Geological Society of New Zealand
New Zealand Geophysical Society
26th New Zealand Geothermal Workshop

6th - 9th December 2004
Great Lake Centre
Taupo

Programme & Abstracts

Organising Committee

Vern Manville (Convenor)
Diane Tilyard (Administration and right-hand)
Paul White, Chris Bromley, Shane Cronin, Ian Smith, Stuart Simmons (Science Programme)
Brent Alloway (Sponsorship)
Geoff Kilgour, Tamara Tait (Social Programme)
Brad Scott, Mike Rosenberg, Peter Kamp, Adam Vonk, Cam Nelson, Jim Cole, Graham Leonard, Karl Spinks and Greg Browne (Field trip leaders)
Nick Mortimer (Web master)

And

Student helpers and off-siders
and Members of the Geological Society and Geophysical Society Committees

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GENERAL INFORMATION

The 2004 joint geosciences conference, comprising the annual conferences of the Geological Society of New Zealand and the New Zealand Geophysical Society, held for the first time in association with the 26th New Zealand Geothermal Workshop has been organised by the Wairakei office of the Institute of Geological & Nuclear Science Ltd., with assistance from members of the constituent societies. One-day field trips are being held on Monday 6th December, followed by an Icebreaker at the A.C. Baths in Taupo in the evening. Oral and poster sessions commence on Tuesday 7th December at the Great Lake Centre, Story Place, Taupo, and continue until Thursday 8th December, when multi-day field trips depart at various times from Thursday evening onwards. A separate New Zealand Geothermal Association Symposium is being held at the same venue on Friday 9th December under a separate registration and organising committee.

Venue

Apart from the field-trips and Icebreaker, activity will be focussed around the Great Lake Centre. Oral sessions and workshops will be held in the Main Theatre, Rimu Room and East Wing. Posters, trade displays, morning and afternoon teas and lunches will be held in the Main Hall. Speaker-ready facilities are available in the Green Room.
See map of venue, inside back cover.

Scope

At the time of going to press, registrations stood at 268 with 136 oral and 86 poster abstracts submitted. Presentations have been grouped into the following themes: sequence stratigraphy and sedimentology, palaeontology, seismology, geochemistry, palaeoceanography, Pacific Plate geology, Taranaki, North and South Island crustal dynamics, geomorphology, petrology and geophysics. In addition, the conference includes a two-day seminar on the Taupo Volcanic Zone, and the 26th Annual Geothermal Workshop.

Registration

Most participants ought to have already registered and paid for the conference and will only need to report to the registration desk to collect their conference packs. We request that all talk presenters deposit their CD-ROMs, electronic files, or slides at this time.

The registration desk will be open at:

- The Great Lake Centre on Monday 6th December from 2:00 to 4:30pm.
- At the A.C. Baths on Monday 6th December from 5:30 to 8:00 pm at the Icebreaker.
- Great Lake Centre lower foyer during the rest of the conference, 8:00am to 5:30pm

Talks

See pages v-x for the programme of talks. Speakers should be prepared to deposit their CD-ROMS and/or slides at the registration desk when they first arrive at the conference. Personal laptops cannot be used for presentations. Mac users please note!

Oral presentations have been scheduled for a maximum of 20 minutes: the breakdown between speaking time and question time is at the speaker's recognisance. Speaker-ready facilities are available in the Green Room.

Public Lecture

A talk on the geological history of the Taupo area, "Taupo: Volcano and Lake" will be given by Colin Wilson and Vern Manville in the Main Theatre at 7:00 pm on Tuesday. This is designed for a general audience and all are welcome to attend.

Posters & Trade Displays

See pages xii-xvi for a list of poster presentations. Posters and trade displays will be available for viewing in the Main Hall throughout the conference, which is also the venue for morning and afternoon teas and lunches. Poster presenters are requested to put their posters up any time after 8:00 am Tuesday and take them down during afternoon tea on Thursday. Dedicated poster viewing times are scheduled on Wednesday and Thursday of the meeting, and presenters are invited to hover by their offerings at these times. Morning and afternoon teas and lunches are to be held in the poster room offering additional viewing and discussion time.

Refreshments

Morning and afternoon teas and lunches are provided in the poster venue, the Main Hall. Alternatively, a number of dining establishments are within easy walking distance of the Great Lake Centre.

Social Events

Icebreaker
Monday 6th December, from 6:00 to 8:00 pm at the A.C. Baths. All welcome: cost is included in the general conference registration. A voucher for use of the baths is provided in your conference pack, valid for the week of the conference, so bring your togs.

Drinks and nibbles
Tuesday 7th October from 5:30 pm. To help celebrate the launch of the New Zealand Geological Timescale monograph, GNS is sponsoring pre-prandial drinks and nibbles following on from the special plenary presentation.

Conference Dinner & Presentation of Society Awards
Wednesday 8th December at the Great Lake Centre. Drinks from 6:30 pm. The theme of the dinner is "A Day at the Races". Ascot-appropriate attire is cordially requested. Geological Society of New Zealand awards that will be made at the dinner are the

McKay Hammer, the Hochstetter Lecturer, the Kingma Award, the Wellman Research Award, the Harold Wellman Prize, and the Pullar Prize. The Geophysical Society will also present their annual award.

Intra-conference meetings

Palaeo Special Interest Group & Fossil Record File Subcommittee
Lunchtime, Tuesday 7th December in the Rimu Room.

Historical Studies Group
Lunchtime, Wednesday 8th December in the Rimu Room.

Geological Society of New Zealand Annual General Meeting
Wednesday 8th December at 5:10 pm in the Main Theatre.

Geological Society of New Zealand National Committee Meeting
Lunchtime, Thursday 9th December in the Rimu Room.

New Zealand Geothermal Association AGM
Wednesday 8th December at 5:10 pm in the Rimu Room.

Multi-day field-trip participants
To be arranged and announced at the conference as appropriate.

Transport & Parking

The Great Lake Centre is located opposite the centre of Taupo and is within easy walking distance of most accommodation options. One-day field trips will leave from the Story Place carpark behind the Great Lake Centre on Monday 6th and return to the A.C. Baths for the Icebreaker. Free parking is available in the Story Place car park at the back of the Great Lake Centre: most parking in town is zoned and the local wardens are zealous.

Taupo Taxis 07 378 5100
Top Cab 07 388 9250
Go Cabs 07 378 5886

Communication

Great Lake Centre office: phone 07 376 0340, fax: 07 376 0341, leave a message which will be passed on to the **GEO³** registration desk.
Messages for registrants will be pinned to the Noticeboard at the Registration Desk.
Two computers will be available in the Main Hall for web-based e-mail access.
Alternatively, there are a number of internet cafés across the road in town.
Ask at the registration desk about photocopying and fax facilities.

Name Badges

These are to be worn at all times. Those attending the conference dinner, note that your dinner ticket is in the back of your name badge.

Mobile Phones

Cellphones should be turned off or silenced in the lecture rooms. Ringing cellphones will be punished with audience heckling and a fine payable to the Convenor's recreation fund.

Student Awards & Grants

Student travel grant cheques may be collected from the Registration Desk Thursday. Awards for the best student talks and posters will be made at the closing ceremony at 4:50 pm on Thursday 9th.

Fieldtrips

One-day

Trip 1 (Taupo Volcano – Michael Rosenberg) leaves from the Story Place car park at 9:30 am on Monday 6th December, returning to the AC Baths in time for the Icebreaker function.

Trip 2 (Waiotapu/Waimangu – Brad Scott) leaves from the Story Place car park at 8:30 am on Monday 6th December, returning to the AC Baths in time for the Icebreaker function.

Multi-day

Trip 5 (King Country – Peter Kamp) leaves from the Story Place car park at c. 5:15 pm on Thursday 8th December following the closing ceremony. Return options include one van travelling via New Plymouth and Awakino to Hamilton, another travelling via Taumaranui and Turangi to Taupo on Sunday12th afternoon/evening.

Trip 6 (Kuripapango – Greg Browne) leaves from the Story Place car park at c. 5:30 pm on Thursday 8th December, returning to Taupo at c. 5:00 pm on Sunday 12th.

Trip 7 (TVZ calderas – Jim Cole) leaves from the Suncourt Motor Hotel, Northcroft Street, Taupo, on Friday 9th December at 8:30 am, but can pick up people at other accommodation beforehand. The trip returns to Taupo by 6:30 pm on Sunday 12th, but will be able to drop people off in Rotorua on the way.

Conference Programme for Monday 6th December

0830	Fieldtrip 2 (Waiotapu/Waimangu) leaves from the Story Place car park
0930	Fieldtrip 1 (Taupo Volcano) leaves from the Story Place car park
1400-1630	Registration desk open in the Great Lake Centre lower foyer
1800-2000	Icebreaker function at the A.C. Baths, Spa Road, Taupo. One-day field-trips will return to this venue.

Conference Programme for Tuesday 7th December

	Main Theatre	Rimu Room	East Wing
0800-1730		Registration in lower foyer	
0830-0910	*Opening ceremony* *Chair: V Manville*	-	-
0930-1000	*Plenary 1* *Chair: Des Darby*	-	-
	M Reyners et al. - Constraints on subduction and magmatism beneath the Central North Island, New Zealand, from seismic tomography		
1000-1030	KJ Bland et al. - Stratigraphic architecture, structure, and paleogeography of Hawke's Bay Basin, eastern North Island	-	-
1030-1050		**Morning tea in Main Hall**	
	Taupo Volcanic Zone – mantle and crust *Chair: Shane Cronin*	*Sedimentology/sequence stratigraphy* *Chair: Bruce Hayward*	*Seismology* *Chair: Jarg Pettinga*
1050-1110	M Salmon et al. - Geophysical observations of processes in the mantle wedge: Central North Island, New Zealand	RJ Hansen & PJJ Kamp – L. Miocene – E. Pliocene Ariki Formation: condensed sedimentation in northern Taranaki Basin associated with graben extension and continental margin progradation	DA Rhoades & FF Evison – Earthquake forecasting: the end of the beginning
1110-1130	W Stratford & T Stern – Crustal structure of the central North Island and the meaning of the "Moho" in a back-arc spreading zone	A Tripathi et al. – The role of unconformities in rationalising Te Kuiti Group lithostratigraphy	EGC Smith & A Christopherson – A time of recurrence model for large earthquakes
1130-1150	IEM Smith - Petrological constraints on the nature of the crust beneath the Taupo Volcanic Zone	SD Hood et al. – Cannibalisation of the Otorohanga Limestone into the basal Waitemata Group, west Coast, North Island	J Beaven et al. – Using geodetic strain rates in seismic hazard models
1150-1210	RJ Arculus et al. - Petrological constraints on the nature of the crust beneath the Taupo Volcanic Zone	H Lever – Oligocene unconformities in the New Zealand region	J Townend et al. – A Bayesian framework for the estimation of tectonic stress parameters from seismological data
1210-1310	GNS Volcano Science Group Meeting	**Lunch in Main Hall** Palaeo Special Interest Group & Fossil Record File Subcommittee Meeting	
	Taupo Volcanic Zone – crust and processes *Chair: Richard Arculus*	*Sedimentology, sequence stratigraphy & paleontology* *Chair: Roger Cooper*	*Seismology* *Chair: David Rhoades*
1310-1330	CJN Wilson et al. – Controls on the nature and evolution of an exceptionally active arc-related silicic focus: central Taupo Volcanic Zone, New Zealand	KN Bassett & C Busby – Application of sequence stratigraphy to volcanic successions	TA Little & DW Rodgers – 1855 Wairarapa Fault earthquake: world record strike-slip displacement now even bigger

1330-1350	VC Smith et al. – The contemporaneously active Okataina and Taupo rhyolitic volcanic centres: trends in geochemistry, mineralogy, and magmatic properties during the last 50 kyr, Taupo Volcanic Zone, New Zealand	SL Nyman et al. – Origin and 3d distribution of calcite concretions in a delta-front: Cretaceous Wall Creek Member, Frontier Formation, Wyoming	R Langridge et al. – Paleoseismology of the northern Wellington and southern Mohaka Fault system: how to deal with 16 trenches!
1350-1410	P Shane et al. – Magma mingling in the ~50 ka Rotoiti eruption from Okataina Volcanic Centre	MK Eagle – Cretaceous Crinoidea in a Tertiary cul-de-sac	MW Stirling et al. – Development of tests for seismic hazard models
1410-1430	D Kear – Taupo Volcanic Zone – a key to NZ tectonics	AJW Hendy et al. – Late Miocene turnover of molluscan faunas, New Zealand: taxonomic and ecologic re-assessment of diversity change at multiple temporal and spatial scales	K Gledhill & GeoNet Team – GeoNet update: core capability and beyond
1430-1450	JW Cole et al. – Calderas of the central Taupo Volcanic Zone, New Zealand	DCH Hikuroa & JA Grant-Mackie – Radially ribbed Buchids in the New Zealand region	BJ Scott – GeoNet: Monitoring our volcanoes
1450-1510	**Afternoon tea in Main Hall**		
	Taupo Volcanic Zone – crust and structure *Chair: Jim Cole*	*Palaeoceanography* *Chair: Hamish Campbell*	*Geochemistry* *Chair: Bob Braithwaite*
1510-1530	L Carter et al. – Deep-ocean record of TVZ volcanism	BW Hayward et al. – Planktic foraminiferal record of the Subtropical Front and Southland Current over the last 1 Myrs	CS Nelson & MJ Pearson – Origins of some New Zealand carbonate concretions: insights from stable isotope and organic geochemistry
1530-1550	V Mouslopoulou et al. – Fault interactions and slip transfer between the North Island dextral fault belt and the Taupo rift, New Zealand	K Holt – Late Quaternary evolution of Chatham Island	NE Whitehead et al. – ESR ages of some Antarctic carbonates and sulphates
1550-1610	A Nicol et al. – Impact of fault interactions on displacement rates and palaeoearthquake occurrence in the Taupo rift, New Zealand	H Grenfell et al. – A ways to go: the Late Holocene foraminiferal record of the inner Manukau Harbour	IJ Graham et al. – ^{210}Pb-^{137}Cs dating of post-European Lake Tekapo sediment
1610-1630	P Villamor et al. – Temporal variability of earthquake occurrence and slip rate on the Rangipo Fault, Taupo rift, New Zealand	AT Sabaa et al. – Ecologic distribution of benthic foraminifera, off-shore north-east New Zealand	B Leitner & M Beggs – Soil gas surveys for petroleum exploration: experiences from two different techniques
1630-1650	CJ Hughes et al. – Structural evolution of the north rim of Taupo volcano	HL Neil et al. – Preliminary evidence of oceanic climate change around New Zealand over the last century: complex steps to ageing deep-sea corals	J Greinert et al. – Cold vents and gas hydrates on the Hikurangi Margin: prospects for a joint German-NZ research cruise in 2007
1700-1730	*Plenary 2* *Chair: Simon Nathan* RA Cooper - Launch of "The New Zealand Geological Timescale" monograph and wall chart	-	-
1730-1800	**Drinks & nibbles to celebrate theTimescale launch in the GLC foyer**		
1900-2000	*Public lecture* CJN Wilson & V Manville – Taupo: volcano and lake	-	-

Conference Programme for Wednesday 8th December

	Main Theatre	Rimu Room	East Wing
0800-1730		Registration in lower foyer	
0830-0900	*Plenary 3* *Chair: Mike Johnston*	-	-
	S Nathan – What's the story? The Online Encyclopaedia of New Zealand		
0900-0930	S Simmonds – What are those water filled holes in geothermal fields? Eruption craters, products of acid dissolution, or gas vents?	-	-
0930-0940	Daily notices	-	-
0940-1030		Poster session in Main Hall	
1030-1050		**Morning tea in Main Hall**	
	Taupo Volcanic Zone – structure *Chair: Nick Mortimer*	*The Pacific Plate* *Chair: Vince Neall*	*Geothermal workshop- extremophiles* *Chair: Pat Browne*
1050-1110	K Berryman et al. – Late Quaternary surface rupture history of the Paeroa Fault, Taupo rift, New Zealand, and interaction with Okataina caldera	J Grobys et al. – Seismic analysis and models from a rifted submarine plateau of continental origin: Great South Basin and Bounty Trough	KA Campbell et al. – Microbes to stone: the full spectrum of siliceous hot spring diagenesis (opal-A to quartz), Taupo Volcanic Zone, New Zealand
1110-1130	RS Marx et al. – High elevation lake level deposits within the Rotorua depression	K Gohl et al. – Animated gridded plate-kinematic reconstructions of the southern Pacific and its tectonic implications	BY Lynne et al. – Siliceous sinter diagenesis at the Opal Mound, Roosevelt Hot Springs, Utah, USA
1130-1150	K Spinks et al. – A caldera-forming ignimbrite eruption at 33 ka: reinterpretation of the Kawerau Ignimbrite as part of the Mangaone Subgroup, Okataina caldera complex	AG Reyes et al. – A submarine magmatic-hydrothermal system at Brothers Volcano, Kermadecs	R Schinteie et al. – Mineralogical and microbial characteristics of an acid-derived silica sinter from a thermal outflow at Parariki Stream, Rotokawa geothermal field, New Zealand
1150-1210	G Lamarche et al. – Characterisation of extensional tectonics in the offshore Bay of Plenty since 20 ka	ME Campbell et al. – Relationships between back-arc rifting and volcanic structures of the proximal arc front in the central and southern Kermadec Arc: insights from new multibeam mapping	BW Mountain et al. – The silicification of thermophilic biofilms: are geothermal deposits analogs for the preservation of extraterrestrial life?
1210-1310	Historical Studies Group Meeting	**Lunch in Main Hall**	
	Taupo Volcanic Zone –seismicity and geology *Chair: Kelvin Berryman*	*Geomorphology* *Chair: Vern Manville*	*Geothermal workshop- geophysics* *Chair: Chris Bromley*
1310-1330	T Hurst et al. – The July 2004 earthquakes near Lake Rotoehu, Bay of Plenty	K Wright & MJ Crozier – The landslide event of February 2004 in geomorphic perspective	F Berindei & GNH Ussher – Topographic corrections applied to geothermal gradient
1330-1350	F Evison & D Rhoades – Long-term seismogenesis and the 2004 Lake Rotoiti earthquake sequence	JR Knauf & MJ Crozier – Escarpment stability: processes and modes of failure	AD Cody – Geyser observations at Orakeikorako, New Zealand
1350-1410	N Mortimer – The Mesozoic greywackes in and around Taupo Volcanic Zone	J Jenkins & P Denys – Laser scanners as erosion monitoring tools: Gaunt Creek case study	M Yamamoto & N Tsuchiya – Application of the thermoluminescence technique for evaluation of geothermal activity

1410-1430	RL Braithwaite – Geochemistry and source of zeolite-bearing lacustrine tuffs in the Ngakuru Formation, Taupo Volcanic Zone, New Zealand	J Mountjoy & J Pettinga – Large deep-seated landslides in Tertiary soft rock terrain: stepped landscape evolution and the concept of critical stratigraphic horizons	S Dravitzki et al. – Structural and hydrothermal inferences from a magnetotelluric transect across Mt. Ruapehu, New Zealand
1430-1450	DJ Robertson & IA Nairn – Palaeomagnetic study of AD 1305 Kaharoa rhyolite		S Tamanyu & T Sato – 2d-3d visualization of subsurface thermal structure – example of the northern part of Miyagi Prefecture, Japan
1450-1510	**Afternoon tea in Main Hall**		
	Taupo Volcanic Zone – Ruapehu lahar and mapping *Chair: Ian Smith*	*The North Island and the Dead Sea Rift* *Chair: John Begg*	*Geothermal workshop- geochemistry* *Chair: Stephen White*
1510-1530	JA Lecointre – Structural mitigation options for volcanic mass flows	M Savage et al. – Deep structure of the southern Hikurangi Margin	CA Werner et al. – CO_2-flux of steaming ground at Karapiti (Wairakei, NZ)
1530-1550	V Manville – Palaeohydraulic analysis of the 1953 Tangiwai lahar	CJ Rowan & AP Roberts – Tectonic rotation of the Hikurangi Margin, East Coast, New Zealand: new constraints from paleomagnetic and magnetic fabric	J Pope – Trace element geochemistry downstream of Waiotapu geothermal discharges
1550-1610	SJ Cronin et al. – Evaluating a 2-d granular-flow numerical model for prediction of lahars from Crater Lake at Ruapehu	K Wilson et al. – Discriminating Holocene uplift mechanisms from 10,000-6,000 year old estuarine deposits of the Raukumara Peninsula	KN Nicholson – Implications for geothermal evolution in the Alvord Basin, USA, as determined from precipitate mineralogy
1610-1630	GS Leonard et al. – Mapping the geology of Taupo Volcanic Zone for the 1:250,000 QMap Rotorua sheet	A Douglas et al. – Investigating aseismic slip beneath the Raukumara Peninsula, North Island, New Zealand	K Yonezu et al. – Adsorption behaviour of Gold(I)-thiosulfate complex anions on the surface of alumina and silica gels: approach to the formation mechanism of low-sulfidation epithermal gold deposits
1630-1650	S Henderson et al. – Coromandel-Central Volcanic Region data intervention: converting data to information to knowledge	H Ginat et al. – Pleistocene tectonic activity along the southern margins of the Dead Sea Rift, southern Israel	Y Aramaki et al. – Formation condition of smectite in silica scale: role of magnesium
1700-1800	GSNZ Annual General Meeting	-	NZGA Annual General Meeting
1830-onwards	**Pre-dinner drinks in the Great Lake Centre foyer followed by Conference Dinner in the Main Hall**		

Conference Programme for Thursday 9th December

	Main Theatre	Rimu Room	East Wing
0800-1730	Registration in lower foyer		
0830-0900	*Plenary 4* *Chair: Geoffroy Lamarche*	-	-
	J Cassidy – Contemporaneous eruptions in the Auckland Volcanic Field? evidence from a geomagnetic excursion record		
0900-0930	K Barnes & N Hiller – The taphonomy of a Late Cretaceous reptile-bearing concretion from mid-Waipara River, North Canterbury, New Zealand	-	-
0930-0940	Daily notices	-	-
0940-1010	Poster session in Main Hall		
1010-1030	**Morning tea in Main Hall**		
	Taranaki *Chair: Euan Smith*	*The Earth's crust and the South Island* *Chair: Rick Sibson*	*Geothermal workshop - geoscience* *Chair: Keith Lichti*
1030-1050	T Stern et al. – Evolution of subduction and back-arc extension at a continental margin	N Balfour et al. – Stress and shear-wave splitting measurements in Marlborough and their implications for fault strength and structure-controlled crustal anisotropy	I Bogie et al. – The Casita geothermal field, Nicaragua
1050-1110	PJJ Kamp et al. – Neogene evolution of the eastern margin of Taranaki Basin with King Country Basin	F Ghisetti et al. – Seismic potential of a compressional inversion province, NW South Island, New Zealand	L Urzúa & G Ussher - Preliminary exploration results at the Mangakino geothermal prospect, New Zealand
1110-1130	VE Neall & DL Birks – Understanding the pre-1000 year BP diamictions in Egmont National Park	R Jongens – East-directed thrusting across the Buller and Takaka terranes, northwest Nelson	P Utami et al. – Overview of the Lahendong geothermal field, North Sulawesi, Indonesia: a progress report
1130-1150	T Platz et al. – The AD 1655 sub-plinian eruption of Egmont volcano – insights from the porosity and permeability of proximal ejecta	S Bourgignon et al. – Mantle deformation and seismic anisotropy due to oblique collision, South Island, New Zealand	H Saibi et al. – Aquifer chemistry of thermal water in Obama geothermal field, Japan, between 1984 and 2001
1150-1210	M Turner et al. – Fingerprinting Egmont eruptives – implications for constructing a magnitude/frequency eruptive spectrum	RH Wightman et al. – Escalators, ramps, and uplift: the kinematic significance of a backshear array in the central Southern Alps	S Henderson et al. – Strategic alliances and collaboration: a fresh approach to Greenfield geothermal exploration using geoinformatics data intervention process
1210-1310	**Lunch in Main Hall**		
	Petrology and geophysics *Chair: Ian Graham*	*The Earth's crust and the South Island* *Chair: Tim Stern*	*Geothermal workshop- engineering* *Chair: Sadiq Zarrouk*
1310-1330	KM Knesel et al. – Secular disequilibrium among U-series isotopes during magma formation by partial melting in the crust	P Barnes – The southern Alpine Fault: new marine multibeam data reveals detailed structure and slip rate	SP White et al. – Evaluating the seal integrity of natural CO_2 reservoirs of the Colorado Plateau

1330-1350	AL Simpson et al. – Remobilisation of gabbro cumulates in arc volcanoes	VG Toy et al. – Interplay between brittle and ductile deformation in the 'Alpine Fault' mylonites	MA Grant – Well performance estimation from brief discharge using heuristic decline analysis
1350-1410	B Davy – Marine seismic reflection profiling of the Auckland region	S Ellis et al. – Simplified models of the Alpine Fault seismic cycle: behaviour of the shear zone in the lower crust	N Watanabe et al. – Permeability measurement for large rock fracture using rubber-confining pressure vessel
1410-1430	NA Horspool et al. – Shear-wave velocity structure of north-western New Zealand: from receiver functions and surface-wave dispersion	J Williams & J Vry – Garnet-albite-biotite zone metamorphism in the Alpine Schist, McArthur Range, central Westland, New Zealand	Y Fujimitsu et al. – Temperature estimation around the conduit of the 1990-95 eruption at Unzen volcano by numerical simulation
1430-1450	W Heise et al. – Magnetotelluric investigations of the Cañadas caldera, Tenerife (Canary Islands)	JM Scott & AF Cooper – Metamorphic, magmatic, and structural aspects of the Mt. Irene Shear Zone, western Murchison Mountains, Fiordland	C Bromley et al. – Subsidence at Crown Road, Taupo, latest findings
1450-1510	**Afternoon tea in Main Hall**		
	Geophysics *Chair: John Beavan*	*The Earth's crust under the South Island* *Chair: Susan Ellis*	*Geothermal workshop- engineering* *Chair: Ed Mroczek*
1510-1530	S Bannister et al. – Crustal imaging using local earthquake waveforms	R Norris & H Campbell – Slip partitioning, strain partitioning and strain localisation: a view from the Alpine Fault	T Kuroda et al. – Design of air conditioning system with a ground-coupled heat pump for a gravity meter room
1530-1550	K Marson-Pidgeon & MK Savage – On the use of teleseismic S and regional ScS in shear wave splitting studies in New Zealand	JD Eusden jr et al. – Structural collapse of a transpressive hanging wall fault wedge, Charwell section of the Hope Fault, NE South Island	N Tsuchiya et al. – Application of a georeactor: sustainable hydrogen generation using solar and geothermal energy sources
1550-1610	AR Gorman et al. – Seismic characterisation of the North Otago sedimentary succession near Herbert	A Stallard & D Shelley – Structural architecture of the Otago Schist: accretionary prism, collisional orogen or core complex?	KA Lichti – Forgotten phenomena of material selection and use in geothermal energy applications
1610-1630	D Eberhart-Phillips et al. – Imaging the transition from Aleutian subduction to Yakutat collision in central Alaska, with local earthquakes and active source data	RH Sibson et al. – Internal structure of a strike-slip dilatational jog on the Overlander Fault, Mt Isa inlier, Australia	S Zarrouk et al. – Reservoir modelling of the Ohaaki geothermal system
1640-1710	Closing ceremony & student awards	-	-
1715 1730	Field Trip 5 – King Country – Peter Kamp - leaves Story Place Field Trip 6 – Kuripapango – Greg Browne – leaves Story Place		

POSTERS

By poster number & theme

TRADE DISPLAYS

POSTERS

Antarctica

1	AE Clifford et al.	A self-sustaining katabatic wind-driven ice shelf in Southern McMurdo Sound, Antarctica
2	R Coulter et al.	Geology of White Island, Southern Victoria Land, Antarctica
3	J Croall & C Hendy	Taylor Valley lake sediments as indicators of climate change
4	S Milicich et al.	"Cryorites", evaporites or whitings? Ancient lake beds from Taylor Valley, Antarctica

Crustal dynamics

5	PJJ Kamp & JI Garver	The contemporary detrital fission track signal of an active collisional orogen, Southern Alps, New Zealand
6	FJ Davey	A Mesozoic crustal suture of the Gondwana margin in the New Zealand region
7	M Duclos et al.	Mantle tectonics of a plate boundary: The North Island of New Zealand
8	DA Borcovsky	The Wainui Shear Zone: Cretaceous deformation along the western margin of the Separation Point Batholith, Northwest Nelson
9	M Gollan & JM Palin	Basement geology and mineralisation of Presqu'lle Bréauté (Treble Mountain Peninsular), southwest Fiordland, New Zealand
10	GM Turner et al.	Three successive geomagnetic polarity reversals recorded in Miocene sediments from N.W. Nelson
11	P Cooper et al.	Structural implications of recent work on the Northland allochthon and autochthon
12	G Baldock & T Stern	Width of mantle deformation across a continental transform: Evidence from upper mantle (PN) seismic anisotropy measurements and implications for simple shear of the mantle
13	VG Toy et al.	Alpine Fault pseudotachylytes
14	D Jugum & RJ Norris	The melanges of the Dun Mountain Ophiolite Belt
15	AM Wandres & KN Bassett	Cathodoluminescence of quartz: Indication for an Early Cretaceous rift-system in the New Zealand region?

Environmental Geochemistry

16	IJ Graham et al.	Use of atmospheric ^{10}Be for quantifying sedimentary processes
17	MJ Ellwood	Zinc/silicon ratios of sponges: A new proxy for estimating changes in the export of organic carbon to the seafloor

Gas Hydrates

18	M Fohrmann et al.	Examination of marine seismic reflection data for the occurrence and distribution of gas hydrate on the continental margin of Fiordland, New Zealand
19	J Greinert et al.	Cold vents and gas hydrates on the Hikurangi Margin: Prospects for a joint German-NZ research cruise in 2007
20	IA Pecher et al.	Erosion of the seafloor at the top of gas hydrate stability in the ocean - evidence from southern Ritchie Ridge, Hikurangi Margin

Geomorphology

21	G Lamarche et al.	Mechanisms of emplacement and interrelationships between slumps, debris flows and blocky avalanches at the Matakaoa Re-entrant, North-East New Zealand
22	G Hughes et al.	Late Quaternary geologic history of the north Horowhenua District, SW North Island, New Zealand
23	NF Stevens et al.	Slope instability and surface deformation in Dunedin
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ABSTRACTS

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Includes 26th New Zealand Geothermal Workshop

THE DISTAL ARCHIVE OF NORTH ISLAND SILICIC VOLCANISM RECORDED IN PLEISTOCENE SHALLOW MARINE SEDIMENTS OF WANGANUI BASIN, NEW ZEALAND

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Vitric-rich volcaniclastic horizons provide an important tool for correlation of glacio-eustatic sedimentary cycles, both within the now well-described shallow marine record of Wanganui Basin, and to other terrestrial and deep-marine records in the New Zealand region. In addition, these horizons provide a well preserved distal record of major rhyolitic eruptions from the Taupo (TVZ) and Coromandel (CVZ) Volcanic Zones that is otherwise not observed and/or preserved in proximal source areas. A total of twenty-eight volcaniclastic horizons are recognised on the basis of glass shard major element geochemistry and stratigraphic position. Many horizons have been dated by a combination of magnetostratigraphy, orbitally tuned cyclostratigraphy and isothermal plateau fission track (ITPFT) ages. From youngest to oldest, the volcaniclastic horizons (with ITPFT and/or astronomical ages, respectively) are: Onepuhi (0.57 Ma), Kupe (0.64 ± 0.08 Ma, 0.65 Ma), Kaukatea (0.87 ± 0.05 Ma; 0.90 Ma), Potaka (1.00 ± 0.03 Ma; 0.99 Ma), Rewa (1.29 ± 0.12 Ma, 1.19 Ma), Mangapipi (1.60 ± 0.18 Ma, 1.54 Ma), Ridge (1.56 Ma), Pakihikura (1.58 ± 0.05 Ma; 1.58 Ma), Birdgrove (1.60 Ma), Mangahou (1.63 Ma), Maranoa (1.63Ma), Ototoka (1.71 ± 0.19 Ma; 1.64 Ma), Table Flat (1.71 ± 0.12 Ma; 1.65 Ma), Vinegar Hill (1.75 ± 0.13 Ma; 1.75 Ma), and Waipuru (1.87 ± 0.15 Ma, 1.83 Ma). The ITPFT-ages of these volcaniclastic layers are consistent with the astronomically-tuned geomagnetic polarity timescale.

These volcaniclastic horizons in Wanganui Basin appear to have been emplaced through a variety of primary and secondary processes. For primary emplacement there is evidence for direct tephra-fall as well as transitional water-supported mass flow through to hyperconcentrated flow emplacement. No gas-supported flow deposits have so far been recognised in Wanganui Basin.

Although some primary and secondary units from Wanganui Basin can be chemically and chronologically linked to known TVZ eruptions, the volcanological relationships of equivalent-aged units between distal to proximal localities have yet to be established. Most volcaniclastic horizons in Wanganui Basin remain uncorrelated with proximal deposits owing to proximal source area erosion and/or deep burial as well as adverse effects of vapour phase alteration and devitrification within near-source welded ignimbrites which restrict comparative geochemical characterisation.

POSTER

FORMATION CONDITION OF SMECTITE IN SILICA SCALE: ROLE OF MAGNESIUM

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To elucidate the formation mechanism of smectite contained in silica scale formed in the pipeline at geothermal power plants, seven silica scale samples were characterized by chemical analysis, powder X-ray diffraction, and ^{27}Al MAS NMR. Smectite was present in silica scale samples whose magnesium content was higher than 10 % as MgO, and aluminium content was lower than ca. 10 % as Al2O3. The peak assigned to 6-coordinated Al was observed in the 27Al MAS NMR spectra for magnesium-rich samples, while, no peak due to 6-coordinated Al appeared in magnesium-poor samples. From the comparison between the ^{27}Al MAS NMR spectra for synthesized precipitates of Al_2O_3 and Al_2O_3-MgO, the half-width of peak for 6-coordinated Al of the Al_2O_3-MgO was narrower than that of Al_2O_3, suggesting that magnesium may stabilize the octahedral sheet (AlO_6) in smectite.

ORAL – geothermal workshop

THE RECORD OF THE TAUPO MAGMA CHAMBER PRESERVED IN MELT INCLUSIONS

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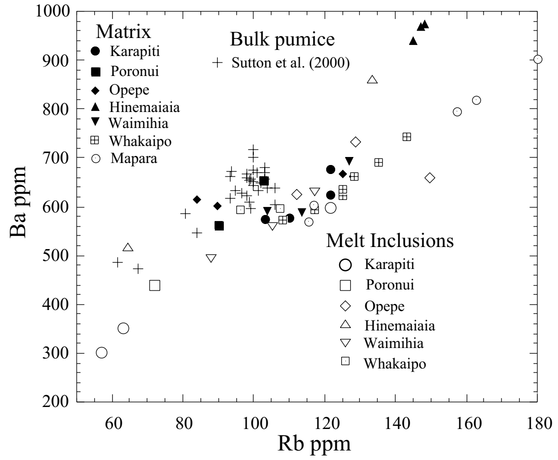
On the basis of whole-rock and mineral compositions, Sutton *et al.* (2000; Jl. Geol. Soc. London, 157, 537-552) recognize four post-Oruanui (~26.5 ka) magma types erupted from the Taupo volcanic centre; the largest (~ 35 km^3) of these erupted at 1.77 ka had a short magma chamber residence time (<10^3 years), possibly resulting in a lack of compositional zonation. We have analysed phenocrysts, matrix glasses, and glass (formerly melt) inclusions trapped within the dominant plagioclase–pyroxene–Fe-Ti oxide phenocryst assemblages of 3 (rhyolitic) of these groups, using electron microprobe (major elements; 5 to 20 µm-diameter spots) and laser ablation, inductively coupled plasma mass spectrometry (LA-ICP-MS) (trace elements; 30 to 40 µm spots).



The most significant of these results are: 1. for the trace alkali (Rb, Cs) and alkaline earth elements (Sr, Ba), there are large abundance ranges both within matrix and melt inclusions (see Figure); 2. the range of individual LA-ICP-MS spot analyses encompasses the compositional range (by X-ray fluorescence) of bulk pumices; 3. distinctive (by individual eruption) and positive correlations between the alkalis, alkaline earths and light rare earth elements; 4. even within a specific eruption, there is more than one trace element correlation trend; 5. individual phenocrysts are compositionally zoned requiring some heterogeneity of former host melts. Using an experimentally-constrained criterion for equilibrium between coexisting ilmenite-magnetite solid solutions, it is possible to calculate sequentially: the equilibrium T-fO_2 of homogenised host magmas (temperature ranges ~ 760 to 860°C; -$\log_{10}fO_2$ ~ 15.8 to 12); the Fe^{2+}/Fe^{3+} and hence Mg/Fe^{2+} of the host magma; and equilibrium orthopyroxene composition. For the 1.77 ka eruption, the equilibrium orthopyroxene $Mg/(Mg+Fe^{2+})$ = 0.5 (cf. 0.55 to 0.45 phenocryst range).

We interpret these results to indicate the preservation within the melt inclusion population of the post-Orunui, Taupo eruption sequence, of the compositional record of individual melt components that became homogenized within the larger magmatic system feeding this eruption sequence. Mutiple crustal sources must be involved in rhyolite generation driven by mantle-derived basalt ingress.

ORAL

WIDTH OF MANTLE DEFORMATION ACROSS A CONTINENTAL TRANSFORM: EVIDENCE FROM UPPER MANTLE (PN) SEISMIC ANISOTROPY MEASUREMENTS AND IMPLICATIONS FOR SIMPLE SHEAR OF THE MANTLE

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Seismic anisotropy values (δV_p) of up to 11 ± 2.5% in the upper mantle (Pn phase) are reported at localities east and west of the Alpine fault in South Island, New Zealand; the Alpine fault being the surface manifestation of an active continental transform between the Australian and Pacific plates. Our Pn determinations are based on high-resolution, onshore-offshore, seismic refraction methods where the data are effectively reversed by creating both shot and receiver gathers. When these data from the upper mantle lid are combined with a previous published SKS splitting results, two distinct zones of mantle deformation are identified within South Island. A deforming zone in the mantle lithosphere up to 335 km wide in southern South Island, and a region about 200 km wide in mid-South Island. The wider region has a fast direction of splitting about 20 degrees anticlockwise from the shear direction, whereas the fast direction in the narrower central South Island is almost parallel with the direction of shear. Both regions display wider zones of anisotropy than found at other continental transforms of the world such as the Dead Sea fault or San Andreas of California. But the width and orientation of mantle anisotropy in southern South Island are consistent with a model of simple shear in a zone that has undergone ~ 800±200 km of right-lateral shear displacement – a value close to that predicted by geological reconstructions. Hence displacement in this domain can be accommodated by distributed shear and no faulting is required in the mantle. For the mid south Island where the fast splitting direction is roughly parallel to the direction of shear an alternative explanation is required. We propose that either strain is much higher here, or the mantle lid is undergoing some degree of dynamic recrystallization.

POSTER

STRESS AND SHEAR-WAVE SPLITTING MEASUREMENTS IN MARLBOROUGH AND THEIR IMPLICATIONS FOR FAULT STRENGTH AND STRUCTURE-CONTROLLED CRUSTAL ANISOTROPY

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The major faults in Marlborough and Wellington play a key role in accommodating relative plate motion in the upper plate of an oblique subduction zone, and are thought to pose a high seismic risk to central New Zealand. Studies of the geometrically similar plate-bounding faults of the San Andreas fault system suggest that those faults slip in response to low resolved shear stresses and that crustal anisotropy is controlled by the ambient stress. However, whether these observations are more generally applicable to major strike-slip faults is yet to be determined. We have used inversions of focal mechanism and first motion data to calculate the principal stress directions in Marlborough and related these results to the frictional strength of the major faults. We have also conducted shear-wave splitting analysis on local S phases to determine the directions of crustal anisotropy in Marlborough, and investigated their geometric relationships to the geological fabric and the principal stress directions.
The observed angle between the maximum horizontal compressive stress direction (S_{Hmax}) and the average strike of the major faults is approximately 60°, a figure substantially higher than the ~30° expected for an Andersonian strike-slip fault. This geometry can be interpreted, in terms of the fault having either a moderately low friction coefficient (~0.35) or moderately high fluid pressure (~0.7 × lithostatic). These end-member values are similar to those inferred for the San Andreas fault in southern California. Since the azimuth of S_{Hmax} is markedly different from the average strike of the major faults, we are able to distinguish between stress- and structure-controlled anisotropy. The anisotropy measurements made on data from earthquakes shallower than 50 km reveal that the fast directions are principally aligned with the NE–SW-striking faults, and we therefore conclude that the anisotropy is mainly controlled by the geological fabric. Fault-parallel fast directions have also been observed in California, but stress-related anisotropy appears to be present there to greater distances from the fault than seen in our results from Marlborough.
The observation that faulting occurs at high angles to S_{Hmax} substantiates the hypothesis that the San Andreas fault is not unique in being frictionally weak. Our shear-wave splitting calculations suggest that anisotropy in the crust varies spatially in regions of active faulting but that in Marlborough, at least, it is controlled more by the geological structures than the prevailing stress field.

ORAL

CRUSTAL IMAGING USING LOCAL EARTHQUAKE WAVEFORMS

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Prestack migration reflectivity imaging using earthquake seismograms has the potential, with optimum data, to provide information on elastic properties of structure in the mid- and deep-crust, without the cost of active source surveys (Louie et al,2002). However, crustal imaging using waveform data from local earthquakes faces several difficulties, including the need to deal with imperfect event locations, as well as the imaging artefacts which result from migration into sparse station arrays. Here we examine improvements in crustal images which can result from sharpening the locations of earthquake swarms, using the double-difference approach of Waldhauser and Ellsworth (2000).
In a first example we attempt to image the Alpine fault zone using migration imaging of local-earthquake coda. We specifically use records of the aftershocks of the Mw 6.7 Arthur's Pass earthquake, the largest earthquake in the region for 65 years, which occurred about 25 kms southeast of the Alpine fault, the aftershocks of which were well recorded by a 6-station portable array (Abercrombie et al., 2000). Pre-processing involved relocation of more than 4000 aftershocks with the double difference technique, utilising the cross-correlation differences between the waveforms, and substantially improving the relative event locations. The distribution of the relocated aftershock events highlights the Bruce fault and other secondary faults in the region. Subsequent migration imaging, using receiver station gathers of the seismograms of the relocated events, results in reflectivity images of the mid-crust near the Alpine fault and beneath the aftershock sequence.
In a second example we relocate more than 700 seismic events just north of Lake Taupo using the double-difference technique, again using measurements of waveform cross-correlation as well as travel-time differences between P and S-

phases. The relocated hypocentres, which extend down to c. 6 k depth, clearly delineate clusters with a northwest-southeast trend, the same orientation as surface faults in the region. Subsequent migrations using the S-wave coda indicate mid-crustal reflectivity to the south-west and south-east of the earthquakes.

ORAL

THE SOUTHERN ALPINE FAULT: NEW MARINE MULTIBEAM DATA REVEALS DETAILED STRUCTURE AND SLIP RATE

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The structure of the southern 230 km of the Alpine Fault, west of Fiordland, is being re-evaluated using unprecedented, high resolution, SIMRAD EM300 multibeam bathymetric data acquired by NIWA on two *RV Tangaroa* surveys in 2003 and 2004. The fault and its sedimentary basins are extremely well expressed in the new images, with active surface traces displacing submarine fans and channel systems that are interpreted to have developed principally during the last and earlier glaciations. The new data confirm recent interpretations of segmentation of the southern part of the fault into three major geometric sections, and provide significant detail of structures on and in between the major traces. Numerous sites are identified at which dextral displacements can be measured, and for the first time, used to determine the slip rate of the fault south of Milford Sound. This allows us to evaluate the role of the southern Alpine Fault in accommodating plate motions in southern New Zealand.

The northern, Milford-Caswell section continues the south Westland section on land for about 90 km south of Milford Sound. Two new step-overs, with widths of ~500 m and 1000 m, are recognised in the surface trace of this section. Between Caswell Sound and Secretary Island, the fault trace steps across the 30 km-long Nancy section and onto the southern, 155 km-long Resolution section. All three sections of the fault are linked at the seafloor by a network of smaller-scale connecting faults. These structures have implications for the assessment of future ground-rupturing, strike-slip earthquakes on the fault, as it now appears likely that very large magnitude, composite ruptures have occurred repeatedly in the past.

Dextral displacements have been identified so far at 11 submarine sites, allowing fault slip rate to be determined on the Milford-Caswell and Resolution sections as far south as Doubtful Sound. Interpretations of the age of displaced geomorphic features have been aided by an extensive seafloor sampling and photography programme, and 16 new radiocarbon dates. The best quality data, from more than one site, indicate a dextral slip rate on the Alpine Fault of 30 ± 3 mm/yr off central Fiordland. This rate represents essentially all of the predicted plate motion parallel to the plate boundary at this latitude, and confirms the extreme strain partitioning evidenced by recent thrust earthquakes in the area.

ORAL

ACTIVE INTERPLAY BETWEEN THE NORTH ISLAND DEXTRAL FAULT BELT AND THE WHAKATANE GRABEN, BAY OF PLENTY, NEW ZEALAND

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Active continental back-arc tectonics associated with the oblique Hikurangi subduction zone, North Island, is characterized by (1) extensional deformation distributed across a 40-50 km-wide zone, but presently concentrated in the east within the 20 km-wide, NE-striking Taupo Fault Belt and Whakatane Graben (2) c. 7 mm/yr geodetic extension rate across the Bay of Plenty coast; (3) 1-3 mm/yr subsidence in the Whakatane Graben; and (4) a seismogenic zone estimated to be 6-9 km thick. A component of the oblique convergence within the plate boundary is partitioned to the east onto the adjacent North Island Dextral Fault Belt (NIDFB), a large NNE-trending strike-slip fault system traversing the entire North Island. At the Bay of Plenty coast, the NIDFB strikes north, with an estimated strike-slip rate of at least 1 mm/yr. Both normal and strike-slip fault systems extend beneath the continental shelf in the Bay of Plenty, and because of differences in their strike, they converge and interact.

Detailed mapping of faults using marine seismic reflection profiles and multibeam bathymetric data reveals the structure of the Whakatane Graben. Tilted basement blocks are associated with large west-dipping faults, and numerous antithetic secondary faults. Eastward migration of the principal extension zone during the last c. 1 Myr has resulted in the encroachment and oblique overprinting of the NIDFB by the Whakatane Graben. The structure and geometry of the White Island Fault, currently the principal structure along the eastern margin of the graben, and lying approximately along strike of the Edgecumbe

Fault, results from interaction and linkage of the two fault systems. The displacement profile of the White Island Fault reveals relatively young NE-striking sections that obliquely link more northerly-striking, inherited components of the NIDFB. Understanding of the fault structure and evolution may have implications for the interpretation of earthquake potential close to urban centres.

POSTER

THE TAPHONOMY OF A LATE CRETACEOUS REPTILE-BEARING CONCRETION FROM MID-WAIPARA RIVER, NORTH CANTERBURY, NEW ZEALAND.

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Taphonomy is "the science of dead, rotting things accompanied by a terrific stench" (Martin, 1999). It has been used extensively in the studies of terrestrial vertebrate and marine invertebrate fossils and assemblages, but little work has been done in the field of marine vertebrates, especially Cretaceous marine reptiles.

In this study taphonomic analysis is used to investigate the death, dismemberment disarticulation, and decay of an elasmosaurid plesiosaur (Zfr145), its incorporation into the surrounding sediment, diagenesis, retrieval and preparation. The 'taphonomic attributes' of the fossil were described, and studies were undertaken to explain the mechanisms involved in its modification – from living breathing (probably) animal to very big doorstop.

The investigation was broken into five parts, including

1. **Bone surface damage.** This is the first full study to date. Bone surfaces were assessed visually for damage caused by bio-erosion, fragmentation, mechanical abrasion, and chemical dissolution. Bioerosion was found to be the main contributor. Identification of the animals (or guilds) responsible resulted in the construction of a community supported by the plesiosaur carcass. The lack of fragmentation, abrasion and corrosion also had important implications for the palaeoenvironment.
2. **Bone disarticulation, mixing and removal.** Many bones are missing, including the head, neck, and many from the left side. Most of what remains are mixed, showing little or no pattern. Only five dorsal vertebrae remain articulated. Why? Gravity, waves and currents, and other animals may have mixed and removed bones. Each process leaves particular evidence behind, and the contribution of each is discussed. This also supports the inferences for palaeoenvironment and fossil preservation.
3. **Geochemistry and biogeochemistry.** Samples from the surrounding sediment provide background sedimentation, geochemistry and diagenesis. Samples taken from the concretion (inside, middle, outside) record both the growth of the concretion and the decay of the carcass. Geochemical and microscope analyses of the bones provide information on the original condition, decomposition and preservation of the specimen itself.

The result is an overlapping series of events in which the animal

- died;
- was scavenged and colonised;
- became buried; and
- was fossilised and encased in a concretion.

PLENARY

HOW TO BUILD A VIRTUAL PLESIOSAUR

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So what's new in the field of Cretaceous biology? Not a lot, really.

But new technologies are constantly being developed in other fields that may be useful to palaeontologists. They need only be identified and applied. The result is the extraction of another layer of information from specimens that we've been studying. Like virtual reality, for example.

During the course of a taphonomic study on a Cretaceous plesiosaur (see accompanying presentation) several significant questions arose that could not be answered without destroying the fossil. This is one of the most significant limitations in palaeontology. The size of the fossil (~2.5m^2) and the resolution required precluded plaster cast or digital terrain modelling. A high resolution small-scale method was needed, so the necessary expertise was found.

ARANZ (Applied Research Associates NZ Ltd) used their equipment and technology to scan (make a digitised three-dimensional image) a Cretaceous elasmosaurid plesiosaur (embedded in a partially excavated concretion) housed at Canterbury Museum, Christchurch. The file images of the fifteen blocks of bone and concretion were then reassembled and re-surfaced (joining the blocks to form one continuous surface). It was necessary to develop new software to do this work and it has spin-off commercial applications.

Once the reconstruction was completed the exhumed bone layer was split into two models that represented

a) bones that came to rest on or above sea-floor surface;
b) bones that were buried below sea-floor.

Supplementary models were also generated to show

a) surface topography; and
b) an inverted image, showing the seafloor surface itself, and subsequent bone depressions.

Why? In the scope of this project (see accompanying presentation) these images illustrate the differing preservational conditions above, within, and below sediment-water interface, and the alignment and orientation of bones.

For palaeontologists in general the application of digital imaging has far-ranging implications. It provides 3D fossil replicas that palaeontologists can catalogue, study and share without the risks posed by transport of the original specimen. The presentation and communication of results becomes exciting and dynamic (illustrated here by the bone plane 'flyover'), and has implications for teaching and interactive displays and museum exhibits.

POSTER

PHYSICAL VOLCANOLOGY AND FUTURE VOLCANIC RISK FROM TE MAARI CRATERS, TONGARIRO

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The Te Maari Craters on the northern side of the Tongariro Cone Complex represent one of at least seven vent systems that have been active on Tongariro since the last glacial maximum. Activity at Te Maari probably began about 14 ka and has continued through historic times, making it the most long-lived of the young eruptives on Tongariro. The older lower crater is a wide (500 m), inclined, flat-floored structure up to 60 m deep, which exposes multiple layers of jointed andesite lava. The morphology of this structure implies some shallow collapse. The upper crater is a steep-sided, funnel-shaped feature constructed from weakly consolidated, very coarse, monolithic andesite breccia, and is largely the product of explosive eruptions through a pre-existing fan of thick autobreccia. The most recent lava flows (probably around 1500 AD) and explosive ash eruptions (notably in 1892 and 1896) have been sourced from this upper crater. From historic observations and analysis of the erupted products in the field, the typical eruptive style of these craters range from phreatic – phreatomagmatic to vulcanian.

The explosive eruption of 1896 was of sufficient intensity to disperse ash at least as far as the Hawkes Bay, and up to 50 mm of ash accumulated on the Desert Road. A repeat of this eruption today would cause severe disruption to agriculture and forestry operations, as well as critical transport and utility networks in the central North Island. The Tongariro Power Scheme would also be affected, as ash fall over Lake Rotoaira would cause damage to hydroelectric power facilities. A lava flow from these craters today on the scale of the 1500 AD flow would also have a major impact on transport networks if it reaches the State Highway, and outgassing would cause local acid rain and health problems in nearby communities such as Turangi and Taumaranui. The location of these craters close to the boundary of the national park also presents a unique hazard, as it would be difficult to prevent members of the public from gaining access to the area following an eruption and endangering their lives through curiosity.

Recent seismicity beneath the craters is a reminder that further eruptions are likely from the Te Maari system. Work on these craters to characterise the mechanisms, timing and magnitudes of typical eruptive activity contributes valuable information in the assessment of the probability and impacts of future eruptions.

A few eruptions have been documented where in the initial stages water was involved and so was classified as phreatomagmatic. As they progressed however, it became apparent that they were displaying characteristics of vulcanian eruptions. This led to an assertion that vulcanian eruptions that involve water may be considered a subclassification of phreatomagmatic eruptions.

POSTER

APPLICATION OF SEQUENCE STRATIGRAPHY TO VOLCANIC SUCCESSIONS

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In volcanic settings, aggradation and erosion can be produced by landscape reponse to eruptions and does not require changes in base level or accommodation, normally called upon for sequence stratigraphic analysis. The style of volcanism determines whether the episodic sediment supply is friable and easily remobilized. "Syn-eruptive" ignimbrites destroy the drainage network followed by increased overland flow, hyperconcentrated flood flow and debris flow resulting in reworking of volcanic material into "early post-eruptive" deposits. As the fluvial systems re-establish, small channels are cut and braided rivers develop followed by meandering rivers in "late post-eruptive" deposits followed by the reincision of the river to original base level. These can be interpreted as "syn-eruptive", "early post-eruptive", and "late post-eruptive" systems tracts followed by a new sequence bounding unconformity.

Sequence stratigraphic techniques were applied to an extremely well exposed intra-arc strike-slip basin in southern Arizona. Sequence boundaries were identified by the presence of unconformities. Five unconformities, proximal to the master fault, show extreme vertical relief (460–910 m), very high paleo-slopes (40°-71°), and pronounced asymmetry. The other three more distal unconformities are more symmetrical, with vertical relief of 200-600 m and paleo-slopes of 20°-25°. The sequences are dominated by small polygenetic, multivent volcanic complexes. Tuffs are reworked becoming progressively more organized and stratified upsection until they are finally cut by small fluvial channels. However, they are not followed by the incision of a new sequence bounding unconformity; instead, more tuffs are deposited. This suggests that "volcanic systems tracts" will work best where eruptions are large and separated in time.

There appears to be no predictable relationship between the unconformities ("sequence boundaries") and the depositional sequences ("systems tracts") indicating that the unconformities were formed by tectonic uplift during basin inversion events along the strike-slip fault rather than by landscape response to the episodic sediment supply of eruptions. Distinction between tectonic and intrinsic volcanic controls on landscape response was possible by the use of sequence stratigraphic models.

ORAL

USING GEODETIC STRAIN RATES IN SEISMIC HAZARD MODELS

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Present-day strain rates at the Earth's surface derived from geodetic measurements should be able to provide information about the processes leading towards future earthquakes. This is an intuitively appealing statement, but is it true? Various strategies have been proposed for utilising geodetic strain rates in the determination of seismic hazard, but all have drawbacks. Three principal problems are as follows.

(1) Strain accumulation at major faults is distributed over a wide region (several fault-locking depths) around the fault, yet the future earthquake occurs on the fault itself. Strain accumulation observed geodetically therefore does not necessarily provide an accurate spatial representation of earthquake likelihood.
(2) Much of the strain accumulation observed geodetically is due to major faults, which are introduced into seismic hazard models through their geologically-determined fault slip rates and recurrence intervals. This produces the risk of "double counting" when geological/paleoseismological and geodetic information are used together in a hazard calculation.
(3) Strain accumulation well away from major faults may provide information about strain build-up towards earthquakes in these regions, but such regions are usually represented in seismic hazard models by a background seismicity rate. Double counting may therefore also occur if both background seismicity and geodetic strain rates are used in hazard calculations for such regions.

Some authors have generated seismic hazard models using only the geodetic data, and have compared these with conventional models. Other authors have attempted to combine the three data types with appropriate weightings.

For regions like New Zealand, where relatively good paleoseismic information is available for the largest faults but the historical seismicity catalogue is relatively short, we propose a new method in which geodetic data are used to estimate both the variation in coupling along major faults and the background strain rates away from major faults. If the method proves to be viable we believe it will provide a much improved way to utilise geodetic data in seismic hazard models.

ORAL

TOPOGRAPHIC CORRECTIONS APPLIED TO GEOTHERMAL GRADIENT

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Topography will influence the level of solar radiation reaching the earth's surface and will also distort the shape of temperature isotherms near the surface. Consequently, terrain will affect any temperature gradient values and methods such as thermal imaging that may be used for locating subtle geothermal anomalies. These effects are especially significant in areas of high and complex relief. If topographic influence is recognised and removed from the observed data, the reliability of these thermal methods can be increased. This paper presents an improved way of estimating the effect of topography upon geothermal gradient taking into account variations of insolation due to terrain slopes.

To estimate the influence of relief upon the temperature data recorded in a conductive geothermal regime, the equation of heat conduction was solved in special boundary conditions. One of the boundary conditions assumes the temperature field at great depth and the other boundary condition refers to the temperature at the earth's surface.

The ambient air temperature and the amount of heating from solar radiation largely control the temperature at the earth's surface. For computing this, mean annual air temperature (from meteorological data) and its gradient with altitude are usually used.

The parameter albedo is a measure of the earth's surface capacity for absorbing solar radiation and characterises the microclimate of an area. In this paper the effect of the microclimate, considering the influence of vegetation cover and slopes, will be included in the value of the temperature at the earth's surface. A linear relation represents a good approximation:

$$T_s = \mathrm{A} - \mathrm{B}h + \mathrm{C}R \qquad (2)$$

where T_s is temperature at the earth's surface (^{o}C), h is altitude (m), R insolation (Kwh m^{-2} year^{-1}) and A,B,C are constants. Constant A would represent the mean annual temperature on the earth's surface at sea level and B the gradient of underground temperature with altitude. Constant C correlates T_s' (underground temperature extrapolated at the surface, reduced to the same altitude) with insolation R. Insolation is recorded hourly by the meteorological stations as the amount of incident direct solar radiation. This data is integrated on an hourly and monthly average basis corrected for sun incidence angle to terrain surface to estimate net insolation on an annual basis at each location.

In order to see the influence of slopes upon surface temperature in the specific environment of New Zealand, a map of the variation with slopes for the solar radiation and temperature was calculated for an area of rhyolite domes in the Taupo Volcanic Zone. Topographic corrections were computed for hypothetical wells located at different positions in the terrain. The heat conduction equation was solved with the relaxation method. The values obtained for the topographic correction vary between 2 to 20% from observed geothermal gradient, emphasising the importance of eliminating the effect of topography from the measured geothermal data.

ORAL – geothermal workshop

LATE QUATERNARY SURFACE RUPTURE HISTORY OF THE PAEROA FAULT, TAUPO RIFT, NEW ZEALAND, AND INTERACTION WITH OKATAINA CALDERA

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The 27 km long Paeroa Fault is the largest normal fault of the currently-active Taupo Rift. Along the northern sector of the fault it displaces the c. 64 ka constructional surface of the Earthquake Flat Breccia and displaces, by 0.5-3.0 m, many of the floors of valleys dissecting the breccia surface. The fault forms a c. 2.5 km wide graben structure comprising at least 11 strands, and at its northeastern end abuts the southern edge of the rhyolite-dominant Okataina caldera

Seven trenches from five of eleven fault strands have been excavated and are reported here. Twenty three rupture events have been identified in the seven trenches, two of which are approximately along-strike of others, and on which there is a similar rupture history. Successive ruptures in individual trenches are highly variable both in size and in recurrence, but most trenches reveal three or four ruptures in the past 16 kyr. Of the twenty three faulting events recognised, nine occurred during eruption episodes from the Okataina volcano, and fourteen occurred between volcanic events. We therefore identify, and distinguish between, tectonic and volcano-tectonic faulting. At least two fault rupture events occurred in association with the 13.8 ka Waiohau eruption, and at least one of the tectonic events appears to immediately precede the Waiohau tephra. Distance and azimuth relationships between the Paeroa Fault and the Okataina caldera, and a correlation between eruptive volume and fault triggering, provide the basis for investigating stress perturbations around a fault or around a rhyolite caldera, enhancing opportunities for fault and volcano interaction modelling.

Trenches that lie on a single transect across the fault zone capture data on about 45% of the strands of the fault and the total cumulative displacement on these strands is also about 45% of the total. The various events identified in each trench in this transect cluster into eight multi-strand rupture events in the past c. 16 kyr, five of which are tectonic and three of which are volcano-tectonic.

Cumulative primary displacement during each of these clustered rupture events range from c. 0.5-2.2 m, with many in the c. 1.0 m range. There is no obvious distinction between size of tectonic and volcano-tectonic rupture events.
In comparison with the 14 km long surface faulting of the 1987 Edgecumbe earthquake, the data from this sector of the Paeroa fault suggests the 27 km long Paeroa Fault may rupture in association with earthquakes up to M_w 6.8, consistent with surface displacement of 2.2 m. Because some of the Paeroa Fault slip rate near to the Okataina caldera accumulates in association with high hazard volcanic eruptions, then the earthquake shaking hazard and fault rupture hazard is perhaps overestimated, at least in proximity to the caldera.

ORAL

STRATIGRAPHIC ARCHITECTURE, STRUCTURE, AND PALEOGEOGRAPHY OF HAWKE'S BAY BASIN, EASTERN NORTH ISLAND

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We report the L. Miocene – E. Pleistocene stratigraphic architecture for the central part of Hawke's Bay Basin, involving an area of 3,500 km^2 within the modern forearc region of eastern North Island, extending west-east from the axial ranges to the coast, and from Waikari River in the north to south of the Ngaruroro River. The basin contains a late Miocene-early Pleistocene sedimentary fill reaching a thickness of about 3 km. Siliciclastic siltstone and sandstone are the dominant lithofacies, with subordinate limestone and conglomerate beds, which nevertheless form many of the prominent topographic features in the basin. The lower units of the succession comprise **Poamoko Fmn, Waitere Fmn** and **Mokonui Sandstone**, previously mapped to the north of the study area by Cutten (1994, IGNS Geological Map 6). These units show a pronounced southward onlap and shallowing in water depth on to Torlesse basement, which is also evident in the distribution of younger (Pliocene) units, although this pattern is complicated from the late Pliocene by faulting parallel to the present margin of the ranges where the outcrop occurs. The succession overlying the Mokonui Sandstone is lithologically diversified, and accumulated exclusively in shelf marine or non marine environments. The principal stratigraphic units are named **Titiokura**, **Te Waka** and **Pohue Formations**, and are overlain by **Petane Group**. The Petane Group exhibits strong cyclothemic character. Individual 41 k.y. (6^{th} order Milankovitch obliquity) sequences or systems tracts have been able to be mapped as formations in the central part of the basin.

The study area comprises one of the few areas where Plio-Pleistocene strata crop out on both sides of the North Island Shear Belt. This enables constraints to be placed on the timing and magnitude of displacement on particular faults in this belt. North of the Ngaruroro River the Ruahine Fault seems to be the dominant strike-slip fault, with displacement on it in the Puketitiri area appears to be of the order of 7-10 km. The Kaweka Fault has very large vertical offset in the Kuripapango area, but this decreases along strike farther to the north. Eastward (basinward) of the Mohaka Fault are a series of sub-parallel faults that splinter off it, such as the Patoka and Rukumoana Faults.
Paleo-ecological and sequence stratigraphic analyses of the Petane Group have enabled detailed paleogeographies to be reconstructed down to the level of particular systems tracts within sequences; that is, a paleogeography can be interpreted for each of sea-level paleo lowstand and highstand intervals. This level of resolution is necessarily built upon a detailed stratigraphic framework underpinned by fine scale geological mapping, section description, and facies analysis.

PLENARY

NEW 1:50 000 SCALE GEOLOGICAL MAPS OF HAWKE'S BAY BASIN, EASTERN NORTH ISLAND

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A series of 1:50 000 scale geological maps covering the central part of Hawke's Bay Basin have recently been completed in the course of systematic basin analysis investigations undertaken by the sedimentary and petroleum geology group at University of Waikato.
An area of about 3 500 km^2 has been mapped so far, much of it as part of a PhD research project. The map units are conventional lithostratigraphic and morphostratigraphic units, and in the Petane Group the formations are also Vail-type sequences, bounded by chronostratigraphic surfaces.
All of the map data and much of the basin analysis data have been entered into a Geographic Information Database, whose structure is modeled on the QMap database of GNS. It is envisaged that the new 1:50 000 maps will be generalized to form the basis of part of the 1: 250 000 QMap Hawke's Bay Sheet currently being prepared.

The western part of the mapping area encompasses the North Island Shear Belt. Regional dip of the basin succession is typically 2-20° southeast. East of the axial ranges the sedimentary succession is mildly deformed into a broad monoclinal fold (Hawke's Bay Monocline) and associated faults. Blind thrusts that deform the Pliocene succession near the axis of the basin have been inferred in the Bay View- Esk Valley area. Most structures post date the accumulation of the units they deform.
The basin analysis and associated geological mapping, as a consequence of covering a large part of the basin, have enabled rationalization of the prior lithostratigraphy. The mapping in particular has shown the exact relationships between many of the "floating" formations, established by Beu (1995, GNS Monograph No 10) for limestone beds in the basin.

POSTER

THE ERUPTIVE HISTORY OF THE ATIAMURI PYROCLASTICS, MAROA VOLCANIC CENTRE, NEW ZEALAND

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The Atiamuri pyroclastic sequence (229 ± 12 ka) is part of the Maroa Volcanic Centre, Taupo Volcanic Zone (TVZ), New Zealand. Stratigraphic, petrographic and geochemical data are used to describe the Atiamuri deposits and their eruptive history. Units from this pyroclastic sequence occupy an area of <1 km^3 and include basal phreatomagmatic airfall layers, three ignimbrite units with different degrees of welding and intervening shower beds, and overlying airfall layers. The Atiamuri pyroclastics are interpreted to have erupted from a single vent beneath Mandarin Dome, from a small un-zoned discrete chamber, or from partial evacuation of a larger chamber.
Comparisons with other known small ignimbrite-forming events (in particular, the ~AD 1315 Kaharoa eruptive episode at nearby Tarawera Volcanic Centre) show that although the Atiamuri is similar in extent and was followed by dome extrusion, it differs in lithic content, does not have associated block-and-ash flows, exhibits interaction with water, is generally chemically homogeneous and exhibits no evidence for a mafic eruption trigger.
A model for the eruptive sequence at Atiamuri is as follows: (a) Small phreatomagmatic airfall eruption into a swampy lakeshore environment with possible early extrusion of a small proto-dome. (b) Emplacement of pyroclastic flows by a small laterally directed eruption from the side of the proto-dome. Pyroclastic flows are of HARI-type (high aspect ratio) and are topographically controlled. (c) Post-ignimbrite airfall with alternating small eruptions from the vent. Some further minor interaction with water possible. (d) Extrusion of Mandarin Dome from vent, through the ignimbrite deposits.

POSTER

THE CASITA GEOTHERMAL FIELD, NICARAGUA

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The Casita geothermal field is held under a concession by Triton Power S.A., a 100% owned subsidiary of Polaris Energy Corporation (of Panama). It is located in the southeast portion of the San Cristobal volcanic complex that is part of the Marribios Range of northwestern Nicaragua. San Cristobal is currently volcanically active, but Casita appears erosionally older and was the site of a major catastrophic mudslide from its southern slopes during Hurricane Mitch in 1998. An even older volcanic centre occurs to the east of Casita in the form of the La Pelona caldera. Casita is a ridge, with volcanic craters along it, which is made up of pyroxene andesites with lavas predominating on its northern slopes and pyroclastics on its southern slopes as a result of the prevailing winds.
In addition to the predominance of pyroclastics in the south a further contributory cause of the mudslide is the presence of widespread hydrothermal alteration on Casita. There is also a very large area of hot and steaming ground, although actual fumarolic activity is relatively feeble. Repeated sampling and analysis of fumarole gases indicates the presence of a vapour-dominated reservoir at a temperature of approximately 235°C. The presence of Cl in warm surrounding ground water wells at lower elevations suggest a possible underlying neutral-Cl reservoir. Further afield, hot bicarbonate-sulphate springs at El Bonete approximately 8 km to the north have an associated resistivity anomaly orientated towards Casita and have been interpreted to be an outflow of condensate from above the vapour-dominated reservoir at Casita.
This interpretation has been reinforced by a recent MT survey over Casita that shows a possible upflow zone under the Casita ridge and the link between the Casita and El Bonete resistivity anomalies. The presence of this significant condensate outflow, the extent of the thermal ground on Casita and the possibility of a major vapour-dominated zone suggest the presence of a significant geothermal resource at Casita. The

concession holder has made preparations for exploration drilling.

ORAL – geothermal workshop

THE WAINUI SHEAR ZONE: CRETACEOUS DEFORMATION ALONG THE WESTERN MARGIN OF THE SEPARATION POINT BATHOLITH, NORTHWEST NELSON

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The Wainui shear zone represents a 400-1400 m thick, 20 km long belt of steeply dipping, well-foliated granitic and schistose rocks that form the western boundary of the Cretaceous Separation Point Batholith in northwest Nelson. The Separation Point Batholith is granitic in composition and makes up the northern-most portion of the Separation Point Suite, which forms the western edge of the greater Median Batholith. Geological units along the western margin of the Wainui shear zone include the Devonian Rameka Gabbro, Paleozoic Mount Arthur Marble and Pikikiruna Schist, and small granitic plutons of the Separation Point Suite.

The shear zone preserves evidence for progressive solid-state deformation and fabric development that generally transcends from the lesser-foliated margins into the centre of the shear zone. Microstructural and mineralogical evidence indicates that the ductile fabrics developed during cooling from a minimum of middle amphibolite facies to greenschist facies conditions. Sense of shear was east-side up and the shear zone is interpreted to have initiated at least soon after crystallisation of the granite batholith as a response to convergence and rapid uplift along the western edge of the Median Batholith. Brittle deformation in the centre of the shear zone and constraints on the maximum amount of uplift that could have occurred during ductile deformation indicate that deformation is likely to have continued to temperatures below the brittle-ductile transition. Several faults and subparallel joint sets through out the Separation Point Batholith at a high angle to the shear zone are suggested to have formed during late Cretaceous extension.

Extensive schists and many quartz-rich foliated rocks in the centre of the shear zone exhibit a distinctive trace element signature characterised by elevated nickel and chromium, which cannot have been derived from rocks presently exposed along the shear zone margins. A component to the shear zone is thus required to have been derived from depth and strong evidence suggests that it may be mafic to ultramafic rocks of the Riwaka Complex, which is presently exposed ~25 km south of the main study area.

Retrogressive metamorphism and fluid-rock interaction coupled with intense leaching of base metal cations during deformation of central shear zone rocks implies a pervasive and mobile fluid phase. Quartz-rich foliated rocks exhibiting the distinctive chromium-nickel trace element signature indicate large syntectonic additions of quartz to the rock, which is also consistent with large volumes of fluid moving through the shear zone. These rocks are interpreted to represent later-stage, lower temperature ductile deformation.

POSTER

MANTLE DEFORMATION AND SEISMIC ANISOTROPY DUE TO OBLIQUE COLLISION, SOUTH ISLAND, NEW ZEALAND

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An important question in geodynamics is how does continental mantle lithosphere shorten in transpressional zones? We address this by measuring properties of the upper mantle beneath central South Island, New Zealand. The obliquely-convergent, Australian-Pacific plate boundary passes through the South Island and the Alpine Fault effectively links two subduction zones of opposite polarities. Crustal deformation is now well documented across this continental transform, with oblique thrusts occurring at the Alpine Fault and distributed deformation to the east of the fault. About 90 km of shortening has occurred across central South Island in the past 7 Myr. Deformation in the mantle, however, remains controversial and surface observations are equally explained by a variety of models.

We use aftershocks to determine Pn along the root of the Southern Alps. High Pn speeds of 8.6 ± 0.1 km/s, as well as thickening of the crustal root from 45 ± 5 km in central (Mt Cook) to 49 ± 6 km in southern (Queenstown-Wanaka) South Island are the main results. Comparison with parallel and crossing lines both on- and off-shore suggest similar Pn speeds on the Pacific and the Australian plate boundaries, but higher values of Pn anisotropy of 11.5 ± 2 % on the Australian side than the 7.7 ± 2.7 % on the Pacific side. We interpret the anisotropy as being due to finite strain in the mantle lid. Two further Pn-anisotropy measurements off-shore East, 0 ± 2.5 % and 6.5 ± 3 %, define an E-W boundary to uppermost mantle deformation east of South Island. Furthermore, gravity modelling of the thick low-density crustal root shows that the Southern Alps are not sufficiently high to compensate for the root, requiring a region of positive density contrast in the mantle, which probably widens towards the south. We interpret this region as cold, thickened lithospheric mantle. Concomitant crustal root thickening, widening of Pn anisotropy and the mantle positive density contrast, suggest material accumulation, e.g. extrusion towards the southeast of South Island, and favour the thesis of thickening of the entire lithosphere.

ORAL

GEOCHEMISTRY AND SOURCE OF ZEOLITE-BEARING LACUSTRINE TUFFS IN THE NGAKURU FORMATION, TAUPO VOLCANIC ZONE, NEW ZEALAND

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In the Ngakuru area on the western side of the Taupo Volcanic Zone, Ohakuri Ignimbrite is overlain by lacustrine sediments of the Ngakuru Formation, a 100-300 m thick sequence of siltstone, vitric and pumiceous tuffs, diatomite and conglomerate. The distribution of the formation is split, by northeast trending normal faults, into the Ngakuru and Guthrie grabens. The older part of the sequence occurs in the Guthrie Graben and is overlain by the Earthquake Flat Pyroclastics (EFP), which have a K-Ar date of 64 ± 4 ka. In the Ngakuru Graben the upper part of Ngakuru Formation is preserved, as indicated from ^{14}C dates of ~20 000 yr BP and >47 000 yr BP in samples of carbonaceous material near the top and 30 m below the top of the sequence, respectively. The EFP were erupted from vents about 15 km northeast of Ngakuru and may have contributed airfall ash to the upper part of the Ngakuru Formation.

The vitric tuffs of the Ngakuru Formation are composed mainly of glass shards and pumice clasts, with minor plagioclase, quartz and biotite crystals. Some beds contain pumice clasts and accretionary lapilli. Sedimentary structures such as load-casts and thin, laterally continuous planar bedding are consistent with deposition of airfall ash in a subaqueous low-energy environment. Zeolite deposits occur within the lower 40-60 m of the formation as a result of replacement of glass shards by the silica-rich zeolites mordenite and clinoptilolite. Because the tuffs mainly consist of altered volcanic glass, elements that were immobile during zeolitic alteration can be used to determine the composition of the precursor volcanic rocks. A Zr/TiO_2-Nb/Y immobile element ratio plot shows that tuff analyses cluster around the boundary between rhyolite and rhyodacite/dacite. Unaltered vitric tuff from the Ohakuri Ignimbrite plots in the middle of the cluster of zeolitic tuff analyses, whereas samples from the EFP have a dacitic composition. Ratios of immobile trace elements (e.g. Zr/Y) and REE (e.g. Yb/Hf) are also distinctly different from the EFP. REE spidergrams for the Ngakuru Formation tuffs show Eu depletion, whereas the EFP spidergrams have a flat pattern. An Eu depleted source has yet to be identified, although Eu depleted ignimbrites have been reported from the Whakamaru and Mangakino volcanic centres.

The zeolite deposits are associated with sinter, hydrothermal eruption breccias and silicified fault breccias that represent surface or near-surface manifestations of geothermal activity. Plant material extracted from sinter overlying the Mangatete Road zeolite deposit in the Ngakuru Graben has a ^{14}C age of 8498 ± 60 yr BP, which is interpreted to be the age of zeolite deposition.

ORAL

SUBSIDENCE AT CROWN ROAD, TAUPO, LATEST FINDINGS

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A subsidence bowl has formed in the Crown Road area of Taupo. Based on data from three new drillholes (THM9-11) and modeling of the bowl shape, we interpret its origin to be recent compaction of a thin lens, about 160m across, of hydrothermally-altered Post Oruanui Sequence, eruption breccia and Oruanui Ignimbrite, between about 35 and 60m depth. At about 50m depth, thermal alteration to soft malleable clay has been pervasive. It consists of ~75% kaolinite, ~10% rectorite (50:50 illite-smectite) and ~15% silica (Opal-A). Once the elastic yield point is exceeded, this material will deform plastically at creep rates which decrease with the log of time. A hard silicified cap with "vuggy macro-porosity" bridges this soft zone at 33m depth. Failure of this thin 'bridge', as a result of underlying pressure drop due to declining groundwater levels, probably triggered the start of this subsidence event. Subsidence rates near the bowl centre (RM59) increased from 11 to 60 mm/yr between 1997 and 2001, peaked at 77 mm/yr in 2003, and reduced to 60 mm/yr by 2004. The total maximum subsidence has been 0.45m at RM59 since 1980. The 'shoulder' of the subsidence bowl has not shifted with time (since detailed monitoring commenced in 2002); this suggests that

it is laterally constrained by changes in formation properties rather than by laterally diffusing pressure changes from channeled down-flow of groundwater. Axially-symmetric 2D modeling of the bowl shape resulted in best-fitting depths of 32-45m, and a radius of 80m. Coupled fluid/compaction modeling fits the observed changes with time, using a 20m thick shallow layer of 25 $kbar^{-1}$ compressibility. The area surrounding the Crown Rd 'bowl' is also subsiding, but more uniformly (with negligible tilt or curvature) at rates that vary with time, up to 30 mm/yr. This can be attributed to wide-spread changes in consolidation of shallow formations as draining groundwaters vary in water level by about ±1 m due to changes in rainfall recharge. Water levels in the upper thermal groundwater aquifer of north-east Taupo (perched 30m above the relatively stable lake-level aquifer) have been declining for several decades, probably due to downflows in boreholes or pumped extraction. Increased decline rates since 1997 are associated with reduced rainfall recharge. Boiling water levels in THM11 (bowl centre), are at about 400m RL or 45m depth, similar to nearby bores THM1 and THM5, but 14m deeper than in THM9, located outside the bowl, 500m to the south-east.
Predictions of accumulated ground curvature (extensional or compressional strain and deformation), using observed level changes and reasonable future scenarios (rates declining over 8 years), are less than 0.12 mm/m/m, well below residential building code tolerances. Predicted maximum accumulated tilts at ~80m radius are less than 4.5 mm/m. Only a few properties near the centre or the shoulder of the 0.2 km^2 Crown Road bowl will experience curvature effects and possible minor distortion to rigid structures; the only observed effect within the bowl to date has been a 5 cm vertical kerb crack near RM59. Cases of damage reported at other buildings, along Invergarry Rd and Kotare Street, are outside the bowl, and mostly correlate with the presence of historically in-filled gullies. Such gullies commonly cause foundation problems of very shallow origin, such as uncompacted fill, sawdust, or thermal clay.

ORAL – geothermal workshop

MICROBES TO STONE: THE FULL SPECTRUM OF SILICEOUS HOT SPRING DIAGENESIS (OPAL-A TO QUARTZ), TAUPO VOLCANIC ZONE, NEW ZEALAND

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Detecting fossils in Precambrian sedimentary deposits on Earth or in hydrous minerals on Mars presents challenges because it is difficult to distinguish biogenic from non-biogenic attributes. Fundamental taphonomic, mineralising and diagenetic pathways in microbially influenced sediments from extreme environments still await characterisation. The Auckland University Sinter Programme is pursuing natural field growth experiments and high-resolution molecular-morphological-mineralogical studies of siliceous hot spring deposits (sinters) to assess such pathways at the nanometre to outcrop scales. New Zealand's sinter record is unique worldwide because it illuminates a continuum of silica mineral transformations from freshly deposited, noncrystalline opal-A to microcrystalline quartz over ~40,000 years. Moreover, some Pliocene sinters from the Coromandel rival the famous Devonian Rhynie Chert hot-spring deposits in their preservation. In TVZ thermal springs, silica deposits on all available substrates, both biotic and abiotic. Post-depositional changes include: (1) overprinting that can obscure primary environmental signals and (2) diagenesis accelerated by weathering or thermal effects. Taxonomic integrity of microbes and other biotic inclusions may be lost during the morphological changes that accompany mineralogic maturation.
XRPD and FESEM analysis reveals the full spectrum of morphologic-mineralogic transitions from opal-A to quartz, and identifies some of the factors controlling spatial and temporal variations in sinter diagenesis. Thermal fluids oversaturated in silica derived from deep reservoirs cool at the surface, depositing porous (polymeric) or vitreous (monomeric) opal-A. In porous deposits, fresh opal-A microspheres first develop micron-sized holes, become hollow, and then unfold into hexagonal silica platelets during transition to opal-A/-CT by solution-reprecipitation. In vitreous deposits, hexagonal silica platelets develop directly upon smooth surfaces. Platelets then group more tightly together and gather into clusters at up to 45˚ from original surfaces. Fuzzy, incipient bladed lepispheres accompany platelet clusters at the opal-CT/-A step. A typical, sharp-peaked opal-CT XRPD trace with tridymite shoulder is produced only when botryoids of bladed lepispheres emerge from the sinter matrix. Blades are aligned in bundles, which radiate at many angles from the opal-CT clusters. Transformation to opal-C involves reorganisation of blades at the micron-scale into rows of "pine plantations," which subsequently align themselves into strongly geometrical patterns. Elongation of these sharply angular, fibrous blades along incipient c-axes marks the opal-C/quartz transition. Further diagenesis yields stubby bipyramidal quartz

microcrystals. The mineralogy and morphology of sinter deposits at all scales is being continually modified by acid steam condensate overprinting, weathering and changes in discharge patterns. Hence we can monitor growth and alteration of hot-spring deposits, and construct more realistic diagenetic models for extreme environments, applicable worldwide.

ORAL – geothermal workshop

RELATIONSHIPS BETWEEN BACKARC RIFTING AND VOLCANIC STRUCTURES OF THE PROXIMAL ARC FRONT IN THE CENTRAL AND SOUTHERN KERMADEC ARC: INSIGHTS FROM NEW MULTIBEAM MAPPING

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Structural features of recently identified active submarine volcanoes of the central and southern Kermadec arc front and proximal Havre backarc are resolved from high resolution multibeam bathymetry data. Variations in fault orientations between backarc and massif areas and along the length of the system are used to investigate possible interactions between rifting of the backarc and the placement and structure of arc front volcanoes. Constraining the tectonic relationship between oblique rifting in the backarc and volcanism is pivotal to understanding the propagation of the active volcanic arc front.

The central Kermadec volcanic arc is represented by survey areas covering the Macauley caldera and nearby Giggenbach volcano, Havre caldera volcano, and part of a massif capped by Oliver and Speight satellite cones. Rift fabric of the Havre backarc is imaged in the two latter survey areas. In the Havre volcano survey area there is a clear division between backarc rift and the plateau on which the volcano lies. In the Oliver and Speight survey area this distinction is lacking and the massif is heavily dissected by rift-related faulting.

The southern Kermadec arc is represented by survey areas covering Haungaroa, Kuiwai, Ngatoroirangi, Sonne, Kibblewhite, Brothers, Healey, Silent II, and Rumble III volcanoes. The northern four of the above survey areas, along with the southernmost, Rumble III, show large stratovolcanoes rising from relatively deep seafloor, with sparse faulting. In between, continuous survey areas covering Kibblewhite volcano, Brothers caldera volcano, Healey caldera volcano, and Silent II volcano show dense rift-related faults around, between, and intersecting the volcanic edifices. To the west of the Kibblewhite survey area the backarc volcanoes Yokosuka, Rapuhia and Giljanes are also intersected by a zone of dense rift-related faulting.

Fault orientation analysis demonstrates that >50% of faults in the study areas strike NE-SW between N030˚E and N060˚E, around a peak at N047˚E. This is oblique to the orientation of the rift, which strikes at N020˚E, by a clockwise rotation of 27˚. The narrowest range of fault trace strikes is seen in regions of dense backarc rift fabric, while broader ranges occur around volcanic massifs. Where volcanoes and rifting co-exist, the placement of some volcanic edifices appears to correlate with termination of faults, shifts in the orientation of surrounding rift-related faults, and possibly offset of rift zones. This coincidence of volcanism and heterogeneity in the rift fabric suggests interaction between magmatic and tectonic processes along the arc front. Interactions that may explain the observed relationships are explored, including extrusion of magmas along rift transition zones and volcanoes acting as accommodation zones.

ORAL

DEEP-OCEAN RECORD OF TVZ VOLCANISM

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The evolution of the Taupo Volcanic Zone (TVZ) and its predecessor, the Coromandel Volcanic Zone (CVZ), is recorded in deep-ocean cores collected by Leg 181 of the Ocean Drilling Program. Cores from Sites 1122-1125, located E and SE of the TVZ, recovered up to 134 macroscopic tephra layers (Site 1124). Using palaeomagnetic, biostratigraphic, isothermal fission track and glass geochemical data, a chronology for the eruptives is established, with further refinement provided by a stable isotope record spanning the last 3 m.y. at Site 1123.

The overwhelmingly dominant rhyolitic tephras began accumulating ~12 Ma, about 1.6-1.0 m. y. earlier than previously documented for CVZ eruptives. The transition from CVZ to TVZ, timed from onshore studies at between ~1.90 and 1.55 Ma

(Briggs et al., submitted), probably equates to a brief cessation of major rhyolitic eruptions recorded offshore between 1.97 and ~1.7 Ma. Since that time, eruptions have been fairly persistent; an observation that is consistent with onshore studies of distal TVZ tephras. Either there were more major caldera-related eruptions than known previously or some eruptions were unrelated to caldera formation, or both. The frequency of TVZ eruptions, large enough to disperse ash 670 km eastwards to Site 1124, is 1 per 35,000 years. This general easterly dispersal prevailed through TVZ and CVZ time with only ~3% of marine tephra layers from eastern New Zealand having counterparts to the west of the country. Nevertheless, there is some long-term variability in wind strength and direction in response to factors including the reorganization of hemispheric wind belts, glacial-interglacial cycles, El Niño-Southern Oscillation cycles, the seasons and even changeable weather.

A preliminary correlation of tephras with the stable isotope curve from Site 1123, show that more than 70% of eruptions occurred during cold phases of glacial-interglacial cycles. While such a correlation may be skewed by the long cooling periods relative to the abrupt warm phases that terminated glaciations, new research (Mason et al., 2004) suggests a link between ice growth, crustal deformation and active volcanism, even on a seasonal scale. The marine record of TVZ and CVZ volcanism provides an opportunity to test that linkage.

Reference.

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ORAL

CONTEMPORANEOUS ERUPTIONS IN THE AUCKLAND VOLCANIC FIELD? EVIDENCE FROM A GEOMAGNETIC EXCURSION RECORD

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Absolute and relative ages for volcanoes in the Auckland Volcanic Field are poorly known, hence patterns of eruption and eruption frequency are poorly constrained. Recurrence intervals, a key parameter in quantifying hazard assessment, have been difficult to realistically estimate; tephra layers from recent drill hole data have provided the best constraints to date but as yet have not been related to specific volcanoes. Fortuitously, basalts from Aucklands volcanoes have recorded a geomagnetic excursion, which potentially provides a relative timing index of high sensitivity since rates of change of the geomagnetic field during excursions are likely to be high. Three volcanoes have previously been documented as sharing an identical anomalous magnetization direction, which has provided the only evidence which might suggest that a number of different volcanoes are closely linked in time. A further two volcanoes have been identified from aeromagnetic data as having magnetic anomalies consistent with such anomalous magnetizations. Paleomagnetic directions and intensities recorded by basalts from all five volcanoes suggest that they erupted during the same excursion event. The age of this event is unknown but Ar-Ar dating of these basalts is currently underway. Thus a strong temporal link, perhaps contemporaneity, is implied for these widely separated volcanoes which appear to be structurally unrelated. Even assuming normal rates of secular variation, the total time period for these eruptions might be only several hundred years, suggesting a recurrence interval much less than any currently estimated for the field and therefore having important consequences for hazard assessment.

ORAL

PHYSICOCHEMICAL TRANSIENTS IN WHITE ISLAND (NZ) FUMAROLIC EMISSION: HYDROLOGICAL INFLUENCES ON THE MAGMA-HYDROTHERMAL INTERFACE.

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White Island volcano (NZ) reawakened from a long period of quiescence in 1976 with the well documented series of phreatic, phreatomagmatic and strombolian-type eruptive events, and the formation of a large eruption vent complex extending to >100 m depth below sea level. Eruption activity continued intermittently through the 1970's and 1980's, and time series fumarolic data from Donald Mound discharges (proximal to the eruption vents) showed thermal and chemical transients which generally corresponded to eruptive phases of the volcano, and adjacent portions of the crater floor showed sympathetic variations in both ground deformation and magnetic field strength. Throughout this period, more distal fumarolic discharges showed few such changes, maintaining temperatures marginally above boiling point, and relatively constant compositions which were of a more "hydrothermal" character than those on Donald Mound.

The behavior of the distal fumaroles changed abruptly in the early 1990's. After a long period of crater floor subsidence and temperature decline on Donald Mound, the distal fumaroles began to show marked increases in the magmatic gas end-member component. Total non-condensable gas fractions (Xg) increased at this time, as did ratios of CO_2/CH_4, CO_2/S_t, SO_2/H_2S and N_2/Ar while discharge temperatures remained constant. Although transient in nature, and clearly caused by a degassing event within the volcano, the observed changes in these distal fumaroles were an uncharacteristic response to the degassing event and reflected a fundamental change in the state of the hydrothermal reservoir at depth.

TOUGH2 and CHEMTOUGH simulations have been carried out to help explain the possible chemical and hydraulic processes responsible for the observed effects. The modeled results suggest that draining of the hydrothermal reservoir fluids into the eruption crater complex through the latter 1970's and 1980's progressively lowered the piezometric surface of the reservoir brine fluids. This led to decreasing hydrostatic control by these fluids on the distal fumarolic discharges, thereby making them more susceptible to "breakthrough" of the magmatic end-member component during magmatic degassing events. The models predict that the thermal fronts associated with these breakthrough events would, in time, also migrate to the surface, with the fumaroles taking on thermal and chemical characteristics rather more like those previously observed on Donald Mound. However, recent declines in activity of the volcano have led to the development of a rapidly expanding crater lake in the eruption crater complex, and it is predicted that this will ultimately reestablish the original piezometric surface in the reservoir.

POSTER – geothermal workshop

A SELF-SUSTAINING KATABATIC WIND-DRIVEN ICE SHELF IN SOUTHERN M^C^MURDO SOUND, ANTARCTICA

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The southern McMurdo Ice Shelf (SMIS) has previously been considered an extension of the Ross Ice Shelf (RIS) into the McMurdo Sound region of Antarctica. Geophysical data collected between Black Island, Mount Discovery and Minna Bluff over two consecutive Antarctic field seasons (2002/2003 and 2003/2004), suggest, however, that the SMIS is a self-sustaining, katabatic wind-driven ice shelf, separated from the RIS by a strike-slip shear zone. The SMIS appears to be independent of the RIS in that it is not fed by ice across this shear zone. The SMIS is also distinguished from the RIS by the fact that there is significant ablation in this region, as opposed to the rest of the RIS, where accumulation is dominant.

There are few published glaciological studies relating to the SMIS and fieldwork reported here has supplied much of the primary data for the fundamental parameters of this ice shelf, including ice thickness, pinning points and flow characteristics. Ice thicknesses were obtained from seismic and GPR surveys along transects across the ice shelf. Thickening, reflecting net accumulation, is observed near the southern shores of Black and White Island, where the ice depth is up to 180 m. Thinning to < 50 m, from mid-shelf values of ~160 m, occurs on the SMIS toward the northern shore of Minna Bluff.

In the 2002/2003 field season, 36 marker poles were established in a 2.5 km-spaced grid over the SMIS, and these were positioned using differential GPS. These poles were subsequently resurveyed in the 2003/2004 field season, when a further 9 poles were added to the survey grid. The resultant motion vectors support sparse measurements made in the 1960s (Swithinbank, 1970), and indicate that the SMIS is moving ~2–7 m/yr; to the W/NW between Black Island and Mount Discovery, and to the W/SW south of Black and White Islands. A pattern of flow southwestward from the accumulation area south of Black and White Islands is supported by the identification of thrust sheets forming the coastal moraines along the northern shore of Minna Bluff.

Satellite imagery, topographic surveying with GPS, and GPR and bathymetry profiles have been used to determine the presence of a crater-shaped bathymetric high, upon which the SMIS is grounded. Located between the SW tip of Black Island and the northern coastline of Minna Bluff, and with a diameter of ~2.5 km, this feature appears to be a significant pinning point for the SMIS. Pinning at this mid-shelf position and from the surrounding coastline exerts a major control on the dynamics of the SMIS, stabilising the ice shelf in such a way that it is self-sustaining. The field data support a hypothesis that ice accumulates in aprons against Black and White islands, generating a gravitational flow in the direction of Minna Bluff, where the cycle is maintained by katabatic winds ablating the surface.

POSTER

GEYSER OBSERVATIONS AT ORAKEIKORAKO, NEW ZEALAND

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Orakeikorako geothermal field has long been known for its geysers and geothermal activity, with many written accounts dating back to the middle and late 19th century. Detailed mapping and description of the geology, hot springs and geysers was published by Lloyd (1972). With the Resource Management Act (RMA) of 1991, Environment Waikato Regional Council (EW) has a statutory authority to monitor the status and condition of geothermal fields within its jurisdiction. As part of this obligation, EW has a continuing program of observations and measurements in geothermal areas, which includes measured and recorded conditions of hot springs and geysers. Inspections are made routinely about every two months. Computer based records of data and recordings are maintained in addition to periodic reports on observations, changes and other issues that may impinge on the sustainable condition of these areas and features.

This paper gives results of geyser records from Orakeikorako through 1995-2004. It is not a complete summary of all geysers there and neither is it a complete analysis of all geyser data collected, but is a presentation of data for several geysers in some detail. In NZ, about 220 geysers existed in the early twentieth century but by 1980 only about 65 remained. During 1995-2004 about 35 geysers have been active at Orakeikorako, 10 at Rotorua and others at Waimangu (2), Rotomahana (5), Waiotapu (4) and Tokaanu (2). Human activity is directly implicated in all instances of loss.

Geyser activity records have been collected by use of a robust datalogger produced by SAPAC. These record temperature at programmed time intervals. Records do not depend on precise temperature recordings but do require clear detection of sudden temperature changes from ambient to very hot and back to ambient. The SAPAC units store 32 kilobytes of data, which equates to about 28,800 readings of date and temperatures. They are unloaded into a computer for data processing.

For detailed evaluation of each geyser, data has been processed to select a range of some 20-40 classes of time intervals. Most data has been graphed to show percentage of time for which activity occurs in each time class. Dormancies have also been analysed.

On Artist's Palette terrace, all known geysers there have eruptions lasting c. 5 minutes or less. This suggests that these geysers have only small volumes (<3 m3) of water available for discharge. Kurupai and Diamond geysers are located on faults away from Artist's Palette terrace and these two typically have much longer eruption times. Kurupai eruption averages are 12-20 minutes and Diamond can be 40-100 minutes up to 15-36 hours.

In this paper, geyser activity is analysed and presented. Earlier accounts of geyser activity at Orakeikorako are given by Lloyd (1972) and Allis (1983). More detailed eruption data and graphs are given in Annual Reports of Geothermal Monitoring to Environment Waikato for each year.

ORAL – geothermal workshop

CALDERAS OF THE CENTRAL TAUPO VOLCANIC ZONE, NEW ZEALAND

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We present the current state of knowledge regarding caldera evolution in the last c. 0.34 Ma in central Taupo Volcanic Zone (TVZ), New Zealand, based largely on 6 PhD studies at the University of Canterbury.

The oldest, Whakamaru caldera (c. 0.34 Ma), is a multiple collapse structure from which >1000 km^3 of ignimbrites have been erupted. The previously documented Maroa caldera is now considered largely a dome complex within the Whakamaru caldera. The four youngest calderas are far better exposed at the surface and better constrained in terms of structure and eruptive history. At least two major collapse events have occurred at Okataina, and further structures may be obscured by voluminous eruptives since 65 ka. Rotorua and Reporoa calderas are both single event structures on either side of TVZ, formed during emplacement of the c. 230 ka Mamaku and c. 240 ka Kaingaroa ignimbrites respectively. A newly identified Ohakuri caldera is postulated 25 km SW of Rotorua for the Ohakuri pyroclastic deposits, early airfall members of which were erupted synchronously with the Mamaku ignimbrite. Taupo caldera is a multiple collapse structure which may have first collapsed c.0.30 Ma, but with the most recent phases of collapse occurring at 26.5 ka to form the c.300 km^3 Oruanui ignimbrite and at 1.8 ka to form the c.30 km^3 Taupo ignimbrite. Central TVZ exhibits considerable variation in structure and eruptive history of TVZ calderas and significantly, temporal clustering of caldera volcanism. The stratigraphic and structural framework established by this research program is crucial to developing an evolutionary model for a multiple-source silicic field such as central TVZ.

ORAL

EROSION OF NEW ZEALAND AND MUD DEPOSITION OFFSHORE – CAN WE SEE ABRUPT CLIMATE CHANGE EVENTS?

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Erosion of the South Island of New Zealand contributes almost 0.7% of the total riverine sediment loading to the oceans per year. This figure is inferred to have been much greater during glacials. Past work has shown that during sea level highstands, the continental shelf around South Island acts to capture terrigenous sediments, and ocean currents transport the sediment northwards. However, during glacials the lowered sea level allows for sediment to bypass the shelf, and get deposited along the troughs and canyons surrounding South Island. Is this shelf-sediment capture pathway breached during decadal-scale abrupt climate changes?

This project aims to investigate whether short-lived, abrupt climate change events (some of which are evident in the New Zealand onland records) have also been recorded in marine cores, offshore South Island. The 3-fold increase in terrigenous input during glacial stage 2 diluted the carbonate production on the northern flanks of Bounty Trough. This, despite the glacial-outwash lakes acting as reservoirs/traps for the eroded sediment. We will also be investigating other sites at millennial resolution to determine if the events and timing of abrupt changes in terrigenous input are in fact evident over a wider area of the Bounty Trough and Campbell Plateau.

New core sites are being investigated off the west coast of South Island, with the aim of determining if the excellent east coast records from Bounty Trough are also available along the Hokitika and Haast Canyons. The West coast system is supplied by 3 of the 5 largest rivers in New Zealand with respect to sediment load. Presently fifty times more sediment is injected into this system than into the Bounty Trough as a consequence of the closer proximity of the Southern Alps source area and the lack of large natural lakes that trap up to 15% of the sediment yield to the east of the Alps. We suggest this high sediment loading would be exacerbated during glacial times.

If the Earth's response to abrupt climate changes is synchronous, then grain size changes linked to these events should match Northern Hemisphere records of abrupt change. If the hemispheres operate asynchronously, then this should also be evident in the grain size trends. Knowing this will contribute to climate change modelling and our understanding of the climate system.

POSTER

STRUCTURAL IMPLICATIONS OF RECENT WORK ON THE NORTHLAND ALLOCHTHON AND AUTOCHTHON.

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We present the results of geochemical and structural investigations of the autochthonous and allochthonous terranes in the Northland Peninsula. This work suggests that the major deformation events seen in Northland were a result of emplacement of the allochthon, and that although the area was affected by major regional tectonic events, such as the opening of the South Fiji Basin, these events did little to disrupt the allochthonous units.

Geochemical evidence and tectonic reconstruction suggest that the Mt Camel terrane and the Tangihua Complex were both formed during a phase of late Cretaceous subduction under the eastern Gondwana margin. The Mt Camel terrane was part of an active volcanic arc with both submarine and aerial volcanism. The Tangihua Complex formed to the east of the Mt Camel terrane as part of a juvenile submarine back-arc system. Dykes cutting the Tangihua Complex are geochemically similar to the Mt Camel volcanic suite indicating that the Mt Camel sequence is older than the Tangihua Complex.

Palaeomagnetic evidence indicates that the Tangihua Complex has moved around 200-250km from the northeast to its current location and was emplaced on top of both the autochthon and the Mt Camel terrane. Detailed structural mapping of specific localities within the Mt Camel terrane indicate that the complex may have been tectonically moved, however there is some evidence suggesting the sequence is in-situ. Deformation within the autochthonous sequences and the Mt Camel terrane are far more complex than the deformation seen within the Tangihua Complex. It appears as if the Tangihua Complex literally slid into place during the Oligocene (?) initiation of the Northland Volcanic Arc (~25-28Ma). Emplacement of the allochthon resulted in major structural disruption of the autochthonous pile and the quasi-autochthonous Mt Camel terrane. The Tangihua Complex itself is dismembered but individual sheets retain a high degree of coherence, are predominately upright, and show little of the deformational characteristics found in the autochthon. Earlier large-scale tectonic events, such as the opening of the South Fiji Basin, are recorded within the Tangihua Complex through the resetting of argon in feldspars and groundmass and probably indicated the initial phases of movement of the allochthon. These events are not recorded in the autochthon or the Mt Camel terrane due to metamorphism during the emplacement of the allochthon.

POSTER

LAUNCH OF "THE NEW ZEALAND GEOLOGICAL TIMESCALE" MONOGRAPH AND WALL CHART

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The geological timescale underpins all aspects of pure and applied geology, from resource exploration to hazard assessment to evolutionary studies. In recognition of this, the New Zealand Geological Timescale Project has sought to achieve precision and accuracy in the definition, calibration and international correlation of the New Zealand geological timescale using as wide a range of techniques as possible. Now, after nine years in the making, over 20 associated papers in peer-reviewed journals, and countless person-hours of painstaking work by 20 authors, the resulting timescale monograph has been published (Cooper 2004).

The monograph brings together, for the first time, comprehensive, integrated descriptions of each stage of the New Zealand geological timescale – original definitions and subsequent usage, biostratigraphy, and calibration and correlation to the international timescale. It also covers methodological, technical and philosophical aspects of timescale creation. Calibration and correlation of the local stages to the international scale has been an important focus of the New Zealand work and has employed a wealth of new geochronological, paleomagnetic, isotopic, geochemical, fission-track, tephrochronologic, cyclostratigraphic and biostratigraphic data. Correlations have been effected using graphical "integration diagrams" – an effective and visually instructive way to depict correlations and their uncertainties. During the latter stages of the New Zealand project, the authors have been working closely with authors of the new international Geological Time Scale 2004 (which is to be published shortly under the auspices of the International Commission on Stratigraphy – see http://www.stratigraphy.org), to ensure that we have used the most reliable combination of new calibrations on international stage boundaries or, where appropriate, have retained previously established, well-tested calibrations.

One exciting aspect of the new New Zealand timescale is the incorporation, for the first time in a regional timescale, of rigorous uncertainty estimates on stage boundaries. These have been calculated for all Cretaceous and younger stages using a numerical fitting procedure that takes account of individual components of stratigraphic, analytic, and correlation uncertainty. The calculated errors range between 1.1 and 0.06 m.y.; the corresponding errors on stage durations range from 0.9 to <0.05 m.y.

This presentation will review the science behind the New Zealand Geological Timescale and will be followed by the official launch of the monograph and associated, full colour wall chart. The launch will be celebrated in a manner befitting such an auspicious occasion.

Reference:
Cooper, R.A. (ed.) 2004: The New Zealand geological timescale. *Institute of Geological & Nuclear Sciences monograph 22*, ~270pp.

SPECIAL PLENARY

MODELLING LANDSCAPE EVOLUTION IN THE CENTRAL TVZ

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Landforms in the central TVZ reflect the competing influence of tectonic and volcanic processes. High eruptive activity has resulted in a heterogeneous crustal assemblage, and a complex history of basin evolution through episodic pyroclastic deposition and consequent drainage disruption, catastrophic flooding, and redeposition. Significant landforms include a series of half-grabens and associated normal faults, constructional lava domes and pyroclastic flows, caldera collapse structures and sedimentary basins. We divide these landforms into genetic classes: tectonic (largely extensional normal faulting), volcanic (ignimbrite sheet emplacement, lava dome formation, caldera collapse), lacustrine sedimentation, and drainage system erosion and deposition.

Landscape evolution is forward modelled by combining sudden constructional and deconstructional events with gradual rate-based processes in a time-step model from an assumed flat datum. Any widespread geological unit or feature with a near-horizontal surface can be used as a datum, including thick ignimbrites and lake terraces. The Waiotapu Ignimbrite (c.710ka) outcrops on both the NE and SW margins of the modern TVZ and represents a relatively old and approximate datum. The widespread Whakamaru Group ignimbrites (c. 330ka) form a 300-500m thick unit that mantles previous topography, producing a reliable datum. Constructional volcanic events are modelled by adding the isopleth contours to the prior terrain surface defined by these assumed datums. Deconstructional events (caldera collapse) are more difficult to model as their effect on stratigraphy is generally poorly constrained. Limited drillhole and geophysical data are used to constrain extent and depth of collapse. Tectonism is modelled on individual major faults using present-day slip rates and kinematic data. Blocks of strata are downthrown and rotated according to position changes on their bounding faults. Lacustrine units of the Ngakuru-Guthrie graben are formed by calculating a sedimentation rate and infilling basins to present day terrace elevations.

Outputs of the model are in the form of 3D digital terrain surfaces for specific stratigraphic units, and 2D rift-perpendicular cross-sections. Results to date include development of distinctive rounded scarp morphology and regular half-graben terrain. Modelling of drainage systems requires further examination of river terraces and may be implemented in an external modelling system. Significant wind gaps across the Paeroa, Te Weta and Puaiti-Whirinaki Blocks suggest a medium-sized river may have incised E-W across the region. Such a paleo-channel may provide interesting kinematic data on the tectonic evolution of the area, testable in the landscape evolution model. The NW-SE and W-E trending topographic lineaments may be related to reactivated basement structures, and are outside the scope of this modelling study.

POSTER

GEOLOGY OF WHITE ISLAND, SOUTHERN VICTORIA LAND, ANTARCTICA

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White Island is a uniquely basanitic volcano in a chain of Cenozoic volcanic islands that parallel the western edge of the West Antarctic Rift System. Glaciation and possibly landsliding has eroded the island, and the volcanic centre as shown by magnetic surveys, extends several kilometres further to the north under the ice sheet. Four main vent types were identified, lava-shields, maars, tuff-rings and tuff-cones, formed during a variety of eruption styles ranging from surtseyan to strombolian.

All but two flow-rock samples (a basanitoid and a tephriphonolite) are basanite. Based on major and trace element chemistry, about 80% crystal fractionation of the basanite occurred to produce tephriphonolite. All rock types are inferred to have resulted from small amounts of partial melting with the basanitoid resulting from slightly higher degrees of partial melting than the basanite. However, based on Zr/Nb ratios, all samples are cogenetic. The tuff-rings and tuff-cones comprise lapilli tuff produced during phreatomagmatic eruptions which have been subsequently transported and deposited by a series of hydroclastic base surges.

The basanites host xenoliths of spinel lherzolite, wehrlite, clinopyroxenite and variously metamorphosed gabbro. The occurrence of spinel lherzolite indicates that the partial melts may have originated in the spinel lherzolite stability zone (25-60 km). Whole rock geochemistry on the gabbros indicates that they originated as cumulates, not of their host magmas, but from an evolving alkaline magma possibly associated with rift-related volcanism of the McMurdo Volcanic Group.

Based on paleomagnetic dating, the basanites were found to be at least 0.78 my old, approximately four times the age of the single previous K-Ar date of 0.17 Ma (Kyle 1981). The extended age range is more compatible with lithospheric flexure models in the area which imply volcanic loading occurred between 1.4 Ma and 11 Ma (Aitkin 2003), and indicates that the island was active for a minimum of 0.6 my.

The island occurs in an area of the West Antarctic Rift System, the Erebus Volcanic Province (EVP) interpreted as being a transtensional accommodation zone. This section of the rift boundary is marked by a change in orientation of the Transantarctic Mountains, and has acted as a tectonically separate block to the rest of Victoria Land for the last 800 my. During that time, the area that is now the Erebus Volcanic Province experienced two main tectonic regimes, the Neoproterozoic to Ordovician Ross Orogeny and the plume-related Cenozoic West Antarctic Rift System. At both times the area is associated with distinctly alkaline magmatism. Geophysical and modelling data indicate that the crust beneath the EVP is very thin (~ 20 km) and that Cenozoic uplift was probably localised to Southern Victoria Land, a possible contributing factor to the extensive alkaline basaltic magmatism.

POSTER

TAYLOR VALLEY LAKE SEDIMENTS AS INDICATORS OF CLIMATE CHANGE

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Lake Joyce and Lake Bonney are both proglacial to Taylor glacier. Analysis of lake waters and sediments shows both lakes have undergone recent lake level rises unrelated to the climatically driven rises seen in other lakes, suggesting the advance of Taylor Glacier is the dominant factor. Ice penetrating radar measurements of Taylor Glacier thickness show a huge submarine depression linked to the Ferrar Fjord which is the probable source of evaporate mineral deposition with aragonite, calcite, halite, hydrohalite and gypsum phases, often with several minerals coexisting. At times varve like deposition occurred and appears to be driven by annual freezing/evaporation cycles from an ice free hypersaline lake.

POSTER

EVALUATING A 2-D GRANULAR-FLOW NUMERICAL MODEL FOR PREDICTION OF LAHARS FROM CRATER LAKE AT RUAPEHU

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For the forecasting of hazards from mass flows, such as future lahars at Ruapehu, numerical modelling approaches are providing an ever increasing potential. A series of 1-D hydrologic models and 2-D geophysical mass flow codes are now available. While it is tempting to use many of these techniques in a "black-box" fashion; it must be recognised that current codes are, for many good reasons, a significant abstraction from reality. We report here on the ongoing evaluation process of a promising new "thin-layer grain flow" code, Titan2D; that offers the possibility to forecast travel times, inundation areas and dynamic routing of a variety of mass-flow events. We have used a dataset of real world lahar observations gathered from historical lahar events in the Whangaehu River, which includes: travel times, inundation areas, discharges and instantaneous velocities for various flow volumes. This dataset enables the calibration of internal parameters involved in the numerical code calculations. In the case of Titan2D, the most important parameters include:

- The location of a starting "pile"
- The height, x-y dimensions and total volume of the pile
- The angle of "internal friction" within the pile
- The angle of "basal friction" with the substrate digital elevation model
- Surface maps to alter basal friction over a flow path
- DEM quality and calculation-mesh density.

The basic assumptions made using this method include that the flow begins with a "fully-bulked" volume and a granular-flow rheology. At present, the model does not allow addition of volume to the flow via erosion – the key process by which Crater Lake outburst floods gather sediment and transform to lahars. This basic method is more suited to "dry" mass flows, such as debris avalanches and block-and-ash-flows, but given the right combination of parameters it appears to simulate the flow properties of a fully-bulked Whangaehu lahar fairly well. Pile height and initial properties are critical to generate a realistic initial discharge out of the low-point in the Crater Lake rim for a lake-breakout simulation, but it is simple to generate "eruption" outflows by producing high initial piles with highly fluid properties. Directed outbursts are simulated by altering pile orientations and basal dimensions. To emulate an ever-increasing sediment concentration and hence rheology change in Ruapehu lahars with distance in the first 10 km of flow passage, surface maps allow the alteration of the basal friction angle, but this approach has yet to be fully calibrated. The main limitations so far discovered include the high sensitivity of the process to the precision and construction method of the digital elevation model, and the propensity of the code to generate very thin (cm-scale), high-velocity layers which spread rapidly and become volumetrically significant in longer simulations. These issues will be considered in ongoing revision and improvement of the Titan2D code, along with the incorporation of erosion functions that enable the flow volume to be changed with distance.

ORAL

A DEEP-MARINE PERSPECTIVE OF THE MID-PLEISTOCENE CLIMATE TRANSITION IN NEW ZEALAND

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The Mid-Pleistocene transition (MPT) at c. 900-600 ka marks a fundamental reorganization of the global climate system from a world that for the preceding 30 million years had been dominated by 41 kyr oscillations in polar ice volume, to a 100 kyr climatic beat coincident with the development of much larger northern hemisphere ice sheets.

ODP Site 1123 on the Chatham Rise, 1100 km east of New Zealand, affords a range of high-quality marine climate proxies spanning the MPT. Time series analysis shows the proxy data to be strongly coherent at 41 kyr (obliquity) and 100 kyr (eccentricity) orbital frequencies. The amplitude of the 41 kyr spectra decreases up core across the MPT and at the same time the amplitude of the 100 kyr spectra increases. This largely occurs between glacial terminations MIS-22 (870 ka) and MIS-16 (620 ka).

The high-resolution planktic foraminiferal record of Site 1123 across the MPT, displays marked variations in warm- and cold-water indicator species at Milankovitch-scale periodicities. The dominance of subantarctic foraminiferal taxa during glacial phases implies periodic expansions of cold southern-sourced surface water and/or injections of cold-southern sourced subsurface water over Site 1123, which is coeval with intensified deep-water inflow into the Pacific Ocean reported by Hall et al. (2001 – Nature). Glacial terminations are punctuated by millennial-scale influxes (spikes) of shallow-water subtropical foraminiferal taxa, coeval with a decrease in subantarctic taxa. This is interpreted as a winding-up of low-latitude circulation and an intensification of the East Australian Current, similar to the present-day circulation pattern.

Modern analogue estimates of surface-water temperatures based on planktic foraminifera show four periods of differing glacial-interglacial (G-I) temperature variability across the MPT; first, a period of decreasing temperatures at glacial-maxima before glacial termination MIS-20 (790 ka); second, a transitional period of climatic amelioration and decreasing G-I temperature variability, culminating in a climatic optimum during the MPT, near MIS-15 (~570 ka); third, a short period of rapidly decreasing temperatures at glacial- and interglacial-maxima, with an abrupt increase in temperatures at glacial termination MIS-12 (420 ka); and last, the period up to the present that includes gradually decreasing temperatures at glacial- and interglacial-maxima. The reliability of MAT sea-surface temperature estimates has not yet been tested, although the long term trends of G-I temperature variations co-vary with other marine proxies, and with perturbations in the Pacific deep-water inflow record.

ORAL

A MESOZOIC CRUSTAL SUTURE ON THE GONDWANA MARGIN IN THE NEW ZEALAND REGION

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Marine crustal multichannel seismic data were recorded offshore South Island, New Zealand, from R/V Ewing as part of the 1996 SIGHT geophysical investigation of the Southern Alps continental collisional orogen. These data also provide a transect across part of the pre-break-up Gondwana margin in the New Zealand region. Upper mantle seismic reflectivity off western South Island has been interpreted in terms of a north-dipping paleo-subduction zone underlying the central West Coast. A similar lower crustal-upper mantle feature is imaged in seismic reflection data off south-eastern Stewart Island, and, if related to the same paleo-suture, would indicate that this structure has an orientation sub-parallel to the former Gondwana margin and to the present Paleozoic and Mesozoic terranes in South Island. The inferred suture lies approximately along the southern margin of the Median Batholith but its detailed relationship to this feature and the other terranes is uncertain. The preferred interpretation is that it is related to the docking of the Brooks Street oceanic island arc terrane to the Gondwana margin in the Triassic. The formation of the large granitoid bodies forming the Median Batholith, the large amount of vertical uplift to expose the bodies, and the large degree of Tertiary horizontal deformation of the region, may be expected to have left a discernable signature in the seismic data, but none is unequivocally observed. Seismic reflectivity in the lower crust east of Stewart Island and southeast South Island has a divergent and step like character that is interpreted to be caused by duplexing in the lower crust as a result of continental compression, and may relate to the boundaries of the various terranes that accreted to this part of the Gondwana margin during the Mesozoic. Alternatively, the reflectivity may be imaging the residual effects in the lower crust of granite formation.

POSTER

MARINE SEISMIC REFLECTION PROFILING OF THE AUCKLAND REGION

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Marine seismic reflection profiling of the Waitemata Harbour – Rangitoto Channel – Tamaki Strait – Firth of Thames region was undertaken in 2000 using a Uniboom sound source and in 2002 using a mini-GI airgun sound source. Processing of this data is almost complete and interpretation is now underway. The data quality is generally very good with the boomer source revealing detailed sedimentary structure in the upper 50 m beneath the seafloor and the airgun revealing horizons down to at least 500m.

The seismic reflection data reveal the glacial drainage valleys and subsequent sedimentary infill as well as the bedding structure of the underlying Waitemata Group Sandstones. Extensive faulting is imaged within the Waitemata Group sandstone and overlying sediment with some of the faulting extending through the interpreted upper post-glacial sediment to the seafloor. Faulting and exposed basement grain can also be recognised in Navy swath bathymetry from the Rangitoto Channel – Waitemata Harbour region. Volcanic flow and intrusive deposits are generally interpreted on seismic records by their reflection character and emplacement pattern. Fault motion breaking the seafloor is imaged between Auckland and Devenport, both on Uniboom seismic reflection records and on the Navy swath bathymetry data. Motion on this fault can be correlated with vertical displacement of a strong, generally flat-lying reflection horizon, visible on airgun seismic reflection records c. 400 m beneath the Waitemata Harbour. This displacement is most likely related to volcanic uplift and intrusion.

Seafloor displacing faults northeast of Motutapu Island can be correlated with fluid (gas/hot water?) discharge into the sea imaged on the seismic records. Similar fluid discharge points are identified within the Firth of Thames. Airgun seismic data from this latter area reveal east-dipping sedimentary horizons broken by numerous faults up-thrown to the east. A number of these faults extend to the seafloor. A structural high (Rawson 1983 etc.) lies down the centre of the Firth of Thames.

ORAL

INVESTIGATIONS OF MASSIVE SULPHIDE MINERALISATION ALONG THE KERMADEC ARC: NZAPLUME PROGRAMME, 1999-2004

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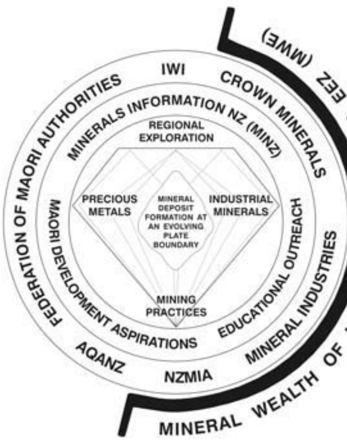
From modest beginnings as a PGSF joint tender project with NIWA in 1998, research into the mineral potential of New Zealand's Exclusive Economic Zone has progressed into a major multi-dimensional, multidisciplinary and widely collaborative component of GNS's newly funded 6-year 'Mineral Wealth of NZ and its EEZ' Programme (MWE).



Over the previous six years, in excess of $5.5M has been expended (including construction by GNS of the MINTS oceanic chemical analyser), and a further $10M+ leveraged via overseas collaborations. Key amongst these has been NOAA (USA) whose scientists have contributed hugely to research cruises, as well as subsequent analysis and publication. German, Japanese, Korean and Australian involvement has also been valuable.

The 1999 NZAPLUME I cruise was the first research expedition to systematically locate, and chemically characterise, submarine hydrothermal vents associated with arc volcanoes of the southern part the Kermadec-Tonga intra-oceanic arc system. This was followed by the 2002 NZAPLUME II and 2004 NZAPLUME III cruises to the mid- and northern-sections of the Kermadec arc, respectively. Combined, 1,400 km of the arc has been mapped, including 60 major volcanoes and numerous subordinate volcanic edifices making this the longest continuous stretch of intra-oceanic arc to be surveyed for hydrothermal emissions. Most of the volcanoes are simple cones although 25% are caldera volcanoes, and compositions range

from basalt through rhyodacite. Results from the NZAPLUME I and II cruises show 16 of the 26 major volcanoes surveyed are hydrothermally active, a 60% frequency of venting. Depths to venting range from 120 to 1,650mbsl. The hydrothermal plumes range widely in composition, both between and within individual volcanoes.
Over the next 6 years the MWE programme will focus on better understanding the Kermadec-Tonga magmatic and hydrothermal system and assessing its mineral potential. Submersible expeditions involving Japan's *SHINKAI6500* (late 2004) and USA's *PISCES V* (early 2005) will provide important vent fluid, mineral, rock and biological samples for analysis. It is hoped that exploratory drilling may also take place in the near future, thus providing core material to reveal further secrets of this hitherto poorly explored and understood oceanic environment.

POSTER

EVOLUTION OF ARC-TYPE VOLCANOES: INSIGHTS FROM THE PYROCLASTIC RECORD

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Evolution of volcanic systems can be understood through analysis of the deposits of their eruptions. Their deep workings can be accessed by chemical studies of erupted materials (igneous petrology) and their shallow and surficial workings by studying the physical characteristics of erupted deposits (physical volcanology).
Andesite strato-cones can be described in terms of two main domains, a cone-building facies and a ring plain facies. The deposits of each of these two facies are assembled on different time scales and contain different parts of the record of the evolution of the magmatic system that gave rise to them. An important consequence of this is that different parts of the geochemical record of the system can occur in different parts of the volcano. Petrological studies tend to concentrate on the lava flow sequences of the constructional cone whereas the less durable, and less easily sampled pyroclastic record of the ring plain facies is the domain of tephra stratigraphers. For a complete picture of the evolution of an andesite volcano, information gained from these two facies needs to be integrated. Our focus is on the nature of the pyroclastic record and the information it can provide about the petrological and volcanological evolution of arc-type volcanoes. Our objective is to develop a methodology in which effusive and pyroclastic materials contribute to an understanding of the petrological and eruptive evolution of andesite volcanoes through time. We have chosen Mounts Ruapehu and Rainier volcanoes because they have similar volcanological and petrological characteristics and show a good record of recent eruptive activity.
The young (< 20 Ka) tephra sequences at Ruapehu and Rainier define temporal change in the magmatic systems that produced them, and trace changes in the conduit architecture that demonstrably correlate to styles of eruptive behaviour. Pyroclastic geochemical and physical data detail a complexity of system behaviour that is not evident in the effusive lava record, but which is crucial to developing a paradigm for andesitic volcanism. As a working hypothesis, the detailed behaviour of active andesite magmatic systems can be linked to tectonism, crustal environment and magma supply.

POSTER

INVESTIGATING ASEISMIC SLIP BENEATH THE RAUKUMARA PENINSULA, NORTH ISLAND, NEW ZEALAND

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In October 2002, an aseismic slip event of 20–25 mm magnitude was observed on two continuous GPS (CGPS) instruments near Gisborne. This event was the first of its kind to be documented with CGPS in New Zealand. Since October 2002, smaller aseismic slip events (of 4–8 mm magnitude) have been recorded on CGPS stations near Gisborne and Hastings. We combine these recent CGPS records with campaign GPS data, and regional seismicity data to help constrain the spatial extent and slip parameters of the Gisborne 2002 aseismic slip event and to examine whether such events may have occurred on the northern Hikurangi margin in the past. With this study, we hope to achieve a greater understanding of the role aseismic slip plays in accommodating relative plate motion on the northern Hikurangi margin, and thereby enable more accurate assessment of the seismic hazard posed by this subduction zone to New Zealand.
We have analysed nearly ten years (1995–2004) of campaign GPS records from the Raukumara Peninsula and use station position time-series to identify the transient behaviour expected during an

aseismic slip event. The large October 2002 aseismic slip event is not obviously discernible in any of the campaign time-series indicating that such events may occur on a more regular basis than previous geodetic data have revealed. Using spatial constraints estimated from the time-series, we apply a forward model to the October 2002 event. The model suggests that the aseismic slip event involved approximately 20 cm of reverse slip on the Hikurangi subduction interface offshore of Gisborne. We also attempt to model the smaller events recorded on both the Gisborne and Hastings CGPS instruments. We are currently analysing broadband seismic records for low-frequency tremor that has been found in association with the aseismic slip events on other subduction zones worldwide. We will also investigate a possible correlation between the October 2002 aseismic slip event and an anomalous seismic swarm above the Hikurangi subduction margin offshore from Gisborne. By evaluating the available GPS and seismicity data sets together, we are able to re-evaluate existing models of deformation for the northern Hikurangi margin, and propose new models that allow for the occurrence of aseismic slip.

ORAL

STRUCTURAL AND HYDROTHERMAL INFERENCES FROM A MAGNETOTELLURIC SURVEY ACROSS MT. RUAPEHU, NEW ZEALAND

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Magnetotelluric measurements have been made at 27 sites on and around Mt. Ruapehu and analysed using the phase tensor technique of Caldwell et al. (2004). Phase tensor analysis is an effective way of determining the dimensionality of the data and allows for distortion removal in areas where the underlying 2-D assumption is inappropriate. A major benefit of the phase tensor approach is the clear visualisation it provides of which frequencies are influenced by different structures. The phase tensor analysis of the MT data clearly indicate that although locally the near surface structure at some measurement sites may be 1-D, the electrical structure associated with Mt. Ruapehu is primarily 3-D in nature. In broad terms this arises because of the different scales of effect of the major factors influencing the MT data. At high frequencies, where the skin-depth is small local 1-dimensionality predominates at many of the sites. With increasing period structure associated with the volcanic massif as a whole start to have a significant effect, particularly on the data measured at sites close to the mountain itself. At the longest periods more regional structure associated with the tectonic structure of the North Island as a whole appear to have a dominating influence. It is also probable that in areas where significant electrical conductivity contrasts exist local 2-dimensionality is exhibited over at least some frequency bands. Examples of this latter effect seem to be associated with the Waimarino Fault and along the eastern margin of the TVC where greywacke outcrops.
Limited 1 and 2-D modelling suggests the existence of a conductor beneath the eastern part of Ruapehu. Resistivity values of 20-30 Ωm suggest that this conductor is most likely to be associated with wet volcanic debris rather than indicating the existence of Tertiary sediments. 2-D modelling is unable to resolve if the conductor extends across the western TVC boundary. On the summit of the mountain there is evidence for the existence of a shallow hydrothermal/volcanic system. 3-D modelling of the data at longer periods would be necessary to further elucidate any deeper magmatic system.

