GEOLOGICAL SOCIETY OF NEW ZEALAND

NEW ZEALAND GEOPHYSICAL SOCIETY

Joint Conference

Geosciences '06 – Our Planet, Our Future

Massey University, Palmerston North
4-7 December 2006

Programme and Abstracts

__Editors__: Bob Stewart, Clel Wallace, Jérôme Lecointre, Martin Reyners

__Organising Committee__: Jérôme Lecointre (Convenor)
Bob Stewart, Clel Wallace, Julie Palmer,
Susan Ellis, Martin Reyners

__Professional Assistance__: Janet Simes (Conference Manager),
Sarah Siebert (Local Coordination)

Geological Society of New Zealand Miscellaneous Publication 122 A
ISBN N°. 0-908678-05-3

__INR Support Team__:

Moira Hubbard (secretariat), Mike Bretherton (computing)

__Student Helpers__: Susan Cole, Rachel Crimp, Kate Holt, Anja Moebis, Clare Robertson, and Anke Zernack.

CONFERENCE INFORMATION

Introduction

The Organising Committee would like to address a very warm welcome to all our delegates, especially to those of you who have made a special effort by travelling long distances in order to join us in the heart of the Manawatu. This year, our traditional annual gathering is co-organised with our colleagues from the New Zealand Geophysical Society. As such, we would like to facilitate contacts between professional geoscientists, students and amateurs, and the selection of scientific themes, and the social events offered, will provide excellent opportunities to maximize interactions between delegates. We hope you will enjoy your stay in Palmerston North. Take the time to explore our rejuvenated campus: new hostels, great food court and cafés with an international flavour, walking tracks meandering through our beautiful gardens…
We wish you a very fruitful and enjoyable Geosciences '06!

\- - - - - - - - - - - -

REGISTRATION

The Registration Desk will be open from Sunday 3rd December, 5pm, in the Foyer area of the Conference venue (**AgHort Lecture Block – blue star on map**). It will also be open each morning and during all breaks between sessions, morning/afternoon teas and lunches. Janet Simes, our Conference Organiser, will be on site to assist delegates with registration/accommodation/travel issues, while Beth Wallace, GSNZ Administrator, will be on site to collect your membership fee if it is due.

Schedule:

DAY	TIME	LOCATION
Sunday	5:00 – 6:30 pm	AgHort Foyer
Monday	8:00 – 9:00 am	AgHort Foyer
Tuesday	8:00 – 8:30 am	AgHort Foyer
Wednesday	8:00 – 8:30 am	AgHort Foyer
Thursday	8:00 – 8:30 am	AgHort Foyer

COMMUNICATIONS

Incoming messages will be displayed on a board sited next to the Registration Desk. If you need to be contacted during the conference, urgent messages can be left with Moira Hubbard, the INR - Soil & Earth Sciences Group secretary, **phone (06) 350.5799 Ext 7871;** fax: (06) 350.5632 or Moira's email: M.Hubbard@massey.ac.nz

Please, **switch off your mobile phones in the lecture theatres** during the conference. Thank you!

PARKING AND TRANSPORTATION

Weekday user pays, casual parking is available at Turitea on Orchard Road near the Recreation Centre and on Bourke Road on the upper terrace by the Massey Child Care Centre (**red stars on the map**). Also, some coin-activated, metered parking is available around University Avenue and the Commercial Complex carpark at Turitea.

Instructions:

Anyone will be able to enter the public carparks.

To exit a car park, drivers will need to have paid a $2/day "casual user" charge and have obtained a ticket from the dispensing machine (usually on entry). As a casual user, it's up to you whether you obtain your ticket immediately after entering the carpark or just before you are due to leave.

There are at least two ticket machines in each public carpark.

The machines accept coins (20c, 50c, $1, $2) and notes ($5, $10, $20).
The machines will dispense change.
The machine will dispense a ticket which is valid for 3 exits to 12pm (midnight) for the day of purchase.
There are two types of reader at each exit to the carpark; one reads the barcode on the ticket purchased by the casual user.
The barcoded ticket will allow you multiple (3) entries/exits for the carpark for the day of purchase.
If you leave the carpark but know you will return on the same day, **do not throw your ticket away** or you will need to buy a new one.
You are not required to display the ticket on your dashboard or in your windscreen.
Don't litter, there are rubbish bins provided in carpark for your used tickets. Thank you!

Notes:

- *Parking is also available next to the accommodation blocks (new student hostels).*
- *A limited number of parking spaces located next to the AgHort Complex (**blue star on map**) will be available ONLY to Sponsors / Exhibitors and Conference Management.*
- *Bus city services are available from the large central car park located behind Science Tower B (**green star on map**). Enquire at Registration Desk for the current timetable.*

MEALS

Morning and afternoon teas, together with lunches, will be provided during the conference (Monday 4 - Thursday 7) in the Foyer Area of the AgHort Lecture Block.

This arrangement should allow people to mix easily during breaks while looking at posters, browsing at exhibitor stands or simply, enjoying a chat with a cup of coffee in hand. Note that lunch packs will be provided to delegates who are joining fieldtrips before or after the conference. Other cash-basis eating facilities are accessible on campus: new Student and Staff Food Court, Options Café in the Commercial Complex, and Wharerata (ex-staff Club).

ORAL PAPERS

All oral papers are scheduled for 20 minutes, **which includes 5 minutes for questions and discussion. Plenary papers** are delivered over a longer time slot**, not exceeding 30 minutes,** including questions/discussion. **These limits will be strictly enforced by the session chairpersons.** We ask that all speakers be ready to give their presentation promptly please.

Papers have been grouped accordingly to the wishes of their authors or by the editors, and distributed across the 5 suggested symposia:

A. Geohazards (Assessment, Reduction, Mitigation; Planning and Management issues)
Convener: Bob Stewart (Massey University)

B. GIS and applications in Geosciences

Conveners: Arne Pallentin (NIWA), Mark Rattenbury (GNS Science) and Jonathan Procter (Massey University)

C. Volcanogenic sedimentation in the SW Pacific

Conveners: Vern Manville (GNS Science, Taupo) and Karoly Nemeth (Massey University)

D. Crust and upper mantle structure of the central North Island and its development over time

Convener: Martin Reyners (GNS Science)

E. General Geology

Five different rooms will be available during the conference. AH 1 (Main auditorium/Plenary sessions), AH2 and AH3 will be used for oral presentations. AH5 will be used as an AV-IT preparation room where speakers will be able to check their Powerpoint presentations and/or slides. A quiet space (AgHort Postgraduate Students Common Room), located in the basement of the complex, will be available for private work and/or meetings.

Please ensure your Powerpoint presentation is checked and properly loaded well in advance in the venue IT system. Plan ahead in order to be familiarised with the light and IT room controls. Do not hesitate to ask a student assistant for help.

As there will be concurrent sessions during much of the conference, changeover times will be synchronised. Lecture theatres will contain one data projector (for PowerPoint presentations only). An overhead projector will also be available in each room. Note that slide projectors (Kodak Carousel type) are available in AH1 and AH2.

Delegates who have requested special computing/AV arrangements for their presentation are required to liaise with Jérôme Lecointre and/or Mike Bretherton at the very beginning of the conference.

POSTERS

Coordinator: Clel Wallace

Posters will be displayed in the AgHort foyer during most of the conference. The poster boards will be numbered and a list indicating the number for an individual poster will be displayed on a Poster Information Board.

Posters may be set up from 8 am on Monday but they MUST be set up by Monday's afternoon tea break. To facilitate viewing and judging, **posters should NOT be removed before Thursday's afternoon tea break.**

A formal poster session is programmed at 9:05 on Tuesday and authors should be present, next to their poster, during this session. To facilitate further contact, authors of posters are asked to fill out the "Author(s) attendance" cards to identify the lunch and tea breaks during which they will voluntarily attend their poster. There will be cards attached to each poster site for this purpose. Authors are asked to ensure that they are present at the times that they have specified.

MEETINGS

Several meetings are being planned during the conference and final times and venues will be confirmed later and shown on the Information Board. Currently, the following have been arranged:

- The Geological Society of New Zealand AGM will take place in AH1 on Wednesday 6 at 4:30pm.
- A breakfast meeting of the National GSNZ Committee will be held at Wharerata on Thursday 7 (time to be confirmed).
- The Palaeontology Special Interest Group will meet on Tuesday 5 at lunch time.
- The Fossil Record File Subcommittee will be convened on Monday 4 at lunch time.

SOCIAL EVENTS

- *Icebreaker Function: a special event organised by Massey-INR Postgraduate Students*

  Location: AgHort Common Room (basement) and Terrace (weather permitting!)
  Date and Time: Sunday 3 December from 6:00 pm.
  Finger food and 2 drink vouchers provided

- *BBQ and Entertainement at Marton: A Cultural Experience*

Location: Turakina Maori Girls' College, Marton
Transport: by bus
Date and Time: Monday 4 December – Departure: 6:00pm from University Avenue, at the bus stop located near Residential Services (**yellow star**). Return departs: 9-9:30 pm approx. A cash bar will be available – NB: there will be NO EFTPOS on site.

- *Conference Dinner: "From Cannes to Cancans"*

  Location: Novotel, Palmerston North (Carlton 2)
  Transport: by bus
  Date and Time: Wednesday 6 December – Departure: 6:15 pm from University Avenue, at the bus stop located near Residential Services (**yellow star**). Dinner starts at 7 pm.

  Participants are encouraged to get dressed appropriately for the evening – Prizes will be awarded to the best costumes spotted during the evening by an anonymous jury.

CAMPUS FACILITIES

- The Commercial Complex is still adjacent to the main Campus Entrance, with direct access from the Wellington to Palmerston North road (**brown star on map**). Note however that relocation of some of the shops is underway towards the central forum (concourse) of the campus (in the newly renovated Student Union Building).

- The following banks are represented on Campus:
  - National Bank (agency with ATM on concourse, Student Union Building)
  - Westpac NZ (ATM on concourse, next to Registry building)
  - BNZ Bank (ATM in Commercial Complex)
  - Kiwi Bank (ATM next to Aston Lecture Theatre/Science Tower A)

- Limited NZ Post mail services are available at Bennetts Bookshop (Commercial Complex).

- Medical facilities: in the event of a medical emergency during the day, contact the **Massey University Medical Centre, extension 5533/2787**. After hours, contact **City Doctors**, 22 Victoria Avenue, Palmerston North (**phone 355.3300**).

	PROGRAMME	
	SUNDAY - 3rd December.	
	Pre-conference field trips return.	
	Field trip 1 .	Sloss, C.: Holocene succession - Manawatu coastal plain.
	Field trip 2 .	Palmer, A., Begg, J. & Townsend, D.: Manawatu & Rangitikei geology.
	Field trip 3 .	Hancox, G. & Perrin, N.: Landslide & slope stability.
5.00 - 6.30pm	Registration	
6.00 pm	Ice-breaker function	
	AgHort Common Room.	

	MONDAY - 4th December.	
8.00 - 9.00 and inter-session breaks.	Registration	
	AgHort 1	Aghort 2
9.00 am	**Chair - Jérôme Lecointre**	
9.00 - 9.45	**Opening ceremony**	
	Professor Judith Kinnear, Vice-Chancellor, Massey University	
	Heather Tanguay, Mayor, Palmerston North	
	Dr Keith Lewis - President, Geological Society	
	Dr Susan Ellis - President, Geophysical Society	
9.50 - 10.20	Plenary 1	
	Sutherland R. - The Marsden Fund: how the Earth Sciences and Astronomy selection panel operates.	
	Notices	
10.25 - 10.50	Morning tea	Morning tea
10.50 - 12.10	**Chair - Bob Stewart**	**Chair - Alan Palmer**
	Geohazards Symposium	**General Geology**
10.50 - 11.10	Turner MB *et al* - Identifying eruption types and implicit hazards from distal tephra deposits.	Woodward C & Schulmeister J - Lord of the flies: what can the world's most common fly tell us about long-term environmental change.
11.10 - 11.30	Bebbington M *et al* - Merging lake cores: towards an integrated Holocene eruptive record of Mt Taranaki.	Litchfield N *et al* - Holocene coastal uplift and erosion in western Hawke Bay: evidence from fluvial terraces.
11.30 - 11.50	Von Veh MW - Vent alignments in the Auckland volcanic field and their significance for volcanic risk assessment.	Shulmeister J *et al* - Diminishing glaciations of the Southern Hemisphere mid-latitudes.
11.50 - 12.10	Kuehler T *et al* - Changes in attenuation related to eruptions of Mt Ruapehu volcano.	Nolan E. - Relative age dating of the Wahianoa moraines, Mt Ruapehu.
12.10 - 1.00	Lunch Fossil Record File Meeting	Lunch
1.00 - 1.30	Plenary 2	
	Chair - Mark Rattenbury	
	Garlick, R. - Data management initiatives at Crown Minerals.	
	Notices	

	MONDAY (continued).	
1.40 - 3.20	**Chair - Jim Cole**	**Chair - Karoly Nemeth**
	Geohazards Symposium	**Volcanology**
1.40 - 2.00	Christenson B *et al* - The 2006 eruption of Raoul Volcano (Kermadecs): a magmatic-hydrothermal event from a hydrothermally-sealed volcanic conduit system.	Guegan EBM & White JDL. - Shallow intrusion conditions in a flood-basalt province; The story from dykes and a sill offshoot along the contact between a vent complex and country rock, Combs Hills, Ferrar Province, Antarctica.
2.00 - 2.20	Manville V & Cronin SJ. - Learning from lahars: understanding the Ruapehu break-out lahar.	Shane P *et al* - Magmatic history of the Tarawera Volcanic Complex.
2.20 - 2.40	Cole S *et al* - Understanding the internal dynamics of lahars using geophysical techniques.	Doyle LR *et al* - The geochemistry and petrography of the 36.8 ka Maketu eruption episode, Okataina Volcanic Centre.
2.40 - 3.00	Patterson N. - Expansion of the GeoNet Seismograph Networks.	Spargo SRW *et al* - Pupuke; one volcano or three?
3.00 - 3.20	Douglas A *et al* - New Zealand Geonet: recording slow slip along the Hikurangi subduction margin.	Fagan CJ *et al* - Stratigraphy, hydrothermal alteration, and evolution of the Mangakino geothermal system, Taupo Volcanic Zone, New Zealand.
3.20 - 3.50	Afternoon tea	Afternoon tea
3.50 - 5.35	**Chair - Hamish Campbell**	**Chair - Richard Norris**
	Geohazards Synposium	**General Geology**
3.50 - 3.55	Notices	Notices
3.55 - 4.15	Cochran U *et al* - On the trail of large subduction earthquakes at the Hikurangi margin.	Jugum D *et al* - New perspectives on the Dun Mountain Ophiolite Belt.
4.15 - 4.35	Delahaye E *et al* - Seismic tremor and small earthquakes associated with slow slip in the Hikurangi subduction zone.	Bourguignon S *et al* - Lithospheric deformation beneath the Southern Alps.
4.35 - 4.55	Sutherland R *et al* - Do great earthquakes occur on the Alpine Fault in central South Island, New Zealand?	Wilson K *et al* - Relationships between late Quaternary coastal geomorphology and subduction zone geodynamics of the Raukumara sector of the Hikurangi margin.
4.55 - 5.15	Little T *et al* - A provisional late Holocene history of surface rupturing earthquakes on the southern part of the Wairarapa Fault.	Christie-Blick N *et al* - Insights on the low-angle normal fault paradox from the Basin and Range Province, Western United States.
5.15 - 5.35	Tormann T *et al* - Time, distance and magnitude dependence of foreshocks in New Zealand.	
6.00 pm	Buses depart for BBQ and performance at Turakina Maori Girls' College (Marton).	
	BBQ 7.30pm	
	NB: Drinks will be available to buy but there is no EFTPOS at the College.	

	TUESDAY - 5th December.	
8.00 - 8.30 and inter-session breaks	Registration continued	
	AgHort 1	AgHort 2
8.30 - 9.00	Plenary 3	
	Chair - Bob Stewart	
	Nathan S. - Te Ara: putting New Zealand Earth Science on the web.	
	Notices	
9.05 - 9.50	Poster session in the Main Foyer.	
	See the list of posters at the end of this timetable.	
9.50 - 10.20	Morning tea	Morning tea
10.20 -12MD	**Chair - Brad Pillans**	**Chair - Julie Palmer**
	Geohazards Symposium	**General Geology**
10.20 - 10.40	Saunders WSA & Glassey P - Landslide guidelines for consent & policy planners - bridging the gap between geological hazards and land use planning.	Armiho R. *et al* - Submarine fault scarps in the sea of Marmara pull-apart (North Anatolian Fault): implications for seismic hazards in Istambul.
10.40 - 11.00	Mazengarb C & Selkirk-Bell J. - Toward an understanding of regional landslide risk in Tasmania.	Buech F *et al* - The Little Red Hill field experiment: seismic response of an edifice.
11.00 - 11.20	McSaveney M. - Why calculate fracture-surface energy?	Pere V *et al* - Constraints on antiscarp formation from physical and numerical modelling.
11.20 - 11.40	Martelli KM & Woodmansey PR. - The management of, and possible management options for debris flows at Pipson Creek, State Highway 6, Makarora, Otago, New Zealand.	Hayward B *et al* - Foraminiferal evidence of large Holocene earthquake displacements in coastal South Otago.
11.40 - 12MD	Lecointre J & Valade S. - Analog modeling of clay-rich debris flows - experimental challenges and preliminary results.	Gorman A *et al* - Geophysical characterisation of the Foulden Hills Maar, near Middlemarch, Otago.
12.00 - 1.00	Lunch Palaeontology Meeting	Lunch
1.00 - 1.30	Plenary 4	
	Chair - Martin Reyners	
	Bibby HM *et al* - Imaging the magma factory: magnetotellurics in the TVZ.	
	Notices	

	TUESDAY (continued).	
1.40 - 3.20	**Chair - Vern Manville**	**Chair - Susan Ellis**
	Geohazards Symposium	**Crust & Mantle Structure Symposium**
1.40 - 2.00	Price S. - Geotechnical assessment of founding conditions for large wind turbines, Tararua Ranges, New Zealand.	Mortimer N. - Cretaceous-Cenozoic Zealandia: Did Pacific subduction ever stop?
2.00 - 2.20	Heron *et al* - Innovative use of geological information for planning and decision-making.	Stratford WR & Stern TA - Active rifting in the central volcanic region, North Island, New Zealand.
2.20 - 2.40	Lindsay J. - the challenge of communicating multiple hazards from multiple adjacent volcanoes: An example from Dominica, eastern Caribbean.	Salmon M *et al* - Geophysical evidence for convectively removed mantle and lower crust below the northwestern North Island.
2.40 - 3.00	Nemeth K & Cronin S. - Lessons for volcano emergency management from the response to the December 2005 crater lake eruption of Ambae Volcano, Vanuatu.	Stern TA *et al* - Uplift of the western-central North Island due to convective removal of upper mantle and lower crust.
3.00 - 3.20	Cole J *et al* - Potential effects of ash from a volcanic eruption on urban and rural infrastructure and lifelines.	Reyners M *et al* - The role of fluids in the evolution of the Taupo Volcanic Zone.
3.20 - 3.50	Afternoon tea	Afternoon tea
3.50 - 5.35	**Chair - Jamie Shulmeister**	**Chair - Tim Stern**
	Geohazards Symposium & General Geology	**Crust & Mantle Structure Symposium**
3.50 - 3.55	Notices	Notices
3.55 - 4.15	Hochstein MP & Prebble WM - Major engineering constructions on top of a high-temperature geothermal prospect: hazards encountered at Tokaanu (N.Z.).	Sherburn S *et al* - Seismic velocity structure of the Taupo Volcanic Zone.
4.15 - 4.35	McMillan HK & Brasington J. - End-to-end flood risk assessment: a model cascade with uncertainty estimation.	Seward AM *et al* - Thermal and mechanical properties of the upper mantle beneath the central North Island, New Zealand.
4.35 - 4.55	Law C *et al* - Preliminary investigation of cold seeps as methane sources off southeastern North Island.	Greve SM & Savage MK. - Strong variations in seismic anisotropy across the Hikurangi subduction zone, central North Island.
4.55 - 5.15	Senger K & Gorman AR. - Wedges at the top of the gas hydrate stability zone: an example from the Canterbury slope, New Zealand.	Eberhart-Phillips D *et al* - 3-D distribution of anisotropy and attenuation in the Hikurangi subduction zone.
5.15 - 5.35	Ring U *et al* - Dating mylonitisation in the Paparoa Core Complex, Westland.	Ewig E & Stern T. - Lithospheric shortening and ductile deformation in a back-arc setting: Wanganui Basin.

	WEDNESDAY 6th December	
8.00 - 8.30 and inter-session breaks	Registration continued	
8.30 am	Mid-conference, half-day, field trip 4 departs.	Trust Power staff: The Tararua wind farm.
12.30 - 1.30	Lunch	Lunch
	Aghort 1	AgHort 2
1.30 - 3.00	**Chair - Bruce Hayward**	**Chair - Andrew Gorman**
	General Geology	**Crust & Mantle Structure Symposium**
	Notices	Notices
1.40 - 2.00	Morrison B *et al* - Fossil record file and national paleontological collection and database - what's new?	Oliver N *et al* - Coupled modelling of heat flow, fluid flow and extension in the Taupo Volcanic Zone: the role of basement faults.
2.00 - 2.20	Todd A *et al* - Developing an on-line atlas of New Zealand fossil pollen types, with an integrated pollen identification guide to assist novice palynologists.	Cole J *et al* - Modelling subvolcanic plumbing systems beneath Okataina Caldera Complex, Taupo Volcanic Zone.
2.20 - 2.40	Eagle M. - Early Triassic crinoids: the New Zealand record and taxonomic implications.	Clarke D *et al* - Seismicity in Taupo Volcanic Zone geothermal systems: preliminary relocation results from Kawerau and Rotorua.
2.40 - 3.00	Daymond-King R *et al* - Architecture and palaeoecology of early Miocene (Otaian) channelised slope deposits at Orongo Point, Okahukura Peninsula, Kaipara, Harbour.	Toulmin SJ & Stern TA - The geophysical exploration of a transtensional basin: Galatea Basin, eastern North Island.
3.00 - 3.30	Afternoon tea	Afternoon tea
3.30 - 4.30	**Chair - Jack Grant-Mackie**	**Chair - Martin Reyners**
	General Geology	**Crust & Mantle Structure Symposium**
3.30 - 3.50	Grenfell HR & Hayward BW. - A microfossil record of estuarine change (Mahurangi Harbour, Northland).	Mouslopoulou V *et al* - Quaternary kinematics and temporal stability of a strike-slip and normal fault intersection, North Island, New Zealand.
3.50 - 4.10	Gregory M *et al* - Moa trackways and footprints: three new discoveries.	Smith EGC *et al* - Principal component analysis and modeling of the subsidence of the shoreline of Lake Taupo, New Zealand, 1983-1999: evidence for de-watering of a magamatic intrusion?
4.10 - 4.30	Pope J *et al* - Control on acid mine drainage chemistry, West Coast, South Island.	Leitner B *et al* - 3D seismic interpretation of the Kupe field area.
4.30 - 5.30	GSNZ AGM	
6.15 pm	Buses depart for DINNER at Novotel.	

	THURSDAY - 7th December.	
8.00 - 8.30 and inter-session breaks	Registration continued	
	AgHort 1	AgHort 2
8.30 - 9.00	Plenary 5	
	Chair: Clel Wallace	
	Pollock J *et al* - Future directions in New Zealand geosciences education - the place of earth science in the science curriculum.	
	Notices	
9.10 - 10.10	**Chair - Clel Wallace**	**Chair - Martha Savage**
	Volcanic Sedimentation Symposium	**Crust & Mantle Structure Symposium**
9.10 - 9.30	Cronin S *et al* - Volcanic hazards planning on rifting island and fissure volcanoes.	Lin F-C *et al* - Something for nothing? Ambient noise Rayleigh wave tomography in New Zealand.
9.30 - 9.50	Thouret JC *et al* - The Whangaehu Formation: a massive debris-avalanche from ancestral Ruapehu?	Langridge R *et al* - Results from recent paleoseismic studies on the Wellington Fault.
9.50 - 10.10	Marx R *et al* - Varying sedimentary facies of six late Miocene age marine tephra beds, East Coast Basin, North Island, New Zealand.	Nicol A *et al* - Large (>50 km) post-Oligocene strike-slip displacements in the North Island; fact or fiction?
10.10 - 10.40	Morning tea	Morning tea
10.40 -12MD	**Chair - Jon Procter**	**Chair - Vince Neall**
	GIS Symposium & General Geology	**General Geology**
10.40 - 11.00	Brathwaite R *et al* - Geology and geochemistry of metalliferrous sediments and the associated Matakaoa Volcanics, East Cape, New Zealand.	Grigull S *et al* - Rheological investigations of natural quartz in a brittle-ductile shear array, central Southern Alps, New Zealand.
11.00 - 11.20	Heron D & Lukovic B. - Geological data - venturing beyond the paper map.	Norris RJ & Cooper AF. - The Alpine Fault mylonites: a zone of localised ductile shear within the mid to lower crust.
11.20 - 11.40	Chapman I *et al* – Preliminary results from a GIS-based utility infrastructure volcanic risk evaluation in Taranaki.	Adams CJ *et al* - Zircon evidence for Early Jurassic age interpretation of transition basement rocks of the central North Island.
11.40 -12MD	Rattenbury, MS. - Qmap 2010 and future geological data needs.	Nicholson K *et al* - The Noumea Basin and Mt Camel Terrane: evidence for large scale subduction during the late Cretaceous.
12.00 - 1.00	Lunch	Lunch
1.00 - 1.30	Plenary 6	
	Chair - Alan Palmer	
	Pillans B. Defining the Quaternary.	
	Notices	

	THURSDAY (continued).	
1.40 - 3.20	**Chair - Mark Rattenbury**	
	GIS Symposium	
1.40 - 2.00	Mazengarb C. - Advances in the extraction of photogeological interpretation into GIS.	
2.00 - 2.20	Lee J *et al* - Identifying areas of flooding using remote sensing and GIS - a case study from the Manawatu storm, February 2004.	
2.20 - 2.40	White P *et al* - Geological models of the Taupo Volcanic Zone.	
2.40 - 3.00	Pallentin A *et al* - Nearshore habitat mapping from multibeam bathymetry.	
3.00 - 3.30	Afternoon tea	
3.30 pm	Closing Ceremony and Student Awards	

	FRIDAY - 8th December.	
8.00 am	Post-conference; field trip 5:	Stewart, R., Zernack, A. & Procter, J.: Volcanic garbology.

	POSTERS	
	Author(s)	**Title**
45	Bannister S, Toulmin S; Henrys S, Reyners M, Pecher I, Barker D, Uruski C & Maslen G.	Imaging the subduction decollement, Hikurangi subduction zone, New Zealand.
1	Becker J, Van Dissen R, Langridge R & Heron D.	From science to practice: use of the active faults guidelines and considerations for geoscientists.
19	Beinlich A, Cooper AF & Palin JM.	Petrology and thermochronology of the deep crust of Zealandia: evidence from the Pigroot Creek, Eastern Otago.
47	Benson AM, Stern TA & Bannister SC.	Crustal structure and bright reflectors under the Taupo Volcanic Zone.
43	Bland L & Page S.	GEONET: Monitoring New Zealand's natural hazards.
2	Carrivick J, Manville V & Cronin SJ.	Modelling a dam break flood from the crater lake of Mt Ruapehu.
20	Crutchley G, Gorman AR & Pecher IA.	Focussed fluid flow beneath an anticline in the Hikurangi margin gas hydrate province, New Zealand.
48	Davey FJ.	Crustal seismic reflection measurements off central North Island - a re-appraisal.
21	Edwards A.	First record of possible Heinrich events in New Zealand.
46	Ellis S. & Wallace L.	Rapid microplate rotation at subduction zones: testing the effect of buoyant indentors using work rate minimization and numerical models.
3	Fohrmann M, Gorman AR & Pecher IA.	Does the presence of gas hydrate on the Hikurangi margin contribute to slope failure?
44	Geonet Volcano Monitoring Group (Sherburn S).	Seismic unrest at Ngauruhoe Volcano.
22	Gorman AR & Ghisetti FC	Seismic reflection imaging of the Ostler Fault, west MacKenzie Country, South Island.
36	Gruender K, Stewart RB & Foley S.	Xenoliths of the subvolcanic lithosphere, Taranaki, New Zealand.
23	Haffert L & Craw D.	Controls on arsenic mobilization and attenuation in the Reefton gold field, Westland, N.Z.
11	Hampton SJ & Cole JW.	Volcanic reconstruction and collapse recognition: a GIS-based approach.
49	Heise W, Bibby H, Caldwell T, Ogawa Y, Takakura S & Uchida T.	Conductivity image of the Taupo Volcanic Zone, New Zealand.
24	Holt K.	Chatham Island Quaternary stratigraphy: an overview.
25	Hyatt O, Shulmeister J, Thackray GD & Evans DJA.	Glacial geomorphology of the middle Rakaia valley, Canterbury, New Zealand.
12	Irwin M, Tuohy M & Cronin S.	Mapping hydrothermal alteration products on Mt Tongariro using hyperion data.

4	Kaye G, King A, Cole J, Johnston D & Wilson T.	Volcanic hazard risk assessment in the Riskscape program - review of existing inventory fragility models and test application in the Rotorua District, N.Z.
26	Kennedy E, Crouch EM, Raine JI, Handley L & Pancost RD.	Paleocene-Eocene transition in South Island terrestrial to marginal marine sections.
13	Kilgour GN & Esler W.	Basal Mamaku ignimbrite: results from recent groundwater drilling in Rotorua.
27	Kilner JW, Norris RJ & Gorman AR.	Seismic imaging of eastern Otago active fault structures.
28	Martin A.	Mantle metasomatism beneath the Ross Sea, Antarctica.
29	Matthews NE, Cole JW & Weaver SW.	Subvolcanic magma reservoirs beneath the Okataina Caldera Complex, Taupo Volcanic Zone.
30	Möebis A & Cronin S.	Opening a Pandora's box: complexity within the Mangatawai Tephra Formation, Tongariro Volcanic Centre.
50	Mortimer N.	Crustal structure of the central North Island basement: a petrotectonic perspective.
5	Mountjoy JM, Barnes PM & Pettinga JR.	Quantifying submarine landslide processes driven by active tectonic forcing: Cook Strait submarine canyon, New Zealand.
6	Mueller A & Davies T.	Interactions of debris/rock avalanches with runout path material - a laboratory approach.
14	Nemeth K & White C.	Intravent peperites in an eroded phreatomagmatic volcano of the western Snake River Plain Volcanic Field, Idaho (USA) and their implication for field-wide eruptive environment reconstruction.
51	O'Keefe B, Smith E & Savage M.	Seismicity of the central Alpine Fault.
31	Paulsen H.	Fenitisation on Mount Morning, southern Victoria Land, Antarctica.
15	Procter J, Zernack A & Cronin S.	Contrasting rheologies representd by volcanic flows deposits west of Mt Taranaki, New Zealand.
32	Rajasekhar VB, Davey R, Das I, Savage M, Little T, Greve S & Louie J.	Petrofabrics and seismic waves speeds of the Red Mountain ophiolites, South Island, New Zealand.
33	Robertson E de J, Smith EGC & Robinson R.	Towards a local Mw scale for New Zealand.
16	Rosenberg MD, Thomas FR & Kilgour GN.	Sea-rafted pumice at Mili Atoll, Marshall Islands: 3000km from source.
34	Sabaa A, Hayward B, Grenfell H & Neil H.	Mapping the deep sea: New Zealand's deep sea foraminifera.
7	Smith RT, Scott BJ, Hobden BJ & Leonard G.	Preliminary hazard impact zones for the next Ngauruhoe eruption.
35	Smith VC, Nairn IA & Shane P.	Further insights into pre-eruption processes at Tarawera, Okataina Volcanic Centre, using melt inclusions.
52	Staff & Students, Instiitute of Geophysics. VUW (Stern T).	Crust and upper mantle structure research, central North Island: a summary of recent results from the Institute of Geophysics (VUW).

53	Stagpoole VM, Bennie SL, Bibby HM, Ingham MR & Dravitzki S.	Upper crustal structure of the Taranaki Fault imaged by a magnetotelluric survey.
37	Talusani RVR.	Nd-Sr isotopic and trace element constraints on the origin of Late Pleistocene Barambah basalts, northern New England Fold Belt, Australia.
38	Tapia C, Wilson G, Ishman S & Wilke H.	Magnetostratigraphy of Pliocene marine cyclicity, Peninsula of Mejillones, northern Chile.
39	Tinto K & Wilson GS.	Magnetic behaviour of Paleogene sediments in the Canterbury Basin.
8	Townsend D.	QMAP Taranaki progress - 2006.
40	Toy VG & Norris RJ.	Effects of pre-existing fabric, high strain and kinematic vorticity number on lineation development in the Alpine Fault zone.
41	Turnbull R, Weaver SD & Tulloch AJ.	Mingling and mixing on Stewart Island.
54	Wessel A, Savage M, Hurst T & Sherburn S.	Seismic anisotropy monitoring at Mt Ruapehu Volcano.
9	Wilson T, Kaye G, Cole J, Johnston D & Cronin S.	Exposure of the New Zealand dairy industry to tephra fall using probabilistic and scenario based models.
42	Woodward C & Schulmeister J.	Lord of the flies: what can the world's most common fly tell us about long-term environmental change.
10	Zeeden C & Wilson GS.	A high-resolution 200 k.y. paleomagnetic record from offshore East Cape, New Zealand.
17	Zernack AV, Procter JN & Cronin SJ.	Cyclic volcaniclastic sedimentation at Mt. Taranaki, NZ - a history of growth and destruction.
18	Zernack AV, Stewart RB & Price RC.	Slab or crust - K_2O enrichment at Mt Taranaki, New Zealand.

Note: Numbers refer to the location of the poster in the poster display area of the AgHort. Foyer.

PAPER

ZIRCON EVIDENCE FOR EARLY JURASSIC AGE INTERPRETATION OF TRANSITION BASEMENT ROCKS OF THE CENTRAL NORTH ISLAND

C. J. Adams, H. J. Campbell and N Mortimer
GNS Science, PO Box 30368, Lower Hutt, New Zealand
argon@gns.cri.nz

U-Pb detrital zircon age patterns of basement Waipapa and Torlesse terrane greywacke in the central North Island are used to supplement meagre fossil evidence of their stratigraphic age. Together with Sr-isotope variations, these establish a western zone of Late Jurassic Waipapa terrane rocks extending southwards from the Auckland (Hunua) to Morrinsville, west of Lake Taupo, through Tongariro National Park and the Wanganui region to Kapiti Island. An eastern zone of Late Triassic Torlesse Composite (Rakaia) terrane rocks extends northwards from the Wellington region, through the Tararua and Ruahine Ranges. Surprisingly, there is a large intervening region, essentially occupying the Kaimanawa and Kaweka Ranges that are of probable Early Jurassic age with both Torlesse- and Waipapa-like characteristics. These successions may thus fill an Early Jurassic stratigraphic gap in both Waipapa and Torlesse terrane stratigraphy.

PAPER

SUBMARINE FAULT SCARPS IN THE SEA OF MARMARA PULL-APART (NORTH ANATOLIAN FAULT): IMPLICATIONS FOR SEISMIC HAZARD IN ISTANBUL

R. Armijo[1], N. Pondard[1], B. Meyer[1], G. Uçarkus[1], B. Mercier de Lépinay[2] & the MARMARASCARPS cruise party
[1]Institut de Physique du Globe de Paris, 4 place Jussieu, Paris 75252, France
[2] Geosciences-Azur, Université Nice Sophia-Antipolis, 250 rue Albert Einstein, F 06560 Valbonne, France
(pondard@ipgp.jussieu.fr)

Earthquake scarps associated with recent historical events have been found on the floor of the Sea of Marmara, along the North Anatolian Fault (NAF). The MARMARASCARPS cruise using an unmanned submersible (ROV) provide direct observations to study the fine-scale morphology and geology of those scarps, their distribution and geometry. The observations are consistent with the diversity of fault mechanisms and the fault segmentation within the north Marmara extensional step-over, between the strike-slip Ganos and Izmit Faults. Smaller strike-slip segments and pull-apart basins alternate within the main step-over, commonly combining strike-slip and extension. Rapid sedimentation rates of 1-3 mm/yr appear to compete with normal faulting components of up to 6 mm/yr at the pull-apart margins. In spite of the fast sedimentation rates the submarine scarps are preserved and accumulate relief. Sets of youthful earthquake scarps extend offshore from the Ganos and Izmit Faults on land into the Sea of Marmara. Our observations suggest that they correspond to the submarine ruptures of the 1999 Izmit (Mw 7.4) and the 1912 Ganos (Ms 7.4) earthquakes. While the 1999 rupture ends at the immediate eastern entrance of the extensional Cinarcik Basin, the 1912 rupture appears to have crossed the Ganos restraining bend into the Sea of Marmara floor for 60 km with a right-lateral slip of 5 m, ending in the Central Basin step-over. From the Gulf of Saros to Marmara the total 1912 rupture length is probably about 140 km not 50 km as previously thought. The direct observations of submarine scarps in Marmara are critical to defining barriers that have arrested past earthquakes as well as defining a possible segmentation of the contemporary state of loading. Incorporating the submarine scarp evidence modifies substantially our understanding of the current state of loading along the NAF next to Istanbul. Coulomb stress modelling shows a zone of maximum loading with at least 4-5 m of slip deficit encompassing the strike-slip segment 70 km long between the Cinarcik and Central Basins. That segment alone would be capable of generating a large magnitude earthquake (Mw 7.2). Other segments in Marmara appear less loaded.

POSTER

IMAGING THE SUBDUCTION DECOLLEMENT, HIKURANGI SUBDUCTION ZONE, NEW ZEALAND

S. Bannister, S. Toulmin, S. Henrys, M. Reyners, I. Pecher, D. Barker, C. Uruski, G. Maslen
GNS Science, P O Box 30-368, Lower Hutt, Wellington.
(s.bannister@gns.cri.nz)

Beneath the eastern coastline of North Island, New Zealand, the subducted Pacific plate dips at less than 3 degrees to the northwest and the subduction decollement is at a depth of less than 15 km. The active-source NIGHT and passive-source CNIPSE experiments carried out in 2001 image the shallow dipping decollement down to more than 6 s (twt) at which point it steepens landward, 120 km from the Hikurangi trench. This change in dip appears to be closely associated with the onset of seismogenesis in the subducted plate. Velocity inversion of CNIPSE earthquake times reveals the forearc to be a relatively low Vp (< 5.5 km/s), high Vp/Vs (>1.85), high Poisson's ratio (>0.29) region overlying the 12-15 km thick subducted crust. In March-May 2005 a new industry-seismic survey, 05CM, was carried out offshore the east coast, seismically imaging the subducted plate. More than 278000 airgun shots were also recorded by temporary seismometer stations placed along the coastline, out to offsets of more than 100 km. The combined marine and offshore-onshore seismic data highlight an area of more than 400 km^2 with higher reflectivity on the subduction decollement up-dip of the up-dip limit of seismogenesis, which we further examine using AVO and finite-difference modelling.

PAPER

MERGING LAKE CORES: TOWARDS AN INTEGRATED HOLOCENE ERUPTIVE RECORD OF MT TARANAKI

Mark Bebbington[1], Michael Turner[2], Shane Cronin[2]
[1]Institute of Information Science and Technology, [2]Institute of Natural Resources, Massey University, Private Bag 11 222, Palmerston North, New Zealand

Probabilistic hazard forecasting for the frequently erupting volcanoes in New Zealand (i.e. the andesitic stratovolcanoes) is an achievable goal, since detailed stratigraphic records with enough events to construct robust statistical models of event recurrence can be obtained, using tephra fall stratigraphies derived from lake or swamp sediments. The challenge lies in obtaining as complete a record as possible. A perfect record at a single site is never achievable, due to variations in the dispersal direction, and to local depositional/erosion conditions. Here we present an example of improving the eruptive history record (and hence eruption forecast) at Mt Taranaki by combining two high-resolution stratigraphic records from lake sites with additional near-source data.

A core recovered from Lake Umutekai, approximately 25km North of Mt Taranaki, contains ash fall deposits of 103 individual eruptions between c. 2000 and 12000 years BP. A similar core taken from Lake Rotokare, approximately 30km East of Mt Taranaki, records 43 fall layers between c. 500 and 7000 years BP. A number (10 and 7, respectively) of the tephras in each core were dated, and the remaining dates estimated from their depth in the cores using a spline to fit the depth-date relations. Along with these, we have a number of individually dated `near-source' events between c. 80 and 2500 years BP. We investigate a statistical method for identifying common events from their fitted dates in the two cores (and the near-source record), in order to obtain a composite record which can be used for forecasting eruption onsets. We have validated this through parallel geochemical correlations of some of the tephra units. In addition, major stratigraphic markers of the rhyolitic Stent Ash and the mafic Manganui Lapilli are present in both cores. Given this combination of stratigraphies, an overall eruption record can be developed and analysed as a renewal process, producing a probabilistic forecast of the time to the next eruption. We will discuss the impacts on the eruption-onset forecast model of using single and composite records and the resulting implications for short and long-term hazard assessment at Mt Taranaki.

FROM SCIENCE TO PRACTICE: USE OF THE ACTIVE FAULT GUIDELINES AND CONSIDERATIONS FOR GEOSCIENTISTS

J. Becker[1], R. Van Dissen[1], R. Langridge[1], D. Heron[1]
[1]GNS Science, PO Box 30 368, Lower Hutt, New Zealand
(j.becker@gns.cri.nz)

Planning for the Development of Land on or Close to Active Faults (also known as the Active Fault Guidelines) are a set of voluntary guidelines published by the Ministry for the Environment (MfE) that aim to assist in planning for the avoidance and/or mitigation of fault rupture hazard. The Active Fault Guidelines were first available in July 2003 in draft form as an interim document, and were finalised in mid-2004. The guidelines are accessible via the MfE Quality Planning website (www.qualityplanning.org.nz).

Two years on from the release of the draft, a follow up study was undertaken to assess whether planners and other relevant professionals had used/adopted the guidelines, how they had used them, whether they found the guidelines useful or not, and how they could be improved.

A few local authorities stated that they had started using the voluntary guidance (and were adapting it to suit their local situation), but others had found some of the issues difficult to resolve and had chosen not to implement the guidelines for the present time. When comparing the differences between those who had, and had not, taken up the guidelines, the study found that input from geotechnical specialists was a strong driver for those that had implemented the guidelines, and was therefore an important element in ensuring that planning for fault rupture becomes integrated into local authority processes and planning documents.

As a result of these findings, it is therefore evident that geoscientists have an important role to play in providing direction to local authorities over planning for active faults. This poster highlights some of the issues that geoscientists should be aware of when identifying faults and providing fault information for developers, consultants or local authorities. Through a number of current case studies we also provide some suggestions on how geoscientists can incorporate active fault information into effective advice for local authorities.

POSTER

PETROLOGY AND THERMOCHRONOLOGY OF THE DEEP CRUST OF ZEALANDIA: EVIDENCE FROM THE PIGROOT CREEK, EASTERN OTAGO.

Andreas Beinlich[1],
Alan F. Cooper[1], J. Michael Palin[1]
[1]Department of Geology, University of Otago PO Box 56, Dunedin 9054, New Zealand

The Cenozoic "mafic phonolite" from the Pigroot Creek, eastern Otago, has often attracted its attention for petrological research due to its fractionated appearance and the concurrent occurrence of abundant spinel lherzolite nodules. In this locality, we found an undeformed cumulate gabbro, composed of intermediate plagioclase, pargasitic hornblende, Fe-Ti oxides, titanite and accessory apatite and zircon. Major and trace elements indicate crystallisation from primitive alkaline magma and subsequently equilibration under amphibolite facies conditions (0.5-0.9 GPa) as revealed by amphibole-plagioclase geobarometry (Holland & Blundy, 1994; Ernst & Liu, 1998).

The combination of ELA-ICP-MS U-Pb dating and Ti-Zr geothermometry resulted in an almost complete t-T path from 100-20 Ma. That is in detail: 1) zircon: $100.7 \pm 2.4 - 88.3 \pm 1.5$ Ma ^{208}Pb-corrected ^{206}Pb/^{238}U zircon ages (n = 35) at 710 ± 20 °C (Ti-in-zircon geothermometry of Watson et al., 2006); 2) titanite: 84.9 ± 1 Ma and 825°C to 33.6 ± 1.4 Ma and 770°C (^{207}Pb-corrected ^{206}Pb/^{238}U ages; n = 49; Zr-in-titanite geothermometry of Hayden et al., 2006 at 0.7 GPa); 3) apatite: 20 ± 3 Ma (n = 27) projected from measured ^{207}Pb/^{206}Pb in plagioclase. Titanite age and temperature data are inconsistent with diffusive loss of Pb and Zr (Cherniak, pers. comm.), and indicate, as also revealed by

REE data and reaction textures, slow cooling and contemporaneous crystal growth at the expense of ilmenite and plagioclase. Apatite ages clearly overlap the K-Ar age of the phonotephritic host rock (Coombs, pers. comm.) and indicate therefore thermal perturbation during transport to the surface.

This record indicates 1) crystallisation of alkaline mafic melt during the early break-up of Zealandia from Gondwana from 100-88 Ma, 2) heating during progressive lithospheric thinning from 88-84 Ma, followed by 3) a period (84-34 Ma) of slow cooling (≤ 2°/Ma) subsequent to separation of the Zealandia microcontinent and opening of the Tasman Sea, and finally 4) transport to the surface in the phonotephritic melt.

The long period of slow cooling indicates tectonothermal stability from 80-35 Ma which is perfectly supported by evidences from southern Zealandia mid-crust (Ar thermochronology) and surface (Waipounamu erosion surface).

POSTER

CRUSTAL STRUCTURE AND BRIGHT REFLECTORS UNDER THE TAUPO VOLCANIC ZONE

A.M. Benson[1], T.A. Stern[1] & S.C. Bannister[2]
[1]School of Earth Sciences, Victoria University of Wellington, PO Box 600, Wellington.
[2]Institute of Geological and Nuclear Sciences, PO Box 30-368, Lower Hutt, NZ.
(adrian.benson@vuw.ac.nz)

Active source seismic profiles across the Taupo Volcanic Zone (TVZ), in central North Island, New Zealand, provide new insights into the crustal structure and magmatic processes in the upper mantle beneath a young back-arc rift. The NIGHT experiment (2000-2001) recorded unusually strong reflections (hereafter PmP_2) from an interface at ~35 km depth, which were interpreted as being from an intra-mantle melt body (Stratford & Stern 2004; 2006). We present some results from the MORC experiment (conducted 2005) that has been designed to augment the NIGHT results by providing high-density seismic reflection/refraction data across the central TVZ (9 shots recorded on a 120 km long, 714 instrument array). These new data allow us to construct high-resolution models of crustal structure and better characterise the PmP_2 reflector.

Inverse and forward ray-trace modelling of MORC first (refracted) arrival data provide perhaps the best available image of upper-crustal structure (< 10 km) in the central TVZ. The thickness of shallow low-velocity material (1.6 – 3 km/s) increases abruptly to >3km at the rift margins (Kaingaroa and Pureora escarpments). Smaller scale structures spatially coincident with negative residual gravity anomalies, the North Taupo Fault belt and normal faulting west of the TVZ are also apparent.

The most striking feature of the MORC data are the bright PmP_2 reflections first recorded during NIGHT. The distribution and amplitude of PmP_2 arrivals depend upon shot offset and the shot position relative to the axis of TVZ rift. For a particular shot, PmP_2 arrivals are observed over a narrow range of offsets; at near offsets for shots close to the TVZ axis and at larger offsets for shots further from the rift. PmP_2 reflections observed at offsets < 50 km are typically weak, with an amplitude of < 0.1 relative to Pg (waves refracted through the crust). At offsets of 70-100 km the amplitude ratio of PmP_2 to P_g is >10, and at least 2 - 10 times as strong as reflections from the top of an inferred Moho transition (Stratford & Stern, 2004; 2006). The systematic variation of the occurrence and amplitude of PmP2 arrivals indicate that the reflector is both limited in size and has strong amplitude variation with offset (AVO) properties. Spatially, the PmP_2 reflector is constrained to be an isolated body at 32-35 km depth directly beneath the eastern margin of the TVZ. The reflector has a maximum extent of ~25 km, but may be < 15 km wide once Fresnel-zone effects are allowed for. The AVO data are somewhat ambiguous; the reflecting interface can be modelled as having either a large positive or negative velocity contrast. Nevertheless, the unusually high amplitude, limited size and position subjacent to the active geothermal fields, lead us to speculate that the PmP_2 reflections are from a body of partial melt. Alternate velocity models or mechanisms that could explain the bright reflections are also explored.

PAPER

IMAGING THE MAGMA FACTORY: MAGNETOTELLURICS IN THE TVZ.

Hugh M Bibby[1], Wiebke Heise[1], T. Grant Caldwell[1], Stephen C Bannister[1] & Yasuo Ogawa[2]

[1.]GNS Sciences, PO Box 30368, Lower Hutt.

[2.]Tokyo Institute of Technology, Japan

(h.bibby@gns.cri.nz)

The Taupo Volcanic Zone (TVZ) in the North Island of New Zealand is characterised by rapid extension, extremely high heat output and very high rates of rhyolitic magma production. The processes that give rise to these exceptional characteristics have not yet been fully resolved. To maintain the geothermal heat output requires the heat equivalent to magma cooling at rates of about 1-2 m^3 per second. Analysis of volatile inclusions within erupted material suggests that large volumes of magma must have resided in the crust at depths of 4-6 km. Despite these indicators of magma, there is little direct geophysical evidence for shallow magma bodies.

Magnetotelluric (MT) methods, which are capable of measuring the electrical conductivity of the earth to great depths, provide an alternative approach to the search for magma because of their sensitivity to the presence of fluids. From the analysis and inversion of more than 100 MT measurements we have constructed an image of the conductivity structure across the TVZ, extending to depths of about 70 km. Near the surface, basins on the east and west of the TVZ are filled with relatively conductive volcaniclastic material. Beneath the surficial structure, a continuous zone of higher resistivity extending down to about 10 km is interpreted as thinned upper crust. Along the eastern margin of the TVZ, the upper crust is more conductive, possibly indicating more elevated temperatures in this region. A rapid increase in the conductivity occurs at about 10 km depth across the width of the TVZ, about 2km beneath the base of the seismogenic zone and well above the base of the quartzo-feldspathic crust (c. 16 km) as identified by seismic surveys. The most plausible explanation for the increase of conductivity is the presence of small fraction (<4%) of connected melt. Lateral variations in the conductance of this zone represent either a greater thickness of the melt or an increase in the melt fraction slightly to the east of the Taupo Fault Belt. Although the thickness of the conductive zone cannot be resolved accurately it appears to extend across the base of the quartzo-feldspathic crust. It is difficult to reconcile the MT results with the recent interpretation of seismic reflection data which suggests the presence of a layer containing a high (~6%) melt fraction at 35 km depth. At deeper levels the subducted plate appears as a dipping resistor beneath a conductive mantle wedge.

POSTER

GEONET: MONITORING NEW ZEALAND'S NATURAL HAZARDS

L. Bland & S. Page

GNS Science, 1 Fairway Drive, Avalon, Lower Hutt

(l.bland@gns.cri.nz, s.page@gns.cri.nz)

New Zealand sits astride a massive tectonic boundary, where the Australian plate and the Pacific plate are pushing against each other. This dynamic geological setting, in conjunction with the country's topography, makes the country vulnerable to a number of potentially disastrous natural hazards, including earthquakes, volcanism, landslides and tsunami. The New Zealand GeoNet Project provides real-time monitoring of these hazards, in the hope that the data collected can then be used for hazard research and detection, as well as toward building effective emergency responses. GeoNet receives funding from the New Zealand Earthquake Commission and is operated by GNS Science. The project uses nationwide seismograph and GPS networks to collect data on New Zealand's earthquake, strain, and deformation patterns. The completion of most of the core national monitoring networks in the last five years has improved the timing and accuracy of earthquake data collection, and volcano surveillance capabilities. These analyses can be used to gain a better understanding of how future earthquake or volcanic events may manifest, and how communities can best prepare for them.

PAPER

LITHOSPHERIC DEFORMATION BENEATH THE SOUTHERN ALPS

S. Bourguignon[1], **M.K. Savage**[1] **& T.A. Stern**[1]
[1] Institute of Geophysics, Victoria University of Wellington, PO Box 600, Wellington. (sandra.bourguignon@vuw.ac.nz)

How the lithosphere deforms within an oblique convergent plate boundary is still controversial. In the central South Island, crustal thickening is well constrained in an orientation perpendicular to the plate boundary from seismic data (SIGHT). How the mantle accommodates transpression and the crust thickens along-strike remain unclear. A further question is how much of the observed deformation may be caused by the nearby Puysegur subduction zone south of the Southern Alps region and/or geological variations along the plate boundary.

We determine crustal thickness and mantle wave speed using an earthquake refraction profile along the Southern Alps, while gravity data across Otago provides constraints on the mantle density. We also use phases from distant earthquakes recorded at GeoNet stations of Otago and their conversions in the crust (teleseismic receiver functions) to image the crustal structure beneath the southern portion of the Southern Alps.

A high average Pn speed of 8.3 ± 0.3 km/s suggests the presence of cold lithospheric mantle beneath the Southern Alps that results from the downwarp of isotherms related to convergence. Anisotropy of 7—13 % suggests distributed shearing of the lithospheric mantle. A maximum crustal thickness of 48 ± 4 km is estimated beneath the southern Southern Alps, which is equivalent to an 18 ± 4 km thick crustal root (relative to c. 30 km at the coast). Crustal thickening of the Southern Alps is approximately twice that required by an Airy-type compensation load. We show that thickening of the mantle lithosphere by a factor ~2 provides the requisite loading to explain the overthickened crust.

PAPER

GEOLOGY AND GEOCHEMISTRY OF METALLIFEROUS SEDIMENTS AND THE ASSOCIATED MATAKAOA VOLCANICS, EAST CAPE, NEW ZEALAND

R.L. Brathwaite[1], **A.B. Christie**[1]. **R.J. Sewell**[2]
[1]GNS Science, PO Box 30368, Lower Hutt
[2]Hong Kong Geological Survey, Geotechnical Engineering Office, Civil Engineering and Development Department, 101 Princess Margaret Road, Kowloon, Hong Kong SAR, China
(b.brathwaite@gns.cri.nz)

Lenses of red, purple and green mudstones, green and grey sandstones, and pale pink micritic limestone occur in the Matakaoa Volcanics. These sedimentary rocks are of Early Cretaceous, Late Cretaceous and Late Paleocene to Early Eocene ages on fossil (foraminifera and radiolaria) evidence. The Matakaoa Volcanics are composed of ophiolitic basaltic pillow lavas, with subvolcanic intrusives of gabbro and dolerite. The sedimentary lenses are discontinuous, ranging in size from a few centimetres to several hundreds of metres in length. The sedimentary rocks host some small lenses of massive pyrite + chalcopyrite ophiolite-type volcanic massive sulphide (VMS) mineralisation and an occurrence of barite + pyrite + marcasite + sphalerite ± gold ± galena mineralisation, which is comparable with Kuroko type VMS mineralisation.

The lenses of sedimentary rocks have been mapped in outcrop and from their relatively high Th and K values in an airborne radiometric survey and anomalous Ba in stream and rock chip geochemical surveys. The mudstones are enriched in Ba (up to 0.28%), which may be hydrothermal or hydrogenous in origin. A hydrothermal source for the Ba is consistent with the occurrence of the barite mineralisation. Bostrom ratios (Fe/Ti, Al/Al+Fe+Mn) of the sedimentary rocks are only locally enriched in Fe, suggesting that they mainly consist of terrigenous sediment with only local hydrothermal inputs. The Matakaoa Volcanics have low to moderate abundances of TiO_2, MgO, Cr and Ni, and are low in both large-ion lithophile elements (K, Rb, Ba) and high field strength elements (Nb, Zr, P, Y), which are all consistent with tholeiitic compositions. Geochemical discrimination diagrams suggest that the bulk of the Matakaoa Volcanics were formed in mid-ocean ridge basalt (MORB) and island-arc tholeiite (IAT) environments. On a $MnO-TiO_2-P_2O_5$ diagram most of the Matakaoa analyses cluster around the boundary between MORB and island-arc basalts.

PAPER

THE LITTLE RED HILL FIELD EXPERIMENT: SEISMIC RESPONSE OF AN EDIFICE

F. Buech[1], T.R. Davies[1], J.R. Pettinga[1], M. Finnemore[1], J.B. Berrill[2]
[1]Dept. of Geological Sciences,
[2] Dept. of Civil Engineering, University of Canterbury, Private Bag 4800, Christchurch, New Zealand
(f.buech@geol.canterbury.ac.nz)

Coseismic mountainside collapses represent one of the most damaging of all seismic hazards. A field experiment was conducted near Lake Coleridge in the Southern Alps of New Zealand, focusing on the kinematic response of bedrock-dominated mountain slopes to strong seismic shaking. Seismic waves interfering with local geological and topographical conditions will produce site-specific ground motions within the mountain edifice. The position of the mountain relative to the direction of the incoming seismic wave field, topographic modifications, and the frequency content of ground motions, local resonance effects, and geometry of the mountain are likely to be important factors for triggering deep-seated failures within mountain edifices. To study topographic site effects of seismic ground motion in a field situation, a small, elongated, and bedrock-dominated mountain ridge was chosen and equipped with a seismic array. In total seven EARSS seismographs were located on the crest, on the flank, and at the base of a 180 m high, 500 m wide, and 800 m long mountain edifice from February till July 2006. Seismic records of local and regional earthquakes as well as seismic signals generated by a small explosive source nearby will provide us with information about site specific amplification and deamplification effects within different parts of the edifice. The ground motion data are used in combination with small-scale physical laboratory modelling, numerical modelling techniques, and geotechnical investigations to infer the location of potential failure surfaces. It will contribute to increased understanding of coseismic landslide initiation within bedrock mountain edifices.

POSTER

MODELLING A DAM BREAK FLOOD FROM THE CRATER LAKE OF MT. RUAPEHU

J.L. Carrivick[1],V. Manville[2], & S.J. Cronin[3]
[1]School of Geography, University of Leeds, Leeds. West Yorkshire. LS2 9JT. UK.
[2]GNS Science, Wairakei Research Centre. Private Bag 2000. Taupo, NZ.
[3]Institute of Natural Resources, Massey University, Private Bag 11 222, Palmerston North.
(j.l.carrivick@leeds.ac.uk)

Ice-covered volcanoes produce many potentially devastating phenomena due to the thermal interaction between hot volcanic materials and ice. Examples include glacial outburst floods or 'jökulhlaups', volcaniclastic debris-laden flows or 'lahars', and explosive phreatomagmatic eruptions. An improved understanding of these phenomena, and thus effective hazard management and mitigation solutions, can only be advanced through multidisciplinary research, which should draw together such diverse fields as remote sensing, sedimentology, fluid-dynamics, and numerical modelling.

This project aims to quantify processes and mechanisms of a lahar from Mt. Ruapehu, New Zealand, through application of a fully integrated hydrodynamic - sediment transport model. Ruapehu is a ~2800m high composite andesite stratovolcano and is the largest and most active volcano of the Tongariro National Park World Heritage Area. Ruapehu's six glaciers and snowfields feed four major rivers, and there are ski fields, roads and bridges, aqueducts and footpaths on the volcano slopes. Lahars have been common in Ruapehu's history and at least 13 lahar episodes have occurred since 1945. Most of these were directly caused by an eruption, but the 1953 event was a dam break from the summit crater lake. Following eruptions in 1995-96, a dam-break lahar was predicted from the refilling Crater Lake and a process to assess risk and develop mitigation measures was initiated.

This project's modelling utilises very high-resolution topographic data (LiDAR) to route a user-specified hydrograph down-slope, given data on roughness, pre-existing sediment fill, and grain size fractions. It is a fluid dynamics model, so whilst considering sediment transport, it does not consider granular interactions. Modelling results offer the first calculations of high-magnitude fluvial flow characteristics, including; simultaneous inundation of multiple channels, sheet and channelled flow, flow around islands, hydraulic jumps, multi-directional flow including backwater areas and hydraulic ponding. These conditions are typical of dam-break or eruption-triggered floods of high magnitude that pass through steep volcanic terrain and contain high concentrations of volcaniclastic sediment. In these cases, flow hydraulics vary considerably in space and time. For example frontal speeds were much slower than main body velocities, and flow pulses occurred as minor obstacles were over-run. This quantified parameterisation is very important for land management and engineering solutions to lahar and outburst flood hazards.

PAPER

PRELIMINARY RESULTS FROM A GIS-BASED UTILITY INFRASTRUCTURE VOLCANIC RISK EVALUATION IN TARANAKI

Ian Chapman[1,2], Shane Cronin[1], Jon Procter[1]
[1]Volcanic Risk Solutions, Institute of Natural Resources, Massey University,
Private Bag 11 222, Palmerston North, New Zealand
[2]Powerco Ltd, Private bag 2065, New Plymouth

The "new" Civil Defence Emergency Management Act (2002) requires lifeline companies to undertake risk assessments of their distribution networks. The Taranaki Region is unique in having the current locus of the nation's petroleum exploration and processing industry, which supplies both the domestic and commercial markets for their natural gas requirements. Four lifeline companies currently operate in the Taranaki Region, Contact Energy, Transpower, Vector Gas, and Powerco and while they have comprehensive risk assessment plans in place for most events, potential impacts of volcanism on their transmission and distribution networks has not yet been fully assessed. Recent research has found that Egmont Volcano eruptions may not just be week- to month-long bursts of activity, but could last much longer. In addition, a range of potential volcanic processes could occur during this period, including repeated pyroclastic flows, ashfall events and lahars. Additional new research also demonstrates that the frequency of eruptions is much greater than once thought.

A "typical" most-likely case scenario eruption from Mt Taranaki/Egmont Volcano, will place Powerco's electrical network at risk from tephra fall and lahars. This will potentially generate immediate downtime of the network across broad areas, and hence engender trading and cause repair-related losses. Initial consideration has already been given to the major gas transmission and distribution networks where risks are greatest for above-ground assets (e.g. aerial crossings of pipelines over potential lahar courses) as well as any functions requiring ancillary power. Potential impacts for the loss in energy-transmission not only affect the immediate supply company sector, but may be particularly devastating on business continuity of the "downstream" dependents. Loss of gas supply for more than three days means the effective loss of milk processing in the North Island and in addition, electrical generation capacity is significantly reduced.

A GIS-based assessment has been made of the most vulnerable areas within the Taranaki Region with respect to most-likely eruption scenarios and the existing hazard map. Four key utilities or areas appear to be subject to the greatest risk. These include the Oanui Gas production Station, the Kapuni Gas Treatment Plant, the Stratford Combined-Gas-Cycle-Generation Power Station, and the Waitara River Catchment. Potential lahar-inundation zones are being refined from the broad earlier mapping around these areas using LaharZ landscape-filling routines as well as Titan2d simulations of lahar flow.

PAPER

THE 2006 ERUPTION OF RAOUL VOLCANO (KERMADECS): A MAGMATIC-HYDROTHERMAL EVENT FROM A HYDROTHERMALLY-SEALED VOLCANIC CONDUIT SYSTEM.

BW Christenson[1], AG Reyes[2] and CA Werner[3]
[1]National Isotope Centre, GNS Science, PO Box 31-312, Lower Hutt
[2]GNS Science, 1 Fairway Drive, PO Box 30368, Lower Hutt
[3]USGS-CVO, 1300 SE Cardinal Ct, Vancouver WAS 98683 USA
(b.christenson@gns.cri.nz)

The March 17, 2006 eruption from Raoul volcano (Kermadec Islands, NZ), which tragically claimed the life of NZ Department of Conservation staff member Mark Kearney, is being interpreted as a magmatic-hydrothermal event triggered by shaking associated with regional earthquake swarm activity. Although the eruption released ca. 200 T of SO_2, thus confirming its magmatic nature, it occurred without significant precursory volcanic seismicity, and without any of the precursory responses of the volcanic hydrothermal system which were observed prior to the last eruption in 1964.

Raoul Island has a long and varied eruption history dating back > 1.4 ma, and has been hydrothermally active throughout historic time. Present day fumarolic and hotspring discharges within Raoul caldera point to the existence of a small but well established, mixed meteoric - seawater hydrothermal system within the volcano. Magmatic signatures are apparent in fumarolic gas discharges, but are heavily masked by their interaction with hydrothermal system fluids (eg. near complete scrubbing of sulphur and halogen gases from the boiling point fumarolic discharges). A diffuse degassing study conducted in 2004 revealed that ca. 80 T/d CO_2 is passively discharged from the volcano, suggesting that ongoing (albeit low level) convective degassing of magma occurs at depth.

Interestingly, vent locations from the 2006 eruption correspond to areas of relatively low CO_2 discharge on the crater floor in 2004. This, in conjunction with the preliminary findings of abundant hydrothermal mineralisation (calcite, anhydrite, quartz) in eruption ejecta, suggests that the main volcanic conduits had become effectively sealed during the interval since the last eruption. Calcite-hosted fluid inclusions are CO_2 clathrate-bearing, and have relatively low homogenisation temperatures (165-180 °C), suggesting that the seal environment was both gas-charged and shallowly seated (< 200 m).

Shaking associated with the regional earthquake swarm activity which commenced on March 12th is thought to have accelerated the release of magmatic volatiles through the plastic-brittle transition zone surrounding the magma conduit at depth. Over the subsequent 5 days, these gases migrated upward to become trapped behind the hydrothermal seal, leading to growth of a vapour-static gas cap beneath the seal, and its eventual failure through elevated pore pressures. The eruption represents the culmination of what is probably a cyclic evolutionary process in the hydrothermal system, a process which poses an eruption threat that is not necessarily related to changes in magmatic activity within the volcano.

PAPER

INSIGHTS ON THE LOW-ANGLE NORMAL FAULT PARADOX FROM THE BASIN AND RANGE PROVINCE, WESTERN UNITED STATES

N. Christie-Blick[1], M.H. Anders[1], B. Renik[1], C.D. Walker[1] & S.C. Schon[2]
[1]Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY 10964, USA
[2]Department of Geological Sciences, Brown University, Providence, RI 02912, USA
(ncb@ldeo.columbia.edu)

The Basin and Range Province of the western United States has been influential in the development of ideas about crustal extension, and particularly the role of low-angle normal faults in brittle deformation. However, the conflict between generally accepted geological interpretations and rock mechanical and seismological considerations has yet to be resolved. Re-evaluation of several important Basin and Range examples suggests an array of interpretive solutions, and that broader scrutiny of the low-angle normal fault paradigm is in order – including comparable features in New Zealand.

The seismically imaged Sevier Desert "detachment" (west-central Utah) is reinterpreted as a Paleogene unconformity traced to depth west of the northern Sevier Desert basin along an unrelated reflection. The absence of evidence in well cuttings and cores for either brittle deformation (above) or ductile deformation (below) is inconsistent with the existence of a fault with as much as 40 km of displacement. Cretaceous thrust faults are erosionally truncated at the western margin of the southern Sevier Desert basin, and not offset by the "detachment" in the manner assumed by those inferring large extension.

The Mormon Peak detachment (southeastern Nevada) is reinterpreted as a series of slide blocks on the basis of detachment characteristics and spatially variable kinematic indicators that are more closely aligned with the modern dip direction than the inferred regional extension direction. The Castle Cliff detachment (southwestern Utah) is similarly regarded as a surficial feature, as originally interpreted, and consistent with its conspicuous absence in seismic reflection profiles from the adjacent sedimentary basin.

The crustally rooted Million Hills Wash fault (also in southeastern Nevada), interpreted by others to have been active at a dip of $< 11°$ on the basis of the downward termination of coeval high-angle normal faults, is demonstrably cut by some of those faults. Details of other intersections cannot be established with confidence. The simplest interpretation of field data is that initially steep faults were tilted to lower dip during extension, and new faults developed once the inclination of early structures became unfavourable.

The Eagle Mountain Formation (~15-11 Ma; eastern California), previously interpreted on the basis of facies evidence and clast provenance to have accumulated close to its source in an alluvial fan-lacustrine setting and then to have been moved tectonically > 80 km, is reinterpreted as fluvial-lacustrine, with no bearing on the amount of tectonic transport. The conglomerate-bearing rocks upon which the provenance argument was based are characterized by pervasive channelization, fining-upward successions and cross-stratification – all features typical of fluvial sedimentation and not of alluvial fans. The result is significant because the Eagle Mountain offset has been viewed as the strongest evidence for extreme extension and hence for the existence of regional detachment faults in the conceptually important Death Valley area of California.

PAPER

SEISMICITY IN TAUPO VOLCANIC ZONE GEOTHERMAL SYSTEMS: PRELIMINARY RELOCATION RESULTS FOR KAWERAU AND ROTORUA

D. Clarke[1], J. Townend[1], M. Savage[1], S. Bannister[2] & S. Sherburn[2]
[1]Institute of Geophysics, Victoria University of Wellington, PO Box 600, Wellington
[2]GNS Science, PO Box 30368, Lower Hutt
(daniel.clarke@vuw.ac.nz)

Geothermal systems are excellent natural laboratories for investigating the mechanisms governing fault slip and earthquake nucleation: fluctuations in shallow- and mid-crustal pressures and temperatures within geothermal systems are larger, more easily monitored, and generally more plausible earthquake triggers than are likely to exist at comparable depths in other regions of the earth's crust. In simple terms, the tendency of a fault to slip is increased as the ambient fluid pressure increases, and it is well documented that spatiotemporal variations in fluid pressure — in response to either natural or induced changes in the hydrological state of a geothermal system — are manifest as corresponding variations in the rate of seismicity. In cases in which geothermal systems are actively exploited, either for electricity generation or heating, borehole measurements provide a means of monitoring in situ fluid pressures at the same time as seismicity is being recorded.

We are currently working to accurately locate small earthquakes occurring near the Rotorua and Kawerau geothermal systems with the aim of producing high-resolution subsurface images of seismically active faults and fluid migration patterns. We have selected two sets of shallow (<20 km) earthquakes that occurred between 1984 and 2004. The Rotorua and Kawerau data sets contain approximately 500 and 1800 earthquakes, respectively, and include earthquakes recorded during the five-month deployment of a dense seismometer array in the Taupo Volcanic Zone (TVZ) in 1995.

We use the highest-quality events to compute one-dimensional P- and S-wave velocity models and corresponding station correction terms for each geothermal system, and relocated both data sets using the double-difference method and catalogue phase picks. The double-difference method uses travel-time differences for earthquake pairs measured at common stations to determine the earthquakes' relative positions. This approach reduces the effects of unknown velocity structure and systematic phase-picking errors on the hypocentres. In the next phase of this research, we will use waveform cross-correlation to measure travel-time differences with greater accuracy than the catalogue phase picks allow. This is expected to yield more S-wave arrival times, and enable first motion polarities to be determined for emergent waveforms based on their correlation with waveforms of known first-motion polarity.

PAPER

ON THE TRAIL OF LARGE SUBDUCTION EARTHQUAKES AT THE HIKURANGI MARGIN

U. Cochran[1], K. Berryman[1], B. Hayward[2], D. Mildenhall[1], K. Wilson[1]
[1]GNS Science, PO Box 30-368, Lower Hutt.
[2]Geomarine Research, 49 Swainston Rd, St Johns, Auckland
(u.cochran@gns.cri.nz)

One of New Zealand's more devastating natural hazard scenarios is a great (magnitude 8+) subduction earthquake at the Hikurangi margin. This is also one of New Zealand's least quantified hazards with no known occurrences and widely varying estimates of likely magnitude and recurrence interval. At other subduction zones worldwide, geological investigations have provided physical evidence of past large subduction earthquakes, as well as estimates for their magnitude and recurrence. We use paleoenvironmental reconstructions at coastal sites to elucidate the nature and timing of Hikurangi subduction earthquakes.

Detection of past subduction earthquakes relies on events causing vertical deformation of the upper plate. Along a margin-normal transect, coseismic uplift is expected trenchward (updip end of the slip plane) and coseismic subsidence arcward (downdip end of the slip plane). Flights of uplifted terraces have been documented at numerous sites along the east coast of the North Island. The age distribution of these terraces suggests they are generally the result of upper plate fault activity. Upper plate faults may rupture simultaneously with the subduction interface but for most terraces there is no reason to infer great earthquakes. More recently, we have worked arcward of the uplifted terraces and targeted sedimentary sequences of subsiding estuaries to derive records of coseismic subsidence. Such events may also be the result of displacement on upper plate faults. However we aim to use numerous earthquake records from widely-spaced sites to describe the length, width and magnitude of coseismic deformation to differentiate between subduction interface and upper plate fault sources.

Currently we have records from four estuarine sites in northern and southern Hawke's Bay that document a minimum of six coseismic subsidence events over the last 7500 years BP. New reconstructions will be presented from cores in Pakuratahi Valley, 15 km north of Napier. Analysis of sediment, diatoms, foraminifera, spores, pollen and radiocarbon content enables reconstruction of past environments and thereby assessment of evidence for sudden vertical displacement. Comparison of the Pakuratahi Valley record with existing reconstructions from Ahuriri Lagoon (southern Hawke's Bay) and from Opoho and Te Paeroa Lagoon (northern Hawke's Bay) enables definition of at least one great subduction earthquake in the last 7500 years. The earthquake is recorded at all sites at c. 7100 cal. years BP, it caused metre-scale subsidence of coastal plains, tsunami inundation and triggering of large bedrock landslides region-wide. Several other events at these sites are likely to be great subduction earthquakes but require further definition. Thus our studies confirm that great earthquakes have occurred at the Hikurangi margin and with reconstructions at further sites we aim to provide estimates of their location, magnitude and recurrence.

PAPER

POTENTIAL EFFECTS OF ASH FROM A VOLCANIC ERUPTION ON URBAN AND RURAL INFRASTRUCTURE AND LIFELINES

J.W.Cole, S.T.Barnard, G.D.Kaye, T.M.Wilson
Natural Hazards Research Centre, University of Canterbury, PB 4800, Christchurch.
(jim.cole@canterbury.ac.nz)

We present an overview of work carried out between 2004 and 2006 under the University of Canterbury subcontract to objective 4 of GNS' 'Resilient New Zealand' FRST programme, and indicate projected activity for the next 2 years.

There have been 3 main areas of research focus during the initial two years, corresponding to the PhD thesis topics of Grant Kaye, Scott Barnard and Tom Wilson respectively:

- Riskscape
- Effects on airports and grounded aircraft
- Effects on the dairy industry

In the first area, data has been collected from the Rotorua District that will eventually be used to test the volcanic risk assessment of that city. This will form part of the national Riskscape programme underway jointly by GNS and NIWA. Study of the effects of ash on aircraft infrastructure have involved visits to Catania (Sicily) to look at the 2002-3 eruption of Etna, and to Quito to discuss impacts of a number of recent eruptions with authorities in Ecuador. Potential effects of ash on the dairy industry was initially tackled by a detailed evaluation of potential effects on one farm at Rerewhakaaitu, SE of Rotorua. This study indicated that the most vulnerable areas were the power and water supplies, and in particular the condenser, in the milking shed. Recommendations were made as to best ways of mitigating these problems.

These studies will be expanded in the next two years, including testing the Riskscape data base and perhaps applying techniques evolved to other volcanoes; consideration of the potential effects of ash on wastewater and telecommunication systems, on viticulture and on some aspects of tourism. Impact on the dairy industry will be broadened to include Taranaki, Waikato, Bay of Plenty and Hawkes Bay, with new input from observations made during the recent eruption of Merapi, Indonesia.

Poster presentations, providing details of some of these activities, will be given at this conference.

MODELLING SUBVOLCANIC PLUMBING SYSTEMS BENEATH OKATAINA CALDERA COMPLEX, TAUPO VOLCANIC ZONE

J.W.Cole[1], C.D.Deering[1], N.E.Matthews[1], R.E.Turnbull[1], H.M.Bibby[2]
[1]Department of Geological Sciences, University of Canterbury, PB 4800, Christchurch
[2]GNS Science, PO Box 30368, Lower Hutt
(jim.cole@canterbury.ac.nz)

This programme, funded through Marsden Grant UOC0508, aims to understand the physical and chemical processes that occur beneath the Okataina caldera complex (OCC). The programme began with an assessment of all data currently available on OCC, and a gap analysis made of the new data needed. Two key units identified were the 1315AD Kaharoa eruption from Tarawera and the c.65ka Rotoiti ignimbrite from northern OCC. Tephras and lavas from the Kaharoa eruption already have extensive analytical data available, and are known to contain both granitoid blocks, and a basaltic input which may well have triggered the eruption. Good analytical data is available for pumice from the Rotoiti ignimbrite, but a detailed study (NM) was undertaken of the blocks (including a large number of plutonic lithic fragments) in an extensive lithic lag deposit (the subject of a poster at this conference). The c.280ka caldera-forming Matahina ignimbrite is also considered important, and a detailed study has begun on this unit by CD. Lithics have been collected and categorised with a view of establishing sub-surface variability at the time of this eruption, and more detailed geochemistry will provide data on physico-chemical conditions within the magma chamber.

Potential analogues of magma systems beneath OCC have been identified in the Coastal Maine Magmatic Province (USA) and the southern Nevada / northwestern Arizona (USA) plutons. Exchange visits have been made to these areas and comparisons made; experts on these areas are also involved in our programme, so the dialogue can continue, as more information becomes available on OCC. In addition a potential analogue exits in the Bungaree Intrusives of Stewart Island, and RT has commenced a study of these plutons as part of our programme.

To provide additional information on subsurface features of OCC, a broadband magnetotelluric geophysical survey (HB) is being employed. This is already indicating highly conductive zones within part of the caldera. Revisions to the gravity map currently underway should also prove invaluable.

PAPER

UNDERSTANDING THE INTERNAL DYNAMICS OF LAHARS USING GEOPHYSICAL TECHNIQUES

S.E. Cole[1], S.J. Cronin[1], V. Manville[2], S. Sherburn[2]
[1]Inst. Natural Resources, Massey University, Private Bag 11 222, Palmerston North
[2]GNS Science, Wairakei Research Centre, PO Box 2000, Taupo

Lahars, or water-containing mass flows, pose a great threat to communities that have grown or expanded near river channels radiating from volcanoes. Historically, more than 23,000 people have died as a direct result of lahar flows within the Circum-Pacific Region alone. Widespread damage to arable land, buildings, bridges and communication networks is a common occurrence. In the context of efforts to engineer mitigation solutions for lahars, or plan for them, there is a lack of information on their internal dynamics, particularly sediment-concentrations and sediment-distribution gradients within them. This is mostly because it is impossible to “see” inside a moving lahar, since they flow with such violence and such a high sediment content that normal flood-monitoring instruments are destroyed. In addition, since they often occur suddenly, not many scientists have been able to mobilise in time to observe and sample them in flow. New monitoring or “imaging” systems to fill this knowledge gap were tested earlier this year at Semeru Volcano, in eastern Java, Indonesia. Constant rock falls and block-and-ash-flows from the growing dome of this volcano provide abundant sediment on its upper slopes. In the rainy season, almost-daily lahars are generated in several catchments. Equipment used to measure the flows as they passed included: a three-component broadband seismometer installed beside the channel, along with two acoustic flow monitors (AFMs). Beneath the flow channel, a pore-pressure transducer and a load-pressure plate were buried to measure the overlying water depth and mass of material, respectively. Despite scouring – the within-bed instruments showed potential to interpret the sediment concentration within the flows if stage heights are well constrained. Similarly, the broad-band records appear to show a range in signal properties (frequency spectra) that correspond to variations in the flow passage as recorded by concurrent continuous video footage. The challenge remains to interpret these signals in relation to particle motion properties (sliding, rolling, bouncing) within the flows. It is hoped that the automatic monitoring techniques at Semeru will help us understand the impact of lahars on structures in their paths and how the sediment is carried within them. The field measurements also enabled testing the effectiveness and reliability of equipment that is also to be installed in the Whangaehu River, Ruapehu. Several problems were encountered with equipment installation, which will help us to prepare more confidently for the anticipated lahar at Ruapehu.

PAPER

VOLCANIC HAZARDS PLANNING ON RIFTING ISLAND AND FISSURE VOLCANOES

Shane J. Cronin, K. Nemeth, R.B. Stewart
Volcanic Risk Solutions, INR, Massey University, Private Bag 11 222, Palmerston North, New Zealand
(s.j.cronin@massey.ac.nz)

Volcanic hazards mapping and planning at central-vent volcanoes is normally carried out by delimiting the main flow paths of mass-flow processes such as lahars, lava flows or floods and examining distribution of tephra from single point-sources. On many island volcanoes, either in arc or intra-arc settings, this approach may lead to significant under-representation of the hazard or lead to flawed hazard planning approaches; such as evacuation plans that endanger refugees from flank volcanism. Islands such as Ambae, Ambrym and Lopevi in Vanuatu, Taveuni in Fiji, Izu Oshima in Japan and Lanzarote in the Canaries all show a similar structure, despite having different geological contexts and variations in geochemistry and magma source. These basaltic and basaltic andesitic volcanoes all share high central summit areas, some with calderas and or crater lakes. It is to these vent sites where initial attention is drawn in volcanic hazard assessment, which is reinforced by the common occurrence of small eruptions centred at the central vents. When larger eruptions are analysed from these locations, along with the nature of the deposits along the rift systems, it is noted that the typically most violent activity is concentrated not at the central vent, but the location where the rift arms enter the sea. These coastal sites typically contain fields of tuff cones and tuff rings, with deposits representing violent phreatomagmatic interactions. The nature and geomorphology of tuff cones and rings have meant that they have been of great utility to human populations, being used as safe harbours, water supply reservoirs, sheltered flat areas for sport grounds, hospitals, schools and settlements. Hence not only are populations built up around these areas, but also major lifeline utilities are located within them. Examples are shown from eruptions of Izu Oshima and Ambae that show natural tendency during eruptions from central vent areas is to evacuate people from areas expected to be at risk from near-vent and downstream areas. These people are often moved to areas where lifelines or utilities can support them, which happen to coincide with where rift arms enter the sea. In both cases evacuees proved to be safe in these locations, but, other historic eruption examples show that these areas are by no means safe. The processes of eruptions on these volcanoes appear to be controlled by dyke intrusion along rift systems. Either magma rises and erupts or degasses in the central vent area before draining down lateral rifts (ala Etna or Kilauea), or it intrudes in several locations along a rift to generate eruptions at widely dispersed locations. The concentration of phreatomagmatic vents where the rift arms enters the sea are the locations of greatest island expansion and outboard lateral growth. During this presentation, locations and structures of a range in island volcanoes with rifted axes will be presented. The rift extremity deposits will be compared and contrasted with central vent and mid-flank units and a basis for hazard mapping and planning on these sites will be proposed.

POSTER

FOCUSSED FLUID FLOW BENEATH AN ANTICLINE IN THE HIKURANGI MARGIN GAS HYDRATE PROVINCE, NEW ZEALAND

G.J. Crutchley[1], A.R. Gorman[1] & I.A. Pecher[2]
[1]Department of Geology, University of Otago, PO Box 56, Dunedin.
[2]GNS Science, 1 Fairway Drive, Avalon, PO Box 30368, Lower Hutt.
(gazmailhere@yahoo.com)

Gas hydrate distributions on the Hikurangi Margin off the east coast of New Zealand have been characterised by the presence of bottom simulation reflections (BSRs) on marine seismic reflection data. These BSRs are primarily an indicator of the presence of gas trapped beneath the gas hydrate stability zone (GHSZ). They do not generally provide quantitative information on the concentrations of hydrate or concentration of free gas in a particular region.

We present results of a one-dimensional, full-waveform seismic inversion study conducted over selected parts of a commercial, multi-channel, marine seismic data set. The data were acquired in March 2005 on a transect over the deforming accretionary wedge of the Hikurangi Margin. Near-trace data reveal strong BSRs at the base of the gas hydrate stability zone beneath several subduction-related anticlines. The strength of the BSR decreases markedly away from the centre of the anticlines and towards the limbs. The full-waveform inversion technique has been applied to selected common midpoint gathers (CMPs) to provide quantitative control on the fine-scale velocity structure of the upper few hundred metres of the seafloor. Elastic, one-dimensional reflectivity seismograms are used for the forward modelling part of the inversion scheme; only P-wave velocities have been fully analysed at this point. Results show the magnitude of the negative velocity shift at the BSR to decrease away from the apex of an anticline. The velocity inversion likely is due to sediments beneath the GHSZ that are charged with some amount of free gas being trapped by sediments that partially saturated with gas hydrates.

The inversion results provide evidence for elevated gas hydrate saturation in the sediments closest to the apex of the anticlines. Elevated hydrate concentration in proximity to anticlines seems to be due to the inherent focusing of fluid flow within these structures.

POSTER

CRUSTAL SEISMIC REFLECTION MEASUREMENTS OFF CENTRAL NORTH ISLAND: A RE-APPRAISAL

F J Davey
GNS-Science, P O Box 30368, Lower Hutt
(fdavey@paradise.net.nz)

Crustal seismic reflection data recorded in 1990 across the Taupo Volcanic Zone (TVZ), along the coast of the Bay of Plenty, have been reprocessed to show additional features in the crust and upper mantle that may contribute to our understanding of the development of the TVZ and its relationship to the extension in the Havre Trough. The northern TVZ is underlain by a lower crustal strong reflector inferred to be caused by a fragmented mafic sill. Below this, the uppermost mantle lies below about 6 seconds two-way travel time and is characterised by region of strong chaotic reflecting elements. A similar, but smaller, region with a strong lowermost crustal reflection and an underlying region of strong chaotic reflecting elements is detected further to west, coincident with the extrapolation of the Havre Trough rifting trend through Mayor Island. It is proposed that the coastal region (ocean-continental boundary) marks the transfer zone for the back arc rifting of the Havre Trough into the continental rifting of the TVZ. The eastern margin of the TVZ is marked by a strong narrow band of reflectivity that dips eastwards under the East Cape peninsula to depths of about 30 km (9 seconds twt) that is interpreted as marking the Moho. A discontinuous reflector lies at a depth of about 11 - 12 seconds twt under the TVZ and may correspond to the strong reflector recently imaged in the upper mantle in this region by wide angle seismic measurements.

ARCHITECTURE AND PALAEOECOLOGY OF EARLY MIOCENE (OTAIAN) CHANNELISED SLOPE DEPOSITS AT ORONGO POINT, OKAHUKURA PENINSULA, KAIPARA HARBOUR

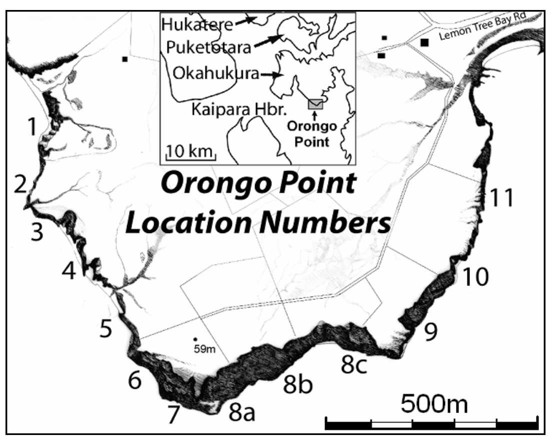
Rhiannon Daymond-King, Bernhard Spörli, Bruce Hayward, Murray Gregory, Kathy Campbell.
Geology Dept., University of Auckland, Private Bag 92019
r.daymondking@auckland.ac.nz

The 3.2 km coastal cliff section of Orongo Point is one of the more important locations on Okahukura Peninsula because of several different formations of the Waitemata Group outcropping, its excellent exposures, complex stratigraphic situations, myriad cross-cutting channels and its fossiliferous units.

A number of studies have been done in the past, most relevant being Ballance and McCarthy's 1975 paper. The present study has produced detailed stratigraphic and lateral sections around the point, describes processes and settings, extends and adds to the palaeoecological interpretation to the collection of macrofossil and microfossil identifications and interpretation, as well as documenting trace fossils which have been noted from this site but not studied in detail previously.

The three nested channels of Location 10 (see map) show the overall lithology: the lowest layer is a silty mudstone, representing 'background' deposition outside the channels; the second layer is onlapping coarse sandstone; and the upper layer is a volcaniclastic grit containing fingernail-sized clasts of pumice, recognisable in two other locations. This sequence represents an increasing signature of volcanic activity.

Certain portions of the field area are structurally complex; Location 2's complex slide structures begin with a N-moving and ramping basal thrust, with pre-existing folds visible in slumped blocks separated by sand intrusions linked to the thrust surface. The second major movement, an overlying slide towards the SE, has contributed to extension faults within the underlying slide unit. Location 5 sports a neatly truncated compression fold, discordantly overlain by siltstone.



The highly fossiliferous grit at Location 5, and similar but less concentrated units around the section, contain macrofossils such as corals and nautiloids, which are evidence of the increased warmth of the early Miocene oceans. Both this and the discordant siltstone above contain reworked foraminifera species derived from the Northland Allochthon, and also species of both very deep and shallower water foraminifera. This reflects the influence of either mixed sediment sources or erosional processes accompanying deposition.

The processes, sediment types and settings that occur in bathyal submarine channels are not fully understood, because it is difficult to study them in modern settings under the sea at these depths. To some degree, surface expression may be observed with mini-subs or side scan sonar imagery, and internal structure can be found by seismic reflection surveys. Uplifted fossil examples, like that at Orongo Point, provide a better chance for detailed analysis of the anatomy of submarine channels.

SEISMIC TREMOR AND SMALL EARTHQUAKES ASSOCIATED WITH SLOW SLIP IN THE HIKURANGI SUBDUCTION ZONE

E.J. Delahaye[1], J. Townend[1], M.E. Reyners[2] & M.P. Chadwick[2]
[1]Institute of Geophysics, Victoria University of Wellington, PO Box 600, Wellington
[2]GNS Science, PO Box 30368, Lower Hutt
(emily.delahaye@vuw.ac.nz)

Recent advances in geophysical monitoring have revealed a much broader spectrum of earth deformation processes than previously recognised, including several mechanisms operating on timescales between those of traditional seismology (in which earthquake rupture occurs in seconds) and geodesy (in which strain accumulates over years to decades). Since the installation of continuously recording Global Positioning System instruments (cGPS) in New Zealand, a number of slow slip episodes have been recorded in the shallow part of the Hikurangi subduction zone (Beavan et al., *J. Geodesy*, in press). The slip events range in duration from days to months, and are similar to slow slip events recently discovered in the shallow parts of subduction zones in Cascadia and Japan. In these regions, slow slip has been associated with seismic signals, or "episodic tremor". We have thus begun a study to investigate whether or not episodic tremor is also associated with slow slip episodes at the Hikurangi subduction zone.

Our study involves two components: 1) detailed visual analysis of broadband seismic data recorded by the GeoNet monitoring network for tremor signals associated with the November 2004 slow slip episode in the Gisborne region (Douglas et al., *GRL*, **32**, L16305), and 2) installation of additional portable seismographs during recent slow slip episodes in the Hawke's Bay region in June 2006 and in the Gisborne region in July 2006. During the visual inspection we have reviewed eight weeks of continuous seismic records spanning the November 2004 event and have identified regional and teleseismic phases, and the location of previously unreported small earthquakes. Preliminary results from the November 2004 slow slip event suggest that seismic tremor is much less conspicuous during the Hikurangi subduction zone slow slip events analysed to date than is the case in Cascadia or Japan. Several prospective tremor signals have been found on close examination to exhibit distinct P and S phases that enable them to be located as small local earthquakes ($M_L < 3$).

PAPER

NEW ZEALAND GEONET: RECORDING SLOW SLIP ALONG THE HIKURANGI SUBDUCTION MARGIN.

A. Douglas[1], J. Beavan[1], L.Wallace[1] & H. Fletcher[2].
[1] GNS Science, PO Box 30368, Lower Hutt, New Zealand.
[2] British Antarctic Survey, Cambridge, UK.
(a.douglas@gns.cri.nz)

In September 2006, a slow slip event (SSE) was recorded on 7 recently installed continuous GPS (CGPS) sites south of Napier. Maximum displacements of approximately 20 mm east, 10mm south, and 5mm down were recorded on two coastal sites in the Blackhead Point area. Smaller displacements were recorded on surrounding sites. The sites are part of the GeoNet Hikurangi Margin Network (HiMNet), which is undergoing rapid expansion. The great increase in number of CGPS sites between Wellington and Napier over the past year means that we can confidently model the slip plane where this SSE occurred.

Over the next five years a further 60 CGPS sites will be installed by GeoNet along the length of the Hikurangi subduction margin, including the Manuwatu and Wanganui regions. Where possible, sites will be co-located with seismometers. Network site selection is based on computer modelling experiments undertaken to determine the configuration of the GeoNet CGPS network best suited to the scientific goals and financial resources of the project. The excellent record of the September 2006 SSE indicates that these models are guiding our CGPS station spacing appropriately. We are confident that the ongoing network expansion will enable us to recognise and quantify other SSEs along the Hikurangi Margin.

PAPER

THE GEOCHEMISTRY AND PETROGRAPHY OF THE 36.8 KA MAKETU ERUPTION EPISODE, OKATAINA VOLCANIC CENTRE

L.R. Doyle[1], P.A. Shane[1] & I.A. Nairn[2]
[1]Department of Geology, The University of Auckland, Private Bag 92019, Auckland
[2]45 Summit Road, Lake Okareka, Rotorua, RD5
(l.fowler@auckland.ac.nz)

The 36.8 ka Maketu eruption episode is the sixth of 14 known episodes of the Mangaone Subgroup which were erupted from within the Haroharo Caldera, OVC, between 40 and 31.5 ka. Analysis of single clasts from the deposits reveals a wide compositional range – whole rock ranges from 65-72 wt% SiO_2 and glass (melt) composition ranges from 69-77 wt% SiO_2 and 2-3 wt% K_2O. Many (42%) of the clasts have a homogenous melt composition. Some have a heterogeneous melt composition with a variation of up to 11 wt% SiO_2. Three distinct compositional groups are identified. The first (T1) has low glass SiO_2 (72.4-73.5 wt%) and high FeO (2-2.5 wt%). They contain plagioclase, orthopyroxene, clinopyroxene and rare olivine. The other group (T2) has high SiO_2 (75.5-77 wt%) and low FeO (1.2-1.6 wt%) and are hornblende-bearing and lack clinopyroxene. A few clasts show a range in SiO_2 which is indicative of hybrid mixing between T1 and T2. The hornblende-bearing clasts occur mostly in the late-stage deposits. Fe-Ti oxide equilibrium pairs in T2 pumice clasts reveal lower temperatures (~830-900°C) and are more oxidised (fO_2 = 1.1-1.3) than T1 (T = 920-980°C; fO_2 = 0.8-1.1). A third melt composition is apparent (T3). This melt is depleted in K_2O and enriched in CaO, although SiO_2 is within the range of T2. T3 is also distinguished from T2 by fO_2, showing that it is more oxidised than T2 (fO_2 = 1.4-1.5).

Plagioclase composition mostly ranges from An_{37-70} although a few clasts contain Ca-rich plagioclase (An_{77-86}). Some clasts contain both normal- and reverse-zoned plagioclase phenocrysts. Orthopyroxene and clinopyroxene compositions range from En_{62-70} and En_{39-48} respectively. Complex zoning patterns in some of the pyroxene phenocrysts point to an open magmatic system.

The magmatic system beneath Haroharo caldera before the Maketu episode probably consisted of multiple bodies of magma, each with separate cooling and oxidation histories. T2 and T3 magmas stagnated in the crust at a shallower depth than T1. T1 magma intersected and entrained the shallower magmas on ascent. Rare olivine, low-An plagioclase and less silicic melts (glass SiO_2 = 63 wt%) in some rhyolite clasts point to basaltic intrusion and mixing. Mafic intrusion may have triggered the eruption.

PAPER

EARLY TRIASSIC CRINOIDS: THE NEW ZEALAND RECORD AND TAXONOMIC IMPLICATIONS

Michael K. Eagle

Geology Department, University of Auckland, Private Bag 92019, Auckland; Natural History Department, Auckland Museum, Private Bag 92018, Auckland. (m.eagle@auckland.ac.nz)

The Permian/Triassic mass extinction all but annihilated crinoids. Early Triassic specimens are rare world-wide. Non-preservation, facies constraints, and collecting bias further complicate collecting specimens. Much debate has ensued on the origins of the Articulata. Some palaeontologists consider *Holocrinus* (Isocrinida) to be the most ancient of Mesozoic-Cenozoic faunas since *Holocrinus* is recorded from the Spathian or Smithian chronological stages in Northern Hemisphere Early Triassic localities (i.e. South Primorye; northern Japan; northern Italy; western United States), and is here first recorded in the Southern Hemisphere from the (Nelsonian; Induan-Olenekian) of the Kaka Point Structural Belt, North Catlins, New Zealand.

Oji and Twitchett (2006) record an Early Triassic Millericrinida (dadocrinid?) in the Griesbachian from the Al Jil Formation, northern Oman. Their study concluded that the post-mass extinction recovery of crinoids was geographically diachronous, thereby demonstrating a complex global pattern of diverisification concordant with other marine animals. The identification of another Early Triassic (Nelsonian) Millericrinida (millericrinid n. gen.; a terminal disc holdfast) from the Wairoa Gorge, Nelson, suggests that both the Isocrinida and Millericrinida concurrently inhabited the Panthalassa Ocean offshore from Gondwanaland. To date, this is the sole occurrence globally of holocrinids and millericrinids co-occurring in the Early Triassic, suggesting the Isocrinida and Millericrinida evolved from an earlier proto-articulate, or that the Millericrinida preceded the Isocrinida, or that both lineages originated from different Palaeozoic stem groups.

Similarity of holocrinids (Isocrinida) and dadocrinids (Millericrinida) has been studied, but each resolved as distinct taxa. Dadocrinids share many characters with the encrinids that lived about the same time. Both occur as Middle Triassic faunas in the Maorian Province of New Zealand, but are unknown from the Early Triassic. The appearance of the Isocrinida and Millericrinida just after the Permian/Triassic extinction event in the Southern Hemisphere suggests these orders the most ancient of all Articulate crinoids. Both taxa survive in the world's oceans today.

Reference:

OJI, T. and TWITCHETT, R. J. 2006: Early Triassic crinoids: their global recovery pattern and the origin of new groups. Yang, Q., Wang, Y., and Weldon, E. A. (eds.) *Ancient life and modern approaches. Abstracts of the second International Palaeontological Congress, Beijing, China, 2006.* University of Science and Technology of China Press: 43.

PAPER

3-D DISTRIBUTION OF ANISOTROPY AND ATTENUATION IN THE HIKURANGI SUBDUCTION ZONE

Donna Eberhart-Phillips[1], Martin Reyners[1], Mark Chadwick[1] & Graham Stuart[2]
[1]GNS Science, PO Box 30368, Lower Hutt 5040, New Zealand
[2]School of Earth Sciences, University of Leeds, Leeds LS2 9JT, UK
(m.reyners@gns.cri.nz)

Imaging the 3-D distribution of anisotropy in seismic velocity shows that mantle flow is not the primary source of anisotropy in the Hikurangi subduction zone. In the central North Island, the subducted slab has seismicity to 300 km depth below the Taupo Volcanic Zone (TVZ). We use these earthquake data in a 3-D velocity inversion for *Vp* azimuthal anisotropy, including local earthquake shear-wave-splitting observations to define the initial model. We also invert for the 3-D attenuation structure, by determining *Qp* based on t* of local earthquakes.

The largest region of trench-parallel anisotropy is the subducted slab, which shows 5-9 % anisotropy from 30-180 km depth. This represents fossil anisotropy in the Pacific plate. The greatest magnitude of anisotropy is in the brittle crust of the overlying Australian plate. The crust has up to 14 % anisotropy oriented normal to the extension direction of the TVZ rift, parallel to shear fault zones, and parallel to schist fabric. In sharp contrast, the active volcanic region in the central rift is distinguished by extension-parallel anisotropy in the upper 15 km. In the TVZ mantle wedge, trench-normal anisotropy of 2-6 % above the slab is imaged from 35-75 km depth. West and south of the TVZ, the mantle wedge shows minor anisotropy with a more northerly orientation.

Attenuation is the seismic parameter that shows the most dramatic variation in the mantle wedge in the North Island. In the mantle wedge, low *Qp* (*Qp*(10hz) <200) is imaged from 35-100 km depth, in a region also characterized by low *Vp* and high *Vp/Vs*. We interpret this as a region of significant partial melt, produced by the reaction of fluid released by dehydration of the subducted plate with the convecting mantle wedge. The low *Qp* extends to shallow depth in zones of active volcanism. At the southwestern termination of the TVZ, the boundary between low *Qp* within the TVZ and high Qp in the crust to the southwest dips to the southwest in concert with the crustal seismicity.

POSTER

FIRST RECORD OF POSSIBLE HEINRICH EVENTS IN NEW ZEALAND

Anthony R. Edwards
Stratigraphic Solutions, P O Box 295, Waikanae 5036 (biostrat@actrix.co.nz)

Eight Heinrich events occurred between about 11 and 60 thousand years (kyr) ago. In the North Atlantic they coincide with major ice-sheet breakouts and drastic reductions in deep water formation, in the South Atlantic with trade wind forcing of upwelling, and in Antarctica with warm atmospheric conditions in the Byrd ice core record. On the Chatham Rise and elsewhere in the South Pacific Heinrich events are recognisable by increased phytoplankton productivity, probably due to “an increased upwelling flux of iron-enriched deep water” (Sach & Anderson 2005). Given the very widespread distribution of Heinrich events it seems very likely that they also occur in New Zealand’s terrestrial record. Information compatible with the occurrence of Heinrich events has recently been found in two new Kapiti Coast road cuts.

At MacKays Crossing a long, up to 20 metre high, cutting has been cut through the outer part of a large thick alluvial fan, the Te Ramaroa, built of debris eroded from the northern slopes of high-standing Mt. Wainui (Cotton 1918). The cut exposes several gently sloping fanglomerates (each mostly consisting of poorly sorted sub-angular gravel & sand) capped by a thin cover bed of aeolian fine sand. Also present are a number of thin beds of well-sorted (aeolean?) fine sand, some of which drape over erosion surfaces within the fan. The four most conspicuous and continuous of these beds are here attributed to Heinrich events H1 to H4; at least some of the other beds seem to have a good fit to certain inter-Heinrich events. These sedimentary patterns suggest that the fanglomerates of this road

cut were deposited between about 40 kyr ago (within MIS3 but below H4) and 11 kyr ago (Termination 1B). This assessment is consistent with the presence in this sequence of a 30 cm thick bed of volcanic glass likely to be the Kawakawa Tephra (26.17 kyr). It occurs in fanglomerate about 1.5 metres below the fine sand bed attributed to event H2 (20.4 to 22.1 kyr).

At Lindale a road cut up to 4 metres high has been excavated down the axis of a small alluvial fan built by the Tikotu Stream. It exposes four sedimentary cycles, each consisting of "thick" poorly sorted angular fanglomerates (some with timber or wood bearing horizons) conformably overlain by a thinner, sometimes gritty, silty fine sand that is partly capped by a thin, in places carbonaceous or ?loessic, siltstone which, except for the youngest cycle, is laterally associated with gully formation. Thus it seems likely that the top of each cycle approximates to a Heinrich event, implying correlation with the YD and H1 to H3 events. This in turn suggests that the deposition of fanglomerate in this section started about 35 kyr ago (below H3 in MIS3) and ended ~11 kyr ago (Termination 1B). This appraisal seems to be compatible with a date of 19,193 ±538 cal. yrs obtained from wood taken from a thin silt that significantly predates H1 (13.4 to 15.1 kyr) in a nearby (~300 metres) road cut (Fleming 1970).

From the above it seems likely that this is the first non-Antarctic southern hemisphere record of Heinrich events in non-marine strata. Further, more detailed, studies are strongly recommended as they could lead to important advances in our understanding of the age and history of New Zealand's terrestrial biota, environment and strata.

POSTER

RAPID MICROPLATE ROTATION AT SUBDUCTION ZONES: TESTING THE EFFECT OF BUOYANT INDENTORS USING WORK RATE MINIMIZATION AND NUMERICAL MODELS

S. Ellis & L.Wallace
GNS Science, PO Box 30-368, Lower Hutt
(s.ellis_at_gns.cri.nz)

We test the hypothesis that collision of buoyant features such as oceanic plateaus and continents at subduction margins plays a causative role in formation of curved, arcuate margins, with large-scale tectonic rotations and accompanying back-arc spreading (McCabe, 1984; Wallace et al., 2005). A global survey of subduction margins (including the Hikurangi subduction margin of New Zealand) shows a strong correlation between a transition from subduction to collision along-strike, and rapid microplate rotations as measured from GPS velocities. This led Wallace (2005) to propose a conceptual model whereby the buoyant feature increases the normal stress across the subduction interface, exerting a torque on surrounding upper plate crust that induces rapid rotation.

Initially, we compare a simple analytical analysis minimising the rate of work in a two-dimensional subduction zone to numerical models, to determine under what circumstances back-arc opening will occur when no along-strike variations are present. This approach allows us to estimate the relative importance of 2D forces operating at subduction zones The numerical models include the subduction interface as a weak frictional contact surface, weak lithosphere with thermal weakening due to back-arc volcanism, slab-pull, and restoring forces in the asthenosphere (e.g., Hassani et al., 1999). We show how the simple work rate minimisation analysis results in analytic expressions for trench retreat rate and back-arc spreading rates as a function of lithospheric buoyancy and strength.

The results from the simple 2D models can be applied to more complex settings where 3D effects dominate such as the Hikurangi subduction margin, provided the extra shear dissipation arising from along-strike coupling terms are taken into account. In the preliminary analysis reported here, we use simple 3D block models with a variation in normal boundary force to test whether rapid rotation is produced. Results indicate that there is a complex interaction between along-strike transcurrent faulting, extensional opening of thermally weakened lithosphere, and rotation of the upper plate. Rotation only occurs when thermal weakening from arc volcanism is present, but because rotation triggers extension in the overlying plate, it can induce further thermal weakening causing a positive feedback cycle. While providing insight, these results are as yet too simple to apply directly to real examples such as the Hikurangi subduction margin. In particular, the influence of viscous drag along the subducting slab may be underestimated. We discuss future model improvements that will incorporate these factors.

PAPER

LITHOSPHERIC SHORTENING AND DUCTILE DEFORMATION IN A BACK-ARC SETTING: WANGANUI BASIN

Erik Ewig & Tim Stern
Institute of Geophysics,Victoria University of Wellington, PO Box 600, Wellington
erik.ewig@vuw.ac.nz

The back-arc region of the North Island subduction zone can be divided into two distinct zones: to the north there is the Taupo Volcanic Zone with extension, recent uplift, volcanism and high heatflow; in contrast, to the south there is the South Wanganui Basin - a region of broad crustal down-warp, with predominantly reverse faulting. The basin is Pliocene-Pleistocene in age, and the subducted plate lies at a depths of 25 to 200 km beneath the basin. The depocenter of this basin has migrated south-southwest with time, driven at least partly by the Quaternary uplift and doming of the central North Island. Therefore, the evolution of the Wanganui Basin is part of the long time progression, Pliocene development of the North Island tectonics in general.

One of the most compelling observations relevant to the origin of the South Wanganui Basin is the –150 mgal Bouguer/isostatic gravity anomaly. Sediment fill can only partly explain this anomaly. 3D models show that the gravity anomaly associated with the basin is generally consistent with a down-warp model of the entire crust. However, the downwarp of the Moho has to be significantly greater than the down-warp of the sediment-basement interface to fit the observed gravity anomaly. Hence we propose a model of ductile thickening of both crust and mantle lithosphere, increasing with depth. Moreover, the crustal thickening can not explained by uniform shortening due to a lack of throw on faults. A vertical pull at the bottom of the crust is one possible explanation for the driving force of the Wanganui Basin. This would distinguish the tectonics in this area from classical orgenic belts.

Initial results of the 3D viscous-elastic modelling of the basin will be presented. We explore two end member models: models that include flexural downwarping due to shear stresses at the interface between the Australian and the subducting Pacific plate; and models that include pervasive thickening of the Australian plate lithosphere.

Teleseismic receiver function data from the Wanganui Basin show a clear double negative peak before the P to S conversion arrival from the Moho at 5.8 s. To explain the observed receiver functions we need a lower crustal layer with a high Vp/Vs ratio (> 2) and small to very small S-velocities in the lower crust. We propose that water released from the subducted plate is been pooled in the lower crust creating the low Vp/Vs ratio. Moreover, because the fluids will be at lithostatic pressure the crust will become embrittled, giving rise to the swarm like crustal seismicity that is associated with the Wanganui Basin.

PAPER

STRATIGRAPHY, HYDROTHERMAL ALTERATION AND EVOLUTION OF THE MANGAKINO GEOTHERMAL SYSTEM, TAUPO VOLCANIC ZONE, NEW ZEALAND

C.J. Fagan[1], C.J.N. Wilson[1], K.D. Spinks[2], P.R.L. Browne[1], S.F. Simmons[1]
[1] The University of Auckland, Department of Geology, Private Bag 92109, Auckland, New Zealand
[2]Mighty River Power, P.O. Box 445, Hamilton, New Zealand

A major part of the ~1.6 Myr history of the Taupo Volcanic Zone (TVZ) is represented by buried and hydrothermally altered rocks penetrated by geothermal exploration wells. The geothermal field at Mangakino is sited in the oldest TVZ caldera on the western edge of the TVZ. Four exploration wells into the field reveal a thick sequence of flat-lying ignimbrites. Basement Mesozoic greywacke metasediments were not reached by the deepest well, MA2 (3192m), implying the presence of a thick caldera infill. Ignimbrites exposed at the surface nearby have distinct mineralogies and crystal contents, which enable correlation with down-hole lithologies. Five ignimbrites are identified in the wells: the 0.32 Ma Whakamaru, 0.93 Ma Marshall, 1.0 Ma Rocky Hill, 1.18 Ma Ahuroa and 1.25 Ma Ongatiti ignimbrites, two of which are >800m thick. The Whakamaru and Marshall units are separated by a thick sequence of lacustrine and volcaniclastic deposits related to infilling of the Mangakino caldera. The ignimbrite sequence is continuous between all wells, with no fault offset, and only well MA3 intersects two rhyolite intrusions at 1190m and 1850m that are thought to be feeder dikes to post-0.32 rhyolite domes to the east of Mangakino.

Alteration assemblages include epidote and wairakite in MA2 below 2200m. Adularia occurs in MA2 and MA3 where it replaces, wholly or in part, primary andesine. Adularia is also locally replaced by illite, indicating a shift in hydrothermal conditions. Other minerals present are chlorite, quartz, calcite, titanite and pyrite. Secondary quartz and calcite veins are seen in thin section, with a first appearance in the lacustrine sediments at 550m in both MA2 and MA3. Fluid inclusions in secondary calcite show high temperatures (300 & 315°C) while inclusions in primary quartz show ~165°C (the current temperature at the sampled depth), recording current conditions. The modern maximum temperature is 250°C at 3000m in MA2 Evidence for two different temperatures in the fluid inclusion data and a shift in alteration mineralogy may reflect an earlier thermal event, possibly related to dike intrusion nearby.

POSTER

DOES THE PRESENCE OF GAS HYDRATE ON THE HIKURANGI MARGIN CONTRIBUTE TO SLOPE FAILURE?

M. Fohrmann [1], A.R. Gorman[1] & I.A. Pecher[2]
[1] Department of Geology, University of Otago, P.O. Box 56, Dunedin, New Zealand
[2] Institute of Geological & Nuclear Sciences (GNS), P.O. Box 30 368, Lower Hutt
(fohmi830@student.otago.ac.nz)

Gas hydrates have been observed on several seismic lines on the accretionary margins of New Zealand, i.e. the Hikurangi and the Fiordland margins. Gas hydrate is an ice-like form of water and natural gas (mostly methane) that exist in well defined temperature- pressure regimes starting from about 500 m water depth and ranging down to over 600 m below seafloor. Its stability field is strongly dependent on seafloor water temperature and the geothermal gradient. Occurrences of hydrate have been interpreted in marine seismic reflection data by the presence of a bottom simulating reflection (BSR) which represents a lower stability boundary within the sediments for solid hydrate (beneath the BSR, temperatures are too high for hydrate to exist). On the Hikurangi margin, east of the North Island, gas hydrate has the potential to provide a resource larger than that of the Maui gas field. In addition to this economical aspect of gas hydrates, they also have the potential to affect seafloor stability. Dissociation of gas hydrate leads to the generation of large volumes of gas (in an ideally saturated methane hydrate, the volumetric ratio of methane gas to solid hydrate equals 164:1), possibly causing overpressure and submarine landslides.

These circumstances led to New Zealand's first research cruise dedicated solely to studying gas hydrates in 2006. Amongst other things, the Hikurangi Margin survey acquired new seismic reflection data across the Rock Garden area, located off Hawke's Bay, which is used in this study.

The seismic data across Rock Garden reveal an 8-km-long BSR running parallel to the inclined seafloor, making it a potential hazard through submarine slope failure. When gas hydrate stability conditions change, e.g., due to recorded short-term temperature variations of the seawater or long-term changes like uplift, it will start to dissociate. This will elevate the local pore fluid pressure, resulting in a destabilisation of the sediment. We address the problem of possible slope failure due to dissociation of gas hydrate through modelling. 1) We treat the whole submarine Hikurangi accretionary complex as a critical Coulomb wedge on the verge of failure to obtain estimates of a) pore-fluid pressure and b) coefficients of friction. 2) The results from the Coulomb wedge model are then compared to actual borehole data for reliability and for confirmation that the model that is used is accurate. This procedure is necessary because geotechnical parameters that are crucial for slope failure analysis are not known for the site that will be modelled. 3) The Coulomb wedge theory will then be applied to the slope that contains gas hydrate. 4) Finally, the resulting pore-fluid pressure and coefficient of friction are used as initial conditions in a 2D finite element code that simulates slope failure. The simulation then accounts for increasing pore fluid pressure due to gas hydrate dissociation that will lead to slope failure.

PAPER

DATA MANAGEMENT INITIATIVES AT CROWN MINERALS

R.D. Garlick

Crown Minerals, Ministry of Economic Development, P.O. Box 1473, Wellington

(richard.garlick@med.govt.nz)

Crown Minerals is responsible for managing and making accessible the technical data submitted by permit holders under the Crown Minerals Act 1991. This data is submitted by both minerals and petroleum permit holders. The type of data submitted is varied including physical lodgements such as core and paper reports through to digital lodgements of well logs and seismic surveys.

Crown Minerals has embarked on an aggressive programme to improve public access to technical information held by the Ministry so that well-informed business decisions can be made. Initiatives in 2004-06 have seen significant progress being made toward fulfilling this key business outcome.

Phase one of the digital catalogue went online in November 2004 enabling internet access to a digital catalogue of reports. Now over 2800 Petroleum, 300 Coal and 1200 Mineral reports are discoverable and downloadable from the Crown Minerals website. As well as this growing wealth of report data improvements have been made to the timeliness of permit change notification, access to permit documents and provision of dynamic permit maps.

Phase two of this programme will see a staged roll out of enhanced online searching for resource and technical data in both map and tabular format including improved access to additional technical information and online data ordering. Permit holders have increasing expectations that permit information and technical data will be available in a digital format and be readily accessible by way of web-based facilities or similar means. This system uses the latest technical and spatial data management technology to allow data to be easily discoverable in tabular or map form. Previewing loaded seismic sections and well curves and ordering directly over the web will also be simple tasks in the new system.

Significant improvements in the timeliness and quality of map services will also be possible when this new system is delivered. Permit maps will be linked to the new permit lifecycle database providing near real-time updates of dynamic web maps.

Crown Minerals has had a parallel programme underway for a number of years to migrate paper based material to a digital form and this new system will provide a mechanism to deliver these results. The transition from paper to digital continues with the scanning of existing reports, plans and logs and the planning toward full digital reporting and data lodgement underway.

These projects will be delivered in the coming year and will provide the foundation to a range of initiatives aimed at improving the quality and cost of services offered by Crown Minerals. They represent a significant milestone at the beginning of a longer journey aimed at improving both access to, and quality of, information.

SEISMIC UNREST AT NGAURUHOE VOLCANO

Geonet Volcano Monitoring Group
GNS Science, Private Bag 2000, Taupo and PO Box 30368, Lower Hutt
(Presenter Steven Sherburn, s.sherburn_at_gns.cri.nz)

Small volcanic earthquakes are occasionally recorded at Ngauruhoe volcano by the seismic network in Tongariro National Park. In late-May 2006, a period of seismic unrest began with a several-fold increase in the rate of volcanic earthquake activity.

On June 6th, in response to the continued volcanic earthquakes, we raised the Scientific Alert Level from 0 to 1, signifying that there had been a departure from typical background activity and that there were consequently signs of volcano unrest. We further responded by installing three additional seismographs close to Ngauruhoe and by beginning a more intensive program of volcanic gas and temperature monitoring. We also installed a continuous GPS station nearby to monitor ground deformation.

Within the first three months of the unrest more than 2000 small volcanic earthquakes have been recorded. These are typical of volcanic earthquakes, having emergent onsets, dominantly low-frequency waveforms, and an absence of obvious S-wave energy. With the data from the additional seismographs we have been able to locate the volcanic earthquakes about 1 km north of the summit of Ngauruhoe at about 1 km below the surface. The largest earthquakes are very small, approximately magnitude 1.

The earthquake waveforms have remained very similar (cross-correlation values above 0.85) over several months, indicating that the source is fixed in one location and that there is a repetitive and non-destructive source process. There appears to be an upper-limit to the size of the largest earthquakes. Because of the absence of S-wave energy and the repetitive, size-limited source, we think that the source mechanism involves fluids (magma, gas, or water) rather than repeated slip on a fault. The exact mechanism cannot be determined directly from our observations and will be the subject of further research. Very few (if any) shallow volcano-tectonic earthquakes have been recorded with this sequence.

We have measured temperatures at fumaroles near the summit of Ngauruhoe and at Red Crater on Tongariro volcano and have collected gas samples for detailed analysis. We have also measured carbon dioxide release through the ground. None of the fumarole temperatures, gas flux, and analysis of gas samples have shown any significant changes from data collected before the unrest began. The continuous GPS has not recorded any ground deformation.

Volcanic earthquakes are considered a common precursor to volcanic eruptions, particularly when there is a significant increase in the number of events. Since 2000 we have observed significant numbers of shallow volcanic earthquakes at Tongariro volcano without any changes in other monitored parameters, and without an eruption. Our recent observations suggest that Ngauruhoe could be an example of a volcano at which changes in the rate of volcanic earthquakes cannot, in isolation, be interpreted as an eruption precursor, rather they may reflect non-volcanic perturbations in the shallow hydrothermal system.

PAPER

GEOPHYSICAL CHARACTERISATION OF THE FOULDEN HILLS MAAR, NEAR MIDDLEMARCH, OTAGO

A.R. Gorman, D.E. Lee, G.S. Wilson, J.W. Kilner, H. Blakemore, G.J. Crutchley, M. Fohrmann, M.G. Hill, B.J. Pooley, and K. Tinto
Department of Geology, University of Otago, PO Box 56, Dunedin.
(andrew.gorman@otago.ac.nz)

The Foulden Hills Maar, 10 km east of Middlemarch, contains exceptionally well-preserved plant and animal fossils of Early Miocene age. The lake sediments – finely laminated diatomites – occur in a small subcircular depression about 700 m by 500 m across that is surrounded by schist basement. This feature had earlier been described as a synsedimentary graben; however we prefer to interpret the origin of the basin as a maar crater lake associated with the Waipiata Volcanic Field. Recent geological mapping has demonstrated that fine-grained basaltic rocks occur in outcrop on the eastern and southern margins of the diatomite deposit, and as hillocks capped with loose boulders on the west and northern margins. One sample of a probable pyroclastic deposit was collected from a 1-m-deep hole during the geophysical survey of the area.

Prior to this work, no physical data had been available to constrain the subsurface structure, shape, and origin of the basin. During August 2006, the University of Otago's Department of Geology conducted their undergraduate geophysics field school at the Foulden Hills Maar. A 1.5-km-long transect traversed the structure in order to compare and contrast the various geophysical techniques that were applied, and also to tie the geophysical data to known near-surface control from two diatomite pits located on the transect. Gravity, magnetic, ground penetrating radar, and three seismic reflection surveys were conducted along this transect. Each of the seismic surveys made use of a 48-channel seismograph with 28-Hz geophones deployed at 5-m spacings. The surveys differed in their sources: (a) 150-g explosive charges at 20-m intervals, (b) shot-gun shell blank charges at 20-m intervals, and (c) 5-fold seismic hammer hits at 5-m intervals. In addition, the magnetic survey was expended to 14 other transects within the maar structure in order to provide three-dimensional control to the feature. A synthesis of these data is presented.

POSTER

SEISMIC REFLECTION IMAGING OF THE OSTLER FAULT, WEST MACKENZIE COUNTRY, SOUTH ISLAND

A.R. Gorman & F.C. Ghisetti
Department of Geology, University of Otago, PO Box 56, Dunedin.
(andrew.gorman@otago.ac.nz)

The Ostler Fault (Western Mackenzie Basin, north of Omarama) is an active structure, sub-parallel to the Alpine Fault, that accommodates components of shortening east of the plate boundary. It is exposed for an overall length of about 50 km, has high rates of activity (~1.0 mm/y of vertical displacement), and offsets deposits as young as 14,000 years. A thick Miocene-Pliocene sedimentary sequence deposited in a lacustrine basin adjacent to the fault records a long history of differential relative motion between the two blocks separated by the fault, and the fault trace itself is marked by a pronounced alignment of scarps from past earthquake surface ruptures. However, its deep geometry remains enigmatic.

In January and February 2006, we acquired two seismic reflection lines across the Ostler Fault between Omarama and Twizel. The source points for the survey were 150-g explosive charges buried to a depth of 0.7 – 1.2 m. Geophones for the 48-channel survey were spaced 10 m apart. The ~9.5-km-long northern line along Lake Ohau Road had a shot spacing of 40 m (6-fold coverage) whereas the ~8.0 km-long southern line at Willowbank Saddle had a shot spacing of 60 m (4-fold coverage.)

The seismic data illuminate a complex fault zone composed of at least three significant segments with the easternmost segment corresponding to the significant surface scarp observed west of State

Highway 8 in the region. Individual faults are identified by distinct breaks in reflectivity patterns and are interpreted to depths greater than 1 km. East of the fault zone, subparallel reflections onlap a distinct basement reflection inferred to be representative of the Torlesse. West of the fault zone, little continuous coherent reflectivity is observed beneath a few hundred metres suggesting that the reflective sedimentary units present east of the fault are not present to the west. Fault geometry, offset of sedimentary horizons, and syntectonic sedimentation are analysed in conjunction with new surface mapping that has been conducted.

PAPER

MOA TRACKWAYS AND FOOTPRINTS: THREE NEW DISCOVERIES

[1]M.R. Gregory, [1]D.Hikuroa, [2]K. Phillips, K.A. [1]Campbell and [3]A. Martin.
[1] Department of Geology, University of Auckland, New Zealand
[2] Victoria St., Whakatane, New Zealand
[3] Department of Environmental Studies, Emory University, Atlanta, USA

Between the 1860's and the mid- to late 1900's moa footprints and trackways had been found at irregular intervals, and at only seven or eight widely separated, North Island localities (Turanganui River Gisborne, Bluff Hill, Napier; Manawatu River, Palmerston North; Tutaenui Stream, Marton; Rangitikie River, Tangimoana; Ruamahunga River, Carterton; Waiwakaiho Stream, New Plymouth; floor of Lake Taupo!). None are known from the South Island. Probable moa pathways where no footprints can be recognized (*ara moa*) are known from both islands, but are even less commonly reported. Herein we record, and briefly describe and illustrate some moa footprints and trackways recently discovered from three previously unknown North Island localities:- Paparoa Peninsula Ohiwa Harbour, Whakatane; and Matata, Bay of Plenty; and Henderson Bay, Northland

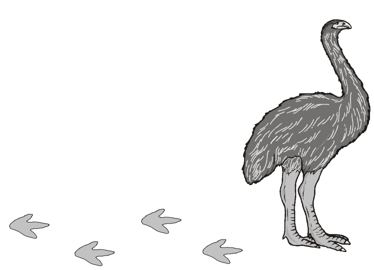
1) Paparoa Peninsula:- Fall from a *c.*10 m cliff face left a slab of rhyolitic mudstone standing near-vertical on the shore platform, where it was washed by the sea at high tide. The trackway consists of three prints, which are true casts, on the base of the overlying bed. Despite a careful search, the underlying, mould bearing horizon, could not be identified.

2) Matata:- A recent debris flow in Matata (May 2005) has yielded a 1.7 x 1.2 x 1.2m block in which 12 moa footprints have been recognized. The footprints are under- prints preserved in a medium tephric sand 2 – 10 mm thick. This caps a sequence of medium to thick, laminated rhyolitic muds and sands underlain by 1.5 m of blocky (unnamed) pumice tephra. The block originally lay between two dated tephra: the 330-340 yk old Rangitawa Tephra and the 280 yk old Matahina Tephra. At least 3 trackways and two directions of motion are recognized.

3) Henderson Bay:- The Quaternary sand-dune country of Aupouri Peninsula, Northland, has given up significant quantities of moa bones and other, now extinct birds, as well as representatives of extant species (Millner, 1981). Recently a trackway with three probable moa footprints has been recognized on the surface of a "coffee rock" exposure. The footprints are under-prints and have been etched in, or stand proud on the surrounding deflationary surface.

References

Millener, P. R. 1981. The Quaternary avifauna of the North Island, New Zealand. Unpublished Ph.D. Thesis, University of Auckland.



PAPER

A MICROFOSSIL RECORD OF ESTUARINE CHANGE (MAHURANGI HARBOUR, NORTHLAND).

Hugh R. Grenfell and Bruce W. Hayward
Geomarine Research, 49 Swainston Rd, St Johns, Auckland
(h.grenfell_at_geomarine.org.nz)

Benthic foraminifera and other microfossils once again illustrate an ability to document ecological changes due to human impact. Eight short cores from Mahurangi Harbour, northern New Zealand, record similar microfossil changes that began during the early European period of deforestation (1850s-1900). A sharp decrease in the absolute abundance of foraminifera and ostracods up-core and provides proxy evidence for the near-order of magnitude increase in sedimentation rate, a result of forest clearance as indicated by the increased abundance of bracken fern sporangia and palynological changes.

The main changes occurred throughout Mahurangi Harbour in mid to late European times (1950s-1980s) and are documented by the decline of soft shore molluscs, increased diatoms and the seaward advance of brackish, agglutinate-dominated, foraminiferal associations. This advance is inferred to be due to pH decrease resulting from increased freshwater runoff since forest clearance (later enhanced by infilling of the upper parts of the harbour with sediment), increased pore water acidity and speculatively by slightly more acid sea and freshwater, due to increased carbon dioxide in the atmosphere. These major changes occurred before and during the early phase of oyster farm establishment, thus precluding any significant contribution from them. Timing of the increase in abundance of large diatoms implicates increased nutrients associated with the increased sediment and freshwater runoff, rather than oyster farm input.

Comparison of the microfossil content of surface sediment samples taken inside and outside of four oyster farms indicates variable effects dependent upon farm location. In less saline sites, the presence of oyster shell debris in sediment beneath oyster farms appears to have buffered the foraminiferal faunas from some of the impacts of lowered salinity and pH. At more tidally-flushed, saline sites the oyster farms appear to influence a wider surrounding area which has lower relative abundance of three species of *Elphidium* and other calcareous foraminifera, attributed to slightly muddier sediment, higher nutrients and consequently lower oxygen.

PAPER

STRONG VARIATIONS IN SEISMIC ANISOTROPY ACROSS THE HIKURANGI SUBDUCTION ZONE, CENTRAL NORTH ISLAND

Sonja M. Greve & Martha K. Savage
Geophysical Institute, Victoria University of Wellington, PO Box 600, Wellington
(Sonja.Greve@vuw.ac.nz)

Strong anisotropy with rapid lateral changes across the mantle wedge of the Hikurangi subduction zone, central North Island, New Zealand is observed using shear wave splitting measurements. The method is based on the fact that shear waves propagating through an anisotropic medium split up into two quasi-orthogonal components travelling with different velocities. We measure fast orientations and delay times separating the two components on SKS, SKKS, S and ScS phases from teleseismic earthquakes.

Across the forearc and the shallow mantle wedge trench parallel fast orientations are consistently observed. Delay times increase towards the arc region, with maximum values up to 5 s, one of the largest delay times measured in the world. Further across the backarc, delay times decrease systematically. Measurements from above the deeper mantle wedge in the western Central North Island show no apparent splitting.

The abrupt lateral change from trench parallel fast orientations with very high delay times in the Central Volcanic Region (CVR), decreasing to no apparent splitting in western North Island can give a tight constraint on the width of the deformation associated with the plate boundary. We use the association of anisotropy with stress to infer three different regions of mantle flow across the Hikurangi subduction zone. Beneath western Central North Island the apparent isotropy may be related to local mantle convection or vertical mantle flow, possibly caused by delaminated lithosphere. Presence of water or partial melt can cause fast orientations to align perpendicular to mantle flow in the CVR, a region with ongoing high geothermal and volcanic activity. We suggest simple corner flow in the mantle wedge, with flow-perpendicular fast orientations. Stations in the eastern central North Island mostly sample mantle beneath the slab. Trench parallel fast orientations in the east are explained by trench parallel mantle flow with possible contribution of trench-parallel fossil anisotropy within the subducting slab.

Interpretation of the observed large delay times is still a challenge. Fresnel zone estimates force the anisotropic body to be shallower than 220 km and therefore in the mantle wedge. Strong anisotropy (max. 10%) over 150 km in the mantle wedge together with upper mantle anisotropy beneath the slab could explain the observed high delay times. One mechanism to create such high anisotropy is melt segregation of partially molten rock. The frequency dependency of this mechanism could also explain persisting discrepancies between local and teleseismic shear wave splitting measurements.

PAPER

RHEOLOGICAL INVESTIGATIONS OF NATURAL QUARTZ IN A BRITTLE-DUCTILE SHEAR ARRAY, CENTRAL SOUTHERN ALPS, NEW ZEALAND

S. Grigull[1], T. A. Little[1], S. Ellis[2]
[1]School of Earth Sciences, Victoria University of Wellington, PO Box 600, Wellington
[2]GNS Science, PO Box 30368, Lower Hutt
Susanne.Grigull@vuw.ac.nz

An exhumed fossil brittle-ductile shear array in the central Southern Alps, New Zealand, provides a natural laboratory for the investigation of the rheological behaviour of natural quartz under mid-lower crustal levels during transiently high stresses that are related to the upramping of the Pacific plate onto the Alpine Fault and followed by a stress drop. At depths >20 km, temperatures of 450-500°C, fluctuating fluid pressures of 310 MPa to 560 MPa (near lithostatic) and minimum strain rates of ~10^{-13} s^{-1}, quartzofeldspathic wall rocks were faulted brittlely, presumably by aseismic stable sliding. Where brittle fault tips encounter older quartz veins embedded in the wall rocks, they terminate into shear zones in the quartz veins, deforming them brittlely and/or ductilely. Some of the embedded quartz veins deformed entirely ductilely to finite shear strains of 5-15. Despite these high strains and despite the smooth, coherent and ductile nature of the shearing of the veins, most of the ductilely sheared quartz veins show randomised or poorly developed CPO patterns. Most of the brittle faults are infilled by quartz-calcite veins indicating their role as conduits of fluids during deformation.

We evaluate geological field observations such as deformed vein shape, scaling relationships between vein thickness and ductility and vein thickness distribution density and spacing of the brittle faults. Using computer modelling, we simulate the observed vein structures in order to derive one or more flow laws that can explain the observed deformation for these naturally deformed quartz veins within the available time constraints and within the constraints of the known physical conditions.

Two-dimensional models were set up and initially deformed to small finite strains in order to gain insight into the observed scaling relationship between the vein thickness and the proportional fraction of ductile creep strain (i. e. ductility of the quartz veins). The results show that the fraction of ductile flow in the veins decreases as a function of strain rate in the shear zones and increases as a function of thickness of the veins. Assuming the quartz flow law from Paterson & Luan (1990) for the deformed veins at a temperature of 500°C and a yield stress of 100 MPa, we can explain the observations if the quartz veins were deformed at maximum strain rates of ca. 10^{-8} to 10^{-7} s^{-1}.

The lack of a CPO in most of the sheared quartz veins and the fluid-rich deformation conditions suggest that more complex flow laws may have been applicable. Wightman et al. (2006) and earlier computer models showed that a combination of existing flow laws for dislocation and diffusion creep could account for the observed shear strains and the randomisation of a pre-existing CPO. These models imply non-steady state flow and a change from dislocation creep to diffusion creep-accommodated GBS in order to weaken the CPOs. The change in flow laws may have been facilitated not only by fluids enhancing diffusive processes between the grain boundaries, but also by a large stress drop once the rocks had been upramped onto the Alpine Fault.

PAPER

SHALLOW INTRUSION CONDITIONS IN A FLOOD-BASALT PROVINCE; THE STORY FROM DYKES AND A SILL OFFSHOOT ALONG THE CONTACT BETWEEN A VENT COMPLEX AND COUNTRY ROCK, COMBS HILLS, FERRAR PROVINCE, ANTARCTICA

Emilie B.M. Guégan and James D.L. White
Geology Department, University of Otago, PO Box 56, Dunedin, New Zealand
(Gueem851@student.otago.ac.nz)

The objective of research conducted at Coombs Hills, Ferrar Province, Antarctica is to characterise the shallow intrusion conditions in a phreatomagmatic complex from a dynamic, structural and spatial view point.

The Middle Jurassic Kirkpatrick flood basalts and comagmatic Ferrar intrusions within the Transantarctic Mountains represent a major pulse of tholeiitic magmatism, and together constitute the Ferrar Large Igneous Province (LIP) of Antarctica. At Coombs Hills, the exposed Ferrar intrusions consist of numerous dykes and sills representing a complex plumbing system.

This research is a systematic study of dyke contact-characteristics, fabric, geometry and orientations at a site within the Ferrar Dolerite Province that combines field observations, with petrology study, stereoscopic relationship and anisotropy of magnetic susceptibility methods are used to interpret the nature of magma flow in the plumbing system of this LIP.

Knowing how magma was moving near the surface will place limits on how we can interpret flow in a postulated deep mega dyke, potentially allowing an indirect test of the hypothesis that magma was transported great distances laterally in dykes at depth.

POSTER

XENOLITHS FROM THE SUB-VOLCANIC LITHOSPHERE OF MT TARANAKI, NZ.

Kerstin Gruender[1], Bob Stewart[1] and Steve Foley[2]
[1]INR, Massey University, Private Bag 11 222, Palmerston North, NZ;
[2]Institut für Geowissenschaften, Johannes Gutenberg Universtität, Becher-Weg 21, 55099 Mainz Germany.
kerstin.gruender@gmx.net

Mount Taranaki is located 140 km west of the Taupo Volcanic Zone, lies 180 km above the Wadati-Benioff-Zone and represents the most westerly expression of subduction-related volcanism on the North Island of New Zealand. Taranaki is a high-K arc volcano and is compositionally predominantly basaltic andesite to andesite with minor dacite and basalt.

The sub-volcanic basement under Taranaki is thought to comprise calc-alkaline plutonic and metamorphic rocks of the Median Tectonic Zone (MTZ), overlain by a sequence of Cretaceous and Tertiary Sediments. There is geophysical evidence of a change to lower velocities at 10 km depth across a narrow zone beneath the volcanic edifice.

The xenolith suite has been initially grouped into six categories based on petrography, geochemistry and inferred genetic relationships; sedimentary rocks (1), mafic hornfels (2), garnet gneiss (3), granite and granodiorite (4), finely banded amphibolitic gneiss (5) and gabbros and ultramafic rocks (6). Groups 1, 3 and 4 are exotic lithologies derived from the MTZ basement and Cretaceous-Tertiary sediments of the Taranaki Basin while Groups 2, 5 and some fine grained gabbros from Group 6 could either be derived from the MTZ or be cognate xenoliths. Group 6 gabbros and ultramafic rocks are dominated by clinopyroxene, amphibole and plagioclase and are predominantly cognate in origin. Rare dunite and wehrlite xenoliths are only found in basaltic andesites and may represent cumulates from more primitive basalts. Some xenoliths contain glass of rhyolitic to trachyitic compositions with up to 6 % K_2O that may represent partial melts of the sub-volcanic lithosphere.

POSTER

CONTROLS ON ARSENIC MOBILIZATION AND ATTENUATION IN THE REEFTON GOLD FIELD, WESTLAND, NZ

Laura Haffert and Dave Craw
Geology Department, University of Otago, PO Box 56, Dunedin, New Zealand

Historic mining and extraction processes used at mine sites in the Reefton Gold field have left a legacy of ongoing arsenic contamination. Based on a GIS database (DAME) and specific sampling campaigns mineralogical controls on arsenic mobilization and attenuation were identified. At Waiuta roasting of the ore introduced secondary arsenic trioxide (As^{III}), which is soluble under surface conditions. Consequent high dissolved arsenic concentrations (up to 52 mg/L) are alleviated on site by the formation of scorodite ($FeAsO_2 \cdot 2H_2O$). In the Reefton gold field arsenic output flux (ca. 25 g/day) from historic gold mine sites is commonly less than the natural background flux from mineralized rocks (>2500 g/day).

Dissolved arsenic is attenuated by dilution, precipitation of scorodite, and/or adsorption to iron oxyhydroxide (HFO). Adsorption to HFO is an important attenuation mechanism in and adjacent to many mine sites. HFO is abundant at mine sites where pyrite was abundant in fresh rock, such as where the mineralised zone is dominated by disseminated pyrite. Pyrite, and resulting HFO, are relatively rare where mineralisation occurred as well-defined quartz veins (Waiuta). Localised HFO occurs also where ankerite oxidises in host rocks. The control of scorodite on dissolved arsenic concentration is also reflected in the database: Maximum dissolved As concentrations increase with increasing pH, corresponding to the increasing solubility of scorodite with increasing pH.

POSTER

VOLCANIC RECONSTRUCTION AND COLLAPSE RECOGNITION: A GIS BASED APPROACH

S.J. Hampton & J.W. Cole
Department of Geological Sciences, University of Canterbury, Pri. Bag 4800, Christchurch
(sjh163@student.canterbury.ac.nz)

Banks Peninsula is the highly eroded remnants of two large Miocene stratovolcanoes, Lyttelton (11.0 – 10.4 Ma) and Akaroa (9.1 – 8 Ma). The morphology of Lyttelton and Akaroa Volcanoes is highly debated with two main models proposed: the Hawaiian shield morphology (i.e. Weaver et al 1992), or the Mt Etna stratovolcano morphology (i.e. Shelley, 1992). Through GIS based analysis the morphology of Lyttelton and Akaroa Volcanoes can be assessed, with preliminary recognition of eruption centres and collapse features.

DEM-based morphometry is used as a method for reconstructing volcanic relief and paleosurfaces from primary landforms (i.e. methodology of Szekely and Karatson, 2004). Using ridge line patterns, slope angles, lava flow dips, volcanic extent below Canterbury Plains, degradation rates, cone sectors of these volcanoes can be established, linked to original volcano elements, and supported by structural and geochemical comparisons with basaltic stratovolcanoes and Hawaiian style volcanoes.

A polar coordinate-transformed (PCT) map located on the centre of the volcano has been produced to highlight concentric and radial features. Multiple eruption centres can be identified, through changes in the radial valley pattern, as well as volcanic collapse features.

It is proposed that the large harbours of Lyttelton and Akaroa are the result of catastrophic collapses. Further proposed collapses of Lyttelton Volcano are highlighted in digital terrain analysis, including the region of the Mt Herbert Volcanics and Gebbies Pass. Correlating collapse regions from digital terrain analysis and mapping of localised fieldwork areas enabled recognition of collapse related features, including exposure of basement lithologies, infilling deposits dipping in direction of collapse, and steep headwall scarps.

PAPER

FORAMINIFERAL EVIDENCE OF LARGE HOLOCENE EARTHQUAKE DISPLACEMENTS IN COASTAL SOUTH OTAGO

Bruce W. Hayward[1], Hugh R. Grenfell[1], Ashwaq T. Sabaa[1], & Rhiannon Daymond-King[1]
[1]Geomarine Research, 49 Swainston Rd, St Johns, Auckland
(b.hayward@geomarine.org.nz)

The intertidal zonation of estuarine and sheltered harbour foraminifera can be used to recognise abrupt, earthquake-related, vertical displacement events in Holocene sedimentary cores. Two of four short cores in Akatore Estuary record a 0.4 m subsidence on the west side of Akatore Fault during its last recorded rupture c. 1100 yrs ago. This may have been a tectonic downthrow or a result of shaking-induced compaction of the estaurine sediments.

Three of four cores around the fringes of Catlins Lake provide evidence of an abrupt subsidence of 0.25-0.3 m at c. 1100 yrs ago, and one core records a further subsidence of c. 1.5 m at ~4500 yrs ago. These displacements probably resulted from movement on the Settlement Fault which defines the east side of Catlins Lake. This inference is supported by our documentation of a 2.2 m difference in elevation of 3500 yr old strata across the Settlement Fault, with the east side upthrown and lake downthrown. This is the first direct evidence of Holocene fault rupture in coastal South Otago, south of the Clutha River. The timings of these two Holocene displacements on the Settlement Fault were similar to the two youngest rupture events previously determined for the Akatore Fault to the north.

POSTER

CONDUCTIVITY IMAGE OF THE TAUPO VOLCANIC ZONE, NEW ZEALAND

W. Heise[1], H. M. Bibby[1], T. G. Caldwell[1], Y. Ogawa[2], S. Takakura[3], T. Uchida[3]
[1] GNS Science, PO Box 30368, Lower Hutt, New Zealand
[2] Volcanic Fluid Research Center, Tokyo Institute of Technology
[3] Geological Survey of Japan, AIST
(w.heise@gns.cri.nz)

The Taupo Volcanic Zone (TVZ) in the North Island of New Zealand is characterised by rapid extension, very high heat flow and high rates of rhyolitic magma production. Earthquake hypocentre data show that the seismogenic part of the crust is only about 8 km thick within the TVZ. Phase tensor analyses of 120 magnetotelluric soundings indicate an approximately 2-D regional structure and show that the conductivity decreases rapidly beneath this highly thinned crust. 2D inversions show that this rapid increase in conductivity occurs at ~8 km and appears to mark the brittle ductile transition as defined from the seismicity. The high conductivities at deeper levels are most plausibly interpreted as being caused by a fraction of connected melt.

PAPER

GEOLOGICAL DATA – VENTURING BEYOND THE PAPER MAP

D. Heron & B. Lukovic
GNS Science, PO Box 30 368, Lower Hutt
(d.heron@gns.cri.nz, b.lukovic@gns.cri.nz)

QMAP is about to release the 13th sheet in the series. These paper maps have proved very useful and sales have been strong proving the worth of the series. But the digital GIS data used to create the maps will be of value long after the paper map has faded or fallen apart at the seams.

Vector data CDs have been released for eight sheets and interim versions which have undergone only limited quality control are available for the other published sheets. The CDs include GIS (ArcMap, ArcView, and ArcReader) projects with data pre-loaded to get users up and running quickly. ArcReader viewing software and other support such as font and marker files are included. Each dataset also comes with extensive metadata.

The published maps illustrate only one way of looking at the data. The maps show rock units coloured for age, which provides a good overview of the geology but hides the detail. With the digital data, users are able to highlight the units which are of interest to them.

Datasets such as geological polygons include additional attributes and by using GIS units can be aggregated on the basis of age, main rock type, terrane, broad rock group, and more. If joined with other tables, for example rock strength or liquefaction susceptibility, completely new maps can be produced.

Vector data from published QMAP and 1:50 000 geological maps have been used in assessing landslide susceptibility, ground shaking amplification susceptibility, and liquefaction susceptibility, in estimating the cost of trenching associated with the installation of underground services, and in mineral prospectivity assessments in mesothermal and epithermal gold terranes.

The QMAP data are currently available on sheet basis at low cost and in the future will be available on the GNS website as a series of seamless themes for the whole country.

PAPER

INNOVATIVE USE OF GEOLOGICAL INFORMATION FOR PLANNING AND DECISION-MAKING

D. Heron[1,] B. Lukovic[1] & P. Willemstein[2]
[1]GNS Science, PO Box 30-368, Lower Hutt
[2]PropertyInsight, PO Box 5098, Wellington.
(pim.willemstein@propertyinsight.co.nz)

Most geoscience is focused on understanding the “bigger picture”. Traditional outputs have been maps (hard copy or in GIS) and reports written in language understandable only by fellow geoscientists. Unfortunately, these traditional outputs don’t capture the opportunity for using geological data for day-to-day decision-making in our complex world, driven by quality, up-to-date and dynamically-delivered information. For example, New Zealand’s legislation has become more complex and requires the use of geological and hazard information for making building consent and resource consent decisions. The application of this specialized information may even be controversial, in particular as part of Land Information Memoranda (“LIMs”).

Geoscientists at GNS Science have taken up the challenge, through the ProperytInsight project, to make geological and hazard information available online to support decision making for individual property transactions. Systems and products have been developed to deliver geoscience information and knowledge in a manner that can be understood by non-specialists. The Manukau City Council has adopted this approach and uses PropertyInsight to deliver customised hazard reports, real-time using internet applications, for its building consents, LIM reports, emergency management and customer service processes. The hazard reports contain landslide, earthquake, flood, wind, salt spray, aircraft noise, flood and geothermal information.

The paper details the compilation of the landslide hazard module as an example. The landslide section of a PropertyInsight hazard report can include three separate assessments of a property's susceptibility to landslide. The first assessment is based on a GIS model that considers rock strength and slope, the second is based on mapping of existing landslides, and the third is based on areas of instability recorded in district plans and other council documents. The rock strength / slope model takes into account rock type and slope and makes an assessment of the susceptibility to land sliding. This model also assesses the susceptibility of a site that occurs at the base of a steep slope to be "over run" by a landslide that originates above the site or the susceptibility of a site at the top of steep slopes to "collapse" if the slopes below it fail. In areas where the data is of lower quality or complex, the assessment is specifically tagged. Existing landslides and areas of landslide instability are also being reported for some areas. Each landslide is buffered to allow for uncertainty in location. A property covered by landsliding or within a landslide buffer is tagged in the hazard report which also includes the source of the original data

PAPER

MAJOR ENGINEERING CONSTRUCTIONS ON TOP OF A HIGH-TEMPERATURE GEOTHERMAL PROSPECT: HAZARDS ENCOUNTERED AT TOKAANU (NZ)

M.P. Hochstein & W.M. Prebble
Geology Department, University of Auckland, Private Bag 92 019, Auckland

The Tokaanu hydroelectric power station, a c. 2 km long section of the headrace tunnel, and an approximately 0.5 km long segment of the tail race, were sited in the late 1950s along the broad, southern low resistivity boundary of the active Tokaanu-Waihi geothermal system. Its high-temperature liquid-dominated reservoir occurs in rugged terrain beneath the south-eastern slopes of the Quaternary, inactive Kakaramea-Tihia andesite volcano. At the time of designing and planning, the actual extent of the geothermal reservoir was poorly known.

Exploration drilling over the tunnel route was completed in 1965 and showed that thermally altered rocks with temperatures up to 42 deg C would be found at tunnel level. However, no toxic gases were detected in the boreholes and excavation of the tunnel went ahead. Excavation of a c. 650 m long section of the tunnel containing thermally altered rocks was difficult since the soft clay-rich material swelled into the tunnel and had to be removed repeatedly. Special procedures were used to stabilize the walls of this section. No concrete was put in place until all swelling had stopped. The entire tunnel was finally lined with poured concrete.

Temperatures above 99 deg C, however, were encountered at shallow depths (<20 m) near the base of the powerhouse and along a section of the tailrace canal. This produced flashing discharges at the wellhead of several test bores drilled in 1966. The potential for hydrothermal eruptions, which could be triggered by reducing the confining hydrostatic pressure by deep excavation, was tested by stepwise dewatering of two, up to 10,000 m2 large artificial ponds during the winter of 1968 and 1969. The ponds were surrounded by dams and higher standing ground to allow for quenching of any hydrothermal eruption during the lowering of the pond level. Although the temperature of the ponds increased rapidly towards the end of each test, no hydrothermal eruption occurred and the tailrace canal was excavated after completing the tests. A heat balance analysis of the last test is presented which shows that conditions during the test were always sub-critical. For safety, the bottom of the canal was raised and widened over the hot ground.

This study shows that with a cautious but forward-looking approach, major engineering constructions can nevertheless be completed despite encountering unexpectedly hot ground.

POSTER

CHATHAM ISLAND QUATERNARY STRATIGRAPHY: AN OVERVIEW

K.Holt
Institute of Natural Resources, Massey University, Palmerston North, New Zealand
k.holt@massey.ac.nz

Chatham Island, situated 800km east of mainland New Zealand, preserves some of the easternmost exposures of Quaternary deposits of the New Zealand microcontinent. These deposits include extensive blanket peats, loess and aeolian sand. Quaternary deposits of marine origin are relatively scarce. These include thin gravels, shell accumulations, beach sands and recently discovered mafic volcanics.

A combination of sedimentology, mineralogy, tephrochronology, pedology and palynology have been applied to construct a Quaternary chronostratigraphy, in an effort to establish the sequence of events preserved, and to estimate rates of uplift of the island.

Volumetrically, most of Chatham's Quaternary deposits are Late Pleistocene in age, having accumulated during the Last Interglacial (Marine Isotope Stage 5), Last Glaciation (MIS 4,3 & 2) and Holocene, and are dominated by peat usually underlain by aeolian sand. However, there are a limited number of sites which preserve records which extend back to and possibly beyond MIS 10 and 11. These are dominated by aeolian sand and loess or clay units interspersed with paleosols and peat beds.

In sequence-stratigraphic terms, units with relatively high proportions of sand-sized material represent warm periods and high sea level stands, while those with relatively high proportions of silt-sized material and in some cases increased soil development, represent cool, low sea level stands.

Two rhyolitic tephra beds derived from the TVZ in mainland New Zealand are present within the Island's Quaternary sequences: the Kawakawa Tephra (26,000yr) and the Rangitawa Tephra (340,000yr). They provide excellent time control within and between the older stratigraphic sequences.

POSTER

GLACIAL GEOMORPHOLOGY OF THE MIDDLE RAKAIA VALLEY, CANTERBURY, NEW ZEALAND

O. Hyatt[1], J. Shulmeister[1], G.D. Thackray[2] & D.J.A. Evans[3].
[1]Department of Geological Sciences, University of Canterbury, Christchurch.
[2]Department of Geosciences, Idaho State University, Pocatello, USA
[3]Department of Geography, Durham University, South Road, Durham, UK
(omh13@student.canterbury.ac.nz)

Here we present a detailed geomorphology map of the Middle Rakaia Valley. The Rakaia Valley has been heavily glaciated during the late Quaternary and at present has two small glaciers in its upper catchments. This map focuses on the area of the Rakaia which has the main limits of the late Quaternary glaciers, called the Middle Rakaia Valley. Aerial photographs and ground work was used to compile the map.

The geomorphology records at least 3 major phases of glacial advances in the valley. We question the previous division of the Acheron and Bayfield advances and propose that they relate to one advance and represent a continual retreat from the height of the Bayfield advance to the last recognised moraines in the map area.

The scale and relative volume of outwash and melt water paths compared to moraines suggests a greater importance of fluvial processes than those of glacial processes. The new detail also highlights the late deglacial sequence (Bayfield-Acheron) recorded by small recessional moraines and associated marginal drainages. These appear to show a slow continuous retreat and are associated with a proglacial lake. Abandoned alluvial fan surfaces along the base of the Mount Hutt Range were active when the proglacial lake was present in the valley.

Provisional cosmogenic dates are also presented here. These are the precursor to a more comprehensive cosmogenic dating campaign in the valley, which will further clarify timing and correlations of glacial advances in and between valley systems.

POSTER

MAPPING HYDROTHERMAL ALTERATION PRODUCTS ON MT TONGARIRO USING HYPERION DATA.

M.Irwin, M.Tuohy and S.Cronin
Institute of Natural Resources, Massey University, Palmerston North, New Zealand

The threat of a major collapse/landslide from a volcanic cone is a primary hazard of concern in the Tongariro National Park. Volcanic edifice susceptibility to this process is exacerbated by hydrothermal alteration and consequent weakening of the rock. The geologic record at Ruapehu and Tongariro volcanoes shows that past debris flows (lahars) have often contained a high proportion of alteration products, indicating the importance of altered flank areas of the volcano in generating these hazards. The present flanks of both volcanoes have several hydrothermally altered zones that could be sources of future collapses, with those on Mount Tongariro being particularly obvious. The purpose of this study was to interpret Hyperion data using field spectra collected from a portable spectroradiometer to assess the overall extent of alteration products and map altered zones on Mount Tongariro. A Hyperion image of the study area was acquired on June 4, 2003. The image was corrected for atmospheric and topographic effects prior to analysis. A range of different alteration-product zones were identified visually on the image. Accessible alteration zones were visited, samples were collected and reflectance spectra recorded using a portable spectroradiometer, with GPS locations stored. X-Ray diffraction analysis was conducted on the field samples to identify the type of alteration products at each location. The XRD identification and the field spectra provided the ground truth for the Hyperion image, allowing the selection of accurate end-members. The derived end-members were used to carry out a supervised classification, which defined the extent of the alteration products within the study area. The alteration products form some of the least stable zones on the volcano. Identifying these zones provides crucial information in the production of a new lahar hazard map for the Tongariro National Park.

PAPER

NEW PERSPECTIVES ON THE DUN MOUNTAIN OPHIOLITE BELT

Dushan Jugum, Richard Norris, J. Michael Palin
Geology Department, PO Box 56, University of Otago, Dunedin
(dushan@geology.co.nz)

Within the Dun Mountain Ophiolite Belt there are two main zones, the Dun Mountain Ophiolite proper to the west and the Windon\Patuki Melange in the east. These can be traced from D'Urville Island (North-East Nelson) in the North to West Dome (central Southland) in the south. South-east of this part of the belt, the lithologies change to a predominantly felsic composition and the melanges are not exposed.

The Dun Mountain Ophiolite shows both spreading ridge and supra-subduction geochemical signatures which are related to both stratigraphic and geographic location; whereas the basalt in the Windon\Patuki Melange shows both spreading ridge and sea mount (OIB) geochemistry.

The Dun Mountain Ophiolite is tholelitic and ranges from basalt through to plagiogranite. The plagiogranite appears as isolated dykes spread throughout the ophiolite north of West Dome. South of West Dome plagiogranite is dominant. Reconstructions of the undeformed configuration of the belt indicate this more evolved part of the sequence originally ran the length of the belt and has since been eroded.

U-Pb detrital Zircon dates from sediments in the Windon, Greenstone and Patuki Melanges show the same age (Late Permian) and similar source regions as the Tramway Formation of the Maitai Group (Adams et al., 2002). Zircons from the Harris Saddle Formation and the West Burn Formation of the Caples Group show a Middle Triassic age which precludes them from being the base of the Caples Group as stratigraphy would suggest. It also precludes these formations and the Caples Group from having an original genetic relationship with the much older Dun Mountain Ophiolite (early Permian).

It is inferred that the Dun Mountain Ophiolite represents a proto arc and that the Windon\Patuki Melange was an associated back arc basin. This would suggest the subducting slab dipped away from the Gondwana margin in the early Permian.

POSTER

VOLCANIC HAZARD RISK ASSESSMENT IN THE RISKSCAPE PROGRAM – REVIEW OF EXISTING INVENTORY FRAGILITY MODELS AND TEST APPLICATION IN THE ROTORUA DISTRICT, NEW ZEALAND

Grant Kaye[1], Andrew King[2], Jim Cole[1], David Johnston[2] and Tom Wilson[1]
[1]Natural Hazard Research Centre, University of Canterbury, PB 4800, Christchurch, New Zealand,
gdk21@student.canterbury.ac.nz
[2]GNS Science, 1 Fairway Drive, Lower Hutt, New Zealand

The Riskscape program, although not yet complete, provides a means to assess risk from natural hazards in New Zealand. Riskscape combines hazard modules and inventory databases in a standalone geographic information system (GIS)-like software environment enabling the user to tailor their specific risk analysis to their particular needs. For volcanic hazard risk assessment, fragility functions relating damage states to hazard intensity are gathered from the literature and modified where needed. Where existing research into fragility curves is not readily available or pertinent to New Zealand inventory classes, new fragility functions are developed as part of work ongoing with colleagues at the Natural Hazard Research Centre-University of Canterbury and GNS Science. Examples include agriculture, horticulture, silviculture, tourism, and ancillary expenses related to tephra cleanup. Riskscape is still in developmental stages, with a planned prototype release to special interests groups for testing and feedback solicitation in August 2006. Current and future directions of research include further refinement of the ASHFALL tephra distribution model to add consideration of wind changes mid-eruption, as well as cumulative modeling of differential episodic tephra eruptions over a long-duration eruptive event. Other fragility functions, for inventory items such as social vulnerability, hazard preparation, evacuation, and traditional culture, are either intended or are already under development. Testing of Riskscape's volcanic hazards modeling capabilities will take place in the Rotorua District in New Zealand, and possibly at Mammoth Lakes in the Long Valley caldera in the United States. Long Valley is an excellent analogue to Rotorua and will provide an opportunity to test Riskscape's ability to model inventory classes and hazard models with different characteristics to those from New Zealand once the program is in final stages of development.

POSTER

PALEOCENE-EOCENE TRANSITION IN SOUTH ISLAND TERRESTRIAL TO MARGINAL MARINE SECTIONS

E.M. Kennedy[1], E.M. Crouch[1], J.I. Raine[1], L. Handley[2] & R.D. Pancost[2]
[1]GNS Science, PO Box 30 368, Lower Hutt
[2]Bristol Biogeochemistry Research Centre, University of Bristol, Bristol BS8 1TS, UK
(e.kennedy@gns.cri.nz)

In New Zealand, studies of the Paleocene-Eocene thermal maximum (PETM, at ~55 Ma), a time of peak global temperatures and greenhouse conditions, and the Paleocene-Eocene transition have primarily focussed on marine successions such as Mead Stream (Marlborough) and Tawanui (Hawkes Bay). While these sections provide detailed records of changes in the marine realm, terrestrial climate and vegetation changes are less well-documented. A significant vegetation change from a gymnosperm-rich Paleocene into *Casuarina*-dominated angiosperm-rich floras of the Early Eocene has previously been documented, but this does not appear to coincide with PETM warming and carbon isotope ($\delta^{13}C$) excursion. Plant microfossil records from Paleocene-Eocene terrestrial and marginal marine sediments at South Island outcrop localities (Mt Somers, Otaio Gorge, Waipara) are being investigated in conjunction with a drill core (Kumara-2) from the West Coast. These investigations will try to determine if there are any specific vegetation indicators of the PETM in New Zealand.

Compound specific (*n*-alkane) $\delta^{13}C$ analyses in the Kumara-2 core indicate the PETM spans a 7-8 m interval, with a notable negative shift in $\delta^{13}C$ values (~4‰) followed by a return to near pre-excursion values. At the current sampling resolution, the onset of the $\delta^{13}C$ excursion appears to be coeval with the beginning of marginal marine sediments, suggesting the abrupt warming associated with the PETM resulted in a sea-level rise. The marine horizon also has abundant dinoflagellate cysts of the genus *Apectodinium* and pollen indicative of warm climates. Plant microfossil assemblages and organic biomarkers indicate the PETM was associated with some vegetation change, but currently the timing and precise nature of vegetation change is unclear.

Sediments at Mt Somers silica sand quarry are dominated by sandy facies of the Broken River Formation (Homebush Sandstone). Thin silt-clay laminae occur at irregular intervals and where possible these were sampled for palynology. Most samples from the lower half of the section were barren of palynomorphs, however one basal sample yielded a Paleocene palynoflora. A ~3 m thick mudstone occurs at 60 m in the c.110 m section and most samples within and above this horizon yielded palynomorphs. Abundant *Apectodinium* dinoflagellate cysts were present in the ~3 m mudstone, indicating an Eocene (early Waipawan) age. As in Kumara-2, this *Apectodinium* acme and the first indications of Eocene flora are coincident with increased marine influence.

Coal measures of the Broken River Formation at Otaio Gorge, inland of Timaru, were measured and sampled for palynology and plant macrofossils. One palynology sample taken from the matrix of a plant macrofossil suggests a Waipawan (earliest Eocene) age and the presence of *Apectodinium* indicates a marine influence in these coal measures. New palynology samples will identify whether the Paleocene-Eocene transition is encompassed by the basal part of the section.

POSTER

BASAL MAMAKU IGNIMBRITE: RESULTS FROM RECENT GROUNDWATER DRILLING IN ROTORUA

G. N. Kilgour[1] & W. Esler[2]
[1]GNS Science, Wairakei Research Centre, Private Bag 2000, Taupo.
[2]Dept. of Earth and Ocean Sciences, University of Waikato, Private Bag 3105, Hamilton.
(g.kilgour@gns.cri.nz)

In 2004, Environment Bay of Plenty commissioned GNS Science to produce a detailed 3-D groundwater flow model for the Lake Rotorua catchment in order to understand the flow paths of nutrients into Lake Rotorua. A 3-D geological model was developed to form the basis for the flow model. The models were constructed from existing geological and geothermal well logs within the catchment as well as new wells drilled for the project. Based on existing and new datasets the main groundwater aquifers in the Lake Rotorua catchment are Mamaku Ignimbrite, Huka Falls Formation lake sediments and alluvium.

In order to identify the aquifer properties of the Mamaku Ignimbrite, a relatively deep (150 m) well was drilled by Environment Bay of Plenty to determine stratigraphy and hydrological parameters within the north western embayment of the Rotorua Caldera margin defined by Milner (2001). This poster outlines the results of that groundwater well and focuses on the identification of a pyroclastic fall deposit beneath the Mamaku Ignimbrite.

Drilling penetrated the upper, middle and lower subunits (Milner, 2001), of Mamaku Ignimbrite, through a ca. 1 m weathered, yellow-brown paleosol and 26 m into a distinct pyroclastic fall deposit. The fall deposit consists of fresh dark brown to dark grey, volcanic glass with common cuspate textures, vesicular, silicic pumice and rare crystal fragments; 2% crystals (plag>>opx ±qtx) cf. 8% for lower Mamaku Ignimbrite (plag>qtz>>opx). Major element chemistry, obtained by microprobe on the volcanic glass in the pyroclastic fall deposit, is indistinguishable from the lower Mamaku Ignimbrite. The fall deposit occupies a similar stratigraphic position to the basal Mamaku Ignimbrite exposure on the eastern shore of Lake Rotokawau.

Due to the presence of a paleosol separating the Mamaku Ignimbrite from the fall deposit, the fall deposit must represent either a distinct early eruptive phase of magma genetically associated with the Mamaku Ignimbrite or is related to an older unit such as Pokopoko Pyroclastics erupted from an unknown source (Nairn 2002).

This borehole stratigraphy is highly significant because it shows very modest thicknesses (117 m) of Mamaku Ignimbrite within Milner's caldera boundary. The drill site is clearly beyond any major collapse structure or caldera infill associated with the Mamaku Ignimbrite eruption. Therefore this bore data is inconsistent with the thickness of Mamaku Ignimbrite predicted by Milner's structural and magma storage model of the Rotorua Basin.

POSTER

SEISMIC IMAGING OF EASTERN OTAGO ACTIVE FAULT STRUCTURES

J.W. Kilner[1], R.J. Norris[1], & A.R. Gorman[1]
[1]Geology Department, University of Otago, PO Box 56, Dunedin.
(jk@geology.co.nz)

The Otago Schist is dominated by a series of sub-parallel north-to-north-east-striking tectonic ridges. Through central and eastern Otago, these ridges vary in size from west to east; however, the tectonic processes controlling them are not fully understood. A lack of surface expression of range bounding faults complicates the evaluation of these structures. Past research has been mainly restricted to geomorphologic evidence. In contrast, this project aims to locate and investigate the range-bounding faults in detail.

Based on geomorphological evidence, a single 2D seismic line was positioned over the probable location of the near-surface expression of the bounding fault of Taieri Ridge, located 60 km NNW of Dunedin. The survey geometry (0.5 m geophone spacing, 1 m shot spacing) was designed to image very shallow features. The seismic data were processed both as reflection and refraction data. Additionally, a Ground Penetrating Radar (GPR) survey was taken over the seismic survey site allowing a comparison of techniques.

Taieri Ridge was selected for the geophysical investigation due to: (1) its relatively small size allowing easy access and a more easily defined fault zone, (2) the presence of Quaternary sediments infilling the valley east of the ridge, thus presenting rock types of differing geophysical properties within the fault zone, and (3) its suitability for future paleo-seismic trenching, which could provide geochronological constraints on fault motion.

Seismic imaging and GPR allow the position, near surface structure, and structure at depth of the range bounding faults to be constrained. Such information will be used to more effectively plan for more invasive techniques such as paleo-seismic trenching.

PAPER

CHANGES IN ATTENUATION RELATED TO ERUPTIONS OF MT. RUAPEHU VOLCANO

Tanja Kuehler[1,2], Martha Savage[2], Tony Hurst[3]
[1] Institute of Geophysics, Victoria University of Wellington, New Zealand
[2] University of Karlsruhe, Germany
[3] GNS Science, P O Box 30368, Lower Hutt, New Zealand
Martha.Savage@vuw.ac.nz

Temporal variations of seismic attenuation have been observed at different volcanoes around the world and seem to correlate with volcanic activity. Long-term attenuation characteristics around Mt. Ruapehu, New Zealand, are measured for the period October 1990 to May 2005 using regional earthquakes originating from the Waiouru earthquake swarm recorded on 5 permanent seismometer stations. Cross-correlation of *P* and *S* waves reveals a remarkable similarity of events from this ongoing seismic source and shows the presence of seismic families, which are especially suitable for the study of temporal changes. The attenuation (Q_C^{-1}) of coda waves following the direct *P* and *S* waves is calculated for five frequency bands centred at *1.5*, *3.0*, *6.0*, *9.0*, and *12.0* Hz using the single-scattering model. A best-fit equation of $Q_C = Q_0 f^{\alpha}$ with $Q_0 = 54(\pm 7)$ and $\alpha = 1.02(\pm 0.06)$ shows an overall high frequency dependence of coda attenuation, which is characteristic for tectonically active regions. α increases at all stations in 1995 and decreases slowly in the years following the 1995/96 eruptions. Small fluctuations of Q_C^{-1} are observed at all stations over the entire time period and do not act as apparent indicator for volcanic activity. Relative change in integrated direct wave attenuation (δt^*), is obtained using a spectral-ratio method in which spectra of individual 1-second P wave windows are compared to a reference spectrum. Results reveal a distinct change of δt^* in the low-frequency band (*1.5 – 6 Hz*) at two stations in 1995. This observation correlates well with variations detected in seismic anisotropy studies, which suggest a model of the change in stress caused by pressurisation of a filling magma dyke under the volcano.

PAPER

RESULTS FROM RECENT PALEOSEISMIC STUDIES ON THE WELLINGTON FAULT

Langridge R.M., K. Wilson, C. Prior, P. Villamor and D. Townsend
GNS Science, P.O. Box 30-368, Lower Hutt
r.langridge&gns.cri.nz

We present new paleoseismic data from two sites along the Wellington Fault north of the Hutt Valley. The first comes from excavations at the Dougan trench site at the southern end of the Pahiatua section of the fault, near Eketahuna. Four to five late Holocene paleoearthquake events have been recognized there. These events correspond in time with the sequence observed at other sites along this part of the fault. In addition, an extended record of events has been obtained from this site.

The second study covers landscape change studies along the Tararua section of the Wellington Fault at Totara Flats. There, we have extracted and dated sections of buried tree stumps. Dated tree ring chronologies suggest that an extreme landscape change event (earthquake?) occurred at c. AD 1450 ± 10 yr. We also discovered landslide dammed sediments in exposure adjacent to the Wellington Fault zone in Aeroplane Gully. These sediments may also date to a specific, but younger, landscape change event.

PAPER

PRELIMINARY INVESTIGATION OF COLD SEEPS AS METHANE SOURCES OFF SOUTHEASTERN NORTH ISLAND

C.S. Law, S.D. Nodder, A. Marriner, J. Mountjoy & P.M. Barnes
NIWA, Private Bag 14-901, Kilbirnie, Wellington.
s.nodder@niwa.co.nz

Methane is the second most significant greenhouse gas in the atmosphere after carbon dioxide, with current atmospheric levels that are unprecedented over the last 600 000 years.

Globally, sources are poorly constrained, but dominated by terrestrial sources including tundra, marshes and agriculture. In New Zealand, methane is the most important contributor to national greenhouse gas emission estimates, arising from livestock agriculture, although natural sources are poorly known. The marine environment is also a source of methane, arising from anaerobic decay of organic matter in sediments and the water column. An additional marine source of methane is in the form of gas hydrates, "ice-like" crystalline forms (clathrate) of methane buried in the ocean sediments of many active and passive tectonic settings. When gas hydrate layers intersect the sea-floor, or where migrating thermogenic and/or biogenic gases and liquids are expelled from sediments, such as at structural discontinuities on convergent margins, methane bubble plumes may occur in the water column, often exceeding heights of 300 m. Such cold seeps are also distinctive biogeochemical environments and often host unique biota that may have chemosynthetic affiliations. Recent observations of high dissolved methane concentrations in surface waters of Cook Strait, and the re-discovery of active methane seeps along the Hikurangi subduction margin have led to preliminary investigations of the sources of methane in the Cook Strait region. Isotopic analyses indicate that the cold seeps are a source of dissolved methane to surface waters in this region, and so contribute to local air-sea emissions. Further work is underway to characterise the physical and biogeochemical environment of cold seeps in the Cook Strait, including methane oxidation rate measurements, characterisation of the microbial methanotroph community and measurement of nutrient and methane flux from sediments.

PAPER

MODELING CLAY-RICH DEBRIS FLOWS: EXPERIMENTAL CHALLENGES AND PRELIMINARY RESULTS

Jérôme Lecointre[1] **and Sébastien Valade**[2]

[1] Volcanic Risk Solutions – INR Earth Sciences, Massey University, Private Bag 11222, Palmerston North, New Zealand (J.A.Lecointre@massey.ac.nz)

[2] Institut Géologique Albert-de-Lapparent – IPSL

13 Boulevard de l'Hautil, 95092 Cergy-Pontoise, France

Clay-rich debris flows represent one of the most potentially destructive mass flows generated by the catastrophic failure of a mechanically unstable portion of a volcanic edifice. The initial fluid-saturated debris avalanche transforms rapidly into a highly mobile, viscous debris flow that can travel 15-120km from source. In New Zealand, deposits resulting from such events have been previously identified on composite volcanoes such as Taranaki, Ruapehu and Tongariro (Lecointre et al., 2002), where clay development in volcaniclastic sequences can be related to weathering of tephras and/or hydrothermal circulations.

In order to better understand the behaviour and emplacement mode of these unusual mass flows, we have designed an experimental setup that allows us (1) to run geometrically- and dynamically-scaled analog models of slurries, and (2) to determine critical physical parameters such as inundated area, runout distance, and morphological characteristics of the analog deposit (e.g. levee dimensions; thickness; megaclasts distribution). Motion-triggered, wireless CMOS colour cameras are used to calculate the velocity of the experimental slurries, while additional full-field video and time-lapse photography record the entire sequence of emplacement. A further development under consideration is the use of a high-precision laser distance-metre measuring, via a reference grid, the surface topography of the modelled deposits. This will allow us to build detailed DEMs on which numerical flow simulation codes can be run.

A range of calibrated clay-sand-gravel mixtures is used for the experiments, based on relative concentrations of particles/clasts observed in the field. For this study, we have selected an artificially Na-enriched bentonite (Rheogel^R-L) as an analog for smectite, thixotropic clay commonly found in hydrothermal settings such as Tongariro. As 'cohesive' debris flows behaviour seems to be dominated by the physical properties of the matrix, a key step was to characterise the rheological behaviour of the prototype slurries in order to ascertain their suitability. Firstly, Haines tests were conducted on clay+fine sand fractions with 0-10% vol. clay to determine the volume of water necessary to reach saturation, and as a guide to prepare well homogenised wet mixtures. Secondly; we tested a range of apparatus that could provide viscosity measurements on water-saturated clay-fine/coarse sand samples. Best results were obtained with a Brookfield digital viscometer DV-1 equipped with a 'helipath' stand and T-bar probe, adapted for non-Newtonian dispersions (intrinsic yield strength). Dynamic viscosities were recorded at ambient temperature for a low range of rotational speeds (0.3-12 rpm), corresponding to low shear rates in natural conditions. Measurements were completed every 5 sec. (in 60 sec. time slots) for each rotation speed on saturated samples placed in 600cm^3 beakers. The range of values obtained *at very low rotation speeds* suggests that the viscosity of our samples is essentially controlled by the clay:fine sand volume ratio, specific to each composite mixture. Flow curves obtained for the prototypes show that a complex, time-dependant rheological evolution (plastic/visco-plastic regime) occurs at a very early stage of shearing with only a small increment of torque, a characteristic already suggested for clay-rich debris flows. As a consequence, the Herschel-Bulkley model (shear-thinning behaviour), usually applied to one-phase viscous fluid suspensions (Coussot et al., 1998; Remaître et al., 2005), could be used to partially describe the rheology of our clay-rich analog mixtures, as long as grain-to-grain interactions do not dominate momentum transfer during the emplacement of our experimental slurries (Iverson, 2003).

References:
Lecointre JA, Neall VE, Wallace RC and Prebble WM (2002) The 55- to 60-ka Te Whaiau Formation: a catastrophic, avalanche-induced, cohesive debris-flow deposit from Proto-Tongariro Volcano, New Zealand. Bull Volcanol 63:509-525
Coussot P, Laigle D, Arattano M, Deganutti A and Marchi L (1998) Direct determination of rheological characteristics of debris flow. J Hydraulic Engineering 124: 865-868
Remaître A, Malet J-P, Maquaire O, Ancey C and Locat J (2005) Flow behaviour and runout modelling of a complex debris flow in a clay-shale basin. Earth Surf. Proc. Landforms 30: 479-488
Iverson RM (2003) The debris flow rheology myth. In 3rd Intern. Conf. on Debris Flow Hazard Mitigation: Prediction and Assessment, Rickermann D, Chen CL (Eds), Millpress, Rotterdam: 303-314

PAPER

IDENTIFYING AREAS OF FLOODING USING REMOTE SENSING AND GIS – A CASE STUDY FROM THE MANAWATU STORM, FEBRUARY 2004

J. Lee[1], R. Jongens[2], W. Power[1]
[1]GNS Science, PO Box 30368, Lower Hutt
[2]GNS Science, Private Bag 1930, Dunedin
(J.Lee@gns.cri.nz)

During disaster events, emergency management need to know the extent of damage so they can plan and prioritise assistance. GNS Science is investigating the use of airborne and satellite imagery to help determine the extent of damage such as flooding, landsliding, or building collapse associated with earthquakes. High resolution satellites are able to capture images with sub-metre resolution and can also cover hundreds of kilometres of area per image. These satellites can be programmed to take images on demand and the images can be delivered quickly. Automating image processing will help hasten delivery of data and we are trialling the ability to provide areal damage assessment information as close to near-real time as possible. The final product delivered to emergency managers will be compatible with any GIS.

Satellite images obtained from the Manawatu storm event from February 2004 were used to trial some automated image processing techniques. Images were acquired of the Manawatu area before and after the storm event so that the extent of change (= flooding) could be determined. A range of different types of software and processing methods were tested on both radar and multispectral images to determine which type of sensor was better at outlining areas of flooding For multispectral images, unsupervised and supervised classifications techniques were employed followed by a thematic change analysis of the “before” and “after” images. Supervised classification gave the best results for change detection. For radar images the data was smoothed and a textural change algorithm used. For areas where a “before” image was not available, a simple classification of low backscatter values (= flooding) was performed.

Both radar and multispectral images used in the Manawatu case study effectively captured the area of flood extent. The biggest disadvantage with using multispectral images was cloud cover which obscured areas of land or water whereas radar can see through cloud.

3D SEISMIC INTERPRETATION OF THE KUPE FIELD AREA

B. Leitner, B. Ilg, P. King, G. Browne, & M. Milner
GNS Science, PO Box 30-368, Lower Hutt
b.leitner@gns.cri.nz

GNS Science has recently started a 4 year government-funded project to develop an atlas describing the geologic architecture of the Taranaki Basin. Approximately 20-30 horizons will be interpreted on digital seismic data and depth converted to provide structural and seismic facies maps. This integrated approach utilizing high resolution biostratigraphy and well-seismic correlation will result in a significantly improved dataset to the previous regional map atlas.

The first-year target is the compilation of a phase shifted regional data set and interpretation framework. Integration of several software packages and the establishment of a project database, with tools for providing public-domain output, should enable a smooth and transparent workflow across the different platforms. The Kupe Field region is used as a case study. Structural and seismic facies mapping is underway in this structurally complex region to provide maps for petroleum system modelling.

The Kupe Field lies offshore, immediately south of Taranaki Peninsula, and is defined by the Manaia Fault to the west and the Taranaki coast to the north and east. A large thrust fault, the Taranaki Fault, runs close to the shoreline and trends north-south. Compression during the Late Oligocene to Late Miocene developed the current oil and gas bearing structures of the Kupe field (currently under development) and the nearby Kapuni and Maui fields. The structural evolution of the Kupe area involved extension in the Cretaceous and Paleocene, followed by postrift subsidence through the Late Eocene and Oligocene. Compression from the Late Oligocene to Miocene reactivated faults and was overprinted by wrenching in the Pliocene (Figure .1). The complicated structural evolution of the area including the fault behaviour in the compartmentalised Kupe Field is being analysed using cross-section balancing software, and these results are to be incorporated in the petroleum system model.

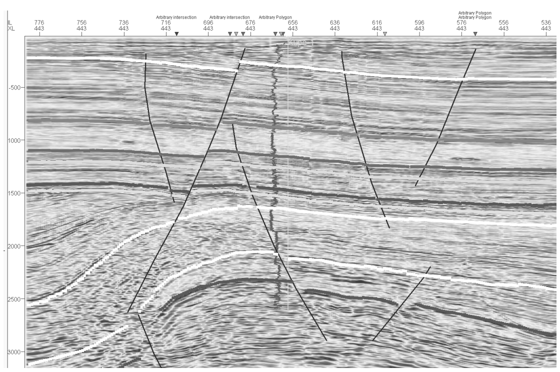


Figure 1. Seismic section through Kupe-1 showing faulting in the Neogene. The Kupe structure is controlled by the Manaia Fault (left side). Gas condensate has been discovered in the Paleocene Farewell Fm. (lowest horizon).

SOMETHING FOR NOTHING? AMBIENT NOISE RAYLEIGH WAVE TOMOGRAPHY IN NEW ZEALAND

F.-C. Lin[1], M.H. Ritzwoller[1], J. Townend[2], S. Bannister[3], & M.K. Savage[2]
[1]Center for Imaging the Earth's Interior, University of Colorado at Boulder, USA
[2]Institute of Geophysics, Victoria University of Wellington, PO Box 600, Wellington
[3]GNS Science, PO Box 30368, Lower Hutt
(john.townend@vuw.ac.nz)

Just as radiographers use ultrasound to image the internal structure of a human body, so seismologists use seismic waves generated by earthquakes or artificial sources to study the earth's interior. Earthquakes produce high-amplitude seismic energy, but occur sporadically in unpredictable locations, whereas artificial sources can be tailored to specific targets, but are less energetic than earthquakes and costly to deploy. Modern seismological networks are designed to record seismic waves generated by earthquakes, but more than 95% of the "signal" recorded by such networks is ostensibly incoherent noise generated primarily by coupled oceanic and atmospheric processes

Theoretical and experimental results obtained originally in condensed matter physics and later in ultrasonics, acoustics, solar imaging, and marine acoustics reveal that a coherent signal can be extracted from records of what looks like noise by comparing sufficiently long streams of data. Most recently, it has been shown that cross-correlating vertical-component noise records from pairs of seismometers reveals a signal, or Green's function, corresponding to the propagation of a seismic wave from one instrument to the other. Over distances greater than ~10 km, this signal corresponds to a wave (Rayleigh wave) propagating just below the earth's surface at velocities determined by the earth's elastic properties and the wave's frequency or period.

The scientific appeal of ambient noise imaging lies in using pervasive, continuous, high-amplitude seismic energy to map subsurface shear wave velocities over large areas and New Zealand is a key target for such techniques. It is surrounded by ocean, spanned by a modern seismological network with relatively uniform instrument spacing, and has a long history of multidisciplinary research into its tectonic architecture.

We present the first New Zealand-wide study of surface wave dispersion using ambient noise observed at 42 broadband stations in the national seismic network (GeoNet) and the Global Seismic Network (GSN). Year-long, vertical-component time series recorded between 1 April 2005 and 31 March 2006 have been correlated with one another to yield fundamental Rayleigh wave Green's functions. We filter these Green's functions to compute Rayleigh wave group dispersion curves at periods of 5–50 s, using frequency–time analysis with phase-matched filters. The uncertainties of the measurements are estimated from temporal variation in the dispersion curves produced by 12 overlapping three-month stacks. After selecting the highest quality dispersion curve measurements, we compute group velocity maps at 7–25 s periods. These maps (and the corresponding 1-D shear wave velocity models obtained to date) exhibit clear correlations with major geological structures, including the Taranaki and Canterbury Basins, the Hikurangi accretionary prism, and previously reported basement terrane boundaries.

PAPER

THE CHALLENGE OF COMMUNICATING MULTIPLE HAZARDS FROM MULTIPLE ADJACENT VOLCANOES: AN EXAMPLE FROM DOMINICA, EASTERN CARIBBEAN

Jan Lindsay
Department of Geology & IESE, University of Auckland, Private Bag 92019, Auckland
(j.lindsay@auckland.ac.nz)

In contrast to most other islands in the Lesser Antilles arc which have one major potentially active volcano, Dominica has nine, making it extremely susceptible to volcanic hazards and providing considerable challenges in communicating those hazards to the authorities. With its small land area of

750 km^2, Dominica has one of the highest concentrations of potentially active volcanoes in the world. Frequent swarms of volcanic earthquakes and geothermal activity characterise these volcanoes, seven of which lie within 10 km of the capital, Roseau (population 25,000). The most recent magmatic eruption occurred some 500 years ago, and two major phreatic eruptions occurred in 1880 and 1997.

Several scenarios for future activity covering the most seismically and geothermally active volcanic centres have been developed, and hazard maps generated for the six most likely of these scenarios. Two hazard maps were prepared for each scenario, one showing the likely impact of each individual hazard, and one in which these individual hazards were integrated into a user-friendly, colour-coded map showing the overall areas of very high, high, moderate and low hazard.

With six most-likely cases to consider, appreciating the long-term hazard for a particular location in Dominica is extremely complicated. In order to effectively communicate the relative likelihood of these scenarios, and to provide authorities with a single comprehensive map of overall hazard for planning purposes, each scenario was weighted according to probability and the zones combined accordingly to produce a single map of overall integrated volcanic hazard zones.

Although the Dominica volcanic hazard maps provide a good indication of areas likely to be affected (and to what degree) by volcanic activity within the next 100 years, they do have some limitations, mostly related to the method used for generating hazard zones. In all eruption scenarios the same parameters were used to delineate the coloured integrated hazard zones. For example, regardless of whether the scenario depicts a dome-forming or an explosive Plinian eruption, the area of moderate hazard (yellow) is defined as the area likely to receive 5-10 cm of ash. In many of the dome-forming scenarios, this area falls within the 5 km ballistic ejecta zone (one of the parameters used to define the zone of high hazard, i.e. orange), and the yellow zone of moderate hazard is therefore limited or even missing on these maps. Furthermore, the hazard maps only show hazards on land, whereas most of these hazards will impact offshore to varying degrees.

These limitations could be addressed in future iterations of these maps, by showing zone boundaries as zones of transition rather than sharp lines, and by somehow extending the hazard zones offshore.

PAPER

HOLOCENE COASTAL UPLIFT AND EROSION IN WESTERN HAWKE BAY: EVIDENCE FROM FLUVIAL TERRACES

N. Litchfield, K. Berryman, J. Hoverd, & U. Cochran
GNS Science, PO Box 30368, Lower Hutt.
(n.litchfield@gns.cri.nz)

The coastline within weestern Hawke Bay, between Tangoio Bluff (south) and Wairoa River mouth (north), is characterised by steep coastal cliffs, suggestive of high rates of uplift and/or coastal erosion. Despite much of this coastline undergoing uplift during the Napier 1931 earthquake, marine terraces recording earlier uplift events are not preserved. Furthermore, the coastline to the south and north has undergone net Holocene subsidence. We investigated fluvial terraces preserved at the mouths of three rivers along this coastline to attempt to quantify rates of coastal uplift and erosion. The study has two main components: (1) using the c. 1.8 ka Taupo Alluvium terrace in the lower Mohaka River valley to quantify coastal erosion rates, and (2) comparison of the altitudes and ages of fluvial terraces at each river mouth as an indicator of coastal uplift.

(1) In the lower Mohaka River valley, fluvial terraces underlain by Taupo Pumice Alluvium were formed by reworking of the 1.8 ka Taupo Ignimbrite. Thus, the highest of these fluvial terraces provides a marker of the riverbed grading to a c. 1.8 ka paleocoastline. Using GPS survey data, a longitudinal profile was constructed from which the uplift resulting from the 1931 Napier Earthquake (≤ 0.3 m) was removed. Assuming there have been no other uplift events post 1.8 ka, and that sea level has remained stable during that time, the projected terrace surface to present sea level indicates a paleocoastline up to 3.8 km offshore of the present coastline. Taking into account aggradation of a fan of Taupo Alluvium and uncertainties in profile projection, coastal erosion rates range from 0.5 to 2.1 m/year. Anecdotal evidence indicates similar historic rates, but measurement is complicated by the widespread coastal landsliding associated with the 1931 Napier Earthquake.

(2) Fluvial terraces have been mapped and surveyed at the Waikari, Mohaka, and Waihua River mouths. The Last Glacial Maximum (LGM) aggradation terrace is at c. 29, c.73, and c.16 m above mean sea level (amsl) respectively. These altitudes are higher than that expected for the LGM, when the rivers were grading to sea level ≤ 120 m below present, suggesting a component of post-glacial uplift, which may increase toward the Mohaka River mouth. At the Waikari River mouth, a lower altitude (c. 14 m) terrace has deposits of silt containing wood, radiocarbon dated at 7860-8020 cal. yr BP. The distinct stratigraphy of this terrace suggests it aggraded in response to infilling of a coastal estuary. Taking into account sea level at 8 ka (-6 to -15 m), and that the now-eroded estuary would have been lower than 14 m amsl, a maximum uplift rate of 2.5-4 mm/yr is calculated. This is considerably higher than the uplift rate calculated by comparing the altitude difference of pairs of fluvial terraces (LGM and MIS 4) at the Mohaka River mouth (0.7-1.2 mm/yr), confirming previous interpretations that tectonic uplift rates form only a component of post-glacial incision rates. Uplift of the axial ranges to the west is interpreted to be the result of aseismic deep-seated subduction processes, and the increase in uplift rate toward the Mohaka River mouth supports this.

PAPER

A PROVISIONAL LATE HOLOCENE HISTORY OF SURFACE RUPTURING EARTHQUAKES ON THE SOUTHERN PART OF THE WAIRARAPA FAULT

T. A. Little[1], R. Van Dissen[2], and L. Schermer[3]
[1]School of Geography, Environment and Earth Sciences, VUW
[2]GNS Science, P. O. Box 30368, Lower Hutt
[3]Geology Department, Western Washington University, Bellingham, WA, USA 98225
(timothy.little@vuw.ac.nz)

Little is known about the frequency and character of earthquakes on the Wairarapa Fault prior to 1855. Due to the scarcity of trench-based paleoseismic data, many have assumed that the raised beaches at Turakirae Head provide a complete record of late Holocene earthquakes on the fault, that previous ruptures on the fault behaved similarly to the one in 1855 (with each causing a co-seismic uplift on Palliser Bay's coast), and that the mean recurrence of Wairarapa Fault earthquakes is similar to the average age difference between the uplifted beach ridges (~1900 yrs). To test this, we undertook several fault-trenching studies on the southern part of the fault south of Featherston.

Two trenches were excavated in a small pull-apart graben on the "Waiohine" gravel surface near Cross Creek (one across each bounding fault). The graben contains abundant peaty sediments, of which we were only able to study the topmost ~3 m due to wet ground. We submitted 18 ^{14}C samples from the two trenches, 16 of which have been analysed at time of the writing. A peat ~2.5 m below the tread of the terrace gravels yielded ^{14}C ages of 10.5 and 11.1 ±0.06 ka, two of the most precise ages yet determined for "Waiohine" gravels. Relationships between the fault strands, deformed peat layers, and colluvial wedges record 5-6 surface rupturing events since ~5000 yrs BP. Of these, three coincide with the known Turakirae Head uplift events since ~5000 yrs BP (dated by *in situ* ^{10}Be surface-exposure method, *McSaveney et al., 2006).* The youngest of the three is 1855. The two older "Turakirae-equivalent" events are dated at 2340-2110 and 5450-4970 yrs BP (calibrated years, 2σ) in the trenches. The remaining 2-3 earthquakes found in the trenches are extra to the "Turakirae" ones. A penultimate event at 920-800 yrs BP is currently regarded as provisional. Other earthquakes occurred at 2870-2130 yrs BP and 3690-3320 BP, one of which overlaps the 2960-2560 yr BP timing of an earthquake in a trench at Tea Creek near Masterton from *Van Dissen and Berryman (1996).* Two trenches were also excavated at Riverslea across the Wharekauhau Fault, a southern extension of the Wairarapa Fault (four ^{14}C samples). These revealed folding(?) of ~1200 yr BP gravels, and their displacement by a minor, discontinuous, vertical strike-slip fault in 1855, and perhaps also during the penultimate event sometime after 897 yrs BP (uncertain). Charcoal recovered from two pits excavated across the offset channels at Pigeon Bush (4 ^{14}C ages so far analysed) record a single burning event at ~500-550 yrs BP, occurring after the penultimate earthquake.

Our preliminary results suggest that the southern Wairarapa Fault has ruptured at a mean recurrence of ~830-1000 yrs since ~5000 yrs BP. Perhaps the oblique-reverse "Turakirae-style" events involved partial rupturing of the subduction interface, whereas other events were confined to the upper plate, and were more nearly strike-slip. More trenching is planned for 2007.

PAPER

LEARNING FROM LAHARS: UNDERSTANDING THE RUAPEHU BREAK-OUT LAHAR

V. Manville[1], & S.J. Cronin[2]
[1]GNS Science, Wairakei Research Centre, Private Bag 2000, Taupo, NZ.
[2]Institute of Natural Resources, Massey University, PB 11-222, Palmerston North.
(v.manville@gns.cri.nz)

The predicted break-out lahar from the summit Crater Lake of Mt. Ruapehu offers an unparalleled opportunity to capture maximum scientific benefit from a single, discrete lahar event. The challenge is to capture as much data as possible from an event which is largely unpredictable in timing, too energetic for traditional river gauging methods, and stretched over 155 km of river channel with 2530 m of relief.

Our proposed scientific response is made up of a number of complementary components that draw on the resources and skills of a diverse range of New Zealand and overseas agencies:

1. Instrumentation of the lahar path as if it were the bed of a giant laboratory flume. Using a diverse range of sensors including radar stage gauges, acoustic flow monitors, conductivity probes, load-cells, pressure transducers, and broadband seismometers we hope to capture time-series data on such key flow parameters as depth, velocity, sediment concentration and profile, bed aggradation/erosion, and degree of mixing with ambient river water. By measuring these parameters at a number of key locations we will be able to track the downstream evolution of the lahar from an initial clear-water flow, to its maximum discharge as a debris flow, and then its subsequent attenuation and debulking through downstream propagation.

2. Fixed digital still and video cameras will supplement the planned sensor arrays, capturing rare footage of a dambreak and lahar event.

3. Determination of changes in the bed of the Whangaehu River through capture of pre-and post-event, high-resolution topographic and ortho-image data. A pre-event survey has already been undertaken using LiDAR technology (airborne laser scanning). This has yielded a sub-metre resolution DEM of the first 58 km of flow path and an 18 cm pixel-size set of vertical digital air photos. A repeat survey after an event will enable changes in channel cross-section and profile to be mapped and identification of critical areas of sediment erosion and deposition. These remote sensing surveys will be supplemented by differential RTK-GPS ground surveys in key locations.

4. Post-event ground surveys of the lahar deposits will allow reconstruction of flow parameters at non-instrumented sites and cross-referencing with hydraulic data at locations with sensor arrays.

5. State-of-the-art numerical models of lahar flow at Ruapehu will be calibrated against the real-world data captured from the predicted break-out event. The newly refined models will be run over the precise DEM's obtained from the LiDAR surveys to improve future risk assessments and mitigation plans at Ruapehu and other cone volcanoes.

PAPER

THE MANAGEMENT OF, AND POSSIBLE MANAGEMENT OPTIONS FOR DEBRIS FLOWS AT PIPSON CREEK, STATE HIGHWAY 6, MAKARORA, OTAGO, NEW ZEALAND

K. M. Martelli and Woodmansey, P.R.
Opus International Consultants, Opus House, Private Bag 1913, Dunedin.
kim.martelli@opus.co.nz

Two debris-flow events impacted and inundated the State Highway 6 Bridge across Pipson Creek (north of the settlement of Makarora) on the 10 March 2004 and 22 April 2006, resulting in the closure of the State Highway and damage to the bridge guardrail and pavement. Opus International Consultants provided emergency response for Transit New Zealand during the debris flow events and completed a Preliminary Hazard and Risk Assessment of Pipson Creek debris flows following the 2004 event (Opus 2004, 2006). Our records of activity suggest a debris flow event can be expected as often as one every two years triggered by high intensity rainfall and sourced from a continuous supply of sediment from two active areas in the McKerrow Range.

During the 2004 debris-flow event, approximately 20-25,000m^3 of debris and water flowed down the valley, much of which was deposited on and around the State Highway Bridge (Opus, 2004). The highway was closed for 22 hours and in excess of 5-10,000m^3 was removed from the riverbed in close proximity to the bridge. The cost of the initial removal operation was around $30,000. An additional $120,000 was spent over the following weeks removing more material and repairing the bridge guardrail and pavement.

The 2006 debris-flow event was slightly larger in size to the 2004 event (approximately 30,000m^3) with debris flowing out into the paddocks and bush area on the northern side of the bridge. The highway was closed and approximately 17,500m^3 of bed load material was removed. The cost of the initial removal operation was approximately $220,000 (Opus, 2006). Since the April event, debris has continued to accumulate around the bridge and the removal of this material is ongoing.

The management of future debris flows at this locality is paramount to Transit New Zealand for the safety of the motorists and ensuring the roading network remains open. At present, regular clearance of debris from under, upstream and downstream of the bridge is carried out, along with regular monitoring of the river bed level and rainfall, and the erection of warning signs. The increasing number and size of recent events have exhausted close-by dump areas for removal of bed load material and has left the creek bed and bridge more susceptible to smaller scale events.

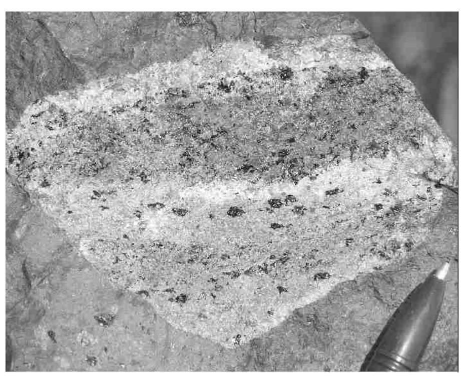
Medium to long-term management options may include the erection of a warning system and/or video surveillance; the construction of bunds and debris basins; stabilisation of the source areas; and/or the relocation of the highway and/or bridge. However, before medium to long-term management options are examined a more detailed study of the hazards needs to be carried out including detailed geological and geomorphological mapping, survey, and risk assessment to gain a greater understanding of the longer term risks to not only the state highway, but to the Makarora Township and any developments proposed in the area.

POSTER

MANTLE METASOMATISM BENEATH THE ROSS SEA, ANTARCTICA

A. Martin[1]

[1]Department of Geology, University of Otago, PO Box 56, Dunedin.
(adammartin2000@yahoo.com)



Located 100km southwest of Scott Base, Antarctica, Mount Morning – a 2,723m high, Cenozoic, trachyte-phonolite-basanite volcano - is host to a diverse suite of mantle and crustal nodules that are providing a window into sub surface processes beneath the Ross Sea. Mineralogical banding (pictured) and mylontisation of spinel lherzolite nodules are indicating a level of heterogeneity in the mantle not indicated in current geophysical models of the region. Primary plagioclase lherzolites are mineralogical markers of a shallowing of the mantle in the vicinity of Mount Morning. Additional Wehrlites, chromite cumulates, anorthosite, clinopyroxene megacrysts, granulites, syenites, and olivine gabbros enable a detailed picturing of the composition of crust and mantle beneath Mount Morning.

PAPER

VARYING SEDIMENTARY FACIES OF SIX LATE MIOCENE AGE MARINE TEPHRA BEDS, EAST COAST BASIN, NORTH ISLAND, NEW ZEALAND.

Ray Marx[1], James White[1] and Vern Manville[2]
[1]Department of Geology, University of Otago, PO Box 56, Dunedin, New Zealand.[2]GNS Science, Private Bag 2000, Taupo, New Zealand.
(ray.marx@stonebow.otago.ac.nz)

Upper Miocene tephra beds are abundant in marine deposits uplifted along the east coast of New Zealand's North Island. These were deposited in the East Coast Basin, which is a major tectonic depression along the NNE-SSW trending accretionary wedge, adjacent to that part of the Tonga-Kermadec-Hikurangi subduction zone along which the oceanic Pacific Plate is obliquely subducting, at a rate of 40-50 mm/yr, beneath continental lithosphere of the North Island. Uplift of the Miocene deposits reflects ongoing convergence along this margin.

The purpose of our study is to differentiate between primary and secondary tephra deposits, to determine the transport mechanisms and possible storage histories involved in their formation, and to extract any remaining interpretable information about the eruptions that produced the tephras.

A succession of six marine-emplaced tephra beds separated by hemipelagic mud is repeatedly exposed in an upright, gently dipping (≈ 2°-3°) anticline and a gently inclined, plunging syncline. This structure allows us to examine ≈ 1 km of correlative exposure for each tephra bed, which is distributed between four locations at regular, ≈2 1/2 km, intervals along 10 km of tidal beach platform, adjacent to the East Cape Road, between Te Araroa and Horoera Point. This succession thickens from west to east, with a total stratigraphic thickness of 6 1/2 m at the western Te Hekawa Point, and 134 m at the eastern Horoera Point. An increase in the thickness of intercalated hemipelagic mud from west to east accounts for this difference.

The succession is fossiliferous and intensely bioturbated, which often results in mixed contacts between tephra layers and their enclosing deposits. Shell beds at Te Hekawa Point contain an articulated macrofossil assemblage that includes *Cucullea* and *Sectipectin wollastoni*, and indicates a Kapitean (latest Miocene) age for these deposits.

This succession is interpreted to have been deposited in a relatively quiet continental shelf setting, proximal to the source volcanic centres. The tephra in the beds is interpreted to have arrived in density currents fed from terrestrial drainage systems into which primary pyroclastic deposits were emplaced. They are pumiceous with both rounded and unrounded grains. Many beds are reverse graded due to hydrodynamic sorting of sediment that includes ash, crystals and pumice lapilli.

POSTER

SUBVOLCANIC MAGMA RESERVOIRS BENEATH THE OKATAINA CALDERA COMPLEX, TAUPO VOLCANIC ZONE

N.E. Matthews, J.W. Cole & S.W. Weaver[1]
[1]Department of Geological Sciences, University of Canterbury, Private Bag 4800, Christchurch, New Zealand
(nem30@student.canterbury.ac.nz)

This study of the Okataina Caldera Complex (OCC), Taupo Volcanic Zone, aimed to reconstruct crystallization processes within magma reservoirs prior to the ~64 ka caldera-forming eruption of the Rotoiti Ignimbrite, to establish whether mafic input played a role in triggering the caldera-forming eruption, and thence to produce a magma reservoir model. Lithic fragments within the Rotoiti lithic lag breccia were analysed petrographically and geochemically with a focus on the plutonic fragments, although volcanic lithic fragments and sediments were also analysed in order to establish subsurface stratigraphy.

Petrographic analysis of volcanic lithic fragments indicates previous rhyolite dome complexes, a hydrothermal system in the north-eastern sector of the OCC, and extensive Matahina and Whakamaru

Ignimbrite sheets in the volcanic pile over the source area. Basement consists of Torlesse Group greywacke, with andalusite cordierite meta-granitoids comprising contact aureoles around magma bodies at depth. Mineralogical and textural features of the plutonic lithic fragments indicate varying degrees of crystallization within various magma bodies, with numerous generations of granophyric intergrowths, high-aspect ratio biotite and glassy, pumiceous interstitial patches and miarolitic cavities indicating a late phase of rapid hypersolvus crystallization and only partial crystallization when incorporated into the erupting ignimbrite. Textural features of these plutonic fragments suggest shallow magma reservoir depths of ~7km.

Whole-rock geochemistry distinguished four separate magma bodies which were evolving separately prior to caldera formation. Two biotite granite bodies were identified, one of which was cognate with the Rotoiti reservoir and characterised by evolved plagioclase feldspar and hydrous mineralogy. A layered biotite granite body displayed a geochemical trend attributed to biotite accumulation, and was geochemically related to the Matahina Ignimbrite, suggesting the existence of a partially crystallised cupola with extended crustal magma residence times of ~200 ka. A mafic lithic fragment group, comprising microdiorites, andesite and mingled basaltic andesite, corresponds geochemically with the Matahi Basaltic Scoria, with textures indicating crystallization within a high-level plumbing system.

Magma mixing processes are suggested on the basis of disequilibrium textures, strongly oscillatory zoned plagioclase and geochemical mixing trends. Mafic input into the Rotoiti system, possibly as an eruption trigger, is indicated by inherited high An feldspars and xenocrystic ferro-hornblende, in addition to the mingled mafic fragments. The existence of numerous isolated reservoirs in a complex sub-caldera silicic magmatic system suggests sill-like or high aspect ratio magma chamber geometries, distributed at shallow levels within the crust, and these features are represented in a comprehensive magma reservoir model for the OCC.

PAPER

ADVANCES IN THE EXTRACTION OF PHOTOGEOLOGICAL INTERPRETATION INTO GIS

Colin Mazengarb[1]
Mineral Resources Tasmania, PO Box 56 Rosny, Tasmania, Australia 7018.
(colin.mazengarb@dier.tas.gov.au)

Traditional approaches to the accurate extraction of geological interpretations from vertical air photos into GIS often requires multiple steps and people. A typical workflow requires stereoscopic interpretation onto an overlay and manual transfer of the linework from the overlay onto a base map. The base map is in turn digitized and attributed, often by another person, to convert the information into a GIS vector format. The accuracy of the transfer from a photo (often older photos up to 60 years old are used) with all its inherent distortions to a map form may not be great. Furthermore the process of digitizing linework into GIS format may also introduce spatial and attribute errors.

An alternative technique is being trialled using a desktop computer application whereby the photointerpetation is orthorectified and vectorised by one person: the geologist. Workflows are being developed to maximize this capability for geological applications. 3D visualization of the linework further enhances the assessment and adjustment of the interpretation. In the near future as other software becomes more affordable, stereoscopes will be replaced by stereographic computer based systems, further reducing a transfer step and the reliance on suitable tracing film that is no longer being manufactured.

The strengths and weaknesses of the alternative approach will be demonstrated with examples from geomorphic mapping in Tasmania.

TOWARD AN UNDERSTANDING OF REGIONAL LANDSLIDE RISK IN TASMANIA

Colin Mazengarb[1] & Jennifer Selkirk-Bell[1]
Mineral Resources Tasmania, PO Box 56 Rosny, Tasmania, Australia 7018.
(colin.mazengarb@dier.tas.gov.au)

With development pressure continuing on marginal lands close to cities and along coastal strips in many parts of the world, there is an obvious imperative for Local Government to avoid or minimize landslide risk in its planning and emergency management functions. There are several ways this can be achieved. In Tasmania regional landslide susceptibility maps are being produced by State Government as information tools for councils. The maps provide confidence for councils to insist that development applications in identified areas have geotechnical reports supplied that address landslide risk. Unfortunately understanding risk on site is often highly subjective because it relies on an understanding of consequence and likelihood. While consequence can be reasonably estimated in some instances, likelihood is often much more difficult to determine because triggering factors and age of the landscape are often poorly understood.

In northern Tasmania, there are extensive areas of landslide terrane associated with highly weathered Tertiary basalts. Unfortunately most of the landslides are prehistoric and poorly constrained in age. A geomorphological approach is being attempted to provide better age constraints. By mapping previously dated uplifted marine terraces and matching fluvial terraces this is helping us to understand landscape evolution over the last 125 000 years. The relationship of landslides to mapped and modelled surfaces is being established by applying simple rules. Preliminary results suggest that some of the landslides are demonstrably younger than the last glacial maximum. This has obvious implications for understanding frequency of past events and the estimation of likelihood.

PAPER

END-TO-END FLOOD RISK ASSESSMENT: A MODEL CASCADE WITH UNCERTAINTY ESTIMATION

[1] H.K.McMillan and [2] J. Brasington
[1] Institute of Natural Resources, Massey University, Palmerston North
[2] Department of Geography, University of Cambridge, UK
(h.k.mcmillan_at_massey.ac.nz)

Traditional flood risk assessment methods in the UK are based on empirical, deterministic techniques, relying on curve fitting of measured flow data to predict future flood return periods. In today's era of climate and land-use change, resulting in non-stationarity of the flood generation process, these approaches increasingly fail to capture the full range of possible future behaviours. Further, it is no longer sufficient to limit the procedure to prediction of discharge; a distributed model of floodplain inundation based on sound hydraulic principles must be integrated into the analysis in order to support today's 'soft engineering' solutions to flood risk. Finally, a rigorous uncertainty estimation procedure must replace outdated deterministic forecast techniques. This presentation therefore outlines a project undertaken to establish a contemporary, process-based framework for flood risk assessment, using a cascade of coupled models which incorporate the best new hydrological data and modelling techniques.

The method is tested and validated through an application to a small, lowland catchment, allowing an assessment of its suitability for use in a typical flood-risk environment. The results of the case study demonstrate that the coupled model chain which forms the 'End-to-End' flood risk assessment structure provides a practical and rigorous flood risk assessment tool. A comparison of results with a study using conventional techniques suggests that the new method achieves a valuable improvement.

PAPER

WHY CALCULATE FRACTURE-SURFACE ENERGY?

Mauri McSaveney
GNS Science, Lower Hutt
m.mcsaveney@xtra.co.nz

A hot topic in recent fault literature is the energy used to fracture rock in fault rupture to form gouge. Volcanologists often calculate the energy used to create fragments in block-and-ash flows, pyroclastic flows and airfall tephra. Landslide papers are written on the energy consumed in fragmenting rock in large landslides. Calculations are based on the industrial concept of fracture-surface energy – energy expended to create a unit area of fracture surface when materials are comminuted. It is used to design such industrial items as ball mills and ore stampers and to determine explosive charge to produce a desired rock comminution. It takes energy to fracture rock; the finer it is fractured, the more energy it takes. In industry, this costs money. Fracture-surface area is the most readily determined parameter characterising the fineness of crushing. Total fracture surface area is measured accurately using gas absorption on particle surfaces. The energy for crushing is applied as a force causing deformation. When a solid is deformed beyond its elastic limit, it breaks; if deformed rapidly, it breaks into many pieces. Elastic strain stored in the mass before it broke is released, and fragments move apart, usually rapidly; the original mass assumes a different shape. The sequence can repeat many times, and the mass crushed finer and finer.

If the same mass were deformed elastically by just a slightly smaller amount, it would not break. If it were then released, it would return to its original shape. The energy used to deform it to the point at which it had just not broken, costs the same as the energy used to deform it to the point at which it would be just about to break, because this is the same point. It costs a little bit more to push it over the limit, because a small amount of super-stressing is inevitable at the high strain rates used in industrial crushing. In industry, there is no useful recovery of elastic strain energy released when the mass fractures, so energy used to strain it to failure is "lost" from the fragments. The energy is used entirely to deform the original mass, and to repeatedly deform its fragments so that they further fragment; it is not used in any other way. Industrial interest is in the fragments, and not the deformation, and so the energy expended is "lost". In many applications in nature, interest is in deformation; the work done in fracturing is manifest in the deformation, and is not "lost" from it. In fault rupture and landsliding, work done in motion is the resisting force times the net strain. This resisting force created many fragments, but left no energy attached to them, rather it spread the fragments around while making them. The spreading is the deformation. There is more deformation where there is more fragmentation; and so fracturing is not at the expense of deformation. Fracture-surface energy is not an energy loss to processes where the deformation is of interest.

POSTER

OPENING A PANDORA'S BOX: COMPLEXITY WITHIN THE MANGATAWAI TEPHRA FORMATION, TONGARIRO VOLCANIC CENTRE

Anja Möbis and Shane J. Cronin
Volcanic Risk Solutions, Institute of Natural Resources, Massey University, PO Box 11 222, Palmerston North, New Zealand.
(a.moebis@massey.ac.nz)

From previous studies we have inherited a comprehensive record of the history of large volcanic events from the main eruptive centres of the Tongariro Volcanic Centre, along with basic geochemical information. There has been a wide range in eruption types and scales from this centre, but normally the smaller eruptions have been grouped together as single stratigraphic Formations in order to facilitate regional mapping. The two main thrusts of this study are to (1) provide more detail of the frequency and nature of the poorly studied small eruptions, and (2) elucidate the physical processes/column heights and tephra distributions of the range in eruptions possible at this centre. Initial work has focused on the Mangatawai Tephra Formation – a composite unit defined by W. Topping in 1974 to encompass tephra falls from Ngauruhoe volcano spanning the time range from

c. 2500 to 1800 yrs B.P. The distinctive tephra layers within this unit are dominantly fine-grained, black or purplish grey ash layers that often preserve plant fragments and leaves. Detailed granulometric and mapping studies reveal several surprising features of these deposits including:

- They are not all sourced from Ngauruhoe; between 20-50% of the units in-fact derive from Ruapehu as indicated by grainsize/distribution trends and also by deposit lithology.
- There are many individual eruptions represented within the Mangatawai Formation; at any one location between 30 to 50 layers can be identified, separated by soil/time breaks.
- Not all deposits are representative of falls – many have the characteristics of surge units.
- Many features of phreatomagmatism are present in the units, including vesiculated tephras, aggregated and accretionary lapilli and extremely highly fragmented fine ash.

These new findings necessitate a major re-evaluation of the volcanic history of this period and provide valuable new constraints on the hazard potential of Ngauruhoe/Tongariro and Ruapehu. Internal Mangatawai Formation stratigraphy and chronology will be used to better constrain the eruptive activity of the peroid. In addition, particle shapes, density, vesicularity and chemistry will be used to constrain eruption properties, including vent conditions. The study aims to fill gaps in our knowledge in this and other parts of the geological record on Ruapehu and Tongariro. These gaps are major hindrances to attempts at volcanic hazard forecasting from this area.

PAPER

FOSSIL RECORD FILE AND NATIONAL PALEONTOLOGICAL COLLECTION AND DATABASE – WHAT'S NEW

B.Morrison[1], I. Matcham[2], I. Raine[2], H.Schlumpf[2] & J.Simes[2]

[1]GNS Science, Private Bag 1930, Dunedin.

[2]GNS Science, PO Box 30 368, Lower Hutt.

(b.morrison@gns.cri.nz)

The GNS National Paleontological Databases (PDB) programme started a year ago with the aim to restore, maintain and develop two Nationally Significant databases – the New Zealand Fossil Record File (FRF) and the National Paleontological Collection and Database (NPC) – which together contain a unique national archive of modern and ancient biodiversity. More specifically we aim to provide improved digital access to the data and promote routine use of the database by national and international researchers.

Prior to the programme commencing GNS had made some progress in developing an online digital database for the FRF, known as FRED (http://www.fred.org.nz). However over the last year the pace of development has increased and there have been a number of significant improvements; a substantial increase in performance, maps of localities and more powerful search functionality. This year we have also opened up the online data entry (locality registration) system to all registered users. This system allows users to enter data for a locality, submit it to a masterfile curator and receive a FR number all from their computer – completely replacing the paper system.

FRED does not contain all the data that exists in the FRF filing cabinets and in a lot of areas only has grid references. As part of the PDB programme we are systematically going through the paper forms and entering the entire record (including taxonomic lists where available) into FRED. We started this mammoth job in November 2005 with 1 part-time data entry person working on the Nelson masterfile area. We now have a team of 6 working at GNS and Auckland, Victoria and Otago universities – even so we estimate it will take another 3 years to finish.

The type and reference paleontology collections of the NPC moved site from Gracefield to Avalon, Lower Hutt, in early 2006, along with much of the GNS Science Lower Hutt campus, an initiative to expand and improve accommodation and facilities. These collections are now housed together in part of the large soundstage adjacent to the main building. We are currently planning to develop these facilities to establish a world-class centre providing stable, secure storage, easy access for visitors and a high-quality laboratory and preparation area. We also have a new staff member specifically employed to curate the collection and have commenced work on a new digital curation system which will ultimately link to FRED.

We have updated and improved the official NPC loan forms and although the process has not been altered, we are more rigorous in ensuring material is loaned to institutions rather than to individuals. We have followed up on many outstanding loans and have managed to see some of these back at GNS. We are also investigating the exciting possibility of developing a system to make 3D scans of fossils available online to reduce the amount of material we send to researchers.

POSTER

CRUSTAL STRUCTURE OF THE CENTRAL NORTH ISLAND BASEMENT: A PETROTECTONIC PERSPECTIVE

Nick Mortimer
GNS Science, Private Bag 1930, Dunedin
(n.mortimer_at_gns.cri.nz)

New petrological work has been undertaken in conjunction with regional geological mapping (QMAP team) and detrital zircon dating (Chris Adams). This abstract summarises some of the emerging results that will be incorporated in the Rotorua and Hawkes Bay QMAPs and, ultimately, into a revised Cretaceous tectonic model.

As outlined below, there are major pre-, syn- and post-accretionary differences in the Eastern Province basement of the northern North Island compared with that of the South Island. All of these differences contribute to a basis for a central North Island regional greywacke classification and require modification of existing models.

PRE-ACCRETION: two “extra” mafic-intermediate volcaniclastic units have been recognised in the central and northern North Island for some years. These are the Waipapa Terrane (Sporli 1978) and the Waioeka subterrane (Mortimer 1995). Morrinsville and Hunua facies (Kear 1971) are still useful and useable subdivisions of Waipapa Terrane. A new proposed tectonostratigraphic unit in the central North Island is the Kaimanawa block. Kaimanawa greywackes have a petrography and geochemistry indistinguishable from the Permo-Triassic Rakaia Terrane, but have Jurassic stratigraphic ages.

SYN-ACCRETION: K-Ar and Rb-Sr ages indicate a Late Jurassic-Early Cretaceous age of accretionary deformation and prograde metamorphism in the Kaimanawa Schist (Kaimanawa block) and Waipapa Terrane. This is significantly younger than the Early Jurassic accretionary fabrics of the Otago Schist flanks. Kaimanawa Schist lacks the flat-lying exhumation-related fabrics of the Otago Schist core.

POST-ACCRETION: substantial Late Cretaceous-Neogene dextral strike-slip movement may have occurred on fault systems east and west of the Axial Ranges. These faults could have linked the Alpine Fault with the Vening Meinesz Fracture Zone and/or other microplate boundaries. The coincidence of the active Whakatane-Mohaka-Ruahine Fault System with a melange-bounded slice of Waioeka rocks between Bay of Plenty and Masterton attests to the control of Neogene faults by pre-existing basement structures.

The identification of the Kaimanawa block is an important link in understanding the differences between the Rangitata Orogen in the South Island and in the northern North Island. It fits a pattern of northward-younging stratigraphic and accretionary ages within New Zealand.

PAPER

CRETACEOUS-CENOZOIC ZEALANDIA: DID PACIFIC SUBDUCTION EVER STOP?

Nick Mortimer
GNS Science, Private Bag 1930, Dunedin
(n.mortimer_at_gns.cri.nz)

Many of us have tended to simplify the Cretaceous-Cenozoic tectonic history of New Zealand into episodes of pre-105 Ma episodic convergence, 105-85 Ma rift, 85-25 Ma drift and 25-0 Ma renewed convergence (in some syntheses and contexts, replace 25 Ma with 45 Ma). The implication is that the Late Cretaceous-Paleogene was a time of tectonic quiescence. Some recent papers (Nicholson et al. 2000, Forster & Lister 2004, Schellart et al. 2006) plus an enlightening fieldtrip to New Caledonia in August 2006 have led me to start to question this interpretation. Although much remains to be tested, there is a growing body of petrological evidence for continued or renewed subduction off some of the Pacific side of Zealandia in most or all of the 105-25 Ma interval.

From c. 230-105 Ma, the Median Batholith (MB) was the site of subduction-related magmatism in Zealandia. 105-85 Ma igneous rocks with a subduction-influenced chemistry (e.g. negative Nb anomalies) lie well east of the MB and include the autochthonous Mt Somers and Mt Camel volcanics, the allochthonous Tangihua and Matakaoa Volcanics and very low TiO_2 (depleted) basaltic lavas in the Wairarapa (Kopi boninite) and Hawkes Bay (Hinemahanga Rocks-Red Island). There may be alternative explanations for the subduction-like geochemistry of these lavas (e.g. inheritance from the 230-105 Ma lower crust or mantle wedge) but, taken at face value, they indicate (1) existence of a renewed and/or rearranged (steeper slab?) post-MB, 105-85 Ma subduction system; and (2) development of a Late Cretaceous-Paleogene intraoceanic back-arc basin off the North Island (NI) and the Norfolk Ridge (NR), and hence a subduction zone and arc still further out in the Pacific.

So, maybe subduction never ceased for any significant length of time off the NI-NR part of Zealandia. In contrast, there seems no scope for back arc basin development off Zealandia between the Hikurangi Plateau (HP) and Chatham Rise (CR). Recognition of this along-strike difference between east and west Zealandia has possible implications for 85-25 Ma regional tectonics including: (1) yet another explanation for the origin of the NZ oroclinal bend as trench rollback north of the pinned end of the HP-CR; (2) proto-Alpine Fault as a periodically active slab-edge/transform/tectonic zone generating 85-68 Ma metamorphism and pegmatites in the Alpine Schist; (3) an emphasis on geological differences in basement and basin geology either side of the Alpine Fault.

Unfortunately, the postulated trench-arc-back arc microplate system off the NI-NR would be invisible to PAC-ANT-AUS plate circuit analyses. The only evidence for it would be geological. For the Late Cretaceous-Paleogene subduction model to become more generally accepted it will be desirable to somehow corroborate the petrological interpretations, and also find evidence of the putative rifted arc (maybe under Fiji or Vanuatu).

POSTER

QUANTIFYING SUBMARINE LANDSLIDE PROCESSES DRIVEN BY ACTIVE TECTONIC FORCING: COOK STRAIT SUBMARINE CANYON, NEW ZEALAND.

Joshu Mountjoy[1,2], Philip M. Barnes[2] & Jarg R. Pettinga[1]
[1]University of Canterbury. Private Bag 4800, Christchurch.
[2]National Institute of Water and Atmospheric Research. Private Bag 14901, Wellington.
(P.Barnes@niwa.co.nz)

The Cook Strait submarine canyon system is a multi-branched, deeply incised and highly sinuous feature of New Zealand's active margin, covering some 1500km^2 of sea floor between the North and South Islands and spanning water depths of between 50 and 2700m. The canyon occurs at the transition from the westward dipping oblique subduction zone adjacent to the SE North Island and the zone of continental transpression in NE South Island. The recent acquisition of high resolution (5-

10m) SIMRAD EM300 bathymetric data allows active tectonic and geomorphic processes to be assessed and quantified at a level of detail previously not possible.

While multiple active submarine fault traces have been identified in the Cook Strait by previous studies, quantitative information on their activity has been limited. Cook Strait is structurally characterized by westward dipping thrust faults and E-W trending dextral strike slip faults. The multiple large magnitude high frequency earthquake sources define zones of very high ground shaking expected to contribute to triggering of extensive submarine slope failures.

Landslide activity within the canyon system is widespread and represents the dominant mass movement process affecting canyon heads and walls, redistributing material into valley fills. Complexes of large (km^3) multi-stepped, deep-seated (100m) translational bedding plane failures represented by gently sloping (<3 degrees) evacuated slide-scar areas with associated blocky valley fill deposits are numerous. Steep catchment heads, channel walls and the leading edges of asymmetric thrust-fault driven anticlines are dominated by gulley and rill systems with associated eroded and/or incipient slump features. Large ($10^7 m^3$+) slide blocks are recognized in discrete failures with quantifiable displacement vectors.

Tsunamigenic landslides in this environment are inevitable. This study will provide quantification of landslide models including triggering mechanisms, discrete geometries and displacements that will contribute to the accurate assessment of tsunami hazard levels through the development of frequency magnitude relationships.

PAPER

QUATERNARY KINEMATICS AND TEMPORAL STABILITY OF A STRIKE-SLIP AND NORMAL FAULT INTERSECTION, NORTH ISLAND, NEW ZEALAND

V. Mouslopoulou[1], A. Nicol[2], T. Little[1]
[1] Victoria University of Wellington, School of Earth Sciences, PO Box 600, Wellington.
[2] GNS Science, PO Box 30 368, Lower Hutt.
(v.mouslopoulou@gns.cri.nz)

The strike-slip North Island Fault System (NIFS) and the Taupo Rift are the longest and highest slip rate active fault systems within the Hikurangi margin. Near the Bay of Plenty coast, the NIFS intersects the Taupo Rift at c. 45° and terminates (Mouslopoulou, 2006). The temporal stability of this fault intersection over timescales of 10 to 1500 kyr is examined using gravity, seismic-reflection, drillhole and outcrop data. Throws on the top of the 280 kyr Matahina ignimbrite and the top-basement surface (600-1500 kyr in age) generally increase northwards along each fault in the NIFS, due to the increasing influence of the Taupo Rift. Throws on the faults that bound the eastern margin of the rift (including the Edgecumbe Fault) decrease near their intersections with faults of the NIFS. This decrease in throw is equal to the throw on the intersecting fault of the NIFS. The total throw across each strike-slip and normal fault intersection is constant and equal to the throw accommodated by the rift alone away from the intersection zones. These observations suggest that fault-throws (or throw rates) on the NIFS and Taupo Rift were interdependent and accumulated synchronously on geological timescales (but during different earthquakes). Interdependent, or coherent, fault kinematics are consistent with rupture of the Edgecumbe Fault during the 1987 earthquake which appears to have been arrested where it intersects the Waiohau Fault, a component of the NIFS. Interdependent fault behaviour in the two systems may have occurred for the last 600-1500 kyr. However, throw rates in the rift, and on those faults in the NIFS that accommodate a component of normal displacement, increased by up to a factor of 3 about 300 kyr ago. Acceleration of extension appears to have been coincident in time with a southward propagation and narrowing of the rift (Villamor and Berryman, 2006), and may locally be due to an eastward migration of fault activity (Davey et al., 1995). Therefore, the rates of faulting and the orientations of slip vectors that typify the contemporary kinematics of the intersection zone, and which have persisted in the late Quaternary (e.g. 30 kyr), may have only been stable for the last c. 300 kyr.

Davey, et al., 1995. *Jour. Volc. Geoth. Res., 68, 209-238.*
Mouslopoulou, , 2006. *PhD Thesis, Victoria Univ. of Wellington, New Zealand.*
Villamor and Berryman, 2006. *NZ J. Geol. & Geophysics*, 49, 23-37.

POSTER

INTERACTIONS OF DEBRIS/ROCK AVALANCHES WITH RUNOUT PATH MATERIAL – A LABORATORY APPROACH

A. Mueller & T.R. Davies
Department of Geological Sciences, University of Canterbury, Christchurch
(amu27@student.canterbury.ac.nz)

Many debris/rock avalanches interact with material in their runout paths. A variety of avalanche-substrate interaction features has been reported in the literature for numerous locations in both volcanic and non-volcanic environments world-wide, suggesting that such interactions are common features of debris and rock avalanches rather than exceptions. During this project the question of how runout path material influences an avalanche's mobility and travel distance is investigated through field and laboratory analyses. Studying avalanche deposits in the field provides information mainly concerning the final stages of emplacement and deposition. In the laboratory, however, direct observations of the timing and mechanism of deformation is possible. For this purpose, a variety of granular materials was placed in a narrow flume to simulate the substrate and crushed coal was sheared over the substrate material. These experiments produced some of the features, i.e. substrate folding, faulting, dragging, redepositing and consequent substrate thickening, bulldozing, and injection into the overriding material, that have been described in the field. Examples of landslide-tectonized substrates that resemble the laboratory results include the Blackhawk landslide in California (Johnson 1978), the Parinacota debris avalanche in Chile (Clavero et al. 2002), the Yarbah Tsho landslide in the Karakoram Himalaya (Hewitt 2006), the Artillery Peak rock avalanche in Arizona (Yarnold 1993), and the Round Top debris avalanche in New Zealand (this study), to name a few. The similarities between laboratory and field observations are striking and improve our knowledge of the processes involved in avalanche-substrate interactions. Frame-by-frame analyses of video recordings of these experiments allow for a detailed study of the mechanisms of substrate deformation and entrainment. Coloured marker layers were used in most experiments and showed complex folding, mixing and injection features within the substrate. For example: folding of marker layers was often preceded by layer thickening and thinning; ramp structures formed where movement of the overriding coal was re-established; inclined marker layers were overturned, folded, faulted and mixed with the surrounding substrate. Regardless of material used (silty sand, medium sand, potting soil, PVC, pulverised dolomite, wallpaper paste, vermiculite, polystyrene spheres in sand) and degree of saturation, injection into the overriding coal and substrate dragging at the base of the coal body almost always occurred. The only exception was wet sand, which was merely eroded at the very surface with "rip-up" clasts entrained into the coal. These experiments form the basis for microscale analogue modeling in which scaling parameters will be considered and the dynamics of debris avalanche emplacement onto different substrates can be analysed and compared to field studies.

PAPER

TE ARA: PUTTING NEW ZEALAND EARTH SCIENCE ON THE WEB

Simon Nathan
Ministry for Culture & Heritage, P.O. Box 5364, Wellington
(simon.nathan@mch.govt.nz)

Te Ara: Encyclopedia of New Zealand is a unique, authoritative source of information on New Zealand topics. It is the successor to the three-volume Encyclopedia of New Zealand published in 1966. At the planning stage it was decided to plan the new encyclopedia specifically for the internet because that is where many younger people now seek information. While other encyclopedias are available on the internet, they are almost all printed versions that have been digitised. Te Ara is unique because it has been designed for the internet. This offers many advantages:

- Information can be corrected or updated
- Electronic files such as video clips can be included
- Te Ara is available free of charge anywhere in the world

- Many more illustrations can be used than in a print version
- Links to other websites can be included

To ensure accuracy, the articles in Te Ara have been written by or in conjunction with subject experts, and have then been peer-reviewed and edited. All entries with substantial Maori content have been translated in Maori. For those who want more information, each article has a "Further Sources" section, with links to up to half a dozen relevant websites or digitised papers as well as conventional print publications.

Te Ara contains almost 40 articles on all aspects of New Zealand earth science, mainly in the "Earth, Sea and Sky" theme launched in mid-2006. The articles can be grouped under 5 main headings:

- General geology (covering land and sea)
- Natural hazards and disasters
- Mining and mineral resources
- Hot springs and geothermal energy
- Maori perspective on earth science

Several more entries relating to landscape and glaciation will be added to this list in 2007.

You can find Te Ara at **http://www.teara.govt.nz**, and there are also links to individual entries through the GSNZ website. Experience shows that many people are led to the Te Ara site through web searches for a particular topic relating to New Zealand.

PAPER

LESSONS FOR VOLCANIC EMERGENCY MANAGEMENT FROM THE RESPONSE TO THE DECEMBER 2005 CRATER LAKE ERUPTION OF AMBAE VOLCANO, VANUATU

Károly Németh & Shane J. Cronin
Volcanic Risk Solutions, Institute of Natural Resources, Massey University, PO Box 11 222, Palmerston North, New Zealand.
(k.nemeth@massey.ac.nz; s.j.cronin@massey.ac.nz)

Ambae Island is the emergent portion of a basaltic volcano located in the northern region of the Vanuatu volcanic arc. It has an NE-SW elongated defined by a rift-like axis, dotted by scoria and tuff cones and fissure-fed lava fields. The islands c. 1500 m summit is occupied by a caldera feature that contains two lakes holding >50 million m^3 of water. