dam reservoir shoreline. Nineteen of the 34 landslides were tentatively classified as “Major Hazard” in 1996 as they were judged capable of generating an overtopping wave at the dam or blocking the reservoir (causing upstream flooding) in the event of large scale, rapid failure. Landslides that are not failing towards the reservoir or are too small to pose a landslide dam or impulse wave hazard were classified as Non-hazardous.

In 2001-2002, following a recommendation from the external Review Panel, an improved landslide hazard classification scheme was introduced subdividing the Major Hazard landslides into three categories based on a scoring system that assessed 6 separate criteria.

In 2020 Contact Energy and AECOM developed separate classifications of Hazard for landslide dams and for impulse waves. The information is mainly presented in table form to allow easy comparison. The tables are separated into Upper Gorge, Mid-Gorge and Lower Gorge to highlight variability along the reservoir. The new classification system recognises that the landslides have different segments/lobes with different geomorphological characteristics that indicate different behaviours and different failure potential or characteristics.

Four Hazard Classes (Major, Moderate, Minor and Non-hazardous) have been developed based on five main factors: potential failure volume, landslide volume v lake volume, slope length to lake width ratio, potential for rapid failure and estimated probability of failure.

The landslides with the greatest potential to form a landslide dam are all located within the middle reaches of the gorge where the slopes are highest and the size and most likely failure volume of the slope or landslide are large relative to the width and volume of the reservoir.

The new classification system provides improved understanding and appreciation of the hazard potential of the landslides. Risk assessment will be addressed separately.

ORAL
Session 4c.

IDENTIFICATION OF SEISMO-VOLCANIC REGIMES AT WHAKAARI (NEW ZEALAND) VIA SYSTEMATIC TUNING OF AN UNSUPERVISED CLASSIFIER

Bastian Steinke[1], Arthur Jolly[2], Roberto Carniel[3], David Dempsey[4] Shane Cronin[1]

[1] *School of Environment, University of Auckland, Auckland, New Zealand*
[2] *GNS Science, Lower Hutt, New Zealand*
[3] *Dipartimento Politecnico de Ingeneria e Architettura, Università degli Studi di Udine, Udine, Italy*
[4] *College of Engineering, University of Canterbury, Christchurch, New Zealand*

bastian.steinke@t-online.de

We present an algorithm based on Self-Organising Maps (SOM) and k-means clustering to recognise patterns in a perennial tremor time series recorded at Whakaari between 2008 and 2020. The approach reduces operator bias and can be used in a variety of settings by systematic tuning of the classifier considering different input data parameters, SOM settings and number of clusters. Input parameters are evaluated by statistical means, yielding a combination of 'ideal' parameters for the given data set. In addition, we tested a tool based on Kernel Density Estimation to automatically detect changes within the observed seismicity. Using this tool, we categorise the Whakaari seismic signal into different regimes, representing distinct volcano-seismic states for the most recent unrest episodes at Whakaari (2012-13, 2016 and 2019).

Classification results indicate a clear separation between regimes representing background activity and more elevated levels of unrest. Regime changes correlate well with DSAR and RSAM values as well as with reported volcanic activity, especially during the 2012/13 and 2019 unrest episodes. Multiple dominant processes including system pressurisation and depressurisation, as well as degassing associated with elevated surface activity appear as a possible set of underlying source processes. This set of labels created a coherent image across EP I and EP III. The 2016 unrest differed from these two unrest episodes in the shape and nature of its seismic regimes, suggesting a different priming and triggering process than the 2012/13 and 2019 episodes. This could reflect a contrast between shallow hydrothermal processes in 2016 and rising magmatic gases from a new intrusion in the other cases.

POSTER
Session 4a.

Refining the Early Geochronological Record for the Dunedin Volcano, New Zealand

Ayla Stenning[1], James White[1], Marco Brenna[1], Sidney Hemming[2], Michael Palin[1] and Rachael Baxter[1,3]

[1] *Department of Geology, University of Otago, Dunedin, New Zealand.*
[2] *Lamont-Doherty Earth Observatory, Columbia University, New York, USA.*
[3] *Department of Earth Sciences, University of Cambridge, Cambridge, UK.*

ayla.stenning@postgrad.otago.ac.nz

The Dunedin Volcano (DV) (South Island, New Zealand) is a composite shield volcano and the single largest centre represented in the Dunedin Volcanic Group, lying within the monogenetic Waipiata Volcanic Field. This long-lived alkaline intraplate volcano was constructed from 16.0 ± 0.4 to 11.0 ± 0.2 Ma (Scott et al. 2020), encompassing submarine to subaerial volcanism. Compositionally diverse pyroclastic and flow deposits, produced from numerous vents, preserve the record of a complex eruptive history.

Current understanding of DV age relationships is inconsistent. Published radiometric dates (38) are dominated by samples collected from the mainland with ages obtained via K-Ar methods. Various dates incur debate, particularly where volcanic units and specific samples have been re-analysed with varied resultant ages. This, alongside a stratigraphic framework divided by "floodplain conglomerates" (Coombs et al. 1960) that are often pyroclastics of questionable age significance, rather than widespread fluvial deposits, has led to an incomplete and skewed understanding of the volcanic timeline.

Here we present new $^{40}Ar/^{39}Ar$ radiometric dates for the DV. Alongside refining and expanding the known geochronology, new dates for the stratigraphically earliest, basal eruptive deposits at different sites elucidate temporal relationships at the onset of volcanism, particularly on Otago Peninsula. We are also undertaking U-Pb zircon dating; a first for the DV, this provides an opportunity to examine results obtained via different radiometric dating techniques applied to the same samples within this study.

By improving the geochronological record, we aim to determine how the DV became established. Was there a single absolute age for the onset of volcanism? Or a staged onset across the volcanic footprint, perhaps an intensification and localisation of the wider volcanic field? A new comprehensive radiometric dataset with corresponding geochemistry will aid identifying any temporal, and potentially spatial, controls to the silica saturated and undersaturated suites of the DV.

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POSTER
Session 1a.

STRATIGRAPHIC INSIGHTS INTO THE ~AD1450 CALDERA-FORMING KUWAE ERUPTION SEQUENCE, CENTRAL VANUATU, SOUTH PACIFIC

Sönke Stern[1], Shane Cronin[1], Stuart Bedford[2,3], Chris Ballard[2], Károly Németh[4], Nichola Strandberg[5], Sandra Nogué[5], Pete Langdon[5], David Sear[5]

[1] School of Environment, University of Auckland, Auckland, New Zealand
[2] Australian National University, Canberra, Australia
[3] Max Planck Institute for the Science of Human History, Jena, Germany
[4] School of Agriculture and Environment, Massey University, Palmerston North, New Zealand
[5] School of Geography and Environmental Sciences, University of Southampton, Southampton, United Kingdom

s.stern@auckland.ac.nz

One of the three largest volcanic eruptions of the last ~1500 years occurred in the AD1450s, an event that has been attributed to the partly submarine Kuwae caldera of central Vanuatu. The climatic impact of this eruption is estimated to be similar to the "year without a summer" caused by the 1815 Tambora event, but ice core-records are inconclusive about whether there was one or multiple events in the 1450s. In this study, we re-examine proximal volcanic sequences and medial tephra records to understand the progression and timing of Kuwae eruption phases.

Surrounding the ~50 km² caldera, pyroclastic density current deposits are found throughout Tongoa and Epi. Ignimbrites show highly variable textures and sedimentary features over topographically complex areas. Valley fills include >30 m of massive ash-rich pumice breccias, with weak flow boundaries between multiple units and welded zones. Ridge-top sequences comprise thin poorly sorted massive lapilli tuffs with grey, denser pumice in lower horizons and pale brown low-density pumice in upper units. Caldera-margin sequences include: mega-clast bearing lag breccias, spatter-bearing ignimbrites, strongly welded and rheomorphic ignimbrites, and fines-poor and fines-rich glassy and pumice-rich breccias. Evidence of eruptive pauses include distinctive separate cooling events (e.g., oxidized tops for each flow unit) and in medial locations a stratigraphic break between ignimbrites, marked by erosion and interbedded ash. A distinctive tephra lobe to the south (towards Emae and Efate), shows clearly separate tephra layers.

Distal fall units to the South capture a narrow range of compositions (glass 65-68 wt% SiO_2; 2.5-2.8 wt% K_2O). However, proximal deposits show a wider compositional range, with more silicic and alkalic compositions (glass up to 72 wt% SiO_2 and 4.8 wt% K_2O). Further targeted field work, geochemical studies and age-dating will help refine our knowledge of this major regional climate-forcing event.

ORAL
Session 1a.

SEISMIC PROPERTIES OF THE LITHOSPHERIC MANTLE UNDER NEW ZEALAND: SOME TECTONIC IMPLICATIONS

Tim Stern[1], Simon Lamb[1], James Moore[1]

[1] *Earth Sciences, Victoria University of Wellington, New Zealand*

tim.stern@vuw.ac.nz

Large variations in P and S-wave speeds of the mantle beneath New Zealand have been long known. Values of P-wave speeds range from 9.0 to 7.4 km/s, which is a large spread given the globally averaged values for the (continental) upper mantle (the P_n phase) is 8.1 km/s. Studies of seismic anisotropy provide new constraints on the significance of this spread in the data, making it possible to distinguish different strain regimes such as simple shear, pure shear, or vertical shortening.

Three distinct mantle domains are identified for New Zealand based on mantle seismic properties: (1) western and central North Island with low P_n speeds (7.4 km/s) and high attenuation; (2) along the Hikurangi Margin (mainly beneath eastern North Island) where the mantle of the Hikurangi plateau has unusually high P-wave speeds (up to 9 km/s), low attenuation, negligible azimuthal anisotropy and strong radial anisotropy; (3) mainly South Island with average P-wave speeds that are close to normal (8.16 km/s), but strong azimuthal anisotropy (range of 8.5 to 7.8 km/s).

The tectonic origins of the three domains are interpreted as:

Domain 1 is linked to recent extension, mantle melting due to back arc spreading, and mantle detachment.

Domain 2 (Hikurangi Plateau) where the high P_n speeds are interpreted as being due to a flow fabric created by vertical shortening in the head of a mantle plume.

Domain 3 is attributed to anisotropy created by simple shear in the mantle due to the Australian–Pacific plate relative motion since the Eocene, including underthrusting of the Australian plate.

In this interpretation, the mantle properties of the Hikurangi Plateau are distinct from those of central and southern South Island and therefore consistent with the view that the plateau does not extend south of the Hikurangi Margin.

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ORAL
Session 1c.

A SYNTHESIS OF SHIELD VOLCANO EVOLUTION BASED ON A 3D LITHOLOGICAL RECONSTRUCTION OF HEYWARD PROMONTORY, DUNEDIN, NZ

Thomas Stevenson[1], Marco Brenna[1] and Stephen Read[1]

[1] *Department of Geology, University of Otago, Dunedin, New Zealand*

steth560@student.otago.ac.nz

This study applies novel technologies to interpret key volcanic sequences of Dunedin Volcano/Rakiriri, an extinct intraplate shield volcano. Rakiriri experienced a prolonged eruptive history between 16-11 Ma and achieved a diameter of ~25 km.[1,2] Part of this history is preserved in cliffs along Heyward Promontory, northeast of Dunedin City. The cliffs contain distinctive outcrops of alkaline basalt, trachyte, kaiwekite[3] and phonolite. Numerous dikes, domes and other structures suggest complex development of the edifice and its internal plumbing.[4] Many aspects remain unclear, such as the locations of craters and vents, and for how long they erupted. The excellent exposures present an opportunity to answer such questions and inform studies of shield volcanoes worldwide.

We have photographed key outcrops at Aramoana, Murdering Beach and Long Beach using an aerial drone. These sites were chosen for their quality and variety of rock exposure. Photogrammetry software has been used to assemble the photographs into a 3D digital model. Geochemical information is required to correlate volcanic strata between the sites. For this purpose, several samples from each site are being analysed by SEM at the University of Otago, or by whole rock testing in an overseas laboratory.

Results will be integrated with existing spatial and geochronological data in ArcGIS to construct a lithological model of Heyward Promontory in 3D. This will enable investigation of the edifice and associated plumbing system. It is recommended that the model later be refined and expanded upon to encompass all of Rakiriri. Such a model would bear considerable research and educational value, as it would allow researchers and students to more easily visualise the edifice and understand its evolution. It would also illuminate processes that continue to form shield volcanoes, such as Kīlauea in Hawai'i and Erta Ale in Ethiopia,[5] which present significant hazards.

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POSTER
Session 4b.

Biogeochemical Cycling of Trace Metals and their Isotopes: Links to Past and Present Climate Change

Claudine Stirling[1,2]

[1] *Department of Geology, University of Otago, Dunedin, New Zealand*
[2] *Centre for Trace Element Analysis, University of Otago, Dunedin, New Zealand*

cstirling@chemistry.otago.ac.nz

Trace metals play many important roles in the biogeochemistry of the oceans, and via connections with the atmosphere, as well as carbon and sulfur cycles, are intrinsically linked to global climate. The oceanic distributions of trace metals are significantly influenced by the concentration of dissolved oxygen, as well as the intensity and efficiency of the ocean's biological pump that helps regulate atmospheric CO_2 levels. Therefore, metal stable isotope systems have recently emerged as powerful tracers of the redox evolution and productivity status of the past and present oceans. A growing inventory of data provide (1) important boundary conditions for modelling future climate scenarios, and (2) reconstructions of the evolution of the ocean-atmosphere system throughout Earth's history, as recorded in marine sediments. However, both applications rely on robust calibration of metal isotope cycling in the modern marine environment, and in-depth understanding of how the dissolved isotopic signatures are transferred to the sedimentary record.

To help address this knowledge gap, we have investigated the biogeochemical cycling of the iron, zinc, cadmium, and uranium isotope systems, together with a wide range of trace element distributions, in under-constrained regions of the world's oceans that are representative of past global ocean regimes. These studies have been aided by the large-scale sampling voyages of the international *GEOTRACES* and *IODP* programmes, as well as smaller, targeted expeditions within and outside of New Zealand. The datasets obtained improve the calibration of these metal isotope systems in the modern ocean and facilitate their robust application to sedimentary records to aid environmental reconstructions throughout Earth's history. Our reconstruction efforts are focused on the glacial-interglacial climate transitions of the Quaternary through to 'deep time' ocean-atmosphere reorganisations, such as the super-greenhouse '*Ocean Anoxic Events*' of the Mesozoic and the Paleoproterozoic '*Great Oxidation Event*'.

KEYNOTE
Session 4e.

ONCE-IN-A-LIFETIME: PLIOCENE FOSSILS OF THE CENTRAL INTERCEPTOR PROJECT, AUCKLAND, NEW ZEALAND [PART B]

Thomas Stolberger[1], Nathan Collins[1] Bruce Hayward[2] and Alan Beu[3]

[1] Natural Sciences department, Tāmaki Paenga Hira Auckland War Memorial Museum, Auckland, New Zealand
[2] Geomarine Research, Auckland, New Zealand
[3] GNS Science (emeritus, palaeontology), Lower Hutt, New Zealand

TStolberger@aucklandmuseum.com

In early 2020, construction on Watercare's Central Interceptor wastewater tunnel in Māngere, Auckland, uncovered thousands of fossil specimens 35 m below the surface within the Pliocene "Kaawa Shell Bed". Although widespread beneath southern Auckland, the "Kaawa Shell Bed" is rarely encountered at the surface, with current knowledge based on scattered outcrops (e.g. Kaawa Creek), borehole data, and fortuitous excavations (e.g. Waitematā Brewery). This rich find therefore represents a unique opportunity to characterise the previously poorly represented Pliocene molluscan fauna of northern New Zealand.

Preliminary investigations of the assemblage have revealed at least 180 taxa including 10 new species, of probable Waipipian age (3.7–3.0 Ma). The dominant components (Glycymerita, Tawera, Maoricrypta) suggest that deposition occurred in a shallow nearshore setting (<20 m) such as a subtidal channel. These components are supplemented by taxa from rocky shore (e.g. Turbo, Crassostrea, Cellana) and sandy beach environments (e.g. struthiolariids, Paphies). The remarkable discovery of several flax snails (Placostylinae) within the deposit represent the oldest fossil evidence for this group and significantly predates previous sub-fossil specimens (~100 kya). Other notable specimens include the first record of Conidae from Pliocene New Zealand and a baleen whale vertebra.

In addition to these paleontological findings, a positive outcome of these discoveries at Māngere has been the development of a closer relationship between a scientific institution (Auckland Museum), and an industry partner (Watercare). This relationship will benefit not only palaeontologists, but also the general public who will have access to the fossil taonga through displays and educational resources. This project has increased public awareness of their local geological history and it is hoped that this will set a precedent for collaborations between science and industry for future discoveries of this nature.

POSTER
Session 1c.

THE GEOMETRY OF THE FIORDLAND-PUYSEGUR SUBDUCTION ZONE

Wanda Stratford[1], Calum Chamberlain[2] and Rupert Sutherland[2], Tim Stern[2] and the SISIE team

[1] *GNS Science, Lower Hutt, New Zealand*
[2] *Victoria University of Wellington, Wellington, New Zealand.*

w.stratford@gns.cri.nz

A new geometric model for the offshore Fiordland-Puysegur subduction zone constrained by onshore-offshore seismic data is presented. The data provides evidence of the shape of the subduction zone as it enters the region where the plate bends steeply and can improve our understanding of the structure and physical properties of the lithosphere for southern South Island, New Zealand. From a global viewpoint, this margin is important as it is regarded as a rare example of a young, and evolving, subduction system. Because of poor earthquake locations in this isolated region, there are still counter views on the shape of the plate at the point of downward inflection just off the south coast. Here is where the subduction zone changes from a relatively normal looking subduction geometry offshore and over a short distance undergoes ~17-degree bend in strike and is contorted to a ~vertical dip. The Fiordland and Southland regions are still relatively poorly explored but are affected by New Zealand's most seismically active subduction zone the Fiordland-Puysegur subduction system. Little is known about the structure, shape, depth-extent and seismic hazard potential of the subduction system for southern South Island or how it is deforming the overriding plate. The Southland Seismic project used an offshore multichannel seismic survey in Solander Basin to record seismic energy onshore on seismographs in Southland and Fiordland. Seismographs were deployed in two arrays in line with the offshore shots, enabling the construction of two onshore-offshore crustal structure models for the region. In addition, stations on offshore islands provide fan-shot images of the subducted slab at depth. The project piggy-backed off a 2018-19, NZ-USA, international project across the Puysegur subduction zone.

POSTER
Session 1c.

PALEOGEOGRAPHIC EVOLUTION OF ZEALANDIA: MID-CRETACEOUS TO PRESENT

Dominic P. Strogen[1], Hannu C. Seebeck[1], Ben R. Hines[2], Kyle J. Bland[1], James S. Crampton[2]

[1] *GNS Science, PO Box 30368, Lower Hutt 5040, New Zealand*
[2]*School of Environment, Geography and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand.*

d.strogen@gns.cri.nz

We present the first paleogeographic maps to illustrate the geological evolution of the entirety of Zealandia, since the mid-Cretaceous, in a geometrically rigorous reconstructed tectonic framework. The maps highlight major tectonic phases, from initial Gondwana rifting through to the development of the modern Neogene plate boundary. They illustrate paleobathymetric and paleofacies interpretations along with well and sample data, outcrop geology, structural features and a synthesis of the regional tectonics. The maps are underpinned by a geologically constrained and structurally-based rigid retro-deformation block model. This model, tied to the global plate circuit, is relatively simple for the main regions of northern and southern Zealandia, but breaks central Zealandia into numerous fault-bounded blocks, reflecting complex Neogene deformation associated with the modern plate boundary. Production of maps using GPlates and GIS allows for simple alteration or refinement of the block model and reconstruction of any geological dataset at any time. Reconstructions are within a paleomagnetic reference frame, allowing assessment of paleo-latitude, critical for paleo-climatic and paleo-biogeographic studies. Map inputs include recent (unreconstructed) regional paleogeographic studies focusing on New Zealand's major sedimentary basins, new reviews of NZ biostratigraphic data, and numerous detailed studies in onshore/nearshore New Zealand. In data-poor frontier regions such as the Campbell Plateau, Bounty Trough and Chatham Rise and much of northern Zealandia, we rely on regional studies based on limited seismic datasets, dredge data and DSDP/IODP wells, as well as recent reassessments of the onshore geology of New Caledonia. A suite of 15 maps have been produced that illustrate the paleogeographic evolution of Zealandia. Future iterative refinements to tectonic models and paleogeographic maps are expected with improved modelling of extensional and contractional deformation, and integration of further regional datasets, as available.

ORAL
Session 1c.

A New Basin-Depth Map of the Fault-Bound Wellington CBD Based on Residual Gravity Anomalies

<u>Alistair Stronach</u>[1] and Tim Stern

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand*

alistair@stronach.co.nz

A new basin-depth map for the Wellington Central Business District is presented, showing a maximum depth of 540 m near the Wellington Stadium. This is twice that previously proposed (Semmens 2010, Kaiser et al. 2019). Our new basin geometry constraints are from a residual gravity anomaly map, the first since Hatherton & Sibson (1969), based on ~600 new gravity observations and funded by the EQC. Residual gravity anomalies are as large as -6.2 mGal with uncertainties <0.1 mGal. Two-dimensional gravity models constrained by boreholes that intersect basement are used to generate the basin depth map. In the deepest areas of the city (Thorndon, Pipitea and CentrePort) previous depth maps have been hindered by a lack of deep boreholes, whereas the residual gravity anomaly map has allowed more detailed interpretations to be made in these areas.

The gravity models also indicate the location of a possible onshore extension of the recently discovered Aotea Fault (Barnes et al. 2019) on the western side of Mt Victoria. A maximum basement offset of up to 130 m and gravity anomaly gradients up to 8 mGal/km are observed across the fault. A secondary splay off the main Aotea fault trace is identified in the NW corner of Mt Victoria, and a possible extension of the Lambton fault is identified beneath the Wellington Railway Station. The Terrace Fault is also apparent in the gravity models. This new basin depth and fault trace data provide valuable constraints to models of seismic hazard assessment for Wellington City, as the sharp impedance contrasts across faults and greater sediment depths will both act to amplify earthquake shaking and hazard through reverberation and basin-edge effects.

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ORAL
Session 4c.

THE GLACIAL HISTORY OF LAKE TENNYSON, NORTH CANTERBURY, NEW ZEALAND

<u>Greta Stuthridge</u>[1], Dr Shaun Eaves[1], Dr Andrew Lorrey[2] and Dr Kevin Norton[1]

[1]*Victoria University of Wellington, Wellington, New Zealand,*
[2] *NIWA, Auckland, New Zealand.*

greta.stuthridge@vuw.ac.nz

New Zealand mountain glaciers are sensitive to atmospheric variability and they etch their length changes into the geological record as glacial deposits in response to paleoclimate events. The last major glaciation (~65-18 ka) involved large readjustments of Earth's climate and cryosphere between ~19-11.5 ka that culminated in ice recession due to warming of 4–6°C. Constraining deglaciation in New Zealand helps to constrain potential drivers of past glacier-climate interactions in the Southern Hemisphere, which supports evaluations of future cryosphere response to modern climate change.

Here we present a new ^{10}Be cosmogenic surface exposure dating chronology of length changes for a glacier that occupied Lake Tennyson in North Canterbury, New Zealand. We have 20 new surface-exposure ages from greywacke boulders embedded in well-preserved moraines that add to an extant dataset. The new developments improve constraints on the timing and extent of glacier length changes at Lake Tennyson to support the first complete record of the catchment's deglaciation.

The Tennyson moraine complex, a large recessional-moraine suite south of the lakefront, was deposited between 19.6±0.4 ka and 17.8±0.4 ka (n=26). These data span the ~2 km-wide moraine complex, yet all ages are indistinguishable within dating uncertainties. The timing of ice recession suggests that the Tennyson glacier retreated rapidly following the termination of the Last Glacial Maximum (LGM). Multiple glacial landforms older than the LGM limit (26 ka) are preserved outboard of the Tennyson moraine, and preliminary exposure ages of ~63.6 ka and ~65.6 ka occur on one landform. This suggests the Tennyson glacier reached multiple expanded positions during the last glacial cycle, including during Marine Isotope Stage-4. The chronology at this site adds to growing evidence that larger glaciers existed prior to the global cold nadir of the last glacial cycle.

POSTER
Session 2a.

SPELEOVOLCANOLOGY IN NEW ZEALAND

S. Suresh[1], S.J. Cronin[1], I.A. Ukstins[1],J.A. Baker[1], C.J.N Wilson[2], S.J. Barker[2], T. Cross[1], J. Hellstrom[3], J. Lang[1], P.W. Williams[1], T. Worthy[3]

[1] University of Auckland, PB92019,
[2] Victoria University of Wellington, PB600
,[3] University of Melbourne,
[4]Flinders University, P.O. Box 2100, Adelaide, South Australia, Australia

Ssur049@aucklanduni.ac.nz

Through this study we extended the knowledge of New Zealand volcanic eruption histories below-ground and into cave systems. We identify volcanic signals within caves across the country via four main mechanisms: (1) direct entry of pyroclastic density currents into caves; (2) post-eruption in-wash of pyroclastic debris; (3) cryptotephra/ash particles trapped within speleothems; and (4) chemical signals of volcanic impact on speleothems.

In the Kawhia-Waitomo area we identified for the first-time evidence for direct PDC entry into caves, including the chemically correlated ~1.6 Ma Ngaroma, ~1.22 Ma Ongatiti and ~1.0 Kidnappers ignimbrites from Mangakino Caldera. These poorly sorted cave ignimbrites comprise dominantly fresh glass shards and phenocrysts with evidence for high-temperature emplacement, often on cave walls and roofs. Fresh fluvially reworked deposits of these eruptives are also found though several caves, with little foreign material, indicating rapid post-eruption inwash. The new ignimbrite discoveries help explain the origin and history of these cave systems, and provide new stratigraphic constraints on fossil flora and fauna.

In the Wairoa area of eastern North Island, signals from four late Holocene eruptions of Taupo volcano are identified through cryptotephra and chemical changes in speleothems. The greatest tephra fall thicknesses (>10-20 cm) engendered the strongest signals, likely due to longer-lived and more-significant impacts on the vegetation and landscape stability (i.e., the ~3.5 ka Waimahia and 1.8 ka Taupo eruptions). However, even tephra thicknesses of ~3 cm caused enough landscape/vegetation change for eruptions to be discernable in chemical signatures, often associated with <0.01 mm glass shards trapped within growing speleothems.

Also cold-climate speliothems show potential for volcano-signal preservation, with rapid growing conditions during the Last Glacial Maximum in both Waitomo and the distal northern South Island (Westland). These sites show geochemical evidence for the 25.4 ka Oruanui supereruption. Like the Holocene examples, greater tephra thickness (Waitomo) produced the most distinctive multi-component signals (due to glass particle entrapment as well as changes to cave dripwater chemistry). Remarkably, at >500 km from the volcano, with only ~5 cm of tephra, deep caves, and a high precipitation, the eruption signals could still be discerned in two westland cave sites examined.

POSTER
Session 1a.

NEOGENE MASS ACCUMULATION RATE OF CARBONATE SEDIMENT ACROSS NORTHERN ZEALANDIA, TASMAN SEA, SOUTHWEST PACIFIC

R. Sutherland[1], Z. Dos Santos[1], C. Agnini[2], L. Alegret[3], A.R. Lam[4], T. Westerhold[5], M.K. Drake[6], D.T. Harper[7], E. Dallanave[5], C. Newsam[8], M.J. Cramwinkel[9], G.R. Dickens[10], J. Collot[11], S.J.G. Etienne[11], A. Bordenave[11], W.R. Stratford[12], X. Zhou[13], H. Li[14] and G. Asatryan[15]

[1] Victoria University of Wellington, PO Box 600, Wellington, New Zealand
[2] Università di Padova, 35131 Padova, Italy
[3] Universidad de Zaragoza, 50009 Zaragoza, Spain
[4] University of Massachusetts Amherst, MA 01003-9297, USA
[5] MARUM, University of Bremen, 28359 Bremen, Germany
[6] University of California, Santa Cruz, CA 95064, USA
[7] University of Kansas, Lawrence, KS 66045-7575, USA
[8] University College London, London WC1E 6BT, UK
[9] National Oceanography Centre, University of Southampton, Southampton SO14 3ZH, UK
[10] Trinity College Dublin, Dublin 2, Ireland
[11] Geological Survey of New Caledonia, Noumea BP 465, New Caledonia
[12] GNS Science, PO Box 30368, Lower Hutt, New Zealand
[13] Rutgers, The State University of New Jersey, NJ 08854, USA
[14] Institute of Oceanology, Chinese Academy of Sciences, Qingdao, China
[15] Leibniz-Institut für Evolutions und Biodiversitätsforschung, 10115 Berlin, Germany

rupert.sutherland@vuw.ac.nz

Sediment mass accumulation rate (MAR) is a proxy for paleoceanographic conditions, especially if biological productivity generated most of the sediment. We determine MAR records from pelagic calcareous sediments in Tasman Sea based on analysis of 11 boreholes and >3 million seismic reflection horizon picks. Seismic data from regions of 10,000-30,000 km^2 around each borehole were analyzed using data from International Ocean Discovery Program (IODP) Expedition 371 and other boreholes. Local MAR was affected by deep-water currents that winnowed, eroded or deposited seafloor sediment. Therefore, it is necessary to average MARs across regions to test paleoceanographic and productivity models. MARs during the Miocene Climate Optimum (MCO, 18-14 Ma) were slightly lower than Quaternary values, but increased on southern Lord Howe Rise at 14-13 Ma, when global climate became colder. Intensification of the Indian and East Asian monsoons at ~8 Ma and ~3.6 Ma approximately correspond to the start and end, respectively, of the Biogenic Bloom, which had MARs at least double Quaternary values. On northern Lord Howe Rise we recognize peak MARs at~7 Ma and ~5 Ma. There is no correlation between Neogene MAR and ocean pH or atmospheric CO_2 concentration. Neogene MARs are on average higher than Quaternary values. We posit that future long-term productivity in the southwest Pacific could be higher than Quaternary values, but new computer models that can fit our observations are required to test this hypothesis.

ORAL
Session 2c.

To what extent does magmatic CO_2 and H_2O drive eruption style in the Kokowai 4 and 7 eruptions, Mt. Taranaki, New Zealand?

Jordan Swann[1], Michael Rowe[1], Ingrid Ukstins[1] and Alex Nichols[2]

[1] School of Environment, The University of Auckland, Auckland 1010, NZ
[2]School of Earth and Environment, University of Canterbury, Christchurch 8140, NZ

jswa555@aucklanduni.ac.nz

Magma volatile budgets influence the style and magnitude of volcanic eruptions, especially in a closed system. These generate more explosive eruptions as overpressure builds in the volcanic conduit. Once the eruption commences, magma depressurisation releases vast amounts of volcanic gases. We use the Kokowai 4 and 7 eruptions of Mt. Taranaki, New Zealand, as testbeds for assessing magmatic volatile budgets for individual eruptions.

The Kokowai 4 and 7 eruptions deposited 1.1 and 0.1 km^3 of ash and tephra 4600-4700 years B.P, with estimated magnitudes of 5.1 and 4.2, respectively, making them some of the largest eruptions to occur at Mt. Taranaki over the last 5000 years. Together, they form some of the largest fallout deposits in recent Mt. Taranaki history, with Kokowai 4 depositing 1.7 m thick pumice beds at proximal locations northeast of the volcano. Here, we quantify the H_2O and CO_2 concentrations of plinian (Kokowai 4) and sub-plinian (Kokowai 7) eruptions using FTIR analysis. The volatile concentrations of plagioclase-, pyroxene-, and amphibole-hosted melt inclusions are compared to groundmass glass concentrations to assess the total degassed volume of CO_2 and H_2O per cubic meter of magma to demonstrate potential correlations between eruption style and volatile concentration.

POSTER
Session 1b.

STRESS FIELD IN THE TOHOKU REGION, JAPAN AND ITS RELATIONSHIP WITH FAULTS OF RECENT EARTHQUAKES (4)

Ayaka Tagami[1], M Matsuno[1], T Okada[1], S Sakai[2], M Ohzono[2,3], K Katsumata[3], M Kosuga[4], Y Yamanaka[5], H Katao[6], T Matsushima[7], H Yakiwara[8], T Nakayama[1], S Hirahara[1], T Kono[1], S Hori[1], T Matsuzawa[1] & aftershock observation group of the 2011 Tohoku Earthquake

[1]Research Center for Prediction of Earthquakes and Volcanic Eruptions, Graduate School of Science, Tohoku University, Sendai, Japan.
[2]Earthquake Research Institute, University of Tokyo, Bunkyo-ku, Japan.
[3]Institute of Seismology and Volcanology, Hokkaido University, Sapporo, Japan.
[4]Graduate School of Science and Technology, Hirosaki University, Hirosaki, Japan.
[5]Graduate School of Encironmental Studies, University of NAGOYA, Nagoya, Japan.
[6]Research Center for Earthquake Prediction, Kyoto University, Uji, Japan.
[7]Institute of Seismology and Volcanology, Kyushu University, Shimabara, Japan.
[8]Nansei-toko Observatory for Earthquakes & Volcanoes, Kagoshima University, Japan.

ayaka.tagami.p6@dc.tohoku.ac.jp

Introduction. Tectonic inversion has observed in some subduction zones. It is frequently observed that tectonic inversion of old normal faults (with high dip angle) occurs acting as reverse faults (e.g., Okamura et al., 1995). Fore an example, high-angle reverse faults are distributed in the area northwest of the Alpine Faults in the South Island of New Zealand. These faults were caused by the extensional stress field during the formation of Tasman Sea and Emerald Basin (Ghisetti et al., 2014, 2016).

In this study, we focused on the inland area of northeastern Japan, where many high-angle reverse faults are also, distributed. It is known that these faults were caused by the extensional stress field during the formation of the Japan Sea (Okamura and Kato, 2000). We estimated the stress field around the three recent moderate-sized to large shallow earthquakes (the 1998 M_{jma} 6.1 Shizukuishi earthquake, the 2008 M_{jma} 7.2 Iwate-Miyagi Nairiku earthquake, and the 2003 M_{jma} 6.4 northern Miyagi earthquake) and investigated the relationship between the stress fields and the fault planes.

Data and methods. We use focal mechanism (moment tensor) data from the National Institute for Earth Science and Disaster Resilience (NIED) of Japan and focal mechanisms estimated from P-wave initial motions from Okada et al. (2019). For estimating the regional stress field, we deploy the stress tensor inversion method (Michael, 1984, 1987). For estimating the likelihood of slip, we use the Slip Tendency (ST) analysis (Morris et al., 1996).

Result and Conclusion. The estimated stress fields were mostly reverse fault type. All the westward dipping planes showed lower ST values suggesting these earthquakes occurred along the fault planes unlikely to slip in the estimated stress fields. High pore fluid pressure and/or low friction coefficient could cause the unfavorable slip.

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POSTER
Session 1c.

A Detailed, Quantitative Investigation into the Physical Properties of Tephra in the Stratigraphical Sequence of the Y5 Phase of the Taupo 232 CE Eruption

Sarah Tapscott[1], Gert Lube[1], Colin Wilson[2], James Ardo[1] and Hannah Walters[1]

[1] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*
[2] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand.*

s.tapscott@massey.ac.nz

Unit 5 (Y5) of the Taupo 232 CE eruption is an unusually well-preserved and well-studied example of a large Plinian fall deposit. Existing studies, however, lack an in-depth quantitative investigation into the physical properties of tephra in the detailed stratigraphical sequence. Here we present a comprehensive analysis of the variation in the physical properties of tephra in a representative stratigraphical profile from the Y5 eruption, through grain-size analysis and the quantification of eruptive components, their densities, and the textural characteristics of juvenile clasts.

The profile is an extremely well-detailed air-fall deposit situated in the central part of the thickest deposit dispersal isopach, determined representative through extensive field observation and location scouting.

Six juvenile component classes are defined: J1) microvesicular pumice; J2) macrovesicular pumice; J3) fibrous pumice; J4) banded pumice; J5) dense grey; and J6) obsidian; which exhibit a systematic increase in bulk densities, respectively. Non-juvenile component classes were defined according to broad estimates of their likely depth of origin in the crust: F1) shallow lavas; F2) intermediate, hydrothermally altered material; and F3) deep microcrystalline intrusives. An additional non-juvenile component, composite pumice (CP), shows evidence of strong brecciation and possible 'recycling' of material in the conduit during the eruption.

The quantitative results will allow for further investigation into the likely conditions in the conduit immediately prior to fragmentation and how this varied with time, adding further complexity to the understanding of the Y5 eruption.

POSTER
Session 1a.

THE CHARACTERISTICS OF SOURCE PARAMETERS OF INTERPLATE EARTHQUAKES OCCURRING IN AND AROUND THE RAUKUMARA PENINSULA IN THE NORTH ISLAND, NEW ZEALAND (2)

Kazuya Tateiwa[1], Calum Chamberlain[2], Martha Savage[2] and Tomomi Okada[1]

[1] *Graduate School of Science, Tohoku University, Japan*
[2] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, New Zealand.*

kazuya.tateiwa.r7@dc.tohoku.ac.jp

Beneath the North Island of New Zealand the Pacific Plate is subducting under the Australian Plate, and a variety of seismic activities have been observed. Seismic reflection surveys and magnetotelluric surveys reveal that diverse seismic activities are associated with features related to frictional properties such as the presence of fluid and subducted seamounts. The North Island of New Zealand is a good study target to investigate the relationship between frictional properties and seismic activities and source parameters. In this study we investigate corner frequencies of interplate earthquakes that occur in and around the Raukumara Peninsula and discuss frictional properties in the seismogenic zone.

We successfully estimated corner frequencies (f_c) of about 40 interplate earthquakes and investigated the spatial distribution of $M_0 f_c^3$ and the ratio of P-wave to S-wave corner frequencies (f_c^P/f_c^S). High $M_0 f_c^3$ is observed at the northwestern part of the Raukumara Peninsula where the shape of the upper surface of the subducted Pacific slab has changed significantly due to the subduction of the Hikurangi Plateau. The reason for the large value of $M_0 f_c^3$ can be explained by considering that the stress drops are high due to the stress concentration caused by the shape of the upper surface of the subducted Pacific slab. The Tokomaru-Tolaga region tends to have a slightly smaller value of f_c^P/f_c^S than other regions, suggesting faster rupture velocity (Kaneko and Shearer, 2015). It has been pointed out that fluid-rich subducted sediments exist slightly up-dip from the seismic zone of Tokomaru-Tolaga. Since low fault rigidity is known to increase rupture velocity, the slightly smaller f_c^P/f_c^S (or slightly faster rupture velocity) at Tokomaru-Tolaga may be due to low-rigidity sediments. Low-rigidity sediments have also been postulated in the region in order to explain high amplitudes and long duration signals offshore after the 2016 Kaikōura earthquake (Kaneko et al., 2019).

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POSTER
Session 1c.

STORIES OF EXPANSION; 20 YEARS OF EVOLUTION AND ENVIRONMENTAL CHANGE IN THE GEONET SENSOR NETWORK

Samuel Taylor-Offord[1], **Timothy McDougall**[1]

[1] *GNS Science, Aotearoa*

s.taylor-offord@gns.cri.nz

The GeoNet Sensor Network stands today as a collection of over 1100 geophysical, geochemical, and environmental sensors canvassing Aotearoa and homed in on its geological hazards. Beginning as a network of predominantly strong motion instruments and seismometers, the network now boasts almost 200 continuous geodetic sites and 130 other sites covering a swath of data types including coastal and deep ocean sea level, cameras, air pressure, and a hydrophone. Despite this vast expansion, the GeoNet Sensor Network today has been relatively stable for the better part of a decade. Now, the GeoNet Sensor Network lies at the core of the GeoNet machine, providing critical data for geohazard monitoring and a stable base for research efforts into understanding the Earth systems we live in.

In this presentation we look back at the GeoNet Sensor Network, its origins, its development, and the forces that drove its growth and support it now in its maturity. We paint this in broad strokes, exploring these ideas through the stories of seminal network expansions, their drivers, and the changes that enabled them. With the dizzying era of network growth seemingly behind us, we conclude with questions for the future: what purpose does the network serve today? How much do each of its parts contribute to this? Where has network growth exceeded expectations, and where has it fallen short? What is next for the GeoNet Sensor Network?

ORAL
Session 2a.

CHARACTERISING SOUTH AUCKLAND GEOLOGY

Briar Taylor-Silva[1], **Samantha Mackay**[2]

[1] Aurecon, PO Box 2292, Tauranga 3140, New Zealand
[2] ENGEO, 8 Greydene Place, Takapuna, Auckland 0622

briar.taylor-silva@aurecongroup.com

Between 2019 and 2021 a large-scale ground investigation was conducted along the State Highway in South Auckland as part of the Papakura to Bombay motorway widening project. The Project area sits in the fault-controlled basin called the Manukau Lowlands, which underlies the Manukau Harbour and south at least to the Waikato River. As the basin has subsided, subsequent deposition of younger sediments has infilled the basin. The basin is inferred as 3 million years old or more (of Pliocene to Pleistocene age), which contributes to considerable local variation in structural (and depositional) histories. From drilling on the alignment to date, three main lithological units have been identified as basin-filling sediments: a younger alluvium (normally-consolidated) and an older alluvium (over-consolidated), underlain by a much more indurated sedimentary (sand/sandstone) unit that may be at least partially marine (locally includes marine fossils). We have assigned the two alluvial units to the Tauranga Group, recognising some similarities with alluvial sediments in Auckland whilst accounting for local variation. The third unit comprising uncemented sand and indurated sandstone is assigned to the Kaawa Formation (KF) which is based on rather limited stratigraphic evidence. It is recognised that the stratigraphic names of these units will be revised in the near future; however, until published, existing stratigraphic terminology terms will be adopted. The depth to 'Kaawa' sandstone varies significantly across the project but is present in outcrop in the Otuwairoa Creek at the Drury boat-ramp (and can be examined at low tide), this outcrop forms our interpretation of underlying 'local' rock. In addition, aligning with work from Kenny et al. (2011), our investigation under covered evidence for several graben structures to exist within the region.

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ORAL
Session 4c.

SEISMIC IMAGING OF QUATERNARY SEDIMENTARY WEDGE AT THE MOUTH OF THE CLUTHA RIVER

Monique Thomas and Andrew Gorman

Department of Geology, The University of Otago, Dunedin, New Zealand.

thomo600@student.otago.ac.nz

The natural processes of sea-level change (controlled by interglacial and glacial periods) and dynamic shoreline processes (controlled by climate variables) can have significant impacts on nearby coastal shorelines in terms of river-borne sediment. Moreover, engineering of hydroelectric dams that are placed in rivers provides major contributions to changes in sediment supply for these coastal shorelines. This has been shown from previous studies on the Otago coastline with retreating and advancing of dunelands due to these natural and anthropogenic processes. South Dunedin is of interest because its low-lying topography is vulnerable to retreating coastlines with high inhabitants. The new river-borne sediment is the same sediment that develops the South Dunedin dunelands and beaches.

This sediment is delivered by the Clutha River, accumulated at the Clutha Mouth forming a sediment wedge in Molyneux Bay, and then carried by northward travelling longshore currents. The sediments are then deposited by aeolian processes to form the dunelands. The sediment supply has shown a decrease since construction of Roxburgh (1950's) and Clyde electric hydro dams (90's) in the Clutha River (Fleming B., 2012). This change should be quantified for further analysis of its future contribution to the Otago coast and can be used as a key example of how the sediment budget can be a method to predict the nature of neighbouring shoreline changes. The Clutha River mouth would contain the sediment wedge that is located between the last glacial maximum seafloor and the current seafloor.

The aim of this study is to quantify and image the development of the Clutha sediment wedge from building on past research (Johnstone T., 1990 & Fleming B., 2012). The methods that will be used include seismic imaging with multibeam data to accurately map the Clutha sediment wedge and collection of seafloor sediment samples in Molyneux Bay.

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POSTER
Session 2d.

WHO ARE YOU TALKING TO – AND WHY ARE YOU DOING IT?

Julian Thomson[1]

[1] *Out There Learning Ltd*

julian@outtherelearning.co.nz

When scientists engage with the public this presupposes that sharing research insights will have tangible benefits to the audience.

These benefits can range from an increased awareness and understanding of a science topic, to a positive appreciation and interest, or even empowerment to act or change personal behaviours. These different examples of outcomes can be seen as a continuum in terms of possible audience responses. Often science communicators are vague in terms of where they are operating on this continuum and what a final call to action should look like, if indeed they are ultimately hoping for an active, motivated response from their audience.

In this presentation, I will illustrate how this response continuum can inform outreach strategies for specific audiences and give some examples of how it can be applied.

ORAL
Session 3e.

PLEISTOCENE–RECENT VOLCANISM WITHIN THE CAPE EGMONT FAULT ZONE

Glenn Thrasher[1], Matthew Sagar[1], Paul Viskovic[1] and Hannu Seebeck[1]

[1] *GNS Science, PO Box 30368, Lower Hutt 5040, New Zealand*

g.thrasher@gns.cri.nz

The Taranaki Peninsula is dominated by the recent volcanic edifice of Taranaki Maunga and its associated ring plain. This igneous rock sequence is referred to by Townsend et al. (2008) as the Egmont Volcanic Centre. Many wells have penetrated the igneous rocks, showing them to be surficial and rarely extending to more than a few hundred metres below sea level.

Active faulting associated with the Cape Egmont Fault Zone affects the southwestern portion of the peninsula. Recent research into that fault zone (Seebeck et al, 2021) reveals the dissection of the Egmont Volcanic Centre by extensional tectonics.

Seismic reflection data document the fault system, which has a complicated history of reactivation since the Cretaceous. The most recent phase has been the post-Miocene extensional formation of a system of grabens underlying the offshore region southwest of the Taranaki Peninsula and the western portion of the peninsula. This major extensional fault system cuts the igneous succession, with the base being offset by hundreds of metres across individual faults. The Egmont Volcanic Centre units rest on an angular west-dipping unconformity cut into Pliocene sedimentary strata.

Seismic reflection mapping reveals several subsurface igneous features spatially associated with the fault zone. Offshore, within 10 km west of the coastline, there are three small (<100 km^2) buried constructional volcanic cones. Each of the three features appears to have been active for a period of a few hundred thousand years, with overall activity ranging from ca. 1.8 Ma to ca. 0.5 Ma. Onshore, at least two more small cones underly the ring plain, resting on the unconformity.

This study reveals an older, and tectonically complicated, history of the Egmont Volcanic Centre, and its association with the underlying Taranaki Basin.

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ORAL
Session 1a.

CLIMATE CHANGE DURING THE LAST GLACIAL TERMINATION IN THE SOUTHERN ALPS - EVIDENCE FROM NEW GLACIER CHRONOLOGIES AND SNOWLINE RECONSTRUCTIONS

Levan Tielidze[1], Shaun Eaves[1], Kevin Norton[1], Andrew Mackintosh[2], Alan Hidy[3]

[1]Victoria University of Wellington, New Zealand
[2]Monash University, Australia
[3]Lawrence Livermore National Laboratory, USA

Here we report the first dataset of Late Quaternary glacial maximum extent and its deglaciation from the Ahuriri River valley, Southern Alps, New Zealand based on 66 beryllium-10 (^{10}Be) surface-exposure ages from terminal-lateral moraine systems and glaciated bedrock surfaces situated at different sites of the valley. Our results show that the former Ahuriri Glacier reached its maximum extent 19.8±0.3 ka, which coincides with the global Last Glacial Maximum. By 16.7±0.3 ka, the glacier had retreat ~18 km up-valley and this deglaciation was accompanied by the formation of a shallow proglacial lake. Our surface-exposure chronology from the moraines situated upper right tributary of the Ahuriri River valley also indicates that other subsequent advance of the palaeo glacier culminated at 14.5±0.3 ka ago, while the next re-advance or still stand phases occurred at 13.6±0.3 ka. About 1000 yr later (12.6±0.2 ka), the former glacier built another prominent terminal-lateral moraine ridge in the lower section of the upper right tributary valley. In overall, our result supports the hypothesis that climate was ~5°C colder (ELA depression ~880 m) than present at 19.8±0.3 ka, while it was ~4.4°C colder (ELA depression ~770 m) at 16.7±0.3 ka. Furthermore, local air temperature was lower by 3.6°C (ELA depression ~630 m) during the 14.5-13.6 ka and by 2.0°C (ELA depression ~360 m) at 12.6 ka respectively relative to present. Our results clearly demonstrate the structure of last glacial termination in New Zealand such as strong glacier recession during this time-period in accordance of at least five glacier re advances or still stand phases.

ORAL
Session 2c.

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THE SOUTHERN ALPS LONG SKINNY ARRAY (SALSA): VIRTUAL EARTHQUAKE ANALYSIS OF THE ALPINE FAULT BETWEEN MILFORD SOUND AND MARUIA

John Townend[1], Caroline Holden[2], Calum Chamberlain[1], Emily Warren-Smith[3], Cassandra Trinh-Le[1], Ilma del Carmen Juarez-Garfias[1], Olivia Pita-Sllim[1], Marine Denolle[4], Finnigan Illsley-Kemp[1], Olivia Mark[1], Ashleigh Matheson[1], Ross McGregor[1], Jessie Schuler[1], Kasper van Wijk[5], Andrew Curtis[6], and Hiroe Miyake[7]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington*
[2] *SeismoCity Ltd., Wellington*
[3] *GNS Science, Lower Hutt*
[4] *Earth and Space Sciences, University of Washington*
[5] *Department of Physics, The University of Auckland*
[6] *School of Geosciences, The University of Edinburgh*
[7] *Earthquake Research Institute, The University of Tokyo*

john.townend@vuw.ac.nz

The ground motions produced by large earthquakes are governed by on-fault factors — the distribution, amplitude, mechanism, direction, and speed of rupture — and by the effects of three-dimensional variations in elastic and anelastic structures further afield. To account for these different factors, we must understand characteristics of the rupture itself (the earthquake source), the propagation of seismic waves (the path), and the interaction of these two effects to produce ground-shaking (the combination of source and path effects). A key challenge in quantifying seismic hazard is to reliably and efficiently compute the ground motions produced by a broad range of plausible but as yet unobserved rupture scenarios represented by a complex distribution of source terms.

The Southern Alps Long Skinny Array (SALSA) is being deployed for 18 months to comprehensively explore how the Alpine Fault's structure, heterogeneity, and present-day state will affect earthquake slip and ground-shaking in future large (M_w~8) earthquakes. Once fully deployed in November 2021, SALSA will consist of 45 broadband seismometers installed 10 km apart along a ~450 km length of the Alpine Fault between Piopiotahi/Milford Sound and Maruia, augmented by short-period sensors installed off the main line and permanent GeoNet and SAMBA instruments.

The data from SALSA will be used in conjunction with recordings made using seismometers and high-rate geodetic sensors throughout southern New Zealand to synthesise Green's functions representing the farfield response to incremental slip anywhere on the fault surface. By combining these Green's functions with rupture models based on recent findings regarding along-strike fault structure, fault rock rheology, and rupture segmentation, we will be able to compute the ground motions at key locations of interest produced by large numbers (millions) of complex, geologically-informed and plausible rupture scenarios — "virtual earthquakes" — which would otherwise be computationally intractable.

POSTER
Session 2a.

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MODERN FRESHENING OF ROSS SEA SURFACE WATERS OUTSIDE THE RANGE OF NATURAL VARIABILITY DURING THE LAST 5,000 YEARS

Olivia Truax[1,2], Christina Riesselman[1,2], Aldo Shemesh[3], Ruth Yam[3], Rebecca Parker[4], Craig Stevens[5], Gary Wilson[6], Jae Il Lee[7], and Kyu-Cheul Yoo[8]

[1]*Department of Geology, University of Otago, Te Whare Wānanga o Otāgo Dunedin, New Zealand*
[2]*Department of Marine Science, University of Otago, Te Whare Wānanga o Otāgo Dunedin, New Zealand*
[3]*Department of Earth and Planetary Science, Weizmann Institute of Science, Rehovot, Israel*
[4]*Camborne School of Mines, University of Exeter, Cornwall, United Kingdom*
[5]*National Institute of Water and Atmospheric Research, Taihoro Nukurangi, Wellington, New Zealand*
[6]*GNS Science, Te Pū Ao, Wellington, New Zealand*
[7]*Korea Polar Research Institute, Incheon, South Korea*

olivia.truax@postgrad.otago.ac.nz

In recent decades meltwater discharge from the Antarctic Ice Sheets has affected the ocean around Antarctica and altered its salinity, density, and upper ocean mixing. This in turn influences the volume of Antarctic Bottom Water, the cold salty water mass supplying the lower limb of the global overturning circulation. The instrumental record (1960 to present) shows the largest salinity changes have been observed in the Ross Sea, Antarctica's largest drainage basin. The trend has been primarily a freshening with a very recent rebound in salinity since 2014. With the limited instrumental record, it is not possible to determine whether the varying trends are outside the range of natural variability. Here, we present a 6,000 year $\delta^{18}O$ diatom record of glacial discharge from a marine sediment core located in the southwestern Ross Sea. Our record shows enhanced glacial discharge between 6 and 5 ka, a period when terrestrial records of glacial lowering and marine sediment cores indicate that the Antarctic Ice Sheet underwent a rapid phase of post-LGM retreat in the Ross Embayment, and during the modern warm period (past ~150 years). Our study establishes that modern freshening in the Ross Sea is outside the range of natural variability during the last 5,000 years and is consistent with a period of sustained ice sheet contraction.

ORAL
Session 2c.

LAVA FLOW INUNDATION HAZARD IN THE AUCKLAND VOLCANIC FIELD

Sophia Tsang[1,2,3]

[1] *School of Environment, University of Auckland, Auckland, New Zealand*
[2] *School of Earth & Environment, University of Canterbury, Christchurch, New Zealand*
[3] *GNS-Science, New Zealand*

s.tsang@auckland.ac.nz

Approximately half of the Auckland Volcanic Field (AVF)'s eruptions have ended with an effusive phase that included lava flows. This suggests there is a strong possibility that a future AVF eruption could also produce a lava flow. To help stakeholders visualise and plan for future eruptions, the DEtermining VOlcanic Risk in Auckland (DEVORA) research team created the DEVORA Scenarios, a suite of eight, hypothetical eruptive sequences that provide ideas about how an urban eruption in Auckland could evolve.

While the vent locations selected for the DEVORA Scenarios could pose disruption to key, communal assets in Auckland, many stakeholders may be more interested in scenarios that could pose large disruptions to their specific entities. To that end, lava flow modelling has been undertaken at every vent location in the "DEVORA Grid." The DEVORA Grid is a set of hypothetical AVF eruptive centres spaced every 500 m inside the AVF boundary with a 5 km buffer around the edge. The cellular automata lava flow model MOdular LAva Simulation Software for Earth Science (MOLASSES) was employed; only subaerial vent locations were utilised as MOLASSES is not intended to model subaqueous lava flows. Additionally, Rangitoto, Motukorea, and Puketutu Islands were excluded as flows on these islands are substantially less likely to have severe impacts to Auckland or Aotearoa. Three different volumes were run at each point to represent a small, medium, or large eruptive volume based on previous eruptions. The outputs could be used to create a graphical user interface to allow stakeholders to "build their own scenario" and to update potential inundation maps in Auckland in a quasi-probabilistic manner. This poster maps where the AVF may inundate in a future eruption.

POSTER
Session 1a.

Primary School Lessons for Increased Community Resilience

Sophia Tsang[1], **Elliott Heremaia**[2], **and Honey McIsaac-Paora**[2]

[1] *GNS-Science, New Zealand*
[2] *Ngātiwai Education, New Zealand*

s.tsang@auckland.ac.nz

At its core, Rapid Characterisation of Earthquakes and Tsunamis (RCET) is about increasing tsunami resilience, especially in Te Tai Tokerau, by expediting incoming seismic and tsunami data. Being able to alert communities to incoming tsunamis alone will not increase resilience, though. To affect change, communities need to know how to act when they recognise the natural signs of a tsunami or receive a tsunami warning.

One way the RCET outreach team is sharing our mahi with communities is by creating a two-term unit on Tangaroa, background earth science, earthquakes, and tsunamis for primary schools. The co-developed unit not only emphasises the multi-disciplinarity of our work but also how science can be a fun and collaborative endeavor that includes many types of science, technology, engineering, and mathematics fields and communities and how to recognise natural warning signs of tsunamis. The unit is aimed for students at New Zealand Curriculum Levels 3 and 4 and consists of weekly, hour-long lessons which teachers can deliver with supplemental visits from the RCET outreach team. As the unit is targeted for schools close to the coast (i.e., in a community that may be required to evacuate for a tsunami), the experiential lesson plans involve both beach and pool activities to learn about tsunamis. Altogether, the unit aims to increase student understanding of earthquake and tsunami science and of actions that will keep them safe after earthquakes while also affecting change by encouraging students to discuss their learnings with their whānau. In this presentation, we will preview the unit's lesson plans and activities in addition to describing where you can keep up to date with progress on this project which will be piloted in the Year 5/6 and Year 7/8 classes at Whangarei Heads Primary School in the first half of next year.

POSTER
Session 3e.

70 YEARS OF RADIOCARBON AND GREENHOUSE GAS MEASUREMENTS IN NEW ZEALAND

Jocelyn C. Turnbull[1,2,*] Dave C. Lowe[3], Martin R. Manning[4], Rodger Sparks[1], Albert Zondervan[1], Margaret Norris[1]

[1] GNS Science, Lower Hutt
[2]CIRES, University of Colorado at Boulder, USA
[3]LoweNZ, Wellington, NZ
[4] Victoria University of Wellington, NZ

j.turnbull@gns.cri.nz

2021 marks the 70th anniversary of New Zealand's first radiocarbon measurements. In this presentation, we will explore the early history of these measurements and the many scientific outcomes that these New Zealand scientific pioneers achieved. Athol Rafter once recounted his entrée into the world of radiocarbon dating: *A few days later I was walking home quietly through the grounds of Parliament Buildings when coming in the opposite direction was the Head of our Department, a Mr Callaghan, who stopped me with the statement, 'Rafter, I have just come from a meeting with geologists who tell me there is a method of dating by means of carbon that should be able to tell the age of our volcanic ash showers. Would you see if you could develop this method and stop the geologists arguing?' I said a confused goodnight and continued on my way home somewhat more puzzled than usual.*

Athol Rafter and his colleagues made their first radiocarbon measurements in 1951, and by 1954 had become leaders in the use of radiocarbon in what would eventually become the field of climate science. Not only did they successfully constrain the age of the most recent Taupo eruption, but their atmospheric radiocarbon measurements immediately demonstrated the existence of an "Industrial Effect" caused by CO_2 emissions from fossil fuel combustion. However within the space of two years this signal was obscured by an "Atom Bomb Effect" caused by the production of radiocarbon from atmospheric nuclear weapons testing. These two gigantic tracer experiments have been utilised via atmospheric radiocarbon measurements over the years to produce a wealth of knowledge in multiple research fields including atmospheric carbon cycle research, oceanography, soil science, and aging of post-bomb materials.

POSTER
Session 4e.

DUNEDIN CITY'S LEGACY OF LEAD

Rose Turnbull[1], Adam Martin[1] Malcolm Reid[2] and Claudine Stirling[2]

[1] *GNS Science, Dunedin Research Centre, Private Bag 1930, Dunedin, New Zealand*
[2] *Geology Department and Centre for Trace Element Analysis, University of Otago, Dunedin, New Zealand.*

r.turnbull@gns.cri.nz

Lead (Pb) pollution in the urban environment is an enduring issue that continues to pose a serious health risk to communities. Previous work (Turnbull et al. 2019) has shown that Dunedin City has soil Pb concentrations that are an order of magnitude greater than those from surrounding rural areas throughout Otago (i.e. Martin et al. 2016). Though elevated Pb was associated with human activities, the exact nature of the source(s) responsible for increasing the Pb content of Dunedin soils remains unknown. In order to determine the source(s) of Pb in Dunedin soils, and assess the current exposure risk from Pb-contaminated soils, Pb-isotopes were measured across a subset of topsoils city-wide. Results demonstrate that Dunedin soils have Pb-isotope compositions that plot along a single array consistent with derivation from local (Dunedin volcanics, Otago Schist, regional coal) and exotic (i.e. Broken Hill ore) hard-rock sources. The Broken Hill signature is consistent with input from leaded gasoline and/or Pb-based paint sources. Overall, Pb concentrations are highest in residential soils, rather than along road verges, suggesting that Pb-based paint sources, rather than derivation from historical leaded gasoline emissions contributes the most to elevated Pb in Dunedin soils. We suggest that the historical and present-day deterioration of surfaces containing old Pb-based paint continues to contribute and raise Pb concentrations in many soils from Dunedin residential properties. Significantly, the highest Pb levels in residential soils correlate to areas with the largest socio-economic deprivation (i.e. the NZDep); households who typically lack the capacity to safely remove and replace Pb-based paint from their properties. Our results have implications for assessing and mitigating the potential ongoing public health risk of Pb exposure within New Zealand urban environments.

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POSTER
Session 4e.

VOLATILES IN NOMINALLY ANHYDROUS MANTLE OLIVINE FROM THE AUCKLAND VOLCANIC FIELD.

Ingrid Ukstins[1], Jie Wu[1], Marco Brenna[2], Shane Cronin[1] and Ian Smith[1]

[1] *School of Environment, University of Auckland, Auckland, New Zealand*
[2] *Department of Geology, University of Otago, Dunedin, New Zealand.*

ingrid.ukstins@auckland.ac.nz

Disaggregated olivine crystals from mantle xenoliths found in the the >200 ka basaltic Pupuke tuff ring of the Auckland Volcanic Field were analysed by synchrotron-sourced Fourier-Transform Infrared (FTIR) microscopy and show the presence of water, carbon dioxide and aliphatic hydrocarbons. Profiles measured across single crystals from core to rim show hydrogen depleted rims that are interpreted to result from partial dehydration by ionic diffusion during the ascent of the xenocrysts to the surface. The main OH absorbance peaks of most samples were located between 3600 to 3450 and 3450 to 3100 cm, which are predicted by experimental data and reflect the range of silica activity and iron content. Water contents are highest in the grain centers and show some variability, which may be linked to the increase in water solubility with increasing water fugacity as a function of pressure. Carbon dioxide was also observed in some olivine xenocrysts and, where present, appears to follow similar cross-section diffusion profiles. Aliphatic hydrocarbons (n-alkanes) are abiogenic and represent undifferentiated mantle olivine, their presence in these unaltered xenocrystic olivines indicates that they were rapidly transported from the lithispheric mantle by the Pupuke basalt eruption. OH in olivine diffusion profiles reflect rapid transport on the order of a few hours and likely reflect volatile degassing during the last stage of magma rise before eruption. Metasomatism by fluids or melts and the ambient oxygen fugacity of the mantle may have generated the initial incorporation of C-H compounds into these olivines, and the volatile-rich mantle lithosphere observed beneath the Auckland Volcanic Field could help explain the location and longevity of volcanic activity.

POSTER
Session 1b.

MARLBOROUGH FAULT SYSTEM: A COMPLEX 4D TRANSITION ZONE IN CENTRAL NEW ZEALAND ILLUMINATED BY TOPOGRAPHIC FABRIC

Phaedra Upton[1], James Crampton[2], Andy Tulloch[3], Matt Sagar[1], Alison Duvall[4], Susan Ellis[1], Robert Langridge[1], Dougal Townsend[1], and Donna Eberhart Phillips[3]

[1] *GNS Science, 1 Fairway Drive, Avalon, Lower Hutt, New Zealand*
[2] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand.*
[3] *GNS Science, 764 Cumberland Street, Dunedin, New Zealand*
[4] *Department of Earth and Space Sciences, University of Washington, Seattle, Washington, USA*

p.upton@gns.cri.nz

Under the current tectonic setting of Zealandia, the Marlborough Fault System (MFS) is a transitional section of the Australian–Pacific plate boundary, linking oblique continental collision in the central South Island with well-established subduction beneath the North Island. We show that this current form of the MFS is relatively recent and argue that to fully understand deformation within the MFS it is necessary to consider pre-existing structures and their evolution. Analysis of the Marlborough terrain reveals distinct topographic regions from west to east. The western and central MFS are dominated by north-south striking faults and parallel valleys which are crosscut by more easterly trending structures. In contrast, the eastern MFS is dominated by four major northeast striking faults with parallel valleys. The western and central MFS consist of a large number of blocky ranges with low length-width aspect ratios (~10 to 40 km). In contrast, the eastern MFS faults delineate the elongate Inland and Seaward Kaikōura ranges (>80 km long). The different topographic fabrics reflect different tectonic histories and highlight the importance of inherited structures for present-day deformation styles within the MFS. Following on from Ghisetti (2021), we show that late Miocene tectonic evolution of the regions (western and central MFS vs eastern MFS) differs markedly and it is only during the last 2–5 Myr that the entire MFS has a common history. Concurrent with the development of the MFS in the upper crust, the plate boundary, which may eventually become a subduction interface, is evolving beneath the MFS. The nature of this part of the plate boundary has implications for how large earthquakes on the Alpine Fault and the Hikurangi subduction zone may interact.

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ORAL
Session 1c.

WHAT CAN WE LEARN ABOUT FAULT GEOMETRIES AND GROWTH MECHANISMS FROM A CT SCAN OF A FAULTED ROCK?

Inbar Vaknin[1], Andy Nicol[1]

[1] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*

Inbar.vaknin@pg.canterbury.ac.nz

Fault surfaces and fault-zones have been shown to have complex geometries comprising a range of morphologies including, segmentation, tip-line splays, fault-bound lenses and fault-surface corrugations. The three-dimensional (3D) geometries of faults (and fault zones) are difficult to determine from outcrops, which are primarily 2D and limited in size, or from seismic reflection data that lacks the resolution necessary to resolve faults of < ~10 m displacement or fault-zone structure. This talk will examine the geometries of small-scale normal faults (displacements <~1 cm) that displace well bedded sand and silt layers in the Mount Messenger and Mohakatino formations in Taranaki, New Zealand. A 10x8x3 cm 3D model of small faults was produced using a high resolution multi-band CT scanner (MARS Bioimaging Ltd). The X-ray based computed tomography (CT) images materials with different compositions and densities, and enable us to map fault geometries and bedding. The CT model indicates that the fault surfaces are hard linked and corrugated parallel to the slip direction, while fault-zones comprise lenses of variable dimensions. Complexities in fault zone geometries occur at fault intersections and are consistent with a segment linkage fault growth model. The talk will be illustrated by MARS imagery and include discussion of its application in geology.

POSTER
Session 4c.

SEISMIC METHODS TO PRESENT THE CRUST OF THE AUCKLAND VOLCANIC FIELD IN THREE DIMENSIONS

Kasper Van Wijk

University Of Auckland

k.vanwijk@auckland.ac.nz

The active, monogenetic, and intraplate Auckland Volcanic Field (AVF) poses a considerable risk to the population of the largest city of New Zealand. The mechanisms driving AVF volcanism have not yet been explained, partly due to a lack of detailed structural information on the crust and deeper lithosphere.

We present an overview of seismic studies that probe the crustal properties of the AVF to complement a vast body of geologic and geochemical studies on the AVF. A 3D image of the AVF crust has emerged with features that align with the NNW-SSE trend also presented by the Junction Magnetic Anomaly (JMA) in the Dun Mountain/Matai Terrane and from geological mapping of basement features. Beneath and east of the AVF, in the Waipapa Terrane, a mid-crustal wedge of low seismic speed is thinning towards the east. West of the AVF a crust with higher seismic speed consists of thickened crust composed of the Dun Mountain/Matai Terrane, overlain by Murihiku Terrane. Most intriguingly, our ambient noise model shows a sharp vertical seismic discontinuity extends at least 15 km in depth, positioned under Rangitoto Volcano of the AVF and lying within a major NNW-SSE-striking, long-lived fault zone that upthrows basement to the East. Seismic travel time anomalies from teleseismic body waves agree with such a discontinuity. Current efforts with seismic body waves from local earthquakes and quarry blasts may also require such a strong near-surface seismic speed contrast to fit the data. These studies show that seismic tomography can be used to explore crustal structures under the AVF that may be crucial to understanding the propagation of magma to the surface. It is hoped that further recordings and additions to the seismic network will allow deeper penetration into the lithosphere, so that the geodynamics responsible for the AVF can also be better explained.

ORAL
Session 1c.

LEGACY DATA AND DATA UPCYCLING

Julian Vearncombe[1]

[1] *PO Box 99699, Newmarket, Auckland, New Zealand.*

julian@vearncombe.com

Mineral exploration and mining are data-driven industries. Computational and technological advances are allowing the collection of an ever-greater variety of data, in larger quantities, at increased speed, and reduced costs. These are both an opportunity and a challenge. The proliferation of data and emerging technologies are reducing the human input in data collection, analysis and assessment, and are likely to change exploration in the decades to come.

To ensure current and future use is ‘fit for purpose’, data must be fully integrated with geological knowledge, and be both verified and verifiable for future use. Here, we emphasize the role of legacy data and the process of data upcycling as a significant contributor to modern and future exploration.

Upcycling can take three basic forms, all aimed at enhancing the veracity of data including legacy data: (1) re-collection of data, (2) collection of complimentary data, and (3) assessment and innovative portrayal of data.

Upcycling of legacy data allows information to be integrated into modern datasets. This paper offers perspectives and examples on how “*data upcycling*” benefits mineral exploration, with short case studies highlighting the role of government, service providers and resource explorers.

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ORAL
Session 4f.

FAULT RUPTURES TRIGGERED BY LARGE RHYOLITIC ERUPTIONS AT THE BOUNDARY BETWEEN TECTONIC AND MAGMATIC RIFT SEGMENTS: THE MANAWAHE FAULT, TAUPŌ RIFT, NEW ZEALAND

Pilar Villamor[1], Nicola J. Litchfield[1], David Gomez[2], Fidel Martin-González[2], Brent Alloway[3,4], Kelvin Berryman[1,5], Kate Clark[1], William Ries[6], Andrew Howell[1,7], India A. Ansell[8]

[1] GNS Science, PO Box 30-368, Lower Hutt 5040, New Zealand
[2] ESCET- Area de Geologia, Universidad Rey Juan Carlos, C/Tulipan s/n, 28933 Madrid, Spain
[3] School of Environment, University of Auckland, Private Bag 92019, Auckland 1142, New Zealand.
[4] Instituto de Geografía, Pontificia Universidad Católica de Chile, Santiago, Chile
[5] Berryman Research and Consulting, 18 Cluny Road, Plimmerton, Porirua 5026, New Zealand
[6] Prae Doc, Department of Geography and Regional Research, University of Vienna, Universitätsstraße 7, A-1010 Vienna, Austria
[7] Department of Geological Sciences, University of Canterbury, Christchurch, New Zealand
[8] Talavera Tce, Kelburn, Wellington 6012, New Zealand

p.villamor@gns.cri.nz

The Manawahe Fault is located at the boundary between the tectonic Whakatane and the magmatic Okataina segments of the northern Taupō Rift. We investigate prehistoric ground surface fault ruptures and their timing in association with volcanic eruptions of the Okataina Volcanic Centre (OVC), using geomorphic fault mapping, paleoseismic trenching, ground penetrating radar and shallow drillcores. Paleoseismic trench data across the major strand of the fault shows that it has ruptured at least seven times in the last c. 9.5 cal. ka (with a possible rupture 8 just prior to c. 9.5 cal. ka). At least four of these surface fault ruptures occurred during, or immediately prior to, volcanic eruptions. These eruptions, namely Whakatane (c. 5.5 ka – 1 fault rupture), Mamaku (c. 8 cal ka -1 fault rupture), and Rotoma (c. 9.5 cal. ka - 2-3 fault ruptures), were all sourced from the nearby Haroharo Volcanic Complex, one of the two currently active volcanic lineaments within the OVC. Average fault rupture interval post-Rotoma eruption is between 1580 and 2000 years. Ground penetrating radar and drillcore data show that the Manawahe Fault has an average slip rate of c. 3 mm/yr since c. 9.5 cal. ka. The fault formed < 26.5 ka ago, which suggests a possible recent spatial migration of the boundary between the magmatic and tectonic rift segments after the last caldera forming eruption, the c. 61 ka Rotoiti eruption. We discuss possible modes of rupture for the Manawahe Fault, and the spatial and temporal relationship with regional tectonism, Holocene eruptions and subsurface magmatic processes. In addition, we examine implications of the study for volcanic and seismic hazard assessment.

POSTER
Session 2a.

CATALOGUING AND PROMOTING THE NATIONAL EARTHQUAKE INFORMATION DATABASE

Paul Viskovic[1], **Annemarie Christophersen**[1], **Jonathan Hanson**[1], **Brain Ferris**[1], **Ashley Holloway-Bryers**[1]

[1] *GNS Science, Avalon, Lower Hutt, New Zealand*

p.viskovic@gns.cri.nz

NZ has a long-storied history in early observational and instrumental seismology and GNS Science acts as the principal custodian of these unique records of NZ seismicity.

In the late 1860s, a network of human observers known as the "Reporter Network" was established. When a member experienced an earthquake, they posted an A5-sized survey form to the NZ Institute, founded in 1867 (now named Royal Society of New Zealand). These felt observations were later addressed to the NZ Geological Survey and other forerunner organisations of GNS Science. This collection also includes collated letters, newspaper cuttings and other first-hand, primary observations of earthquake intensity.

The first instrumental recording in NZ began with a Milne seismograph installed in Wellington in 1900, Christchurch was next in 1902 and the network gradually expanded to span all of mainland NZ. These original paper seismograms, recorded from 1900 to 2005, extend to the Pacific Islands and Antarctica and consists of over 1,000,000 individual records.

Preservation of these records is critical because researchers need to utilise all available information for understanding historic long cycle geological events, this is particularly true in a place like NZ with a relatively short history of human occupation. Research into historic NZ seismicity requires a well-managed, curated, and published collection of records. GNS has recently embarked on efforts to catalogue all these records, digitise documents, and improve the completeness of published metadata and make inventory information of the collections available online.

We will highlight recent efforts in collating and scanning significant earthquake collections, digitising Annual NZ Seismological Reports, and publishing records of instrument metadata and deployment dates. We hope to increase the utility of the paper seismogram collection and felt reports to enable future research and will continue to invest in digitising key records.

POSTER
Session 2a.

AN EMPIRICAL APPROACH TO MODELLING MULTI-FAULT RUPTURES

Ethan Walsh[1], Tim Stahl[1], Tom Robinson[1] and Andy Howell[2]

[1] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand.*
[2] *GNS Science, Lower Hutt, Wellington, New Zealand.*

ethan.walsh@pg.canterbury.ac.nz

Multi-fault earthquakes are becoming recognised as a common occurrence but remain poorly understood. The 2016 Kaikōura earthquake in New Zealand ruptured a series of >20 faults, raising questions whether empirical 'rules' for fault rupture complexity, established from global earthquake catalogues, apply in structurally complex regions. This study modelled empirically derived relative likelihoods of different surface rupturing earthquakes in the Kaikōura region to test how much of an outlier the 2016 event was in a global context. First, we collated six different 2D co-rupture rules or passing ratios from historical earthquakes: angular change, jump distance, fault type change, stepover type, number of steps, and total absolute angular deflection. Then, we combined these parameters to quantify the relative co-rupture likelihoods of adjacent fault sections and performed a Monte Carlo rupture simulation. Results have thus far found that the sub-optimally oriented faults with differing slip sense in the 2016 Southern Kaikōura ruptures have a low relative likelihood of co-rupture. For example, all sections that constitute a full-length Humps and Leader fault rupture have a 1 in 18282 likelihood of co-rupturing. By comparison, the empirical co-rupture likelihood of the Hanmer to Kaikōura section of the Hope fault is 1 in 2.17, or ~8500x more likely. One preliminary interpretation could be that empirical co-rupture likelihoods more accurately represent mature fault systems in structurally 'simple' settings. Conversely, relative likelihoods (and empirical rupture constraints) are less meaningful and accurate in structurally complex or immature settings, with complicated geometries both at the surface and depth, as in North Canterbury. Furthermore, empirical approaches are 2D and cannot currently consider plate interface interactions or physical parameters reliant on 3D fault geometries such as coulomb stress changes. Our results suggest that empirical approaches in weighting or down-weighting rupture scenarios in seismic hazard models could be beneficial, but only in specific settings.

POSTER
Session 2a.

COMCOT SIMULATION MODEL, ITS FEATURES AND RECENT APPLICATIONS

Xiaoming Wang[1], William Power[1], Aditya Gusman[1], Jean Roger[1] and David Burbidge[1]

[1] *Earth Structures and Processes, GNS Science, Lower Hutt, New Zealand*

x.wang@gns.cri.nz

COMCOT (Cornell Multi-Grid Coupled Tsunami) is a numerical model to simulate physical processes of tsunami, including its generation, transoceanic propagation, nearshore run-up, and coastal inundation. The model was born at Cornell University (USA) in the 1990s. Since 2009, it has undergone further development at GNS Science and underpins our tsunami modelling capability. Multiple source mechanisms have been integrated into this modelling tool to simulate tsunami generated by various sources such as earthquakes with time-dependent rupture and variable slip distributions, subaerial/subaqueous landslides, or their combinations.

The tsunami module in this numerical model typically uses a modified staggered finite difference scheme to solve conservative forms of Shallow Water Equations that govern long period water waves, floods and river flows. Together with shock-capturing upwind schemes, friction models, and an ad-hoc wave breaking algorithm, this model provides improved stability and accuracy over traditional schemes in dealing with discontinuities and approximates energy dissipation effects during tsunami runup and inundation. In the model, a flexible two-way nested grid configuration is implemented at cascading spatial resolutions to balance the computational efficiency and numerical accuracy requirements of tsunami simulation which needs to have both an ocean-wide model coverage and a large variation in spatial resolution, particularly close to the coast.

COMCOT has been widely used by researchers to study various aspects of tsunami. It is also adopted by multiple agencies, organizations and companies for tsunami hazard risk assessments, tsunami early warning and forecast. Its recent applications at GNS include tsunami hazard modelling at New Zealand's Scott Base in Antarctica, combined earthquake and landslide source modelling of the 2018 Palu Bay tsunami in Indonesia, the Tsunami Threat Level Database, landslide tsunami and seiche effects in Lake Tekapo, the 11 Feb 2021 Loyalty Island tsunami, and the 05 March 2021 triplet of tsunamis.

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ORAL
Session 4a.

GEOLOGIC CHAMPAGNE: ENIGMATIC SEAFLOOR POCKMARKS ON THE CHATHAM RISE

Fynn Warnke[1], **Jess IT Hillman[2], Ingo Pecher[1], Bryan Davy[2] and Lorna Strachan[1]**

[1] *University of Auckland, Auckland, Aotearoa New Zealand*
[2] *GNS Science, Avalon, Lower Hutt, Aotearoa New Zealand*

fynn.warnke@mailbox.org

We have developed a novel hypothesis linking a regulatory mechanism for CO_2 concentration in the atmosphere to release of geologic CO_2. The Chatham Rise appears to be a "smoking gun" for this mechanism as evidenced by sharp carbon and boron isotope anomalies observed in cores at the end of the last glacial termination. We hypothesize that the Chatham Rise and central Bounty Trough are locations of geologic CO_2 release during the last glaciation (Stott et al., 2018). The CO_2 is likely to originate in limestone sequences of the subducted Hikurangi Plateau, a large igneous province, and to subsequently migrate upwards towards the seafloor.

The mechanism controlling the release of this CO_2 at the end of glaciations remains unclear. Abundant seafloor pockmarks found on the Chatham Rise appear to have formed during glacial terminations. Formation of seafloor pockmarks is usually attributed to sudden release of fluids removing sediments and forming craters. We therefore hypothesize these pockmarks may act as "valves" for sudden release of CO_2 after being accumulated during interglacial periods.

Newly acquired hydroacoustic data allows us to characterize these pockmarks and investigate their correlation to subsurface paleopockmarks and fluid flow associated with faults. Here we present the initial results of subsurface data analysis (2D seismic and TOPAS sub-bottom profiler data), as well as geostatistical analysis of pockmarks on the present-day seafloor. Furthermore, we discuss the use of random forest analysis in automated detection of pockmark distribution and other geomorphological features.

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POSTER
Session 2e.

HETEROGENEITY IN MICROSEISMICTY AND STRESS NEAR REPEATED RUPTURE TERMINATIONS ALONG THE LATE INTERSEISMIC ALPINE FAULT

Emily Warren-Smith[1], Calum J. Chamberlain[2], J. Townend[2], Carolyn Boulton[2], Konstantinos Michailos[3], I. Juarez Garfias[2]

[1] *GNS Science, Lower Hutt, NZ*
[2] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, NZ*
[3] *Institute of Earth Sciences, University of Lausanne, Lausanne, Switzerland.*

e.warren-smith@gns.cri.nz

The size of an earthquake and the character of the seismic radiation it produces are strongly controlled by the length of the fault that slips, yet this is rarely the full length of a fault's surface exposure. Understanding the on-fault processes influencing eventual rupture length is an ongoing challenge in earthquake science. Extensive paleoseismic studies along New Zealand's Alpine Fault have shown that large (M7+) earthquakes occur remarkably regularly, every 291+/-23 years, but typically rupture different combinations of fault segments. Specifically, ruptures often terminate at the South Westland and Central segment boundary, near Haast, and near the Central and North Westland segment boundary near Inchbonnie at the intersection with the Hope Fault. However, some ruptures propagate through these boundaries in multi-segment events, increasing the earthquake magnitude from M7+ to M7.8+.

To understand the transitional behaviour of these segment boundaries, and their role in conditionally halting through-going ruptures, we quantify spatial heterogeneity in factors which have elsewhere been proposed to influence rupture arrest, using the locations and physical properties of small earthquakes. Compared to the relatively well studied central Alpine Fault, these boundary sections are remote and understudied; our knowledge of their active seismogenic behaviour is restricted to incomplete catalogues constructed using sparse networks. Using high precision micro-earthquake catalogues from new and existing dense local seismic networks we map along-strike variations in seismogenesis including: seismogenic depth distribution, on-fault seismic slip, triaxial stress field orientations, aseismic fault patches, fault geometry/structure and connectivity with intersecting faults. We present results of the geometry and mechanical state of these complex rupture barrier regions near Haast and Inchbonnie and discuss their contrasting behaviour with the more uniform central Alpine Fault segment in the context of large-scale rupture processes and how we plan to incorporate these observations in future dynamic rupture simulations.

ORAL
Session 2a.

INSIGHTS FROM A VOLCANOLOGY VIRTUAL FIELD TRIP TO ICELAND

Alex Watson[1], Ben Kennedy[1], Alison Jolley[2], Jonathan Davidson[1], and Erik Brogt[3]

[1] School of Earth and Environment, University of Canterbury, Christchurch, 8041, New Zealand
[2] Te Puna Ako – Centre for Tertiary Teaching & Learning, University of Waikato, Hamilton, 3240, New Zealand
[3] Future Learning & Development, University of Canterbury, Christchurch, 8041, New Zealand

alexander.watson@pg.canterbury.ac.nz

Field trips are a critical component of learning in the geosciences to develop skills, integrate knowledge and motivate student engagement. Virtual field trips (VFTs) are a widely used form of teaching to support or provide alternatives to in-person field trips. However, little research has established the effectiveness of VFTs at aiding the development of geological skills normally developed during in-person field trips (e.g., sketching and interpretation). To investigate this, the recently developed Iceland VFT for undergraduate physical volcanology was used in combination with an in-class exercise, completed pre and post VFT. The in-class exercise required students (n=49) to sketch and interpret a photograph of a lava flow from Sumner Beach near Christchurch, New Zealand. The impact of the VFT on sketching and interpretation was measured by comparing the pre and post VFT in-class exercise responses (i.e., learning gains). In addition, an evaluation exercise allowed students to reflect on the VFT experience, which also provided valuable feedback to the research team.

In-class exercise results indicated that students experienced positive learning gains for sketching and interpretation. Based on feedback in the evaluation exercise possible reasons for these positive learning gains include 1) the 3D visualisations and instructional videos embedded in the VFT allowed students to spatially explore volcanic features within lava flows around Iceland, 2) the reinforcement of course content in the VFT, and 3) students found the VFT a fun, interesting and motivating learning experience.

Recommendations for VFT design based on this research include 1) providing learning spaces that encourage classroom discussion, 2) implementing VFTs that facilitate the flipped classroom, 3) minimising technical difficulties, 4) providing appropriate assessment opportunities with scaffolding, 5) constructively aligning content, 6) providing opportunities for reflection, 7) implementing appropriate technologies to deliver VFT content, and 8) connecting students to the VFT experience.

POSTER
Session 3e.

USING LOCAL INFRASOUND ARRAYS TO DETECT PLUNGING SNOW AVALANCHES ALONG THE MILFORD ROAD, NEW ZEALAND (AOTEAROA)

Leighton M. Watson[1], Brad Carpenter[2], Kevin Thompson[2], and Jeffrey B. Johnson[3]

[1] *Department of Earth Sciences, University of Oregon, Eugene, OR, USA*
[2] *Milford Road Alliance, Te Anau, New Zealand*
[3] *Department of Geoscience, Boise State university, Boise, ID, USA*

lwatson2@uoregon.edu

Snow avalanches pose a hazard in alpine environments. There is a need to improve monitoring capabilities in order to reliably detect and locate avalanche activity, which will help to validate avalanche hazard assessments. Recent work has demonstrated the utility of infrasound as it can provide continuous monitoring and broad geographic coverage.

Here, we present the first use of infrasound to monitor snow avalanche activity in a maritime climate along the Milford Road in Fiordland, New Zealand (Aotearoa). The Milford Road travels through a glacial-carved valley with steep cliffs (slope angles can exceed 50^0) that are over 1000 m tall and masses of the wet, plunging avalanches can exceed 150,000 tonnes.

We deployed two infrasound arrays on the eastern side of the Homer Tunnel and recorded triggered and natural avalanches during our month-long field campaign. We use array processing to identify avalanche signals, calculate back-azimuths, and triangulate source locations. Source locations are well constrained for avalanches that are in-network but are worse for avalanches that occur out-of-network, likely due to topographic scattering of acoustic waves from the steep valley walls. The infrasound amplitudes are substantially larger than previously recorded at other locations with a maximum peak-to-peak amplitude of 37 Pa detected for a large, triggered avalanche, which reflects the massive scale and unique physics of the avalanches along the Milford Road. This study demonstrates the utility of infrasound for snow avalanche monitoring in maritime climates and showcases an efficient processing workflow that could be easily operationalized.

ORAL
Session 2a.

INFRASOUND RADIATION FROM IMPULSIVE VOLCANIC ERUPTIONS: NONLINEAR AEROACOUSTIC 2D SIMULATIONS

Leighton M. Watson[1], Eric M. Dunham[2,3], Danyal Mohaddes[4], Jeff Labahn[5], Thomas Jaravel[5], and Matthis Ihme[4]

[1] *Department of Earth Sciences, University of Oregon, Eugene, OR, USA*
[2] *Department of Geophysics, Stanford University, Stanford, CA, USA*
[3] *Institute of Computational and Mathematical Engineering, Stanford University, Stanford, CA, USA*
[4] *Department of Mechanical Engineering, Stanford University, Stanford, CA, USA*
[5] *Center for Turbulence Research, Stanford University, Stanford, CA, USA*

lwatson2@uoregon.edu

Infrasound observations are increasingly used to constrain properties of volcanic eruptions. In order to better interpret infrasound observations, however, there is a need to better understand the relationship between eruption properties and sound generation. Here we perform two-dimensional computational aeroacoustic simulations where we solve the compressible Navier-Stokes equations for pure-air with a large-eddy simulation approximation. We simulate idealized impulsive volcanic eruptions where the exit velocity is specified, and the eruption is pressure-balanced with the atmosphere.

Our nonlinear simulation results are compared with the commonly-used analytical linear acoustics model of a compact monopole source radiating acoustic waves isotropically in a half space. The monopole source model matches the simulations for low exit velocities (up to 100 m/s or M ~0.3 where M is the Mach number); however, the two solutions diverge as the exit velocity increases with the simulations developing lower peak amplitude, more rapid onset, and anisotropic radiation with stronger infrasound signals recorded above the vent than on Earth's surface. Our simulations show that interpreting ground-based infrasound observations with the monopole source model can result in an underestimation of the erupted volume for eruptions with sonic or supersonic exit velocities. We examine nonlinear effects and show that nonlinear effects during propagation are relatively minor for the parameters considered. Instead, the dominant nonlinear effect is advection by the complex flow structure that develops above the vent. This work demonstrates the need to consider anisotropic radiation patterns and jet dynamics when interpreting infrasound observations, particularly for eruptions with sonic or supersonic exit velocities.

POSTER
Session 1a.

REGIONAL-SCALE MAPPING OF LANDSLIDE DEPOSITS IN MARINE SEISMIC REFLECTION DATA

Sally J. Watson[1], Joshu Mountjoy[1], Susi Woelz[1], Jess Hillman[2] & Gareth Crutchley[3]

[1] *National Institute of Water & Atmospheric Research (NIWA), New Zealand.*
[2] *GNS Science, Lower Hutt, Aotearoa New Zealand*
[3] *GEOMAR Helmholtz Centre for Ocean Research, Kiel, Germany*

Sally.watson@niwa.co.nz

Documenting and characterising submarine landslide deposits is fundamental to understanding the distribution and frequency of submarine landslide events through geological time. Such information is critical to assess the hazard potential of submarine landslides.

The availability of marine geophysical data spanning ~1,200 km along the eastern margin of Aotearoa/New Zealand provides an excellent basis to map regional trends in landslide occurrence, and better constrain the causes of submarine landslides. This expansive and high-quality geophysical dataset has already been used to understand geomorphic and tectonic controls observed in >2,200 submarine landslides mapped on the seafloor (Watson et al., 2020). In this study, we present a complementary subsurface database that documents Mass Transport Deposits (MTD) in all available seismic reflection data. Seismic reflection data were collated from >30 marine surveys, encompassing >43,000 km of seismic lines along eastern New Zealand.

The database includes >600 individual observations of MTD, ranging in thickness from 0.03-0.2 s (~50-400 m). Most observations of MTD are within 1.6 s of the seafloor and initial results suggest they are best preserved within basin structures and on the open continental slope.

The development of the MTD database will enable us to 1) identify where MTD are likely to be preserved within the geological record, 2) investigate locations where landslides have occurred periodically throughout history, and 3) provide complementary subsurface information for mapped surficial landslides in New Zealand.

New Zealand's submarine landslide and MTD databases will be incorporated into a worldwide submarine landslide catalogue that is being developed as a part of a UNESCO funded program (www.S4SLIDE.com), and can be used to investigate global drivers of submarine landslides.

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POSTER
Session 2e.

ANCHORING BY HIGH-TONNAGE VESSELS: A GLOBAL DRIVER OF SEABED DAMAGE

Sally J. Watson[1], Marta Ribó[2], Sarah Seabrook[1,2], Lorna J. Strachan[2], and Rachel Hale[1]

[1] *National Institute of Water & Atmospheric Research (NIWA), New Zealand.*
[2] *School of Environment, Faculty of Science, The University of Auckland, New Zealand.*

Sally.watson@niwa.co.nz

Anchorage sites, where ships lie on anchor awaiting port calls, are a common feature of marine ports globally. While the shipping industry is known to contribute to air, water and noise pollution, the physical footprint of shipping practices, such as anchor use on the seafloor, has received much less attention.

In this study, we show that use of the anchorage for a relatively low congestion port, Picton, has resulted in substantial increases in seafloor rugosity across ~1.8 km^2. Anchor use manifests on the seafloor as linear scouring, up to ~0.8 m deep, and zones of abrasion characterised by irregular seafloor morphology. Similar seafloor morphologies are also observed adjacent to other ports in Aotearoa/New Zealand and globally. Repeat multibeam mapping across the Picton anchorage site shows that scouring and abrasion due to anchor use is persistent on the seafloor over >4 years. Repeat mapping after four years revealed an additional 5.2 km of linear scouring and ~97,000 m^2 of abrasion on the seafloor. Satellite vessel tracking data from the Picton region between 2019 and 2021 shows that high-tonnage passenger and cargo vessels are the most common vessels using the Picton anchorage.

Our results show that anchor use is significantly changing the structure of the seafloor, impacting benthic habitats, and likely having downstream effects on ecosystem functions. The global reliance on shipping for trade, commerce and travel, and the widespread usage of anchorage sites for maritime and port operations, suggests that anchor use may represent a major driver of benthic habitat destruction worldwide. With the increasing trends in global marine traffic predicted in the future, a less destructive method of managing high-tonnage vessels awaiting port calls is necessary to mitigate the impact of maritime activities on the marine environment.

ORAL
Session 2e.

WILD FIRE GEOCHEMISTRY: LESSONS FOR MANAGING FUTURE IMPACTS ON WATER SYSTEMS

<u>Jenny Webster-Brown[1,2]</u>, John Revell[2] and Cassandra Irvine[2]

[1] *Our Land and Water National Science Challenge, Lincoln, New Zealand*
[2] *Waterways Centre for Freshwater Management, University of Canterbury, Christchurch, New Zealand.*

Jenny.webster-brown@agresearch.co.nz

Research into the impacts of two major forest wildfires on freshwater in their respective catchments has just concluded, providing an unprecedented geochemical record of the immediate to short term (3year) effects of such fires on water quality. The first of these wildfires occurred in February 2017 in the Port Hill of Christchurch, and the second in the Waimea catchment in Nelson in February 2019. Both were in areas dominated by pine forest, with surficial loess and other fine sediment deposits. The loss of vegetative cover was predicted to increase the erosion of these fine sediments, increasing the sediment load in the receiving water bodies; spring-fed streams draining into the Ōpāwaho/Heathcote River in Christchurch, and into the Wai-iti River, a tributary of the Waimea River, in Nelson.

Immediately following the fire, a stream monitoring programme was implemented to detect changes in water systems draining the burnt areas, using an unburnt catchment as a control. Monitoring of stream discharge, and of suspended sediment (TSS), trace element (Fe, Mn, Cu, Pb, Zn, Co, Ni, Cr, As, Cd, Sb, Ge, U and V), major ion, nutrient and organic carbon concentrations continued for over 3 years. Fire-related effects on stream geochemistry included the immediate changes in nutrient concentrations that have been reported following forest fires in Australia, but also very high TSS concentrations in Port Hills streams (up to 1900 mg/L) due to loess erosion. Suspended sediment geochemistry was consistent with a direct derivation from local loess deposits for many trace elements, but Cu, Pb, Zn and As were elevated well above the concentrations present in the source loess. Higher fine sediment and attendant trace element loads following such fires, signal the importance of adequately managing suspended sediments during high flow events, as forest fires are predicted to become increasingly frequent as a consequence of climate change.

ORAL
Session 4e.

IS TARANAKI EXHALING? DETECTING VOLATILE EMISSIONS FROM A DORMANT VOLCANO

Cynthia Werner[1], C. Ian Schipper[2], Shane J. Cronin[3], Peter H. Barry[4], Michael K. Stewart[5]

[1] *University of Auckland (contractor), New Plymouth, New Zealand*
[2] *Victoria University, Wellington, New Zealand*
[3] *University of Auckland, Auckland, New Zealand*
[4] *Woods Hole Oceanographic Institution, MA, USA*
[5] *Aquifer Dynamics and GNS Science, Wellington, New Zealand*

cwerner@volcanogeochemistry.com

Indicators of volatile emission from subsurface magmas are often subtle at dormant volcanoes. As a result, carbon dioxide (CO_2) emissions from deep magmatic sources can easily go undetected. CO_2 reacts with cold groundwaters in the subsurface, providing a long-term mechanism for deep CO_2 transfer to the surface. While rarely used as a monitoring tool, understanding how dissolved volatiles vary in time could provide important insight into the reawakening of dormant volcanic systems.

Here we provide an update on a geochemical survey of mineral springs and associated degassing at Mount Taranaki volcano, New Zealand. Cold mineral springs (kōkōwai) emerge on flanks between 1.5 to 5 km from the summit, and warm springs are found in a zone ~13 km from the summit on the ring plain. Springs were sampled in 2020 and show little change in their chemistry since the last sampling ~40 years ago. The cold springs degas CO_2 and sometimes hydrogen sulphide (H_2S) as they emerge at the surface. Concentrations of CO_2 and H_2S in the air downwind of some springs have been observed up to 3000 and 0.3 ppmv, respectively. The $\delta^{13}C$ of the dissolved inorganic carbon (DIC) in the Kōkōwai springs is -5.2, suggesting a magmatic source. The correlation of the $\delta^{13}C$ with DIC concentrations in the warm springs point to a Kōkōwai-type primary source water and form a trend that is different to trends observed in waters from sedimentary source rocks that lie directly beneath the volcanics, suggesting a relatively shallow flow path from the summit. Modelling of tritium data suggests a mean residence time of only 7.8 years at the Kōkōwai spring. This young age combined with elevated magmatic DIC suggests present-day degassing of magmatic CO_2 into the upper edifice of Mount Taranaki, and possible steady state degassing over the last 40 years.

POSTER
Session 2a.

SHORT-TERM ERUPTION FORECASTING IN NEW ZEALAND

Melody Whitehead[1], Mark Bebbington[1], Jonathan Procter, Matthew Irwin, and G. Paul Viskovic[2]

[1] *Volcanic Risk Solutions, School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*
[2] *GNS Science, Avalon, Lower Hutt, New Zealand*

m.whitehead@massey.ac.nz

We need reliable short-term forecasts for accurate and timely information on the evolving state of our volcanoes. This information directly impacts crisis management from evacuations to exclusion zones, and decisions on when it is safe to return. Eruption forecasting is thus not purely an academic exercise, nor is now the time for 'we-told-you-so' hindcasting demonstrations. To produce a short-term eruption forecast, a method should be selected via a systematic evaluation of options, including a critical assessment of outstanding issues and assumption validity. We run this lens over six existing short-term eruption forecasting methods and provide a straightforward metadata-driven methodology for forecast selection[1]. The eruption forecasting methods discussed are: (1) Expert interpretation, (2) Event trees, (3) Belief networks, (4) Failure forecasting, (5) Process / Source models, and (6) Machine-learning algorithms, with a view to forecasting: eruption occurrence (onset time), vent locations, eruption size, eruption style/phase, eruption phase duration, and eruption-specific hazards.

This methodology is applied to twelve volcanoes in New Zealand, considering available monitoring equipment, knowledge/expertise, and data. Significant potential is identified in methods that are generally data-hungry (e.g., belief networks and machine-learning algorithms), and/or by the coupling of probabilistic methods to process/source models.

Most volcanic systems in New Zealand are data-poor, due not least to the relative paucity of monitored eruptions. If significant volcanic unrest occurred now, expert interpretation is the only viable forecasting method (with the potential exception of event trees at Auckland[2] and Taupō[3]). To assist these experts in a time of crisis, forecasting methods should be developed in quiet periods, when careful deliberation of each parameter or concept is possible. With focussed effort towards the exploitation of existing data (vectorisation and processing of paper and film seismograms), and existing knowledge (e.g., expert elicitations), eruption forecasting in New Zealand could become more robust, transparent, and objective.

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POSTER
Session 2a.

NATURE VS NURTURE – QUANTIFYING EVOLUTIONARY RATE AND ECOPHENOTYPIC VARIATION IN *PELICARIA VERMIS*

Callum Whitten[1], James Crampton[1] and Cliff Atkins[1]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, NZ*

callum.whitten@vuw.ac.nz

It is well documented among molluscan species that external environmental factors can affect shell morphology [1,2] – independently of genetically determined variation. This can complicate identification and lead to over-specified taxonomic descriptions. Such an example was shown in the Late Neogene-Quaternary marine gastropod genus *Pelicaria*, endemic to New Zealand. Previously over 15 species and subspecies of *Pelicaria* were described based on variations in shell characteristics [3].

Many of these species were later synonymised by Beu [4], who suggested shell morphology variants were a result of habitat ecological differences and temperature variations, rather than evolutionary change. Our research focuses on quantifying evolutionary rate, mode, and style in the genus *Pelicaria* through morphometric analysis across different shell character suites, related to widespread ecophenotypic variation. We apply a new quantitative tool developed by Collins et al. [5], for describing gastropod shell form in terms of empirical Raupian coiling parameters, as well as another tool for quantifying shell sculpture [6]. We aim to understand how juvenile ecology, life habits, and climate and temperature variation throughout ontogeny, control adult shell morphology.

We will apply this new tool to conduct detailed analyses on different shell morphometric parameters of *Pelicaria vermis* specimens collected from two Pliocene-Pleistocene shelf deposits in northern and southern Wairarapa to quantify the evolutionary and ecophenotypic patterns in the species. We also aim to understand shell variants within the genus between spatially separated populations, at a local scale (assessing variants over 10's of metres to kilometres), and at a regional scale (between northern and southern Wairarapa populations). We hope to provide insight into which key environmental controls affect shell development within the species.

Currently we have collected over 250 specimens, approximately half of these have been completely processed, and the shells digitized. We will present preliminary results and interpretations of ecophenotypic variation and evolution within *Pelicaria.*

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ORAL
Session 2e.

SHORT-TERM ERUPTION FORECASTING FOR THE AUCKLAND VOLCANIC FIELD USING A BAYESIAN EVENT TREE

Alec Wild[1], Mark Bebbington[2] and Jan Lindsay[1]

[1] *School of Environment, University of Auckland, Auckland, New Zealand*
[2] *Volcanic Risk Solutions, Massey University, Palmerston North, New Zealand*

awil302@aucklanduni.ac.nz

Auckland's metropolitan area is situated upon the monogenetic Auckland Volcanic Field (AVF), posing a significant risk to the population. The probability of eruption using monitoring data will provide imperative information for crisis support to make critical decisions, such as when and where to call an evacuation. An approach gaining prominence in eruption forecasting is the use of statistical frameworks, such as the Bayesian Event Tree for Eruption Forecasting (BET_EF). A BET_EF can assess short- and long-term probabilities, depending on the input at each node, which are connected by branches to evaluate an overall state, such as eruption probability. For short-term forecasting, the probability of each branch is controlled by monitoring parameters (e.g. number of seismic events) with associated thresholds and weights.

A previous BET_EF was developed for the AVF as part of the 2008 Exercise Rūaumoko. However, since then there have been significant improvements in the scientific understanding of the AVF, which include constraining the field's geographic extent, spatial vent likelihood, eruptive style, and the age of past eruptions as well as the increased seismic network in Auckland to support monitoring in the field. Hence, as part of developing an AVF evacuation crisis decision-support model, it was evident that the previous AVF BET_EF required revisiting. To inform the monitoring parameters for the AVF BET_EF, an expert opinion workshop was held with 25 monitoring scientists and volcanologists, who were asked to review, update and add to the original inputs. The eight AVF scenarios were used to test the performance of the revised AVF BET_EF. The updated BET_EF for the AVF will assess the eruption probability and likely vent location, and subsequently applied within an evacuation decision-support tool.

ORAL
Session 2a.

A 10-YEAR CATALOGUE OF SLOW SLIP EVENTS AT THE HIKURANGI SUBDUCTION MARGIN (2006-2016)

Charles A. Williams[1], Laura M. Wallace[1,2], Noel M. Bartlow[3] and John Haines[1]

[1] *GNS Science, Lower Hutt, New Zealand*
[2] *University of Texas Institute of Geophysics, The University of Texas, Austin, Texas, USA*
[3] *Department of Geology, The University of Kansas, Lawrence, Kansas, USA.*

C.Williams@gns.cri.nz

Slow slip events (SSEs) occur frequently along the Hikurangi Margin, and understanding these events is critical to our understanding of interseismic coupling, plate motion budgets, and the potential for damaging earthquakes. Deeper and less frequent SSEs are observed along the southern part of the margin, while shallower and more frequent events are observed along the northern section. We have compiled a catalogue of Hikurangi SSEs covering the period from 2006 to 2016 to help us understand the spatial and temporal patterns of slip along the Hikurangi Margin. Using this catalogue, we can begin the process of characterizing the behaviour of Hikurangi SSEs, looking at properties such as depth, peak slip rate, total slip, and recurrence interval. The catalogues also allow us to explore possible scaling relationships, such as that between moment release and event duration.

We use the Network Inversion Filter (NIF) [Segall and Matthews,1997] to perform our time-dependent slip inversions. We generate the Green's functions for our inversions using the PyLith finite element code [Aagaard et al., 2013] to allow consideration of elastic property variations provided by the New Zealand-wide seismic velocity model [Eberhart-Phillips et al., 2010]. Previous results [Williams and Wallace, 2015; 2018] have shown that SSE inversions that consider elastic heterogeneity provide significantly different results than inversions based on elastic half-space solutions. Incorporating these effects significantly improves the accuracy and reliability of our inversions. We also include recent absolute pressure gauge (APG) data to constrain offshore vertical movement during a recent SSE observed in 2014. The catalogue represents the most comprehensive to date for the Hikurangi Margin, and the usage of APG data and consideration of elastic heterogeneity effects will provide the best possible constraints on the predicted slip distributions.

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POSTER
Session 4a.

INSAR FOR LANDSLIDE MONITORING: COMBINED APPROACHES LEAD TO BETTER RESULTS

Forrest Williams[1], Sam McColl[1], Ian Fuller[1], Hugh Smith[2] and Andrew Neverman[2]

[1] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*
[2]*Manaaki Whenua – Landcare Research, Palmerston North, New Zealand*

f.williams1@massey.ac.nz

Time-series InSAR techniques may be able to greatly increase our landslide monitoring capabilities, but in many landslide-prone areas of New Zealand, high rates of temporal decorrelation due to landslide movement and the presence of steep, vegetated terrain limit the utility of many InSAR techniques. Recent advances in both time-series InSAR techniques and pixel offset tracking techniques have however begun to overcome these limitations. In this study, we use an SBAS InSAR technique that highlights local deformation and an SBAS-like pixel offset tracking technique to remotely monitor over 800 landslides within a 10,000 km^2 region of New Zealand's North Island. Even though landslide movement rates in our study area range from 0.01 to 10 m/yr and the entirety of the study area suffers from high rates of temporal decorrelation, we have found that our analysis framework is capable of monitoring both landslide activity states and movement rates. The results of this analysis are being used to estimate the sediment contribution of deep-seated landslides to local rivers, and may help prioritize the targeting of erosion control measures that seek to improve the health of New Zealand's rivers.

ORAL
Session 4b.

BUILDING THE CASE FOR GEOHERITAGE AS A TOOL FOR TSUNAMI HAZARD RISK RESILIENCE IN A SOUTHWEST PACIFIC ISLANDS CONTEXT

S. Williams[1], L. Talia[2], R. Paulik[3], C. Bosserelle[1], K. Pogi[2], J. Chan Ting[4], M. Leavasa[2]

[1]NIWA Taihoro Nukurangi, PO Box 8602, Christchurch, Aotearoa New Zealand
[2]Geosciences, Meteorology Division, Ministry of Natural Resources and Environment, Private Bag, Apia, Samoa
[3]NIWA Taihoro Nukurangi, PB 14901, Wellington, Aotearoa New Zealand
[4]Disaster Management Office, Ministry of Natural Resources and Environment, Private Bag, Apia, Samoa

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Geoheritage is broadly recognized as a soft adaptation and educational tool which can help strengthen resilience to geohazards through enhanced appreciation of earth processes that in turn, can assist with strengthening capacity to deal with natural hazards and subsequent disaster risks. In this talk we explore the evidence-base for tsunami hazards risks in the central southwest Pacific region with a focus on recent events that have impacted Samoa in the last century or so, as well as older events in this region based on historical and paleo evidence. We draw specific attention to culturally significant events where behavioural changes or shifts in practices appeared to have occurred. These range from modern event analogies (e.g., 2009 and 1917 earthquake generated tsunamis in Samoa), to older ones apparent in the paleo, ethnohistorical and/or oral records (e.g., 1905–1911 volcanic generated tsunamis as well as the c. 1600–1800 AD and c. 1100–1300 AD paleotsunamis in Samoa).

We also explore enigmatic events such as the potential 1883 meteotsunami that impacted Salelologa in Savai'i Island, as well as remote-based identification of other potential localised tsunamigenic processes such as submarine landsliding off the shelf edge in the island chain. Comparison of available evidence with those used to underpin tsunami geoheritage initiatives in other parts of the world is made (e.g., Pacific Tsunami Museum in Hilo, Hawai'i), which includes geotourism initiatives in Tonga associated with prehistoric, massive, tsunami boulders weighing up to more than several tonnes each deposited at Fahefa as well as Haveluliku on Tongatapu Island. These are discussed within the context of implementing similar initiatives which might help to strengthen tsunami resilience in other vulnerable southwest Pacific Island countries such as Samoa.

ORAL
Session 3c.

A MAGNETOSTRATIGRAPHY OF THE EOCENE TO OLIGOCENE OREPUKI CORE

Caroline Wilsher[1], Christian Ohneiser[1], Catherine Beltran[1], Daphne Lee[1], Ulrich Salzmann[2] and Michael Amoo[2]

[1] *Department of Geology, University of Otago, Dunedin, New Zealand*
[2] *Department of Geography and Environmental Sciences, Northumbria University, Newcastle upon Tyne, England.*

wilca717@student.otago.ac.nz

Geological paleoclimate reconstructions can be used to reduce the uncertainty of the Equilibrium climate sensitivity (ECS) which describes the amount of warming Earth will experience in response to a doubling of PCO2. Current IPCC assessments indicate the ECS is "likely to lie in the range of 2°C to 4.5°C, with a most likely value of about 3°C". Paleoclimate reconstructions of the Eocene Climatic Optimum may allow us to calibrate the ECS for very high atmospheric CO2 conditions (around 600 - 1000 ppm) and mean annual surface air temperature of 6-8°C warmer than today. The Orepuki-1 core from Southland provides an opportunity for an Eocene paleoclimate reconstruction. The core is thought to span the Eocene-Oligocene boundary with the basal coal rich Beaumont formation and overlying Orauea mudstone providing a window into the E-O transition and New Zealand climate state.

Here we present results of a paleomagnetic study which aimed to provide a chronostratigraphic framework for a paleoclimate reconstruction. Below 140 metres there is no stable magnetisation, likely because of diagenetic alteration of magnetic minerals. Above 140 m the sediments appear to have a stable magnetisation which is carried by detrital magnetite. Overall, the core is dominated by normal polarity with very few reversed polarity intervals. Sporomorphs examined from the basal Beaumont formation places these sediments in the *Nothofagidites matauraensis* Assemblage Zone suggesting a latest Eocene (Runangan) age. The late Eocene to early Oligocene portion of the magnetic polarity timescale is dominated by reversed polarity chronozones whereas our magnetostratigraphy is dominated by normal polarity magnetozones. It is possible that younger sediments in the Orepuki succession have been remagnetised or that, fortuitously, sediments were deposited rapidly during a short normal polarity interval. Alternatively, our study demonstrates that the calibration of Eocene palynological zones should be reassessed for the South of New Zealand.

POSTER
Session 2c.

CHARACTERISATION OF THE ANOMALOUS SUB-ALKALINE MANIOTOTO BASALTS IN THE ALKALINE DUNEDIN VOLCANIC GROUP; SOURCES AND MECHANISMS

L. J. E. Wilson[1], J. M. Scott[1] and P. J. le Roux[2]

[1]Department of Geology, University of Otago, Dunedin, New Zealand
[2]Department of Geological Sciences, University of Cape Town, Rondebosch, South Africa

wilsonla321@gmail.com

The Maniototo area in the north-western corner of the Dunedin Volcanic Group (DVG) (Oligocene-Miocene) is geochemically anomalous within the established context of the DVG. This is due to the presence of a series of subalkaline flows, in addition to alkaline basalts more typical for the DVG. These flows originate from three principal eruptive centres: Swinburn South, Waipiata and Haughton Hill. The Maniototo basalts are primitive, geochemically unfractionated but are distinguished by subtle differences in the high field strength element and light rare earth abundances. These subalkaline lavas are unusual and clearly distinguishable from typical DVG alkaline rocks through their geochemistry and isotopic compositions. Geochemically, the subalkaline lavas have lower abundances of trace elements compared to equivalent alkaline lavas. Isotopically these subalkaline lavas have more radiogenic $^{87}Sr/^{86}Sr$ ratios with equivalent $^{143}Nd/^{144}Nd$ values compared to the alkaline lavas and both the $^{206}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$ are elevated. These elevated lead ratios are especially significant and interesting as they form distinct clusters above both the measured DVG and mantle array values.

A notable feature of the Maniototo area is that these subalkaline rocks occur often within areas that also contain alkaline volcanism. For example, alkaline units have been identified in the north-eastern edge of the Waipiata flow and proximal alkaline intrusions at Swinburn. Available data and our preliminary model for this unusual volcanism indicates that Maniototo (subalkaline) basalts have a distinct mantle reservoir to that of the alkaline basalts that characterise the rest of the volcanic field.

POSTER
Session 1b.

RECONSTRUCTING SEISMIC SHAKING AND STORM EVENTS IN LAKE GUNN

Inez Wilson-Harding[1], Sean Fitzsimons[1] and Jamie Howarth[2]

[1] *School of Geography, University of Otago, Dunedin, New Zealand*
[2] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand.*

wilin507@student.otago.ac.nz

Research over the past two decades has highlighted lacustrine sediments provide a valuable paleoseismic archive because they offer a well-preserved, continuous sedimentary record that spans long timeframes. It has been demonstrated that lakes can record coseismically triggered subaqueous mass wasting along with a postseismic signal derived from hillslope landsliding. The sedimentology of subaqueous mass wasting deposits and hyperpycnite deposits formed by coseismic shaking is consistent over a range of Westland lakes (lakes Kaniere, Mapourika, Paringa and Ellery). This consistency has enabled Howarth *et al*. (2014) to develop a model of sediment deposition over multiple seismic cycles in Westland. This conceptual model, founded on the work by Tailing *et al*. (2012), is characterised by an event sequence of a debrite (mass flow deposit, Type 1 rapidly deposited layer (RDL)), overlain by a turbidite (megaturbidite, Type 2 RDL), which in turn is overlain by hyperpycnites (Type 3 RDL).

In this presentation we describe an investigation of the sedimentary record of Lake Gunn in Fiordland. Three 6 m cores and eight 1.5 m cores together with a seismic survey have been used to reconstruct landscape events over the last ~4200 years. Deposits include greyish brown units inferred as background sedimentation, thick organic-rich units with a very coarse green unit at the base, dark brown units with pale yellowish-brown caps, along with a repeating sequence characterised by a very dark brown basal unit overlain by a greyish brown intermediate unit which is overlain by a reddish-brown cap. Deposits at the southern end of Lake Gunn, separated by a large landslide deposit, are distinctly different providing a challenge for the development of a coherent reconstruction of the catchments environmental history. Here we develop a facies model based on physical sedimentology and geochemistry that is used as the basis for the reconstruction of seismic shaking and storm events.

References.

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POSTER
Session 2a.

A National Landslide Dam Database for New Zealand

Andrea Wolter[1], Regine Morgenstern[1], Biljana Lukovic[1] and Akansha Sirohi[2]

[1] *GNS Science, Avalon, New Zealand*
[2] *WelTech, Petone, New Zealand.*

a.wolter@gns.cri.nz

Landslide dams are a critical component of multi-hazard cascading systems around the world and in Aotearoa New Zealand, linking slope and fluvial processes. They form when landslides block a watercourse, and can result in catastrophic flooding if they fail rapidly. Nonetheless, they are under-researched given the potentially high consequences of sudden dam breach and failure. Their formation, longevity, and breaching behaviour are not well understood, which is critical information needed for effective risk management.

As part of a larger programme on earthquake-induced landscape dynamics focussing on the 2016 Kaikōura earthquake sequence, we present a nation-wide database of landslide dams, spanning pre-historic to historic natural dams and compiling several existing datasets. The database includes more than 700 landslide dams, as well as information for each dam such as catchment properties, landslide and dam dimensions, dam type, and dam composition where available. Where possible, quantitative attributes have been calculated automatically using arcpy (a Python site package that utilises ArcGIS processing tools), which allows consistency and repeatability in the database. A data quality ranking scheme has also been developed to assess the reliability of each dataset and case study.

Several case studies, including the Hapuku, Stanton, Leader, Linton, and Conway landslide dams that formed during the 2016 Kaikōura earthquake, have been analysed in detail. Multiple field and remote sensing campaigns completed since 2016 – including field mapping, RTK surveying, drone photogrammetry, and LiDAR – show the evolution of the landslide deposits and dams, providing high-resolution spatiotemporal data on the formation and breaching characteristics of various landslide dams.

The database is currently being analysed to improve our understanding of dam formation potential and longevity, as well as breaching behaviour. These analyses will ultimately contribute to filling the information gap on this important hazard.

ORAL
Session 4c.

MAGMATIC PROCESSES INFERRED FROM OLIVINE XENOCRYSTS FROM THE AUCKLAND VOLCANIC FIELD, NEW ZEALAND

Jie Wu[1], Shane J. Cronin[1], Ingrid A. Ukstins[1], Marco Brenna[2] and David Adams[1]

[1]*School of Environment, The University of Auckland, Auckland, New Zealand*
[2]*Department of Geology, Otago University, Dunedin, New Zealand*

jie.wu@auckland.ac.nz

Using diffusion modelling on olivine xenocrysts, Brenna et al. (2018) showed that basaltic magma erupted at Pupuke Maar in the northern Auckland Volcanic Field (AVF) ascended in only 10-30 days after residence for up to 1 year. Here we explored whether the Pupuke model is applicable to other volcanoes across the AVF, by examining hundreds of samples from Three Kings (TK) (central AVF), Motokorea (MK) (east), Maungataketake (MT) (south), and Onepoto (OP), Pupuke (PK) and Tank Farm (TF) (north). Olivine xenocrysts from all six monogenetic basaltic volcanoes were analyzed using electron microprobe to characterize major element variations across the core-rim boundary. The cores are homogenous and forsterite-rich [$Fo\#_{90.0–93.5}$, calculated as Mg/(Mg+Fe), molar proportions], consistent with a depleted lithospheric mantle origin. Diffusive rims are commonly observed in contact with basalt matrix, with decreasing Fo# and Ni, and increasing Ti, Mn and Ca across the diffusion zone towards the rim ($Fo\#_{73.3–82.9}$). The width of diffusion zone is normally between ~20 and 90 µm, but can be >200 µm in some TK, MT and PK crystals. Most diffusion profiles of Fo# are relatively simple, with the outermost rims showing either constant or rimward decreasing Fo#. However, some olivine grains from the MT and PK volcanoes show near-rim reverse zoning with increasing Fo# resulting in hooked diffusion profiles. Such a texture reflects a complex diffusion process, and has been previously documented at PK and explained as resulting from a low-Fo# overgrowth followed by mixing with a higher-Fo# magma. Olivine xenocrysts in MK show multiple zoning patterns at the outer rim (thickness of ~100 µm), likely representing more complex processes of magma mixing, overgrowth and diffusion. Our preliminary results suggest that at least four modes of basaltic magma rise and storage processes may occur across the field, including cases of possible magma mixing.

References.

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ORAL
Session 1b.

GEOPHYSICAL CHARACTERIZATION AND MODELING OF METAMORPHIC AND SEDIMENTARY UNITS IN EAST TIMOR: INSIGHT INTO TECTONIC AND BASIN EVOLUTION

Francelino A. Xavier-Conceicao[1], Jennifer D. Eccles[1], Brendan Duffy[2,3] and Lorna Strachan[1]

[1] *School of Environment,The University of Auckland, New Zealand*
[2] *The University of Melbourne, Australia*
[3] *GHD, Australia.*

fcon069@aucklanduni.ac.nz

East Timor, including the entire island of Timor, is the product of the collisional tectonic between southernmost edge of the Australian continent and the Asiatic Banda volcanic arc. Five tectonostratigraphic units are recognized across the island, the Australian Gondwana megasequence including Aileu metamorphic complex, the Australian passive margin megasequence, the Banda terrane including its Banda forearc and lower plate Australian affinities, the syn-orogenic mélange, and the syn-orogenic sedimentary megasequence. However, the affinity of metamorphic units of the Banda terrane have been subject to debate. These metamorphic units have been interpreted in entirely different manners by previous researchers, as over-thrusted Banda affinity, rebound/basement-involved thrust of Australian continental basement, over-thrusted/back thrusted Australian continent basement, and the far travel over-thrusted micro-continent of the Australian continent basement.

This study aims to address gain insight into the crustal structure and hence tectonic evolution through geophysical characterization and an integrated modeling based on the recently acquired aeroradiometric, aeromagnetic and aerogravity data in East Timor region. Qualitative interpretation of the data and results of geophysical data enhancement allow units in the study area to be spatially distinguished. The Banda forearc affinity can be differentiated from the lower plate Australian affinity, including sedimentary and Aileu metamorphic units based on geophysical signatures and in combination with the geological data. This study also addresses the structural elements in the region, and together can give insight into tectonic and basin evolution of Timor orogen.

ORAL
Session 1c.

CO_2 EMISSIONS OF THE TAUHARA GEOTHERMAL SYSTEMS, TAUPO VOLCANIC ZONE, NEW ZEALAND.

Tsung-Han Jimmy Yang[1,2], Isabelle Chambefort[1], Agnes Mazot[1], Michael Rowe[2], Cynthia Werner[3], Tobias Fischer[4], Naoto Takahata[5], Jun Seastres[6], Thomas Brakenrig[1], Nick MacDonald[1], Lauren Coup[1].

[1] GNS Science, Wairakei research Centre, New Zealand.
[2] School of Environment, University of Auckland, New Zealand.
[3] U.S. Geological Survey, David A Johnston Cascades Volcano Observatory, Vancouver, U.S.A.
[4] Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, U.S.A.
[5] Atmosphere and Ocean Research Institute, The University of Tokyo, Japan.
[6] Contact Energy, Wairakei Power Station, Taupo, New Zealand.

tyan870@aucklanduni.ac.nz

In a volcanic geothermal area, greenhouse gases are naturally emitted through steaming ground, fumaroles, and mud pools, as well as from industrial power generation processes. Tauhara geothermal field is the newest geothermal development in the Taupo Volcanic Zone, New Zealand. The geothermal field's chemical behavior and geology are relatively well understood concerning resource sustainability. However, Governmental regulations to reduce carbon emission are leading field operators to consider to future reinjection of CO_2 and other non-condensable gas. But to monitor efficiently in the future, the present-day surface gas emission needs to be understood to obtain a proper base line budget for future field operations.

Here we present a CO_2 emission map of the Tauhara geothermal field, including the Ring of Fire, Crown Park, Craters of the Moon, Taupo City, and Aratiatia farm, that show the variation of emission rates in different areas of the field. To provide a temporal control of the flux, we repeatedly monitored the CO_2 flux at Crown Park and Craters of the Moon over the last 2 years. Together with fluid geochemistry and isotopic data from production wells, we aim to understand large-scale gas emission based on geothermal and volcanic carbon output of the Tauhara geothermal field.

ORAL
Session 4d.

TRACE FOSSILS ON THE ST BATHANS FAUNA: USING SKELETAL MARKS AND PATHOLOGIES TO MAKE PALAEONTOLOGICAL INTERPRETATIONS

George Young[1], Paul Scofield[2], Catherine Reid[1], Trevor H. Worthy[3], Aaron Camens[3]

[1] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*
[2] *Canterbury Museum, Christchurch, New Zealand*
[3] *Flinders University, Adelaide, Australia*

gyo15@uclive.ac.nz

The Early Miocene (19-16Ma) St Bathans Fauna represents a diverse terrestrial ecosystem containing a unique Gondwanan biota. The St Bathans fauna also bridges a significant gap in New Zealand's terrestrial fossil record and so is crucial for understanding the evolutionary history of New Zealand's biota and the geological history of the Zealandia continent. Trace fossils can provide a way to make novel interpretations on palaeoecology and taxonomic diversity of the St Bathans Fauna. Bones from the Home Hills Station were examined for traces on the bone surface, and the observed traces were characterised and categorised into 11 morphotypes after binocular microscopic assessment and SEM imaging. These morphotypes represent a diverse collection of trace-forming mechanisms that impacted the bones both in the Miocene and in recent times. Identified trace forming mechanisms include multiple bite marks from both toothed and beaked animals. Additionally, traces associated with digestive corrosion on the bone, vegetative bioerosion from both the Miocene and the Recent, and potential invertebrate feeding traces have been identified. Anthropogenic trowel marks were identified, but no marks caused by sieving were found. Trace makers for each morphotype were interpreted through a literature review of species present and their known or inferred modern trace analogues. Additionally, modern analogues for some potential trace makers poorly represented in the St Bathans assemblage were also experimentally tested. The interpretations on the species responsible for specific trace morphotypes were hampered by gaps in knowledge, due to many species of the St Bathans Fauna having only small and fragmentary material attributed to them. However, the identified morphotypes and data collected on modern analogue traces can provide a framework for future work on the topic and add to a growing dataset on the traces present in this unique and important fossil assemblage.

POSTER
Session 1c.

THE QUICK METHOD TO IDENTIFY THE MOST VALUABLE GEOSITES

Vladyslav Zakharovskyi[1], **Karoly Nemeth**[1]

[1] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*

v.zakharovskyi@massey.ac.nz

Coromandel Peninsula is a well-known territory with a vast biological diversity, Maori, and European archeological sites together with beautiful geological and geomorphological features throughout the whole region. While geological research through this region is concentrated around the places with alteration processes, due to their prospect for silver and gold epithermal deposits from the past and current mining. Even though, most current tourism hot spots are almost entirely located on known geological sites they are not acknowledged for visitors so far in a level similar sites normally appreciated in Europe, Asia or South America (e.g. Hot water beach, Cathedral Cove, Black Jack)

Our research is to develop a method of assessment of geodiversity, which will help people to find geological sites with their highest values, which will help to concentrate on pre-selected places to setup the knowledge for geoconservation, geotourism and geoeducation planning. The method requires standard data about geology and geomorphology. To select the most valuable places based on main values of geodiversity (geological and geomorphological elements), were calculated according to the 5-point system (1 is the lowest value and 5 is the highest). The main equation, based on the weight of the element multiplied on its covered area, while the scale of research was chosen as 6.25 km^2 (2.5 km each side), which is good enough for humans to recognize a geological object inside the studied location.

The peninsula is a remnant of different types of volcanic activities through history, creating the unique geomorphological relief, where volcanic and sedimentary rocks provide a sequence of meadow rolling hills with spots of remnants of volcanoes appearing as mountain like formation with cliff-rate of steepness. Hence, it will be beneficial for the region to show it from the geological perspective with the aim of tourism and education of geological evolution.

ORAL
Session 3c.

ORIGIN OF CRYSTALS IN MAFIC TO INTERMEDIATE MAGMAS FROM CIRCUM-PACIFIC CONTINENTAL ARCS: IMPLICATIONS FOR THE COMPOSITION AND ORIGIN OF PARENTAL MELTS

Georg F. Zellmer[1], Yoshiyuki Iizuka[1] and Susanne Straub[2]

[1] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*
[2] *Institute of Earth Sciences, Academia Sinica, Taipei, Taiwan*
[3] *Lamont-Doherty Earth Observatory, Columbia University, Palisades, New York, USA*

g.f.zellmer@massey.ac.nz

Crystals in arc magmas have traditionally been used as faithful recorders of magmatic conditions experienced by magmas prior to their eruption. Xenocrysts are easily identified if they display mineral-melt disequilibria. The identification of antecrysts is more challenging. Complex zoning including repeated resorption and overgrowth in crystals is characteristic for arc magmas and occurs in response to closed-system changes in magmatic P-T-f_{O2} conditions and open system processes such as magma mixing and degassing or regassing. However, over which time frame do such changes occur? Do zoning patterns record changes occurring during the polybaric ascent of the magma that carries the crystals, or indicate the uptake of antecrysts that experienced long periods of cold storage? *A priori*, these possibilities are endmember models, with the former traditionally preferred over the latter. Here, we discuss the evidence for dominantly antecrystic cargo in some continental arc magmas, identified by considering mineral phase proportions and through U-Th disequilibria and hydration of crystal rims that indicate hydrothermally altered crystals picked up by fresh melts. We then turn to two-pyroxene thermobarometry and review the evidence for antecryst dominance revealed by this method, implying that uptake of crystals by aphyric melts is prevalent in many continental arc magmatic systems. Thus, a significant proportion of parental melts of continental arc magmas are more felsic than the whole rocks, too hot to carry crystals, and typically too hot to be generated by differentiation in frequently postulated lower crustal hot zones. Felsic parental melts therefore originate from the hot mantle wedge. Our data indicate that bimodal parental melt generation in the mantle wedge of continental subduction zones is very common, irrespective of the age and temperature of the subducting slab, and we discuss implications for processes such as subduction erosion, subduction melange diapirism, and more generally continental crustal growth and recycling.

POSTER
Session 1b.

PUNGAPUNGA – WORKING WITH IWI TO EXPLORE TRADITIONAL USE OF PUMICE AND ITS FUTURE POTENTIAL FOR SUSTAINABLE MĀORI BUSINESS SOLUTIONS

Anke Verena Zernack[1], Derrylea Hardy[2], Walter Tangohau[3,4], Desterney Mana Newton[5], Aaron McCallion[4,6] and Jon Procter[1]

[1] Volcanic Risk Solutions, Massey University, Palmerston North, New Zealand
[2] School of People Environment and Planning, Massey University, Palmerston North, NZ.
[3] Te Pumautanga o Te Arawa Trust, Rotorua, New Zealand.
[4] Zymbl Innovation Ltd., Rotorua, New Zealand.
[5] Tauhara North No. 2 Trust, Taupo, New Zealand
[6] Waka Digital, Tauranga, New Zealand.

a.v.zernack@massey.ac.nz

Pumice (pungapunga) is a versatile natural resource that has traditionally been used by Māori for a wide range of spiritual and practical purposes, from carved figurines, containers (ipu), abraders (hoanga), net floaters for fishing (pouto), drainage for caught fish and toys (e.g. potaka). Similar pumice artefacts are found worldwide. Pumiceous deposits have also been used as building material and cement additives since the Romans discovered their pozzolanic properties. To this day, pumice remains a valuable resource that is mostly used as component in lightweight construction materials with further applications in horticulture, landscaping and other areas.

While abundant in the North Island, pungapunga is still underutilised in Aotearoa, thus offering a unique opportunity for tangata whenua as landowners and industry partners to explore its full commercial potential. This research project was co-developed with Te Arawa iwi and hapū to investigate the potential role of their pumice resources in developing innovative solutions for more sustainable Māori business practices. Using a Kaupapa Māori approach, the project is guided by Te Arawa's long-term aspirations focused on the social, economic and cultural well-being of their people. We are combining indigenous knowledge with western science methods to explore the abundance and properties of natural pumice resources in Te Arawa's rohe while also closely working with hapū and whanau members on gathering pungapunga Mātauranga-a-Te Arawa and testing pumice as sustainable hydroponic substrate in horticulture.

Despite being in its early stages, this project highlights the long-term benefits of applying a Kaupapa Māori approach to tackle an applied, multidisciplinary research question. Being co-developed and co-led, the objectives are tailored to the specific needs of Te Arawa iwi thus following tikanga Māori and enabling direct uptake by iwi stakeholders. It also fosters strong relationships between research organisations, iwi and Māori businesses providing pathways for future collaborations and ongoing exchange of Mātauranga Māori and RS&T relevant to Māori organisations, their aspirations and priorities.

POSTER
Session 1a.

THE ORIGIN AND GEOARCHAEOLOGICAL SIGNIFICANCE OF OCEAN-RAFTED PUMICE FOUND IN MESOLITHIC TO MEDIEVAL CONTEXTS IN NORWAY

Anke Verena Zernack[1], Erlend Kirkeng Jørgensen[2], Anthony Newton[3] and Felix Riede[4]

[1] *Volcanic Risk Solutions, Massey University, Palmerston North, New Zealand.*
[2] *High North Department, Norwegian Institute of Cultural Heritage Research, Tromsø, Norway.*
[3] *School of GeoSciences, University of Edinburgh, Edinburgh, United Kingdom.*
[4] *Department of Archaeology and Heritage Studies, Aarhus University, Moesgård, Denmark.*

a.v.zernack@massey.ac.nz

Ocean-rafted pumice has been reported from archaeological sites across the North Atlantic, the majority from Mesolithic to Norse-medieval contexts in Scotland (Newton 1990). Our study investigates frequently found, yet largely neglected pumice pieces from sites along the coast of Northern Norway and aims at exploring the prehistoric human use of the pumice, its origin, age and spatiotemporal patterns of deposition.

We conducted use-wear and geochemical analysis on 38 samples from 19 well-controlled, spatiotemporally diverse archaeological contexts, dated to between 10,100 to 587 cal. years BP. The pumice varies macroscopically in colour, vesicularity, phenocryst assemblage and proportion, roundness and degree of alteration. Most pieces show evidence of being used as an abrasive tool on wood, bone, antler, or hide, with marks ranging from one or more grooves and furrows to flattened, polished surfaces, some creating a facetted appearance.

Microprobe glass analyses revealed that all but two trachyandesite pieces were produced by silicic eruptions of the Katla Volcanic System in Iceland, similar to most pumice reported from Scottish sites and raised shorelines in Southern Norway. While several samples could be correlated to distinct, well-dated eruptions such as the 7,000-7,200 BP SILK-B tephras and the early Holocene Vikurholl pumice, the bulk overlaps with the SILK-A tephras, which were erupted between 6,600 and 1,676 BP and have similar major element concentrations (Larsen et al. 2001).

Our study provides additional albeit mostly coarse-grained age control for pumice-bearing archaeological contexts in the North Atlantic and sheds new light on the availability, use and curation of natural pumice resources throughout the Holocene. Furthermore, these results contribute to a better understanding of ocean-circulation patterns and the nature, frequency and frequency of Holocene silicic eruptions from Katla with implications for the potential distal impact by ocean-rafted pumice from future Icelandic eruptions.

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ORAL
Session 1a.

The Volume Relationship Between Monogenetic Volcanic Cone And Its Associated Lava Flow: Digital Elevation Model-based Analysis

Rong Zhang[1], Marco Brenna[1], Gabor Kereszturi[2] and James White[1]

[1] *Department of Geology, University of Otago, Dunedin, New Zealand*
[2] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand.*

zharo178@student.otago.ac.nz

Improvements in resolution of Digital Elevation Model (DEM) optimize the analysis of monogenetic volcanic geomorphological parameters. Previous studies on the volumetric correlation between volcanic cone and associated lava flow were limited and accompanied by large errors (e.g. Wood 1980). The focus of this study is to explore the application and accuracy of global free DEM data Shuttle Radar Topography Mission (SRTM) 30 m and Advanced Land Observing Satellite (ALOS) World 3D 30 m (AW3D30) in monogenetic volcanic fields.

We compared SRTM 30 m and AW3D30 with four reference DEM data, including National Elevation Dataset 10 m in Uinkaret Volcanic Field (VF) (USA), WorldDEM 12 m in Longgang VF (China), Contour Line Based DEM 1 m in Jeju Island VF (South Korea), and LiDAR 1 m in Lunar Crater VF (USA). The results show that the elevation and slope of AW3D30 are more accurate than those of SRTM, although AW3D30 quality is almost same affected by slope as SRTM. AW3D30 also shows higher accuracy than SRTM in terms of the volume, height (thickness) and average slope of scoria cone and associated lava flow. In addition, SRTM is superior to another global free DEM (ASTER GDEM, Fornaciai et al. 2012) in extracting the volume of volcanoes.

Based on the free DEM data, 36 pairs of volcanic cones and associated lava flows from the Late Pleistocene to the present were selected to analyse their volume relationships. The volcanic cones have well-preserved crater rims and independently distinguishable lava flows. The lava flow volumes are greater than 10×10^6 m^3 to ensure that the error is less than 15%. The relationships between scoria cone and associated lava flow volume are obtained.

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POSTER
Session 4b.

INVITATION-ONLY SPECIAL SYMPOSIUM SESSION

The New Zealand National Seismic Hazard Model 2022 Revision Project:

Overview and Update

Co-conveners: *Matt Gerstenberger & Russ Van Dissen*

ABSTRACTS

IN CHRONOLOGICAL ORDER

AN UPDATE ON THE 2022 NSHM REVISION PROJECT

M. Gerstenberger[1], B. Bradley[2], A. Kaiser[1], A. Nicol[2], M. Stirling[3], K. Thingbaijam[1], R. Van Dissen[1] and the NSHM Team

[1] *GNS Science, Lower Hutt, New Zealand*
[2] *University of Canterbury, Christchurch, New Zealand.*
[3] *University of Otago, Dunedin, New Zealand.*

m.gerstenberger@gns.cri.nz

The NSHM revision project has made substantial progress over the past 18 months and is aiming for finalisation of a new model by August 2022. The revision includes an update of all major components of the model including aspects of the Seismicity Rate Model (SRM) and Ground Motion Characterisation Model (GMCM).

A key focus in the SRM has been the use of multiple datasets to constrain rates, magnitudes and locations of earthquake occurrence. The SRM has two components: 1) the fault-based model of earthquakes on faults in the Community Fault Model; and 2) the distributed seismicity model which models all earthquakes independently of the CFM. For the fault-based model we use multiple models that are constrained by geodetically and geologically derived slip rates with the magnitude-frequency distribution constrained by earthquake catalogue observations. We have relaxed the segmentation requirements of past models and also allow for complex multi-fault ruptures. For the distributed seismicity model we have developed a "hybrid model" that combines data from the earthquake catalogue, geodetic strain rates, and earthquake geology. We also include a component that targets earthquake rates in low seismicity regions and the larger uncertainty and increased variability in rates that we observe in these regions.

In the GMCM we have developed an understanding of the performance of internationally developed ground motion models (GMMs) to New Zealand data through evaluation against newly developed site and ground motion databases. These evaluations are being used to develop summary "backbone models" which efficiently model the wide uncertainty across the GMMs and can be adapted to specific NZ path and site effects. We are also modelling the impact of the Wellington Basin on expected ground shaking for the region. This includes producing a large suite of simulated ground motions using a new 3D geological model for the region.

ORAL
NSHM Special Symposium

NEW ZEALAND COMMUNITY FAULT MODEL V1.0

<u>H. Seebeck</u>[1], R. Van Dissen[1], N. Litchfield[1], P. Barnes[2], A. Nicol[3], M. Gerstenberger[1]
on behalf of the New Zealand Community Fault Model team

[1]GNS Science, PO Box 30368, Lower Hutt 5040, New Zealand
[2]NIWA, Wellington, [3]University of Canterbury, Christchurch

h.seebeck@gns.cri.nz

Many fundamental aspects of earthquake science are influenced by the properties of fault zones. The location and geometry of a fault is a key determinant in seismic hazard assessment whereby the location and magnitudes of past and future earthquakes are estimated using geologic, seismologic or geodetic observations. Community fault models aim to provide consistent and broadly agreed upon representations of fault structures for a specific region.

The New Zealand Community Fault Model (NZ CFM) is an object-oriented, three-dimensional representation of active faults in New Zealand and adjacent offshore regions. The NZ CFM will serve as a unified and foundational resource for many societally important applications such as the New Zealand National Seismic Hazard model, Resilience to Natures Challenges Earthquake and Tsunami programme, physics-based fault systems modelling, earthquake ground-motion simulations, and tsunami hazard evaluation.

The NZ CFM is a recently-initiated, multi-organisational project led by GNS Science. The NZ CFM builds on the Active Fault Model of New Zealand (Litchfield et al. 2014), up-dates that model through community engagement and input, and extends the updated faults from the surface to seismogenic depths. This first 3D version is termed NZ CFM v1.0

The NZ CFM v1.0 is fully populated from 36 to 49.8° S and from 163.5° E to 179°W and is comprised of 880 faults and fault segments in two complementary datasets. The first dataset is a 2D map representation of active (or potentially active) fault traces with associated geometric and kinematic attributes, while the second dataset is a 3D triangulated representation of the fault surfaces.

We present the NZ CFM, comparison with previous models, key aspect of design and build parameters along with the availability of that model in readily accessible form(s) to support and facilitate varied applications.

More information about this project can be found at: https://www.gns.cri.nz/Home/Our-Science/Natural-Hazards-and-Risks/Earthquakes/Community-Fault-Model.

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ORAL
NSHM Special Symposium

WHAT DO LARGE EARTHQUAKES LOOK LIKE IN NEW ZEALAND AND HOW SHOULD THEY BE INCORPORATED INTO OUR NATIONAL SEISMIC HAZARD MODEL?

A. Nicol[1], A. Howell[1,2], R. Van Dissen[2], M. Gerstenberger[2], C. Chamberain[2], B. Shaw[3], H. Seebeck[2], and M. Stirling[4]

[1]School of Earth & Environment, University of Canterbury, Private Bag 4800, Christchurch, NZ
[2]GNS Science, PO Box 30-368, Lower Hutt, NZ
[3]Lamont Doherty Earth Observatory, Columbia University, USA
[4]Department of Geology, University of Otago, PO Box 56, Dunedin, NZ

andy.nicol@canterbury.ac.nz

Key to successfully modelling seismic hazards is understanding the locations, sizes and frequencies of large magnitude earthquakes. Over the last 30 years studies of historical earthquakes and physics-based earthquake simulations highlight the importance of multi-fault ruptures. In the 2022 version of the National Seismic hazard Model (NZ NSHM 2022) we have employed the NZ Community Fault Model in conjunction with 3D fault geometry and coulomb stress rules to determine which faults could rupture together in the future. Using these rules we find that faults with moderate changes in strike (e.g., <60°), differences in slip sense and slip rate, and separated by distances of up to 15 km in map-view could rupture together in the same earthquake. Permitting multi-fault ruptures in the seismic hazard model increases the maximum fault-rupture lengths and earthquake magnitudes. The longest multi-fault earthquakes in test versions of the NZ NSHM 2022 rupture set primarily involve high slip rate faults along the central spine of New Zealand (i.e., Alpine, Marlborough and North Island Shear Belt faults), where they can exceed 1000 km in length with magnitudes of 8 or more. These large earthquakes can rupture along and across the main plate boundary faults, consistent with historical events (e.g., along in 1855 M_w 8.2 Wairarapa and across in 2016 M_w 7.8 Kaikōura earthquakes). Analysis of historical earthquakes suggests that maximum slip on individual faults is often independent of whether they rupture one fault or multiple faults. Therefore, multi-fault ruptures decrease the frequency of large earthquakes, while increasing their magnitudes and likely reducing the chances that all large earthquakes on individual faults will have similar magnitudes even if they have characteristic slip. Collectively our observations support a model where large earthquakes have non-characteristic magnitudes and multi-fault earthquakes constitute an important component of the regional seismic moment and slip-rate budgets.

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GEODETIC DEFORMATION MODEL FOR THE 2022 NEW ZEALAND NATIONAL SEISMIC HAZARD MODEL

Laura Wallace[1,2], Kaj Johnson[3], Jeremy Maurer[4], Ian Hamling[1], Charles Williams[1], Chris Rollins[1], Matt Gerstenberger[1], and Russ Van Dissen[1]

[1] *GNS Science, PO Box 30368, Lower Hutt 5040, New Zealand*
[2] *University of Texas Institute for Geophysics, Austin, Texas, USA*
[3] *Department of Earth and Atmospheric Sciences, Indiana University, USA*
[4] *Geological Engineering, Missouri University of Science and Technology, Missouri, USA*

l.wallace@gns.cri.nz

Geodetic measurements of crustal deformation in plate boundary zones enable quantification of the modern-day distribution and rate of tectonic strain accumulation, and contain important information about future earthquake rates. Such measurements have been undertaken in New Zealand since the early to mid-1990's. One of the major new components of the 2022 update of the New Zealand National Seismic Hazard Model (NZ NSHM 2022) is incorporation of a fault source model based on geodetic data. Previous versions of the NZ NSHM contained some basic information from geodetic studies, such as informing fault slip rates on some faults where geologic slip rate constraints were not available, and utilizing geodetic coupling studies to inform the Hikurangi subduction interface fault source. However, the degree to which geodetic data were utilized in the earlier versions of the NZ NSHM was limited.

To incorporate geodetic measurements of contemporary deformation into NZ NSHM 2022, we utilize strain rate and fault slip deficit rate models derived from New Zealand's interseismic campaign GPS velocity field spanning 1995-2013. The strain rate maps (derived from the GNSS velocity field using four very different methods) are used to underpin "backslip models" that invert the suite of strain rate models for slip deficit rates on all of the crustal fault sources (derived from the NZ Community Fault Model) to build a geodetically-based fault source model. Most of the fault slip rates agree well with those estimated geologically, with a few exceptions where the geodetic data suggest higher fault slip rates (such as northern Canterbury), and in some cases lower slip rates (e.g., parts of the Wellington Fault). This source model will be incorporated into the NSHM in a similar way that the geologically based fault source models are used. The geodetic strain rate models we have developed are also being used in a multiplicative hybrid model to inform the distributed seismicity model.

ORAL
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Fault Orientation and Length Analysis for Informing Regional Distributed Seismicity Potential and Ground Motion

<u>Mark Rattenbury</u>[1] and Russ Van Dissen[1]

[1] GNS Science, PO Box 30368, Lower Hutt 5040, New Zealand

m.rattenbury@gns.cri.nz

Fault rupture resulting from the 2010 M_w 7.1 Darfield Earthquake heightened awareness of seismic hazard that extends beyond our fragmentary record of known active faults, and how important estimating distributed "off-fault" seismicity is for characterizing earthquake hazard. To help quantify distributed seismicity for the National Seismic Hazard Model (NZ NSHM 2022) revision project, we have undertaken a region by region characterization of both fault orientation and fault length using neotectonic domains recently re-defined in the New Zealand Community Fault Model (NZ CFM v1.0).

We have assessed the completeness and appropriateness of several fault digital datasets of national extent and utilized 1) the 1:1M Geological Map of New Zealand (GMNZ) fault dataset that provides consistent portrayal of onshore bed-rock faults (both active and not), and 2) the more representational NZ CFM v1.0 that focuses primarily on active (and potentially seismogenic) faults both onshore and offshore.

As fault length is potentially related to earthquake size, we have determined the range of fault orientations in each neotectonic domain based on three fault-length classes that roughly correspond to earthquakes of >M 6, >M 7 and >M 7.5. The orientations of longer faults generally reflect an accentuated tectonic grain in the local neotectonic domain. Away from faster slipping parts of the plate tectonic boundary, there is more variety in orientation, particularly for shorter faults. The next step is to consider the domain- and length-based fault orientations in terms of regional principal stresses as a predictor of slip-type. The orientations of earthquakes in the distributed seismicity component of NZ NSHM 2022, especially at larger magnitudes, are expected to have an impact on final hazard estimation.

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CONSTRAINING THE RATES OF LARGE, MODERATE AND SMALL EARTHQUAKES IN NEW ZEALAND FOR THE 2022 NATIONAL SEISMIC HAZARD MODEL

Chris Rollins[1], Matt Gerstenberger[1], Annemarie Christophersen[1], Kiran Kumar Thingbaijam[1] and Russ Van Dissen[1]

[1] *GNS Science, Lower Hutt, New Zealand*

c.rollins@gns.cri.nz

The 2022 New Zealand National Seismic Hazard Model (NSHM) consists of three layers: a Seismicity Rate Model (SRM), which describes the occurrence rates of earthquakes of various sizes throughout New Zealand; a Ground Motion Characterisation Model, which describes how those earthquakes will shake the ground; and an uncertainty model, describing the uncertainty in both components and how they are put together. The SRM itself consists of several components. On the Hikurangi-Kermadec and Puysegur-Fiordland subduction zones, the SRM is a "grand inversion" [Page et al., 2014; Field et al., 2014] that solves for the rates of earthquake ruptures at various locations along the subduction interfaces, subject to several constraints. One of these constraints is that the rates at each magnitude must sum to a total prescribed magnitude-frequency distribution (MFD) (within some uncertainty). For crustal earthquakes, we use a grand inversion to solve for the rates of ruptures on known active faults [Nicol et al., GSNZ], including a crustal MFD constraint. To characterize the likelihoods of earthquakes not on known faults, we also use two distributed seismicity models [Rastin et al., GSNZ] scaled up to a prescribed MFD. The crustal SRM is then a blend of the on-fault and distributed seismicity models.

The total magnitude-frequency distribution of earthquakes is therefore a crucial constraint within the SRM and the NSHM as a whole. To compute the crustal MFD, we use the instrumental earthquake catalogue in New Zealand accounting for magnitude corrections [Christophersen et al., GSNZ]; earthquake depths and their uncertainties (and those of subduction interfaces); heterogeneity introduced by the Taupo Volcanic Zone (TVZ); and variability in earthquake rates through time. For the Hikurangi-Kermadec interface, we use the earthquake catalogue of Heuret et al. [2011] and Marzocchi et al. [2016], as well as a global subduction MFD scaled down to the length of the Hikurangi-Kermadec arc. For the Puysegur interface, we use both the magnitude-corrected NZ catalogue and the scaled-down global subduction constraint.

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ORAL
NSHM Special Symposium

Development of a Seismogenic Slab Model For New Zealand

Kiran K S Thingbaijam[1], Chris Rollins[1], Matt C Gerstenberger[1], Annemarie Christophersen[1], Charles Williams[1], Jeffrey Fraser[2], John Ristau[1] and Russ J Van Dissen[1]

[1] GNS Science, PO Box 30368, Lower Hutt 5040, New Zealand
[2] Golder Associates (NZ) Ltd, Christchurch, New Zealand

k.thingbaijam@gns.cri.nz

Intraslab earthquakes within the Hikurangi and Puysegur subduction zones constitute a significant portion, about 40%, of overall seismicity (M_W>=3.0 events) in New Zealand. The 2010 version of the NZ National Seismic Hazard Model (NSHM) incorporates the intraslab seismicity through subcrustal zones at discrete depth levels. In the NZ NSHM 2022 revision, we envisage an advanced seismogenic slab model that conforms to the slab geometry. To develop the slab model, we use recently improved datasets that include a geospatial configuration of subduction interfaces, an updated earthquake catalogue, and a focal mechanism database. We consider two different strategies to model the seismicity, namely, smooth seismicity and areal zones of uniform seismicity. The smooth seismicity model is realized through a quasi-3D approach with the following steps: (1) delineation of mid-slab based on hypocenters, (2) orthogonal projections of hypocenters onto the mid-slab, (3) generation of uniform grid of 0.1 degrees on the mid-slab, and (4) application of gaussian smoothing using different sub-catalogues of data completeness. For the areal zones, we compute annual frequency magnitude distributions, with maximum magnitudes of M_W 8.0 – 8.3, based on historical intraslab earthquakes following a global assessment.

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NSHM Special Symposium

CAPTURING LOCAL GROUND MOTIONS IN SEISMIC HAZARD: THE WELLINGTON BASIN CASE STUDY

Anna Kaiser[1], Brendon Bradley[2], Matt Hill[1], Liam Wotherspoon[3], Robin Lee[2], Elena Manea[1], Daniel Roten[4], Chris de la Torre[2], Sandra Bourguignon[1], Aascha Pancha[5] and Matt Gerstenberger[1]

[1] GNS Science, Lower Hutt, New Zealand
[2] University of Canterbury, Christchurch, New Zealand
[3] University of Auckland, New Zealand
[4] San Diego State University, California, USA
[5]Aurecon, Wellington, New Zealand

a.kaiser@gns.cri.nz

Over the past decade, the development of global empirical ground motion models has advanced, drawing on increasingly large databases of earthquake recordings. Tested against New Zealand data, these models have been shown to perform well overall, forming a robust foundation for the National Seismic Hazard Model 2022. However, it is widely recognised that these models treat site response in an ergodic fashion, i.e. they reproduce global averages for a given simplified site condition (often in practice represented by a single metric of V_{s30}). The question of how to appropriately represent local or regional ground motion variations and characteristics is a challenge for the seismological community and one being explored within the NSHM programme with a Wellington basin case study.

Many New Zealand urban centres are situated on sedimentary basins that can trap and amplify seismic waves. Central Wellington is an example where basin amplification at 1 – 2 s periods has been consistently observed. During the Kaikōura earthquake, the large magnitude source generated significant energy in this period range which, when coupled with amplification of waves in the basin, led to large spectral amplitudes and damage concentrated in mid-rise structures.

To understand and model these site/basin effects in Wellington we are employing both physics-based ground motion simulation methods and empirical analyses. Physics-based methods allow us to model complex 3D wave propagation for a specific basin, and investigate the spatial variability of amplification for a range of earthquake sources, including the Hikurangi subduction interface. These methods are complemented by site-specific nonlinear site response analyses to investigate the influence of the near-surface soils. In parallel, the performance of empirical models applied to Wellington will be assessed using a large database of observed (weak to moderate) ground motions. To underpin these modelling methods, we have developed a new regional 3D velocity model and central Wellington V_{s30} map.

ORAL
NSHM Special Symposium

Recurrence Interval Derivation for the New Zealand National Seismic Hazard Model 2022

Genevieve Coffey[1], Chris Rollins[1], Russ Van Dissen[1], David Rhoades[1], Matt Gerstenberger[1], Kiran Thingbaijam[1] and Nicola Litchfield[1]

[1] *GNS Science, Lower Hutt, New Zealand*

g.coffey@gns.cri.nz, c.rollins@gns.cri.nz

A wealth of earthquake timing, size and rate information has been obtained through numerous paleoseismic field studies in the last fifty years, and this has recently been compiled into a single integrated paleoseismic site database (Litchfield et al. in prep). This database describes earthquake history along many faults in New Zealand and offers the potential to inform and guide output of the inversion-based hazard modelling being undertaken in NZ NSHM 2022. Formally incorporating paleoseismic data into the hazard modelling will facilitate tuning of parameters used and contribute to a more robust and holistic estimate of hazard.

Single event displacement (SED) and earthquake timing data from the paleoseismic site database (Litchfield et al. in prep), and slip rates from the NZ Community Fault Model (Seebeck et al. in prep) and the NZ NSHM 2022 geodetic deformation model (Johnson et al. in prep) were utilized to derive recurrence intervals for faults in NZ NSHM 2022. Three approaches were taken depending on the availability of SED, earthquake timing, and slip rate data. 1) For sites with three or more event ages, SED measurements and slip rate estimates, a Rhoades and Van Dissen (1994) approach was undertaken, integrating earthquake ages, SED, and slip rate to derive recurrence interval. 2) Where there were three or more event ages, but insufficient SED information, we take a modified Biasi (2013) approach and use maximum likelihood parameter estimation to calculate recurrence intervals. 3) For sites where insufficient earthquake timing information is available but robust SED measurements have been obtained, we apply methods similar to those described in Madden et al. (2013), to calculate recurrence interval from SED and slip rate data. Here we present the recurrence interval and uncertainty results from these three different methodologies, which will be utilized directly as inversion constraints in NZ NSHM 2022.

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POSTER
NSHM Special Symposium

DISTRIBUTED SEISMICITY MODELLING FOR THE NEW ZEALAND NATIONAL SEISMIC HAZARD MODEL 2022

Sepideh J. Rastin[1], David A. Rhoades[1], Matt Gerstenberger[1], Chris Rollins[1] and Annemarie Christophersen[1]

[1] *GNS Science, Lower Hutt, New Zealand*

c.rollins@gns.cri.nz

A distributed seismicity model is being developed to forecast the long-term (e.g., 50-100 years) spatial distribution of seismicity for NZ NSHM 2022. The distributed spatial rates combined with the rates on known fault sources should provide a comprehensive representation of seismic sources for the new model.

Multiplicative hybrid models help us to assess the relative value of information from fault studies, tectonics, earthquake catalogue and strain rate models for forecasting the long-term spatial earthquake rates. We use time-invariant and time-variable inputs to fit the hybrid models to 70 years of NZ earthquakes (1951-2020) with magnitudes $M > 4.95$, using a revised magnitude scale. The inputs and hybrid models are defined on a spatial grid with 0.1 degree spacing.

Time-invariant covariates include Proximity to Plate Interface (PPI), Proximity to Mapped Faults weighted by slip rate (PMF), Haines and Wallace (2020) maximum Shear Strain rate (HWS) and presence or absence of a mapped fault in each cell (FLT). Time-dependent covariates are smoothed seismicity models using a variety of spatial kernels and declustering methods. These are designed for fitting to seven 10-year windows with strict separation of contributing and fitting data.

We aim to optimize the information gain of hybrid models with respect to a spatially uniform baseline model. The most informative time-invariant covariate over 70 years is PMF, followed by PPI, HWS and FLT. This contrasts with previous findings that strain rates are more informative than all other covariates for forecasting over a few decades. The information value of smoothed seismicity covariates depends on details of how they are defined. When extracted from declustered learning catalogues and combined in additive/multiplicative mixtures they are more informative than all other covariates.

Final selection of the distributed seismicity model(s) will depend on a range of considerations, only one of which is the information gain.

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POSTER
NSHM Special Symposium

Shape of Average Coseismic Slip Profiles

Kiran K S Thingbaijam[1], **Russ J Van Dissen**[1], **Bruce E Shaw**[2] **and Matt C Gerstenberger**[1]

[1] *GNS Science, PO Box 30368, Lower Hutt 5040, New Zealand*
[2] *Columbia University, Palisades, New York 10964, USA*

k.thingbaijam@gns.cri.nz

A general approach to earthquake rupture forecasting in seismic hazard analysis involves matching fault-slip rates to earthquake rates, wherein single-event displacements are described by an average slip profile. Here, we address a research gap to present improved insights on average slip profiles from a set of rupture models of past earthquakes. Key findings from our analysis include: (1) along-strike slip profiles are well approximated by a power-of-sine function with index = 1/2 (i.e. *sinesqrt* function); (2) elongated ruptures (with aspect ratios >5.0) have a flatter profile; and (3) down-dip profiles for buried ruptures conform to the *sinesqrt* function, whereas those for surface rupture events have lesser tapering at the upper fault edge. These findings are well corroborated by simulated quasi-dynamic rupture models. Furthermore, they are also consistent with characterisation of slip heterogeneity through a random field model.

POSTER
NSHM Special Symposium

PRE-CONFERENCE WORKSHOP

- ABSTRACTS -

IN ALPHABETIC ORDER

PETROLEUM GEOSCIENCE

Achievements and New Directions

Convenor:	Mac Beggs, University of Canterbury (Adjunct) *mac@beggs.nz*
Date:	Monday, 29 November 2021
Cost:	Workshop Registration for GSNZ conference attendees $65 Registration for Workshop Only $130 Student registrants $30

The workshop will comprise three sessions:

1. Recent research achievements – soliciting presentations covering recently completed and near-completed Endeavour Fund programmes
2. Case studies from industry – New Zealand fields, prospects and exploration plays. May incorporate a keynote international speaker showcasing latest geoscience applications to petroleum
3. Geoscience for future energy systems – scope for redirection of expertise in such areas as low-enthalpy geothermal, offshore wind farms, hydrogen geostorage, carbon sequestration.

The third session would feature keynote presentations and panel discussions

Posters are welcome and will be up all day. There will be an opportunity for authors and registrants to discuss the posters during morning tea, lunch and afternoon tea.

Additional Information:

The morning and early afternoon session will provide opportunity for students to attend and participate in the workshop. The registration for students includes morning tea and lunch. Most students will want to leave by 2pm to attend the careers fair being held on campus.

In addition to the workshop a session "Geoscience for Future Energy Systems" will be held during the conference.

WHAT FLAVOUR IS YOUR BODY? NEW AGE CLASSIFICATION OF MARGINAL MARINE DEPOSITIONAL SYSTEMS

Bruce Ainsworth

Todd Energy, New Plymouth

Recent detailed studies of modern marginal marine depositional environments and ancient strata have revealed complexities that existing 20th Century classification systems are unable to capture and describe. Furthermore, concurrent advances in 3D modelling software capabilities have enabled these complexities and details to be captured in reservoir models.

In order to harness these developments, new and improved methods of description and classification of these systems are required. Any new classification must be able to describe the natural hierarchies that exist in paralic depositional systems and that can be mimicked by most 3D reservoir modelling packages. Hence an architectural classification of depositional bodies built around a natural hierarchy is a first step in any new classification. Once a body has been defined and placed in an architectural hierarchy, the 'flavour' of that body must then be described. The key 'flavour' in paralic systems is the depositional process or combination of processes that were responsible for deposition of the body. Three key processes need to be considered in the paralic realm; waves, tides and fluvial processes. Each process can act individually or in combination at the coastline depending on a number of regional and local variables.

In terms of the architectural hierarchy, paralic systems self-organise into regressive and transgressive units on the scale of a shoreline progradation and retrogradation respectively. In the ancient, this would be represented by one forward-stepping unit(s) overlain by a back-stepping unit(s) or flooding event (parasequence). In the modern, this would be equivalent to the progradation of a system through the Holocene and a subsequent flooding. Studies of Holocene progradational systems are therefore direct analogues for the regressive portions of ancient regressive parasequences. This is fortuitous since most reservoir flow units in paralic systems are represented by these parasequences which are usually bounded top and bottom by flooding shales.

THE LAST FRONTIER (FOR THE MOMENT)

Dave Bennett

(Independent Researcher)

Most of Taranaki's onshore producing oil and gas fields are sourced fairly directly from the Eastern Foredeep Sub-Basin (EFSB), west of the Taranaki Boundary Fault. These fields have contributed significantly to NZ's energy supply over the last 40 years. Oil and gas 'shows and flows' have also been recorded in most of the exploration wells within and adjacent to the EFSB.

Deep wells such as Waihapa-1 and Toko-1 intersect the (Eocene) Mangahewa Coal Measures, which enable good estimates of hydrocarbon generation parameters. Deeper coals and carbonaceous shales within the Paleocene and Late Cretaceous can be expected to augment this potential.

A generation/expulsion depth can be extrapolated across the EFSB, and using existing seismic mapping one can conclude that reserves in existing conventional fields represent a very minor percentage of the free hydrocarbons within the system. Play potential is present throughout the Tertiary section, in the form of structural and stratigraphic traps associated with the Taranaki Boundary Fault, as well as unconventional trapping potential. Gas discoveries in the 100+ BCF range could be achieved.

Despite these advantages for oil and gas entrapment, the EFSB is still only lightly explored, due to the difficult terrain, which makes seismic exploration expensive and of generally poor quality. This is a deterrent for major and minor companies alike (for differing reasons); and incentives to explore should be considered, when EFSB acreage is next offered for lease.

As electricity demand grows, so does the price. The average wholesale price has tripled in the last five years. Renewables cannot meet this demand by themselves– they merely extend the life of more reliable generation sources such as hydro, geothermal, gas and coal. There is a need to find more gas and to restructure the electricity market to improve resilience and enable more energy efficient generation.

REPURPOSING EXPLORATION DATASETS FOR NATURAL HAZARD SCIENCE: TASMAN SEA UNDERWATER LANDSLIDES

Suzanne Bull

[1] *GNS Science, PO Box 30368, Lower Hutt 5040, New Zealand*

s.bull@gns.cri.nz

A new research project supported by the MBIE Endeavour Fund will use subsurface data acquired for resource exploration purposes to learn about tsunami generated by underwater landslides. The pre-existing data, taken from the 2018 New Zealand Exploration Data Pack, allows us to address the complex challenge of including diverse, long-term tsunami sources in hazard assessments. Global understanding of underwater landslide-tsunami is poor as there are relatively few examples of underwater landslides identified from the present-day seafloor. However, numerous underwater landslides are archived in the geological records of sedimentary basins, and have been discovered using reflection seismic and drillhole data. We propose a pioneering, interdisciplinary approach combining techniques from the field of sedimentary basin analysis with the latest numerical simulations, to describe the dynamic evolution, impacts and frequency of the largest known underwater landslides in New Zealand (up to 4,000 km^3 in volume). The landslides are located 80km off the central west coast of the North Island in the Deepwater Taranaki Basin, and are buried below the modern seafloor. The outputs here will provide considerable new understanding of links between underwater landslides and tsunami generation and have the potential to refine our hazard assessments for the regions bordering the Tasman Sea.

INTERPRETATION OF MIOCENE INVERSION STRUCTURES USING REFLECTION SEISMIC DATA VALIDATED BY STRUCTURAL MODELLING, AND IMPLICATIONS FOR THE PROSPECTIVITY OF THE SOUTHERN TARANAKI BASIN

Ian Brewer, Evelien Wallace, Joanna Elliott, Aaron Johnston, Rick Henderson, Roland Swift, and Tim Carter

Todd Energy, New Plymouth, New Zealand

ibrewer@toddenergy.co.nz

The southern Taranaki Basin has had a complex geological history, from initial Cretaceous rifting during separation from Gondwana to its current location at the Australian-Pacific plate boundary. This geological history is recorded in the basin fill and architecture, which can be imaged using reflection seismic methods. Seismic data collection has been driven by the hydrocarbon industry and regional 2D data has underpinned our understanding of the south Taranaki Basin. However, seismic imaging can be impeded by overburden complexities, complex subsurface structures, and acquisition and processing limitations. In these instances, data interpretation is typically assisted by regional observations and model-based approaches.

In 2018 a pilot 3D survey was acquired in the south Taranaki Basin to assess the potential of modern seismic techniques to improve the imaging of complex structural traps. The survey crossed the Manaia inversion anticline and the Taranaki Boundary thrust structures which were subject to compression in the Late Miocene and remain poorly imaged. Palinspastic structural restoration has influenced interpretation in these areas of poor seismic data and furthered understanding of the basin's evolution and prospectivity. A similar approach has been applied to the Kaheru 3D survey, which underwent Pre-Stack Depth Migration reprocessing in 2019. This survey images the Kaheru structure which underwent compression in the late Miocene and remains one of the last undrilled inversion anticlines in the Taranaki Basin.

DIVERSE MANIFESTATIONS OF CONCENTRATED GAS HYDRATES IN SEISMIC REFLECTION DATA AT THE HIKURANGI MARGIN - IMPORTANCE OF SEISMIC FREQUENCY

Gareth Crutchley[1], Francesco Turco[2], Jess Hillman[3], Joshu Mountjoy[4], Sally Watson[4], Peter Flemings[5], Bryan Davy[3], Susi Woelz[4], Andrew Gorman[2], and Joerg Bialas[1]

[1] GEOMAR Helmholtz Centre for Ocean Research, Kiel, Germany
[2] University of Otago, Dunedin, Aotearoa New Zealand
[3] GNS Science, Avalon, Lower Hutt, Aotearoa New Zealand
[4] NIWA, Hataitai, Wellington, Aotearoa New Zealand
[5] University of Texas, Austin, USA

gcrutchley@geomar.de

The manifestation of gas hydrates in seismic reflection data is a function of both sub-surface geology (lithology, structure and gas hydrate concentration) and seismic acquisition parameters. In this contribution, we investigate the distribution of gas hydrate and free gas beneath anticlinal thrust ridges of the Hikurangi margin, using complementary seismic reflection datasets. Both low frequency (dominant frequencies of 10-20 Hz) and high frequency (dominant frequencies between 60 and 100 Hz) seismic data show evidence, in terms of wavelet polarity, for complex relationships between the distribution of free

gas and gas hydrate. We observe several examples of free gas existing above the regional base of gas hydrate stability, and not only within vertical gas chimneys that have been widely reported in the literature. We present evidence for zones of co-existing gas and gas hydrate expanding out laterally from the bases of gas chimneys, as well as an example of layer-constrained free gas above a concentrated hydrate deposit. Hydrate deposits are often associated with thick (e.g. >200 m) underlying free gas accumulations, with their bases marked by “flat spots” representing the gas-water contact. These free gas accumulations are held in place by effective capillary seals, but the relative importance of fine-grained lithologies versus gas hydrate clogging of the pore space is unclear. The occurrence of thick free gas zones, as well as zones where free gas and gas hydrate appear to co-exist, has interesting implications for our understanding of gas hydrate formation in focused fluid flow systems.

NEW INSIGHTS INTO THE TARANAKI BASIN PETROLEUM SYSTEM – AN OVERVIEW OF OMV NZ'S EXPLORATION CAMPAIGN 2019-2020

Miko Fohrmann[1], Craig Rodriguez[1] and Alan Clare[1]

[1] *OMV NZ Ltd., 100 Willis Street, Wellington, New Zealand*

miko.fohrmann@omv.com

Two wells were drilled within the Taranaki Basin in OMV New Zealand's Exploration campaign in 2019-2020; Gladstone-1, targeting Miocene deep-marine reservoirs of the Moki formation, and Toutouwai-1, targeting Paleocene shallow marine Farewell Formation equivalents and Cretaceous transgressive sands of the North Cape Formation. Both wells delivered valuable insights into the petroleum system as both wells demonstrated the generation of hydrocarbons within the mature kitchens of the northern Taranaki Basin.

Toutouwai-1 encountered hydrocarbons within the targeted formations and is therefore classified as the play-opening discovery within the Cretaceous, highlighting also the potential for surrounding prospectivity.

The presentation will focus on the key geological and geophysical findings of the drilling campaign, their implications on each of the elements of the petroleum system and questions that have since arisen due to the requirement to substantially curtail the testing programme because of Covid-19 restrictions. Nevertheless, both wells clearly demonstrate the resource potential that remains within the Taranaki Basin.

APPLICATION OF GEOPHYSICAL WELL DATA AND TECHNOLOGIES BEYOND PETROLEUM EXPLORATION

Angela G. Griffin[1], Richard Kellett[1], Mark J.F. Lawrence[1], Cécile Massiot[1] and Sarah D. Milicich[1]

[1]*GNS Science, PO Box 30368, Lower Hutt 5010, New Zealand*

a.griffin@gns.cri.nz

Geophysical well data (wireline and borehole-image logs) are typically acquired in petroleum exploration boreholes to characterise and assess potential hydrocarbon-bearing strata, lithological properties, depositional environments, fault and fracture trends, and *in-situ* stress.

This presentation will show how GNS Science have been successfully applying these well data (open-file, and newly acquired) and technologies to answer geoscience questions in geothermal, geomechanical, and groundwater investigations.

New Zealand's geothermal industry use borehole image data to identify fracture and fault patterns, and permeable feed zones in boreholes, advancing the understanding of these fracture-dominated systems. Image logs can also aid the identification of hydrothermally altered rocks in geothermal fields, where cuttings and core are difficult to acquire and/or recover. However, the high sub-surface temperatures (>200–300° C) encountered in some geothermal fields can pose challenges for operation of typical petroleum-industry image-logging tools.

Geophysical log data have recently been acquired in geotechnical boreholes to aid structural investigations. A pilot project utilising image and open-hole log data from shallow (50–150 m) boreholes provided rock property information such as density, compressional and shear-wave velocity, and natural gamma counts, along with fracture orientation and distribution. These data improve the characterization of subsurface conditions in urban areas where outcrop is poor. The data are used to model the behaviour of a slope during ground shaking that is likely during an earthquake. In a regional sense, these studies provide a better understanding of how faults behaved during past earthquakes, and how a specific section of a fault might behave in the future.

Groundwater studies provide another opportunity to use existing petroleum well log data to improve the level of detail in the mapping. The data are focused on depths shallower (< ~500 m) than the original exploration targets. Sediment type and grain size information gleaned from log data can lead to a better understanding of aquifer heterogeneity, which in turn can help with future water resource allocation.

SEDIMENT PATHWAYS FROM NW NELSON TO PETROLEUM PROSPECTS IN NORTH TARANAKI BASIN: APPLICATION OF ZIRCON U-PB DATING AND APATITE FISSION TRACK THERMOCHRONOLOGY

Peter Kamp[1], Aaron Johnston[2], Ian Brewer[2] and Bradley Hopcroft[3]

[1] *School of Science, University of Waikato, Hamilton, New Zealand*
[2] *Todd Energy, New Plymouth, New Zealand*
[3] *Chevron, Perth, Australia*

p.kamp@waikato.ac.nz

The Late Eocene to earliest Oligocene Tangaroa Sandstone is a proven deep-water sand system and prospective petroleum play in central Taranaki Basin (e.g. Tangaroa-1; Kora-4) and is a prospective play in North Taranaki Basin. Seismic reflection mapping of sediment pathways to the north is complicated by poor seismic imaging due to the extent of Miocene volcanics. Our investigation has applied zircon U-Pb dating of sandstone facies to delineate possible sediment pathways to prospective plays in North Taranaki Basin. Detrital grain age spectra from individual sandstone samples indicate the main source area is clearly NW Nelson, with erosion of the Karamea and Separation Point granite suites. More minor sediment input from erosion of structural highs exposed in the southern Taranaki Basin is also possible. Inverse thermal history modeling of apatite fission track data demonstrates significant Late Eocene to mid-Oligocene erosion for samples from NW Nelson north of Murchison Basin. Distinctive Separation Point zircon grain-ages are also present in Ahirau Sandstone and Hauturu Sandstone members of the Te Kuiti Group as far north as Port Waikato. This requires a sediment pathway northwards from the southern part of Taranaki Peninsula along the eastern margin of the Patea-Tongaporutu-Herangi High. Sediment input westward to the deep-water North Taranaki Basin could have occurred through conduits diverting sands from a coastal pathway at the northern end of the Herangi High (approximately the Present-day Kawhia Harbour entrance) or farther north (Raglan Harbour entrance area). This provides a viable mechanism to extend the deep-water Tangaroa Sandstone play fairway significantly northwards of the proven distribution. Our modified paleogeography for central Taranaki Basin-Waikato Basin also helps constrain the spatial and temporal interplay between extension (uplift at the northern end of the Challenger Rift System) versus shortening (thrust displacement on Taranaki Fault and foreland basin subsidence) during the Early Oligocene.

GEOLOGICAL STORAGE OF HYDROGEN: CHALLENGES AND OPPORTUNITIES FOR NEW ZEALAND'S LOW-CARBON ENERGY FUTURE

A. Nicol[1], A. Bischoff[1], E. Yates[1], L. Adam[2], M. Beggs[1], M. Villeneuve[3], D. Dempsey[1], K. Bromfield[4], M. Rossetti[1], J. Fensom[1]

[1] *University of Canterbury, Christchurch, New Zealand.*
[2] *University of Auckland, Auckland, New Zealand*
[3] *University of Leoben, Austria*
[4] *Elemental Group, New Plymouth, New Zealand*

andy.nicol@canterbury.ac.nz

New Zealand's energy sector is expected to undergo a fundamental transformation in the next 20 years, with significant investment in low-carbon technologies to replace petroleum-based systems. Underground geostorage of green hydrogen offers an opportunity to decarbonise New Zealand's economy. Geostorage represents the safest and cheapest means of holding large volumes of hydrogen with the smallest environmental footprint, enabling hydrogen to be generated when production costs are low, and sold when market demand is high. New Zealand's high proportion of renewable energy, varied geology, and diverse cultural communities provide an opportunity to investigate the technical viability, socio-environmental impacts, and economic benefits of large scale hydrogen geostorage (>1 TWh). Globally, commercial hydrogen geostorage is presently restricted to artificial salt caves, which do not exist in New Zealand. Therefore, new research is needed to demonstrate the feasibility of hydrogen geostorage in New Zealand porous reservoirs, while developing the policies necessary to commercialise this technology. Here, we summarise the geological, social and economic conditions required for storing large volumes ($>10^9$ Nm^3) of green hydrogen near renewable energy generation sites and future markets across New Zealand. We present the foundation for understanding the opportunities for hydrogen geostorage in New Zealand and in other countries where salt caves are not an option.

DIAGENETIC CLAY MINERALS AND FORMATION DAMAGE IN DEEP RESERVOIR TARGETS, ONSHORE TARANAKI, NEW ZEALAND

Julie Palmer

School of Agriculture and Environment, Massey University, Palmerston North

j.a.palmer@massey.ac.nz

Studying core from reservoir units in petroleum fields can help with the production and management of the field. Coring reservoir units is an expensive exercise but thankfully one that several operators opted for throughout New Zealand's exploration history. Late Eocene McKee Formation was extensively cored in the McKee-Toetoe Field and spot cores cut in Tuhua, Pukemai, Manganui and Onaero. All these wells are located within or adjacent to the Tarata Thrust Zone. The presence of McKee Formation at two structurally distinct levels (overthrust and *in situ*) provides opportunity to study the effects of time and depth on the diagenetic history of this important Taranaki Basin reservoir unit. Core studies complement petrophysical evaluation and drill-stem test results. Overall reservoir potential is primarily controlled by the depositional lithofacies but the precipitation of authigenic clay minerals, initially the kaolinite group, commenced early during burial reducing primary porosity and permeability. With increasing depth, the kaolinite morphology changed, and ubiquitous illite and some smectite appeared. The kaolinite and illite co-exist in *in situ* McKee Formation. Illite prevalence increases at greater depths and clay minerals together with authigenic syntaxial overgrowths on detrital quartz grains reduce the effective porosity and permeability of the reservoir.

The discovery of smectite was a game changer. Tasked with finding an explanation for drilling difficulties incurred while drilling into *in situ* McKee and underlying Mangahewa formations core analyses found the montmorillonite group clay mineral smectite. These clays swell when water enters the clay lattice. Exploration wells drilled in Taranaki at this time used water-based drilling fluids. It was proposed adsorption of water from the drilling fluid into the clay lattice could be an explanation for formation damage and the resultant drilling difficulties. The recommendation was to use a non-water-based drilling mud and so KCl polymer based drilling fluid was introduced and that successfully mitigated formation damage.

UTILISATION OF PETROLEUM PROJECT DATA TO SUPPORT THE INTERPRETATION OF AIRBORNE ELECTROMAGNETIC DATA FOR GROUNDWATER STUDIES

Tusar R. Sahoo[1, 2], **Zara Rawlinson**[1], **Richard Kellett**[1]

[1] *GNS Science, P O Box 30368, Lower Hutt, New Zealand*
[2] *University of Canterbury, Private Bag 4800, Christchurch, New Zealand.*

t.sahoo@gns.cri.nz

Shallow geological and geophysical data are essential for evaluating groundwater resources of a region. Hawke's Bay region is one of the areas where despite the availability of thousands of groundwater boreholes, the subsurface geology is still poorly constrained. The boreholes do not provide a complete lithological characterisation of the aquifer system because most of these boreholes are shallow (<50 m) and do not penetrate to the base of the aquifer system. It is also often difficult to map the lateral continuity of the aquifers in areas with poor/no borehole data coverage. Recently, Airborne electromagnetic data (SkyTEM) were collected in this region to better map the 3D geometry of aquifers in the shallow subsurface. These data were collected over the Heretaunga Plains, Ruataniwha Plains, and Poukawa and Otane basins. SkyTEM is a geophysical technique that uses electromagnetic waves to investigate the shallow (up to 500 m) resistivity structure of the earth. All available data were integrated to better define the 3D lithological structure relevant to groundwater investigations, including: SkyTEM, borehole, seismic, digital elevation model, QMAP geology and other 1D resistivity soundings. Petroleum borehole and seismic datasets provide critical high-quality information at depths not provided by other datasets. This study provides examples of mapping of lithological structure and potential aquifers in the Hawke's Bay region.

The primary aquifers of interest for water management and modelling are the younger unconsolidated sediments composed of gravels and sands although groundwater resources are also found within the limestone hydrogeological unit. These aquifers show higher resistivity compared to background muddy lithology. Identifying potential aquifers in the limestone hydrogeological unit is complex as the character of limestone changes laterally and it interfingers with other lithologies. SkyTEM data have also proven useful for visualising shallow faults on closely spaced cross-sections - improving the mapping of fault geometries.

DETERMINING EARTHQUAKE AND TSUNAMI HAZARD FROM PETROLEUM INDUSTRY DATA: CAPE EGMONT FAULT ZONE

Hannu Seebeck[1], Glenn Thrasher[1], Paul Viskovic[1], Suzanne Bull[1], Clarrie Macklin[1], Xiaoming Wang[1], Caroline Holden[1,*], Yoshi Kaneko[1,2]

[1] *GNS Science, PO Box 30368, Lower Hutt 5040, New Zealand*
[2] *Kyoto University, Yoshida-honmachi, Sakyo-ku, Kyoto 606-8501 Japan.*
**now at SeismoCity Ltd., 16 Buckley Road, Wellington 6023, New Zealand*

h.seebeck@gns.cri.nz

We present the results of a recently completed Endeavour Fund project examining the earthquake and tsunami hazard of the Cape Egmont Fault Zone using petroleum industry data (Seebeck et al. 2021).

The seismically active Cape Egmont Fault Zone is located in close proximity to the Maui Oil and Gas Field (and associated infrastructure) in the southern Taranaki Basin, New Zealand forming a complex series of synthetic and antithetic dip-slip normal faults accommodating present-day extension. The fault zone comprises new and reactivated faults developed over multiple phases of plate boundary deformation during the last 100 Myrs. The fault zone is well imaged on petroleum industry seismic reflection data, with a number of faults exposed and studied onshore.

A three-dimensional depth structure model developed from open-file petroleum seismic reflection and well data provides basic geometric and kinematic constraints on the length, maturity and slip rate of faults in the study area. Isopach maps, cross-section restoration and fault analysis provide further information the likely geometry of faults at seismogenic depths and their along-strike segmentation.

Fault lengths of post-Pliocene normal faults indicate the most likely earthquake magnitude from the fault population sampled is M_W 5.4 $\pm$ 0.5. The largest, most mature fault - the Cape Egmont Fault - is at least 53 km long and, depending on the number of segments ruptured during a future event, is capable of generating an earthquake between M_W 7–7.3 every 2000-3000 years.

Ground motion and shaking intensity M_W 7.1 Cape Egmont Fault earthquake scenarios are generated from deterministic and stochastic simulations and compared to observations from the Darfield earthquake. A tsunami model indicates that an east-directed tsunami, with a focused maximum wave height of 2 m, could sweep the coastlines around the South Taranaki Bight.

References.

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INVESTIGATING THE PALEOGEOGRAPHIC EVOLUTION OF ZEALANDIA: A SYNTHESIS IMPOSSIBLE WITHOUT EXPLORATION DATA

Dominic P. Strogen[1], Hannu C. Seebeck[1], Kyle J. Bland[1]

[1] *GNS Science, PO Box 30368, Lower Hutt 5040, New Zealand*

d.strogen@gns.cri.nz

We have produced the first suite of paleogeographic maps to illustrate the geological evolution of the entirety of Zealandia, since the mid-Cretaceous, in a geometrically rigorous reconstructed tectonic framework. They illustrate paleobathymetric and paleofacies interpretations along with well and sample data, outcrop geology, structural features and a synthesis of the regional tectonics. These 15 maps highlight major tectonic phases, from initial Gondwana rifting through to the development of the modern Neogene plate boundary.

A presentation in the main conference will focus on the maps themselves. Here we will focus on the datasets used to produce them, which are for the most part, the result of petroleum exploration efforts in the sedimentary basins of Zealandia. These largely frontier basins and their associated data are mostly in New Zealand territory, but also include basins in Australian and French (New Caledonian) territory in northern Zealandia.

These datasets consist of reflection seismic data, of varying quality and density, and where available exploration wells and any related biostratigraphic and facies interpretations. Also relevant are more regional datasets such as gravity and magnetics, and regional basin syntheses carried by exploration companies or government agencies looking to aid exploration. These include the recently completed Atlas of Petroleum Prospectivity (APP) programme, which provided updated interpretations of New Zealand's frontier basins. Further scientific datasets include dredge data and DSDP/IODP wells.