ORAL – geothermal workshop

MANTLE TECTONICS OF A PLATE BOUNDARY: THE NORTH ISLAND OF NEW ZEALAND

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We constrain the extent of lithospheric and asthenospheric deformation by measuring and modelling anisotropy in the North Island of New Zealand through shear wave splitting of teleseismic waves, petrophysical analysis of mantle xenoliths and finite-element modelling of the mantle deformation in a back-arc spreading environment. We use seismic data collected on the GeoNet broadband stations deployed between 2001 and 2004 and a portable deployment in the Northland region. The results for the eastern part of the North Island confirm the earlier pattern. The fast directions are roughly NE/SW, which is parallel to the strike of the Hikurangi subduction zone. In the north of the North Island, two stations present back-azimuthal dependence of the splitting

parameters. This dependence suggests a broader and more complex anisotropic effect, such as a dipping axis of symmetry or multiple layers, might be present beneath New Zealand, influencing the measurements on a regional scale. Results from the Northland deployment suggest that splitting from SKS phases decreases as the effects of present plate boundary deformation weaken and allow us to quantify the extent of the plate boundary deformation zone.

The petrophysical analysis of mantle xenoliths from the Raglan (North Island) region allows us to constrain the lithospheric contribution to the observed seismic anisotropy. The spinel lherzolites analysed represent mantle material from depths shallower than 75 km and temperatures in excess of 1000°C up to 1150°C. Their extraction ages are less than 2 Myr. The maximum intrinsic anisotropy on the S-wave measured, 3.5%, seems too low to explain the delay times. This indicates that asthenospheric deformation plays the major role there. Through modelling of the lithospheric deformation, derived from surface deformation rates, in the North Island transtensive Central Volcanic Region, we will compare the anisotropy values obtained from the xenoliths to the modelled regional values derived from geodetic movement rates.

POSTER

NEW 1:50000 GEOLOGICAL MAP OF MASON RIDGE-MARAEKAKAHO AREA, CENTRAL HAWKE'S BAY, EASTERN NORTH ISLAND

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An area of about 300 km^2 has been mapped in central Hawke's Bay as part of an MSc research project investigating the stratigraphy and sedimentology of a Late Pliocene limestone-bearing succession. This has resulted in a new 1:50 000 scale geological map, which is illustrated in the associated poster presentation. The geological map is underpinned by a GIS database, which has structure and specifications similar to the QMap (GNS) guidelines (Rattenbury & Heron 1997).

The Mason Ridge-Maraekakaho area of Hawke's Bay to the west of the Raukawa Range and to the south of the Ngaruroro River, is underlain by an interbedded, variably cyclothemic carbonate-siliciclastic succession. Historically, the relationship of this succession to the Petane Group exposed immediately north of the Ngaruroro River has not been known and a significant fault has been suspected along the river channel.

The stratigraphy of the mapping area includes the following formations, which young towards the west: Te Onepu Limestone (Mangapanian); Makaretu Mudstone (Mangapanian), Mason Ridge Formation (lower Nukumaruan), Taradale Mudstone (lower Nukumaruan), Park Island Limestone (upper Nukumaruan), Okauawa Formation and Poutaki Pumiceous Formation (upper Nukumaruan); and Salisbury Gravel (Castlecliffian).

Formations typically dip at 2-12° southwest. The Mason Ridge Formation differs from the other units in that it has been gently folded into a series of asymmetric anticlines and synclines, with shallow dips (2-4°), the eastern limbs being steeper and also offset by a series of faults strike NE-SW.

The results of this project together with those of a related study to the north of the Ngaruroro River by Bland et al. (this volume) confirm the existence of a fault along parts of the Ngaruroro River, which separates lower Nukumaruan formations to the south in Mason Ridge from upper Nukumaruan formations north of the river in the Matapiro area. We infer that Mason Ridge is underlain by an east to southeast-dipping thrust fault (Maraekakaho Fault), the leading edge occurring along the western side of Mason Ridge more-or-less along SH50. The fault is not exposed because it is overlain by the Okauawa Fmn, which onlaps older Mason Ridge Formation. Maraekakaho Fault also has a west-east trace, buried by Recent Alluvuim, along SH50 beneath the prominent northern margin of Mason Ridge. Towards the east this fault may splinter into two traces, one having a more northerly strike and passing to the west of Roys Hill, while the other passes to the south of it, to explain different structural levels of the stratigraphy at the surface in Roys Hill versus Mason Ridge, and versus the Matapiro area. We envisage the Marakakaho Fault as having displaced the Mason Ridge block to the west or northwest during the middle of the Nukumaruan (after accumulation of Park Island Limestone and before accumulation of Okauawa Formation), thereby building topography, on to which younger formations lapped from the west. This deformation is the most western expression of the development of the inboard margin of the modern accretionary prism, and defines a triangle zone.

POSTER

CRETACEOUS CRINOIDEA IN A TERTIARY CUL-DE-SAC

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The Late Triassic extinction event was the last to impact greatly upon the evolution of New Zealand crinoid taxa. New Zealand Jurassic and Cretaceous radiations, and those of the Cenozoic have been gradual in comparison to those of the Triassic when contrary to global records crinoids reached their zenith in numbers and diversity.

A lack of appropriate facies precluding crinoid collection in the Early Cretaceous of New Zealand, neither confirms nor denies claims for an Aptian mass extinction or the evidence of a modest late Cenomanian extinction. New Zealand Millericrinina appeared Late Triassic, survived the Jurassic, occur late Cretaceous to survive the K-T extinction event and remain extant. As in Europe the Isocrinina dominated Cretaceous faunas at generic level. Sessile, benthic Bourguetacrinina appeared in the Northern Hemisphere Middle-Late Cretaceous, as they did in New Zealand. All New Zealand Cretaceous genera are either Cosmopolitan or Tethyan, and all Late Cretaceous species are endemic, possibly due to provincial radiation and/or geographic isolation.

The Cretaceous-Tertiary extinction event does not appear to have directly affected New Zealand crinoid diversity. Sparse, but conclusive evidence suggests that New Zealand Late Cretaceous genera survived into the Tertiary (e.g. *Isselicrinus*, *Neilsenicrinus*, *Isocrinus*, and *Apiocrinites*). Basal New Zealand Danian fauna is marked by a complete absence of hard-ground taxa, indicating a pioneer community capable of directly colonising a soft benthic substrate, typical of the New Zealand Continental Shelf today. Instead of a major, catastrophic K-T boundary extinction event, New Zealand crinoids appear to have steadily declined in both generic and species diversity from the Late Cretaceous (Piripauan) until Mid- to Late Palaeocene when a significant faunal turnover appears to have taken place, particularly at generic level.

The appearance of hybrid stalked genera in the Paleocene (e.g. *Metacrinus* (Isocrininae), *Phrynocrinus* (Bourgueticrininae), and Hyocrinus (Millericrininae)) ushered in the faunal mix of most modern deep-sea crinoid populations, including that of New Zealand. Genera and species existing in the Cretaceous reduced to a greatly diminished diversity in the Paleocene, with crinoid form and function remaining largely unchanged – supposedly unable to change – entered a 'Tertiary cul-de-sac'. The main evolutionary thrust involving isocrinids, bourgueticrinids, millericrinids, and comatulids radiated from those Cretaceous and Paleocene genera in the Tertiary to continue in New Zealand to the present day.

ORAL

IMAGING THE TRANSITION FROM ALEUTIAN SUBDUCTION TO YAKUTAT COLLISION IN CENTRAL ALASKA, WITH LOCAL EARTHQUAKES AND ACTIVE SOURCE DATA

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In central Alaska, the rapid subduction and active volcanism of the Aleutian subduction zone gives way to a broad plate boundary zone with mountain building and strike-slip faulting, where the Yakutat terrane joins the subducting Pacific plate. We are imaging the 3-D velocity structure using the abundant local earthquakes, which occur to 200-km depth, supplemented by active source data. Both permanent AEIC (Alaska Earthquake Information Center) stations and temporary BEAAR (Broadband Experiment Across Alaska Range) stations are included. Low velocity in the upper crust correlates with the Cook Inlet and Copper River basins. The relatively high-velocity slab and low-velocity mantle wedge are readily observed. Lower velocity mantle underlies the active volcanism in contrast to higher velocity mantle of the relatively undeformed southwestern Alaska area further inboard of the arc. Underlying volcanic systems, high Vp/Vs in the mantle is consistent with partial melt and depths are similar to those inferred petrologically. The Denali fault is a dominant feature with a large change in crustal thickness across the fault. In the region north of Cook Inlet, a low-velocity, high Vp/Vs zone overlies the high-velocity slab to over 100-km depth and may represent the underthrust Yakutat terrane, consistent with BEAAR receiver function and attenuation results. The subduction of thick crust in central Alaska at the end of a subduction zone is similar to the northern South Island of New Zealand.

ORAL

QMAP WAIKATO: THE NEW 1:250 000 GEOLOGICAL MAP OF THE WAIKATO REGION

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A pre-publication version of the new 1:250 000 geological map of the Waikato region is presented. The map covers 11 000 km^2 of western North Island from Rotowaro in the north to just south of Taumarunui, and east to the edge of the central North Island volcanic plateau. It includes the offshore area up to 100 km west of the coast. Up to 7000 m of Late Cretaceous to Quaternary sedimentary and volcanic rocks are mapped in the offshore area, overlying Mesozoic basement terranes and plutonic intrusives of the Median Batholith. In contrast, a relatively thin Late Eocene to Quaternary sequence of sedimentary and volcanic rocks is mapped onshore, overlying basement rocks of the Murihiku and Waipapa (composite) terranes. Some of the significant changes from the earlier series of 1:250 000 maps are highlighted.

Late Eocene and Oligocene rocks of the Te Kuiti Group are mapped in greater detail, particularly north of Kawhia Harbour. Mapping of Miocene rocks in the southern part of the map is substantially revised to be compatible with new stratigraphic architecture developed for Taranaki Basin (King & Thrasher 1996) and the King Country Basin (Kamp et al. 2004). Rocks of the Wai-iti Group west of Herangi High are correlated with rocks of the Mahoenui, Mokau and Whangamomona groups to the east.

With the assistance of Colin Wilson (GNS), a new formation-based schema for mapping ignimbrites has been adopted, rather than continuing with volcanic genetic terminology that has been used previously. The schema distinguishes all the major silicic eruptive episodes in the central North Island and their associated deposits. QMAP Waikato includes four of these new formations, within the early Quaternary Pakaumanu Group that erupted from the Mangakino Volcanic Centre. The formations are regional landscape forming units that include ignimbrites and fall deposits otherwise unmappable at this scale.

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POSTER

SIMPLIFIED MODELS OF THE ALPINE FAULT SEISMIC CYCLE: BEHAVIOUR OF THE SHEAR ZONE IN THE LOWER CRUST

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The Alpine Fault of New Zealand is thought to fail in large earthquakes with a recurrence interval of a few hundred years (Norris and Cooper, 2000). Recent GPS repeat campaign measurements (Beavan et al., 1999) and results from a profile of continuous GPS measurements (Beavan et al., 2004) have shown how strain is accumulating across the Southern Alps and Alpine Fault, with about 25% (9 mm/yr) of the ca. 40 mm/yr oblique relative motion across the plate boundary taken up by orthogonal shortening near the Alpine Fault. Inversion of the interseismic velocities using elastic dislocation models suggests that part of the observed signal is due to slip on a localized dipping shear zone beneath the Alpine Fault, with the remainder of the surface motion originating from a deeper source (Beavan et al, 1999, 2004; Moore et al., 2002).

We examine the expected elastic and inelastic strain accumulation and release across the Alpine Fault using a finite element model which incorporates full elastic, viscous, and frictional behaviour. Investigations of the nature of deeper deformation that controls the broader falloff in surface velocity suggest that it cannot have a wavelength of more than about 100 km. A zone of elevated ductile creeping is predicted below the fault, whose position roughly coincides with a high-conductivity body imaged in magnetotelluric data (Wannamaker et al., 2002). This creeping zone controls the shorter-wavelength feature seen in the GPS velocities at the surface. We show that (1) spatial variations in elastic strength (as derived from seismic inversions) do not significantly influence the deformation on seismic timescales; (2) seismic faulting can load the lower creeping shear zone and may contribute to localization in lower crustal flow; (3) additional thermal weakening, due to long-term advection and exhumation of rocks along the Alpine Fault, is required in order to explain the shallow depth of creeping and elevated creep rates below the Alpine Fault several hundred years after an earthquake; and (4) a weakened shear zone helps to reload the fault, i.e. stress is passed back and forth between upper and lower crust. Model surface velocities show a transient response after faulting that lasts ca. 100 years, with fairly constant velocities after this time until the next faulting event occurs.

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ORAL

THE EFFECTS OF MAGMA BENEATH TAUPO: MODELS CONSTRAINED BY OBSERVATIONS FROM PAST ERUPTIONS AND PRESENT GEOPHYSICS

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Catastrophic, caldera-forming eruptions represent a major volcanic hazard in the Taupo Volcanic Zone of New Zealand and worldwide. We combine geological information from the past behaviour of magma bodies beneath Taupo caldera, and geophysical information on the present state of the crust in the Taupo region, in order to model a rapid (hypothetical) inflation event as well as the effects of long-lasting partial melt in the magmatic system that underlies Taupo volcano. We use information derived from geochemical studies of the 26.5 ka rhyolitic Oruanui eruption to constrain maximum magma body size and geometry. These studies indicate that the magma body prior to eruption had a minimum volume of 530 km^3, a depth of ca. 5-10 km, and had grown and matured over ca. 40 kyr (Wilson et al., submitted).
We use two- and three-dimensional numerical models to investigate: (1) what are the main signals of inflation of an Oruanui-like body on surface deformation and changes in stress? (2) How do these signals depend on inherited crustal structure, regional stress levels, and elastic/viscous/plastic crustal rheology? (3) How would a quiescent but partially molten region interact with regional extension tectonics? (4) Would a weak magma chamber of Oruanui dimensions cause episodicity in fault slip in the surrounding region?
Preliminary results for inflation models indicate that a moderate inflation pressure of 10 MPa building rapidly in the weeks to months prior to eruption of an Orunaui-sized body would cause several metres uplift at the surface. The pattern of uplift is more sensitive to the ellipticity of the magma body than to the thickness/width ratio of the body, but this pattern may be altered by near-surface strength variations due to caldera fill and/or weak faults. A roughly circular caldera structure with weak elastic strength can mask the ellipticity of the underlying magma body by focusing uplift and deformation near its boundaries. Two-dimensional models including regional stresses and faults predict that the proportion of extension taken up by fault slip near the surface can increase in response to emplacement of a weak, partially molten body in the mid-crust, although fault slip may actually decrease at greater depths.

POSTER

ZINC/SILICON RATIOS OF SPONGES: A NEW PROXY FOR ESTIMATING CHANGES IN THE EXPORT OF ORGANIC CARBON TO THE SEAFLOOR

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Reconstruction of past carbon export events can be difficult. Most proxies for carbon export suffer from problems related to remineralisation and diagenetic effects above, at and below the sediment-water interface. Here we show that the zinc content of deep-sea sponge silica is correlated to sediment particulate organic carbon (POC). Such a relationship suggests that zinc incorporated into siliceous sponge spicules is from zinc associated with particulate organic matter 'raining down' from overhead waters. The dissolved zinc pool does not appear to be a major zinc source to deep-sea sponges. In addition, other parameters such as water temperature and pressure do not seem to influence zinc incorporation into sponge silica. These results suggest that the zinc to silicon ratio (Zn/Si) of deep ocean sponges will serve as a useful proxy for reconstructing past POC export events. To investigate this, sponge spicules were isolated from sediment cores located on and to the east of the Campbell Plateau (46–52S; 168E–179W) and their zinc content determined. At present, algal production in overlying subantarctic waters is low and is largely controlled by irradiance and the availability of iron and silica. The Zn/Si results obtained for spicules picked from these cores suggest that the amount of organic carbon reaching the seafloor during glacial times was similar to the present day. This implies that variations in surface productivity in this subantarctic region are unlikely to have been major contributors to the reduction in atmospheric CO_2 seen during glacial times. Such a finding is comparable to previous work carried out in this sector of the Southern Ocean.

POSTER

STRUCTURAL COLLAPSE OF A TRANSPRESSIVE HANGING WALL FAULT WEDGE, CHARWELL SECTION OF THE HOPE FAULT, NE SOUTH ISLAND

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The NE trending dextral-reverse oblique slip Hope fault is one of the major structures of the Marlborough Fault Zone and the Australia-Pacific plate boundary zone in the South Island. This study presents an analysis of the structural and tectonic geomorphic development of the Hope fault zone in the vicinity of the Charwell River. Our key objective is to understand the near-surface temporal and spatial structural style of deformation and fault zone kinematics along a 10 km section of the fault. Paradoxically, the transpressive rangefront setting includes a collapsing internal fault zone wedge in the lower hanging wall, superbly expressed in the structurally-driven geomorphic landscape.

Significant fault-related landscape units include: 1) flights of aggradation-degradation terraces in the footwall forming an extensive piedmont; 2) fault dissected, sloping topography in the hanging wall containing 95% of all the faults; and 3) eroded sub-horizontal piedmont terrace remnants that indicate the rangefront has repeatedly propagated to the SE into the footwall block.

We recognise four distinct types of fault scarps: 1). The main rangefront trace of the Hope fault defines a releasing bend geometry, with a projected step-over width of ~1000m; 2). At the foot of the rangefront two thrust faults ramp over the aggradational surfaces in the footwall block; 3). In the toe of the hanging wall block, ~20 normal fault scarps are mapped near-parallel the main Hope fault; and 4). More than 100 late normal faults oblique to the main Hope fault, and cutting obliquely across all other faults. The overall fault pattern outlines an initial fault wedge between the thrust and early normal faults that is 5 km in length, 1 km at its widest point and tapers in a westerly direction to 200 m in width. A secondary wedge defined by the late normal faults is 7 km in length, 2 km at its widest and overprints the initial wedge. The structural/geomorphic interactions between the initial and secondary fault wedges developed in a series of at least four successive stages.

These spatial and temporal changes in the structural geometry and style of deformation of the Hope fault zone at Charwell are interpreted to reflect the role of topographic loading in adjusting the fault zone break-out along the rangefront, and is recorded by the world-class tectonic geomorphic landforms there.

ORAL

LONG-TERM SEISMOGENESIS AND THE 2004 LAKE ROTOITI EARTHQUAKE SEQUENCE

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The Lake Rotoiti earthquake sequence of July, 2004, can be added to some sixty major events in California, Greece, Italy, Japan and New Zealand, ranging in magnitude up to 8.2, which together indicate that earthquakes are governed by self-organized criticality (SOC). The Lake Rotoiti sequence was preceded by a typical precursory scale increase of seismicity, starting on 24 October 2002. This marked the onset of the long-term seismogenic process. SOC phenomena display the property of scaling. Accordingly, the parameters of the seismogenic process – the level of the increased seismicity, the area occupied, and the duration – all scale with the mainshock magnitude. Moreover, the level of the increased seismicity is equal, on average, to that of the aftershocks.

A sub-class of major events, to which the Lake Rotoiti sequence belongs, is the multiple-mainshock event. In such events, the several largest earthquakes have about the same magnitude, which is substantially larger than the next largest. In New Zealand, prominent events of this kind have occurred previously in N Hawke Bay (1976), near Lake Tennyson (1990), and at Hawks Crag (1991). Multiple mainshock events have dominated the recent seismicity of Italy. In the Lake Rotoiti sequence the mainshocks were of magnitude 5.4, 5.0 and 5.0, and the largest aftershocks were of magnitude 4.4, 4.1 and 4.1. For this kind of event, the scaling relations refer to the largest mainshock.

Triggering by small effects is another feature of SOC phenomena. Final triggering of the Lake Rotoiti sequence can be attributed to the latest of the precursory earthquakes, but may also have involved the exceptionally heavy rainfall that occurred in the area at the time.

SOC fully explains the occurrence of each major earthquake event without reference to any cyclical repetition of similar events. This renders redundant the concept of the seismic cycle, which has dominated thinking about the earthquake phenomenon since 1911. SOC can now replace the seismic cycle as the central principle of seismogenesis.

ORAL

TRANSITION FROM TARARUA RANGES TO WANGANUI BASIN: AN ACTIVE SEISMIC STUDY OF THE SOUTHEASTERN BOUNDARY OF THE WANGANUI BASIN

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The Wanganui Basin is located between the south Taranaki Basin and the axial ranges of the North Island. The Wanganui Basin is a region of broad crustal down-warp with reverse faulting. The Basin is of Plio-Pleistocene age, with sediments directly over Mesozoic basement. The structure is defined by gently dipping sediments towards the depocenter and these sediments are cut by NE-NNE-trending faults which are generally downthrown towards the basin. Furthermore, the depocenter of this basin has moved and continues to move south-southwest, driven at least in part by the Quaternary uplift and doming of the central North Island.
The onshore part of the basin is known only from scattered geophysical surveys and a few exploration wells. This study is directed to find out more about the structure of the southeastern boundary between the Wanganui Basin and the Tararua Ranges. Therefore, an active seismic line has been carried out, that ran from Peka Peka Beach along Peka Peka and Hadfield Road and into the foothills of the Tararuas. Also gravity measurements were taken along the same line. First results from both methods indicate the depth of the basement to be around 300-500m. Tomography results from the seismic refraction data show a low velocity layer right under the surface which thickens to 150-200m towards the mountain range. The velocity of this layer is around 1km/s and is interpreted by means of drill hole data as sand and peat. The deeper layer has a velocity between 2 and 3km/s and is also interpreted as marine sediments. The basement dips slightly to the east. Furthermore, the results show shallow faulting and a late Cenozoic structural deformation of the subsurface. A high angle fault disrupts the basement under Highway 1. Another two high angle fault structures can be seen in the middle of Peka Peka Road in a distance of around 1 km. It is highly likely that these faults are still active.

POSTER

THE APPLICATION OF HIGH RESOLUTION SEISMIC REFLECTION SURVEYING TO GROUNDWATER EXPLORATION, NORTH CANTERBURY

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Shallow seismic reflection P-wave surveying is capable of delineating sedimentary architecture related to groundwater resources. In the fluvial sediments of the thrust controlled Omihi Valley high permeability pathways and aquitard (low permeability) units can be differentiated, and be applied to understanding groundwater resource in the Valley. Methodologies used to identify aquifer units in the Late Quaternary sediments of Omihi Valley using shallow seismic reflection surveying, include:

- Combined geological mapping, seismic surveying and borehole logging to define medium scale (10m-2 km) structures and lithologies which affect aquifer/aquitard location and extent;
- Tailored 2D and 3D shallow seismic reflection surveying to define sedimentary unit architecture within the larger scale sediment packages, and delineating high porosity/permeability pathways such as paleo-channels; and
- Changes in seismic reflection attributes directly reflect sediment changes in permeability and porosity, such as the decrease in interval velocity with reduced matrix clay/silt content.

The main research outcome achieved in the 33 km^2 Omihi Valley study is that by integrating geological mapping and geophysical surveying with lithological borehole logging, a groundwater resource model is developed, allowing a predictive approach for the exploration and utilization of the resource. The research demonstrates that high resolution shallow seismic reflection P-wave surveying is capable of delineating subsurface sedimentary facies, including hydrologically important unit architecture, down to sub-two metre vertical resolution for the fluvial and shallow marine derived sediments in the 20–500m depth range. The sub-surface paleo-sedimentary units successfully delineated in the Omihi Valley study include paleo-channels, channel fill, floodplain surfaces, and alluvial fans.
Aquifer/aquitard contrast in the Omihi Valley survey is not characterised by porosity, but by permeability differences (which is also affected by porosity). Aquifers are saturated high porosity/permeable sediments with low silt/clay content, while aquitards are saturated units with low permeability which, in this study, appear to be controlled by silt/clay content, not low porosity. P-

wave seismic reflection surveying is shown to be insensitive to sediment permeability variations, while limited data from the Omihi Valley indicate that seismic P-wave velocities may be sensitive to matrix clay/silt content. If proven elsewhere in Canterbury, this may lead to a preferred method for defining aquifer/aquitard geometry directly, without the need to use indirect methods such as paleo-fluvial facies architecture delineation.
Shallow seismic reflection surveying is capable of characterizing sedimentary lithofacies architecture, near-surface structural deformation, and delineate the main groundwater resources, as part of a multi-faceted investigation program. Further research is required to determine if direct aquifer geometry identification is possible by seismic P-wave interval velocity inversions and to increase seismic reflection acquisition speed to allow efficient coverage of large areas.

POSTER

A 250 YEAR RECORD OF ENVIRONMENTAL CYCLICITY IN THE OHAU CATCHMENT – A SEDIMENTARY AND PALAEOMAGNETIC STUDY

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Environmental magnetic methods were used to determine the environmental history recorded in sediment cores (L – 1407 and L – 1408) collected from the bed of Lake Ohau, South Island, New Zealand. Fluctuating magnetic intensity in both cores exhibits 100 year periodicity interpreted to originate from palaeoclimatic cycles. Small magnetic intensity fluctuations possibly reflect El – Nino and La Nina cycles. Stratigraphy in both cores mainly comprises of varves which provide a means for dating changes in environmental processes. Turbidites at 810 mm and 1810 mm in sediment core L – 1407 closely correlate with palaeoseismic events during September 1888 in North Canterbury and rupture of the Alpine Fault during 1717, respectively. Inclination and declination obtained from the processed data exhibits secular variation. From the constructed age models sediment cores L – 1407 and L - 1408 have a mean sedimentation rate of ~ 8 mm/yr and ~ 7 mm/yr, respectively.

POSTER

EXAMINATION OF MARINE SEISMIC REFLECTION DATA FOR THE OCCURRENCE AND DISTRIBUTION OF GAS HYDRATE ON THE CONTINENTAL MARGIN OF FIORDLAND, NEW ZEALAND

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Evaluation of seismic data on the Fiordland margin reveals a widespread zone of Bottom Simulating Reflections (BSRs) east of the incipient subduction zone. BSRs are most commonly used to infer the presence of gas hydrates in marine sediments. We have compiled the distribution of gas hydrates on the Fiordland margin based on the occurrence of BSRs in an extensive database of seismic data, acquired by academic, government and petroleum research cruises over the last 30 years. BSRs can be recognised by a negative reflection-coefficient that occurs at the boundary between shallow sediments that contain gas hydrate and deeper sediments storing free gas. Further, it is characteristic for BSR structures to follow isotherms which are nearly parallel to the morphology of the sea floor.
Because methane is the prevalent enclosed gas in hydrates, it becomes an important agent of climate change in the case of fast destabilisation of the hydrates. We present seismic observations that suggest that hydrate instability, due to a change in water temperature and/or of hydrostatic pressure, may cause subsea landslides on the continental slope - perhaps triggering tsunamis. Thus, evaluation of the distribution of gas hydrates can contribute to natural hazard prevention.
The interest in gas hydrates as a possible resource is increasing due to the vast energy potential of methane, even though the engineering challenges of producing methane from gas hydrates are daunting. Based on the distribution of BSRs, it is therefore possible to calculate the resource potential in the gas hydrate province off Fiordland.

POSTER

PRELIMINARY RESULTS FROM A PALEOSEISMIC INVESTIGATION OF THE WAIMEA-FLAXMORE FAULT SYSTEM, NELSON, NEW ZEALAND

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Geomorphological mapping and trenching of the Waimea-Flaxmore Fault System up to 20km southwest of Nelson provides new evidence for surface-rupturing earthquakes over the last ca.

20kyr. The fault system is characterized by a zone of sinuous reverse faults and westward verging fault-propagation folds along the eastern edge of the Waimea Plains. In places reverse faults coincide with the base of the range front, while at the Wairoa River late Pleistocene aggradational river terraces, Holocene degradational river terraces and alluvial fans are deformed. Within the ranges, east of the Waimea Plains many discontinuous active fault traces were mapped and often record normal displacements with uphill-facing scarps. To date there is no unequivocal evidence for strike slip in the Waimea-Flaxmore Fault System.

The most compelling evidence for the timing of prehistoric earthquakes on the Waimea-Flaxmore Fault System is present where the active trace crosses terraces on the south bank of the Wairoa River. Here we have dated offset terraces using seven C^{14} and two OSL samples extracted from two trenches across the fault and two pits on the terrace surfaces. Collectively the data suggest a minimum of two events and a possible maximum of three or four events on the fault trace over the last ca. 16-20kyr. The oldest of these events post-dates cessation of aggradation of the Last Glacial Maximum terrace (estimated age 18±2kyr) and predates degradation of this surface ca. 16.3±1kyr ago. C^{14} dates from displaced and undisplaced peat beds in one of the trenches and from an undeformed degradation terrace bracket the last rupture event between 5018±35 cal. yrs BP and 5924±44 cal. yrs BP. This timing is consistent with data from a third trench15 km northeast of the Wairoa River, near Bishopdale, which suggests that the last surface-rupturing event predates 3897±35 cal. yrs BP.

The Last Glacial Maximum terrace surface is vertically displaced in a reverse sense by 4±1m along a fault which locally dips at 30-70^{o} south east. If the terrace surface is 18±2kyr in age then the vertical slip rates on this strand are ca. 0.2±0.8mm/yr. This slip rate may reflect average recurrence intervals of 4-10kyr and vertical slip/event of ca. 0.5-2.5m.

POSTER

TEMPERATURE ESTIMATION AROUND THE CONDUIT OF THE 1990-95 ERUPTION AT UNZEN VOLCANO BY NUMERICAL SIMULATION

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A conduit drilling (Well USDP-4) has been completed in 2004 in the Unzen Scientific Drilling Project (USDP). Some conduit materials of the 1990-95 eruption have been obtained at the bottom of Well USDP-4 (-150 m sea level), and the bottom temperature of 180 ^{o}C was estimated by using the logging data, although the temperature of about 700 ^{o}C had been inferred before the drilling. Accordingly, the evaluation of possibility of the conduit cooling from the initial temperature (850 ^{o}C) to the observed temperature (180 ^{o}C) was conducted by the numerical simulation.

The numerical model proposed by Fujimitsu and Kanou (2003) was used for the initial model in this study, and revised by using the new information obtained from the conduit drilling. The N-S width of the conduit of the latest eruption was confirmed as about 20 to 30 m in the conduit zone of about 300 m, which includes the conduits of the past eruptions, by the drilling. However, the conduit width in the initial model was 100-300 m, which had been estimated by the result of seismic survey data. Therefore, the revised model has a conduit of 25 m width in the conduit zone of 300 m width in N-S direction. Two cases were calculated for the conduit width in E-W direction (100 and 300 m), because there is no information for the width. In the simulation, the cooling process of the conduit, which has the initial temperature of 850 ^{o}C, from 1995 (the end of the eruption) to 2004 (completion of the conduit drilling) was calculated, and the temperatures of the conduit and the surroundings at -150 m sea level were monitored.

To begin with, the permeability of the mountain body was fixed at 1 mdarcy and that of the conduit zone was set as a parameter and the values of 1, 10, 30 and 50 mdarcy were assigned. However, the temperature of the monitoring area was not sensitive to the permeability of the conduit zone and showed higher than the observed data. Therefore, the permeability of the mountain body was also treated as the parameter, and the same value with the conduit zone was assigned. As the result, the temperature of 180 ^{o}C was obtained near the conduit of the monitoring area under the permeability conditions of 10 mdarcy and 30 mdarcy in the case of the conduit width of 100 m in E-W direction.

References:

Fujimitsu, Y. and Kanou, R. (2003). Numerical modeling of the hydrothermal system in Unzen Volcano, Japan. *Proc. 25th New Zealand Geothermal Workshop 2003*, 173-178.

ORAL – geothermal workshop

SEISMIC POTENTIAL OF A COMPRESSIONAL INVERSION PROVINCE, NW SOUTH ISLAND, NEW ZEALAND

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In the NW South Island of New Zealand, large historical earthquake ruptures (1929 Murchison M7.7 and 1968 Inangahua M7.2) have dominant components of reverse slip. At the surface, active reverse faulting occurs along closely-spaced (10-20 km apart), N-S to NNE-SSW trending faults continuous over >150 km, and dipping 50-80º both east and west. Some of the high-angle faults are inherited from Cretaceous extension, and have been subsequently inverted, consequent on right-lateral shearing and transpression on the Alpine Fault since the early Miocene. However, the deep geometry of these faults, their penetration into the basement and their relationship to the Alpine Fault are poorly understood. These problems have been addressed by reconstructing structural contours at the base of the Oligocene carbonate sequence for the whole northwestern margin of the South Island. This represents a convenient strain marker, because it was deposited close to sea level, is extensively preserved on land, and is a prominent high energy reflector in seismic lines.
Since the early Miocene shortening of the Oligocene sequence has produced sets of N-S folds with wavelength < 10 km. Crests of anticlines range in elevation from 1000 to 3000 m asl, whereas troughs of synclines are as low as -2000 m bsl. Large vertical displacements are partly accommodated by reverse faulting (throws < 3000 m), and partly by bedding-parallel slip along the steep limbs linking anticline-syncline pairs. Shortening calculated from section restoration is highly variable, ranging from < 10% up to 30%. These estimates represent a minimum because large-scale detachments of the cover sequence are likely accommodated by blind thrusts that ramp across the crystalline basement and follow layer-parallel trajectories along detachment horizons. Large-scale bulk shortening of the sedimentary sequence occurs between two basement buttresses. The eastern basement block is bounded by the subvertical to steeply E-dipping Alpine Fault. The western margin is a complex basement high that can be followed all along the coast line, bounded by a segmented system of interconnected high-angle inverted normal faults and low-angle thrusts dipping both east and west. The overall style of deformation is suggestive of strong components of crustal shortening to the west and in the footwall of the Alpine Fault, accommodated by inversion of high-angle normal faults in the basement, folding and detachment of the sedimentary covers, and propagation of new, low-angle thrust faults, that cut across the early structures and the detached folds.
Nucleation of seismic ruptures in the basement at depths of ~10-15 km may therefore lead to distributed deformation in the near-surface. Conversely, large seismogenic faults that have not ruptured in the past 200 years may be concealed beneath thick detached portions of the cover sequence.

ORAL

PLEISTOCENE TECTONIC ACTIVITY ALONG THE SOUTHERN MARGINS OF THE DEAD SEA RIFT, SOUTHERN ISRAEL

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The Dead Sea Rift (DSR) is a NNE trending geological structure, running from the Gulf of Aqaba to northern Syria. The Arava Valley, the Negev and Edom Mountains are located in the southern part of this rift. Horizontal and vertical displacements have taken place along this structure, between the Arabian plate and the Israeli/Sinai subplate since the Miocene. The current climate in this area is extremely arid.
During the Pliocene the central Arava Valley and the southern Negev were part of a continuous westward declining terrain that drained toward the central Negev.
Three different kinds of tectonic activity took place during the Pleistocene in the Southern Negev and Central Arava valley. Each one of them influenced the drainage systems in a different way:
1) Left-lateral displacement (15 km) resulted in significant basin changes. Two Pliocene channels on the western side of the rift valley were disconnected from their catchments. Likewise a few of the large alluvial fans in the Arava valley were cut off from their feeding drainage basins. The resulting average long-term rate of movement is 0.3-0.75 cm/year.
2) Normal fault activity caused vertical movement along the margins of the Rift Valley. These faults along NE-SW tectonic lines caused the formation of blocks that became the main control of the present drainage system in the margins of the rift valley. The Pliocene regionally wide drainage system evolved into local basin systems with new valleys. Local continental and lacustrine sediments were deposited in these valleys.
3) The southern Negev plateau tilted eastward regionally by 2^0. This tilting happened gradually and cause reversal of most of the streams in the southern Negev. Red paleosols developed in the alluvial sediments and were found to be a good indicator to the intermediate stage whereas the inclinations were zero in the valleys.
By reconstructing the different stages of the landscape evolution we can find close relationships

between the structural development of the DSR and the different stages of evolution.

ORAL

GEONET UPDATE: CORE CAPABILITY AND BEYOND

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After three years the GeoNet project has reached an important milestone with almost all of the core national geological hazards monitoring and data collection coverage in place. This includes the national seismograph, strong motion and CGPS networks. During the last year the number of operational broadband National Seismograph Network stations increased from eight to 35 (of the 38 funded sites), and the LINZ funded PositioNZ CGPS network increased from mainly North Island coverage to only two short of the target of 30 sites. The core National Strong Motion Network, which was completed in 2002, continues to grow slowly by the addition of utility and locally funded sites.
Progress continues to be made on the regional geophysical networks (seismic and CGPS) used to monitor and collect data in regions of enhanced hazard such as above the subduction zone and in the volcanic regions. New volcano gas sampling techniques have been introduced, and the use of satellite radar to monitor the Auckland volcanic field has moved from experimental to routine.
A major achievement of the last year has been the re-establishment of the National Seismograph Network as a modern broadband network with Internet Protocol satellite based data communications. This was delayed for more than a year when our original satellite communications provider pulled out of the contract to provide the service and we were forced to find an alternative. The network stations continuously record six components of ground motion (three high-gain velocity sensors and three low gain accelerometers) and have significant amounts of onsite data storage and power backup so that data is not lost if the communications network is down.
The emphasis of the GeoNet installation programme now shifts to regional monitoring and data collection with the extension of the Wellington Geophysical Network up the east coast of the North Island, continuation of the upgrade of the volcano-geophysical networks, and the start of the installation of the Canterbury Strong Motion Network. More downhole strong motion and building arrays will follow, as well as remote volcano-chemistry monitoring.
The establishment of the core GeoNet capability has improved the timeliness and accuracy of felt earthquake information and the surveillance of New Zealand volcanoes and other geological hazards. A large amount of high quality data is being recorded for research into New Zealand's tectonic environment and natural hazards. The GeoNet web site (www.geonet.org.nz) continues to be the portal for GeoNet data and information. Enhancements in the last year have included better maps of recent earthquakes, improved access to the earthquake catalogue and online forms for reporting the felt effects of earthquakes. Additionally, the entire collection of New Zealand strong motion data has been made available.

ORAL

ANIMATED GRIDDED PLATE-KINEMATIC RECONSTRUCTION OF THE SOUTHERN PACIFIC AND ITS TECTONIC IMPLICATIONS

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Accurate plate-kinematic reconstructions at relatively high spatial and temporal resolution are the basis for understanding the opening of ocean basins and the evolution of seafloor relief and the effect it has had on controlling deep ocean current directions. We developed an animated, grid-based plate-kinematic reconstruction of the southern Pacific Ocean from 90 Ma to present, using the satellite-derived gravity anomaly field, and interpolated isochrons and plate rotation parameters from both published and new studies using marine geophysical data.
The earliest opening with formation of seafloor between Chatham Rise (New Zealand) and Thurston Island (West Antarctica) occurred at 92-90 Ma along a Pacific-Antarctic plate boundary developing along the Bounty Trough and Great South Basin of New Zealand. The break-up between Campbell Plateau and Marie Byrd Land began at 83 Ma. The onset of an independent motion of the Bellingshausen Plate adjacent to the West Antarctic margin can be estimated at 79 Ma. Its motion generated a transpressional eastern plate boundary. The Pacific-Bellingshausen spreading centre developed a set of long offset transform faults (e.g. Udintsev, Tharp, Heezen) that the Pacific-Antarctic plate boundary inherited around 61 Ma when the Bellingshausen plate ceased to move independently as part of a Pacific-wide plate tectonic reorganization event. Southwest of these transforms, the Pacific-Antarctic Ridge saw an increase in transform-fault segmentation by about 58 Ma. At about 47 Ma, the Pacific-Phoenix Ridge

jumped northward to directly link the Pacific-Antarctic ridge to the Pacific-Farallon ridge as a result of an unstable Pacific-Antarctic-Phoenix triple-junction configuration. Further reconstruction time steps illustrate the development of the dominant transform and fracture zones systems in the South Pacific.

ORAL

BASEMENT GEOLOGY AND MINERALISATION OF PRESQU'LLE BRÉAUTÉ (TREBLE MOUNTAIN PENINSULA), SOUTHWEST FIORDLAND, NEW ZEALAND.

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Southwest Fiordland, contains Mesozoic and Paleozoic granitoid plutons and smaller late stage mafic bodies in an arcuate belt extending from Dusky Sound to east of Puysegur Point. In Preservation Inlet, Cretaceous plutonic rocks intrude Ordovician basement rocks of the Preservation Formation. Base metal vein mineralisation hosted in Cretaceous granite occurs at the old Tarawera Mine site. Preliminary geochemical analysis of the Early Cretaceous Revolver Pluton and the younger Treble Mountain Granite in Preservation Inlet shows no obvious correlation with known New Zealand suites. The Revolver Pluton is coeval with the Median Suite and older Rahu plutons (Tulloch, per com.), but it has distinct trace element chemistry. Similarities in geochemistry are noted to granodiorite from Lake Hauroko in Eastern Fiordland, though dating suggests a difference in age of c.20 m.y. Geochemical variation in the Revolver Pluton may be explained by fractionation processes and requires the division of the Revolver Pluton into two plutons with distinct magma evolution. In addition, modelling suggests that Sr/Y ratios change with fractionation and may not be a robust discriminant for defining magma suites. REE patterns imply a source within the garnet stability field for both the Revolver Pluton and Treble Mountain Granite, similar to the Separation Point Suite. The Trevaccoon Diorite intrudes the Revolver Pluton, though its relative age relationship to the Treble Mountain Granite is not constrained. Enrichment of REE in the Trevaccoon Diorite possibly indicates a more enriched source than the Revolver Pluton or Treble Mountain Granite.

Initial geochemical analysis of the Preservation Formation suggests a correlation with the eastern Buller Terrane, which supports faunal correlations by Park (1922) and Cooper (1979). Geochemical similarities between the Preservation Formation and the Aorangi Mine and Leslie Formations allows for a direct correlation and more accurate positioning within the eastern Buller Terrane stratigraphy. These preliminary geochemical correlations for the Preservation Formation, may prove useful in subdividing this extensive unit.

Work to date suggests the Tarawera Mine contains Cretaceous mineralisation of likely magmatic origin. Most mineralisation studies to date have concentrated on Westland-northwest Nelson, with little comprehensive work conducted on correlative rocks of southwest Fiordland. The Cretaceous host importantly precludes a correlation with the Silurian-Devonian mesothermal mineralisation of the region, and implies a magmatic origin related to Cretaceous magmatism in the region. The mineralisation potentially represents a previously undescribed low-sulphidation epithermal base metal deposit; a style not well documented in the Western Province, and thus has implications for future exploration models in the Western Province proximal to Cretaceous magmatism.

POSTER

SEISMIC CHARACTERISATION OF THE NORTH OTAGO SEDIMENTARY SUCCESSION NEAR HERBERT

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The sedimentary succession exposed in coastal North Otago is a much thinner onshore continuation of that present in the offshore Canterbury Basin. Between Palmerston and Oamaru, onshore Cretaceous and younger sedimentary rocks overlie a narrow basement platform that rarely extends more than 12 km inland from the coast. The base of the sedimentary succession is marked by a nonconformable contact with the Otago Schist. In general, older terrestrial units grade upward into marginal marine, then marine units; formations dip toward the southeast and the total thickness of the succession rarely exceeds 1 km at the coast.

Locally, the North Otago succession is quite variable: many of the terrestrial or marginal marine units change in thickness, lithology, or environment of deposition over very short distances; the Waiareka (Eocene) and Deborah (Oligocene) volcanic units appear locally as sills and dykes; and local faulting is often significant. Many of these observations were apparent in an earlier seismic data set acquired by the New Zealand Department

of Scientific and Industrial Research in 1988. However, the acquisition and processing methods utilised with these data failed to image much of the more subtle stratigraphic complexity of the region. Our major goal was to collect new seismic data with significantly greater resolution at depth in order to more accurately interpret facies variations within and between formations.
Participants in the University of Otago 2004 Geophysical Field School – part of the required coursework for students taking the second- and third-year geophysics paper in the Department of Geology – collected geophysical data in the gently rolling countryside between Herbert (~20 km south of Oamaru) and the coast. Data collected include approximately 3.5 km of seismic reflection data using a combination of sources (hammer and buffalo gun), 6 km of gravity profiling, and 9 km of magnetic profiling. The seismic data set was the first to be collected by the University of Otago's new Seistronix RAS-24 48-channel seismograph. Also, a new high-resolution buffalo gun seismic source makes use of 12-gauge blank cartridges detonated approximately 80 cm beneath the surface. The dual source types add complexity to the processing of the data; the successful procedure followed using GLOBE *Claritas* will be detailed in this presentation. The gravity and magnetic data sets have both been used to constrain the final seismic interpretation of the succession imaged between Herbert and the coast.

ORAL

USE OF ATMOSPHERIC ^{10}BE FOR QUANTIFYING SEDIMENTARY PROCESSES

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Cosmogenic ^{10}Be, continuously generated by spallation reactions with oxygen and nitrogen in the atmosphere, travels rapidly to the Earth's surface via precipitation, and accumulates in soils and marine deposits. With a half-life of c. 1.5 m.yr., this isotope has the potential to date sedimentary processes younger than 12-15 Ma. Its strong attraction to mineral surfaces makes it also a useful tracer for determining relative sedimentation rates. Three examples illustrate well the value of atmospheric ^{10}Be for addressing key stratigraphic problems:
Slow-forming Antarctic soils have the potential to yield critical climatic information, if an accurate chronology can be established. In situations where medium-long term flux rates are available from ice core data, nitrate inventory can be used to fix the soil formation age. This can be refined further using the atmospheric ^{10}Be/^{9}Be profile. Such an age model has been tested on a complex soil from the Taylor Valley, South Victoria Land, which yielded a nitrate inventory age of c. 18 Ma and a ^{10}Be/^{9}Be decay age of 17 Ma, consistent with estimates from morphological studies.
ODP 181, Site 1121 core was drilled through sediment in c. 4500m water depth on the western margin of the Campbell Ferromanganese Nodule Field, SW of New Zealand. Lacking detailed biostratigraphy, a ^{10}Be/^{9}Be-based chronology is derived from nodules entrapped in the upper part of the core. Measured ^{10}Be/^{9}Be ratios of nodule rims decrease systematically with depth in the core, in line with radioactive decay. Given that the nodules were *in situ* and had remained intact physically and isotopically since cessation of growth, and that the rim ratios reflect contemporary seawater, the age of the core to c. 4m depth is c. 10.5 Ma, consistent with diatom biostratigraphy to 1m depth. Calculated net sedimentation rates range from 8 to 95 cm m.yr.$^{-1}$ (mean of 39 cm m.yr.$^{-1}$), the lowest rates coinciding with the occurrence of trapped nodules, and reflecting periods of increased bottom current flow.
Marine shelf sediments of the Wanganui Basin, New Zealand spanning oxygen isotope stages 23-11 (c. 890-405 ka) contain spikes of enriched ^{10}Be concentrations (and enhanced ^{10}Be/^{9}Be ratios), up to 10 times background values. The spikes, which appear in the sequence just above the base of each cyclothem at the presumed location of the local flooding surface (LFS), apparently originated in response to seafloor sediment starvation during transgression.

POSTER

^{210}Pb-^{137}Cs DATING OF POST-EUROPEAN LAKE TEKAPO SEDIMENT

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^{210}Pb data for Lake Tekapo sediment cores L1395 and L1401 (NIWA, November 1991) cannot be interpreted in a straightforward manner. This is because of low unsupported (atmospheric fallout) ^{210}Pb relative to supported (sedimentary matrix) ^{210}Pb, and scatter resulting from catchment reservoir effects and changes to the lake's sedimentary regime resulting from dam construction in the late 1940s. Nevertheless, it has been possible, through variable-leaching experiments and careful data analysis to produce reasonably precise chronologies for both sediment cores to c. 700 mm depth. Consistent with the location of the first appearance of ^{137}Cs bomb fall-out in 1953 and peak concentration in 1965, the ^{210}Pb data plot on decay curves yielding mean sedimentation rates of c. 6.7 mm yr^{-1} (L1395) and 4.7 mm yr^{-1} (L1401). These sedimentation rates are significantly slower than the published ^{137}Cs-based sedimentation rate of c.15 mm yr^{-1} for nearby Lake Pukaki.

^{210}Pb-^{137}Cs dating of L1395 is at variance with that derived from varve counting, the discrepancy being c. 35% (6.7 vs. 10 mm yr^{-1}) which, at 700 mm depth, corresponds to an age difference of c. 35 years (105 vs. 70 yr). This means that either (i) c. 35% of the annual varves are missing from this part of the record, or (ii) c. 35% of the varves ascribed to short-term flood events are, in fact, annual. The ^{210}Pb-^{137}Cs sedimentation rate of L1395 is only 30% of that of that implied by the first appearance of *pinus* pollen at c. 2200 mm depth (i.e., c. 22 mm yr^{-1}). This inconsistency could be explained by a much faster sedimentation rate (c. 25 mm yr^{-1}) prior to 1953 when the hydroelectric dam construction was completed, and the lake level raised and controlled.

ORAL

WELL PERFORMANCE ESTIMATION FROM BRIEF DISCHARGE USING HEURISTIC DECLINE ANALYSIS

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Traditionally stable well outputs have been determined by extended discharge: flowing the well to waste for a period of weeks or months. This has become increasingly difficult because of environmental constraints, resulting in well testing requiring injection wells and pipelines in order to allow extended flow periods, and this means that tests cannot be carried out routinely in the exploration program.

Brief vertical or horizontal discharges to waste are still possible, and indeed a brief discharge is required to clear the well of debris. Data from a period of several hours of open flow has been used for a decline analysis. The analysis is an heuristic adaptation of flow at constant pressure. For wells which were reasonably well warmed up before discharge, such decline analysis has given acceptable estimates of ultimate stabilised flow, even though it involves extrapolation well beyond the accepted limit of validity.

Examples from Mokai are used to illustrate the application of the method.

ORAL – geothermal workshop

COLD VENTS AND GAS HYDRATES ON THE HIKURANGI MARGIN: PROSPECTS FOR A JOINT GERMAN-NZ RESEARCH CRUISE IN 2007

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Submarine cold vents (seeps) are areas where specific geochemical species (CH_4, H_2S, Ba, NH_4) are transported from deeper sediment horizons towards the seabed surface, into the water column and probably to the atmosphere. Cold vents are often associated with gas hydrates, which act as temporally variable sinks/sources for methane, the dominant compound at cold vents. Upward-migrating fluids and gas hydrates have a strong impact on local, regional and maybe global biogeochemical cycles. In particular the expulsion of methane as dissolved or free gas (bubbles) and of H_2S from marine sediments are important for local biogeochemical cycles, allow chemoautotrophic fauna to settle, and cause the precipitates massive carbonate. Gas hydrates directly influence the amount of released methane, create unique ecosystems and might be a possible future energy resource. Massive gas hydrate decomposition can cause gigantic submarine landslides, perhaps triggering tsunamis and endangers oil/gas infrastructure.

Although cold vents and gas hydrates exist all over the world, our knowledge is restricted to some well-investigated areas such as the Gulf of Mexico, Hydrate Ridge, Eel River, Blake Ridge, and the Black Sea. On a global scale we know very little about seep ecological variability, lifespans or changes in fluid activity through time. To extend this knowledge we have proposed to undertake detailed investigations in the Hawke's Bay region. Here, gas hydrates and methane venting is inferred from: (1) the widespread occurrence of seismic BSR structures; (2) bubble clouds in the water column (CH_4?); and (3) methane-derived carbonates and chemoautotrophic clams, which were recovered previously by dredging. The Hikurangi Margin is an ideal place for integrative petrographic, biogeochemical, geophysical and biological studies as fossil carbonate vents can also

be found on land in Miocene strata. However, only very limited information is available from offshore vents, which provides us with an unique opportunity to extend our knowledge about gas hydrate-associated cold vent regimes, including structural controls on fluid flow, seepage zone biogeochemistry, seep geographic distributions, and seep community composition and ecology.
We are planning to conduct these detailed studies with the German vessel RV SONNE in March-April 2007. The integrative studies will comprise state-of-the-art studies (bathymetry, side scan, streamer seismic, OBH/S deployments, seafloor observations, TV-guided sampling, in-situ experiments, CTD, ADCP), in a geographically extensive geophysical, geochemical and biological work. The overall aims are to study the role of methane in the global biogeochemical cycle, to enhance our knowledge about the global phenomena of cold fluid venting and to provide a more detailed data base to evaluate the possible use of gas hydrate as a future natural energy resource in New Zealand.

ORAL

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We are planning to conduct these detailed studies with the German vessel RV SONNE in March-April 2007. The integrative studies will comprise state-of-the-art studies (bathymetry, side scan, streamer seismic, OBH/S deployments, seafloor observations, TV-guided sampling, in-situ experiments, CTD, ADCP), in a geographically extensive geophysical, geochemical and biological work. The overall aims are to study the role of methane in the global biogeochemical cycle, to enhance our knowledge about the global phenomena of cold fluid venting and to provide a more detailed data base to evaluate the possible use of gas hydrate as a future natural energy resource in New Zealand.

POSTER

A WAYS TO GO: THE LATE HOLOCENE FORAMINIFERAL RECORD OF THE INNER MANUKAU HARBOUR

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Because estuaries are sinks for pollutants, and are often the most stressed of marine systems, it is imperative that management authorities know about the current health of such coastal ecosystems. Just as important is knowing whether remedial initiatives are resulting in a return to "healthy" pre-impact communities. In most cases there is no documented historic record of what the pre-impact coastal marine ecosystems were like. The only clues come from the fossilised hard-parts of a small portion of the original biota that are preserved in late Holocene sediment. The macrofossil record is at best patchy and not easily recovered from cores. Foraminifera have a particularly good record and their taxonomic composition and general ecological distribution in these environments is the best known of all the microfossil groups.

The Manukau Harbour, and especially Mangere Inlet, is arguably the most contaminated estuary in New Zealand. The fossil foraminiferal faunas preserved in intertidal sediment in six cores help document the impact of sewerage outfalls on the local environment. They indicate that Polynesian forest clearance had negligible impact on the harbour biota. High nutrient organic-rich discharges from freezing works in the early European period (1840-1960) produced subtle faunal changes and increased sediment accumulation near the outfalls into Mangere Inlet. Two cores near freezing work outfalls record the existence of weak hypertrophic zones of increased foraminiferal and ostracod abundance during this period. A core close to an outfall passed up into an abiotic zone possibly because of the excessive nutrients, low oxygen and resultant acidic conditions.

In 1960 the Mangere Sewerage Treatment Works (MSTW) was opened and the freezing works and other outfalls progressively closed. This change coincided with a sharp increase in Zn and Pb levels in sediments throughout the inlet, attributed to a rapid increase in motor vehicles, roads and stormwater run-off. The MSTW discharged very significant volumes of nutrient-rich freshwater into the harbour north of Puketutu Island. In most places the sediment accumulation rate increased at this time and the foraminiferal faunas changed dramatically with abundance decreasing and species diversity increasing. The increased diversity is largely attributed to many small displaced shells carried in by the incoming tide from subtidal habitats nearer the harbour mouth. Increased flocculation and sinking of suspended mud, together with mucus-secretions from benthic algae (diatom increase in abundance), possibly helped trap the fine sand-sized, displaced microfossils before they could be carried away by the outgoing tide. While heavy metal levels have decreased in recent years, in most cores the foraminiferal faunas do not show any significant reversal of trends back towards their pre-impact state.

The results of this study should provide a basis for future research documenting the effects of new sewage treatment technology implemented in 2002-3 following decommissioning of the old oxidation ponds and restoration of the area to intertidal mud flats.

ORAL

TRAVEL TIME RESIDUALS AND ANISOTROPIC ATTENUATION: A STUDY IN THE CENTRAL VOLCANIC REGION

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New Zealand's Central Volcanic Region is characterized by backarc extension associated with the subduction of the Pacific Plate underneath the Australian Plate. SKS splitting results show large delay times and trench parallel fast directions. Teleseismic broadband data were acquired in 2001 along a trench perpendicular line (striking North-West to South-East). An unusual attenuation and travel time pattern was observed on an SKS and SKKS record comparing fast and slow components. Going from South-East to North-West across increasing path length in the mantle wedge, the amplitude of the fast component decreases and it appears to arrive earlier with respect to the ak135 propagation model, whereas the amplitude and arrival time of the slow component stays more consistent.

To examine the phenomena we determine travel time residuals relative to arrival times estimated from the ak135 propagation model. For earthquake to station distances from 20° to 120°, P waves residual times vary between –3.66 s to 3.24 s. Values for fast and slow S waves range between –5.00 s and 5.00 s. Results are dependent on backazimuth. Waves arriving from West to North-West show a decrease of residual time and therefore an increase of apparent/mean velocity from West to East along the line. This is consistent with what would be expected due to the increasing length of the travelpath through the higher velocity slab. On the other hand there is an increase in travel time residuals for waves arriving from Eastern directions, consistent with longer paths through the mantle wedge. The high frequency fast and slow shear waves examined by this technique show similar trends. We attribute the apparent early arrivals of the fast wave in the SKS/SKKS records to waveform modification during attenuation. We

are currently examining the spectral characteristics to quantify the anisotropic attenuation.
The anisotropic attenuation cannot be caused by fluid filled cracks, as this would cause the amplitude and arrival time of the slow component to decrease. Another hypothesis to be tested is that the attenuation could be due to the loss of energy during phase conversions from aligned heterogeneities.

POSTER

SEISMIC ANALYSIS AND MODELS FROM A RIFTED SUBMARINE PLATEAU OF CONTINENTAL ORIGIN: GREAT SOUTH BASIN AND BOUNTY TROUGH

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The Campbell Plateau and Chatham Rise are large submarine plateaux of continental origin forming part of the submarine New Zealand continent. Bounty Trough lies parallel to the former Gondwana subduction zone along the northern margin of Chatham Rise. At its western end, Bounty Trough (BT) connects with the Great South Basin (GSB). The whole region formed part of Gondwana until extension and subsequent seafloor spreading formed the Southern Ocean in the Late Cretaceous. Prior to the break-up of Gondwana, New Zealand was situated at the proto-Pacific plate boundary of Gondwana. Although the timing of break-up is relatively well defined, processes of break-up and the development of the continental fragments forming Campbell Plateau and Chatham Rise are not yet understood. It is expected that these processes played a key role in the development of Gondwana's plate boundary from a convergent margin to continental rifting. One model suggests that the Cretaceous rift evolved from an already existing back-arc basin, a proto-Bounty Trough. It may also be possible that the trough first developed as a rift system of the Southern Pacific's early opening as plate-kinematic reconstructions of the South Pacific region suggest.
A geophysical and geological survey was conducted across the Campbell Plateau and Bounty Trough in 2003, comprising two deep seismic transects with an ocean-bottom seismograph (OBS) spacing of 10-20 km in combination with a series of crustal multichannel seismic (MCS) reflection lines across the GSB and BT. The OBS records were bandpass-filtered and deconvolved. Magnetic and gravity data provide further constraints on the crustal models.
The MCS profiles across the Bounty Trough show about 1.2 s (TWT) thick layered sediments with an incised valley. In most parts, basement can be identified in the reflection data, how-ever, in places only the OBS model allows discrimination of basement from older sediments. Internal basement reflections are clearly visible in some areas, but Moho is not observed on any of the MCS lines. The travel-time inversion model of the Bounty Trough implies a reduction of crustal thickness to some 14 km (b.s.f.) in the area of the Bounty Channel, including 2-3 km of sedimentary cover, while crustal thickness increases to 20-25 km (b.s.f.) underneath the Bounty Platform and the southern Chatham Rise. P-wave velocities are about 2-3 km/s for sediments and range from 5 km/s for the upper basement to 7.5 km/s for the lower crust. The MCS profile across the Great South Basin shows generally well-layered sedimentary sequences. The travel-time model shows a crustal thickness of about 20-23 km (b.s.f.) including a sedimentary cover of up to 8 km under the channel. Crustal thickness increases to 27 km towards the South Island of New Zealand and 26 km with only 1 km of sedimentary cover towards the Campbell Plateau. P-wave velocities range from 2-4 km/s for sediments and increase from 5.5 to 7.5 km/s for the lower crust. Velocity models for both the Bounty Trough and Great South Basin are consistent with the gravity-anomaly models.
Crustal models of both Bounty Trough and Great South Basin infer an extremely thinned crust beneath the Bounty Trough and the Great South Basin. This information related to the magnitude and style of rifting along Bounty Trough and Great South Basin, helps constrain models of the break-up process between New Zealand and Antarctica.

ORAL

DIFFERENTIAL OPTICAL ABSORPTION SPECTROMETER: A NEW TOOL FOR VOLCANIC GAS SURVEILLANCE IN NEW ZEALAND

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Sulphur dioxide (SO_2) emissions at New Zealand's volcanoes have been monitored periodically for about 30 years using correlation spectrometry (COSPEC). Under the recently running GeoNet program these measurements are carried out in intervals of approximately 4–6 weeks. These data only show long-term variability. However, short-term fluctuations of the emission rates due to, for instance, puffing or changes in permeability in the conduit, are not currently monitored. Also, during periods of increased activity, frequent measurements involve higher costs and significant risk. Thus, multiple reasons exist to obtain continuous short-term measurements of SO_2 emissions. In the last ten years volcanologists have extensively tested a new optical spectrometer, called Differential Optical Absorption Spectrometer (DOAS). Presently, two real-time installations have been deployed at the Soufrière Hills volcano (Montserrat) and Kilauea volcano (Hawaii). Volcanic gas monitoring on Montserrat over the last three years monitored continuous SO_2 emissions, which were correlated to changes in permeability and eruptive behaviour of the Soufrière Hills volcano. This presentation introduces the new optical spectrometer for future volcanic gas surveillance at White Island volcano in New Zealand. Two DOAS instruments are planned for permanent measurements and to gain real-time data of the SO_2 emission rates, which will improve hazard forecasting and analysis of magmatic processes at depth.

POSTER

L. MIOCENE - E. PLIOCENE ARIKI FORMATION: CONDENSED SEDIMENTATION IN NORTHERN TARANAKI BASIN ASSOCIATED WITH GRABEN EXTENSION AND CONTINENTAL MARGIN PROGRADATION

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The Ariki Formation is a highly calcareous marl characterised by abundant planktic foraminiferal content, which accumulated during the L. Miocene and E. Pliocene mainly over parts of the Western Stable Platform in northern Taranaki Basin. The unit is thin (maximum 109 m) and spans the Kapitean to Opoitian and Waipipian Stages. It represents a significant period of terrigenous sediment starvation in northern Taranaki Basin before the progradation of the continental margin wedge (Giant Foresets Formation) across the region. Equivalent units have been identified beneath the fill of the Northern Graben (Mangaa Fmn), giving a maximum age (latest Miocene) for the start of the crustal extension that formed this graben. Uplift on the margins of the graben appear to have enabled Ariki Fmn to continue to accumulate into the Waipipian. The Ariki Formation often displays a distinctive barrel-shaped to blocky gamma ray wireline log motif (reflecting the high carbonate content), which is frequently accompanied by an increase in sonic, resistivity, and bulk density values. Distinct deflections on GR and SP wireline logs, corresponding to high-amplitude seismic reflectors, delineate the upper and lower boundaries of Ariki Fmn. Differences in wireline log motif and seismic characteristics at different exploration hole sites reflect spatial differences in lithology and the degree of condensation within Ariki Fmn.

The accumulation of the Ariki Fmn is a result of local depositional controls, and oceanic processes occuring on a more regional scale. The Ariki Fmn is inferred to have accumulated beneath fully oceanic watermasses at middle to lower bathyal water depths. Paleoecological analyses show a marked decrease in planktic foraminiferal content between the Ariki Fmn and the Giant Foresets Fmn, corresponding to a significant decrease in oeanicity, but *not* paleobathymetry. This suggests a reduction in the availablity of nutrients, possibly as a result of deflection oceanward of nutrient-rich coastal upwelling cells ahead of the prograding foresets, which formed the more proximal continental margin. The accumulation of the Ariki Fmn can also be related to the cessation of andesitic arc volcanism (~7-8 Ma) in northern Taranaki Basin, which minimised the local supply of clastic sediment to the basin floor, and to structural and topographic elevation of the western and eastern margins of the Northern Graben. However, the limited availability of terrigenous sediment in northern Taranaki Basin during the L. Miocene and E. Pliocene was due mainly to the southern Taranaki and King Country locations of the contemporary Late Miocene-Early Pliocene continental margin where terrigenous sedimentation was focussed.

ORAL

WHAT CAUSED THE EXTINCTION OF DEEP-SEA FORAMINIFERA IN THE MIDDLE PLEISTOCENE ?

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The last major extinction of deep-sea benthic foraminifera began in the late Pliocene but mostly occurred during the Middle Pleistocene Climatic Transition (1.2-0.6 Ma). Globally it caused the disappearance of at least 2 families, 20 genera and over 70 species (~20 % of the deep-sea foraminiferal biodiversity). These taxa had similar morphologies, being elongate cylindrical, dominantly uniserial, and included all species with

apertures that were slit lunate, hooded with two teeth (Pleurostomellidae), necked with a secondary tooth (Stilostomellidae), or cribrate (*Chrysalogonium*).
In the South-west Pacific, North Atlantic and Caribbean, the absolute abundance of this group of elongate, cylindrical foraminifera exhibit dramatic declines during the late early and middle Pleistocene. The rate of decline was pulsed, with declines often associated with the onset of glacial intervals, and partial recoveries in intervening interglacials. The timing of the declines and the last occurrence levels of individual extinct species varied between the nine DSDP and ODP sites studied so far. Over a period of several hundred thousand years leading up to its extinction, the group appears to have withdrawn progressively from upper bathyal and abyssal deep water sites into mid-lower bathyal sites bathed in intermediate waters. The peak period of local disappearances was 0.95-0.7 Ma, with the youngest occurrence of any of the extinct species (*Stilostomella* extinction) similar in all sites (0.7-0.58 Ma).
The middle Pleistocene extinction was the final phase in the progressive world-wide decline of elongate, cylindrical taxa, which reached their greatest abundance in the late Eocene, and exhibited major declines during periods of global cooling at the end of the Eocene, and in the middle-late Miocene. The precise mechanism causing the middle Pleistocene extinctions (e.g. rapid changes in food supply, increased ventilation) is not yet determined, but was clearly distinct from the cause of the other two major deep-sea extinction events, during the Cretaceous and Paleocene-Eocene Thermal Maximum, which had no impact on this group of foraminifera.
Does the pattern and timing of this extinction reflect changes in the global deep and intermediate water circulation patterns during the middle Pleistocene?

POSTER

PLANKTIC FORAMINIFERAL RECORD OF THE SUBTROPICAL FRONT AND SOUTHLAND CURRENT OVER THE LAST 1 MYRS

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Modern analogue technique has been used to estimate sea surface temperatures (SSTs) for the last 1 million years at three deep sea core sites east of the South Island, based on census data from 647 fossil planktic foraminiferal faunas (160,000 specimens). The core sites, on the north (ODP 1125) and south (DSDP 594) flanks of the Chatham Rise and in the South Canterbury Bight (ODP 1119), are well placed to document the SST history of the East Cape and Southland Currents and any movement of the Subtropical and Southland Fronts.
Interglacial SST estimates in the north are similar to the present-day throughout this period, whereas to the south they are more variable with peaks 4-7°C cooler than present during MIS 27-15. Warm peaks in MIS 11, 5.5, and early 1 are estimated to have been 2-4°C warmer than present. These high temperatures are attributed to southward spread of the Subtropical Front across the submarine Chatham Rise and increased Subtropical Water flowing around the south of New Zealand in the Southland Current. Interglacial SSTs were similar in ODP 1119 and DSDP 594, indicating that both were overlain by Subantarctic Water and the Southland Front was located landward of both.
For much of the last 1 million years, glacial SST estimates in the north were only 1-2°C cooler than the present interglacial, except in MIS 16, 8, 6, and 4-2, when estimates were 4-7°C cooler. These cooler temperatures are attributed to jetting of Subantarctic Water through the Mernoo Saddle (across the Chatham Rise) and/or waning of the East Cape Current. To the south, glacial SSTs in Canterbury Bight (ODP 1119) were generally 4°C warmer than offshore (DSDP 594) indicating that during periods of lowered sea level, the Southland Front had migrated eastwards to lie between the two sites with a warmer landward band of the Southland Current overlying ODP 1119. Glacial SSTs as cold as those in DSDP 594 were recorded in ODP 1119 in MIS 20, suggesting that this was the only period in the last 1 million years when no Subtropical Water flowed around southern New Zealand, resulting in the disappearance of the Southland Front with exceptionally cold Subantarctic Water sweeping along the coast of Southland, Otago and south Canterbury.
Glacial SST estimates offshore in the south (DSDP 594) were consistently c.10°C colder than present, similar to temperatures and faunas currently found in the vicinity of the Polar Front. These cold temperatures may be attributed to strong eddies of cold Circumpolar Water passing through the Pukaki Saddle and spinning off the Subantarctic Front and into the Bounty Trough.

ORAL

MAGNETOTELLURIC INVESTIGATION OF THE CAÑADAS CALDERA, TENERIFE (CANARY ISLANDS)

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Tenerife is the largest island of the Canary archipelago and – after Hawaii – the third highest ocean-island volcano in the world. The Las Cañadas caldera in Tenerife is a well-exposed caldera depression in which the active Teide-Pico Viejo complex stands. Las Cañadas is an elliptical depression of 16 x 9 km making up the caldera of the Teide Volcano at an elevation of 2100 m, at the centre of Tenerife. The geological history of the caldera comprises several episodes, characterised by sector collapses probably induced by successive collapses of the magma chamber. The floor of the caldera goes from basaltic and phonolitic lava flows up to pyroclastic deposits. Recent basaltic volcanism has left strombolian cones and associated lava flows. In addition to its volcanological interest, Las Cañadas also holds the main groundwater reservoir of Tenerife.

In 2000, an audiomagnetotelluric (AMT) and magnetotelluric (MT) survey was carried out in order to image the interior of the caldera. The field campaign consisted of thirty-three AMT sites in the period range from 0.001 to 0.3 s and eleven MT sites from 0.004 to 200 s.

A detailed mapping of the electrical conductivity of the subsurface was obtained. For the long period data a 3D modelling of the island – including the bathymetry – was carried out to assess the effect of the ocean. This effect starts to be important at periods longer than 10 s. Accordingly, the sites were arranged into six profiles and a two-dimensional joint inversion of all data until 10 s was performed for each profile. The geometry of the high conductive zones found indicates that the caldera includes two closed depressions in the western (Ucanca) and central (Guajara) sectors, whereas in the eastern sector (Diego Hernandez) the top of the main conductive zone shows a gentle inclination towards the north-east (La Orotava valley). A narrow and marked high conductive anomaly, probably caused by the presence of highly fractured rocks and fossil hydrothermal alteration along a fracture zone, runs parallel and close to the present caldera wall, suggesting the position of the structural border of the caldera. The results indicate that there are two main aquifer zones separated by the Roques de García spur, coinciding with the western and central depressions. The eastern depression could be hydrologically disconnected from the central depression by another structural boundary not visible at the surface. The saturation zones would have a thickness of more than 700 m starting at a few hundred metres below the present caldera floor. The data are consistent with a multiple vertical collapse origin for the caldera depression rather than a sector collapse origin.

ORAL

COROMANDEL-CENTRAL VOLCANIC REGION DATA INTERVENTION: CONVERTING DATA TO INFORMATION TO KNOWLEDGE

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Glass Earth Limited, a private New Zealand company established to discover and develop precious metal and geothermal opportunities; and Geoinformatics Exploration (Australia) Pty Ltd formed an alliance to carry out a 'Sponsored Data Intervention' in the Coromandel-Central Volcanic Region, North Island, New Zealand.

Geoinformatics has a track record of compiling large datasets from disparate sources, they are leaders in 3D terrane scale to mine scale geodynamic modeling, and have a multi-disciplined team of geoscientists that applies a risk managed focus to exploration.

The Geoinformatics process enables the rapid and efficient integration of datasets unlocking and enhancing the interpretation process by allowing the concurrent evaluation of multi-disciplinary information. The key to the process is decreasing the evaluation time, enhancing understanding of the multi-dimensional geology and how it relates to mineral deposit occurrences, and allowing objective exploration target ranking based on available data.

The Project outcomes were:

A 40 gigabyte 3D database; query capability via comprehensive capture and validation of factual and interpretive data

Computer aided analysis using modern techniques such as Frac Worming

Presentation and visualization of potential exploration targets using the FracSIS sytem.

For ongoing exploration:

New data can be added at any time

Changing priorities can be evaluated in the context of the geoscientific data
Competing/contrasting strategies (both economic and scientific) are able to be evaluated.
Technical Outcomes included:
Complete compilation of new digital GIS geology and structure for the CCVR area.
New caldera outlines, and modification of existing outlines.
Major northwest-southeast cross structures highlighted.
Temporal relationships of major gold deposits and rift developments established.
A strong association of gravity highs and with known mineralisation established.
The Project involved a multinational team of geoscientists working collaboratively over a seven month period, and demonstrates what may be achieved with strategic alliances and collaboration across business and research organizations. A case study will be presented to illustrate several of the technical outcomes.

ORAL

STRATEGIC ALLIANCES AND COLLABORATION: A FRESH APPROACH TO GREENFIELD GEOTHERMAL EXPLORATION USING GEOINFORMATICS DATA INTERVENTION PROCESS.

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Glass Earth Limited, a private New Zealand mineral exploration company and Geoinformatics Exploration (Australia) Ltd established a strategic alliance to carry out a sponsored Data Intervention Project over the Coromandel-Central Volcanic Region (CCVR) in North Island, New Zealand.
The Data Intervention included the aggregation, validation and construction of 3D geoscience databases, the construction of a 3D geodynamic model that provided a basis for a targeting strategy for developing prioritized areas in the CCVR for regional and prospect scale evaluation of energy sources within these areas.
The first order data aggregation and data inventory for the CCVR area was carried out at a regional scale from Glass Earth's own sources, "open-source" data, and various data provided by a number of collaborators, the principal being the Institute of Geological and Nuclear Sciences Ltd, along with University and energy companies.
A hierarchical framework was established for the structuring of the various databases and other geological information into the 3D database, to allow multi-dimensional knowledge based querying of the data. This includes a scaling of the data in order to facilitate zooming from the regional scale through to the prospect scale, facilitating rapid assessment of prospectivity of terranes, as well as development of and ranking of targets at all scales.
The Geoinformatics Process that is the key to the Data Intervention follows a decision tree-flow diagram of process summarized as:
Data sourcing and audit
Data collection, validation and compilation
A complete set of terrane scale geophysical interpretations and interpretations of the mega-elements of the CCVR Project region. This involves the use of Frac Wormer technology as well as other technologies.
Critical cross and long sections at various scales
A time based geodynamic reconstruction
A 3D digital terrane scale model of the CCVR project area
A 3D data interpretation and visualization FracSIS/Fracviewer computer software system.
The Project involved a multinational team of geoscientists working collaboratively over a seven month period, and demonstrates what may be achieved with strategic alliances and collaboration across business and research organizations. A case study of a geothermal system will be illustrated in the presentation.

ORAL – geothermal workshop

LATE MIOCENE TURNOVER OF MOLLUSCAN FAUNAS, NEW ZEALAND: TAXONOMIC AND ECOLOGIC RE-ASSESMENT OF DIVERSITY CHANGE AT MULTIPLE TEMPORAL AND SPATIAL SCALES

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The terminal Miocene (Kapitean) extinction of molluscan genera is regarded as one of the more significant events in the evolutionary development of New Zealand's Cenozoic marine molluscan fauna. This interval of diversity decline is interesting for: (i) its coincidence with an apparent paucity of near-shore facies in the stratigraphic record, (ii) its occurrence within relatively deep-water sediments, and (iii) the concurrent intensification of regional thermal cooling. This terminal Miocene extinction event has been inferred to result in an estimated 23% reduction in

recorded genera, including many ecologically dominant lineages.
In this study, the significance of the terminal Miocene event is tested with respect to both taxonomic diversity and ecological change throughout the Late Miocene and Early Pliocene. Furthermore, these patterns are tested at two spatial and temporal scales. Using an occurrence-based dataset (655 collections) we present synoptic and sub-sampled genus richness curves for Late Miocene and Early Pliocene biostratigraphic stages, and compliment that approach with a multivariate analysis of associated ecological change. We also apply similar analytical protocols to an extensive field-collected macrofaunal dataset (560 collections) from Wanganui Basin, resolved to a high-resolution (Milankovitch-scale) chrono-stratigraphy.
At the regional scale, synoptic genus diversity appears to decrease significantly during the latest Miocene, rebounding during the Early Pliocene. Rarefaction of this dataset reveals a significantly flatter diversity trajectory, indicating that the synoptic pattern is strongly biased by variations in sampling intensity. Within Wanganui Basin, the fauna of the Kapitean Stage are as diverse as that of the following Opoitian Stage, contrasting with the pattern of diversity rebound observed at the regional scale. Late Miocene-early Pliocene biodiversity therefore appears to be expressed dissimilarly at varying spatial scales and temporal resolution. These findings suggest that spatial scale and temporal resolution are important considerations in determining the magnitude of diversity and ecological change through geologic time. Regional patterns of diversity change are governed by a complex interplay of not only large-scale environmental factors, but also basinal-scale processes and local sampling intensity.

ORAL

RADIALLY RIBBED BUCHIIDS IN THE NEW ZEALAND PUAROAN

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Due to their high diversity, rapid species replacement, and widespread distribution members of the bivalve family Buchiidae are important as index fossils in Late Jurassic and Early Cretaceous strata worldwide (e.g., Imlay 1959, Zakharov 1981, Li & Grant-Mackie 1988, Crame 1990). Buchiids have been found through northern Europe, Siberia, China and North America in the northern Hemisphere and in Indonesia, Australasia, Antarctic Peninsula, South America (S. Damborenea pers. comm. 2004) and are used for intercontinental correlation.
Three new species and two new variants – *Australobuchia* n. spp. A & B, *Australobuchia* n. sp. aff. *A. partimlirata* n.sp., *Australobuchia* sp. aff. *hochstetteri* (Fleming, 1959), *Australobuchia* sp. aff. *A. plicata* (Zittel, 1864), are recorded in Late Jurassic (Puaroan, Middle – Late Tithonian) rocks from Port Waikato to Kawhia. All five share a common morphologic feature: the presence of radial lirae over some, or the entire valve. The association of radially-ribbed variants with *A. hochstetteri* and *A. plicata* raises interesting evolutionary questions. These will be explored and some possible phylogenetic lineages presented.

ORAL

THE 9.7 ka POUTU LAPILLI AND THE EFFECTS ON MODERN INFRASTRUCTURE OF A SIMILAR FUTURE ERUPTION, TONGARIRO VOLCANIC CENTRE, NEW ZEALAND.

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Taupo Volcanic Zone (TVZ) comprises a number of volcanic centres that in the last 1.6 Ma have erupted >10,000km³ of pyroclastic ejecta and lava. At the southern end of TVZ the andesitic-dacitic Tongariro Volcanic Centre (TgVC) includes the historically active Mt. Ruapehu and Mt. Tongariro.
The Pahoka-Mangamate formation is thought to have been erupted rapidly from Tongariro volcano over a period of a few hundred years and concluded with the c. 9.7 ka Poutu Lapilli eruption. The Poutu Lapilli (1.1km³) erupted from multiple vents aligned parallel with the regional NNE-SSW tectonic trend of southern TVZ. Preliminary studies of the physical characteristics of the deposit suggest a fluctuating eruption column of at least one vent with dispersal calculations indicating a sub-plinian style eruption with vents dispersing wind controlled pyroclastic material in a tri-lobed pattern to the NNW, NNE and ENE. Within 20km of source pumice lapilli is present and includes larger lithic clasts, beyond 20km the pumice andesitic lapilli grades into ash that is deposited hundreds of kilometre's from source.
Settlement of the region surrounding Tongariro volcano and infrastructure construction associated with regional and national development has only occurred in the last 100 years. Infrastructure within 20 km of source includes The 'Desert Road' plus additional provincial state highways, the township of Turangi as well as other small rural communities

and a regional hydro-power scheme. A similar magnitude lapilli eruption with similar wind strengths and directions would disperse a lapilli and ash plume that would impact on these communities and infrastructure on a local and national scale. The major population centre of Taupo and smaller rural Waikato and Bay of Plenty communities would accumulate ash with varying thickness resulting in differing degrees of disruption.

This study describes and evaluates the future impacts from a similar eruption to the Poutu Lapilli and focuses on the effects of a lapilli eruption on local national lifelines such as; road, power-lines, hydro-schemes as well as roof bearing capacities of local domestic structures close to source as well as fine ash fall impacts further a field.

POSTER

ELECTRICAL PROSPECTING TECHNIQUES: A LABORATORY SIMULATION AND GEOTHERMAL APPLICATIONS

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Geophysical prospecting techniques rely on complex mathematical formulae and/or data management processes to represent the reality of buried orebodies and structures. This complexity can make for difficulties in presenting these techniques in an engaging way for students.

Our approach to make this learning easier was to use simple laboratory experiments involving measurements of voltage or electrical resistance at the surface of a solution in which a metallic foil ore-body was immersed, viz.,

(1) Measurement of electrical resistance between the surface of the solution and a the 'ore-body', the so-called mise à la masse method, and
(2) An 'electric sounding' technique which measure voltage between two electrodes across the solution within the 'ore-body' is immersed. Effectively the electric field is distorted by the presence of the 'ore-body'.

It is very clear that the body's effect is being sensed remotely as the resistance or voltage measurements are obtained systematically on a grid pattern over the solution's surface. The data obtained were easily presented as three dimensional images of the 'ore-body' using Chart Wizard software. This makes it easy to determine how well each technique reveals the ore-body's 'true' shape and depth from the surface. The effect of geophysical contrast between the country rock (the solution) and the target (the foil) can be investigated by changing the salt concentration of the solution. Furthermore, the limitations of the size of the body that can be detected by differing electrode spacing and configurations can also be investigated. Thus, the principles and limitations of geophysical prospecting using electrical methods can be readily determined in a semi-quantitative way, without undue distraction by the mathematical complexity associated with this so-called 'inverse problem'.

We imagined that the same techniques could be applied in field situations where the 'ore-body' was relatively close to the surface, and was of a markedly different conductivity from the surrounding materials. Geothermal springs and hydrothermally altered ground seemed obvious contenders. We found that the technique successfully maps and presents images for the location of geothermal waters that are 'backed-up' in beach-sands behind the silica reefs formed where the warm water meets the cold water of Lake Taupo. It also 'found' the location of near-surface conducting fluids at Karapiti (Craters of the Moon). Using existing electrical resistivity data, the Chart Wizard software enhances the representation of 'large scale' geothermal fields (e.g., Wairakei, Horahora and Ngatamariki).

POSTER

SURFACE DEFORMATION AT ROTORUA MEASURED BY ERS RADAR INTERFEROMETRY, 1996-2003

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The Rotorua Geothermal field is one of many geothermal systems within the Taupo Volcanic Zone (TVZ) that have been exploited to provide energy by the drilling of private boreholes and wells. Although these wells are relatively shallow (20-200m), the demand on the system was such that during the 1980s, it was discovered that the increasing water draw-off was affecting the natural geothermal features area. As a result of this, heat and water extraction was greatly reduced in 1987 and water levels subsequently rose. In recent years there has been increased surface activity including a series of hydrothermal explosions in Kuirau Park and the Tarawera Road area.

Radar Interferometry (InSAR) is a technique that is potentially capable of measuring deformation over large areas (~10^4 km), with high spatial resolution

(~25m), and with high accuracy (~1cm). We have studied Rotorua city using InSAR in the recent years since this new management regime for the geothermal system was introduced. Using ERS SAR satellite data from 1996-2003, we have shown that deformation is occurring in Rotorua city in a region on the margin of the known active thermal area. The natural recharge of the geothermal system, after the well closure programme, may have resulted in an inflation signal, but this study indicates a subsidence in the area south of Kuirau Park at rates of up to 13mm/year during 1996 to 2000. We are currently investigating what the causes of this might be and whether the deformation is related to the geothermal field or other environmental factors.

POSTER

LATE QUATERNARY HISTORY OF CHATHAM ISLAND

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The Chatham Islands, located 850km east of Christchurch, are a geologically and ecologically diverse part of New Zealand. However, as to date they have not received a comprehensive investigation into the extent of the Quaternary record preserved there or the impacts that the Pleistocene climate fluctuations had on the Islands' landscape and flora. Previous work e.g. Campbell *et al.* (1993) has indicated that previous high sea level surfaces may be present on Chatham Island. They are almost certainly preserved on nearby South East Island.

My Ph.D. research aims to identify and map these high sea level surfaces on Chatham Island (the largest of the Island group) and investigate the nature and stratigraphy of the cover deposits using mineralogy, palynology, phytolith analysis and tephrochronology.

One site of interest is located near the well-known basalt columns at Ohira Bay. A wave cut surface overlain by a basal conglomerate and sands is exposed in a quarry cutting. These deposits are in turn overlain by around 2m of peat, with the Kawakawa tephra present at around 0.5m depth. This surface may be the equivalent of the Rapanui surface in the Wanganui region and thus correspond to the sea level high during the last Interglacial (MIS 5e). Coarse resolution palynological and phytolith analyses have been undertaken on this overlying peat.

Preliminary analysis of pollen spectra show changes from *Dracophyllum*/ *Myrsine*/*Olearia*/*Coprosma* forest near the base, through to a vegetation dominated by *Dracophyllum* and Pteridophyte species at the top of the sequence. Pollen spectra also contain varying levels of 'exotic' pollen species derived from mainland New Zealand. These are predominantly *Podocarpus totara/Prumnopitys* type, and Fuscospora (*Nothofagus*) with lesser amounts of, *Dacrydium cupressinum* and *Phyllocladus*. Ratios of *Nothofagus* to podocarp pollen change considerably through the sequence, which may facilitate correlation with Late Quaternary pollen records from mainland New Zealand, as suggested by McGlone (2002).

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ORAL

CANNIBALISATION OF THE OTOROHANGA LIMESTONE INTO THE BASAL WAITEMATA GROUP, WEST COAST, NORTH ISLAND

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The Early Micoene (Otaian) Te Akau Member of the basal Waitemata Group consists of multiple cannibalised limestone-in-limestone beds cropping out in coastal exposures at Gibsons Beach, western North Island. It has previously been described by Hayward & Brooks (1984, NZJGG v. 27; 101-123). This study aims to establish the paragenetic sequence recorded within these mass-emplaced, lithoclastic, cool-water limestone beds, and the tectonic implications for the region.

The Te Akau Member is up to about 8 m thick, and is composed mainly of mass-emplaced, sometimes channelised, lithoclastic limestone beds that sit unconformably on an irregular surface cut into the top of Te Kuiti Group, and in particular over a possible correlative of the Otorohanga Limestone. The Otorohanga Limestone is the upper formation of the Te Kuiti Group in the Waitomo area, and Sr dating work is underway on the Gibsons Beach outcrops to test correlations with the type area. Nevertheless, the Otorohanga Limestone at Gibsons Beach has experienced pressure-dissolution cementation, and is a non-tropical shelf limestone with a well-developed flaggy nature.

Individual beds within the Te Akau Member comprise highly-indurated and well-cemented limestone clasts of pebble to typically cobble size. Clast supported fabrics are infilled by a muddy to sandy, often coarse shell-hash, matrix. Clasts commonly have subrounded morphologies. Individual beds are generally poorly sorted but can show evidence of reverse grading and may be tightly packed and imbricated. Diagenetic overprinting has produced a pseudo flaggy appearance, with some clasts displaying fitted or interpenetrating fabrics indicative of pressure-dissolution effects during burial.

Preliminary petrographic data suggests that the lithoclasts have been derived from the stratigraphically older and adjacent Otorohanga Limestone and that they were well-cemented prior to Waitakian-Otaian uplift and erosion. The pressure-dissolved fabrics indicate burial cementation, which we interpret from other studies occurred at burial depths of 0.3 – 1 km. Following burial the succession was exhumed and eroded. The lithoclasts in the basal Waitemata beds were worked in a high energy (?beach) environment prior to being redeposited offshore on to a shelf setting from an easterly direction. The beds hosting the limestone lithoclasts were then buried by the overlying Waitemata Group, and the often coarse-grained carbonate matrix itself experienced burial cementation.

The cannibalisation of Otorohanga Limestone into the basal Waitemata Group raises several interesting questions: what unit buried the Otorohanga Limestone to sufficient depths to allow for burial cementation prior to the basin inversion; by what mechanism and at what time was the overlying sediment eroded? The occurrence of these limestone-in-limestone beds indicates a level of tectonic activity not previously documented for the mid-Cenozoic succession in western North Island, and it clearly has implications for better understanding the tectonic evolution of the region.

ORAL

SHEAR-WAVE VELOCITY STRUCTURE OF NORTHWESTERN NEW ZEALAND: FROM RECIEVER FUNCTIONS AND SURFACE-WAVE DISPERSION

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The crust and upper mantle structure of northwestern New Zealand is investigated by applying an emerging method that jointly inverts teleseismic receiver functions and surface wave phase velocities for the shear-wave velocity structure. Receiver functions of teleseismic earthquakes are routinely employed to provide insight into the shear-wave velocity structure beneath a seismic station. An inherent problem with receiver functions is that they are nonunique and the use of *a priori* constraints is advised. We address the nonunique nature by employing a joint inversion for the shear-wave velocity structure, using receiver functions and surface wave dispersion. This method utilises the absolute velocity information from surface waves and the fine-scale velocity contrasts from receiver functions to provide a robust method for determining crustal and upper mantle structure.

Northwestern New Zealand is a region that has been somewhat neglected as a target by crustal scale geophysical experiments compared to 'hot' areas such as the Taupo Volcanic Zone and the Southern Alps. What is known about the crustal and upper mantle structure is derived solely from a reconnaissance seismic refraction survey in 1987. We analyse teleseismic waveforms recorded at six broadband seismometer stations from Waikato to Cape Reinga between August 2002 and February 2004. The long deployment time results in a large amount of high quality receiver functions. The receiver functions exhibit a strong, but broad phase that is coherent across events at 3-4 seconds delay time. We interpret this to be a P-to-S conversion from a shallow Moho. This arrival is consistent over a range of back-azimuths for each station, indicating a rather homogenous crust along the station array. Initial results obtained from receiver function inversion show a thin crust of 25-30 km in the south, thickening to 27-32 km in the north. The broad phase suggests a sharp Moho is absent; instead a strong velocity gradient is present from the lower crust to upper mantle, making identification of a Moho challenging. We expect impending surface wave analysis to help constrain the Moho depth. Receiver functions on the southern stations show a negative polarity phase at 1-2 seconds delay time; inversion models attribute this to near surface low velocity layers.

ORAL

STRUCTURAL EVOLUTION OF THE NORTH RIM OF TAUPO VOLCANO

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The Taupo Volcanic Zone (TVZ) forms a NE-trending rifted volcanic arc, characterised by extensive rhyolitic volcanism (c. 0.3m^{3}s^{-1} rhyolite magma over the last 340ky), and earthquake swarm activity. Geodetic surveys indicate that ~8mm/yr extensional strain is accommodated across the TVZ, at least in part by normal faulting. Given these rates of extension and volcanic activity, feedback between magmatic and tectonic processes is likely. Interactions of these processes were investigated along the northern shoreline of Lake Taupo, an active caldera margin dissected by a swathe of closely- spaced, parallel-striking normal faults. Deposits emplaced during the 26.5ka Oruanui eruption blocked the natural lake outlet allowing the lake to refill to c. 500m a.s.l, forming a shoreline orthogonal to the fault belt. This shoreline can be correlated across the fault belt to determine vertical deformation for the north Taupo region over the last 26ky. The northernmost post-26.5ka shoreline site has an elevation of 503m and lies within an inferred graben structure at Whangamata Bay. Elevation at this site is similar to that of other sites outside the boundaries of the active extensional zone. If the Whangamata fault, which bounds this graben, is moving with vertical slip rates comparable to those of faults in the Ngakuru Graben (0.1–1.5mm/yr), vertical offsets of the post-26.5ka shoreline should be in the range 2.6-to-39m. The lack of vertical offset within this range and the observation that these shoreline sites are at similar elevations to sites outside the zone of active rifting, suggest that little vertical fault motion has occurred within the Whangamata graben since the formation of the post-26.5ka shoreline. Therefore, normal faults may not be the predominant mechanism currently accommodating extensional strain in this region. Rather, dike intrusion and associated extension fractures, as well as distributed deformation across the region, may explain continued rifting without long term vertical fault movement. This raises the possibility that magmatic and rifting episodes are closely related in time (see also Leonard et al., this volume). We recognise a temporal association between eruptions from Taupo volcano and ground shaking events. Evidence includes: (1) the occurrence of syn-eruptive fault displacement indicators associated with the eruption of the 9.9ka Unit E (Opepe) tephra; and (2) fissures formed in unconsolidated soils as a consequence of ground shaking. These have planar walls and are filled with 1.8ka Taupo ignimbrite. Cracks in such weak material are unlikely to stay open for any reasonable length of time; we infer that they formed either immediately prior to or during emplacement of the 1.8ka Taupo ignimbrite. Horizontal extension therefore accompanies eruptive events from Taupo Volcano. We note, however, that rifting episodes without eruption have occurred in historic times (1922, 1983 earthquake swarms) and were associated with pre-seismic uplift, followed by fault rupture, fissuring and regional subsidence. Magma injection initiating deformation prior to normal faulting has been invoked to explain these phenomena. We suggest that the syn-eruptive fissuring and faulting described here, as well as the historic rifting episodes, may be intimately linked to magmatic cycles within Taupo Volcano.

ORAL

LATE QUATERNARY GEOLOGIC HISTORY OF THE NORTH HOROWHENUA DISTRICT, SW NORTH ISLAND, NEW ZEALAND

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This project analyses sediment samples collected from a borehole near Levin with the aim of determining the Late Quaternary geologic history of the area. Cuttings were collected from c.280m flat lying strata and were analysed using sedimentology, palynology, and paleontology. Sedimentology and paleontology was used to deduce depositional environments, whereas palynology was used in conjunction with five radiometric dates (two Radiocarbon and three Uranium series) to create a stratigraphic-chronologic framework for correlation with marine oxygen isotope stages (OIS).

Marine strata dominates the lower 150m of the borehole being comprised of alternating sand, silt, mud, and minor gravel units. Fossil foraminifera and molluscs show changes from estuarine to open marine shelf and back to estuarine conditions occurred between 250-235m and 215-205m depth. These are interpreted as representing two marine transgressive-high stand periods. Pollen assemblages from these intervals contain diverse conifer broad leaved forest taxa characteristic of warm interstadial conditions. A unit containing a pollen assemblage from mixed conifer broad leaved-beech forest taxa separates them indicating a cooler stadial period. These deposits most likely span OIS 5e, 5d, and 5c but will be confirmed with Uranium series dates.

A change from estuarine through marginal marine to fluvial deposition occurs from 130m to 60m depth representing infilling of the Last Interglacial marine embayment during relative sea level fall. Pollen analysis shows conifer broad leaved forest remained dominant at this time indicating warm climatic conditions and possibly the end of the last interglacial, OIS 5b-5a.

Terrestrial gravel, sand, and silt units dominate the upper 60m of the borehole. Radiocarbon dates from wood at 70m and 30m depths indicate these units are older than 50ka. At 60m depth a pollen assemblage dominated by grassland-scrubland taxa indicates glacial climatic conditions, most likely OIS 4. A brief reappearance of broad leaved and beech forest pollen taxa at 31m depth represents minor climate amelioration, most likely OIS 3. Last Glacial Maximum, OIS 2, deposits comprise the top 30m of the borehole and are indicated by grassland-scrubland and beech pollen assemblages. No Holocene sediment was encountered in the borehole.

POSTER

THE JULY 2004 EARTHQUAKES NEAR LAKE ROTOEHU, BAY OF PLENTY

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A series of earthquakes commenced on 18 July 2004, centred just north of Lake Rotoehu. The earthquakes were initially thought to be a swarm, but during succeeding days they showed the normal behaviour of an aftershock sequence, with the maximum magnitude steadily declining until the end of July. The largest event, at 0422 UT (1622 NZST) on 18 July, was Mag 5.4, the largest onshore earthquake in the Taupo Volcanic Zone since the Edgecumbe earthquake of 1987. The sequence began during a time of heavy rain and flooding, and earthquake shaking was at least a partial cause of the many landslides which occurred around the Lake Rotoehu area.

The earthquakes are high-frequency tectonic events, and initial indications from focal mechanisms are of normal faulting. The pattern of activity was similar to a series of events which occurred in April 1998 at Haroharo, about fifteen kilometres south of the latest activity. In the Haroharo sequence the largest event was a bit smaller, with a magnitude of 4.7.

We relocated the hypocentres of the Rotoehu earthquakes using the double-difference technique of Waldhauser and Ellsworth(2000). This technique attributes differences in travel times for any two events observed at one station to the spatial offset between the two events, with high accuracy. In our analysis we utilised differences in the phase picks, as well as differential travel times from phase correlation of the P and S waveforms, to relocate 361 of the events in the sequence. The distribution of the relocated hypocenters shows two tight groups of events, extending spatially as a whole no more than 5 by 5 km. The larger of the two groups has a NE-SW orientation, following the trend of local faults which run parallel to the Whakatane graben. The event cluster as a whole extends in depth between c.2 km to c.10 km, and appears to be near-vertical.

ORAL

LASER SCANNERS AS EROSION MONITORING TOOLS GAUNT CREEK CASE STUDY

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The development of terrestrial laser scanners has allowed small scale mapping and modelling of a variety of features from topographical sites e.g. sand dunes, Maori Pa sites, traffic accidents, to 3D models of extensive industrial complexes e.g. paper mills, to detailed building facades (e.g. Dunedin Railway Station. The main advantage of laser scanners is their ability to measure the distance to thousands of points in a few seconds, and to measure points that would otherwise be inaccessible using traditional survey methods. A DTM can be constructed from a single scan, or by referencing several scans to a common orientation. The accuracy, depending upon the type of instrument used, can range from 6mm at 50 metres to 3cm at 300 metres.

An I-SiTE laser scanner has been used to monitor the change in exposure of the Alpine Fault at Gaunt Creek, Westland. Three scans of the fault surface over a two year period have been carried out since July 2002. From these scans we are able to determine the volume of material that has been eroded from, as well as identifying the most active areas of the exposed fault.

ORAL

EAST-DIRECTED THRUSTING ACROSS THE BULLER AND TAKAKA TERRANES, NORTHWEST NELSON

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Previous tectonic models of Paleozoic Northwest Nelson have either become untenable (the “allochthonous Central Belt” model) or lack a mechanism that accounts for all major structures observed. A new structural model is proposed, based on thin-skinned tectonics, that better accounts for major structures associated with Paleozoic shortening in the Buller and Takaka terranes. These structures include: north-south trending recumbent folds in the Ordovician-Silurian rocks of the Takaka terrane; north-south trending, upright or steeply inclined folds observed in both terranes that coaxially refold the earlier recumbent folds; east-over-west reverse movement recorded on the terrane boundary, the Anatoki Fault; west-over-east reverse movement on the Devil River Fault and its related zone of ductile shear (Waingaro Schist Zone); north-south trending faults in the Central Belt of the Takaka terrane.

The model assumes the two terranes were adjacent to each other, probably juxtaposed by significant strike-slip movement, prior to formation of contractional structures. Paleozoic convergence of the two terranes began with a major horizontal shear zone postulated at the base of the Buller terrane turbidite assemblage which detached the turbidites from the underlying crust and initiated major eastward thrusting on to the Takaka terrane. The shear zone ramped up over the more competent Cambrian arc assemblage of the Takaka terrane into the rheologically weaker Ordovician limestones resulting in extensive eastward-directed recumbent folds separated by thrusts. At a latter stage in the deformation, a footwall splay of the major shear zone propagated along the base of the Cambrian assemblage. Most eastward-directed movement was transferred to the footwall splay resulting in the formation of the Waingaro Schist Zone. The footwall splay, which has now become the major shear zone, propagated upwards towards the surface (Devil River Fault) carrying the arc assemblage with it. A back thrust (Anatoki Fault) preferentially developed along the terrane boundary. As the Buller terrane was pushed eastward, the Takaka terrane lithologies between the eastward migrating back thrust and the major shear zone was tectonically wedged up. This tectonic wedge is today represented as the Central Belt of the Takaka terrane. Simultaneous with the onset of the tectonic wedging process was the initiation of upright north-south trending folds in both terranes, north-south faulting in the Central Belt, and coaxial refolding of existing recumbent folds.

Formation of the contractional structures can be constrained to the late Early-Middle Devonian: north-south trending folds and associated slaty cleavage affect the Early Devonian Baton Formation but are cut by undeformed Middle-Late Devonian intrusives in both terranes. The shortening probably relates to final stages of Buller and Takaka terrane amalgamation.

ORAL

ACTIVE FAULTS DATABASE OF NEW ZEALAND

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GNS has compiled an Active Faults Database that contains information on more than two hundred active faults in New Zealand. Having this valuable information centralised will allow a wide range of users to query the information and it will enable better understanding than would be possible with the data scattered.

Via the internet, the public can query the database spatially via a web map or by attribute via an attribute query interface. Attribute queries include by fault name, fault sense, last event (rupture) category, recurrence interval category, slip-rate category, single event displacement category, or a combination of these. An attribute query will produce a range of information about an active fault, or faults, and its location will be displayed on a map. Hyperlinks to oblique aerial photographs of the faults will also be available.

The active faults raw data is stored in a geodatabase which resides in an Oracle Database Management System. The geodatabase has the ability to calculate attributes from other attributes e.g. the slip-rate can be calculated from measured fault displacement and the time interval in which the displacement occurred. The geodatabase also has a hierarchical structure of features which is used for aggregating values. For example, two slip-rate values from two different trench locations (point data) along a fault trace (line data) will be averaged to populate the fault trace slip-rate value. Access to the raw data is restricted to GNS scientists but can be made available on enquiry.

The Active Faults database represents the synthesis of many decades of observation and studies by paleoseismologists. In combination with the New Zealand earthquake catalogue, the Active Faults Database will become the basis for updating seismic hazard models in New Zealand. Other applications will include revising building codes, emergency management studies, and geotechnical investigations. The wide range of end-users to benefit will include the insurance industry, local government, and general public awareness.

The database can be accessed at
http://data.gns.cri.nz/af

POSTER

THE MELANGES OF THE DUN MOUNTAIN OPHIOLITE BELT

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Within the Southland section of the Dun Mountain Ophiolite Belt there are two main melange zones, the Upukerora Melange in the west and the Windon Melange in the east (Craw, D., 1979, NZJGG 443-454). These can be traced from the Livingstone Mountains in the North to West Dome in the south. The Upukerora Melange consists primarily of ultramafic and mafic plutonic blocks in a serpentinite matrix. Sedimentary and volcanic blocks also occur, although these seem to be restricted to shear zones on either side of the melange and are petrologically related to bordering lithologies. It is therefore suggested that the Upukerora Melange be renamed and included in the Dun Mountain Ultramafics (Johnston, M. R., 1981, 1:50,000 Map) as they share the same lithology, structural position and deformation style. The Windon Melange includes blocks of volcanics and sediments with rare mafic plutonics cut by numerous shear zones and progressively develops a serpentinite matrix towards its southern end. This unit shares many similarities with the Patuki Melange (Johnston, 1981) in Nelson, including structural position, sedimentary provenance and the general lithology of the blocks. However, as the melange exposure is sporadic south of the Alpine fault, the relationship remains speculative. Geochemical research on these relationships remains ongoing.

Preliminary data from Nelson shows a consistent structural trend within the shear zones of the Dun Mountain Ultramafics (down to the west) which differs from that of the bordering Patuki Melange (down to the east). However, as only the latest two deformation events are recognisable in the Ultramafics due to the highly sheared nature of the serpentinite, older similarities between the two can not be excluded. These structural trends also continue through major blocks within the melange (>100m in length) but leave smaller ones undeformed. The strike slip component of these units shows a greater degree of variability.

The main fault rocks identified within the Dun Mountain Ultramafics in Southland and Nelson are recrystallised foliated serpentinite and serpentinite cataclasite. In Nelson the cataclasite still contains partly unserpentinised ultramafics, whereas in Southland it consists of massive serpentinite. It is inferred from field relations that the foliated serpentinite predates the two most recent deformation events, which are prevalent in the cataclasite. The block in matrix style of the deformed Dun Mountain Ultramafics is prevalent in both foliated and cataclastic serpentinite.

POSTER

SHALLOW SHEAR-WAVE VELOCITY FROM THE REMI™ SURFACE WAVE METHOD: A CASE STUDY OF THREE WAIRARAPA SITES LOOKING AT LIQUEFACTION POTENTIAL

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The ReMi™ surface wave dispersion method provides a useful tool for determining shallow shear-wave velocities. Surface waves are recorded on standard seismic refraction equipment and dispersion information can be obtained with a simple sledgehammer source or using a noise source such as a vehicle travelling along the length of the array. The measured dispersion can be inverted for an average shear-wave velocity profile. This study investigates this surface wave method at three Wairarapa sites along the Ruamahanga River. Varying noise sources and other collection parameters are compared for their effectiveness, with the aim of determining useful velocity profiles at each site. Where possible seismic refraction P-wave velocities have also been determined and help to constrain the final models.

The shear-wave velocity determined through this method can also be related to the liquefaction potential during a large earthquake. The study aims to make an assessment of the liquefaction risk at each site, adding to information from other methods, such as cone penetrometer testing, already conducted in the area.

The Wairarapa sites include next to the Lake Wairarapa Barrage, Kahautara Bridge and the Ruamahanga Bridge just out of Martinborough. Results indicate low velocities at each site, in particular at the Barrage where shear-wave velocities remain below 200m/s to a depth of around 30m. Velocities are also low at the Kahautara Bridge site where liquefaction has occurred in the past, causing damage to the bridge in the 1942 Wairarapa earthquake. Shear-wave results indicate a potential liquefaction risk at these two sites, whereas the Ruamahanga Bridge site may have a lower liquefaction potential.

POSTER

NEOGENE EVOLUTION OF THE EASTERN MARGIN OF TARANAKI BASIN WITH KING COUNTRY BASIN

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Taranaki Fault is the major structure defining the eastern margin of Taranaki Basin and marks the juxtaposition of basement to the east with a late Cretaceous-Paleogene succession to the west in Taranaki Basin. Although the timing of the basement over-thrusting on Taranaki Fault and subsequent marine onlap on to the basement block are well constrained as having occurred during the early Miocene, the subsequent history is poorly known. We are undertaking basin analysis of the Oligocene and Miocene succession within King Country Basin east of Taranaki Fault, including extensive mapping and paleo-environmental analysis, to establish the early Miocene - early Pliocene subsidence, sedimentation and exhumation history of the region, particularly of the eastern margin of Taranaki Basin.

We make the following conclusions from our work to date. During the late Eocene - early Oligocene, slow basement subsidence formed a basin east of Taranaki Fault in which non-marine and shelf marine sediments accumulated to form the Te Kuiti Group. A basement high persisted between Taranaki and King Country Basins during the Oligocene, hosting shorelines, which otherwise had migrated far to the south in Taranaki Basin. During the late Oligocene the structural high subsided in places, and bioclastic carbonate, which had formed in shelf environments over the high, was redeposited into Taranaki Basin to accumulate at bathyal depths as the Tikorangi Formation. During the early Miocene (Otaian Stage) the Taranaki and Manganui Faults accommodated the westward transport of Murihiku Terrane basement into the eastern margin of Taranaki Basin, but the amount of topography generated over the Herangi High at that time can only have amounted to a few hundred metres. The Mahoenui Group concurrently accumulated mainly in bathyal environments in a piggyback basin east of the overthrust blocks. The Altonian Stage (19-16 Ma) marked the start of the strong collapse of the structural high and eastern margin of Taranaki Basin, leading to the eastward retrogradation of a shelf-slope continental margin into the King Country region during the middle Miocene. Retrogradation and transgression were reversed during the late Miocene, from about 11 Ma, as a consequence of the north to northwest progradation of a thick shelf-slope continental margin wedge, sourced from the Southern Alps, comprising the Mt Messenger, Urenui, Kiore and Matemateaonga Formations. During the Pliocene and Pleistocene the whole of central North Island became involved in long wavelength up-doming with 1-2 km of erosion of much of the former Neogene succession in the King Country region. This regionally elevated the eastern margin of Taranaki Basin on both sides of the Taranaki Fault.

ORAL

THE CONTEMPORARY DETRITAL FISSION TRACK SIGNAL OF AN ACTIVE COLLISIONAL OROGEN, SOUTHERN ALPS, NEW ZEALAND

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The history of exhumation of active orogenic belts is contained in the underlying basement and in the sedimentary detritus deposited in adjacent basins. The Southern Alps formed during the late Neogene through the collision of continental Pacific and Australia plates. The Pacific crust has overthrust the Australia plate on the oblique-slip Alpine Fault. Erosional exhumation concurrent with overthrusting and associated deformation has exhumed a crustal section across the orogen. The Main Divide watershed runs the length of the mountain belt and is located at about the boundary between zeolite- to prehnite-pumpellyite-grade greywacke (Torlesse Supergroup) exposed to the east, and greenschist to amphibolite facies metamorphic equivalent (Alpine Schist) to the west. A foreland basin has formed on Australia plate, whereas a piggyback basin has formed on Pacific plate. Detrital apatite and zircon in east-flowing rivers contain only a partial record of low-temperature cooling, whereas cooling ages in west-flowing rivers record cooling associated with full orogenic exhumation.

On the east, the base of the apatite fission track (AFT) partial annealing zone (PAZ) lies in the catchment of the east-flowing rivers, and as such, detrital apatite have pre-orogenic and synorogenic FT ages reflecting the erosion of the upper crustal section. Zircon crystals from east-flowing rivers have mainly pre-orogenic ages with a very minor component of synorogenic ages reflecting the location of the zircon PAZ along the Main Divide. Therefore, zircon crystals mostly carry provenance ages relating to the original provenance of the Triassic-Jurassic accretionary complex, and Cretaceous thermal disturbance and exhumation.

On the west, the signal is dramatically different. AFT ages in west-flowing rivers are exclusively

late Neogene in age and commonly less than 1 m.y. B.P., reflecting very rapid cooling of the exhumed Alpine Schist east of the Alpine Fault. Apatite crystals entering the foreland basin west of the orogen have minimal inherited age and will effectively be completely reset. Zircon FT ages in these west-flowing rivers are also synorogenic and mainly reflect active exhumation of middle to lower crustal section: the majority of the crystals entering the foreland basin will nearly date (1 to a few m.y.) the stratigraphic age of the sediments. For the piggyback basin, the zircon crystals will mostly carry provenance ages relating to the original provenance of the Triassic-Jurassic accretionary complex, and Cretaceous thermal disturbance and exhumation.
The asymmetry in the tectonic structure of the Southern Alps Orogen, coupled with the effective erosion processes, means that the watershed divide partitions the FT age signals such that the foreland basin records the synorogenic deformation and timing of exhumation, whereas the piggyback basin records the pre-orogenic (provenance) signal.

POSTER

MID-PLEISTOCENE EXTINCTION OF DEEP-SEA FORAMINIFERA IN THE NORTH ATLANTIC AND SOUTHWEST PACIFC GATEWAYS

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The pulsed decline and eventual extinction of 51 species of elongate, cylindrical deep-sea benthic foraminifera (Stilostomelliidae, Pleurostomelliidae, and some Nodosariidae) occurred at intermediate water depths (1100-2100 m, ODP 980, 982) in the North Atlantic during the Mid-Pleistocene Climatic Transition (1.2-0.6 Ma). In the early Pleistocene, prior to their disappearance, these species comprised up to 20 % of the total abundance of the benthic foraminiferal assemblage at 2100 m, but only up to 2 % at 1100 m. The extinction of 51 species represents ~20 % of the total benthic foraminiferal diversity (excluding the myriad of small unilocular forms) at bathyal depths in the North Atlantic. Comparison with similar studies in intermediate depth waters of the Southwest Pacific (Hayward, 2001, 2002) indicates that ~73 % of the extinct species, diachronous pattern of declines and extinctions of each species were common to both regions. However, while the pattern of pulsed decline was similar, the precise order and timing of the extinctions of individual species were generally different at opposite ends of the world. Previous studies have indicated that this extinct group of elongate, cylindrical foraminifera lived infaunally and had their greatest abundances in poorly ventilated, lower oxygen environments. This is supported by our study where there is a strong positive correlation (r = ~0.8) between the flux of the extinction group and low oxygen tolerant species (such as *Uvigerina*, *Bulimina* and *Bolivina*) in the North Atlantic Gateway sites during the mid-Pleistocene, suggesting a close relationship with lower oxygen levels. The absolute abundance, flux, and number of the extinction group of species show a progressive withdrawal pattern with major decreases occurring in glacial periods. This might be related to increasing intermediate water circulation (ventilation), i.e. strengthening of Glacial North Atlantic Intermediate Water (GNAIW), as well as the extinction relating to the possible glacial expansion of Antarctic Intermediate Water (AAIW) in the Southwest Pacific.

POSTER

TAUPO VOLCANIC ZONE - A KEY TO NZ TECTONICS

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The 1987 Edgecumbe Earthquake provided crucial tectonic data for the TVZ:- 1.8 m of SE movement; a 100 yr return period; slower movement continuously; and a long-term average SE movement of ca 2.5 cm/yr. The "Volcanic Front", today's SE limit to the migration of North Island volcanism, is the SE boundary of the TVZ and CVR, and has no vents to its SE. Three young dacitic-andesite volcanoes are aligned along it from Taupo to Whakatane. A comparable line through the similar Manawahe volcano (age 424 ka), passing through the Okataina and Taupo rhyolitic centres (ca 400 ka old), had no older vents to its SE at 400 ka. These lines are identical in all but age, and that through Manawahe was the volcanic front at 400 ka. They imply SE movement of 10 km in 400 k.y. – averaging 2.5 cm/yr - when new strips of the Earth's surface, each ca 1.8 m wide, were created at ca 100 yr intervals, with lesser continuous movement between. Together they created the new surface area of the Rangitaiki Plains where nothing had existed before, at a typically incessant, cm/yr, "plate tectonics" rate.
The TVZ has been redefined *in time* as covering the CVR's youngest activity (since 400 ka), and *in area* as the above newly-created land, plus an overlapping NW area where volcanism was active since 400 ka. Two earlier zones, Manawahe (950-400 ka) and Mangakino (2.5 Ma - 950 ka) are

assumed to have been formed similarly. All three constitute the total CVR, created since ca 2.5 Ma where nothing existed before. As the southern termination of the concurrent 2,500 km parallel-rifting structure that includes the Havre Trough, the CVR was formed by rotational-rifting, initially away from the weakened abandoned trace of the presumed Alpine Fault (accepted as moving through both the North and South Islands from ca 15 to ca 5 Ma). Each zone shows major andesitic volcanism in the south, rhyolitic & geothermal activity centrally and in the north, and small dacitic-andesite volcanoes located on the then volcanic fronts of the younger two. At 400 ka, the line of rifting "jumped" from the initial Alpine Fault to a subsidiary parallel fault some 40 km to the east, leaving behind a large block of Jurassic greywacke, and suggesting tectonic control of the birth of the TVZ. This parallel fault line has been the NW boundary of the Rangitaiki Plains since 400 ka.

The "volcanic front" technique, developed for the TVZ, recognises volcanic fronts in the Coromandel-Kiwitahi Region from 15 to 5 Ma, and thus identifies SE migration of volcanism then - consistent with concurrent transcurrent movement recorded by many authors. That moved a number of features, including the East Coast Region and the active subduction system, progressively and relatively smoothly to the south and east. It also caused progressive development from the NW of intraplate replacing subduction-related volcanism, and of the steady extension accompanying the former of a zone of relative tectonic quiescence from Northland to the Waikato. Rotation since 15 Ma has been recognised by three authors as totalling 60-70^{o}. Its restoration implies that, prior to 15 Ma, the North Island would have been aligned NW-SE, parallel to the presumed Pacific margin of that time. The South Island could well have been aligned similarly.

ORAL

IMPROVED SEDIMENTOLOGICAL UNDERSTANDING OF THE LATE CRETACEOUS RAKOPI FORMATION – THE REAL FOUNDATION OF NEW ZEALAND'S HYDROCARBON INDUSTRY

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Comparatively little is known about the precise sedimentological character and depositional setting of the Rakopi Formation, despite it being the principal hydrocarbon source rock in the Taranaki Basin. This situation is due in part to the weathered nature of the only outcrop exposures located in NW Nelson, and limited penetration of the formation in exploration wells. Most existing knowledge has been derived from seismic facies interpretations. Recent forestry operations near Collingwood and an extensive section exposed in Paturau River have enabled us to evaluate the sedimentology of the formation in greater detail.

Typically the formation consists of interbedded pebbly sandstone, sandstone and siltstone forming a series of stacked fining-upward cycles observed in both outcrop and SP and gamma logs. The cycle motif in outcrop comprises up to 25 m-thick units, with a planar or erosive base, overlain by trough cross-bedded and faintly planar-laminated sandstone and pebbly sandstone, grading upward through interbedded sandstone and siltstone, to carbonaceous mudstone and coal at the cycle top. These are interpreted as high-sinuosity fluvial successions. The uppermost mudstone and coal represent a channel abandonment facies when lacustrine conditions prevailed.

In the upper part of the formation, the presence of glauconite and rare dinoflagellates suggests increasing marine influence in the transition to tidal-facies rhythmites of the North Cape Formation. Terrestrial palynofloras indicate the lower part of miospore Zone PM2. They are dominated by podocarp pollen, including abundant *Phyllocladidites mawsonii*, a taxon related to the modern Tasmanian Huon Pine which has a preferred flood-plain habitat.

Outcropping Rakopi sandstones are quartz-rich lithic feldsarenites and litharenites, depending on location, with the distinctions a reflection of different sediment sources. The feldsarenites are interpreted to have been derived from a granitic province, either the Cambrian-Devonian Buller Terrane and Karamea Suite granite located to the west and south of Paturau River or the Cretaceous Separation Point Granite, which outcrops to the south and east of Paturau River. The litharenites are rich in strained and polycrystalline quartz and lithic grains that display a schistose texture, suggesting they were derived from a metamorphic province, probably the Takaka Terrane which outcrops to the east of Paturau River.

In a regional allostratigraphic sense, the Rakopi Formation is regarded as a series of transgressive-regressive cycles, representing a depositional continuum from non-marine to fully marine lithofacies, and we would predict a greater marine influence further north into the basin. An improved depositional model will help refine models of hydrocarbon generation from the Rakopi Formation.

POSTER

ESCARPMENT STABILITY: PROCESSES AND MODES OF FAILURE

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Escarpments are steep, abrupt linear features in the landscape that separate terrain of different elevations. Escarpments are major landscape features in much of New Zealand, and thus pose legitimate questions about what leads to their development, particularly their rate and form of development. In addition, an understanding of the nature of geomorphic processes and process-response systems is essential to adequate assessment of escarpment stability and landform evolution. This study contributes to the understanding of escarpments as hazardous landforms. Hazard is a particular issue at this site because the escarpment runs adjacent to State Highway 83 and the formerly proposed Project Aqua hydro development.

The escarpment, near Duntroon in the Waitaki Valley, North Otago, was investigated to examine its processes and modes of failure (Figure **1**). The site represents an eroding escarpment separating the Tertiary sedimentary rocks from the contemporary floodplain of the Waitaki Valley. The escarpment consists of a faceted slope sequence. It is capped by Pleistocene gravels which overly a near-vertical sequence of Otekaike Limestone. The limestone overlies a group of weaker rocks that provide a 20-30° angled basal slope. The basal slope either merges with the current floodplain or abuts a series of terraces. Numerous boulders and boulder debris cover the slope, which also shows evidence of rotational slumping; debris lobes; weathered notches; and, remnant river terraces. Three modes of failure are recognised:

1. Failure by rotational sliding beneath the vertical limestone unit causing blocks to be carried down slope with the slump.
2. Failure by rotational sliding at the edge of (but not beneath) the vertical limestone unit; a notch develops and undermines the limestone blocks and they drop off (allows for rotations of boulders as they fall).
3. Rotational sliding acting as a purely transportation mechanism by which blocks are moved progressively down slope leaving behind a clear back slope at base of scarp cliff. With time blocks are moved further down slope with the lobe. The lobe becomes progressively more degraded. The blocks may be partially submerged and the scarp edge becomes weathered with the development of a basal notch.

Some indication of the cycle of retreat and episodicity of movement on the escarpment has also been determined based on evidence from aerial photographs, digital photographs, pollen analysis of buried soils and [historic] climate data. Processes leading to scarp development at this site (block failure & rotational slumping) are mass movement driven, episodic in nature and very much active in this locality.

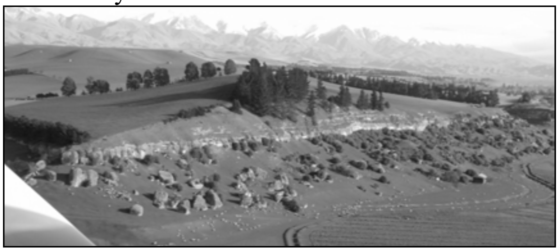

Figure 1: The Kokoamu Bluff Escarpment

ORAL

SECULAR DISEQUILIBRIUM AMONG U-SERIES ISOTOPES DURING MAGMA FORMATION BY PARTIAL MELTING IN THE CRUST

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Short-lived nuclides of the U-series decay chain provide fundamental constraints on the processes and time scales involved in the generation of magma in Earth's mantle. However the effects of melting and assimilation on U-series isotopes during ascent and storage of magma in the crust have only recently begun to be fully appreciated and have yet to be studied in laboratory experiments. Here we present U-Th-Ra isotopic measurements of partial melts and residual minerals produced by experimental melting of granite and explore some constraints these place on the application of U-series isotopes in the study of magmatic rocks.

In these 1-atm. experiments, mineral-contact relationships exert strong control over melting reactions and therefore melt composition. Melting along biotite-feldspar-quartz grain boundaries produce brown-colored melt, enriched in FeO, MgO, CaO, TiO_2 and radiogenic Sr. In contrast, melts formed along quartz-feldspar grain boundaries are colorless and are characterized by high K_2O and low $^{87}Sr/^{86}Sr$. All of these melts have low ($^{230}Th/^{232}Th$) activity ratios, consistent with the low U/Th (~0.07) of the granitic starting material, and are characterized by ($^{230}Th/^{238}U$) ratios ranging from 0.93 to 1.13. Residual mineral phases show both ^{230}Th and ^{238}U excesses and yield internal mineral-mineral and mineral-glass apparent ages between 10,000 and 200,000 years. Ra-Th isotope measurements in one experiment also reveal marked disequilibria with ($^{226}Ra/^{230}Th$) ratios varying from about 0.04 to 21.2 for brown and clear melt, respectively.

These results have several implications for the application of U-series isotopes to the study of the processes and time scales involved in magma production, transport, storage and differentiation. For example, our experiments show that both the U and Th excesses commonly observed in young, continental volcanic systems can potentially reflect rapid melting and remobilization of granitoid bodies in the crust, following underplating of hot, mantle-derived magma. Internal isochrons in young silicic magmas produced in this way may have little or no age significance. The most striking feature of our experiments is the large excess of ^{226}Ra relative to ^{230}Th in the quartzo-feldspathic melt. Assimilation of such a melt (as might be derived, for example, from heating of plutonic products of earlier magmatic activity) provides an intriguing, although somewhat speculative, mechanism for the controversial discordance among ^{238}U-^{230}Th and ^{230}Th-^{226}Ra ages in many arc volcanic suites. In this case, the Ra-enrichment preserved in some young arc lavas may be inherited in the crust, rather than the mantle wedge.

ORAL

DESIGN OF AIR CONDITIONING SYSTEM WITH A GROUND-COUPLED HEAT PUMP FOR A GRAVITY METER ROOM

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Research of gravity changing on geothermal fields by our laboratory shows that influence of seasonal change of temperature to the sensor of gravity meter cannot be compensated completely. Therefore, the thermostatic room for gravity meter is due to be built in new campus of Kyushu University. Recently, the air conditioning system and the snow-melting system with ground-coupled heat pumps are attracting many people's attention with environmental adaptability in Japan. Considering using the air conditioning system with a ground-coupled heat pump for a gravity meter room, the authors carried out numerical simulations for designing of the air conditioning system. The area of the gravity meter room is 26 m^2 and good heat insulation. The maximum cooling load and maximum heating load is 0.56 kW and 0.68 kW, respectively. The parameter of the simulations are indoor setting temperature, flow rate of heat extraction medium, and the length of a Down Hole Coaxial Heat Exchanger (DCHE). As a result of the simulation, the optimal values of the indoor setting temperature, the flow rate of heat extraction medium, and the length of DCHE were expected to be 18 degree C, 5 l/min, and 12 m, respectively, from the viewpoints of heat balance of the ground, operating temperature of heat pump, the coefficient of performance (COP), and economical efficiency. Under the designed conditions, the average COP over the first year of operation was estimated at 5.85. And stable operation of the system over the long-term was expected.

ORAL – geothermal workshop

CHARACTERISATION OF EXTENSIONAL TECTONICS IN THE OFFSHORE BAY OF PLENTY SINCE 20 KA.

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Active continental back-arc extension in the North Island, associated with oblique subduction along at the Hikurangi Margin, is characterised by intense normal faulting distributed across the 20 km-wide, NE-striking Taupo Fault Belt and Whakatane Graben. The Extension rate at the Bay of Plenty coast is c. 7 mm/yr in a ENE direction, i.e. sub-perpendicular to the regional fault trend. A component of the oblique convergence within the plate boundary is partitioned to the east onto the NNE-trending North Island Dextral Fault Belt (NIDFB).

The Whakatane Graben extends offshore onto the continental shelf, where favourable conditions for marine sedimentation have resulted in a spectacular record of the faulting history at and beneath the seabed in the sedimentary sequence. We used an extensive network of multi-channel and high-resolution marine seismic reflection profiles along with multibeam bathymetry to construct a detailed fault map of the offshore Whakatane Graben. The broad fault pattern is that of titled basement blocks controlled by large west-dipping faults and associated with numerous antithetic secondary faults, most of which rupture the post-last glacial (<20 ka) erosional surface (PGS) and the seafloor. The offshore Whakatane Graben is bounded to the west by the Rurima Ridge and to the east by the White Island Fault. The White Island Fault is characterized by a seafloor escarpment up to 80 m high. Large faults, including the White Island Fault and the Rangitaiki Fault in the centre of the graben, are thought to rupture the entire 6-9 km thick seismogenic zone. Active normal faulting is observed east of the White Island Fault along the offshore extension of the NIDFB.

Age estimates on seven seismic reflectors provide constraints on the timing of faulting. Of particular interest for active tectonic studies and hazard assessment, is the widespread measurement of displacements of the seafloor and the PGS from which we have derived vertical separation rates over the entire offshore graben. Particular focus was placed on estimating the diachronous age of the PGS, which formed between 20 and 9 ka as sea-level rose from 120 m below present sea level, by taking into account subsidence of 1-3 mm/yr in the centre of the graben and less than 1 mm/yr of uplift on either sides where the PGS is outcropping at the seafloor.

Vertical displacements were measured along a series of N47E transects, 5-8 km apart, and perpendicular to the active fault zone, from Rurima Ridge to the offshore extension of the NIDFB. The cumulative vertical displacement along the transects range from 80 m to 180 m from south to north. Considering the diachrounous age of the PGS, a cumulative vertical separation rate of 9±3 mm/yr was derived across the offshore Whakatane Graben and NIDFB.

ORAL

MECHANISMS OF EMPLACEMENT AND INTERRELATIONSHIPS BETWEEN SLUMPS, DEBRIS FLOWS AND BLOCKY AVALANCHES AT THE MATAKAOA RE-ENTRANT, NORTH-EAST NEW ZEALAND.

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The 45 km-long, ~30 km-wide Matakaoa re-entrant near the collisional Australian-Pacific plate boundary off New Zealand, has incised the >1000 m thick, seaward dipping sedimentary section of the East Cape margin. Swath bathymetry and seismic reflection data provide clear insights into the margin's evolution, and in particular the mechanisms associated with submarine debris avalanches and flows.

The re-entrant morphology suggests active erosion at its head, as shown by pervasive gully formation, large slump blocks in the process of collapse, and an active, fan/channel system. Blocks up to 2.8 km across scatter the area north of the re-entrant, and indicate the large Matakaoa debris avalanche.

North of the re-entrant, three major debris flows are identified within the first kilometres beneath seafloor. (1) The oldest flow is ~60 km wide and extends ~70 km north from a large basement anticline at the re-entrant mouth. At the base of the flow, coherent reflections indicate numerous imbricated thrusts and faults over a distance of at least 50 km. This may indicate viscous behaviour possibly due to dewatering during flow emplacement. (2) The second flow overlies the first over its entire ~70 km-length. Its western flank is eroded into a conspicuous 200 m-high NNE-trending scarp, outlined by numerous kilometre-scale angular blocks detached from the main body of the debris flow. The scarp forms the eastern limit of the major channel that guides turbidity currents descending from the re-rentrant. (3) The youngest flow, the Matakaoa debris flow, fills the major channel, and extends 200 km north. It appears contemporaneous with the Matakaoa avalanche. First estimates give debris flow volumes ranging 500-1000 km^3.

The eastern re-entrant is filled by an estimated 15 km^3 of material slumped from the margin either contemporaneous with or post-dating the Matakaoa debris flow. Rapid sediment accumulation, from high discharge rivers draining the rapidly uplifting East Cape region, may provide enough material to generate ~20 km^3 debris flows every 500-2000 yrs. Deposition of thick sediment piles about the faulted headward scarp of the re-entrant, coupled with the region's high seismicity, are prime factors controlling the multiple margin failures.

POSTER

PALEOSEISMOLOGY OF THE NORTHERN WELLINGTON AND SOUTHERN MOHAKA FAULT SYSTEM: HOW TO DEAL WITH 16 TRENCHES !

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An attempt to apply fault segmentation models to the continuous Wellington-Mohaka Fault System has resulted in the Wellington Fault (WF) being divided into three "sections" –Wellington-Hutt Valley, Tararua, and Pahiatua - on the basis of geometry, geomorphology and slip rate. Paleoseismic studies offer a means to test this model.

Nine paleoseismic trenches have now been excavated along the c. 42 km long Pahiatua section. Data from six of these trenches shows evidence for the last four surface faulting events having occurred during the last c. 4100 years (see Berryman et al 2002 EQC report). Events are recognised on the basis of upward-terminating faults, colluvial deposits, "co-seismically" generated, organic poorly sorted units, and ponded units. The events occurred at c. 1670-1840 A.D. (most recent event =MRE), c.1160-1260 AD (Event II =EvII), c. 400 BC to 50 AD (EvIII), and c. 2140-1960 BC (EvIV). The 4 events are spaced 650-2000 yr apart, which is consistent with an estimate of the recurrence interval based on slip rate (5.1-6.2 mm/yr) and single event displacement (3.5-4.5 m), which gave an RI range of 550-1060 yr. Two new EQC-funded trenches opened at Dougan farm (S25/266590) last week have the potential to answer some of the questions posed by fault segmentation vs. paleoearthquake records for the WF, e.g., why is that MRE not recognised?/dated at trenches near the Tararua-Pahiatua section boundary?

Seven paleoseismic trenches have also been opened along the southern 20 km of the Mohaka Fault, north of Manawatu Gorge. Five trenches were opened by Massey University in the 1990's. Two further trenches were opened by GNS in 2003. at the Trotter farm. We used the same criteria to identify events and also re-assessed the events from the older trenches. There is evidence for the MRE at c. 1840-1520 A.D. The timing of EvII is tightly constrained by faulting and dragging in Trotter4 to be c.997-1009 AD in age. EvIII is correlated on the basis of stratigraphy (Δ environment/ influx of debris) to a time of c. 170 BC to 80 AD, while EvIV, probably occurred soon after 1320-1020 BC, which is midway in time between Events III and IV along the Pahiatua section.

The combined results of this work show that the southern end of the Mohaka Fault (MF) also has a record of multiple surface-rupturing paleo-earthquakes, that mostly occurred at similar times to those on the Pahiatua section of the WF over the last c. 3300 yr. Paleo-earthquake results from the 4 southernmost fault sections of the Wellington-Mohaka Fault system yield similar (overlapping) and perhaps younging to the north, event ranges for the last 2-4 events. These results have significant implications for the way we consider seismic hazard in the lower North Island – are we seeing very long ruptures of the WF and MF, or, is there a time-dependence to surface-rupturing events that are related to large-scale strain release and/or stress triggering processes, i.e., cascading, along-strike ruptures, segment by segment, at times of wholesale plate boundary failure?

ORAL

STRUCTURAL MITIGATION OPTIONS FOR VOLCANIC MASS FLOWS

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Volcaniclastic mass flows are a common occurrence on New Zealand andesite stratocones, and a major source of hazard for communities established in (or transiting through) the surrounding ring plains. Ruapehu, Tongariro, and Taranaki are all prone to eruption- and rain-triggered lahars. In addition, their steep slopes and the presence of saturated, low-yield strength clays resulting from the weathering of ash (allophane; Taranaki) or thixotropic clays from hydrothermal alteration (smectites; Ruapehu and Tongariro), lead to mechanical instabilities that have triggered in the past catastrophic sector collapses, generating large-scale debris avalanches and 'cohesive' debris flows (DFs). If structural mitigation solutions are to be considered for these events, the behaviour and physical properties of the various types of mass flows must be accounted for.

Damage generated by volcaniclastic mass flows to infrastructure includes:

(1) Flooding (lateral hydrostatic pressure from differential depth; contact by slow rising waters); (2) Destruction due to the frontal impact of the flow (dynamic overpressure), dragging, and erosion by turbulence and transitory waves; (3) Damage created by the collision of debris carried by the mass flow due to its buoyancy (point impact forces and dynamic thrust); and (4) Long-term and diffuse effects: infiltration-saturation by capillarity and corrosion (chemical attacks).

Sabo engineering structures (training dykes; deflection dams) in conjunction with sediment retention basins have been traditionally used to reduce hazards from lahars in Japan and Indonesia. In British Columbia, *deflection walls*, *lateral walls* (berms) and *terminal walls* (barriers) have been built in order to mitigate damage caused by non-volcanic DFs running in open channels. These diversion structures, initially conceived for small- to medium-size DFs on active debris fans, take into account two critical parameters: *the maximum discharge of the flow (Q_p)* and the *flow depth (h)*. The discharge depends on the geometry of the stream channel (gradient, cross-sectional shape) and the velocity of the flow at a specific location. Q_p is determined via an empirical relationship with the magnitude (volume) of the flooding event V_{DF}. It is essential for the design of engineering options to consider also impact forces, run-ups and superelevations (additional freeboard).

The relation $Q_p = fV_{DF}$ is described in the New Zealand context and an approximate upper limit is graphically suggested when considering the 1995 sequence of lahars at Ruapehu and the record of large prehistoric events at both Taranaki and Ruapehu-Tongariro. The corresponding maximum flow depths, for different channel morphologies and measured (or calculated) velocities, are determined by using the *Poiseuille equation* $v = \gamma\theta h^2/l\upsilon$. Results are presented and discussed, as an initial attempt to provide quantitative information to use in future numerical, GIS-based, modelling tests of structural designs.

ORAL

SOIL GAS SURVEYS FOR PETROLEUM EXPLORATION: EXPERIENCES FROM TWO DIFFERENT TECHNIQUES

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Soil gas detection has been promoted as a useful technology for oil and gas exploration for many years, but is not routinely applied because although relatively inexpensive, the method is not widely considered reliable in actually identifying economically viable prospects. However, GeoSphere has undertaken two surveys in the past two years to address specific uncertainties, with some success in identifying anomalies that appear to correlate to as-yet untested subsurface prospects. The two techniques selected detect different levels of hydrocarbon seepage that can be utilised for different stages of exploration appraisal.
In 2003 we undertook a 160-sample survey across South Taranaki, calibrated with patterns of 15 samples around each of six well locations (two over known gas accumulations, two over known oil accumulations, and two over dry hole locations). The proprietary GoreTM method applied involved insertion of a module containing adsorbent resins at a depth of about 60cm for three weeks, followed by measurement of 90 hydrocarbon compounds by GCMS. In spite of low levels of hydrocarbon microseepage, a consistent geochemical signature is associated with Kapuni Group gas reservoir. Miocene oil reservoir is not well discriminated by the data. Survey results support the prospect cases for structures mapped at the Moki Formation level in PEP 38749, and point to potential footwall and stratigraphic traps in the former PEP 38750.

In 2004 we undertook a smaller pilot project in a South Island basin. For this project we adopted a lower-cost approach, collecting samples from 0.5-1m depth at about 30 sites by hand auger, sealing them in paint tins and having the headspace gas analysed by Selected Ion Flow Tube MS, a proprietary technique developed by Syft Technologies in Christchurch. The presence of n-alkanes up to octane in some samples at one location offers strong support to the case for a petroleum reservoir at depth, but the survey method needs further development to be reliable as a reconnaissance exploration technique.

ORAL

MAPPING THE GEOLOGY OF TAUPO VOLCANIC ZONE FOR THE 1:250,000 QMAP ROTORUA SHEET

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Compilation of Taupo Volcanic Zone (TVZ) volcanic geology for the new 1:250,000 Rotorua geological map sheet is currently underway. This is part of the QMAP digital mapping program, drawing on existing maps, both published and unpublished, and the results of new field work.
The most recent maps covering the entire TVZ are the New Zealand Geological Survey (NZGS) 1:250,000 map sheets 'Rotorua' (Healy et. al., 1964) and 'Taupo' (Gindley et al., 1960). Substantial new mapping has since been conducted as part of university research, by the NZGS and more recently the Institute of Geological and Nuclear Sciences (GNS), and by various other institutions. The majority of this has remained unpublished with many maps existing as only one or a few paper copies, often hand-coloured.
In 2003 many of these maps were synthesised in a review and generalised compilation of TVZ geology, as part of the Crown Minerals/GNS publication "Epithermal gold in New Zealand: GIS data package and prospectivity modelling". The publication is available free on CD-Rom from Crown Minerals. Approximately 150 individual sources were checked for new mapping, and universities and other institutions kindly supplied over 50 of what appeared to be the most recent and geologically-consistent sources; these were compiled as a single GIS layer. The review found a range in coverage of new mapping since the 1960's; from detailed studies in overlapping areas by multiple workers (especially 1:50,000 NZMS 260 sheets U16 and V16), to areas which have seen almost no post-1960s mapping (especially west, east and southeast of Lake Taupo, some areas

around Reporoa, patches of the western edge of TVZ, patches north and northeast of Okataina Volcanic Centre, and the fringes of the Mamaku plateau). Authors' stratigraphic nomenclature and structural mapping were also found to vary.

The QMAP Rotorua sheet program will compile these and other sources in greater detail, along with input from the myriad of researchers who have worked on developing the understanding of TVZ geology over the last 40 years. New field work will target uncertainties and inconsistencies between different sources, and those areas mentioned above where little detailed mapping has been done. The program will also partly support some new postgraduate student mapping projects targeted in these areas through QMAP scholarships.

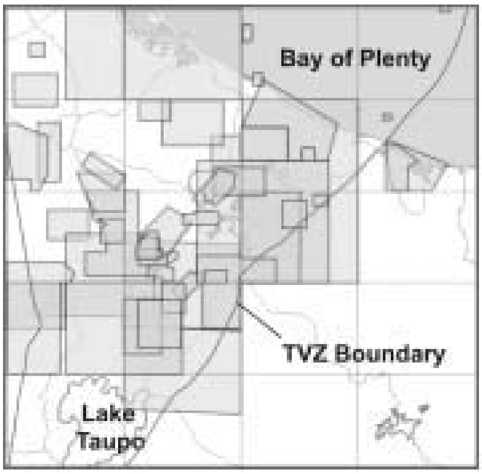

Figure 1: QMAP Rotorua sheet with grey polygons representing most of the mapping compiled in 2003 by Crown Minerals and GNS. Note the variability in coverage. Grid is 40 km-wide NZMS 260 sheets.

ORAL

DIKE-INDUCED EXTENSION DURING THE 1.8 KA TAUPO ERUPTION, NEW ZEALAND

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Volcanism in the Taupo Volcanic Zone is intimately intertwined with extensional faulting. TVZ faults range across a continuum from a) those directly related to eruptions (discussed here) to b) rifting-related faulting, occurring independently of eruptions (e.g. Rowland and Sibson, 2001, *NZJGG* 44: 271-283). This raises the question of causative relationships between magma intrusion, volcanic eruptions and surface faulting (Leonard et al., 2004, P*roc. IAVCEI Gen. Assemb., Pucon, Chile*).

New field evidence for extension during the 1.8 ka Taupo eruption from Taupo volcano is presented. The extension was most likely due to the blind emplacement of a dike along strike from the Taupo eruption vents.

The Taupo eruption vents are aligned northeast, in the area of Horomatangi Reef now submerged below eastern Lake Taupo. At Two Mile Bay, 10 km further to the northeast and along strike of the vents, 20 normal faults are exposed in a 40 m wide cutting through a sequence of Taupo eruption deposits and lacustrine sediments. The faults appear to have been accommodating purely extensional strain. There is little net vertical offset of horizons across the sum of the faults and they variably dip (mean 68°) to either the southeast or northwest with several faults intersecting and/or truncating one-another (Fig. 1). The maximum throw on a single fault is 1.8 m and the offset on most faults decreases upwards through the eruption sequence. No offset is seen in the overlying shallow-water beach sediments of the post-caldera lake, which formed immediately after the eruption. The mean fault strike (083°) is greater than that of the eruption vents, possibly influenced by buried regional structures and/or Taupo-caldera-related strain. A volcanic origin for the faults is supported by the lack of any geomorphic expression of active tectonic faulting in older deposits (26.5 ka Oruanui deposits 1.5 km away, and ~190 ka Tauhara dome) along strike from the three faults displaced most (> 1.5 m).

The faults seen in outcrop would be classified as 'active' (Holocene) from a purely tectonic perspective, but they are clearly volcanic in origin presenting no elevated hazard risk from ongoing regional tectonic events. Similar intrusion-driven faulting has been identified related to the 26.5 ka Oruanui caldera-forming eruption from Taupo volcano (Hughes et al., this volume), and the extrusion of 229-239 ka lava domes at Maroa volcano.

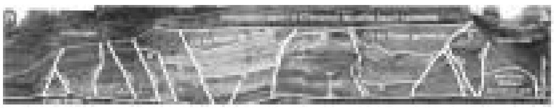

Figure 1: Extensional faulting during the 1.8 ka Taupo eruption. R = Rotongaio ash.

POSTER

FINITE-DIFFERENCE MODELLING OF SEISMIC REFLECTION DATA IN A HARD ROCK ENVIRONMENT: AN EXAMPLE FROM THE MINERALISED OTAGO SCHIST

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The interpretation of seismic reflection data in non-sedimentary environments is problematic. In the Macraes Flat region in eastern Otago, ongoing mining of mineralised schist has prompted the development of a seismic interpretation scheme that is capable of imaging a gold-bearing shear zone and associated mineralised structures accurately to the metre scale.
The anisotropic and complex structural nature of this geological environment necessitates a more cost-effective computer-based modelling technique that can provide information on the geological characteristics of the schist. This method has been tested on seismic data acquired in 1993 over a region that has been mined over the intervening years. Correlation to measured structural data permits a direct comparison between the seismic data and the actual geology. Synthetic modelling utilises a 2-D visco-elastic finite difference routine to establish the expected seismic characteristics, including the velocity, anisotropy and contrast of the shear zone structures. Iterative refinements of the model result in a more representative synthetic model that most closely matches the seismic response of the geology. The comparison between the actual and synthetic seismic sections provides promising result that will be tested by new data acquisition over the summer of 2004/2005 to identify structures and zones of potential mineralisation. Downstream benefits of this research could also contribute to earthquake risk assessment analyses at similar faults.

POSTER

OLIGOCENE UNCONFORMITIES IN THE NEW ZEALAND REGION

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Recent publications of results from drilling ODP Leg 181 (Carter et al. 2004) have highlighted some inconsistencies and problems with published Oligocene stratigraphy in both onshore and offshore areas. The Leg 181 publications attribute an unconformity in the lowest Oligocene to the formation of a proto-Antarctic Circumpolar Current (ACC) at around 33.0-33.5 Ma, due to the opening of a passage between Antarctica and Tasmania. This unconformity is then correlated with the regional 'Marshall Paraconformity' which occurs prominently in eastern basins in New Zealand, and has been correlated to other basins as well as to drilling results in the Tasman Sea.
The dating of onshore examples of the Marshall Paraconformity is limited, biostratigraphic differentiation is made difficult by the length of the Whaingaroan and rather inadequate knowledge of the Duntroonian and Waitakian stages. In addition the unconformities are often associated with dissolution and stratigraphic. A strontium isotope age of ~29-32.5 Ma has been documented (Fulthorpe et al. 1996) in the type locality of the Marshall Paraconformity near Oamaru (Carter et al. 1982).
In many successions there are multiple unconformities throughout the Oligocene, starting near the Eocene-Oligocene boundary (lower Whaingaroan) and finishing near the Oligocene-Miocene boundary. In a few locations an angular relationship has been reported (e.g. Lewis and Bellis 1984), otherwise the unconformities range from disconformities to paraconformities, often with hardground formation, encrustation, erosion, karst formation, phosphatisation, and glauconite concentrations associated with the surfaces. In a few locations there are no recorded unconformities, including DSDP site 277, and some onshore successions in Southland.
Why do some successions, especially shallow marine sections, show multiple unconformities, with sedimentation between often unaffected by current activity? Why do angular unconformities occur? Some areas show rapid deepening through this time period, while others have definite shallowing. Karst formation is associated with some unconformities but not others. Why, if a deep water current is involved, do shallow water successions develop unconformities?
The unconformities could have been caused by local basinal tectonic reactions to changing plate tectonic motion through the Oligocene, to sea-level changes related to Antarctic glaciation, or to the development of the ACC. Each possibility has implications for the age of the unconformities, and the use of the unconformity surfaces in regional correlation. Resolving the cause of unconformity development and the dating of the unconformities has international implications for the study of the development of the ACC, Antarctic glaciations and the development of the plate boundary zone through the New Zealand region.

ORAL

FORGOTTEN PHENOMENA OF MATERIALS SELECTION AND USE IN GEOTHERMAL ENERGY APPLICATIONS

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Pioneering activities of experimental testing and application of engineering experience identified a range of materials and process design guidelines for early geothermal energy plant developments in New Zealand. The success of these guidelines is evidenced by energy plant operation periods extended well beyond design lifetimes, not only in New Zealand but around the world. The efficacy of these guidelines has frequently been tested and in many cases failures have been encountered where the specific conditions of environment-material combinations have not been reliably defined. The "rules" of materials selection for geothermal energy applications have been stated and restated on many occasions and have been proven by experienced successes and failures, the majority of the failures being attributable to readily identifiable forgotten phenomena.

The historical "rules of thumb" that are at times forgotten are:

1. Corrosion of carbon and low alloy steels is controlled by formation of protective sulphide and oxide corrosion products in near neutral pH fluids. These films are unstable when oxygen is present. Hence, oxygen contamination of geothermal fluids must be avoided.
2. Where stainless steels are selected, to avoid the thick films which are encountered with carbon steels or where erosion can occur, the stainless alloys specified must be resistant to pitting corrosion and chloride and sulphide induced Stress Corrosion Cracking (SCC).
3. H2S is present in most produced geothermal fluids and hence hydrogen diffuses into the steels. Historically, NACE Standard MR0175 was applied so low strength materials with a minimum of cold work were preferred. The guidelines of this standard have been recently improved with the issuing of a Joint NACE International/ISO standard, NACE MR0175/ISO 15156-1:2001(E) Petroleum and natural gas industries---Materials for use in H2S-containing environments in oil and gas production---in 3 Parts.

Recent New Zealand and International R&D has progressed interpretation of these basic rules to include means of utilising more aggressive environments as are encountered for example in acid wells and in volcanic / near volcanic environments. Opportunity to avoid historical materials constraints include process changes such as pH adjustment, design changes to reduce the severity of the material-environment combination, selection of new materials and materials combinations and by attention to detail with respect to fabrication practices.

In spite of these advances the basic rules must still be acknowledged and occasional failures have occurred when developers have pushed the boundaries of materials selection and use and when these rules and guidelines have been forgotten or miss-interpreted.

The paper provides further discussion of the impact of these forgotten phenomena.

ORAL – geothermal workshop

1855 WAIRARAPA FAULT EARTHQUAKE: WORLD RECORD STRIKE-SLIP DISPLACEMENT NOW EVEN BIGGER

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Dextral-slip associated with the 1855 M8.0+ event on the Wairarapa Fault was reported to be 12 ±1 m along a rupture length of ≥148 km (Grapes, 1999), the largest known strike-slip offset documented worldwide. Initial results from a new study involving detailed microtopographic surveys and neotectonic mapping of offset landforms indicate that dextral-slip was as much as 50% greater than previously measured.

Between Tauwharenikau River and Lake Wairarapa, the 1855 surface trace preserves steep (30-90°) scarps exposing terrace alluvium, and is marked by a series beheaded stream channels. Over ~11 km to the south of Featherston, the fault zone is strongly segmented, consisting of fifteen, 1200 ±500 m-long strands arranged left-stepping pattern. Anticlinal bulges deform the ~100-200 m wide overlap zones between the stepovers. There, slip is distributed amongst two or more ruptures and intervening anticlines, a situation that causes variations in slip and which locally complicates the interpretation of 1855 slip.

We focused on the best-preserved sites, including 5 attributed by Grapes (1999) to slip during the 1855 earthquake. At each site, we made detailed topographic maps with GPS and laser survey instruments. Smallest dextral-slip offsets, here attributed to 1855, include 16.4 ±1.0m, 12.9 ±2.0m, 17.2 ±2.5m, 18.7 ±1.0m, 13.0 ±1.5m, 15.1 ±1.0m, and 16.0 ±1.5m. Vertical-slip varies from 0.5 to 3.8 ±0.5m. Tape measurement of two other offset streams in dense bush yielded dextral-slips of 13.5 ±0.5m and 17.5 ±1.5m.

Pigeon Bush includes two beheaded channels that preserve distinct offsets with respect to a narrow gorge on the opposite side of the fault. The linear channels are perpendicular to the scarp and do not deflect in proximity to it, but are truncated. There is no evidence that their beheading was the last step in a multistage offset. The youngest is partially filled by fluvial gravel containing charcoal that yielded ^{14}C calibrated dates of AD 1364 ±63 and

AD 1355 ±60 (2 σ). The 18.7 ±1.0 m offset of this stream is inferred to have occurred entirely in 1855. At Tauwharenikau an abandoned channel is dextrally offset by ~16m. On the downthrown side, it is filled by swamp deposits due to post-offset groundwater seepage. Two basal peat samples yielded calibrated dates of AD 1709 ±26 (27% probability) or 1869 ±60 (71%) and AD 1723 ±49 (34%) or 1871 ±70 (64%). Further dating studies are underway to confirm that these and other offsets could not have accrued during more than one earthquake rupture.
The Wairarapa Fault experienced (by far) the largest single-event strike-slip offset so far documented worldwide. The unusually large slip and high D/L ratio can be explained either by a large down-dip width (and small aspect ratio) of the oblique-slip rupture, perhaps including part of the subduction interface, or by a large static stress-drop.

ORAL

PALEOCEANOGRAPHIC SIGNIFICANCE OF QUATERNARY RADIOLARIAN ASSEMBLAGES FROM ODP SITE 1123, OFFSHORE EASTERN NEW ZEALAND, SOUTHWEST PACIFIC

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A medium-resolution, quantitative study of Quaternary radiolarian assemblages from ODP Site 1123, located 1100 km offshore from eastern New Zealand and in a water depth of 3290 metres, helps to understand the local oceanographic effects of climatic changes over the last 1.2 million years. At Site 1123, this time interval is represented by 45 m of clayey nannofossil ooze. Samples were selected according to an orbitally-tuned age model using high-resolution stable isotope records, which resulted in an average sample spacing of ~15 kyr. The census recorded 167 counting groups, ranging from subspecies to undifferentiated families. This full faunal inventory permitted determination of a wide range of radiolarian assemblage characteristics (abundance, preservation, diversity, and relative abundance of orders, families, and selected species). Emphasis was given to changes in radiolarian assemblages through the Mid-Pleistocene climate transition (MPT) in which a fundamental reorganisation in Earth's climate system is shown by a change from 40,000 to 100,000 year Interglacial-Glacial (I-G) cycles.
No significant changes in radiolarian assemblages were found to coincide with the onset or termination of the MPT. However, four distinctive phases were identified within the 1.2 m.y. radiolarian succession. Phase 1 (1.2-1.1 Ma), – radiolarians are relatively rare, the I-G cycle trend is one of decreasing radiolarian abundance, diversity and nassellarian abundance; Phase 2 (1.1-0.7 Ma) – radiolarians are common to very abundant; the well-defined I-G cycle trend is one of increasing of total abundance and increasing diversity and abundance of nassellarians; Phase 3 (0.7-0.4 Ma) – radiolarians and especially nassellarians are too rare to identify assemblage trends but abundance tends to increase in Interglacials; Phase 4 (0.4-0 Ma) – radiolarians are abundant; the weak I-G cycle trend is one of decreasing total abundance, diversity and nassellarian abundance. In summary, radiolarians tend to have been most abundant and diverse in Interglacials for the last 1.2 m.y. at Site 1123, with sparse spumellarian-dominated radiolarian assemblage typical of Glacials during Phases 1, 3 and 4. Phase 2, which spans the onset of the MPT, shows a contrasting trend in which abundance and diversity is highest in the Glacials.
Interglacial-Glacial cycles are well defined in radiolarian assemblages by variations in relative abundance of warm-water (e.g. Didymocyrtis tetrathalamus, Theocorythium trachelium) and cool-water taxa (e.g. Larcopyle butschlii, Saccospyris antarctica). Radiolarian climate indices based on these variations are significantly correlated with δ18O. A similar correlation is noted for depth indicators, with deep-water taxa (e.g. Prunopyle antarctica, Larcopyle butschlii) increasing in abundance during Glacials. At this stage it is not certain if this phenomenon is due to (i) many deep-water indicators also tending to be cool-water taxa, (ii) increased influence of southern-sourced deep waters, or (iii) increased mixing due to strengthening of local current systems.

POSTER

SILICEOUS SINTER DIAGENESIS AT THE OPAL MOUND, ROOSEVELT HOT SPRINGS, UTAH, U.S.A.

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Siliceous sinter from the Opal Mound at Roosevelt Hot Springs preserves a complete diagenetic continuum from opal-A to quartz. Sinters from vent, near-vent and mid- and distal-apron environments were studied. ^{14}C AMS dating yielded ages of 1900 years BP for a sample of quartz mineralogy and 1600 years BP for a distal slope sample with opal-A/CT mineralogy. The transformation from opal-A to quartz in the near-vent sample is more rapid than in sinter deposits of the Taupo Volcanic Zone, New Zealand, which take as long as 40,000 years to transform to diagenetic quartz. Two generations of quartz occur at Opal Mound, diagenetic and hydrothermal quartz. Diagenetic quartz is identified by the presence of moganite, and equant, blocky nanocrystals of opal-C incorporated into quartz crystals growing parallel to the sinter surface. Hydrothermal vein quartz infills fractures with crystals that grow perpendicular to the sinter surface and do not contain moganite. Conductive heat transfer from the injection of thermal fluids that deposited vein quartz in fractures may be responsible for accelerating diagenesis at Opal Mound.

ORAL – geothermal workshop

PALAEOHYDRAULIC ANALYSIS OF THE 1953 TANGIWAI LAHAR

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On Christmas Eve, 1953, the summit Crater Lake of Mount Ruapehu breached an unstable barrier composed of volcanic material deposited during the 1945 eruption sequence, buttressed by the Crater Basin Glacier. Approximately 1.8 million cubic metres of water was released into the headwaters of the Whangaehu River, where it rapidly entrained snow, ice, and volcanic debris to form a lahar that reached the Tangiwai railway bridge c. 39 km downstream in a little over 2 hours. Tragically the flow critically damaged the bridge moments before passage of the Wellington-Auckland express: unable to stop in time the train fell into the lahar-swollen river with the loss of 151 lives, making it New Zealand's worst volcanic disaster.
Palaeohydraulic analysis of the 1953 event indicates that the former summit glaciers did not impede the outflow of 26 ^{o}C Crater Lake water. A coupled hydraulic and thermo-dynamic model shows that enlargement of the ice tunnel kept pace with growth of a trapezoidal breach in the tephra barrier at the outlet to generate a peak discharge in the 300-400 m^3/s range. This starting hydrograph was then routed along a digital model of the Whangaehu River, divided into Gorge, Fan, and Valley reaches, using a dynamic flow routing technique calibrated against travel time, flow velocity, stage level, peak discharge and sediment concentration data from the 1995/96 lahar sequence plus what little is available from the 1953 event. These data indicate that by c. 10 km downstream, flow bulking through the entrainment of particulate material along the Whangaehu Gorge (0-10 km) had increased the 1953 peak discharge to c. 2000 m^3/s. Implied bulking factors along this reach are hence 5-6, suggesting that pore water was entrained along with particulate material. Rapid attenuation on the Whangaehu Fan (10-23.6 km) was achieved in the model by substantially reducing bulking factors in order to match the c. 60 % reduction in peak discharges observed during the 1995 lahar sequence while preserving travel times. This suggests that volumetric losses occurred by deposition of sediment on the low gradient braided fan and by infiltration losses of water to permeable channel beds. Minimal further reductions in modeled bulking factor between the fan toe at 23.2 km and Tangiwai at 39.0 km were required to match contemporary discharge estimates of c. 590-647 m^3/s at the railway bridge as determined by slope-area methods.
Primary results of palaeohydraulic analysis of the 1953 Tangiwai lahar are (i) confirmation of the limited role of the former summit glaciers in limiting the rate of outflow from Crater Lake; (ii) the positive correlation between lahar magnitude and bulking factor; (iii) identification of infiltration losses on the Whangaehu Fan; and (iv) derivation of a calibrated lahar attenuation curve for the Whangaehu River. Some of these insights should be of utility in predicting the magnitude and behaviour of future lahars in this catchment.

ORAL

CAPTURING MAXIMUM SCIENTIFIC BENEFIT FROM THE PREDICTED RUAPEHU CRATER LAKE LAHAR

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The 1995-96 eruption sequence at Mt. Ruapehu, New Zealand's largest and most active onshore andesite volcano expelled the summit Crater Lake and deposited c. 7 m of unconsolidated tephra on the rock rim of the lake basin. Subsequent refilling of the hot acidic lake has raised the possibility of a lake break-out sometime in the next 6-18 months with the potential to release up to 1.45 million m^3 of water. This flood will rapidly develop into a hazardous lahar. Although eruption-triggered lahars have accompanied all historic eruptions of Ruapehu, lake break-out events are much rarer and equally poorly understood. The last known lake break-out occurred in 1953 following the 1945 eruptions, triggering a lahar that caused New Zealand's worst volcanic disaster when a railway bridge was swept away, resulting in 151 fatalities at Tangiwai.

In response to the threatened lahar the Department of Conservation has installed an automated system using USGS acoustic flow monitor technology to provide warning of lahars in the Whangaehu valley. However, the fact that a lahar is almost certain to occur once the lake has risen to c. 3 m above the stable rock rim provides a unique opportunity to capture maximum scientific information from a discrete lahar event. Teams from GNS and Massey University, in association with overseas colleagues are planning deployment of a suite of automatic instruments to measure key parameters of the lahar at various points between the Crater Lake and the first hydrographic gauging station 57 km downstream. These are intended to resolve current uncertainties in (i) the rate and mode of dam breach, and (ii) changes in the size and composition of the lahar as it progresses downstream. Such time-series data on flow velocity, discharge, stage height, and density is critical to the calibration of predictive lahar models at Ruapehu for the better mitigation of future events.

High resolution recording of the level and hence drawdown rate of Crater Lake will permit reconstruction of the outflow hydrograph: comparisons with peak discharges determined further downstream will allow quantification of contributions to lahar volume through particle entrainment. Acquisition of before- and after high-resolution digital terrain models (ALS or photogrammetric) of the lahar path will identify areas of net erosion and deposition and constrain sediment redistribution patterns and volumes. Instrumental methods of lahar sensing under investigation include ultrasonic and radar stage level and velocity gauges, and 2-d load cell/pressure transducer arrays. Such an array would enable time-series reconstruction of the discharge, density, and sediment concentration profile of the flow. Other systems being evaluated include closed-circuit video cameras to record the rate and mode of dam failure and the physical appearance and stage level of the lahar, conductivity gauges to measure pH changes, acoustic flow monitors, and resistivity surveys and piezometer methods to monitor seepage in the tephra barrier. Traditional aerial and ground-based inspections and surveys of the dam, lahar path, and flow deposits will also provide extremely useful information.

POSTER

ON THE USE OF TELESEISMIC S AND REGIONAL SCS IN SHEAR WAVE SPLITTING STUDIES IN NEW ZEALAND

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In New Zealand we are able to gain insights into the processes of plate boundary deformation by studying seismic anisotropy. Anisotropy studies are routinely performed around the world; commonly local S phases are used to study crustal anisotropy and SKS phases are used to study mantle anisotropy. However, there is currently fairly limited use of other phases such as teleseismic S and regional ScS. The use of teleseismic S and regional ScS in addition to SKS has two main advantages. The first is that the initial polarisation direction depends on the focal mechanism of the earthquake, unlike SKS where it depends on the earthquake-station geometry. This leads to a wider range of initial polarisation directions than using SKS alone, which is particularly important when trying to model complicated anisotropic structures. The second advantage is that teleseismic S and regional ScS have frequencies intermediate between local S and SKS phases, which is important when frequency dependent anisotropy is present. The disadvantage of using teleseismic S and regional ScS is that unlike SKS, the measurements can be affected by anisotropy near the source. However this problem can be overcome by only using deep events. We have studied shear wave splitting at the permanent broadband station SNZO in South Karori, Wellington, using a combination of teleseismic SKS and S phases and regional ScS phases recorded over a 10 year period. The use of shorter period ScS phases in addition to longer period SKS phases led to the observation of frequency dependent anisotropy. The SKS phases come from a limited range of backazimuths, therefore by including ScS and S phases we obtain splitting measurements at a wider range of initial polarisation directions. The good azimuthal coverage enables us to undertake detailed modelling of the complicated anisotropic structure beneath SNZO. Using S and ScS waveforms recorded on the L-shaped Leeds Tararua array we observe significant spatial variations in shear wave splitting. These observations contrast with previous SKS studies in New Zealand where little spatial variation is seen, and highlights the importance of using a variety of phases with different periods. SKS and local S splitting have recently yielded different results at stations across the Marlborough fault zone. We intend to examine teleseismic S and regional ScS phases recorded in Marlborough to determine the relative contributions of frequency dependent vs. depth dependent anisotropy, as well as determine whether the lateral variations observed at the Tararua array extend this far south.

ORAL

HIGH ELEVATION LAKE LEVEL DEPOSITS WITHIN THE ROTORUA DEPRESSION

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The late Quaternary lacustrine sedimentary record in the Rotorua depression probably began shortly after the Rotorua Caldera formed with the eruption, ≈ 220 ka, of the voluminous Mamaku Ignimbrite. Initial sedimentation probably began with debris and hyperconcentrated flows, followed by lacustrine deposition as the new catchment adjusted to the newly created accommodation space.

Three distinct sets of littoral terraces formed during periods of stable high water levels surround the Rotorua depression. Deposits exposed in these terrace outcrops include paleobeach deposits, subaqueous channels, fine-grained deltaic suspension deposits and well formed foreset beds. These can be separated by their geomorphology and field relationships, in particular by identifying the unconformities that separate each highstand deposit. They were also characterised by Electron Microprobe analysis of glass shards, their ferromagnesian mineral assemblage, granulometric, XRD and SEM analysis of samples obtained from different lacustrine deposits. Their comparison allows individual deposits and outcrops to be arranged into an inferred stratigraphic model. This informally subdivides them into three alloformations based on their bounding unconformities and provides an objective means of defining heterogenous lacustrine deposits that are nevertheless genetically related.

Highstand lacustrine beds were deposited during three time intervals, when the water level of Lake Rotorua lay between 65 m and up to 120 m higher than it is today. Each suite of deposits has been informally named for the volcanic event that seems to have initiated the high lake level.

1. Post-Mamaku alloformation (up to ≈ 415 m a.s.l.).
2. Post-Rotoiti alloformation (up to ≈ 380 m a.s.l.).
3. Post-Hauparu alloformation (up to ≈ 349 m a.s.l.).

The first highstand, after the Rotorua depression formed, may have ended when the caldera wall adjacent to the Pohaturoa Dome collapsed, this breech formed the Hemo Gorge. Subsequent high stands have followed eruptions from the neighbouring Okataina Volcanic Centre, which deposited large, north trending, tephra deposits that formed natural dams across the northern outlet of Lake Rotorua.

ORAL

"CRYORITES", EVAPORITES, OR WHITINGS? ANCIENT LAKE BEDS FROM TAYLOR VALLEY, ANTARCTICA

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Calcareous lacustrine sediments mark deposits of several ancient lakes perched on the walls of Taylor Valley. Surficial sediments within the Taylor Valley indicate alternating advances of ice from opposing ends of the valley, both of which were accompanied by proglacial lakes (Fig. 1).

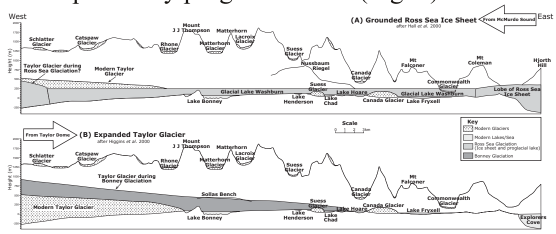

Figure 1: Model of opposing glacial advances into Taylor Valley. In the upper diagram, an ice sheet builds in McMurdo Sound as sea levels are lowered and dams the mouth of Taylor Valley trapping Glacial Lake Washburn. In the lower diagram, expansion of East Antarctic Ice Sheet causes Taylor Glacier to advance into the Lower Taylor Valley.

This poster examines the evidence for the origin of three ancient lake beds, to distinguish between deposition driven by freezing of water out of an enclosed lake basin, evaporation of water from an enclosed lake basin, or precipitation driven by algal consumption of CO_2 from a stratified lake. The presence of halite and gypsum within the fabric of the aragonite dominated carbonates; the absence of mirabilite and the presence of radial aragonite, suggest that evaporative concentration played a major role in the formation of these lake beds.

Chemical and isotopic analysis of the carbonates show that they have formed from distinctly different water bodies, two originating from Taylor Glacier melt waters, and one from Ross Sea Ice Sheet melt waters.

POSTER

THE MESOZOIC GREYWACKES IN AND AROUND TAUPO VOLCANIC ZONE

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For the last 20 years, the Mesozoic greywackes of the Central North Island have been divided into two compositional groups that lie east and west of Taupo Volcanic Zone (TVZ). East of TVZ, the Kaimanawa Ranges (south of Napier-Taupo road) and Ikawhenua Ranges (north of Napier-Taupo road) are dominated by quartzofeldspathic greywackes whereas west of TVZ, the Hauhangaroa and Hunua Ranges, and basement rocks of the Coromandel Peninsula consist mainly of volcaniclastic greywacke. This twofold difference is embodied in the names Torlesse and Waipapa Terranes, respectively. Argillite is a common rock type in both terranes and metabasite and chert are subordinate lithologies. Low grade schist is known from parts of the Kaimanawa Ranges but its full extent is not yet mapped out.

Average Waipapa and Torlesse greywackes have different bulk chemical and Sr, Nd and Pb isotopic compositions, a difference that is important when considering the petrogenesis of present day TVZ lavas. Torlesse greywackes have average rhyolite-dacite compositions and moderately radiogenic isotope ratios, Waipapa greywackes are more andesitic (and more variable) and are isotopically more primitive.

The strike of bedding and foliation is slightly oblique to the edge of TVZ, indicating that the Taupo rift did not necessarily open exactly along an old Waipapa-Torlesse Terrane boundary. Intra-TVZ basement samples have been obtained from the Moawhango (eastern TVZ) and Whakapapa (western TVZ) hydro tunnels, geothermal bores at Wairakei, Kawerau and Rotokawa, xenoliths from Mount Tongariro and an inlier near Matata. Most indicate Torlesse-type basement below TVZ, with Waipapa only confirmed in the Whakapapa Tunnel and at Kawerau and Matata.

Recent work indicates that both the Waipapa and Torlesse Terranes around TVZ can themselves be subdivided on a 10 km scale. One current model is that the western (Waipapa) rocks comprise two compositionally distinct units: (i) a volcaniclastic Late Jurassic Waipa Supergroup, probably restricted to the upper crust, that unconformably overlies (ii) a mixed volcaniclastic and quartzofeldspathic Bay of Islands (BOI) Terrane which may well penetrate the entire crust. The BOI Terrane may possibly underlie much of the TVZ at depth and be in subvertical, imbricated contact with the older Torlesse (Rakaia) Terrane within the Kaimanawa Ranges. The younger Torlesse (Pahau) Terrane underlies the Ikawhenua Ranges and the Rakaia-Pahau contact (Esk Head Melange) possibly strikes into TVZ along the trend of the Napier-Taupo Road.

Regional mapping, petrofacies work and detrital zircon dating are currently underway by GNS to clarify the picture.

ORAL

INVESTIGATING GEOLOGICAL RELATIONSHIPS BETWEEN NEW ZEALAND, AUSTRALIA AND NEW CALEDONIA

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The 2002-2003 Fraser Institute survey of mining companies ranked New Zealand 44th out of 47 countries in terms of attractiveness based on executives' perceptions of geology. Work in part of GNS's new Mineral Wealth of NZ and its EEZ Programme aims to encourage overseas mineral companies to explore in New Zealand by (i) emphasising that NZ is a rifted part of mineral-prospective Australasia (ii) providing geologically credible comparisons and contrasts between selected trans-Tasman and SW Pacific geological provinces and units, especially those that contain significant mineralisation in Australia.

Over the decades many New Zealand geologists (e.g. Larry Harrington, Bruce Waterhouse, Russell Korsch, Roger Cooper, Jonathan Aitchison, Peter Cawood, Philippa Black, Jack Grant-Mackie) have published papers pointing out broad similarities and/or specific correlations of rocks exposed in New Zealand, Australia and New Caledonia. So what is to be gained from yet another look?

First of all, the GNS research group has built up important new datasets (e.g. mapping, petrochemistry, tracer isotopes, U-Pb zircon dating of plutons and detrital grains in greywackes) that did not exist even five years ago, and has used them to construct new models of the New Zealand basement (e.g. Median Batholith, terrane paleogeography). Second, there are an increasing number of offshore dredge samples with which to bridge trans-Tasman gaps. Third, satellite gravity data has removed some uncertainties associated with rigid plate reconstructions. Paleogeographic reconstructions emphasise that, even with a closed Tasman Sea, New Zealand terranes are about 1500 km along strike from their Australian counterparts: in this context geological differences as well as similarities should reveal interesting first-order information about processes along the Paleozoic-Mesozoic Gondwana margin.

Initially we will be focussing on the New England Orogen, followed by the Lachlan Orogen and then geological units in New Caledonia. Our first year's sampling in Queensland has been in the volcanic, sedimentary and metamorphic host rocks of the Paleozoic Yarrol, Shoalwater and Wandilla Terranes near Rockhampton, and in marine Permian and Triassic sequences near Gympie. Investigation of New England Orogen plutonic rocks will commence next year.

POSTER

THE SILICIFICATION OF THERMOPHILIC BIOFILMS: ARE GEOTHERMAL DEPOSITS ANALOGS FOR THE PRESERVATION OF EXTRATERRESTRIAL LIFE?

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Hot spring sinter deposits display a wide variety of complex textural types. They also contain abundant evidence of microbial activity in the form of thermophilic and mesophilic biofilms that show varying degrees of preservation. The presence of these biofilms suggests that they are necessary for the formation of at least some of the silica sinter textures. However, some have concluded that all of these textures can form by abiotic processes such as intermittent wetting, capillary rise and splash. The requirement that biofilms be present for the formation of certain textural types has profound implications for the evidence of early life on Earth and to the interpretation of similar deposits that may be found on extraterrestrial bodies. If extremophilic organisms are necessary for the creation of macroscopic textural details then the presence of these textures on some extraterrestrial body may give paleoevidence for the existence of life outside Earth.

Field studies of natural sinters at Waiotapu have shown that most silica deposits are in the form of silica laminates. These are always associated with biofilms formed by thermophilic micro-organisms. However, the relationship between the biofilms and the silica laminae remains inconclusive. In order to address this inadequacy, laboratory experiments were conducted to simulate the growth of silica sinters under controlled conditions. This allowed growth of silica sinters without the participation of micro-organisms, a process that is impossible to simulate in the field.

Experiments were conducted using filtered borewater from the Wairakei Power Station wastewater drain (570 ppm SiO_2). This was passed through a 6 m stainless steel coil heated to 300^oC to sterilise the water and depolymerise any silica polymers or colloids (~450 ppm at 25^oC). The treated water was then passed into a teflon tray containing upright glass microscope slides. This tray was enclosed in an oribital shaker/incubator heated to 60^oC. Abiotic experiments showed that meniscal growth, silica laminae and oblate shelf textures formed in the absence of bacteria. Experiments that included bacteria were accomplished by the addition of small amounts of microbial nutrient (Tryptic Soya Broth). Bacterial growth ensued and covered the air-water interface with a thermophilic biofilm. In biotic experiments, using Wairakei borewater, the biofilms also became silicified. SEM examination of the silica sinter showed extensive evidence of biofilm silicification and the interaction between micro-organisms and silica. Also found, were colonies of thermophilic bacteria that resemble protospicules found in field experiments. It appears that the growth of silica laminae does not require the participation of micro-organisms, however, the development of more complex textures such as spicules or microstromatolites, requires a biotic input.

ORAL – geothermal workshop

LARGE DEEP-SEATED LANDSLIDES IN TERTIARY SOFT ROCK TERRAIN: STEPPED LANDSCAPE EVOLUTION AND THE CONCEPT OF CRITICAL STRATIGRAPHIC HORIZONS

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Late Quaternary sediment production from catchments located in the Neogene soft rock terrain of east coast North Island is often directly linked to the occurrence of surficial mass wasting processes responding to both climatic and tectonic forcing. Yet in many catchments lithology and bedrock structure are key factors in controlling the geometry and progressive development of large, deep-seated landslides. Such large-scale failures in turn dominate late Quaternary landscape evolution, and also regulate the temporal variations of sediment production from these catchments.

Catchments incised into alternating sandstone and siltstone/mudstone strata are characterised by stepped landform morphology, and where failure shear planes are preferentially associated with laterally continuous weak stratigraphic horizons. The slide block geometry is further determined by the presence and spacing of lateral and head-wall defects (joint and fault), facilitating the block release. In the upper and middle Ponui and Makara catchments adjacent to the south margin of the Maraetotara Plateau, southern Hawke's Bay, landscape evolution is defined by the occurrence of large (10^7 m^3) bedrock controlled landslides. The location of the basal shear planes within the stratigraphy is controlled by the presence of thin (5-10 mm), laterally continuous and very weak (ϴ'<7°) tuffaceous beds. At least 3 such tuff beds are identified, separated by stratigraphic intervals of 60-70 m. Each horizon is associated with multiple examples of such bedrock failures, and catchment topography is stepped relative to each horizon.

The combined effects of long-term climatic (sea-level change) and tectonic (regional uplift) forcing factors will directly influence the lowering of base-levels in catchments, and so contribute to slope destabilisation. Incision will progressively daylight critical stratigraphic horizons that are pre-disposed to failure, and are associated with deep-seated landslides. In addition, back-analysis shows that seismic triggering is required to initiate the large deep-seated bedrock failures. Failure modelling reveals that full failure coincident with the earthquake trigger is not essential. Once initiated, with the presence of the thin weak horizons, the development of defect controlled head-wall tension crack openings define the block slide mass. Full failure and disintegration of the slide block will then occur progressively with subsequent precipitation events. Such deep-seated failures in dissected topography will continue to enlarge by head and lateral scarp retreat, and continue as a long-term sediment supply source in such catchments, often perched well above base level.

The bedrock controls on deep-seated landsliding and landform geometries, as well as the consequent spatial and temporal control on sediment production, can be considered as being less stochastic and more predictable, and hence provide a basis for developing numerical landscape evolution models in tectonically active terrains.

ORAL

FAULT INTERACTIONS AND SLIP TRANSFER BETWEEN THE NORTH ISLAND DEXTRAL FAULT BELT AND THE TAUPO RIFT, NEW ZEALAND

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In the upper plate of the Hikurangi margin of New Zealand the Taupo Rift and the North Island Dextral Fault Belt (NIDFB) accommodate a significant component (e.g., ≥70%) of the active extension and strike slip, respectively. The onshore components of these two fault systems extend for approximately 200 km (rift) and 450 km (NIDFB) and are discrete entities for much of their length. In the Bay of Plenty region, however, the two fault systems intersect and questions arise as to how strains are accommodated in the intersection zone? And to what extent displacements are transferred between fault systems? In this presentation we utilize displaced landforms <100 ka in age and trench data to track changes in fault kinematics along and across the NIDFB as it approaches the Taupo Rift. We find that faults of the NIDFB become increasingly dip slip approaching the rift. The Whakatane Fault, for example, carries an increasing component of extension (from ca. -1 to 2.5 mm/yr) and a complementary decreasing component of strike slip (from ca. 4 to 0.5 mm/yr) over a strike distance of approximately 100 km. The net displacement rate is uniform along the Whakatane Fault and we propose that transfer of slip from the NIDFB to the Taupo Rift is facilitated, in part, by a gradual rotation of the slip vector towards sub-parallelism with fault-slip vectors in the rift. At the intersection of the two fault systems slip vectors in the NIDFB are sub-parallel to the lines of fault intersection. This sub-parallelism reduces potential space problems that would be expected to arise at the intersection of two synchronous faults with non-colinear slip vectors and permits efficient transfer of extension from the fault belt to the rift. If all of the displacement in the NIDFB were transferred to the rift an increase in extension rates across the rift of ca. 3-6 mm/yr would be expected, increasing from an estimated 7-8 mm/yr (Darby and Meertens 1995; Villamor and Berryman 2001) near Rotorua in the south to 10-14 mm/yr 20 km north of the coastline. This increase in extension rates across the rift would therefore account for a significant component of the observed change in rates which, in the Bay of Plenty region, are presently estimated to be 15-25 mm/yr (Darby and Meertens 1995; Davey et al. 1995).

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ORAL

What's the story?
The Encyclopedia of New Zealand

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The last New Zealand Encyclopedia produced by the New Zealand Government was published in 1966. A valuable reference source, it has long been out of print, and there have been many requests for an updated edition.

Te Ara, the new encylopedia is planned as an online version that will be freely available anywhere in the world. As an authoritative source of information on New Zealand, it will contain entries on the natural environment, history, culture, institutions, peoples and social development of the country. Short essays on each topic will be combined with photographs, sounds, video clips, documents, graphs and maps - in fact, any information that can be preented digitally. Links will allow access to other web sites as well as pathways to the digital collections of libraries, archives and museums.

The Online Encyclopedia will be published progressively over a nine-year period, with a major theme each year. The first theme, "New Zealanders" will be launched in February 2005. It will be accompanied by “New Zealand in Brief”, a series of eight entries covering the natural environment, Maori, economy, society, history, society. government and nation, sports and leisure, and arts and culture. At the same time a complete, searchable version of 1966 Encyclopedia will go online.

The natural and modified environment of New Zealand will be covered in themes over the following three years:

(a) **Earth, Sky and Sea**: geology, the marine realm, the atmosphere and climate.
(b) **The Bush**: landscape, soils, and indigenous fauna and flora
(c) **The Settled Landscape**: Clearing the land, agricultural conversion; introduced fauna and flora.

About half the entries are undertaken by in-house writers, and the remainder are contracted externally. In addition we are making extensive use of reviewers to ensure that the content is as accurate and up-to-date as possible.

Entries are written at a non-technical level, similar to that of a newspaper, with a minimum of technical terms. Scientists in every discipline have their own language, but it is a challenge to write a clear description of geological concepts avoiding jargon terms such as eustacy, facies, and subduction.

PLENARY

UNDERSTANDING THE PRE-1000 YEAR B.P. VOLCANIC DIAMICTONS IN EGMONT NATIONAL PARK.

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Abutting the lava cone of Egmont stratovolcano is a thick (>30m) succession of weakly stratified andesitic diamictons. Most of these are massive and show little stratigraphy. Their great bulk is now interpreted as being of pyroclastic flow (block- and ash-flow) origin. Few direct radiocarbon dates have been obtained from the diamictons, but together with basal tephra cover bed stratigraphy a pattern of emplacement is emerging. The oldest proven diamictons occur in the northern sector. These appear to be direct correlatives of the Kahui Formation debris flows, which accumulated to the northwest and northeast of Egmont National Park. Deposition then shifted to the east, where most of the surfaces within Egmont National Park originate from this time. These can be directly correlated with the Te Popo and Ngatoro Formations outside the Park. By 3600 yr B.P. the main area of active deposition had shifted to the southwest amphitheatre between Bobs Ridge and Fanthams Peak, before the current configuration to the northwest was established post-1000 yr B.P.

ORAL

PRELIMINARY EVIDENCE OF OCEANIC CLIMATE CHANGE AROUND NEW ZEALAND OVER THE LAST CENTURY: COMPLEX STEPS TO AGEING DEEP-SEA CORALS

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Many stony corals and octocorals occur on seamounts, as well as areas of comparatively flat deep-sea reef. The majority of such corals exist at water depths in excess of 100 m, with many living well below 1000 m. Coral ages can extend from decades to hundreds of years and relatively rapid changes in the environment e.g. fishing practices, climate and associated oceanic patterns can effect growth. An understanding of deep-sea coral systematics, biology, longevity, and growth rates is essential in order to appreciate the nature and extent of any impacts, and to mitigate them.

The diversity in coral systematic and skeletal composition, and in morphology is vast, with many corals depositing their calcite skeleton in different ways. Understanding the carbonate source and what proportion comes from the ocean and metabolism, as well as the effects of climatic events on the laying down of coral matrix is complex, as is interpreting growth zones. All make for a multifaceted study and indicate that no single method can be applied to obtain measures of age or growth rate for all coral varieties.

This paper summarises coral ageing work that has been carried out in the New Zealand region, including the application of several methods to both age and validate ages of some deep-sea coral species. Methods include counting radial growth zones, radio-isotopic dating, radiocarbon (^{14}C) dating, stable isotopes and climatic records. It is clear from the present study that coral ageing methods need to be combined to successfully confirm and validate age and growth.

Chemical analysis of these deep-sea corals collected near 1000 m depth around New Zealand indicate two different climatic patterns; long-term cooling from the mid-19th century or a variable oceanic state. These patterns potentially reflect a response of isotherms along the continental shelf to changing coastal sea-surface temperatures, which in turn reflect variability in the East Auckland and East Cape Currents. Or correlations between temperate New Zealand and El Niño-Southern Oscillation or Antarctic indices suggest these long-term changes might also be a significant response to both tropical and Antarctic climate.

ORAL

RECORDS OF CLIMATE VARIABILITY OVER CAMPBELL PLATEAU, THE SUBANTARCTIC ZONE OF NEW ZEALAND'S SOUTHERN OCEAN

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Campbell Plateau occupies a key position in the Southwest Pacific sector of the Southern Ocean, as it confines and steers the Antarctic Circumpolar Current (ACC) along its flanks, isolating the subantarctic plateau from cold polar waters. In this study four time-scales of climate variability records are considered from this region of the Southern Ocean. Oxygen and carbon isotope records from Campbell Plateau cores provide new records of water mass stratification for the past 130 ka. During glacial climes, constriction and intensification of the Subantarctic Front (SAF) resulted in waters over the plateau flanks being deeply mixed and cooler. Waters of the plateau interior remained stratified and isolated from the cold southern waters. On the western side, waters cooled markedly due to reduced entrainment of Tasman Sea water. Marked cooling also occurred north of Campbell Plateau due to increased entrainment of polar water by a branch of the SAF.

Oxygen and carbon isotopes in modern brachiopods (Neothyris lenticularis) and octocorals are used to investigate seasonality in the Subantarctic zone of New Zealand over millennial to decadal time-scales. This study uses Antipodes Island collections to produce a long-term record of oceanic temperature. Periodic oxygen isotope depletions (cooler oceanic temperatures at depth) appear to correlate with El Niño-Southern Oscillation (ENSO) events, while coincidence with the 'high-latitude mode' or Antarctic Oscillation is low. It is likely that oceanic temperatures at this location respond to increased westerly winds and deep mixing or upwelling of cooler waters as opposed to fluctuations in the neighbouring ACC. Octocoral growth can occur over hundreds of years and record relatively rapid changes in the environment since climatic variations and associated oceanic patterns can affect growth. Here, we also summarise coral records from the subantarctic region in an effort to extend seasonal records to several millennia.

Deployment of time-incremental sediment traps in the subantarctic zone provided a one-year record of seasonal variation in biogenic flux. Over Campbell Plateau ~90% of the annual mass and particulate organic carbon flux occurred in a single pulse during mid-spring. The Plateau margin exhibited several sedimentation events. During spring 45% of the annual mass and particulate organic carbon flux occurred. During summer, 25% of the annual flux was deposited, while only 15% was deposited during autumn and winter. The relationships between living planktic foraminifera collected in MOCNESS tows in the upper 800m of the water column, and the tests collected in sediment traps and deep-sea sediments over Campbell Plateau are also assessed. These comparisons will improve our knowledge of climate variability over varying time-scales and allow proxy calibration, thus improving paleoceanographic reconstructions using the sediment records.

POSTER

ORIGINS OF SOME NEW ZEALAND CARBONATE CONCRETIONS: INSIGHTS FROM STABLE ISOTOPE AND ORGANIC GEOCHEMISTRY

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A variety of carbonate concretion bodies and associated calcite fracture fills from New Zealand (Northland, Waikato, Taranaki, Otago) Cretaceous-Tertiary strata have been studied both organically and inorganically. Their carbonate contents vary significantly, probably reflecting sediment porosity at the time of earliest cement crystallisation, even if most cement is later. Higher insoluble residues are associated with sandy or siltier host rocks and later carbonate emplacement by upward fluid or gas migration.

On the basis of stable isotope signatures, marine calcitic concretions and their fills are mainly sourced by CO_2 from bacterial sulphate reduction. Sideritic concretion signatures are consistent with dominant or partial methanogenic input. Late siderite and Northland late calcite cements probably also incorporated CO_2 from organic matter oxidation during iron reduction. Very light oxygen in some tectonic fractures is probably due to mineralisation at elevated temperature. Taranaki 'paramoudra' carbonate has the most extreme carbon isotope composition. Large ferroan dolomite structures with methanogenic carbon probably grew in expulsion pathways of iron-rich fluid during burial. Smaller pipe-like calcite concretions have extremely light carbonate carbon and may mark gas escape conduits associated with oxidation of methane.

Colour of sparry calcite fills is mainly due to organic material within or between the crystals. Dark brown colour of early septarian calcites is due to their dominant 'polar' or polymeric organic fraction. Pale yellow colours of later calcites are largely attributed to the presence of crude lipids, but also reflect iron content. The orange colour of 'paramoudra' fracture fills is due to their high crude lipid content.

Organic lipid extracts of both concretion bodies and fracture fills contain variable amounts of fatty acids and hydrocarbons. Hydrocarbons are generally at trace levels in fracture fills but extremely high fatty acid contents are found in fracture fills associated with the Waikato Coal Measures at Rotowaro. Dicarboxylic acids are especially abundant in these fracture fills. We consider this convincing proof that such fatty acids are fluid transported and incorporated into carbonate crystals.

Fatty acid signatures of most concretion body extracts are similar and bimodal in *n*-fatty acids. Long chain acids are presumed to be kerogen derived, ultimately sourced from terrestrial vegetation. Bull Point, Northland calcitic concretion bodies have unimodal acid signatures with abundant diacids, similar to Rotowaro septarian calcites. They also have higher biomarker maturities and probably also trapped fluid-transported acids.

Substantial biomarker maturity differences that cannot be explained by burial differences are apparent in both the Rotowaro and Northland strata. The interpretation of this is uncertain, but could be partly due to the preservation of labile biomarkers by early carbonate cement and partly a thermal effect of invading warm fluids. It providesanother potential 'handle' on the timing of carbonate crystallisation.

ORAL

IMPLICATIONS FOR GEOTHERMAL EVOLUTION IN THE ALVORD BASIN, USA, AS DETERMINED FROM PRECIPITATE MINERALOGY.

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The Alvord Basin is a north-northeast-trending graben in the continental USA Basin and Range Province, southeastern Oregon. Bounded on the east by the Sheepshead and Trout Creek Mountains and on the west by tilted fault block mountains of the Steens and Pueblo Ranges (2975 m elevation), the north-central portion of the valley (roughly 250km^2) is covered by a large playa known as the Alvord desert. The basement in the area consists of Permian and Triassic quartzites, greywackes and schists cut by Cretaceous siliceous intrusions, and overlain by Miocene and younger volcanic rocks and Plio-Pleistocene and Holocene alluvium.

The area experienced regional extension during the Cenozoic resulting high crustal heat flow and the observed geothermal activity. Within the basin there are three main groupings of thermal springs: Borax, Mickey and Alvord hot springs with approximately 180, 60 and 10 active springs respectively. The two dominant systems, Mickey and Borax, are aligned along the trace of northeast-striking, steeply dipping, normal faults. Minor earthquakes in the 1920's and 1940's, and geomorphic studies of Alvord Basin have established that faulting is active along the western boundary of the basin.

Water chemistry, spring temperatures and pH from both systems are similar, however precipitate mineralogy differs significantly. Both areas demonstrate sodium-bicarbonate-chloride-type waters with high sulfate content, and standard geothermometers indicate reservoir temperatures in the range of 200 – 250°C. The Borax system is dominated by precipitation of calcite (forming travertine deposits), with minor amounts of a boron-carbonate, amorphous silica and rare clays (smectite and illite-smectite). The Mickey system has a much more diverse range of precipitates including: quartz, opal-A, opal-CT, hematite and calcite. The clay mineral assemblage at Mickey includes: smectite, illite-smectite, illite and kaolinite. This assemblage suggests much shallower boiling (near surface) in the Mickey system. The occurrence of opal-A, opal-CT and quartz at Mickey suggests the system is older than Borax where rare opal-A and microcrystalline quartz are found. We propose that the Mickey occurs at an active fault intersection, whereby movement increases permeability along the fault. Although the Borax system is also fault controlled, there has been little movement in the fault over the lifetime of the system, resulting in a decrease of permeability and hence lowering the water table and increasing depth to boiling. Using remote sensing techniques it is apparent that the Mickey system occurs at the southern tip of an active area of regional extension, whereas the Borax system occurs in an area where extension is no longer active.

ORAL – geothermal workshop

IMPACT OF FAULT INTERACTIONS ON DISPLACEMENT RATES AND PALEOEARTHQUAKE OCCURRENCE IN THE TAUPO RIFT, NEW ZEALAND

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Paleoearthquakes at the Earth's surface often generate variable fault-slip rates. The origin of these variations and the extent to which they result from systematic processes is unresolved. To address this question we measure displacements of geomorphic surfaces and of tephra horizons in 26 trenches excavated across normal faults in the Taupo Rift, New Zealand. These data provide displacements on 23 faults for up to 12 dated surfaces/horizons, ranging in age up to ca. 60 ka, and record ca. 30-40% of the total extension across the rift. Displacement accumulation on individual faults, and associated paleoearthquake occurrence, was highly variable. The apparent disorder in the system can be significantly reduced, and in some cases removed, by increasing the size of the spatial and temporal sample window. We find that much of the variability in displacement rates occurs over time periods of <18 ka and reflects a temporal clustering of paleoearthquakes. Spatial variations in displacement rates are inversely related to fault size, with larger faults having more stability. Aggregating displacement rates across the entire rift produces uniform rates over time intervals of at least 60 ka. This relation suggests that fluctuations in fault displacement rates are not driven by changes in the rift boundary conditions. Instead, we propose that variations of displacement rates arise principally from fault interactions, with all faults being components of a single kinematically coherent system for which the earthquake histories of each fault are interdependent. Fault interactions generate both short term (<18 ka) fluctuations in, and longer term (>18 ka) stability of, displacement rates.

ORAL

STRAIN RATES AND HOLOCENE FAULT ACTIVITY IN EAST OTAGO

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A peneplain cut across the basement schist in central and east Otago during late Cretaceous to mid Tertiary time has been deformed into a series of NE-trending, asymmetric anticlinal ranges bounded on their east side by Quaternary fault zones. From the deformation of overlying sediments as young as Pliocene, the growth of these ranges is thought to be mainly Quaternary. Estimates of the cumulative offset of the peneplain across the major faults may be used to calculate average displacement rates across the province over the last 2.5 Ma. Assuming the underlying faults dip at c. 45°, these represent average NW-SE contraction rates and are: northern transect (Karitane–Hawea) – 2.2 mm/yr; central transect (Dunedin–Cardrona) – 2.6 mm/yr; southern transect (Akatore–Arrowtown) – 1.5 mm/yr. For the region east of the Dunstan Fault (Alexandra), these are 0.7, 1, 0.5, mm/yr respectively. These are minimum values as many small faults and inter-fault deformation has not been included.

In addition to the continuous Dunedin station, two survey stations (1017 Hyde Rock near Roxburgh and AADY near Makarora) have been occupied for extended periods by GPS receivers at intervals since 1995. We occupied these for several weekends in 2003 to extend the data. Best fits to displacements of each of these relative to Dunedin over the 8 year period give NW-SE contraction rates of 1.58±0.18 mm/yr for Hyde Rock and 2.22±0.88 mm/yr for Makarora. The latter value is close to the long-term rate across Otago. The Hyde

Rock rate is higher than the long-term rate across east Otago and suggests that strain accumulation has perhaps shifted from west to east.

Reconnaissance observations of tectonic geomorphology along the SE rangefronts between the Dunstan Range and the coast indicates distributed deformation with few single, continuous, range-scale surface ruptures evident. On a large scale, rangefront deformation is revealed by lineaments formed of stream course deviations and slope breaks. Small-offset range-parallel faulting and folding found within the ranges and within basin sediments are the norm. These observations are consistent with a model of fold propagation above buried reverse faults. Some of the rangefronts are distinctly sigmoidal and their departure from linearity appears structurally controlled. Many ranges appear to have formed by amalgamation of en-echelon segments rather than growth on a single continuous structure.

Optical luminescence dating of sediments at a number of sites indicate dominantly Holocene ages for the last displacement on the Rough Ridge, Rock and Pillar and Taieri Ridge systems. On Taieri Ridge, a displacement at the rangefront can be bracketed between 10 and 7 ka. Holocene activity on both the Rock and Pillars and Rough Ridge is also indicated, and has previously been reported on the Dunstan Range. The Akatore Fault has two displacements in the last 4 ka. These results are consistent with the 1.5 mm/yr estimated from GPS measurements across east Otago and indicate the seismic hazard in east Otago may be greater than hitherto thought.

POSTER

NUMERICAL SIMULATION OF THE VOLCANO-HYDROTHERMAL SYSTEM OF WHITE ISLAND VOLCANO

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In 1990s, Geological Survey of Japan and Institute of Geological & Nuclear Sciences had carried out microearthquake, self-potential (SP) and audio-magnetotelluric surveys in White Island volcano, one of the most active volcano in the world. The results of these geophysical data were summarized as a conceptual model of volcano-hydrothermal system at shallow depth beneath the Main Crater Floor [Nishi et al., 1999].

For more detailed discussion, numerical simulation technique has been applied to model this volcano-hydrothermal system. Computer code for this hydrothermal simulation and calculation of SP was developed for geothermal reservoir monitoring [Ishido et al., 2003]. The result of 2-dimensional modelling across the crater showed “mushroom”-type temperature profile beneath the Main Crater Floor, which is consistent with the distribution of volcano-tectonic earthquakes in this region. Three dimensional modelling is now carried out to reproduce the SP profile in the outer rim of the volcano.

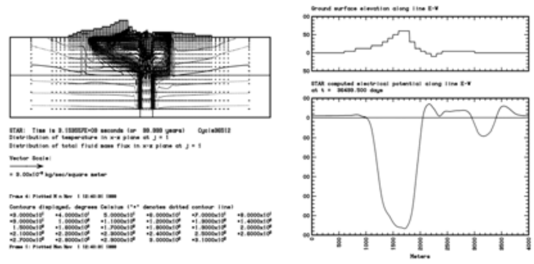

Figure : The result of two-dimensional numerical simulation of subsurface fluid and heat flow (left) and corresponding SP profile through electrikinetic coupling (right)

POSTER – geothermal workshop

SLIP PARTITIONING, STRAIN PARTITIONING AND STRAIN LOCALISATION: A VIEW FROM THE ALPINE FAULT

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In areas of crustal deformation, particularly those involving transpression or transtension, displacements may be accommodated by a mixture of pure shear and simple shear strains. Strain localization along narrow zones is dominantly simple shear, whereas pure shear strain is more likely to be distributed over a wider area. This is because, for a localized zone of simple shear, a constant displacement rate occurs at a constant strain rate whereas, for a pure shear zone, it requires an exponentially increasing strain rate. Strain localization may occur along a zone oriented so that all the displacement can be accommodated by simple shear along it. In other cases, two differently oriented zones of localized simple shear, with different slip directions, may accommodate crustal displacements. This latter would be termed slip-partitioning and has been described from many transpressional systems. Alternatively, a single structure may accommodate part of the displacement by simple shear with the balance distributed over a wider zone dominantly by pure shear (e.g. crustal thickening/thinning). This could be termed strain partitioning and has also been described in many areas of crustal deformation.

The South Island plate boundary segment shows several examples of these types of partitioning. For instance, in the area around the Cascade River, faults of the Livingstone and Hollyford systems coalesce with the Alpine Fault. Reactivation of these structures has led to a wide zone of distributed deformation. Within this zone, ductile strain localization in mylonites along these faults is dominantly simple shear, whereas the intervening rocks exhibit more of a co-axial (pure shear) deformation.

Along the main Alpine Fault, the dipping structure has a high-strain mylonite zone at depth which is dominantly a zone of simple shear. The crust of the Southern Alps in the hanging-wall has been approximately doubled in thickness over the width of the orogen, suggesting a pure shear strain. This is supported by dominantly flattening fabrics and conjugate ductile shear zones in hanging-wall schists (Little et al., J Structural Geology 24, 219-239, 2002; Holm et al., Tectonics 8, 153-168, 1989). Systems of parallel thrust faults extend out to the east again suggesting distributed shortening strain.

Development of high-strain mylonite zones beneath major faults such as the Alpine Fault require a process of strain localization. Many models envisage localization being driven by tectonics in the mantle or deep crust and propagating upwards. An alternative may be that during distributed deformation, localization occurs along pre-existing structures in the seismogenic crust and cyclical loading of the ductile crust beneath is accompanied by periods of high shear strain-rate. Strain weakening resulting from this process begins to develop a downward propagating zone of localized strain. Feedback mechanisms between this weakened ductile shear zone and the overlying brittle crust leads to the development of a highly localized mylonite zone penetrating into the deep crust.

ORAL

ORIGIN AND 3D DISTRIBUTION OF CALCITE CONCRETIONS IN A DELTA-FRONT: CRETACEOUS WALL CREEK MEMBER, FRONTIER FORMATION, WYOMING

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Calcite concretions reduce reservoir quality, but there are no studies that examine the 3D distribution and the consequences for reservoir quality in outcrop analogs. In addition, there is significant debate about the origin of concretions, and specifically whether they tend to be early or late in shallow marine reservoirs. We investigate the timing and origin of concretion growth within a mixed fluvial, tide influenced shallow-marine deltaic reservoir analog in Cretaceous-age outcrops exposed in central Wyoming. Petrography, diagenesis, and geochemistry have been integrated with 3D Ground Penetrating Radar and borehole data in order to constrain the 3D distribution of these concretions and the resulting effects on reservoir quality.

Concretions in the Turonian Wall Creek sandstone Member of the Frontier Formation fill up to 15% of the sandstone volume. These concretions are not uniformly distributed and vary in size and shape from 70cm to 5.5m in length, and from 20cm to 60cm in height. Concretions range from almond shape to long, thin ellipsoids, associated with tidal bar facies, and thick ellipsoids, within more fluvial-dominated distributary channel facies. 3D mapping suggests that the concretions are moderately connected, but do not form continuous impermeable sheets, but rather a complex series of overlapping lenses. These will likely be more significant as baffles to flow rather than extensive horizontal barriers.

Several concretions have clear nucleation sites that consist of carbonaceous muds, marine shell material, and/or organic matter. Precipitation patterns indicate some concretions grew in the traditional concentric pattern, while many followed a more complex growth pattern. Absence of detrital clays resulted in a more permeable sandstone with higher fluid flow regimes, thereby enhancing calcite precipitation.

Isotopes range from a $\delta^{18}O$ of -7.4 to -16.1 $^{o}/oo$ (PDB), and $\delta^{13}C$ of -1.3 to -11.3 $^{o}/oo$ (PDB). Sources for carbon are a mixture of in-situ marine skeletal fragments and later emplaced organic carbon, the more depleted values representing a larger influence of organic carbon. With deeper burial, the concretions become enriched in $\delta^{18}O$ as marine-derived pore-waters trapped within the overlying Cody shale were expelled into the underlying more permeable Wall Creek. Calcite precipitation began within the first 100 meters of burial and continued throughout nearly 900m of burial, the majority of growth between 400 to 800 meters.

The fact that cements are confined to the middle parts of the sandstone body suggests that initial preferential flow paths become sites for later cementation and reduction of porosity. Rather than reflecting with an early or late origin, these concretions are much more complex and show a long-lived history of growth. Growth is ultimately terminated by a lack of further reagents (e.g. shell material) as well as changing eH/pH conditions.

ORAL

A NEW HIGH-RESOLUTION, MIDDLE MIOCENE MAGNETOSTRATIGRAPHY FROM WESTERN SOUTHLAND

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At approximately 14Ma a global cooling event of 1-2 myr duration occurred at which time, it has been suggested, the east Antarctic ice sheet was permanently established. This event is recognised in the oxygen isotope record as a 1-1.3‰ δO^{18}enrichment of oceanic water, or the removal of a mass of water equivalent to one Antarctic ice cap from the world's oceans.
The Waicoe formation mudstone of Western Southland offers a unique opportunity to study this global climatic event. The Bryce Burn section of the Waicoe Formation comprises a 600m thick, nearly continuous sequence of mid-Miocene (12-16Ma) massive blue-grey, deep water (600-2000m), hemi-pelagic mudstone.
In 2000, B.D. Field of GNS initiated a high-resolution, multi-proxy, palaeoclimatic study of the Bryce Burn sequence. In 2003, a palaeomagnetic study was initiated to develop a magnetostratigraphy for the Bryce Burn section. Over 650 oriented specimens from 162 sample sites were analysed at the Otago Palaeomagnetic Research Facility as part of the study. Specimens were thermally demagnetised to between 400°C and 500°C, at which point samples thermally altered. Magnetic moment measurements were made using an automated 2G industries Cryogenic magnetometer.
The Waicoe Formation mudstone was found to be weakly magnetised with typical natural remanent magnetism (NRM) intensities of $5x10^{-7}Am^{-1}$ being carried by low concentrations of magnetite. Saturation magnetisation and demagnetisation spectra suggest that a Viscous (VRM) overprint persists to between 200°C and 250°C and that the Characteristic remanence (ChRM) is demagnetised between 300°C and 500°C. Over 65% of specimens displayed multiple magnetic components, yet only 2 did not exhibit stable magnetic behaviours.
The magnetostratigraphic age model suggests a uniform sedimentation rate of 20cm/kyr throughout the section. The study identified polarity chrons C5B through C5AA, correlation with the Geomagnetic polarity time scale (GPTS) is defined by the thick reversed chron (C5Br) and two moderately thick normal chrons (C5ADn and C5ACn), respectively. The average sample interval is 4 meters, which equates to 20 kyr.

POSTER

BENTHIC FORAMINIFERAL RECORD OF THE MIDDLE PLEISTOCENE CLIMATE TRANSITION IN THE SOUTH ATLANTIC OCEAN

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Once thought to have limited use in biostratigraphic studies, benthic foraminifera have proven very useful in deep-water paleoceanographic interpretations, providing useful information on deep-water mass properties, ocean circulation, upwelling history and history of surface productivity.
The Middle Pleistocene Climate Transition (MPCT) refers to the transition observed in the proxy climate records from orbital obliquity (41 k.y) - to eccentricity (100 k.y) –forcing. This change in the Earth climate system occurred over several hundred k.y (between c.950 and 640 k.y) and resulted in the global extinction of two families (Pleurostomellidae, Stilostomellidae) and at least 50 species of benthic foraminifera (*"Stilostomella* Extinction*"*) (e.g. Schönfeld, 1996; Hayward, 2002).
Benthic foraminiferal faunas from lower bathyal ODP 1082 and ODP 1088 sequences provide a proxy record of oceanographic and Benguela Current upwelling changes through the MPCT on either side of the Subtropical Front (STF) and at contrasting proximity to the Benguela upwelling centre, South Atlantic Ocean. Census data on faunas (>150 μm) reveal the decline and later extinction of selective elongate, cylindrical benthic foraminifera. In both ODP 1082 and 1088 there is a major drop in the absolute abundance and diversity of the "extinction group" taxa at the start of the MPCT (MIS 25-24). Abundance of some species (e.g. *Myllostomella fijiensis, M. hyugaensis, Siphonodosaria hispidula*) and diversity recovered slightly (MIS 23-22), before a more permanent decline during MIS 21-20 and final disappearance of this group c.MIS 15 (c.680 to 600 k.y) at both sites.
Fluctuating periods of low levels of dissolution are most evident in ODP 1082, and are thought to parallel cyclic variations in organic carbon (TOC) flux/primary productivity in the overlying waters.

The precise cause of the *Stilostomella* Extinction is yet to be resolved, but it is likely to be a combination of rapidly changing factors such as decreased bottom-water ventilation, TOC flux variations, and food supply changes during the MPCT, resulting in the decline and extinction of these taxonomically predisposed families of benthic foraminifera.

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POSTER

EROSION OF THE SEAFLOOR AT THE TOP OF GAS HYDRATE STABILITY IN THE OCEAN – EVIDENCE FROM SOUTHERN RITCHIE RIDGE, HIKURANGI MARGIN

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We have discovered a location on the Hikurangi margin, Southern Ritchie Ridge, where seafloor erosion appears to take place close to the top of gas hydrate stability (TGHS) in the ocean at about 600 m water depth. Strata that are perhaps as old as the Late Cretaceous are uplifted and appear to be eroded at this depth. Pinchouts of bottom simulating reflections (BSRs) confirm that the ridge crest is close to the TGHS. "Conventional" erosion mechanisms are unlikely to take place at this location. We therefore propose that seafloor erosion may be linked to the TGHS. We present two possible mechanisms that may lead to seafloor erosion at the TGHS.
Gas hydrates are commonly thought to play a significant role in seafloor stability. It is mostly assumed that overpressure caused by pore volume expansion during gas hydrate dissociation may lead to weakening and sliding along the base of gas hydrate stability (BGHS) in sediments. A variation of this model is when uplift causes the BGHS to move upward with respect to the seafloor, leading to gas hydrate dissociation, overpressure, and slope failure along the BGHS. Subsequently, pressure and temperature conditions on the seafloor may move back deeper into the hydrate stability field so that the process can repeat itself during continued uplift, leading to erosion of the seafloor close to the TGHS. However, for this model, the seafloor would need to remain entirely within the stability field, which contradicts the presence of BSR pinchouts observed at Ritchie Ridge. We therefore favour an alternative mechanism for seafloor erosion, a process similar to frost heave. Temperature measurements at this water depth show mesoscale fluctuations by about ±1 °C suggesting that the ridge repeatedly crosses the gas hydrate phase boundary. We propose that repeated pore volume expansion and contraction during gas hydrate dissociation and formation leads to weakening of the seafloor. According to this model, the weakened material cannot support the relatively steep slopes of the uplifted ridge and is predicted to slide down the ridge flanks.

POSTER

THE TOTANGI LANDSLIDE DAM, NGATAPA, GISBORNE: IMPLICATIONS FOR CLIMATICALLY FORCED SEDIMENT FLUX BETWEEN ~27.7 AND ~14.7 kyr BP.

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The Ngatapa area lies within the forearc region of the Hikurangi subduction margin ~30 km northwest of Gisborne on the east coast of the North Island, and forms a sub-catchment of the greater Waipaoa River catchment. Approximately 28 kyr BP a 4.1 km^2 deep-seated bedrock controlled landslide, the Sunworth landslide, is inferred to have been triggered by a large earthquake, and slid into the Ngatapa Valley. The landslide blocked the upper valley drainage, with the formation of the 0.5 km^3 Totangi landslide dam, which remained unbreached for ~13 kyr. Identification of the landslide was the result of vertical air-photo interpretation and detailed geomorphic field mapping, at a scale of 1:10 000.
Two lakes formed within the now isolated 6.15 km^2 Ngatapa catchment as a result of the failure of the Sunworth landslide, the 2.35km^2 Lake Totangi within the paleo-valley axis, and the 0.3 km^2 Lake Kareka within the headscarp graben. Analysis of the 33.5m of sediment that accumulated within these lakes over the 13 kyr period that the dam was in place provides constraints on the perturbation to sediment flux from the sub-catchment to the

Waipaoa River, caused by the imposition of the Totangi landslide dam.

Constraints on the timing of events are achieved using dated tephras in conjunction with radiocarbon (^{14}C) samples found within the lake sediments. Sedimentation was initiated ~27.7 kyr BP, constrained by the presence of Mangaone tephra in the basal lake sediment sequence, and had ceased by ~14.7 kyr BP, as indicated by Rerewhakaiitu tephra mantling the lake sediments.

A Digital Elevation Model (DEM) of the paleo-valley was constructed, based on shallow seismic reflection and refraction surveys in the lower reaches of the valley, as well as GPS data from remnant terraces formed on lake sequences to calculate the volume of sediment that accumulated within the lakes. A total of 120 Mt is determined to have accumulated during the 13 kyr period giving an averaged sediment yield of 1479 t/km^2/yr. Several discrete chronostratigraphic horizons, identified during trenching of the lake sediments, are used to model variations in the sediment yield over time, giving values ranging from ~700 – 3800 t/km^2/yr.

The variations in sediment yield during the lifespan of Lake Totangi show a distinct peak at ~22 kyr BP.This peak correlates well with the period of climatically forced aggradation associated with the Waipaoa 1 aggradation terraces in the greater Waipaoa catchment. While the Ngatapa sub-catchment provides only a small component of the total annual Waipaoa Catchment sediment yield, the occurrence of a large landslide that stopped much of the sediment flux from the drainage for over 10kyr highlights the role of such failures in modulating the volume of sediment delivered to the offshore depo-centre.

POSTER

THE AD1655 SUB-PLINIAN ERUPTION OF EGMONT VOLCANO – INSIGHTS FROM THE POROSITY AND PERMEABILITY OF PROXIMAL EJECTA

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Mount Taranaki, Egmont volcano, the largest andesitic volcano in New Zealand, erupted at least seven times over the past 800 years. Main eruptive processes were characterised by dome growth and destruction producing predominantly block-and-ash flow and surge deposits. By contrast, the Burrell eruptive episode (c. 1655 AD) was a small-scale sub-Plinian eruption, producing pumice fall and flow deposits. The fallout deposits extend to the NE, E and SE due to prevailing wind directions. Pumice flows generated by partial column collapse travelled down the southern flanks as well as northwestern slopes.

On the southern flank between Fanthams Peak and Bobs Ridge three units are distinguished in proximal pumice flow deposits. The lower and upper units are characterised by predominantly pale grey to grey pumice with banded pale grey – dark brown pumice at the top and base, respectively. The middle unit consists of brown pumice with banded pumice at its upper and lower portion. In places, this unit is partially welded and forms small ridges on the steep upper slope of Mt. Taranaki. Banded pumice is only observed in proximal pumice flow deposits

Cores of 2.5 cm diameter and length were made of pumice clasts from a range of colours within proximal deposits. A multivolume He-pycnometer was used to determine the total He accessible volume of pumice cores and powders in order to calculate bulk density, solid density, connected porosity, and isolated pore volume. Connected porosity and gas permeability was measured on the pumice cores using a capillary flow porometer with air as working gas.

The pumice samples show a wide range in connected porosity from 27.4 to 82.0 %. Isolated pore volume is less than 10 %; mostly ranging between 2 and 7 %. The solid density of pale grey pumice range from 2.72 to 2.76 g/cm^3 whereas brown pumice shows solid densities between 2.75 and 2.86 g/cm^3. Permeability calculations are still in progress.

Field data and porosity measurements imply that the sub-Plinian eruption occurred in two episodes. The highly vesiculated magma within the conduit (lower unit) was trapped underneath a plug or cryptodome preventing volatile escape. Gas overpressure caused removal of the plug, triggering magma fragmentation. Progressive fragmentation tapped deeper, hotter and initially less-vesicular magma; high decompression rates caused homogenous bubble nucleation and growth, and rapid ascent (middle unit). The eruption waned for a period or even paused for a short time. During this period magma was able to rise again; bubbles nucleated heterogeneously within it and grew to the point of fragmentation and eruption. The connected porosity data suggest that a lesser permeable bubble network was formed, implying that this last phase was a less intense eruptive event than those earlier.

ORAL

ESTIMATES OF THE VOLATILE CONCENTRATIONS OF AN EXPLOSIVELY ERUPTED MAGMA FROM EGMONT VOLCANO

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The Burrell Lapilli eruption in c. 1655 AD is the youngest sub-plinian eruption at Egmont volcano. The pumice fallout extends to the NE, E and SE and accompanying pumice flows were deposited on the southern and northwestern flanks.

Although the eruptive periods of the past 800 years at Egmont volcano were characterised by periods of effusive dome growth and destruction cycles, the Burrell Lapilli event was an explosive magmatic eruption. The shift from a normally slow rising, degassed and highly viscous magma (open degassing system) to a much faster ascending three phase magma (melt, bubbles, crystals) in a closed degassing system is yet still poorly understood.

To reveal the degassing history of this particular eruption, porosities and permeabilities of pumice clasts from proximal flow deposits were analysed. The next step was to determine the initial water concentration of the pre-erupting magma using melt inclusions within clinopyroxene phenocrysts. Clinopyroxene was selected, despite its only moderate suitability, because biotite and hornblende have partially decomposed rims and plagioclase with excellent cleavage is notoriously "leaky".

Melt inclusions of nine clinopyroxene crystals of selected pumice and juvenile clasts were double polished and analysed using Fourier transform infrared spectroscopy (FTIR). Because the melt inclusions in cpx are small and non-spherical, estimates of inclusion thicknesses were often made. Only a few inclusions were intersected from both sides with accurate thickness measurements.

Preliminary water concentrations in melt inclusions range between 0.7 to 7.4 wt. %. This huge range may reflect differing times of cpx formation during magma rise and degassing, but more likely represents volatile loss along cleavage planes of clinopyroxene crystals due to changes in pressure experienced by the ascending magma. The higher (more original) values indicate that these magmas were extremely hydrous, corroborated by their high hornblende contents and the relatively late onset of plagioclase crystallisation within them. By contrast, the erupted volcanic glass reveals only water concentrations between 0.2 and 0.3 wt. %. Hornblende crystals show only minor decomposed margins implying a very short time outside the hornblende stability field; i.e. a rapid magma rise from this field. Hornblende-plagioclase equilibrium temperature estimates range between 867 and 909 ˚C at 5 kbar. A better estimate of pressures during crystallisation will be possible when dissolved carbon dioxide contents are also calculated from the analysed melt inclusions.

POSTER

TRACE ELEMENT GEOCHEMISTRY DOWNSTREAM OF WAIOTAPU GEOTHERMAL DISCHARGES

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Geothermal activity is a diffuse, chemically variable source that enriches many dissolved components and contributes acid and bicarbonate alkalinity to Waiotapu Stream. Most enriched components are partitioned strongly into dissolved species and therefore behave conservatively in Waiotapu Stream. However, Fe and As partition into suspended particulate material (SPM) between pH 3 and 5 and similarly, Al and Y partition into SPM between pH 4.5 to 6.5. Partitioning of Fe into SPM relates to precipitation of Fe(III) minerals and these minerals adsorb As between pH 3 and circum-neutral. Precipitation of $Al(OH)_3$ partitions Al into SPM and Y is likely to substitute for Al in this precipitate. The diffuse and chemically variable nature of geothermal input in Waiotapu catchment makes it difficult to determine if input and dilution or geochemical processes cause concentration variations in the stream. Measurements of the flux of components at selected sample sites indicates that input of conservative components is largely from the central reach of Waiotapu Stream coincident with intense geothermal activity, whereas non-conservative components have substantial input from the lower reaches of Waiotapu Stream where geothermal activity is sparse. These observations suggest that non-conservative components partially sourced from sediment within Waiotapu Stream. Storage and release of Fe, As, Al and Y in Waiotapu Stream sediment implies that measurement collection of representative samples for water quality monitoring will be difficult within this catchment.

ORAL – geothermal workshop

VEGETATION OF TWO OLIGOCENE GLACIOEUSTATIC SEDIMENTARY CYCLES FROM THE CAPE ROBERTS PROJECT, VICTORIA LAND BASIN, ANTARCTICA

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The Cape Roberts Project recovered over 1500 m of coastal glacimarine sediments of Oligocene and early Miocene age (Davey et al., 2001). The strata are characterised by cyclic repetition of facies in a glaciomarine setting, and are interpreted to be a record of glacial-interglacial episodes involving significant changes in eustatic sea level (Naish et al., 2001a). We have recovered pollen and spores from two of these sedimentary cycles. The lower cycle is of early Oligocene age (31 Ma), and the upper cycle is late Oligocene (24 Ma).

Previous studies of miospores from Ross Sea sediments have encountered problems differentiating between reworked and *in situ* palynomorphs. Here, only samples containing a low relative abundance of an Eocene marine palynomorph group (the Transantarctic Flora), have been used to infer the contemporaneous Oligocene miospore flora.

The flora of the early Oligocene cycle is dominated by three species of *Nothofagidites*, and four types of *Podocarpidites*. The assemblage from the upper Oligocene cycle is also dominated by *Nothofagidites* and *Podocarpidites*, but with the addition of *Tricolpites* sp.a and one taxon of Marchantiaceae. There is a slight decrease in floral diversity between the two cycles.

While this study confirms that some floristic changes did occur during the Oligocene on the Victoria Land coast, the present data suggest that the changes were not extensive. The vegetation of both cycles is likely to be a low stature, low diversity scrub consisting of mainly *Nothofagidites,* Podocarps, and bryophytes. This vegetation was growing in a climate significantly warmer than is found on the present day Victoria Land Coast, although colder that the temperate climate suggested by the diverse flora found in Ross Sea sediments of Eocene age.

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POSTER

SIMULATING VOLCANIC MASS FLOWS FROM MT. TARANAKI; INITIAL IMPLICATIONS FOR HAZARD FORECASTING.

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Volcanic flows from large stratovolcanoes such as Mt Taranaki (2518m) can pose high risks to the communities that populate the surrounding areas. Although there have been no significant events since 1755AD, renewed activity could have a devastating effect on the Taranaki region's communities, infrastructure and economy. The Volcanic Hazard map of Taranaki created by Neall and Alloway (1996) displays hazard zones relating to the frequency with which areas were inundated by volcanic flows in the past, which are interpreted to represent areas of relatively higher or lower future hazard. A large number of past volcanic mass flows, including pyroclastic flows, lateral blasts, hyper-concentrated flows, debris flows and debris avalanches have been identified and incorporated into the frequency calculations used to create the reported hazard zones. However, if eruptive activity or other triggering mechanisms initiated a voluminous volcanic flow today, what effect would it have to the current topography; and how would it compare to the hazard zones based on past activity? A geophysical mass flow model is being used to determine this and to test whether there may be a better way of constructing a more dynamic style of hazard map that takes changing topography into account. The Titan-2D program is a depth averaged, "shallow water" granular flow model. The computer simulation attempts to solve the movement of a granular flow over a terrain by using a parallel adaptive grid. The program is used within the GIS GRASS environment and is adapted by the user for various flow rheologies by changing values for representing "internal" and "basal" friction as well as the dimensions of the initial pile. Titan-2D was tested against two typical types of Taranaki flow using specific geological examples to calibrate the results. The first, the Opua Formation, is a 0.5 km^3, c. 7000 B.P. debris avalanche that inundated a broad area of southwest Taranaki. This unit formed the basis of an "intermediate" hazard zone on the Neall and Alloway map. The second example is a block-and-ash-flow that occurred around 1655AD on the NW volcano slopes, during the Maero Eruptive Period.

Following GIS analysis of each simulated flow it was found that the Titan2D-predicted inundation areas are contained within the respective Hazard Zones of each of the examples. However the degree to which these can be compared needs to be further scrutinised with the development of a more suitable GIS analysis. Similarities also exist between the mapped extents of the geological deposits and the Titan-2D simulations, although difficulties remain in the accurate calibration of modelled flow heights and velocities. Future simulations and comparisons using this and other models will have to take into consideration the limitations of the numerical methods. Particular attention needs to be paid on ways to interpret and implement factors such as: flow initiation process, the effects of gas-fluidisation, the effects of interstitial water, the vast range of volumes, the differing rheologies between each type of flow and within individual flows, and also the variable types of geological material contained in each flow.

POSTER

LITHOSPHERIC DOMING OF CENTRAL NORTH ISLAND AND THE ROLE OF THE UPPER MANTLE.

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Recent crustal structure investigations (NIGHT) in the central North Island (CNI) have unearthed an intriguing, isostatic, contradiction: an association of profoundly thin crust with recent rock uplift. We explore properties of the upper mantle that might lead to sufficient buoyancy to overcome the thin crust and raise the solid surface of the CNI into a lithospheric dome with a wavelength ~ 400 km. Constraints for this study are:

A/ Mudstone porosity analyses show that over 2 km of exhumation has occurred in central North Island since 4 Ma. This combined with a coeval surface uplift of ~ 500 m, indicates a maximum 2.5 km of rock uplift in the central North Island. The magnitude and wavelength (~ 400 km) of the uplift is dome-like and similar to that observed in continental areas associated with mantle upwelling (e.g. Yellowstone).

B/ Marine terraces 100-150 km from the centre of maximum exhumation show uplift rates of ~ 0.2-0.3 mm/y consistent with about 1 km of exhumation if averaged over 4 my, which compares well with results of mudstone porosity analyses.

C/ An early Pliocene unconformity within (offshore) North Taranaki Basin. About 1 km of erosion has occurred across the unconformity.

D/ Seismic attenuation (Q) studies show strong attenuation throughout the mantle wedge below CNI.

E/ Explosion and earthquake data show Pn wave-speeds 8% lower than normal, which suggest a degree of partial melt in the mantle.

F/ Strong seismic reflections from within the mantle wedge that we interpret as coming from a pooled body of melt at a depth of ~ 35 km.

Isostatic modelling is used to define a process consistent with these observations. The observed rock uplift pattern may be explained by the replacement of a 75 km thick mantle lid of asthenosphere with a density ~ 88 kg/m^3 less than the lid. Such a density contrast cannot be explained by temperature change alone, and a partial melt of perhaps 5% is required. The lateral extent of the anomalous upper-mantle body corresponds to the eastern boundary of the TVZ but extends well to the west of the conventional western boundary of the TVZ.

POSTER

HIGH RESOLUTION ENVIRONMENTAL MAGNETISM OF SHORT SEDIMENT CORES FROM LAKE TEKAPO, NEW ZEALAND

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U-channel samples from two lake sediment cores (L-1397 and L-1398) collected by NIWA in 1991 from Lake Tekapo, New Zealand, have been used for an environmental magnetic study. Lithostratigraphic analysis was carried out on the cores, which contain turbidites and laminae that are interpreted to be varves. A varve count gave an age of 353 years before 1991 for L-1397 and 303 years before 1991 for L-1398. High-resolution magnetic measurements of natural remanent magnetisation intensity and magnetic susceptibility, and a stepwise alternating field demagnetisation were performed on the u-channels. Declination, inclination and mean destructive field down through the core were obtained from a principal component analysis of orthogonal component projections at 1 cm intervals. An age model was constructed and a sedimentation rate of 6.2 mm/year determined for Lake Tekapo. Natural remanent magnetisation intensity has been plotted against age in attempt to compare cyclicity within the data to paleoclimatic events. The occurrence of two turbidites has been correlated to large paleoseismic events within the South Island in 1861 and 1888, respectively. The cyclicity of declination is the same as the cyclicity of natural remanent magnetisation intensity, suggesting an annually resolvable record of fluctuations in the intensity of the Earth's magnetic field has been obtained. Declination and inclination have been used to reconstruct secular variation for the last 300 years for the Lake Tekapo area.

POSTER

GEOLOGY OF METASEDIMENTS AND INTRUSIVE ROCKS OF THE HAAST REGION, SOUTH WESTLAND.

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Contrary to previous assumptions, basement rocks west of the Alpine Fault in the Haast region, South Westland, are dominated by Greenland Group metasediments, with granite only occurring as minor sills. Glacial erosion during the Quaternary is considered the most likely cause of the morphology of the conical knobs in the Haast region.

Greenland Group metasediments are dominated by resistant, massive psammite with thin subordinate interbanded pelites and minor calc-silicate bands. Sillimanite was observed in some pelite samples, allowing classification in the amphibolite facies. Quartz-albite-biotite-muscovite assemblages are common in psammite (quartz-rich) and pelites (biotite-rich) with variations in ratios between the two end members. The quartz-rich nature is a reflection of the homogeneous polycyclic continental source region. Geochemical analysis showed a slightly higher CaO and Sr contents compared with samples from North Westland.

Two feldspar, subsolvus granites contain quartz, biotite and two micas, reflecting their high K_2O/Na_2O character. ASI and normative corundum values are typical of S-type crustal melts formed by local anatexis. On the basis of their geochemistry and previous geochronology, Haast granitoids are correlated with the Karamea Suite intrusives of Northern Westland and Nelson. Zircon saturation temperatures show that these low volume partial melts were formed at low temperatures consistent with melting of a crustal source (650-800^{O}C). These melting temperatures required significant fluid input into the crust (> 5wt %) for melt generation. Field relationships suggest that the granite melts were expelled during active deformation along foliation planes in mechanically weaker pelite layers.

Porphyroblasts in narrow hornfelsic contact zones (<5m), are associated with granite intrusions and overprint earlier regional metamorphic rock fabrics. The folding of some granite sills appears to have occurred during progressive emplacement and only retrogressive reactions are observed in the metasediments post-orogenically.

Cross-cutting lamprophyre dikes can be correlated with late Cretaceous opening of the Tasman Sea.

POSTER

A SUBMARINE MAGMATIC-HYDROTHERMAL SYSTEM AT BROTHERS VOLCANO, KERMADECS

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Dacite and rhyodacite with minor andesite, volcanic sandstone, and fragments of sulphide-rich chimneys were dredged from the Brothers Volcano. Thirty-eight secondary minerals were identified in 55 samples and include silicates, silica polymorphs; Na-Al, Ca, Ba and Ba-Sr sulphates; Fe, Cu, Zn, As and Pb sulphides; Fe and Mn oxide/oxyhydroxides and native S. The variety and range of mineral compositions indicate deposition in different parts of a submarine hydrothermal system characterised by differences in temperature (ambient seawater to >300^{o}C), fluid compositions, degree of magmatic-hydrothermal water-rock interaction and degree of seawater influence. The Brothers submarine hydrothermal system is divided into a zone of direct magmatic influx into the seafloor, associated with a crack-zone from the crystallising magma to the seafloor surface (Fig. 1), and later manifesting itself as sulphide-rich chimneys on the sea floor. Away from the main upflow zone, where faults form conduits for hydrothermal fluids to ascend to the seafloor, sulphate-rich chimneys or opal-A + pyrite are deposited.

On the surface of the seafloor is a thin zone of seawater-rock-plume interaction and just below this a region where hydrothermal waters, seawater and rock interact. Secondary minerals in the Brothers Volcano dredge samples originate from a partly exhumed waning hydrothermal system/s (NW caldera); the main upflow of a relatively well-established active magmatic-hydrothermal system on the seafloor where sulphide-rich chimneys are extant (SE caldera) and a nascent magmatic-hydrothermal system where crack zones localize upwelling acid waters from depth (cone).

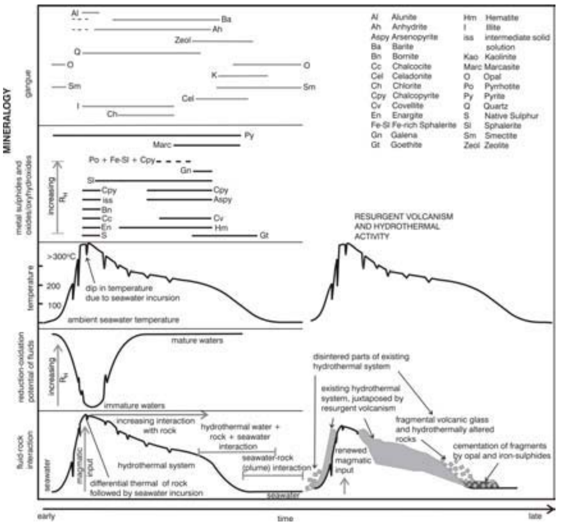

Fig. 1. Mineral paragenesis and evolution of a submarine magmatic-hydro-thermal system, Brothers Volcano, Kermadecs.

ORAL

MINERALOGICAL HARBINGERS AND THE DISTRIBUTION OF CORROSIVE FLUIDS IN SELECTED GEOTHERMAL SYSTEMS IN THE TAUPO VOLCANIC ZONE

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Casing damage in geothermal wells in the Taupo Volcanic Zone has been reported in high-gas (e.g., Ohaaki-Broadlands, Kawerau and Rotokawa) and low-gas systems (Wairakei and Mokai). The hydrothermal mineralogy and fluid inclusion characteristics in the formation were examined to determine the propensity of a geothermal well to be affected by external casing corrosion (ECC). The formation often has moderate to excellent permeability at the depths of corrosion, characterised by the presence of abundant veins and or open fractures partly filled with drusy and platy minerals. Anhydrite, in veins and as a replacement mineral associated with near acid-SO_4 waters (1, Fig. 1), has only been found so far in Rotokawa. Acid-SO_4 waters forming alunite $\pm$ silica polymorphs $\pm$ kaolinite $\pm$ sulphur $\pm$ Fe-sulphides often occur at very shallow depths in the TVZ where 2 to 3 casings may deter corrosive fluids from entering the well. At this stage of the study no ECC is associated with this alteration assemblage. Most late-stage minerals, however, suggest that the generation of corrosive dilute waters are the products of (1) boiling of neutral pH silica-saturated Cl fluids that may or may not contain high contents of dissolved CO_2 (e.g., drusy wairakite, quartz, albite, calcite; deposition of colloidal silica at high temperatures; dissolution of magnetite and pyrite) followed by (2) steam condensation associated with cooling either by cold rock, dilute oxygenated groundwaters or reinjected waters (deposition of Mg-rich chlorite, goethite and hematite) and (3) condensation in shallow steam-dominated zones (kaolinite + marcasite + chalcedony + smectite $\pm$ carbonates (calcite, dolomite and/or ankerite)). For these corrosive fluids to remain reactive the following factors are necessary (1) persistence of hydrological conditions including boiling and condensation, and cold water influx (2-7, Fig. 1), (2) pathways for flow e.g., fractured rock in faults or hydrothermal eruption vents, permeable lithologic units, well annulus (6-8, Fig. 1), and (3) triggering mechanisms to continually generate these fluids e.g., intermittent episodes of rock fracturing and depressurisation or drawdown caused by exploitation.

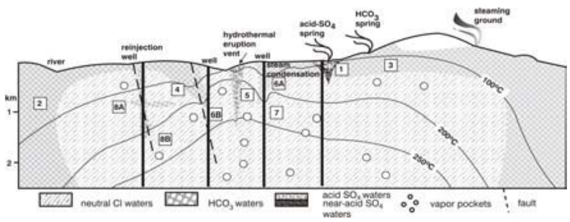

Fig. 1. Possible sites for corrosive fluids in a composite TVZ geothermal system.

POSTER

CONSTRAINTS ON SUBDUCTION AND MAGMATISM BENEATH THE CENTRAL NORTH ISLAND, NEW ZEALAND, FROM SEISMIC TOMOGRAPHY

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Recent dense deployments of portable digital seismographs have provided excellent control on earthquakes beneath the central North Island of New Zealand. Here we use a subset of the best-recorded earthquakes in a progressive inversion for the 3-D *Vp* and *Vp/Vs* structure. The data set includes 39,123 *P* observations and 18,331 *S* observations from 1239 earthquakes and 9 explosions. The subducted plate is imaged as a high

Vp, low *Vp/Vs* feature. *Vp* within the mantle of the subducted slab is almost always > 8.5 km/s, which requires the > 85 Ma slab to be unusually cold. The low *Vp/Vs* within the subducted plate closely parallels the dipping seismic zone. It most likely represents fluid resulting from dehydration of serpentine in the slab mantle, and the earthquakes themselves are likely to be caused by dehydration embrittlement.

The mantle wedge is generally imaged as a low *Vp*, high *Vp/Vs* feature. However, there are significant changes evident in the wedge along the strike of the subduction zone. The region where *Vp* < 8.0 km/s extends deepest northwest of the Lake Taupo region. The lowest *Vp* occurs at 65 km depth, locally reaching 7.4 km/s. This region is best interpreted as a significant volume of partial melt, produced by the reaction of fluid released by dehydration of the subducted plate with the convecting mantle wedge. The region with lowest *Vp*, while paralleling the dipping seismic zone, lies about 30 km above it. Material with *Vp* > 8.0 km/s directly above the dipping seismic zone can be interpreted as sinking, entrained with the motion of the subducted slab and forming a viscous blanket that insulates the slab from the high-temperature mantle wedge. Material in the overlying low *Vp* region can be interpreted as rising within a return flow within the wedge. The volcanic front appears to be controlled by where this dipping low *Vp* region meets the base of the crust. The back-arc crust also shows significant variation along strike. In the central Taupo Volcanic Zone the crust is ~30 km thick, with a very transitional Moho. The tomography results are consistent with a heavily intruded or underplated lower crust. Southeast of the Mt Ruapehu, the crust thickens significantly.

The seismic tomography results, when combined with constraints on mantle flow from shear-wave splitting, provide a plausible model for both the distribution of volcanism in the central North Island, and the exceptional magmatic productivity of the central Taupo Volcanic Zone.

PLENARY

EARTHQUAKE FORECASTING: THE END OF THE BEGINNING

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Proposed methods of earthquake forecasting can be coarsely classified as belonging to one of three stages: the anecdotal stage, the testing stage, and the operational stage. Scientifically based operational forecasting cannot begin until a proposed method has been demonstrated, through tests independent of its formulation, to be more informative than time-invariant estimates of earthquake occurrence.

The EEPAS forecasting model is a simple point-process model of earthquake occurrence in which *E*very *E*arthquake is regarded as a *P*recursor, *A*ccording to *S*cale, of larger earthquakes to follow it in the long term. It adopts predictive scaling relations derived from many examples of the precursory scale increase phenomenon, and applies them to all earthquakes, thus setting aside the problem of identifying those earthquakes that are actually precursory. The model was originally fitted to New Zealand earthquakes with M > 5.75 over the period 1965-2000, where it explains the data much better than a quasi-static baseline model with a location distribution based on proximity to the epicentres of past earthquakes. It has subsequently been shown to be much more informative than the baseline model when tested, with unchanged parameters, on the CNSS catalogue for California with M > 5.75 over the period 1975 – 2001, and on the JMA catalogue for Japan with M > 6.75 over the period 1965-2001. It has also been successfully applied at lower magnitudes (M > 4.75) to the NIED catalogue of the Kanto area, central Japan. Its performance on the New Zealand catalogue since 2000 also confirms the superiority of EEPAS over the baseline model.

The EEPAS model is now poised to move from the testing stage into the operational stage of earthquake forecasting. The time-varying estimates of earthquake occurrence that it provides can now supplement the time-invariant estimates provided by traditional probabilistic seismic hazard analysis. The model can give probability gains of the order of 5 for individual large earthquakes, with a warning time that depends on magnitude, e.g,, up to twelve years for M 7, and up to four years for M 6. An important research task is to strengthen the EEPAS model by incorporating a procedure for identifying those earthquakes that are actually precursory, thus reducing the artificial part of the hazard and increasing the real probability gains.

ORAL

DILUTE HYDROTHERMAL FLUIDS WITHIN THE GROUNDWATERS OF THE MONTURAQUI BASIN, NORTHERN CHILE: THE ROLE OF VOLCANO SOCOMPA

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The Monturaqui Basin of northern Chile forms part of a large aquifer system that lies at the foot of the Central Andean volcanic arc (068º 30'W, 24º 25'S) within the hyper-arid Atacama Desert. The basin formed contemporaneously with emplacement of the current magmatic arc during the early Miocene. The easternmost margin of the basin is dominated by a large, recently active Pleistocene stratovolcano, Volcano Socompa (6051 m). The large volcanic edifice grew through and sits upon the primary aquifer which is comprised of a laterally extensive sequence of poorly consolidated, highly permeable, rhyodacitic volcaniclastics. The aquifer occurs ~100 – 150 m below the surface of the basin, is between 100 – 200 m thick, and contains an estimated 10^{10} m^3 of water. Groundwater flow is from E-W beneath the volcano.

Sampling of groundwaters from production wells at base of the volcano, 18 – 25 km from the summit revealed elevated groundwater temperatures (27ºC to 37ºC) relative to a mean annual surface temperature of –1ºC. CO_2 partial pressures within these waters range between 0.007 to 0.05 atm. pCO_2, TºC, and SO_4 concentration increase exponentially towards the volcano and groundwaters are of the $Na\text{-}HCO_3\text{-}SO_4$ type. Groundwaters are fresh to brackish, with TDS (total dissolved solids) ranging from 826 mg L^{-1} to 3 632 mg L^{-1} and DIC (dissolved inorganic carbon) up to 11 mmol L^{-1} in regions of high CO_2 degassing.

We propose the existence of a volcanic hydrothermal system associated with Volcano Socompa in which ascending fluids and gases are strongly diluted by cold meteoric waters in the overlying aquifer. Whereas CO_2 degassing is diffuse and decreases exponentially with distance from Volcano Socompa geochemical evidence of discrete inputs of deep, neutral chloride fluids and associated magmatic volatiles are probably related to localized structural controls on fluid seepage (caldera related faulting, regional faults). Both the scrubbing of magmatic gases by shallow subhorizontal aquifers and the emergence of mature geothermal (neutral chloride) fluids at the periphery of volcanic hydrothermal systems has been well documented in similar volcanic settings in Japan, Indonesia, and Taiwan.

Although the modern climate precludes any significant vertical recharge from the summit of Volcano Socompa the large groundwater reservoir that bathes the main volcanic vent still acts to suppress any surficial thermal activity. $\delta^{18}O$ and δD compositions for groundwaters taken in conjunction with paleoclimatic data for this region suggest aquifer recharge to have occurred during the last two Quaternary humid phases that spanned 15 - 9 Ka and 8 - 3 Ka. The aquifer is now in a state of gradual decline.

ORAL

THE MAGNETIC SIGNATURE OF NEW ZEALAND CENOZOIC MUDSTONES EXPLAINED

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Thick, tectonically uplifted fine-grained Cenozoic siliciclastic marine sequences from New Zealand provide standard sections for mid-latitude foraminiferal biostratigraphic zonations. Magnetic polarity stratigraphy is a powerful tool for global calibration of such zonations. However, classic first generation magnetostratigraphic studies of New Zealand sequences were adversely affected by strong present-day geomagnetic overprints that often went unrecognised in the early studies. More sophisticated instrumentation and data analysis techniques now enable routine identification of such overprints. Nevertheless, longstanding questions concerning the magnetic signature of these sedimentary rocks have remained unanswered. For example, routine identification of the dominant magnetic mineral in these sediments has been elusive, as has been the cause of the widespread present-day overprint.

New Zealand Cenozoic mudstones have been strongly affected by chemical reactions associated with microbial degradation of organic matter. Sulphate reduction results in build-up of dissolved sulphide in sedimentary pore waters, which causes dissolution of detrital iron-titanium oxides and produces generally weak magnetisations; the released iron reacts with sulphide to form non-magnetic pyrite (FeS_2). Pyrite forms as the end product of a series of precursor phases, which usually includes the magnetic iron sulphide, greigite (Fe_3S_4). If pyritisation reactions are arrested, through lack of availability of key reactants, greigite can be preserved in the geological record.

Results from a large sample collection from the eastern North Island and Marlborough suggest the widespread presence of greigite in New Zealand Cenozoic mudstones. This evidence suggests that greigite is the dominant magnetic mineral in many New Zealand sequences (as is the case with similar lithologies in Italy and Taiwan). Scanning electron microscope (SEM) observations indicate that oxidation of fine-grained iron sulphides, probably resulting from percolation of oxic groundwaters during subaerial exposure, is responsible for the strong present-day geomagnetic field overprints. Most worryingly, our detailed SEM observations suggest the presence of multiple generations of

pyrite and greigite, which invalidates the interpretation of magnetic polarity records from such sediments in terms of syn-depositional processes. Furthermore, in one case, different horizons within the same sequence record opposite polarities, but whereas normal polarity samples indicate large tectonic block rotations about vertical axes, samples with reversed polarity indicate much less rotation. These data suggest that different horizons were magnetised at different times with earlier magnetisations recording more complete information concerning tectonic rotations.
The magnetisation of some New Zealand sequences, such as Pleistocene sediments in the Wanganui Basin, is probably carried by disseminated detrital iron-titanium oxide grains of volcanic origin. Supply of abundant detrital magnetic grains will offset the negative effects of reductive diagenesis. Nevertheless, routine petrographic studies should be conducted in support of paleomagnetic studies from New Zealand Cenozoic marine sediments to preclude the possibility of remagnetisation resulting from late diagenetic greigite formation.

POSTER

PALAEOMAGNETIC STUDY OF AD 1305 KAHAROA RHYOLITE

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Palaeomagnetic studies have been carried out on 41 oriented cores obtained from 5 sites within the Wahanga and Crater rhyolite domes, on outcrops exposed by the AD1886 Tarawera eruption. The domes were extruded on Mt Tarawera summit during the Kahaora eruption, radiocarbon dated at AD1305 ± 12 years. The fresh rhyolite rock is consistently strongly magnetised with NRM of 1 to 12 Am^{-1}. Complete progressive thermal demagnetisation was applied to every sample and straight-line Zijderveld trajectories were obtained, giving a palaeofield direction of declination 354.6°, inclination –61.2°, α_{95} 4.3° relating to the time of emplacement of the rhyolite. The palaeofield directions for the respective domes are not distinguishable, which suggests that they are penecontemporaneous. These results complement the existing database of archaeomagnetic information for the NZ region, comprising historical records and palaeomagnetic studies on volcanic and sedimentary material. Detailed reconciliation of these various data at sub 5° level requires an algorithm for compensating regional gradients in magnetic declination and inclination, and an appreciation of the specific merits of the different data types, in terms of relative and absolute declination, inclination and chronology.

ORAL

TECTONIC ROTATION OF THE HIKURANGI MARGIN, EAST COAST, NEW ZEALAND: NEW CONSTRAINTS FROM PALEOMAGNETIC AND MAGNETIC FABRIC DATA

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GPS and geodetic studies demonstrate that the Hikurangi Margin is currently rotating clockwise at 2-4°/m.y.; the forearc region is acting as a linkage between regions of back-arc extension to the north and transpression to the south. Plate tectonic reconstructions require the margin to have rotated by up to 90° since the initiation of subduction in the Early Miocene, indicating that these rotations have persisted for at least part of the Neogene. This hypothesis is confirmed by paleomagnetic studies, which also suggest that the forearc is divided into a number of independently rotating domains, a feature common to areas of oblique convergence, but not observed in the short-term velocity field.

We have obtained extensive paleomagnetic results from uplifted marine sediments on the Hikurangi Margin, collected to more firmly establish the existence and boundaries of the proposed rotational domains, and hence to establish the style and length scales of deformation in the East Coast region. In addition to stepwise demagnetisation to isolate characteristic remanences, the anisotropy of magnetic susceptibility (AMS) was measured. In relatively undeformed sediments the magnetic fabric is closely related to the regional strain field, and can therefore potentially be used as an independent rotation marker, enabling easier identification of localities affected by late diagenetic remagnetisations or present day field overprints.
These new data permit a better understanding of the timing, magnitude and spatial variability of rotations on the Hikurangi Margin. Most or all of the Neogene rotation has occurred since the late Miocene, with its initiation possibly linked to the collision of the Hikurangi Plateau. Data from the hitherto poorly-constrained Wairarapa region show rotations consistent with sites of similar age in the Wairoa area; rather than showing independent rotation histories, the whole margin between Marlborough and Gisborne appears to have rotated coherently during the Neogene. This long-term

pattern is more consistent with the short-term velocity field, and is consistent with the lack of crustal-scale basement structures apparent in geological and seismological data. However, in the north a boundary accommodating large differential rotations must still exist between the unrotated Raukumara Penisula and the rest of the Hikurangi Margin. Accurate delineation of this boundary has proven problematical, partly as a result of unreliable data. Early Miocene rocks in the Rakauroa area, previously reported as being rotated, are in fact unrotated, consistent with local structural trends; whereas coastal localities between Gisborne and Tolaga Bay show large clockwise declination anomalies. Together, these results suggest that the boundary has a northeast-southwest trend, more parallel to the margin than has previously been suggested. Overall, rotation of the forearc appears to be principally controlled by the degree of coupling with the subducting Pacific plate.

ORAL

ECOLOGIC DISTRIBUTION OF BENTHIC FORAMINIFERA, OFF-SHORE NORTH-EAST NEW ZEALAND

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Nine benthic foraminiferal associations are recognised and mapped in the offshore region north-east of New Zealand (50-3800 m depth) based on cluster analysis of faunal census data (>63 µm, 235 species, 56 samples). Similar associations are identified using cluster analysis based just on the presence or absence of species. Canonical correspondence analysis shows that the associations correlate most strongly with factors related to water depth, especially decreasing food supply (organic carbon flux) with increasing depth. The depth-stratified distribution of mid bathyal to upper abyssal (>1000 m) associations accords well with the deep water masses, and is attributed to lower oxygen concentrations in the bottom waters. The two deepest associations dominated by *Alabaminella weddellensis, Epistominella exigua, Bulimina marginata* f. *aculeata*, *Globocassidulina subglobosa*, and *Oridorsalis umbonatus*, underlie the oxygen minimum zone of Circumpolar Deep Water. A mid-lower bathyal association dominated by *Cassidulina carinata, A. weddellensis, Abditodentrix pseudothalmanni,* and *Trifarina occidentalis*, underlies Antarctic Intermediate Water. In addition to their bathymetric stratification, mid shelf to upper bathyal (50-600 m) associations also show latitudinal variation that may reflect differences in terrigenous mud, food supply, nutrient remineralisation on the seafloor and bottom current strength.
At depths of <1000 m, the benthic foraminiferal assemblages of this study are more similar to those off the west coast of central New Zealand than those further south down the east coast. This possibly reflects similar levels of phytoplankton productivity and consequent benthic food supply, to the north-east and west compared with higher levels in the vicinity of the Subtropical Front east of central New Zealand.
At greater depths, west coast faunas are intermediate in composition between the two offshore east coast study regions, consistent with intermediate chlorophyll *a* values in surface waters.

ORAL

AQUIFER CHEMISTRY OF THERMAL WATERS IN OBAMA GEOTHERMAL FIELD, JAPAN- BETWEEN 1984 AND 2001

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The Obama geothermal field is located in western part of Kyushu Island, Japan and composed by Quaternary-Neogene volcanic formations. Abundant geothermal manifestations discharged at the surface are aligned along the faults. 54 hot waters are the subject of this study. Chemical and isotope geothermometers have been applied to estimate the reservoir temperature of the thermal waters in the Obama geothermal area. 22 samples of hot springs are analyzed for major elements in 1984, 15 drilling wells have been sampled and analyzed for major, trace elements, and for isotope ^{2}H, ^{18}O (in water) in 1984 and 17 samples of hot springs for major and trace elements and ^{18}O, ^{2}H in 2001. The measured surface temperatures of thermal waters in 1984 vary between 51.8 and 99.6 ^{o}C and between 79 and 100 ^{o}C in 2001, with total dissolved solids around 8404 mg/kg in 1984 and 8196 mg/kg in 2001. The water quality is hyperthermal common salt spring. All the thermal waters are alkali-chloride waters and have high dissolved contents. The isotopic data of hot waters in 1984 defines a linear regression equation of $\delta^{2}H=2.34\delta^{18}O-23.6$ and the isotopic data of hot waters in 2001 defines a linear regression equation of $\delta^{2}H=2.75\delta^{18}O-23.1$. The parent liquid cools through steam loss/boiling and dilution and/or

mixing with cold waters (sea water and meteoric water). The chloride-enthalpy diagram gives the chloride composition of the reservoir fluid (6200 mg/kg in 1984 and 3800 mg/kg in 2001). The silica-carbonate mixing model gives the silica composition of the reservoir fluid (310 mg/kg in 1984 and 400 mg/kg in 2001) and also shows that a reservoir with a temperature of 190 ^oC in 1984 and 210 ^oC in 2001 exists which agree with results of fluid/mineral equilibrium diagrams. Thermal waters of Obama geothermal field are oversaturated at discharge temperature for calcite, dolomite, pyrite, quartz, albite, anorthite, K-feldspar, illite, kaolinite, Na-smectite minerals giving rise to a carbonate-rich scale and undersaturated with halite, fluorite, gypsum, anhydrite, siderite, gibbsite minerals indicating that dissolution of SO_4 is still taking place in the reservoir. The Obama hot waters are results of mixing of three phases: sea water, meteoric water and magmatic water. The Obama geothermal field is in recovering state with rising in the water temperature and decreasing in the salinity. The increasing of the reservoir temperature around 20 ^oC may be correlated with the rapid decrease in thermal water production since 1955 to preserve the geothermal resource.

ORAL – geothermal workshop

GEOPHYSICAL OBSERVATIONS OF PROCESSES IN THE MANTLE WEDGE: CENTRAL NORTH ISLAND NEW ZEALAND

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Both passive and active seismic investigations show the mantle wedge beneath North Island, New Zealand to be highly attenuative, have low seismic wave speeds and, by inference, contain mantle melts. The Central Volcanic Region (CVR) New Zealand is the apparent extension of the Lau-Havre trough back-arc spreading centre into the continental lithosphere of New Zealand. A clear manifestation of this extension is the observation from explosion seismology that the original crust beneath the CVR is now about half (16 km) the thickness of regular continental crust. Despite this crustal thinning the CVR remains above sea level, indicating buoyant support from a low-density mantle.

Passive seismology provides some insight into the source and distribution of anomalous mantle. The mantle wedge below the CVR is characterised by high seismic attenuation (Qp = 250). High seismic attenuation results from the combined effect of increased temperature and water content. Attenuation-temperature relationships indicate a lateral increase in effective temperature of 100-120 K between the northwestern North Island and the CVR and 300-350 K between the CVR and normal mantle. This is insufficient to produce the density decrease required to explain the uplift. The presence of mantle melts must therefore contribute to the mantle buoyancy in the region. This melt component is evidenced both at depth as low mantle velocities and poor shear wave propagation, and at the surface in the CVR where rhyolitic eruption rates of $0.28 m^3 s^{-1}$ make it one of the most active silicic volcanic centres on earth.

ORAL

DEEP STRUCTURE OF THE SOUTHERN HIKURANGI MARGIN

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The Tonga-Kermadec subduction zone stretches across most of the southwestern Pacific; its southernmost segment, called the Hikurangi Margin, ends in a transform fault in the northern South Island, New Zealand. We examine this transition at depths of 0-700 km using seismic waves converted from P to S at boundaries, or so-called “receiver functions”, from arrays of seismographs in Marlborough (the northern South Island), and Wellington and the Tararuas (the southern North Island). Post-P wave times up to 80 seconds and frequencies of 0.03-1 Hz were used along with common midpoint stacking to study the deeper arrivals, and multi-taper analysis of the first 20 seconds was used to study the shallow crustal structure beneath the North Island. The ray-tracing code of Frederiksen and Bostock was used to compute forward models of anisotropic structures with dipping boundaries.

Isotropic layers dipping with the slab can explain many of the gross features in the first 20 seconds of the records at long periods. Yet to explain the short-period data the upper 30 km of the velocity structure must differ from north to south. A prominent arrival comes from a depth of 9 km at station SNZO in South Karori, Wellington, and deepens to about 15 km beneath the Tararua Ranges near Kapiti Island. Phases from the slab interface and the oceanic Moho are strong on the North Island. These arrivals change in arrival time consistent with the dip of the Benioff zone beneath the stations. Arrivals at the South Island stations are also consistent with conversion from the top of the dipping Benioff zone. Including anisotropy determined from a separate shear-wave splitting study helps to explain the arrivals on the transverse components in the North Island data.

Anisotropy is also needed to explain the later arrivals apparent in the CDP stacks, which come from below about 200 km depth. The polarity of the arrivals in the CDP stacks near 200 km depth are consistent with those from a model including a conversion from a lower layer with fast direction oriented N20E, and an upper layer with fast direction of N60E, which was previously determined from shear-wave splitting analysis. Transverse energy from phases generated at discontinuities at 250-700 km also suggests that anisotropy above 250 km averages between N and N45E. Arrivals from depths of 400-700 km (within the transition zone) show shallowing of the 410 km discontinuity and deepening of the 660 km discontinuity in the region where the steeply dipping seismicity from the (30-170 km depth) Benioff zone is projected to intersect. The changes in depth of the deeper discontinuities are consistent with the slab being continuous to depths of 660 km, cooling the material in such a way that the olivine α-β phase transition, which normally occurs at 410 km depth, shallows, while the γ-spinel-perovskite + magnesiowustite phase transition (normally at 660 km depth) deepens. The temperatures inferred to account for the changes in depth of the transition zone discontinuities are consistent with cooling of more than 300 K.

ORAL

MINERALOGICAL AND MICROBIAL CHARACTERISTICS OF AN ACID-DERIVED SILICA SINTER FROM A THERMAL OUTFLOW AT PARARIKI STREAM, ROTOKAWA GEOTHERMAL FIELD, NEW ZEALAND

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Unusual deposits of siliceous sinter form around high temperature (>75ºC) vents, on a thermal outflow at Parariki Stream, in the Rotokawa geothermal field. The vents are characterised by acidic pH (2.3), and a relatively high discharge of acidic steam and silica-rich (568 ± 90 ppm) waters. These waters belong to the acid-sulphate-chloride type, with most of the silica, like chloride, being derived from a deep reservoir. The low pH is predominantly caused by the oxidation of hydrogen sulphide, resulting in the formation of sulphuric acid. The sinter forms subaerially on pumice clasts and pine cones with abiotic and biotic factors affecting its formation, morphology and texture. The main mineral phase of these deposits is noncrystalline opal-A silica with XRPD traces showing a full width at half maximum intensity (FWHM) of 1.34-1.42 ΔÅ (8.1º Δ2θ). Silica drapes the existing substrate topography and deposits as layers that can become substantially corroded, with only dissolution ridges, nodules and remnant islands of the formerly parallel layers remaining. Pervasive silicification also is observed on diatom frustules from cooler environments which have been washed or blown onto the sinter. Silica deposits predominantly as vitreous spheres that are <10 nm to 50 nm in diameter. Over time, these initially deposited silica spheres become progressively ill-defined by repeated episodes of dissolution and redeposition. Apart from opal-A, gypsum, barite and sulphur are also present and become engulfed in silica and hence incorporated into the main sinter body. Much of the sinter surface is covered by coccoidal microorganisms (1-1.5µm in diameter) that connect to one another through extracellular bridges and/or a meshwork of extracellular polymeric substances (EPS) that constitute a biofilm. The microbial diversity is low, as only one or two morphotypes are discernable. In several places, the microbes form isolated clumps of cell clusters, which can become progressively encrusted by nanospheres of silica. Eventually, these encrustations are recolonized by a new succession of biofilm, forming vertically upright pillar-like structures. The capability of microorganisms to form templates for the build up of macroscopic spicular structures should therefore not be overlooked. Silicification of the microbes must occur while they are still alive as no sign of biological decay is apparent. Care must be taken when characterizing *in situ* microbial compositions, because samples that were not treated with a biological fixative and were stored for two months in a moderately dry environment showed pervasive, unsilicified fungal overgrowth. The fungi are interpreted to have grown after the samples were collected, as no fungal growth was observed on samples immediately treated with glutaraldehyde in the field and subsequently examined under a scanning electron microscope (SEM).

ORAL – geothermal workshop

MICROENVIRONMENTAL CHANGES IN THE SILICA MINERALOGY AND MICROBIOLOGY OF AN ACIDIC THERMAL SPRING OUTFLOW AT PARARIKI STREAM, ROTOKAWA GEOTHERMAL FIELD, TAUPO VOLCANIC ZONE, NEW ZEALAND

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A notable thermal spring outflow is located along the west bank of the Parariki Stream, 750 metres north of Lake Rotokawa, situated in the Rotokawa geothermal field. Silica-rich water from this outflow is discharged by numerous vents ranging in temperature from 90°C to 50°C. The emitted waters are appreciably acidic (pH 2.3) and belong to the acid-sulphate-chloride type. A range of siliceous deposits have formed in this outflow, the morphology, texture and formation mechanisms of which depend on a variety of environmental constraints: (1) size and shape of the substrate; (2) exposure to thermal water; (3) water temperature; (4) water flow rate; (5) fluctuations in water level; (6) exposure to acidic steam; and (7) presence and nature of mat-forming microorganisms. Numerous substrates such as pumice clasts, twigs, branches and pine cones are located along the outflow channels and provide sufficient relief for the subaerial deposition of noncrystalline silica. Along most of the outflow, no splash nor spray from the vents are evident, with water reaching the substrates through wave wash, water level changes after heavy rainfall, and/or diffusion through capillary creep. The precise hydrodynamic mechanism, however, depends on the location of the substrates and their degree of contact with thermal waters. The morphology and texture of these siliceous deposits can be distinguished into five different types: (1) cup- to ridge-shaped deposits forming close to vents with relatively high water and gas discharge and a temperature >75ºC, and sinter surfaces characterised by microspicular textures and corrosion; (2) spiculose deposits forming in areas with relatively low water flow rate, low acidic steam discharge and a temperature <84ºC, with deposition of silica between spicules resulting in rim formation; (3) parallel laminated deposits forming on slightly steepened areas that are exposed to changing water levels and; (4) thin siliceous rims forming on predominantly small pumiceous clasts that rest on moist sandy substrates; and (5) silica encrustations of pumice clasts resting on steaming ground but without water contact. Initial deposition of silica is abiotically induced, as silica is driven to precipitate through subaerial water cooling and evaporation. The effects of corrosion are visible on deposits grown in the presence of significant exposure to acidic steam. Morphologic changes occur along a thermal gradient, with each distinctive type of siliceous deposit covered by different biofilms consisting of microorganisms and extracellular polymeric substances (EPS). Microstromatolites, form by the clustering of cell colonies, becoming progressively silicified and reoccupied by a new succession of biofilm. These yield the spicular texture, visible in many of the deposits.

POSTER – geothermal workshop

GEONET: MONITORING OUR VOLCANOES

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In the early 1950's scientists started monitoring our volcanoes, and although several significant eruptions occurred over the next 20-30 years no one national surveillance programme was put in place. Equipment, staff and capabilities were spread across several Divisions of DSIR and the Universities. In 1992 DSIR was disestablished and the Institute of Geological & Nuclear Sciences formed, this saw most of the capability grouped together for the first time, at the Wairakei Research Centre.

A structured surveillance programme was put together and partnerships developed with some of the Regional Councils and DoC. Random collections of seismographs were grouped together to build volcano-seismic networks, funding was obtained to add more, equipment purchased to measure gas flux and generally enhance our capabilities. Data links were established to bring information from Tongariro National Park, Rotorua-Okataina and White Island to Wairakei, the start of near real-time monitoring. Our capabilities were tested during the 1995 and 1996 eruptions of Ruapehu volcano. Then in 2001 the GeoNet project was launched and took on the responsibility of monitoring our volcanoes.

Seismic networks have now been established about all the major volcanoes in New Zealand. The networks that extend from the Tongariro National Park volcanoes, through Taupo and Rotorua to the Bay of Plenty, together with stations on White and Mayor Islands are operated by GNS (GeoNet), while networks on Mt Taranaki/Mt Egmont and the Auckland volcanoes are operated by the Taranaki and Auckland Regional Councils. All these networks are linked for real-time analysis of the recorded signals by GNS staff at the GeoNet data centres. Gas and water samples are regularly collected from fumaroles, lakes and springs. Airborne measurements quantify the gas flux from the volcanoes and GPS and InSar satellite data help monitor the deformation of them along with lake levelling.

This presentation will outline data collected by various techniques from our volcanoes, ranging from Raoul Island in the Kermadecs, through the Bay of Plenty-Taupo area to National Park, Taranaki and Auckland. A catch up on what they are up to.

ORAL

METAMORPHIC, MAGMATIC AND STRUCTURAL ASPECTS OF THE MT IRENE SHEAR ZONE, WESTERN MURCHISON MOUNTAINS, FIORDLAND

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A low-angle ductile shear zone, the Mt Irene Shear Zone (MISZ), separates amphibolite facies, meta-igneous Robin Gneiss, from the overlying, amphibolite facies, meta-sedimentary Irene Complex in the Murchison Mountains of Fiordland. The Robin Gneiss is a metamorphosed HiSY (high Sr, low Y) dioritic body, now a hornblende biotite gneiss, that hosts porphyroblastic garnet migmatite, rafts of calc-silicate gneiss, hornblendite pods, and is intruded by small gabbroic pods and unmetamorphosed HiSY trondhjemite dike swarms and plugs. Partial melting of the Robin Gneiss has produced thin lenticular pods of garnet migmatite, the leucosome component of which has a HiSY character. The major element composition of the leucosome (CaO ~6%, Na_2O ~3%) is not compatible with the regionally extensive, HiSY, Separation Point Suite magma (Na_2O 5-6%; Muir et al. 1998). The Irene Complex comprises horizons of gneissic calc-silicate, marble, pelitic schist, pyritic-quartzofeldspathic schist, amphibolite, and granitic orthogneiss. Geothermobarometric estimates from a pelitic schist indicate the Irene Complex was metamorphosed at c.560° $\pm$ 50° and c.4.5-5.2 kbar, an episode that is correlated with a c.330 Ma event of similar P/T constraints elsewhere in Fiordland. The Irene Complex is intruded by unmetamorphosed HiSY granite dikes and plugs, and by small dioritic pods. On the basis of metamorphic overprint, the granitic orthogneiss is considered unrelated to the HiSY granitoids.

The MISZ is characterised by a five to sixty metre thick zone of calc-silicate mylonite. The mylonites grade into a hanging wall composed of Irene Complex calc-silicate gneiss. Two opposing senses of shear are evident in the calc-silicate mylonites: one to the N-NE, and the other to the S-SE. Mylonites are absent in the footwall Robin Gneiss, and it is hypothesised that the MISZ preferentially sheared along limbs of macroscopic, isoclinally folded calc-silicate horizons or recumbent folds in the Irene Complex, and that the calc-silicates locally partitioned strain. Retrogressive mineral assemblages within both the Robin Gneiss and Irene Complex suggest the MISZ was a conduit for fluid under lower-amphibolite and greenschist facies conditions. The MISZ is correlated with the metamorphic core complex-bounding Doubtful Sound Shear Zone.

With only several exceptions, granitoid dikes in the Robin Gneiss cannot be traced across the MISZ into the Irene Complex, and vice versa: the MISZ abruptly truncates dikes. The exceptions are several HiSY trondhjemite dikes which can be traced from the Robin Gneiss into mylonitic foliation of the MISZ, but become sheared out metres after crossing the shear plane and are thus inferred to be late-stage, but synchronous to shearing. On the basis of similar major and trace element chemistry, all unmetamorphosed granitoids in the field area can be explained as products of varying fractionation from a single source, and therefore appear to have been intruded as different magmatic pulses during extensional shearing along the MISZ. The granitoids have similar chemistries to other Separation Point Suite granitoid rocks in Fiordland.

ORAL

PRELIMINARY RESULTS OF UPPER MANTLE WAVE SPEEDS IN THE CENTRAL NORTH ISLAND, NEW ZEALAND

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The central North Island of New Zealand represents a rare example of back-arc spreading impinging on continental lithosphere. Back-arc spreading is a well documented phenomenon in the oceanic environment, but there have only been a few places where researchers have argued that it is operating in a continental setting. Waves from shallow earthquakes that have travelled through the upper mantle, known as Pn and Sn wave phases, provide a tool for studying the properties of the mantle. By studying both Pn and Sn velocities, an insight into the amount of thermal disturbance in the upper mantle can be estimated, as both temperature and partial melting in the rocks can affect wave-speeds. Thus the main goal of this study is to measure Pn and Sn at a variety of azimuths to try and estimate the temperature distribution with depth and also to measure seismic anisotropy in the mantle. Measurements of Pn anisotropy can be used to constrain flow directions in the mantle wedge, as individual crystals of common mantle material such as olivine, have been shown with laboratory experiments to have high anisotropy of up to 25% [*Kumazawa and Anderson, 1969*].

The method of Haines (1979) is utilised, whereby velocities are determined for the Pn and Sn phases from wave travel times between pairs of seismograph stations. 26 seismograph stations from the National Seismograph Network, Bay of plenty volcano-seismic Network, Taupo volcano-seismic Network, and the Tongariro volcano-seismic Network were used, in combination with shallow earthquake data from the year 2000. Earthquake epicentres lying within a 10º offset from the station pair azimuth are used to produce preliminary results of upper mantle wave speeds.

The preliminary results suggest that the mantle beneath the Taupo Volcanic Zone is anything but simple. Within the TVZ the mantle velocity appears lower than the surrounding regions. There are also indications of variations in velocity around the Volcanoes to the south of Taupo within the TVZ, with hints of higher velocities to the West and lower velocities on the more active side, possibly due to the fluid content of the mantle in this area.

POSTER

MAGMA MINGLING IN THE ~50 KA ROTOITI ERUPTION FROM OKATAINA VOLCANIC CENTRE

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Examination of glass and crystal chemistry in the Rotoiti Pyroclastics (>100 km^3 of magma) demonstrates that compositional diversity was produced by mingling of the main rhyolite magma body with small volumes of other magmas that had been crystallizing in separate stagnant magma chambers. Most (>90%) of the Rotoiti deposits were derived from a low-K_2O, cummingtonite-bearing, rhyolitic magma (T1) discharged throughout the eruption sequence. T1 magma is homogeneous in composition (melt SiO_2 = 77.80 ± 0.28 wt %), temperature (766 ± 13°C) and fugacity (NNO+0.92 ± 0.09). Most T1 phenocrysts formed in a shallow (~200 MPa), near water-saturated (*a*water = 0.8) storage chamber shortly before eruption. Basaltic scoria erupted immediately before the rhyolites, and glass-bearing microdiorite inclusions within the rhyolite deposits, suggest that basalt emplaced on the floor of the chamber drove vigorous convection to produce the well-mixed T1 magma. Lithic lag breccias contain melt-bearing biotite granitoid inclusions that are compositionally distinct from T1 magma. The breccias which overlie the voluminous T1 pyroclastic flow deposits resulted from collapse of the syn-Rotoiti caldera. Post-collapse Rotoiti pumices contain T1 magma mingled with another magma (T2) that is characterized by high-K glass and biotite, and was cooler and less oxidised (712 ± 16°C; NNO-0.16 ± 0.16). The mingled clasts contain bimodal disequilibrium populations of all crystal phases. The granitoid inclusions and the T2 magma are interpreted as derived from high-K magma bodies, of varying ages and states of crystallisation, which were adjacent to but not part of the large T1 magma body. We demonstrate that these high-K magmas contaminated the erupting T1 magma on a single pumice clast scale. This contamination could explain the reported wide range of zircon U-Th ages in Rotoiti pumices, rather than slow crystallization of a single large magma body.

ORAL

INTERNAL STRUCTURE OF A STRIKE-SLIP DILATIONAL JOG ON THE OVERLANDER FAULT, MT ISA INLIER, AUSTRALIA

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The Overlander Fault is one of a set of NE-SW subvertical dextral strike-slip faults which, together with a NW-SE conjugate sinistral set, disrupt the Mt Isa Proterozoic orogen (1590-1500 Ma) in NW Queensland, Australia. A late- to post-orogenic regional stress field is thus defined with σ_1 and σ_3 trending roughly E-W and N-S, respectively. The Overlander Fault trends ~060° across the metamorphic assemblage except where it refracts to 070-074° across an outcropping granitic pluton, the margins of which it offsets dextrally by ~1.5 km. The stepover width of this dilational fault jog approaches 1 km, comparable to dilational stepovers within active strike-slip faults. In the surrounding amphibolite facies assemblage the fault trace is comparatively inconspicuous and unmineralised, but where it crosses the granite it is defined by ridges of silicified microbreccia and associated quartz veining.

Shearing across the stepover region is accommodated by a mesh structure with principal components that include: (1) a series of silicified microbreccia-cataclasite 'walls' <10 m or so thick with associated quartz veins <1 m thick trending 070° and defining a 'main zone' about 100±20 m wide; (2) parallel subsidiary strike-slip cataclastic shear zones occurring <200 m laterally from the main zone; (3) a set of subvertical <1-2 m thick extension veins oriented 090-100°, some with evidence of marginal shearing (both sinistral and dextral); (4) a conspicuous sinistral extensional-shear curving eastwards for ~250 m from the main fault core on a trend of 100-115°; and (5) a set of unmineralised faults with sinistral separations trending 120-130°. Slickenfibres and striations along the main fault-parallel components indicate predominantly strike-slip motion on subvertical planes with some local evidence for dip-slip. Mutual cross-cutting relationships between all these components indicate penecontemporaneous development. Orientations of the various components are broadly compatible with the inferred regional stress field but there is evidence for fluctuation of stress trajectories. Vein textures record histories of incremental growth and are generally consistent with hydrothermal deposition under low effective stresses, probably in the epizonal environment (<1-2 km depth). Incremental dextral separations along the major shear fracture components in the stepover are commonly of the order of 1-10 cm, consistent with small-to-moderate seismic displacements, with significant dilatation accompanying the increments of shear displacement.

Rigid-body analysis of the deflected fault trace across the granite suggests that total dilatation in the stepover should be ~300 m but the major veins account for <10-20% of this. Nonetheless, it is clear that incremental slip transfer across the jog involved substantial dilatation and massive fluid influx. The complex array of sub-structures within the stepover mesh invites comparison with structural complexity revealed by high resolution aftershock studies of dilational jog structures on seismically active strike-slip faults (e.g. Parkfield, Coyote Lake, Landers earthquakes in the San Andreas fault system) which are recognized sites of rupture perturbation or arrest.

ORAL

WHAT ARE THOSE WATER FILLED HOLES IN GEOTHERMAL FIELDS? ERUPTION CRATERS, PRODUCTS OF ACID DISSOLUTION OR GAS VENTS

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Craters are common features of geothermal fields. Most are water-filled depressions that originate from either hydrothermal eruption or acid dissolution and ground collapse. Both are typically circular but are distinguished by the presence or absence of an apron deposit comprising ejected brecciated material. Examples occur throughout the Taupo Volcanic Zone, including Wairakei, Rotokawa, Waiotapu, Orakeikorako, Waimangu, Te Kopia, Ngatamariki and Tikitere. Knowledge of their origin is important for hazard assessment.

Craters that form by hydrothermal eruptions result from short lived bursts of steam and water that discharge explosively. They can excavate rock material from >100 m depth though several recent eruptions, such as those at Craters of the Moon and Kuirau Park, had shallow focal depths (<20 m). They form permeable conduits which allow hot water to ascend and discharge at the surface, such as at the Champagne Pool (Waiotapu), but more commonly they are simply filled with cold lake water (e.g. Lake Ngakoro, Waiotapu). The most significant hydrothermal eruptions of the last century occurred between 1900 and 1920 at Waimangu in the aftermath of the 1886 basalt eruption of Mt Tarawera. Several triggering mechanisms have been proposed though the answers to how and why they form are elusive.

Craters that form by acid dissolution and collapse result from the formation of steam-heated acid water in and above the water table. They generally extend to a few metres depth and develop within relatively reactive volcanic deposits that are glassy and easily dissolved. Extensive development occurs near the Champagne Pool at Waiotapu where approximately 70,000 tonnes of surficial volcanic deposits have been dissolved.

By contrast, lake-filled depressions in the high temperature Ngawha geothermal field in Northland appear to have formed by neither eruption nor collapse, at least in a conventional sense. Lake Waiparaheka is the largest (100x300 m) extending to 38 m depth. A bathymetric survey revealed the presence of funnel shaped features, one of which is the site of CO_2 venting and bubbling. Peats interbedded with lenses of fine silt and clay represent the only subaerial deposits in the vicinity of the lake margins. There is no evidence of hydrothermal eruption breccias. These craters appear to have formed through sub-aqueous elutriation of fine-grained sediments occurring in the shallow stratigraphy by vigorous bubbling of CO_2 gas.

Holes in geothermal fields clearly form from several different processes.

PLENARY

REMOBILISATION OF GABBRO CUMULATES IN ARC VOLCANOES

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Crystal fractionation, assimilation and magma mixing are commonly invoked as processes that transform and overprint mantle-derived arc magmas; however, the modification of magmas by remobilisation of lower crustal cumulates may be under-appreciated. This process is well illustrated at the Quaternary Tatara-San Pedro Complex (TSPC)(36°S, Chilean Andes) where several eruptive sequences, late in the volcanoes history (235 ka and Late Holocene lavas), show evidence for the entrainment and partial melting of gabbroic cumulates by ascending mafic magmas (Costa et al. (2002) *J.Pet. v*.43/2; Dungan & Davidson (2004) *Geology v*.32/9). Strikingly, our research shows that this process also operated during the onset of magmatism at the centre. The earliest mafic eruptions at the centre (925-826 ka), preserved as a series of basaltic andesites intercalated between two voluminous silicic eruptions, have unequivocal evidence for the remobilisation of a gabbro by the intrusion of a fractioned basaltic andesite.

Phenocrysts and crystal clots, which compose up to 45% of some early basaltic lavas, are xenocrystic with only the groundmass microlites (± 2% microphenocrysts) crystallised from the host magma. Phenocrysts are disaggregated from crystal clots (<10 mm in size), which have retained original cumulate textures (heteradcumulates). Non-uniform reheating has resulted in variably sieved anorthite phenocryst cores surrounded by rims with sudden drops in anorthite content (up to 40 mol% over <100µm). Clinopyroxene and olivine phenocrysts have strong rim zoning and may be mantled by orthopyroxene. Three cumulates types are identified: anorthite ± olivine with poikilitic clinopyroxene, olivine with poikilitic anorthite and megacrysts of clinopyroxene enclosing plagioclase micro-phenocrysts. These cumulate lithologies suggest incorporation from a layered gabbroic intrusion. Bent plagioclase twins imply ductile behaviour either during crystallisation or remobilisation. This mafic body is inferred to have crystallised in the lower crust under moderate temperatures (~1100°C) and high water contents, evidenced by single-pyroxene geothermometry and anorthite-rich plagioclase. The groundmass corresponds to the intruding basaltic andesite magma, distinguished by a strong fractional crystallisation imprint (low Mg#, Ni, Cr), slightly more radiogenic $^{87}Sr/^{86}Sr$ (0.70415 compared to 0.70408 for the cumulate) and higher temperatures of crystallisation (~1240°C).

Constrained by fluid dynamic studies (e.g. Huppert & Turner (1981) EPSL v.54) remobilisation may have occurred as the basaltic andesite ponded below the gabbro triggering melting, eventually enabling turbulent incorporation of cumulates into the magma. Alternatively, rapidly ascending dykes may have entrained gabbroic cumulates via wall-rock disaggregation. In any case, the time between cumulate entrainment and eruption is inferred to be relatively short due to the thin rims on the disaggregated phenocrysts.

ORAL

A TIME OF RECURRENCE MODEL FOR LARGE EARTHQUAKES

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We have developed a new type of model for recurrence time between earthquakes greater than some (large) reference magnitude M_r. Mathematically, the model is a mixture: the sum of two parts representing 'aftershocks' and 'background' earthquakes. The model allows ready computation of quantities of interest in seismic hazard. In particular it allows a calculation of the distribution of time of occurrence to the next (large) earthquake in a region given any elapsed time since the last.

The Poisson (uniform) model is the well-known standard model for earthquake recurrence if aftershocks are discounted. We have searched a global database of earthquakes of $M \geq 5$ since 1964, without removing aftershocks, to assemble empirical distributions of the time intervals between earthquakes of magnitude greater than a reference magnitude M_r e.g. $M_r = 7$. Inspection shows that the distribution consists of two parts: 'aftershocks', which follow a power law equivalent to Omori's Law, in which the time interval between successive earthquakes increases as log(time); and 'background' which is modeled well with a Poisson process.

The model has the form:

$$f(t) = w_1 f_0 (1/t) (1- \exp (-t/t_s)) \exp(-t/t_0) + w_2 \exp (-t/t_0)$$

where f(t) is the probability density function for recurrence time t; w_1 and w_2 are the weights of the two parts ($w_1 + w_2 = 1$); t_s is a time constant associated with initiation of the aftershock process and is set to some small time e.g. 0.001 day; t_0 is the time constant for the Poisson process; and f_0 is a normalising constant for the first part, which depends on t_s and t_0 . Thus two parameters w_1 and t_0 need to be determined from data e.g. by maximum likelihood. However, before fitting an adjustment is made for the finite duration of the earthquake catalogue.

We have drawn these conclusions from the global dataset:

1. No meaningful distinction can be made between 'aftershocks' and other 'triggered earthquakes' within a region that scales with magnitude – both are part of the same process.
2. The 'aftershock' process is dominant for several years after an M 7 event.
3. The weights w_1 and w_2 are both approximately 0.5. This means that the subsequent earthquake has a probability of about 0.5 of being either after aftershock/triggered event or a 'new' earthquake.
4. The model allows ready computations of quantities useful for static and time varying seismic hazard, such as the expected time of the next earthquake given the time since the last one.

The model fits the well the time between earthquakes of $M \geq 7$ in New Zealand since 1840.

ORAL

PETROLOGICAL CONSTRAINTS ON THE NATURE OF THE CRUST BENEATH THE TAUPO VOLCANIC ZONE

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The chemical compositions of the volcanic rocks forming the Taupo Volcanic Zone (TVZ) reflect the source rocks and processes that produced the magmas from which they crystallised. Felsic magmas, erupted from the caldera volcanoes in the central part of the zone, show isotopic signatures and trace element abundance patterns that are consistent with an origin by partial melting of highly heterogeneous metaluminous sources at amphibolite facies pressures and temperatures. These high-Si magmas are variably mixed with basaltic magmas from the underlying mantle wedge. Magmas erupted from the mountain volcanoes in the southern part of the zone differ mainly in the relative proportions of these two components. Thus the petrographic features and geochemical signatures shown by andesites of the Tongariro Volcanic Centre are explained by mixing mantle wedge melts with crustal melts. Logically the middle crust beneath the TVZ at depths between 12-15km is a zone of partial crustal anatexis together with magma mingling and mixing. The middle crust can be modelled as a complex plexus of magma, country rock and restite. At shallower depths fractionation and mixing are the predominant processes and it is here that magmas assemble prior to eruption. In the lower crust, below the melting zone, mantle wedge melts mingle with the mafic granulitic restite complementary to the voluminous felsic melts that dominate in the caldera volcanoes.

ORAL

TEPHRA FALL DISPERSAL AND SEDIMENTATION DURING PHREATOPLINIAN ERUPTIONS

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Tephra fall is potentially the most widespread and disruptive of all volcanic hazards, and development of models to predict dispersal behaviour and rates of tephra accumulation are current goals in physical volcanology. While the products and processes of ‘dry’ plinian-style plumes are broadly understood, a considerable gap exists in our understanding of tephra dispersal and sedimentation during large-scale phreatomagmatic eruptions. In part, this gap reflects limited historic observations and the incomplete characterisation of complex phreatoplinian deposits. Advances are hampered by difficulties in accurately constraining even basic parameters such as deposit volume and whole-deposit grain size distribution. A particular problem in modelling “wet” plume dispersal is that the true grain size distribution of the eruption plume is often lost due to depositional disintegration of aggregates into their constituent particles.

We seek to address these problems through layer-by-layer analysis of the very fine-grained and multiple-bedded phreatoplinian phases of the 1.85 ka Taupo eruption (Hatepe and Rotongaio tephras), and of the c. 55 ka Rotoehu eruption. Identification of three main lithofacies groups in the Taupo phreatoplinian units shows that deposition involved not only ash aggregate fallout (ash clusters, mudlumps and mudrain) but also episodes of discrete particle fall, as well as mixed accumulation of aggregates and discrete particles produced either during periods of rapidly fluctuating eruption intensity, or in response to changing plume conditions. Our studies have identified considerable variability in grain size both spatially and over narrow stratigraphic intervals, which is at odds with conventional views of uniform phreatoplinian deposits produced by sustained eruptions. Proximal beds of the ash aggregate facies are very fine grained and unimodal (63-32 µm), but a second coarse mode (500-250 µm) emerges progressively downwind and dominates distal ash beds at 50-60 km from vent. This distal bimodality/coarsening suggests that the processes and intensity of particle aggregation were not uniform in time or space. Using in-situ bulk density analyses we can track the mass accumulation of individual tephra size fractions giving some insight into patterns of ash aggregation. For fractions ≤125 µm and ≥1 mm, peak mass accumulation is within 10 km of the vent and decreases steadily, while for 125-500 µm fractions there is a secondary distal accumulation peak. It appears that proximal tephra accumulation was dominated by wet aggregates (mudlumps, mud rain) that were effective at removing fines (and water) from the plume. In contrast, distal tephra accumulation also involved drier aggregates and discrete particle fall, as a response to both changing plume dynamics and an evolving, relatively fines-depleted grain size population.

POSTER

VIRTUAL VOLCANOLOGY OF THE TONGARIRO CROSSING: E-LEARNING IN THE EARTH SCIENCES

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We have developed a CD-ROM-based virtual field trip that explores in detail the volcanology of Tongariro volcano. The CD-ROM consists of four main components:

1. an interactive field trip, providing a virtual tour of Tongariro volcano following the Tongariro Crossing track,
2. a volcanology module, which brings together the latest research on the eruptive history and nature of Tongariro's volcanism (including animated maps and interactive diagrams),
3. a "scenes" module, which contains an indexed slide-show of all photographs, videos, animations and virtual reality panoramas used in the field trip and volcanology modules, and
4. a glossary of key geologic terms hyperlinked to the text in the field trip and volcanology modules.

One of the unique advantages of this virtual field trip of the Tongariro Crossing is that, in addition to viewing the spectacular 360-degree panoramic images, geological maps, and movies of eruptions, you can also (virtually) reach out and touch any part of the landscape and have the geology explained via a "hotspot". Interactivity is also achieved through maps and photo-overlays that identify the products of individual eruption episodes with a simple "roll-over" of the mouse cursor.

The original intent of the CD-ROM was to provide an interactive introduction to Tongariro volcano for undergraduate volcanology students, prior to a 'real-world' field trip to the area, run in March every year. We have found that this pre-trip e-learning exercise builds students' enthusiasm for the real field trip and increases their engagement and understanding. The CD-ROM has also proved very beneficial as a follow up exercise if the weather and visibility are less than ideal on the actual field trip.

Initially developed with advanced undergraduate Earth Science students in mind, we have found the virtual field trip appeals to a much wider audience including secondary school students and the general public. Tongariro is perhaps New Zealand's most accessible active cone volcano, providing an ideal context for raising awareness of NZ's volcanic landscapes and active volcanic hazards. As part of our outreach activities we are working with the Department of Conservation to include the CD-ROM in a resource pack to be distributed to over 200 North Island schools that come to Tongariro for geography field trips. It is also being promoted to the general public and tourists walking the Tongariro Crossing via computer kiosks at Whakapapa visitor centre and Taupo museum.

The CD-ROM and virtual field trip will be demonstrated during the conference.

POSTER

THE CONTEMPORANEOUSLY ACTIVE OKATAINA AND TAUPO RHYOLITIC VOLCANIC CENTRES: TRENDS IN GEOCHEMISTRY, MINERALOGY, AND MAGMATIC PROPERTIES DURING THE LAST 50 KYR, TAUPO VOLCANIC ZONE, NEW ZEALAND

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The Taupo Volcanic Zone of New Zealand is the most frequently active rhyolitic zone on Earth. Since a major caldera-forming eruption episode at ~50 ka, > 50 rhyolitic eruption episodes have occurred at Okataina Volcanic Centre (OVC) and Taupo Volcanic Centre (TVC). These two active calderas provide an opportunity to examine contemporaneous magmatic processes at high temporal and spatial resolution. Temporal trends indicate OVC intra-caldera eruption episodes tapped progressively more evolved (~71- 77 wt % SiO_2), shallower (~400 -150 MPa), and cooler

(940- 730°C) magmas. At TVC, pre-26.5 ka activity was relatively infrequent, and eruption episodes were derived from shallow (~100 MPa), cool (~750°C) magmas, containing hydrous mineral phases. Following the caldera-forming 26.5 ka Oruanui episode, initial eruption episodes were dacitic and were derived from small volume, deep (>400 MPa), and hot (>900°C) magmas. At 12 ka, rhyolitic activity at TVC re-commenced, and eruption episodes have tapped progressively deeper (~140- 300 MPa) and hotter (~790- 850°C) magmas. At both OVC and TVC volcanoes, the least evolved magmas were erupted following the caldera-forming episodes.

Equilibrium between glass and phenocrysts in OVC and TVC rhyolites suggests that crystallisation occurs shortly prior to eruption. Low crystal contents (~5- 15%), and the lack of pre-eruptive gradients suggests rapid convection and/or short crustal residence times. Melts are extracted from greater depths, as indicated by high whole-rock temperatures, before ponding in shallow storage chambers. The distinct pressure, temperature, and oxygen fugacity of each magma erupted, and the lack of temporal (fractionation) trends, suggests that the magmas are not derived from a single common magmatic system/source at their respective centres. Volumetrically subordinate pumice clasts in some OVC ejecta display mingled glasses and disequilibrium crystal populations resulting from the intrusion and mingling of separate rhyolite magmas prior to eruption. At OVC, some crystal-rich stagnating magmas have become reactivated by new intrusions or engulfed into larger magma bodies, and some eruption episodes were primed and triggered by mafic intrusion.

ORAL

A CALDERA-FORMING IGNIMBRITE ERUPTION AT 33 KA: REINTERPRETATION OF THE KAWERAU IGNIMBRITE AS PART OF THE MANGAONE SUBGROUP, OKATAINA CALDERA COMPLEX

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A major revision to the eruptive stratigraphy of Okataina Caldera Complex (OCC) is presented. Implications for the development of the caldera and for geologic hazard assessment in northern Taupo Volcanic Zone (TVZ) are considered.

Kawerau Ignimbrite is a partially-welded pumice-rich ignimbrite that fills Puhipuhi Basin on the eastern side of the caldera complex and forms a thick terrace in and around the Kawerau township area. Within Puhipuhi Basin it is ~100 m thick, exposed on clear-felled knolls and locally forms jointed bluffs in thickest sections where it is valley ponded. Originally mapped as Kaingaroa Ignimbrite, it was subsequently separated and renamed Kawerau Ignimbrite (Beresford & Cole, 2000), with an accepted age of 240 ka.

Further investigation of the Kawerau Ignimbrite during a current study into the development of the OCC has revealed a much younger stratigraphic position. In Puhipuhi Basin the ignimbrite overlies ~280 ka Matahina and ~65 ka Rotoiti ignimbrites, and older tephras of the Mangaone Subgroup. Whole-rock and glass geochemistry tie the ignimbrite specifically to the 33 ka Unit I (Mangaone Tephra) phase of the subgroup, vastly increasing the eruptive volume of that unit and implying caldera collapse in this recent phase of OCC activity.

Two magma types are identified, and the large compositional gap between them is interpreted to represent eruption of two distinct compositions. Vertical variation in the ignimbrite records rapid depletion of a subordinate dacite magma such that pumices of this composition are rare beyond proximal exposures. Lithic and pumice size distribution data indicate a source within southern OCC to the west of Puhipuhi Basin. Probable residual volume of the ignimbrite is <15 km^3, but estimates of the original volume may be >50 km^3 when intra-caldera volumes are considered.

Kawerau Ignimbrite thus represents the largest eruption from Okataina in the last 65 ka since the Rotoiti event. The recognition of a large partially welded ignimbrite with an emplacement age within the last 35ka necessitates some reassessment in terms of the potential hazards of such events.

ORAL

CALDERA GEOMETRY AND EVOLUTION AS A FUNCTION OF RIFT ARCHITECTURE: OKATAINA CALDERA COMPLEX, TAUPO VOLCANIC ZONE, NEW ZEALAND.

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Taupo Volcanic Zone (TVZ) is a transtensional intra-arc rift characterised by a silicic central portion with both axial and off-axis silicic calderas.

The two currently-active caldera complexes (Okataina and Taupo) within the axial rift zone of Modern TVZ (<300 ka) have complex eruptive and collapse histories that contrast with off-axis calderas. The inter-relationship between rift geometry and volcanic centre formation is particularly clear at the intra-rift Okataina Caldera Complex (OCC).

OCC is located at a major bend in the transtensional rift where local rotation of the extension direction results in a zone of orthogonal extension. Multiple collapse events, related to at least two major ignimbrite eruptions, are spatially concentrated in an extensional sector between two offset rift segments. The rectangular 28 x 22 km caldera complex is elongate normal to the local rift-segment trend, with a complicated topographic margin largely controlled by regional faulting. Major embayments occur on each side of the OCC where it is intersected by adjacent rift segments. These are contiguous with two intra-caldera dome complexes forming two overlapping linear vent zones, which transect the caldera complex and are interpreted as the lateral continuation of the adjacent rift segment axes.

The boundaries of individual collapse events are complex and largely overprinted by subsequent volcanism and tectonism, but caldera reconstructions suggest the major collapses are centered on the axes of the intersecting rift segments. OCC represents an exceptional example where rift architecture and fault geometries are closely responsible for caldera geometry and evolution.

POSTER

STRUCTURAL ARCHITECTURE OF THE OTAGO SCHIST: ACCRETIONARY PRISM, COLLISIONAL OROGEN OR CORE COMPLEX?

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The Otago Schist has been variously described as (i) the exhumed lower levels of an accretionary prism, (ii) the product of orogenic-scale crustal thickening during collision of terranes at a convergent margin, and (iii) a metamorphic core complex. It is reasonable to argue that at various times in the Mesozoic the rock mass that we now call the Otago Schist was subject to each of these three tectonic settings. Such a view is consistent with the observation of accretionary-wedge structures in non-metamorphic Rakaia terrane rocks, the well documented Late Jurassic-Early Cretaceous deformation, metamorphism and thickening of the Otago crust to >55km, and extension-related exhumation of the schist belt by ~105Ma. The aim of this talk is to consider which of the major structural features of the schist are related to each of these three contrasting tectonic environments.

The important structural features of the Otago Schist that should be considered in formulating a tectonic interpretation include:

1. gross metamorphic and structural symmetry of the belt
2. broad antiformal geometry of the dominant foliation
3. presence of a prominent mineral lineation
4. widespread parallelism of fold axes and mineral lineation
5. presence of gently-inclined and recumbent folds in higher-grade rocks
6. extensional ductile shear zones and low-angle normal faults

The structural architecture of the schist, as observed today, is not consistent with the structures known to result from accretionary processes, and the continued use of the accretionary model misrepresents both the tectonic history and structural character of the schist belt.

The structural architecture of the schist compares favourably with that of metamorphic core complexes of North America and elsewhere, which are characterised by a gross antiformal structure of the dominant foliation, a pronounced mineral lineation oriented normal to the belt, exhumation along low-angle extensional shear-zones, and elongation subparallel to the axes of recumbent, flattened and attenuated folds. Metamorphic rocks in Fiordland and the West Coast of similar (exhumation) age and structural character to the Otago Schist have also been interpreted as extension-related core complexes.

Structures related to collision and crustal thickening may be best seen at the low-grade margins of the schist belt such as those at the western arm of Lake Hawea. These rocks sit structurally above zones of extension-related strain and instead record crustal thickening and progressive deformation of increasing structural complexity with increasing grade. The schistosity and related structures in such areas are probably best interpreted as collision-related rather than steepened equivalents of the subhorizontal extension-related schistosity within the core of the belt.

ORAL

EVOLUTION OF SUBDUCTION AND BACK-ARC EXTENSION AT A CONTINENTAL MARGIN

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In central North Island, New Zealand, there exists one of the more complete geological and geophysical records of subduction initiation and evolution. Geological data provide us with evidence of how subduction initiated in late Oligocene times, while geophysical data provide an image of how back-arc spreading and an active mantle wedge have developed beneath central North Island in the past 5 my. Principal information on subduction initation processes come from oil–industry bore hole data located in Taranaki Basin, at least 500 km from the trench where subduction initiated. Subsidence is almost wholly expressed in paleobathymetry and shows a rapid and coeval platform subsidence across a wide area (> 200 km) of western New Zealand. The wavelength of the subsidence is too broad to be explained by crustal shortening and flexure, but is consistent with a subsidence induced by hydrodynamic flow in the mantle. Similar subsidence events are seen in the geological record of North America and other parts of the western Pacific.

Nearly 20 Myr of compression and foreland basin development (Taranaki Basin) in western North Island followed the platform subsidence. At around 5 Ma a rapid switch in tectonics took place that was marked by the development of lithospheric, dome-like uplift centred on the central North Island. This uplift signal (2500 m of rock uplift or 1200 m of tectonic uplift and up to 400 km wide) is principally derived from mudstone porosities that are used as a proxy for exhumation. Timing for the start of uplift comes from the cutting of a widespread unconformity in Taranaki Basin that is dated at the Miocene-Pliocene boundary. From about 4 Ma to the present andesitic and then rhyolitic volcanism developed across the domal uplift, accompanied by extension and tectonic rotation of central North Island.

Recent geophysical experiments in the central North Island have begun to define the structure and conditions within the subjacent mantle wedge. Pn wave speeds are low (7.4-7.8 km/s) and seismic attenuation (Q^{-1}) is high. Explosion seismology results show the pre-existing greywacke-schist crust (≤ 6 km/s) has been stretched to at least half its original thickness (i.e. 30 to 15 km). Beneath 15 km we see, from wide-angle reflection analysis, a reflective sequence down to about 18 km where velocities increase rapidly from 6.7 to 7 km/s. At 20 ± 2 km P-wave speeds of ~ 7.4 km/s are measured and these are seen from passive seismic studies to extend down through the mantle wedge. We interpret the rocks from 15 to 20 km as new lower crust and from below 20 km as an anomalous upper mantle.

On the basis of our seismic velocity model and the rock uplift data constraints are placed on the buoyancy and degree of partial melt in the mantle wedge. Our best estimate is that the mere replacement of say 75 km of the mantle lid by asthenosphere (density contrast ~ - 40 kg/m^3) is insufficient to explain the rock uplift. Instead we require a density contrast more like –70 to -90 kg/m^3, which implies an important negative buoyancy contribution from fluids, and/or melts, in the mantle wedge or a delayed rebound from platform subsidence.

ORAL

SLOPE INSTABILITY AND SURFACE DEFORMATION IN DUNEDIN

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The city of Dunedin, on the South Island of New Zealand, contains a number of active landslides in Dunedin that have affected residential properties, roads and infrastructure. Landslide damage in Dunedin is best illustrated by the Abbotsford landslide of 1979, a catastrophic slope failure following a period of accelerated ground motion, which destroyed 69 houses. Many of these slides have had, or currently have, surface deformation monitoring networks, with repeat surveys over various periods to measure horizontal and vertical deformation. However, repeated measurements of millimetre- and centimetre-scale slope movement are costly to obtain, and are time-consuming to acquire at a high spatial resolution if using traditional field-based techniques for resurveying, such as levelling and differential GPS (global positioning system) measurements.

In this study, we investigate the viability of ERS and Envisat differential radar interferometry as a potential solution to this problem, as the technique has already proven successful for monitoring slope instability in the French and Austrian Alps. In general, we found that the technique worked well over the urban, built-up areas of Dunedin. However, there were relatively few, or only very small, independently documented landslide movements within the intervals of the DInSAR image acquisitions in urban areas, as these are controlled by engineering works as soon as they are discovered. Several slides which were likely to be deforming actively during the study period coincided with forestry and agricultural areas, and are completely decorrelated in the ERS data. Although ERS radar interferometry did not yield the results as we had hoped for, we were able to make several interesting observations, including a deformation signal which appears to correspond to an area of reclaimed land in central Dunedin, and we hope that our results will be invaluable to other groups considering similar studies to this, in similar environments.

POSTER

TOWARDS NEAR-REAL-TIME RADAR INTERFEROMETRY AT ACTIVE VOLCANOES

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The ability to measure surface deformation at active volcanoes has obvious value, and measurement of volcanic surface movement is already an established operational technique at many volcano observatories to help understand internal processes and to aid in eruption forecasting. Differential synthetic aperture radar interferometry shows excellent promise as a near-real-time tool to supplement such measurements, with an already well-proven ability to map patterns of surface deformation on volcanoes.

However, repeat-pass interferometry as a technique has not yet become operational, partly because current spaceborne radars were not designed for the task. We illustrate some of the drawbacks at volcanoes in South America and New Zealand, chosen to represent a range of conditions and volcano morphological types. Freely-available global datasets of vegetation cover and atmospheric water vapour content can be used as proxy measures of coherence and path delay effects, which are the two main determinants of data quality.

We also consider the issue of whether near-real-time (NRT) measurements from an instrument such as Envisat ASAR, with a repeat-pass interval of 35 days, are valuable in an operational sense. Ultimately, we argue that any additional information that informs emergency managers in a crisis situation has value, regardless of the interval of measurements attainable, especially that of centimeter-scale volcanic deformation in the weeks or months preceding an individual SAR acquisition. Of course, with the seven imaging modes of Envisat ASAR, a new acquisition could theoretically be acquired of an area as often as every few days, if emergency data commissioning procedures allow it. However, interferometric processing is restricted by compatibility with, and availability of, existing archived data, which often requires advanced planning to ensure adequate data archives are in place. The latter can be problematic if the volcano has not shown any signs of previous unrest, and if nobody actively ordered the data in the first place.

Lastly, the entire NRT observational capability then hinges on the rate of data delivery, or the turnaround time between data acquisition by the satellite and delivery of the RAW product to the end-user. With concerted effort, operational volcano DInSAR should be viable in the near future. In the meantime, our experience using existing systems, such as Envisat, will inform the construction of future orbital radar systems designed specifically for this purpose.

POSTER

EXPERIMENTS WITH ORBITAL RADAR INTERFEROMETRY TO DETERMINE CONTEMPORARY DEFORMATION IN THE TAUPO VOLCANIC ZONE

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Future volcanic and tectonic activity at the TVZ represents a real risk to the contemporary New Zealand population and infrastructure, and measurement of the deformation field is thus important for modelling and understanding the physical processes operating within the TVZ, which has obvious benefits towards risk mitigation.

At present, TVZ deformation is measured via differential GPS at widely spaced continuous installations and on 3-5 yearly campaign revisits. The GPS network was designed originally for measuring tectonic deformation, and has a low spatial density. Although some continuous sites are being installed with a view to volcano monitoring, the low spatial density of measurements means that this network could miss pre-eruptive deformation signals.

Differential radar interferometry using data from the ERS-2 satellite was investigated, using a time series of data acquired during 1996-2003. In optimum conditions, radar interferometry could potentially provide centimetre-scale measurements of relative deformation over several tens of metres over swaths of 100 km (the width of an ERS scene). Although this project was largely unsuccessful due to the low correlation between ERS SAR pairs in this highly vegetated area, some localised deformation signals were observed, and these are presented here.

We are now investigating the use of permanent scatterer processing in areas of the TVZ where there is a sufficiently dense concentration of point scatterers. The successful launch of the European Space Agency ENVISAT ASAR C-band instrument in 2002 provides the opportunity to extend the measurements to 2006 and beyond. Imaging modes were chosen to reflect the styles of deformation previously observed in the TVZ – on descending passes (parallel to the axis of previously observed TVZ tectonic motion) the IS5 imaging mode is chosen because it is likely to be more sensitive to horizontal crustal motion, unlike the IS2 mode, which is chosen for ascending passes to seek volcanic and geothermal extraction deformation signals.

The surface deformation measured in the TVZ during this period (ERS: 1995-2003, Envisat: 2003-2006) will have direct relevance to current and future monitoring and modelling efforts, and will provide a unique data set from which future projects are sure to evolve.

POSTER

NASA EOS Terra ASTER: VOLCANIC TOPOGRAPHIC MAPPING AND CAPABILITY

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Up-to-date, accurate topographic data are crucial for volcanic research and risk mitigation efforts. In this paper, we examine the utility of the NASA Terra ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) instrument, which provides near infrared stereo imaging from which topography can be derived. We wrote software to generate digital elevation models (DEMs) from ASTER level 1A data, which employs automated stereo matching to calculate the parallax offsets between the images acquired by the nadir- and aft-looking sensors.

Comparing ASTER DEMs with DEMs derived from other sources (digitized topographic maps and aerial interferometric radar) at Ruapehu volcano revealed an RMS error of about 10 meters for the ASTER DEM, in the absence of significant atmospheric water vapor. A qualitative assessment of surface features showed that the ASTER DEM is superior to the digitized map product, but is not as detailed as aerial interferometric radar, especially in terms of stream channel preservation.

A second ASTER DEM was generated for Taranaki volcano, where previously only 1:50K topographic map data were available. Although the 2000 Space Shuttle radar topography mission (SRTM) will largely remedy the previous global paucity of adequate topographic data at volcanoes such as Taranaki, we anticipate that at active volcanoes, the topography may change significantly following activity, rendering the SRTM data inaccurate. ASTER not only provides a means to update significant (>10 meters) topographic measurements at active volcanoes via a time-series of DEMs, but also provides a simultaneous means to map surface cover change via the near infrared sensors.

POSTER

MAGMATIC PROCESSES IN A YOUNG OCEANIC ARC STRATOVOLCANO: LOPEVI ISLAND, VANUATU

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The basalt to basaltic andesite island of Lopevi in central Vanuatu is a 7 km diameter and 1400 m high stratovolcano that extends at least 1000 m below sea level. It has a history of frequent eruptive activity; the most recent in 2003 was concentrated along a NW-SE trending fault system that cuts the entire island. Eruptive activity can, however, occur from either the flank rift vents and/or the summit craters. Activity at Lopevi is characteristically intermittent with eruptive sequences occurring over a c. 6 year period, separated by longer periods of repose. A major eruptive episode in 1939 caused evacuation of the island and the next eruptive episode in the 1960's also led to evacuation. The 1960's sequence of eruptions began in July, 1960, after a 21 year period of repose and was a large eruption by Lopevi standards. It started with a plinian event, sending an ash cloud to greater than 10,000 m altitude and lava flows constructed a new peninsula on the SE coast. This cycle of activity ended in 1982. The lasted phase of activity commenced in 1998 with a return to eruption of more siliceous, high alumina basaltic andesite from vents along the SE flank rift.

Recently acquired XRF whole rock major and trace element data show that the chemistry of the sequence of eruptions in the 1960's was different from both earlier and later eruptives. The 1960's lavas are olivine basalts with up to 9% MgO, 70 ppm Ni and 300 ppm Cr. Al_2O_3 content is about 12 wt%. The 2003 lavas and pre-1960's lavas, in contrast, are basaltic andesites with c. 4% MgO, <25 ppm Ni, <100 ppm Cr and c. 20 wt% Al_2O_3. We therefore interpret the 1960's sequence of eruptions as resulting from the injection of a much more primitive magma into the volcano's plumbing system during or at the end of the 21 year quiescent period after the major eruptions of 1939. This behaviour, injection of small batches of magmas of differing composition over decadal time periods, is similar to that interpreted for Ruapehu volcano over the last 50 years of activity.

POSTER

DEVELOPMENT OF TESTS FOR SEISMIC HAZARD MODELS

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A deficiency in the methods of probabilistic seismic hazard assessment (PSHA) is that no formal procedure currently exists for validation of the PSH models. Our collaborative work is focused on developing formal tests for PSHAs from historical and prehistorical criteria. Our historically-based tests compare the New Zealand and US Geological Survey/California Geological Survey (USGS/CGS) PSH models against the one to two Century record of felt intensities (Modified Mercalli Intensity, or MMI) for 30 towns and cities distributed uniformly across New Zealand and southern California.

Our results show a tendency for the historical rate of exceedance for given levels of ground motion to exceed those of the USGS/CGS PSH model at the southern California towns and cities by an average factor of 7, but for there to be reasonable agreement between historical data and PSH model at the New Zealand centres. The discrepancies at the southern California centres appear to be due to the historical estimates of MMI being representative maximum values whereas the New Zealand MMIs represent mean estimates across a centre. From the southern California analysis it is clear that the PSH methodology underestimates the strongest of a very irregular spatial distribution of ground motions across a town or city that accompany moderate-to-large earthquakes, and the question will need to be addressed as to whether or not the PSH methodology should be altered to better represent these ground motion maxima and provide a more completely representative PSHA.

The development of historically-based tests of PSH models is being complimented by parallel efforts to use the distribution of delicate landform features to place upper bounds on the ground motions predicted from PSH models for long return periods (thousands to tens of thousands of years). Preliminary results from both New Zealand and USA show the PSH models may significantly overestimate the long-term hazard.

ORAL

CRUSTAL STRUCTURE OF THE CENTRAL NORTH ISLAND AND THE MEANING OF THE "MOHO" IN A BACK-ARC SPREADING ZONE

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Near vertical and wide-angle arrival seismic data provide evidence for a new lower crust and a perturbed Moho and mantle beneath the Central Volcanic Region. Seismic data were collected along two regional (~100-200 km long) profiles in central North Island, approximately east-west and north-south; the north-south line being entirely within the boundaries of the Central Volcanic Region. Beneath the active volcanic region the dominant seismic event is a wide-angle reflection at 15 ±1 km where velocities above are < 6 km/s and below, jump to ~ 6.7 km/s. We interpret this interface to be the base of the original greywake-schist crust that has been extended by a factor of about 2. This extension would be a minimum as an unknown percent of intruded rock of andesitic/dioritic composition is likely to be present. Refracted arrivals from below this interface have a P-wave speed of 6.7 ± 0.2 km/s. Such high velocities in the lower crust in New Zealand are uncommon and are only found in regions of old, cratonic, thick crust. We argue that here, the 6.7 km/s layer represents new crust formed by magmatic underplating. From careful analysis of refracted and reflected phases in the offset range 70-160 km we find true, albeit perturbed, mantle velocities, of 7.4 km/s start at depths of 20 ± 2 km. This is similar to that found from earthquake studies. These Pn arrivals are low frequency and come from within a zone of reflectivity that continues from the 15 km deep interface, to upper mantle depths of ~ 35 km. The deepest example of layering in the upper mantle is a strong reflecting interface found at depth of 35 ± 3 km that is laterally confined to be subjacent to the surface expression of the volcanic zone. Analysis of amplitude variation with incidence angle of this reflection event implies a 40-90% drop in S-wave velocity. Such a large velocity drop can be explained by ~ 7-12 % partial melt. A fan shot array of Pn arrivals was recorded from the North-South line out to the western North Island. Using crustal and upper mantle velocity constraints from this study and others, a model of the crust and upper mantle structure of the western margin of the Central Volcanic Region, and the western North Island is made that fits the observed Pn arrival times. These arrivals show an increase in crustal thickness at the western margin of the Central Volcanic Region, and a 0.1 km/s increase in mantle velocity beneath its northwestern corner. From analysis of Pn arrivals and earthquake studies we infer a Moho interface beneath the central North Island with ~ 10 –15 km of topography. The seismic Moho is found at 25 km depth beneath the western North Island and at 35 km depth beneath the eastern North Island. However, between these two regions, in the Central Volcanic Region, we find the idea of a traditional Moho to be not applicable. Instead, we infer a crust-mantle transition zone starts at the base of the 15 km thick extended original crust with a continuum of velocity increase into a perturbed low velocity mantle that starts at a depth of ~20 km.

ORAL

CONTINUOUS GRAVITY RECORDING WITH SCINTREX CG3M/CG5 METERS FOR MONITORING GEYSERS

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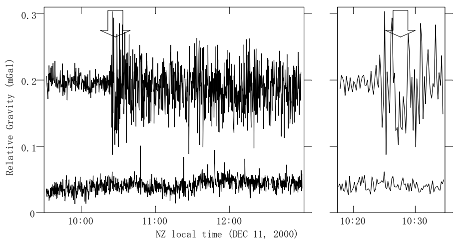
A microprocessor-based automated gravimeter, Scintrex CG3M can be operated in cycling mode, when data acquisition is triggered at a pre-defined sampling rate (10 points per minute or lower). In February 1997 we set a CG3M gravimeter at Whakarewarewa Geyser flat and detected a particular signals whose amplitude are about 10 microGal (Sugihara et al., 1999). Since the pilot study we have made continuous gravity measurements at three geysers, Lady Knox and Waikite in New Zealand, and Hirogawara in Japan. Two CG3M meters were set 35 m apart at Lady Knox geyser in December 2000. A columnar geysering was observed to be accompanied by a negative pulse whose amplitude is about 30 microGal at the vent (see Figure). We made another continuous gravity measurement at dormant geyser Waikite. Even at an overflowing event whose duration time is shorter than 1 minute we recognized a gravity change whose amplitude is larger than 20 microGal by stacking the data. In December 2003 a new CG5 meter was tested at Hirogawara, where a gassy cold geyser is activated primarily by the evolution of carbon dioxide. The CG5 meter has a new capability of raw data acquisition, which enables us to store the unprocessed 6 Hz data (gravity, tilt-x, tilt-y, and internal temperature) in memory. We detected a particular signal not in gravity but in tilt. Continuous gravity record at each site constrains the volume and/or the depth of the reservoir which is supposed to supply fluid for each geyser activity. This result is of particular interest in field surveys of temporal gravity changes related to some environmental or geodynamical processes, where gravity variations are expected to occur in hours or shorter period.



POSTER

2D-3D VISUALIZATION OF SUBSURFACE THERMAL STRUCTURE -EXAMPLE OF THE NORTHERN PART OF MIYAGI PREFECTURE, JAPAN

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The distribution maps of topography, geology, seismic hypocenter, electric resistivity, Curie-point isotherm, and subsurface isotherms were collected and summarized as input data to the database for 2-D and 3-D visualization. After digitizing, 6 kind of maps are correlated each other. Then, following three data sets become clear to be good correlative sets: volcanic front and microseismic hypocenter,

resistivity and microseismic hypocenter, Curie-point isotherm and microseismic hypocenter.
The first good correlation between volcanic front and microseismic hypocenter indicates microseismicity is caused by upward migration of magma and hydrothermal fluids. The second good correlation between resistivity and microseismic hypocenter indicates microseismicity tends to occur near the transitional zone of resistivity where is corresponded to the change of geologic structure. The third good correlation between Curie-point isotherm and microseismic hypocenter indicates the cut-off depths of crustal seismicity is almost equivalent to Curie-point isotherm depths around 600□ (Fig. 1).

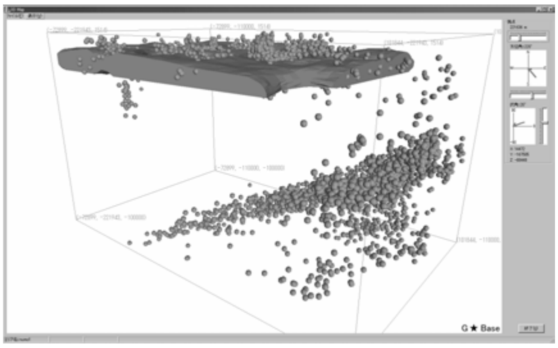

Fig. 1. A bird's-eye picture of disitibution map of micro-seismicity (circle) and subsurface temperature higher than 500℃ (downward view from southeast direction).

ORAL – geothermal workshop

INCIPIENT RIFTING AT THE SOUTHERN TERMINATION OF THE TAUPO VOLCANIC ZONE FROM GRAVITY DATA

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The Taupo Rift is an extensional fault belt within the Taupo Volcanic Zone of the North Island of New Zealand. At the southern end of the Taupo Rift, we have undertaken gravity studies to investigate the geometry of the rift termination. In this area, active faulting studies indicated that Taupo Rift terminates abruptly at two active fault sets, each with a predominantly normal displacement, striking at moderate to high angles (E-W to NE-SW) to the marginal faults of the graben (NNE-SSW). New gravity measurements were obtained for the southern flank of Mt Ruapehu ring plain and were incorporated to the existing gravity database of the Institute of Geological and Nuclear Sciences. Total errors on the new gravity observations are 0.6 mGal. The residual gravity map shows an elongated gravity low that runs from Lake Taupo to Mt Ruapehu. At the southernmost end, gravity anomaly gradients (-20 to -10 mGal) broadly define the NNE trending gravity low but in detail, gradients show E-W, NE-SW and NNE-SSW trends which correspond with mapped active fault traces. Gravity models of cross-sections perpendicular to these faults were constrained by surface geology and a published seismic refraction study on the southeast of the ring plain. Gravity modelling suggests that down-faulting is $\leq$ 300 m for any individual structure, except for the Rangipo Fault which could have up to 500 m displacement. Most values are consistent with offset estimates from surface geology but a few indicate smaller offsets. In general, these displacements are smaller than those found further north within the Taupo Rift. These results suggest that south of Mt Ruapehu rifting is incipient and developing on a mesh of E-W, NE-SW and NNE-SSW striking fault sets.

POSTER

TECTONICS OF THE GALATEA BASIN, EASTERN BAY OF PLENTY, USING GEOPHYSICAL TECHNIQUES

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The Galatea Basin is an unusual basin that straddles the boundary between the North Island Shear belt and the Taupo Volcanic Zone. The Waiohau fault bounds the eastern margin of the basin and is an active dextral-normal oblique-slip fault with 0.6-0.9mm/yr dip-slip. This study is directed at learning about how both strike slip and extension are accommodated in this finite deformation zone.
Seismic reflection and refraction data were collected along a line perpendicular to the strike of the Galatea basin (and Waiohau fault).
The seismic refraction line was 5 km long and spanned the width of the basin. Shots consisted of 50 kg of explosive in 15m drill holes, with two shots located in a greywacke quarry at the southeast end of the basin, and a third in ash and alluvium to the northwest of the basin. 96 geophones at 50 m spacings perpendicular to the basin and Waiohau fault recorded each of the shots.
The reflection line was 2.5 km long and consisted of 100 shots at 20 m spacings. Each shot was recorded by a 2x48 channel array of geophones at 10 m spacings. Initial processing shows strong reflection horizons to a depth of approximately 1

km and zones of intense structure, suggesting active faulting beneath the basin.
Published gravity maps show that the basin has a distinctive negative residual gravity anomaly of about –20 mgals. This motivated us to collect additional gravity data over the basin and a 3D interpretation of the subsurface structure will be presented.

POSTER

A BAYESIAN FRAMEWORK FOR THE ESTIMATION OF TECTONIC STRESS PARAMETERS FROM SEISMOLOGICAL DATA

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What do routine seismological observations of faulting — focal mechanisms or moment tensors — imply about either much longer-term tectonic deformation or the mechanisms by which earthquakes interact? In general, observational uncertainties and inherent ambiguities mean that the picture of faulting provided by individual focal mechanisms is *not* the same as that obtained from geological data, which typically reflect many episodes of deformation. However, the crustal stress tensor is one parameter with which we can potentially relate discrete, short-term (earthquake) and distributed, long-term (plate boundary) deformation. Moreover, estimating tectonic stress parameters from seismological data may also help in understanding earthquake interaction if, for instance, coseismic stress change models can be tested using reliable stress estimates rather than simply the spatial distribution of aftershocks.
We are developing a probabilistic (Bayesian) technique for estimating tectonic stress directions from primary seismological observations. The Bayesian formulation combines a geologically motivated prior model of the state of stress with an observation model that implements the physical relationship between the stresses acting on a fault and the resultant seismological observation. This procedure yields updated probability distributions for each earthquake's focal mechanism parameters and the common stress parameters.
We show our Bayesian formulation to be equivalent to a well-known analytical solution for a single, errorless focal mechanism observation (McKenzie, *BSSA*, **59**, 1969). The new approach has the distinct advantage, however, that including (1) multiple earthquakes, (2) fault plane ambiguities, (3) observational errors, and (4) any prior knowledge of the stress field is mathematically tractable, though numerically challenging.
Our approach is intended to yield reliable tectonic stress estimates that can be confidently compared with other tectonic parameters, such as seismic anisotropy and geodetic strain rate observations, and used to investigate spatial and temporal variations in stress associated with major faults and coseismic stress perturbations.

ORAL

INTERPLAY BETWEEN BRITTLE AND DUCTILE DEFORMATION IN THE 'ALPINE FAULT' MYLONITES

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At Harold Creek, Westland, two different groups of mylonites occur to the SE of the recent Alpine fault trace. The mineral assemblage of the first group (notably allanite, K-feldspar and residual equant micas inside porphyroclasts) indicates derivation from a granite protolith. Mylonitisation occurred under retrogressive greenschist facies metamorphic conditions.
Granite- and Alpine Schist-derived mylonites occur in repeated slices in the creek, and both have E-W striking foliations, similar to present-day strike-slip Alpine fault segments. The granite-derived mylonites often have a subhorizontal stretching lineation defined by elongate porphyroclasts, although shear sense is commonly ambiguous in this plane. It is possible that they experienced more coaxial/flattening strain than has been proposed for the schist-derived mylonite zone by Norris & Cooper (2003; J. Struct. Geol. 20: 5141-5157). The lineation has formed because of the variation in deformation style of different minerals in these rocks, and this may provide clues about why rare well-developed stretching lineations in the Schist-derived mylonites are often associated with deformed pegmatite veins.
In some granite-derived mylonites, quartz crystals within late-stage veins and syn-mylonitic cracks in feldspar porphyroclasts are further dynamically recrystallised, indicating cyclic brittle-ductile deformation processes. Either these rocks have undergone repeated burial and exhumation events during mylonitisation or this cycling results from transient fluid overpressures or transiently high stress during down-dip propagation of an earthquake rupture. In any of these scenarios, dynamic recrystallisation probably occurred at low temperatures (below 500ºC). This differs from mostly higher-temperature crystal-plastic

deformation mechanisms that were active in other Schist-derived Alpine fault mylonites (Walrond, 2001; GSNZ Conf. Abstracts: p.154). There is also a transition in some outcrops to statically annealed cataclasite. Hence these mylonites did not follow a simple uplift path along the Alpine fault which would have resulted in further high level cataclastic deformation.
Did the observed outcrop pattern result from interchange between thrust and strike-slip near-surface fault segments due to variable erosion as has occurred in other parts of the fault zone (e.g. Hare Mare Creek), or were these mylonites formed on a now abandoned structure that accommodated the strike-slip component of deformation during Alpine fault inception, prior to localisation of both lateral and convergent strain components on the present c. 50º SE-dipping fault zone (Koons et al., 1998; GSNZ Conf. Abstracts; p.138)? Combined cathodoluminescense and crystallographic preferred orientation studies of both granite- and schist-derived mylonites are planned to obtain further information about the relative timing of brittle and ductile processes, and the deformation mechanisms and type of strain at work in the late-stage crystal-plastic deformation. We hope this information will allow us to refine the model for formation and exhumation of these mylonites.

ORAL

ALPINE FAULT PSEUDOTACHYLYTES

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Frictional melts generated during faulting (pseudotachylytes) have been described in a variety of tectonic settings, but questions still remain about whether they are the products of 'ordinary' or abnormal high-stress rupture events.
Pseudotachylytes in the Alpine fault zone are hosted in granite-derived augen mylonites, deformed granites, and schist-derived mylonites. In most cases, pseudotachylytes were formed during the first brittle deformation event; however they have also been found overprinting cataclasites close to the recent fault plane. Evidence for a melt origin for the veins is provided by flow textures and the presence of injection veins. Most samples do not preserve quench textures although devitrification effects can be observed in thicker veins. In all examples, the percentage and angularity of clasts is variable within individual veins and often material with a melt-appearance is only preserved on one margin of a cataclasite zone or in internal patches, indicating that frictional wear/comminution processes are associated with melting. Measurement of wear to melt ratios and high-resolution optical studies are planned to provide more information on the process of pseudotachylyte generation.
In the granite-derived mylonites, in particular, some pseudotachylytes occur in anastomising networks of brittle faults, but only on certain strands, indicating that slip rate or frictional properties differed between fault strands. Pseudotachylytes hosted in deformed granitoids on the margins of the mylonite zone also frequently contain evidence for multiple generations of pseudotachylyte separated by cataclastic events, and often cross-cut the foliation and previous generating surfaces. Linking structures between paired fault veins are common. By contrast, pseudotachylyte veins hosted in schist-derived mylonites generally lie parallel to foliation and are frequently overprinted by anastomising brittle shear zones in the same plane.
In order to investigate the relationship between strain accumulated in the ductile regime and the localisation of seismic faulting events, a 2 m section of schist-derived mylonite hosting pseudotachylyte has been examined in detail. Deformation in these mylonites within 1 cm of the pseudotachylyte veins is more strongly localised to C'-type shear planes than in more distal mylonites of the same section. There is no systematic quartz/feldspar grain size variation or variation in quartz/feldspar to mica ratio associated with the pseudotachylyte veins at this scale.
Ages previously determined from pseudotachylytes from this region are generally <2 Ma, coeval with Alpine fault deformation. Historical seismicity records show that some small (M_w <5) earthquakes do occur along this comparatively aseismic section of the Alpine fault. It is hoped that further dating and structural studies will allow us to determine whether (and if so, which of) these pseudotachylytes formed during large Alpine fault earthquakes and their aftershock sequences, or are the 'fossils' of these smaller seismic events.

ORAL

THE ROLE OF UNCONFORMITIES IN RATIONALISING TE KUITI GROUP LITHOSTRATIGRAPHY

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The Te Kuiti Group marks widespread marine flooding of central-western North Island during the Oligocene to early Miocene. The constituent facies are calcareous, and variably glauconitic, siliciclastic, and carbonaceous (Waikato Coal Measures). The Te Kuiti Group is a transgressive succession involving mainly the repetitive occurrence of limestone, siltstone and sandstone units, reflecting a subtle cyclothemic character of 3rd to 4th order cyclicity. This cyclicity possibly reflects interplay between glacio-eustatic sea level oscillations in an evolving icehouse world, and basin-scale tectonism due to the inception of the Australia-Pacific plate boundary system through the New Zealand platform at that time.

Te Kuiti Group lithostratigraphy has evolved during the past century through successive investigations, no one alone considering the whole extent of its occurrence in outcrop in central-western North Island. The combination of marked lithofacies variations within and between formations, the degree of erosion of the group in critical areas, burial by younger volcanics in key areas, and the lack of a prior synthesis across the whole region of outcrop, have led to a plethora of formation and member names, and uncertainty in lithostratigraphic correlations. This study attempts to rationalise Te Kuiti Group lithostratigraphy by applying sequence stratigraphic concepts, which involves emphasizing the significance of surfaces of various types within the succession.

We propose a lithostratigraphic scheme for the Te Kuiti Group involving six formations: Mangakotuku, Glen Massey, Whaingaroa, Aotea, Te Akatea, and Otorohanga Formations. The sequence boundaries between all of these formations are disconformities. Erosion on the post-Whaingaroa unconformity is more pronounced than on the others, with the exception of the regional angular unconformity at the base of the group. In places this erosion cuts-out the whole of the Whaingaroa Formation. Erosion at the level of the post-Aotea Formation can also be marked, but is not as extensive. In a few places these two unconformities are superposed, such as at Waitomo Quarry and at Mangaotaki Bridge. The degree of erosion on some of these unconformities has not previously been appreciated, which has contributed to what we now regard as invalid prior correlations of formations. The rationalised lithostratigraphy enables a better understanding of the contemporary facies variations, linked depositional systems, and paleogeography to be reconstructed for individual sequences, and the group as a whole. This will lead to more confidence about identification of the Oligocene sea level history from these rocks, and the tectonic response of central-western North Island to inception of the new Australia-Pacific plate boundary zone.

ORAL

APPLICATION OF A GEOREACTOR: SUSTAINABLE HYDROGEN GENERATION USING SOLAR AND GEOTHERMAL ENERGY SOURCES

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Hydrogen is regarded by many as the ultimate "clean energy resource", even though no large-scale hydrogen generation system has yet been designed. Meanwhile, sulphur is a by-product of petroleum refining, with its disposal raising serious environmental waste management issues. Hydrogen generation, e.g. $2HS^- \rightarrow H_2 + 2S^{2-}$ using new, high performance solar energy photocatalysis has the potential to resolve both problems. To achieve an efficient hydrogen generation system, however, requires waste sulphur ionic species (S^{2-}) to be converted to HS^-, in order to facilitate sulphur recycling. Worldwide, geothermal resources have been developed for (electric) power generation, as well as providing hot water to green houses, district heating and other facilities, but they could also constitute an energy source to support advances in hydrogen production technology.

The focus of this paper is the development of methodologies to facilitate the conversion of waste sulphur to usable sulphur species, which could be achieved by directly utilising geothermal energy resources, via a low impact, subsurface (chemical) "georeactor". The georeactor could comprise double and/or multiple tubes, with an extremely high aspect ratio for material processing, with starting materials supplied via an injection tube and fluid flow towards an outlet tube. Material processing on a sustainable industrial scale would require sensitive temperature-pressure control, as the conditions affect chemical reaction behaviour - this constitutes the major challenge for use of the georeactor in advanced material-chemical reaction processes. The range of chemical reactions possible in a closed-loop geothermal reactor, however, provides the possibility to design technologies for a variety of industrial-scale applications. Sustainable hydrogen generation, where hydrogen is produced from hydrogen sulphide by high performance photo-catalysis, with sulphur recycling in the georeactor, is a case in point.

Sulphur formation is complex, and the concentration/formation ratio of sulphate and sulphide ions differs due to complex self-oxidation and reduction reactions. As reaction products, H_2S or HS^- are possible raw materials for hydrogen production. We examined their chemical behaviour and self-oxidation/reduction reaction potential over a range of chemical and temperature conditions (i.e. via batch-autoclave, elemental sulphur-water interaction experiments, over a range of pH and temperatures, 150-250°C), which show the dominant chemical species and formation ratio of sulphate - sulphide ions differ over the temperature range. For example, $S_2O_3^{2-}$ is dominant at 150°C, but SO_4^{2-} is the main ionic species at 250°C. It is necessary to carefully consider the chemical reactions that occur, in order to describe the mechanisms of sulphur–water interaction at high temperature (e.g. at 200°C) and saturated vapour pressure, to facilitate the design an efficient georeactor. The highest HS^- yield was ~44% at 250°C, after 5 hours, however the conversion ratio of HS^- decreased with the duration of the experiment. The same tendency was recognized at 200°C, where the peak yield time shifted to longer experiment times, due to complex, parallel self-oxidation and reduction processes.

Our work is ongoing, but hydrogen generation by solar energy from hydrogen sulphide, and recycling of waste sulphur and its compounds using geothermal energy could prove to be an environmentally-friendly energy supply system, with an enormous impact on future (geothermal) energy generation and utilisation.

ORAL – geothermal workshop

FINGERPRINTING EGMONT ERUPTIVES – IMPLICATIONS FOR CONSTRUCTING A MAGNEITUDE/FREQUENCY ERUPTIVE SPECTRUM

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Egmont volcano has been frequently active throughout the Holocene, displaying a wide range of eruptive processes, including dome-building, vulcanian, and sub-plinian events. Traditional approaches to evaluating future potential hazards at Egmont have been based on analysing the ages and partial distribution of the obvious and easily recognizable deposits from past eruptions. However, this neglects the apparently more frequent, lower-magnitude eruptives from the volcano. These small eruptions represent a potentially huge and hidden part of the volcanic eruption magnitude/frequency spectrum, and our lack of knowledge of them hinders an effective probabilistic forecast of future potential hazards. Accurately evaluating the frequency and magnitude of various eruption episodes from Egmont volcano involves identifying the stratigraphy within individual eruption episodes and the spatial distribution of these products. This involves not only correlating fall deposits from one site to the next but also by correlating falls, lavas and pyroclastic flows from any one eruptive episode. Correlations based solely on stratigraphic position and field characteristics can be very tenuous, particularly with andesitic systems where the impacts of variable weathering rates (including variations in site-hydrology) can overwhelm any similarity in the deposits of any one event from one place to another. In addition, the highly-confined distributions of the products mean that grain-size and thickness of individual deposits change rapidly. To improve correlation, and hence hazard estimation, we have undertaken a pilot study to test various geochemical correlation techniques. We conclude at present that micro-phenocryst titanomagnetite compositions are most useful for this purpose. This phase co-crystallises with pyroxene and is commonly found either with pyroxene in glomerocrysts or closely spatially associated with pyroxene phenocrysts. However, titanomagnetite appears to be more sensitive to prevailing melt conditions than the co-crystallising pryoxene. It therefore has the potential to fingerprint individual eruptive episodes, irrespective of the eruption processes involved. Deposits from packages of minor eruptions occurring between wide-spread and larger correlated units can then be more reliably mapped, and thus provide more reliable data for the development of an eruption magnitude/frequency model.

ORAL

THREE SUCCESSIVE GEOMAGNETIC POLARITY REVERSALS RECORDED IN MIOCENE SEDIMENTS FROM N.W. NELSON

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Palaeomagnetic studies of the 35m thick section of Tarakohe Mudstone that overlies the Takaka Limestone at Tarakohe Quarry, Golden Bay, have yielded excellent results, including a high resolution record of a sequence of geomagnetic polarity reversals as well as a novel and unusual magnetic mineralogy.

Unlike most uplifted marine sediments previously studied in NZ, the Tarakohe Mudstone carries a strong stable natural remanent magnetization (NRM). NRM intensities range between 1 and 10 mA/m. In most specimens the NRM is easily resolved into two components: a thermoviscous secondary component, close to the present day field direction, which is removed in the initial steps of thermal demagnetization, and a characteristic component carried by grains with blocking temperatures above 200^{o}C, which is interpreted as detrital in origin. Only rarely is a third component observed, which might be attributed to diagenetic alteration of the detrital magnetic minerals and degradation of the primary palaeomagnetic record.

Preliminary reconnaissance work of the entire section revealed at least 6 polarity reversals. The mean normal and reversed directions are antipodal at the 95% level of confidence and yield a pole position coincident with the early Miocene pole of the Australian polar wander path. Along with other similar results from the region, this implies that the N.W. Nelson domain has moved with the Australian plate, and suffered no significant local tectonic rotation in the past 20myr.

Subsequent detailed sampling of the lowermost 5m of the section has enabled us to locate three of these reversals to within 1cm, and has captured some rare records of the field while actually in the process of reversing. After correction for drift of the Australian plate, these transitional directions will be used to construct preliminary paths of virtual geomagnetic poles (VGP's) through the reversals, and these will be compared with paths from other locations and the predictions of theoretical models.

Thermomagnetic analyses show two ferrimagnetic mineral phases, the dominant one having a Curie temperature of about 560^{o}C. Electron microprobe analysis suggests that this is not a simple titanomagnetite, but is a spinel containing significant amounts of Cr, and minor amounts of Al, Mg and Mn in addition to Fe and Ti. Little has been published on the magnetic properties of natural chromium-bearing spinels. However our studies seem to imply that they are stable and can carry a strong stable component of detrital remanent magnetization that is resistant to the diagenetic degradation common in most other NZ marine sediments.

POSTER

PRELIMINARY EXPLORATION RESULTS AT THE MANGAKINO GEOTHERMAL PROSPECT, NEW ZEALAND

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A 2004 exploration program in the Mangakino geothermal prospect has identified drilling targets for a high temperature resource 5-7 km southeast of the Lake Maraetai. Crown exploration well MA-1, drilled to 607m in 1986 discovered a shallow geothermal resource with a maximum temperature of 185°C. Geothermometry of well discharges and two widely separated surface manifestations indicate resource temperatures up to 250°C. Results of an 80-site combined MT-TDEM geophysical survey shows a low resistivity layer consistent with a hydrothermal clay cap extending beneath a field of young rhyolite domes southeast of MA-1 and covering an area of more than 50 km^2. The apex in this conductor lies about 5 km southeast of MA1. Similar features have been correlated with the shallow tops of high temperature geothermal reservoirs.

Based on this information, Mighty River Power plans to drill at least two deep exploration wells in the prospect in early 2005. The objective of these wells is to discover and delineate productivity and reserves sufficient for geothermal power development.

ORAL – geothermal workshop

OVERVIEW OF THE LAHENDONG GEOTHERMAL FIELD, NORTH SULAWESI, INDONESIA: A PROGRESS REPORT

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The Lahendong geothermal field occurs in the Sangihe volcanic arc, in the northern part of the North Arm of Sulawesi. It is the first field to be developed in the eastern part of Indonesia. Lahendong is a water- dominated field with reservoir temperature > 300 ^{o}C. Re-examination of cores and cuttings recovered from 5 geothermal wells with depths ranging from 1900 to 2300 m, re-interpretation of air photographs and field checking has helped reveal the geology and hydrothermal alteration of the field. This paper is a progress report of a study aiming to determine the subsurface geology of the Lahendong hydrothermal system and to reveal its evolution.

The system is centred in the Pangolombian caldera. The thermal manifestations are of steam-heated type, and their occurrence is mainly controlled by the NE – SW trending faults. However, the hydrothermal alteration of cores and cuttings shows that the reservoir fluid is thermal water of near neutral pH. The shallow (to 275 m a.s.l) reservoir is hosted by Pangolombian andesite lavas and pyroclastics. The deep reservoir is hosted by Tondano tuff of Pleistocene age and Pre-Tondano volcanic and sedimentary rocks of Pliocene age, which are intruded by diorite dykes.

The hydrothermal fluid-rock interactions at depths produced clays, calcite, anhydrite, pyrite, iron oxide, quartz, epidote, prehnite, pumpellyite, adularia, secondary albite, and possibly tourmaline. The mineralogy of the hydrothermal alteration at Lahendong is relatively simple but the textural relations are quite complex. The mineral paragenesis suggests that at least 3 alteration episodes have taken place. The earliest formed mono-mineral veins and cavities. The second and the third episodes yielded veins and cavities with more diverse mineralogy and texture. Nevertheless, the hydrothermal mineral geothermometers suggest that the productive reservoir has not undergone significant thermal change since the minerals formed.

Future studies on the relationship among the veins and observations of the sequence of mineral replacements may reveal the evolution of the hydrothermal system at Lahendong. Systematic fluid inclusion measurements should identify changes of temperature and fluid composition. Comparison with the present-day reservoir characteristics will also be necessary to understand the temporal behaviour of the system.

ORAL – geothermal workshop

TEMPORAL VARIABILITY OF EARTHQUAKE OCCURRENCE AND SLIP RATE ON THE RANGIPO FAULT, TAUPO RIFT, NEW ZEALAND

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The Rangipo Fault (formerly the Desert Road Fault) is a prominent NNE striking, W dipping, active normal fault that defines the eastern boundary of the Taupo Rift at the southern termination of the Taupo Volcanic Zone. Surface fault traces can be mapped for at least 32 km with its closest trace c. 15 km from the crater lake of Ruapehu Volcano.

Detailed mapping of offset geomorphic features and excavation of four trenches across the fault just south of the Whangaehu River escarpment has revealed a detailed history of the fault slip rate post-dating the deposition of Rerewhakaaitu Tephra at c.17.3 cal. ka., and evidence for extensive erosion during the Last Glacial Maximum (LGM). This suggests that previous fault slip rate estimates of c. 3 mm/yr, based on the height of the Whangaehu River escarpment, are over-estimated. The escarpment height appears to have been accentuated on the downthrown side of the fault by erosion and incision during the LGM.

New fault slip rate estimates were obtained from a different location about 5 km south of the Whangaehu River escarpment, where the total vertical displacement of the ring plain surface is c. 27 m. The age of the surface at this location is constrained between 17.3 to 26.5 cal. ka., based upon the occurrence of Rerewhakaaitu (c.17.3 cal. ka) and Kawakawa (26.5 cal. ka) Tephras enveloping the laharic units that comprise the ring plain surface. Thus for the last c. 17.3 to 26.5 ka., the average vertical slip rate of the Rangipo fault at this locality is c. 1.2 mm/yr which converts to a dip slip of c. 1.5 mm/yr for a 60º fault dip. In contrast, post-Waiohau (13.4 cal. ka) tephra beds exposed within the trenches were offset by a total of c. 3 m, yielding an average dip slip rate of approximately 0.2 mm/yr for the last 13.5 ka. Taken collectively, these data indicate significant variability in slip rate on the fault over the last 26.5 ka, with an incremental slip rate value of 2.6 to 5.8 mm/yr for the time period between 13.4 ka and 17.3-26.5 ka.

The change from high fault slip rate (2.6 to 5.8 mm/yr) to low slip rate (0.2 mm/year) around c.13.4 cal. ka could be explained by a correlation with the decrease in the eruptive activity at nearby Ruapehu Volcano after c. 15 ka, or by purely tectonic processes such as earthquake clustering in time. A similar drastic reduction in slip rate, over the same time period, has been observed on the Shawcroft Road Fault immediately adjacent to the Rangipo Fault, suggesting a likely correlation with volcano activity.

ORAL

A NEW 1:50 000 GEOLOGICAL MAP OF MIOCENE STRATA (MOKAU AND WHANGAMOMONA GROUPS) IN SOUTHERN KING COUNTRY AND EASTERN TARANAKI PENINSULA

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Geological mapping at 1:50,000 scale of southwestern King Country and northern Taranaki Peninsula has revealed the internal details and extent of a succession of siliciclastic-dominated sedimentary rocks of Miocene age. The ~2100 km^2 area of interest comprises heavily dissected hill country, extending from Tangarakau Gorge - Aotuhia in the east to Tongaporutu - Inglewood in the west. Historically, the focus of prior geological investigation has been on the well exposed North Taranaki coastal section (King et al. 1993), and the economically significant Ohura-Tangarakau Coalfield for which detailed maps exist in coal reports (Manhire & Phelps 1986). Significant new mapping has been undertaken in the context of basin analysis, aimed at elucidating the depositional architecture of what we infer to be paleo-continental margin strata. In particular, emphasis has been placed on mapping the inland extent of the formations cropping out spectacularly in the north Taranaki coastal cliffs from Motunui to Tongaporutu River.

The stratigraphy of the map area comprises two major stratigraphic units: 1) Mokau Group, which contains shallow marine sandstone, conglomerate and paralic coal measure units of Altonian age (c. 19-16 Ma); 2) Whangamomona Group, comprising the Moki, Mangarara, Otunui, Mount Messenger, Urenui, Kiore and Matemateaonga Formations of Clifdenian to lower Opoitian age (c. 16.0 to 4.7 Ma). The Whangamomona Group represents a phase of marked subsidence and retrogradation of a continental margin into the King Country, followed by a significant phase of continental margin progradation to the north-west, which was forced by a substantial sediment flux derived from uplift and erosion of the Southern Alps.

The beds typically have a regional dip of 2-5° to the southwest, with variations occurring about localised faults. The Ohura Fault is the predominant Neogene fault east of Taranaki Fault. In the map area the Ohura Fault has a rectilinear trace with a NNE-SSW strike. It is down-thrown to the east. It juxtaposes Mokau Group sandstone and coal measure units to the west against Otunui and Mt Messenger Formations to the east, with an estimated throw on the fault at Tangarakau Gorge of about 400 m. The combination of the regional southwest dip and vertical offset on Ohura Fault produces an outcrop pattern that appears to horizontally offset formations to the northeast from those to the southwest by approximately 20 km. A set of normal faults trending NE-SW (020-040), are prevalent throughout the entire field area, however their identification in the field is limited to beds (Mokau Gp, parts of Mount Messenger Fmn, Matemateaonga Fmn) where there is significant lithological variation such that offsets are revealed and throws can be estimated. These faults are also considered to displace the lithologically homogenous formations, but the degree of activity of slope processes obscures their occurrence except in well exposed outcrops. This late phase of normal faulting is a product of extension across central North Island during the Pliocene and Pleistocene.

POSTER

PRELIMINARY OXYGEN ISOTOPE DATA FOR INTERPETATION OF PALAEOCEANOGRAPHIC CONDITIONS OF THE TASMAN FRONT NEAR LORD HOWE ISLAND.

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The Tasman Front is a major oceanographic boundary in the Tasman Sea; it brings warm tropical waters associated with the East Australian Current southward, converging with cool temperate waters. The warm currents of the Tasman Front allow coral reef growth (the southern most limit) around Lord Howe Island. During the Last Glacial Maximum, the Tasman Front was thought to have fluctuated around Lord Howe Island with an overall net movement northward, allowing cooler waters to encircle Lord Howe Island. Lord Howe Island is a significant subaerial landmass in the centre of the Tasman Sea, a slightly smaller shelf, Balls Pyramid is situated 20 km to the south. The current position of the Tasman Front is along the same latitude as Lord Howe Island.

A piston core was collected from a water depth of 780 m in the trough between Lord Howe Island and Balls Pyramid. This core recovered approximately 2.8 m of carbonate sediment composed of fine grained sandy-mud.

Oxygen and carbon isotope analyses have been conducted on this core using the planktonic foraminifera *Globigerina ruber* and *Globigerinoides bulloides* as well as the benthic *Uvigerina* sp.. Preliminary analysis combined with radiocarbon dating indicates the core dates back to isotope stage 3, with the transition into and out of the LGM being well preserved. The rate of sedimentation also appears to be much higher than for other cores collected in the Tasman for this period and probably represents the influence of the two islands.

Data analysis is still in its preliminary stages and the core will be analysed in the next year to refine the interpretation of the isotope data. Such investigations will include, compositional analysis, foraminifera species associations and other microflora/fauna. The data so far suggest a great potential to reconstruct a high-resolution record of both oceanic circulation, as it lies at a major oceanographic boundary, as well as carbonate production across a periodically flooded shelf.

POSTER

CATHODOLUMINESCENCE OF QUARTZ: INDICATION FOR AN EARLY CRETACEOUS RIFT-SYSTEM IN THE NEW ZEALAND REGION?

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Igneous conglomerate clasts from the Pahau terrane of New Zealand are indistinguishable from the Tutoko Complex plutons (previous Median Tectonic Zone) in terms of age, major and trace elements, and isotopes.These clasts represent the upper structural level of the Tutoko Complex. The igneous clast lithologies attest to a silicic, rhyolitic/dacitic magmatism in the source. This differs from "normal" supra-subduction zone arc volcanism, which is dominated by basaltic to andesitic magmatism.
Scanning electron microscopy – cathodoluminescence (SEM-CL) combined with optical microscopy on individual quartz crystals is a promising tool for provenance analysis. SEM-CL is useful to identify primary internal features in quartz crystals, acquired during crystallization, such as randomly oriented microcracks and healed fractures, zoning, homogenous or patchy appearance, which are not visible with an optical microscope. We have analysed quartz grains from four samples from the sandstone facies of the Ethelton conglomerate. The CL data indicate that volcanic and hypersolvus quartz dominate over granitoid and metamorphic quartz. In addition we have analysed igneous clast quartz grains (volcanic, hypersolvus and granitoid) and found strong similarities between igneous clast quartz and matrix quartz. CL data from matrix quartz and igneous clasts combined with igneous clast geochronology and chemistry suggests that the magmatic activity in the Tutoko Complex is thus most consistent with caldera-type silicic volcanism. Such silicic volcanism is not unique to continental break-up, but can characterise any continental region undergoing extension that is underlain by hot mantle and has a hydrous lower crust receptive to melting.

POSTER

PERMEABILITY MEASUREMENT FOR LARGE ROCK FRACTURE USING RUBBER-CONFINING PRESSURE VESSEL

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To understand the rock fracture permeability under confining pressure, permeability measurements using the large fracture, which reflects two-dimensional fluid flow, are needed. The experiments using the large fracture, however, become more difficult to perform as increasing confining pressure for the methods used in pervious studies. Therefore, the new type confining pressure vessel for simple and easy permeability measurements for a sample including large fracture under high confining pressure, called the rubber-confining pressure vessel (R-CPV), have been developed. In this presentation, we report about outline of the R-CPV and the results of permeability measurements for granite samples including the large tensile fracture of 100 x 150mm with various lateral displacements along fracture surfaces under confining pressure up to 100MPa using the R-CPV. For fractures without lateral displacement, the permeability decreased with increasing confining pressure until 40-50MPa, beyond which the permeability decreased gently or became constant (Fig. 1).
For fractures with lateral displacement, significant increase of permeability occurred even for lateral displacement as small as 1mm. The permeability, however, decreased as increasing confining pressure, and abrupt decrease occurred at 80MPa for 1mm displacement. For the fracture with sufficiently larger lateral displacement-more than 3mm, obvious decrease of permeability did not occur as increasing confining pressure, and the large permeability remained even under high confining pressure (Fig. 2).

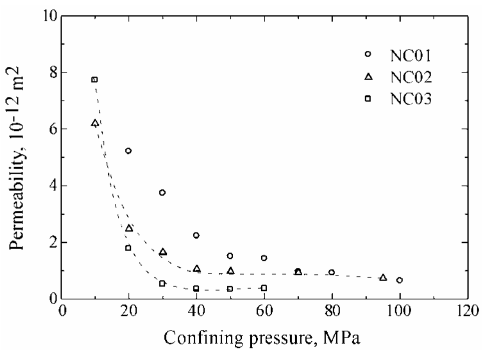

Fig. 1. Relationship between permeability and confining pressure for the samples without lateral displacement.

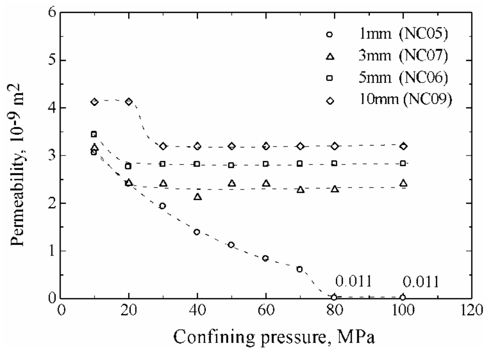

Fig. 2. Relationship between permeability and confining pressure for the samples with lateral displacement.

ORAL – geothermal workshop

VARIABILITY OF VOLCANIC EMISSIONS DURING A CRATER LAKE HEATING CYCLE, RUAPEHU VOLCANO, NEW ZEALAND

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We present the first measurements of CO_2 emissions made coincident with SO_2 emissions from Ruapehu volcano, New Zealand. Gases emit from two main venting regions within the crater lake, and emission measurements were made on an airborne platform at distances of 2-4 km downwind of the summit and crater lake depending on the strength of the CO_2 signal. CO_2 and SO_2 emissions were initially measured using the plume contouring method and COSPEC, respectively. In April, 2004 additional sensors were added to the platform to measure plume concentrations of SO_2 and H_2S. Emission estimates derived from the contouring method for SO_2 were similar to the results from COSPEC, lending confidence to the contouring approach. CO_2 emission rates using the contouring method were consistently lower than estimates based on the plume CO_2/SO_2 ratio method, which can be explained by choosing an atmospheric background cutoff that is too high for the contouring method. Emissions were generally at a low level consistent with quiescent degassing of the volcano. Maximum concentrations (~3-4 km downwind) during the highest measurement in May, 2004 were 14 ppm, 0.37 ppm, and 7 ppb for CO_2, SO_2 and H_2S, respectively. CO_2 emissions varied between ~50 and 900 t/d. SO_2 was not detectable until February, but gradually increased to 35 t/d. Emissions of H_2S were detected in April and May, although were < 1 t/d. The CO_2/SO_2 molar ratio in the plume was ~ 50 for each measurement suggesting that significant scrubbing of SO_2 occurs through the crater lake, and also a constant source of both gases. The detection of measurable SO_2 suggests that either a dry pathway exists for magmatic gases, or that the gas must emit in large enough bubbles so that the SO_2 does not react completely while rising through the crater lake. All gases increased above a zero baseline coincident with the peak in the crater lake heating cycle and earthquake detections in the summit region in March, 2004. While both lake temperatures and earthquake detections declined, gas emissions continued to rise with maximum emissions ~ 2 months following the peaks in the other signals (May). By mid-July all gases were below detection limits.
Existing models explain the periodic heating of the crater lake with changes in the heat pipe performance and mineralization at the crater floor-central conduit boundary. Periodic disturbances in the crater lake floor area are thought to allow lake waters to circulate deeper into the volcanic conduit carrying heat to the surface. Our results suggest that volcanic emissions do not reside in the hydrothermal system directly beneath the crater floor as no increases in emissions were observed during the heating phase. Magmas are thought to exist in relatively small pockets (<0.05 km^3) at shallow depths beneath the volcano (~1-2 km). Our observations suggest that the source of volcanic emissions is perhaps a vapor zone at the top of an existing magma pocket. Further analysis will focus on determining the depth of origin for the gas emissions and the volume of magma needed to supply observed integrated emissions.

POSTER

CO_2-FLUX OF STEAMING GROUND AT KARAPITI (WAIRAKEI, NZ)

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Carbon dioxide gas is discharged together with steam at the surface of high temperature geothermal reservoirs. Steam and CO_2 fluxes were recently measured at a large steaming ground area at Karapiti (Wairakei geothermal reservoir) to assess the total CO_2 emission rate from this area and the relationship between steam and CO_2 degassing. Steam is discharged at Karapiti both by fumaroles and focussed steam vents (c.107 MW heat transfer) and by diffuse emission (c.69 MW); another 69 MW of heat is transferred by conduction. Using CO_2/H_2O ratios of published fumarole analyses, the subtotal of CO_2 discharged by all visible steam vents at Karapiti is likely to be 16 ± 2.3 tonnes (CO_2) /day.

CO_2 fluxes were measured using an accumulation chamber at 84 sites over the 0.35 km^2 Karapiti steaming ground area where the soil steam flux had been measured or could be inferred from a separate heat flux survey. CO_2 fluxes have a log-normal distribution, varied between 5 and 90 ($g\ m^{-2}\ d^{-1}$), and exhibit significant daily and (short-distance) spatial variations. Allowing for a biogenic flux of 5 ($g\ m^{-2}\ d^{-1}$), the diffuse geothermal emission for the whole area was found by integration of contours to be c. 6 t CO_2/d. Using observed CO_2 and steam fluxes (Figure 1), an apparent soil-gas ratio was computed with a mean (n=80) of 150 ± 110 (mM CO_2/100M H_2O) . Using this ratio and measured steam fluxes we calculate c. 7 t CO_2/d for the diffuse component. This value contains a large uncertainty, reflecting the local variations of CO_2 fluxes over steaming ground; however, it is relatively consistent with emission rates calculated from direct CO_2 flux measurements. Near-surface CO_2 concentrations beneath each site are variable, likely due to steam condensation, CO_2 dissolution in condensates, and different proportions of vapour components. Despite this, we observe an overall decrease (factor of 2) in CO_2 concentration in the diffuse emissions across the field from north to south over a distance of c. 600 m.

The total CO_2 discharge at Karapiti is therefore 23 ± 7 t CO_2/d. In comparison to gas discharges from other geothermal areas, the CO_2 emission at Karapiti is moderate; it amounts to only c. 12 % of the total amount of CO_2 produced in recent years by exploitation of the nearby Wairakei geothermal reservoir.

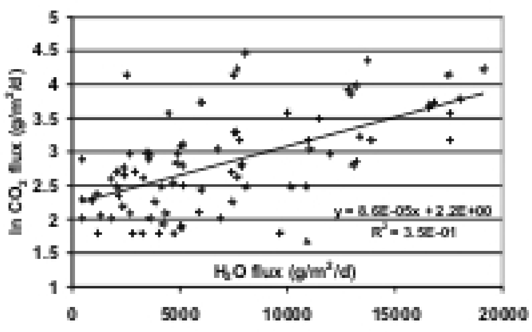

Figure 1. Mass flux rates of CO_2 and subsurface steam in soils of Karapiti steaming ground area.

ORAL – geothermal workshop

EVALUATING THE SEAL INTEGRITY OF NATURAL CO_2 RESERVOIRS OF THE COLORADO PLATEAU

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The existence of natural CO_2 reservoirs on the Colorado Plateau and adjacent Southern Rocky Mountains confirms that CO_2 can be trapped by favorable structures. Our understanding of these reservoirs is incomplete because data on the characteristics of the critical sealing units and field measurements of gas leakage rates needed to evaluate the effectiveness of the seals are lacking. This paper presents our latest results from an ongoing study of the geologic sequestration potential of the Colorado Plateau. Mercury injection porosimetry measurements on commonly occurring seal rocks in the Plateau suggest excellent sealing properties, with CO_2 column heights of at least 100 m being supported by data from samples of Paradox Formation anhydrite, Mancos Shale, and Moenkopi Formation. Numerical modeling of subsurface CO_2 injection into possible reservoirs near two large power plants in central Utah suggests the loss of more than 50% of injected CO_2 to the surface over several hundred years when no mineral reactions are considered, but permanent sequestration of 70% of the CO_2 after 1500 years when likely reactions are included. The remaining 30% represents some migration through cap rocks and formation of secondary reservoirs. The presence of many natural CO_2 fields with multiple, stacked reservoirs highlight the need to carefully evaluate seal integrity and probable CO_2 plume migration paths prior to injection. Preliminary results of soil CO_2 flux measurements over natural CO_2 fields will be presented and compared with predictions from numerical modeling. The implications of this work on the use of soil gas flux measurements as a tool for long-term environmental monitoring of injection sites is discussed.

ORAL – geothermal workshop

ESR AGES OF SOME ANTARCTIC CARBONATES AND SULPHATES

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Mineral salt samples mostly from the southern Dry Valleys region, Antarctica, and collected about 1970, were dated using ESR (dose assessment was via gamma spectrometry).
The valleys sampled, south of the usual study areas, were Miers, Ward, Pyramid Trough, the Radian Glacier moraine, and are southwest of the frozen Ross Sea. Gypsum, calcite and mirabilite are found as salt layers and mineral growths on exposed rocks. Mineral samples had ages in the range 0.5 – 6.0 ka in the Dry Valleys (significantly less than the 10-20 ka calcite samples nearby previously dated by U/Th methods and possibly showing that these more southern valleys became ice-free more recently). However an additional calcite sample from the Scott Glacier region gave an older age of 21 ka which would correspond to the first decrease in ice thickness after the last glacial maximum.

Table: Samples, and results

ID#	Loc.	Mineral	Form	ESR Signal	Age	1 σ range
244	S	Calcite	On granite	CO_2-	21 ka	20.9-22 ka
75	N	Gypsum	Vein (dolerite)	O_2-		Est. 1700-7300a
1	R	Gypsum	On marble	O_2-	462a	58-866a
8	P	Gypsum	Salt pan	O_2-	1760a	0-3160a
14	M	Calcite	On moraine		6800 a (U/Th est.)	
15	M	Gypsum	On ice	O_2-	5310a	2170-8440a
19	M	Calcite	Salt deposit		5990a (U/T hest.)	
21	W	Calcite	Layer	CO_2-	5280a	3810-6740a
22	W	Mirabilite	Layer	CO_2-	6190a	4760-7620a
24		Mirabilite	Layer	CO_2-	< 3000a	

244: **S**cott Glacier, 86 ^{o}13.2S, 147 ^{o}33.7E, 2000m; 299: Scott Glacier, 85 ^{o}28S, 157^{o}30E, 600m. 75: **N**orthwind Valley, 76^{o}40S, 161^{o}E, >300m; 1:**R**adian Glacier, 78 ^{o}15S, 163 ^{o}15E, 500m; **P**yramid Trough Valley, 78 ^{o}19S, 163 ^{o}30E, 30m; 14,15: **M**iers Valley, 78 ^{o}5S, 164 ^{o}05E, 80m: 19: Same but 100m; 21,22: **W**ard Valley, 78 ^{o}11S, 163^{o}40E, 370m; 24 same but 20 m north, 370m

ORAL

ESCALATORS, RAMPS, AND UPLIFT: THE KINEMATIC SIGNIFICANCE OF A BACKSHEAR ARRAY IN THE CENTRAL SOUTHERN ALPS

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An array of near-vertical backshears exposed in the central Southern Alps have particular significance in the interpretation of the geometry of the underlying Alpine Fault ramp. The array of dextral-oblique backshears lies subparallel to the Alpine Fault, exposed only in the central region of the Southern Alps around Fox and Franz Josef glaciers. The backshears themselves strike subparallel to the Alpine Fault trace, displaying a systematic anticlockwise rotation in attitude from 070°-striking at the northern end of the array, to 030°-striking towards the south. They exhibit an up-to-the-northwest sense of shear, which is antithetic to the Alpine Fault. The backshears are systematically spaced (53 ± 4.7 cm), with an average offset of 14.1 ± 1.2 cm, comprising both a ductile and a brittle component. The backshears offset the quartzofeldspathic Alpine Schist host in a predominantly brittle manner, whereas pre-existing quartz veins in this schist are ductilely offset to a ductile shear strain of 4.8 ± 0.8. The interpretation of these backshears is that they sequentially formed due to tilting and uplift onto the Alpine Fault ramp at depth in an escalator-like fashion.
Shear strains accommodated by the backshears were measured over several transect lengths of 10 to 500 m. The inverse tangent of the vertical component of this cumulative shear strain divided by the fault-orthogonal distance is interpreted to reflect the minimum footwall ramp angle of the Alpine fault at depth, averaging 22 ± 12° over five individual transects. Estimation of strain-rates transiently accommodated by shearing at this bend can be made from field data, by combining the boundary-normal component of the plate motion vector with the shear strain accumulated on the backshears (assuming an escalator model for sequential backshear activation). The maximum shear strain rate estimate, assuming only one backshear is active at a time, is 1.0 x 10^{-8} s^{-1}; a minimum shear strain rate estimate, calculated using an 100 m-width of simultaneously active backshears, is 1.0 x 10^{-11} s^{-1}. These high strain-rates are in agreement with existing numerical modelling of two-sided orogens that predict a region of elevated stresses and strain-rates propagating from the bend in the fault ramp.
Previous analogue and numerical modelling of backshear development in convergent settings suggests that backshears will form dipping moderately in the opposite direction to the ramp but strike parallel to the underlying bend in the fault ramp. The change in strike attitude displayed by the backshears in the Southern Alps is here interpreted to reflect a corresponding change in strike of the base of the Alpine Fault ramp at depth. For the strike of the fault ramp base to change but maintain a linear trace at the surface implies a bend or curve in the ramp at depth. This curve is expressed as a steepening of the fault ramp in the central section of the Southern Alps, with the maximum curvature lying parallel to the plate motion vector. In this way, the kinematics and

orientation of backshears exposed at the surface today can be used to infer fault ramp geometries created during crustal oblique convergence.

ORAL

GARNET ALBITE BIOTITE ZONE METAMORPHISM IN THE ALPINE SCHIST, McARTHUR RANGE, CENTRAL WESTLAND, NEW ZEALAND

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Preliminary chemical and petrographic analyses of the Alpine Schist from the McArthur Range, near Hokitika, Central Westland, New Zealand, show the presence of a garnet-albite-biotite zone rarely recognised in the Alpine Schist, ~3 to 4km east of the Alpine Fault. The 88 samples of Alpine Schist collected from the McArthur Range produced an ~3.5km wide transect orientated east to west, with the western most sample located ~2.5km east of the 055 striking Alpine Fault. The metamorphic grade of the Alpine Schist in the study area increases continuously east to west from: albite-biotite zone to garnet-albite-biotite zone to garnet-oligioclase-albite-biotite zone.

The oligioclase-in isograd in the study area has been placed ~2.7km from the Alpine Fault, and ~1.5km east of the mylonite zone. No mylonitic overprinting of garnets from the study area is seen in petrographic and chemical analyses to date. The garnet-albite-biotite zone extends at least through to the Griffin Range ~ 3km northeast of the study area (M. Cavanagh, 2004). However, Alpine Schist samples from the Griffin Range do not reach garnet-oligioclase-albite-biotite zone metamorphism, yet garnets exhibit a mylonitic overprint (M. Cavanagh, 2004).

Results of garnet-biotite thermometry indicate that peak metamorphic temperatures in the study area increase from 410°C in the garnet-albite-biotite zone to 425°C in the garnet-oligioclase-albite-biotite zone. Results of garnet-biotite-muscovite-oligioclase barometry indicate a peak pressure of 5.8kbars in the garnet-oligioclase-albite-biotite zone.

The generally accepted metamorphic grade sequence for Alpine Schist in increasing grade is: biotite-albite to biotite-albite-oligioclase to biotite-albite-oligioclase-garnet. However, the discovery of the garnet-albite-biotite zone in the Alpine Schist of the McArthur Range suggests that the current metamorphic grade sequence for the Alpine Schist may not be as representative for all Alpine Schist. It is therefore possible that the Alpine Schist of the McArthur Range may have experienced different metamorphic conditions during its deformational history.

ORAL

TAUPO: VOLCANO AND LAKE

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Volcanism has played a major role in shaping New Zealand, with the greatest impacts on the present-day landscape and environment of the central North Island occurring during the last 1.6 million years. At present, Taupo is the single most frequently active and productive rhyolite caldera volcano in the world. Rhyolite is a silica-rich, gas-rich, sticky magma that gives rise to highly explosive eruptions. These eruptions spread their products so widely that no large cone (like Ruapehu) forms, while the term 'caldera' is used because the eruptions are sometimes so large that the land surface collapses into the emptied underground magma chamber to form a vast 'hole'. Although Taupo first began erupting about 300,000 years ago, the caldera shape of the modern volcano reflects two large eruptions about 26,500 and 1,800 years ago. Lake Taupo partly infills the Taupo caldera, and interactions between lake water and magma have influenced the styles of volcanism. There have been 28 eruptions at Taupo since 26,500 years ago, varying enormously in size, from < 0.01 km^3, up to the largest (the Oruanui eruption 26,500 years ago) which involved about 530 km^3 of magma (equivalent to 2 or 3 Ruapehu-sized mountains), and spaced at very different intervals from decades to thousands of years apart. This complexity makes it very difficult to forecast when the next eruption will occur and how big it will be. The latest eruption (the Taupo eruption) 1,800 years ago was the most violent volcanic event in the world during the past 5,000 years and has left marks on the landscape which are still visible today.

Lake Taupo, the largest body of freshwater in Australasia owes its existence and much of shape to the caldera-forming eruptions of Taupo volcano. The Oruanui eruption destroyed a large, long-lived lake that formerly extended between the Turangi and Reporoa areas. Deposition of thick volcanic deposits in the Taupo-Wairakei area during the Oruanui eruption infilled the middle part of this lake and closed off the Taupo basin which was largely created by caldera collapse during this eruption. Subsequently, Lake Taupo refilled to well above its current level (357 m above sea level) with extensive shoreline terraces developed to heights of 140 m above the modern level. This huge lake held nearly three times as much water as Lake Taupo does today, and overflowed for a while to the north through the Waihora Bay area towards Mangakino. After some time, the modern outlet was restored, resulting in the sudden release of 60 km^3 of water as the lake level fell by 80 m. The flood involved enough water to cover the entire North Island knee-deep, at flow rates that were temporarily greater than any river on Earth and may have changed the course of the lower Waikato River. During the Taupo eruption the outlet was again dammed by volcanic debris, causing the post-eruption level of Lake Taupo to rise to 34 m above its modern height, forming a clear highstand shoreline terrace around much of the lake. Eventually, overtopping of the dam of pumice and ash triggered the release of 20 km^3 of water during another major break-out flood whose effects can be traced for over 200 km downstream, and include boulder fans and buried forests.

PUBLIC LECTURE

CONTROLS ON THE NATURE AND EVOLUTION OF AN EXCEPTIONALLY ACTIVE ARC-RELATED SILICIC FOCUS: CENTRAL TAUPO VOLCANIC ZONE, NEW ZEALAND

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The ~120x60 km rhyolite-dominated central Taupo Volcanic Zone (TVZ) in New Zealand is founded on ~15-km-thick Palaeozoic-Mesozoic 'greywacke' crust. Foci of volcanism and magmatism appear to change in distinct steps, rather than gradationally. Modern TVZ vents cluster along a ~30 km wide linear belt from which basalt to rhyolite has been erupted, notably rhyolite averaging 0.38 m^3/s in central TVZ for the past 65 kyr. However, geothermal fluxes imply that crustal magmatism is more important (1-2 m^3/s) and widespread in central TVZ. We suggest that active rifting processes modulate the surface volcanic expression of magmatism. Geochemical characteristics of individual silicic eruptives range from those with coherent zoning patterns, through ones with compositional clustering interpreted to reflect multiple chambers or intra-chamber mixing of discrete compositions, to uniform unzoned deposits. Previous isotopic data collectively implied a minor role for greywacke assimilation in rhyolite genesis, but new data from Taupo volcano indicate that this conclusion should be reassessed. Evidence from Taupo suggests that rhyolites there are mixtures of new fractionates, recycled plutonic material and greywacke, that they are assembled at rates often >1 m^3/s, and held in distinct holding bodies at depths of ~4-8 km for short pre-eruptive periods. Spatial and temporal variations in rhyolites at Taupo imply that their characteristics are mainly controlled by crustal processes acting at depths of between ~15 and 5-8 km. Comparisons with other Neogene silicic systems suggest variable thermal focii in time and space and rift-related tectonic controls explain much of TVZ magmatic evolution.

ORAL

THE 26.5 KA ORUANUI ERUPTION, TAUPO VOLCANO: DEVELOPMENT, CHARACTERISTICS AND EVACUATION OF A LARGE RHYOLITE MAGMA BODY

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The 26.5 ka Oruanui eruption from Taupo volcano erupted ~300 km^3 of extracaldera (>99% rhyolitic, <1% mafic) and ~230 km^3 of intracaldera magma. The rhyolite is zoned (71.8-76.7 SiO_2, 76-112 ppm Rb), but dominantly 74-76 % SiO_2, with 6-13% crystals. Similar compositions were erupted for ~40 kyr prior to 26.5 ka. Overall compositional variations are explicable by crystal fractionation involving the minerals present. However, scatter in some element concentrations and $^{87}Sr/^{86}Sr$ ratios, and the presence of non-equilibrium crystal compositions imply mixing processes also were important in assembling the compositional spectrum sampled during the eruption. Age spectra from zircons show that the crystal population includes remobilised older mush, and 1-2% of the plagioclase population includes xenocrystic cores incorporating zones crystallised from metasedimentary melts. Although compositionally variable, the rhyolite was erupted non-systematically such that average compositions change negligibly through the eruption sequence. Mafic compositions define two lineages, one olivine-free 'tholeiitic' (higher Fe, Ti: 52.2-63.1 % SiO_2), the other olivine-bearing 'calc-alkaline' (lower Fe, Ti: 56.7-60.5 % SiO_2). Both lineages have chemical variations attributable to AFC processes, but show evidence also for limited mechanical mingling ('tholeiitic') with, or incorporation of crystals ('calc-alkaline') from, the Oruanui rhyolite. Both mafic lineages are distinct from other Taupo Volcanic Zone mafic eruptives of comparable percentage SiO_2, and are genetically distinct from each other as well as from the rhyolite. Accumulation and destruction by eruption of the Oruanui magma body occurred within ~40 kyr, and Oruanui compositions have not been replicated in vigorous younger activity.

POSTER

DISCRIMINATING HOLOCENE UPLIFT MECHANISMS FROM 10,000 - 6,000 YEAR OLD ESTUARINE DEPOSITS OF THE RAUKUMARA PENINSULA.

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Estuarine sediments at two locations along the eastern coast of the Raukumara Peninsula are being studied with the aim of obtaining a Holocene record of tectonic uplift along this segment of the Hikurangi Margin. During the early - middle Holocene estuaries commonly formed in drowned river valleys under post-glacial sea level rise conditions. At the Pakarae River mouth and Wharekahika River mouth (Hicks Bay) estuarine sediments deposited from ~10 ka to 6 ka have been preserved due to uplift. Estuarine geomorphology, faunal distribution and sediment deposition patterns are intricately related to sea level hence they are sensitive indicators of relative sea level change.

The Pakarae River sediments are exposed up to ~20m above modern mean sea level along a stretch of riverbank; this study concentrates on four sections where frequent alternations between silt, mud, sand and gravel are seen. At Hicks Bay the estuarine sediments were drilled to obtain two cores of 10 m and 12 m length, these are composed of peat, silt, and sand. At these locations we are seeking to distinguish between environmental change due to sea level rise and change which may be due to tectonic uplift (hence a relative fall in sea level). Our methodology for studying the estuarine sediments includes micropaleontology (foraminifera and diatoms), sedimentology, stable isotopes and comparisons with the geomorphology of modern estuaries.

That the sediments are above present sea level is unequivocal evidence of tectonic uplift since ~6 ka, their proximity to Holocene marine terraces and uplifted beach ridges supports this. The question we seek to answer regards the tempo of uplift: was it sudden or gradual? Were there intermittent large subduction zone earthquakes or was uplift achieved through slow, possibly aseismic processes? These results will have implications for the tectonics and seismic hazard of the Raukumara Peninsula - a part of the Hikurangi subduction zone uplifting relatively fast, displaying upper plate normal faults, and where the plate interface is currently believed to be weakly coupled.

ORAL

THE LANDSLIDE EVENT OF FEBRUARY 2004 IN GEOMORPHIC PERSPECTIVE

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In February 2004 a severe (1 in 100yr) storm impacted the lower half of the North Island. The Manawatu-Wanganui area experienced widespread and intense flooding and landslide damage. Landslide damage from the event occurred over an area of ~6500km² (Hancox, 2004). What are the implications of such damage in terms of geomorphic work done: sediment removal, transport, re-distribution, and transfer to fluvial systems; and changes to landforms? This ongoing study involves a general comparison (landslide density and range of damage) of this event with other rainfall-triggered, multiple landslide events (e.g. Bola 1988, Gisborne 2002, Wairarapa 1976), as well as a detailed examination (involving production of a sediment budget, mapping of individual landslides and creation of Digital Elevation Model) of a typical damaged catchment (figure 1) in the Mangawhero River hill country, near Wanganui.

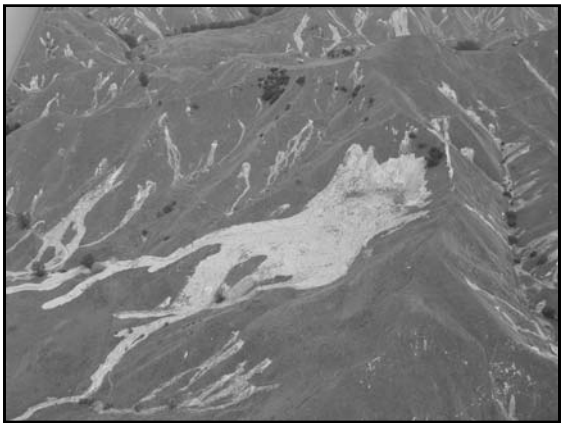

Figure 1. Study Catchment, Mangawhero River Valley
Photo: G Hancox

From these studies the February 2004 event can be placed into perspective in terms of frequency and magnitude. While some studies suggest that most geomorphic work is done by high frequency (~5yrs) -low magnitude events (Wolman and Millar, 1960), other studies (Selby 1974, Crozier and Glade 2000) suggest that low frequency-high magnitude events are required to produce large-scale and longer-term geomorphic change to hillslope and coupled fluvial systems.

ORAL

APPLICATION OF THE THERMOLUMINESCENCE TECHNIQUE FOR EVALUATION OF GEOTHERMAL ACTIVITY

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Thermoluminescence is a phenomenon that the mineral emits light when a rock is heated. This method has been applied to date archaeological and geological minerals younger than approximately 1 Ma. This technique has potential as a sensitive geothermal/geochemical sensor in geothermal systems because thermoluminescence is a thermally derived phenomenon, with the thermoluminescence signature of minerals and rocks in the geothermal setting strongly affected by alteration processes and natural heating. Laboratory analysis of quartz was undertaken to identify the effect of hydrothermal fluid and rock alteration in the active Waiotapu Geothermal Field, New Zealand. The results of measurements showed a strong relationship between "hydrothermal alteration" and "TL behaviour", especially related to "temperature effects" on quartz lattice defects (Fig. 1). Two-dimensional TL and spectroscopy of rock samples were measured for sample from the Kamaishi Mine, Japan. This rock sample includes the hydrothermal veins and surrounding altered zone. Results showed some differences between the altered and unaltered zones. Minerals in the altered zone showed stronger thermoluminescence than those in the unaltered zone (Fig. 2), and then different phenomena for wavelength could be observed between them. These results show possibilities of thermoluminescence techniques for geothermal exploration, and a new approach for geological applications, a chemical sensor that detects mass transport front in rocks. In addition, it may be possible to apply the thermoluminescence technique to evaluate environmental problems related to soil and rock pollution, or radioactive waste deposition.

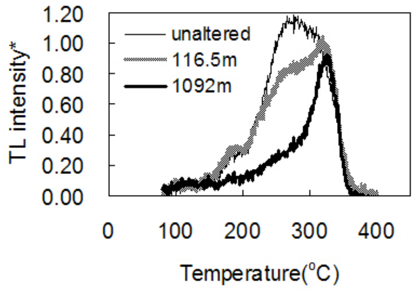

Figure 1. Artificial TL measurement of Waiotapu drillcore samples from different depths (different temperature).

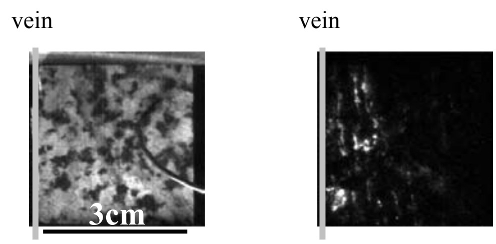

Figure 2. Result of two-dimensional TL measurement. Images on left side are samples in natural light and images on right side are natural TL (620 nm, 220°C).

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ADSORPTION BEHAVIOR OF GOLD(I)-THIOSULFATE COMPLEX ANIONS ON THE SURFACE OF ALUMINA AND SILICA GELS: APPROACH TO THE FORMATION MECHANISM OF LOW-SULFIDATION EPITHERMAL GOLD DEPOSITS

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In order to elucidate the chemical relationship between gold and aluminum in quartz veins of low-sulfidation epithermal gold deposits, it is important to investigate the role of aluminum for the enrichment of Au(I) ions. As the above model experiment, adsorption behavior of $[Au(S_2O_3)_2]^{3-}$ complex anions (Au(I)-S) on the surface alumina and silica gels was examined in this study. In the pH range of 4 to 9, the amount of Au(I)-S adsorbed on alumina gel decreased with increasing pH and the amount abruptly decreased between 6 and 7.

The amount became almost zero at pH 8 and 9 under 30 °C. Based on the zeta potential of the alumina gel, its isoelectric point was around pH 7, indicating that its surface charge was positive below pH 7. The both results suggest that the adsorption of Au(I)-S on the alumina gel was mainly controlled by electrostatic interaction. While, Au(I)-S were significantly adsorbed under 60 °C even at pH 8 and 9. This fact suggests that they were adsorbed due to formation of Al-O-Au bonds (chemical adsorption) at 60 °C. On the other hand, only a little adsorption of Au(I)-S occurred on the surface of silica gel at 30 °C and 60 °C. It deduce us that aluminum may play more important role for enrichment of gold than silica (quartz) during the formation of low-sulfidation epithermal gold deposits.

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RESERVOIR MODELLING OF THE OHAAKI GEOTHERMAL SYSTEM

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The Ohaaki geothermal system is situated on the eastern margin of the Taupo Volcanic Zone (TVZ). Following after Wairakei it was the second geothermal system in New Zealand to be developed. It is used primarily for electricity generation. Drilling started in the early 1960's and was followed by a long period of well testing. Then there was a period of approximately 15 years of field recovery before steam production for electric power generation started in 1988.
A large three-dimensional numerical model of Ohaaki geothermal system has been developed at the University of Auckland in collaboration with Contact Energy Limited (and its predecessors) over many years, and calibrated against data from the natural state, the well testing period, the recovery period and the production period.
Recently the model was reviewed and re-calibrated to improve the match between model results and measured data. This was done by changing the heat input at the base of the model and by adjusting the permeability structure. However, although the deep temperatures obtained in the re-calibrated model were closer to those indicated by deep drilling, the shallower temperature profiles, in general, needed further improvement.
In order to improve the match between model results and measured data it was decided that a more refined model was required. The new model has more and smaller blocks to allow better well-by-well matching. Also the model grid is better aligned with the faults in the Ohaaki area and the permeability structure was based on a recently developed three-dimensional geological model developed by IGNS. Thus the rock structure used in the new model, more closely matches the geological strata. The shallow groundwater data was also reviewed to give a better representation of the top surface of the model.
The development and calibration of the new Ohaaki model was assisted by the implementation of several new features in MULGRAPH (the University of Auckland graphical interface for the reservoir simulator TOUGH2), particularly the feature for matching temperature and pressure profiles in deviated wells.

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WHAT WAS MT. TARANAKI C. 120 000 YEARS AGO?

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The present day Mt. Taranaki is a 2518 m high stratovolcano, primarily made up of stacked layers of laharic and pyroclastic breccias and lava flows. Lithologies on the volcano span a large range between basaltic and dacitic compositions and the consequent range in eruptive processes in the recent geological past reflect this. It has been hypothesised that this volcano has evolved to its present state from a much more basic system with a much more restricted range in compositions. Hence, does the present state represent a mature stage of this relatively young volcano? Has there really been a trend of evolution to this present state? How long has it taken before this centre has been able to produce this range in compositions? These questions, along with elucidating the processes and cycles of growth and destruction of the volcano are the subject of a new PhD study being undertaken on Mt. Taranaki.
The first results of this study have been a surprise. Some of earliest identified deposits of Mt Egmont are the Motunui and Okawa Debris Avalanche deposits, exposed best in the coast near Waitara. These deposits represent two large-scale collapses of the proto Mt. Taranaki, and both units contain clasts that are primarily derived from this ancestral volcano. The nature of the deposits and the lithologies contained within imply that by c. 120 000 years ago and again at 100 000 years ago Mt. Taranaki was a high and unstable stratocone of an apparently similar composite structure to the present cone. Similarly, the range in compositions

present in these ancestral Taranaki deposits span a huge range of lithologies, almost as wide as those of the modern volcano. Clasts from this former edifice include evolved andesitic and dacitic glassy magmas that appear to have been produced by vesiculated sub-plinan style eruptions.

These initial results imply that at 120 000 years ago, ancestral Mt. Taranaki was already a large stratovolcano, producing a similar range of eruptive compositions and eruption styles as the modern volcano. This either indicates that Taranaki began as an apparently mature andesite volcano, or, more likely, that it is considerably older than we have thought until now.

POSTER

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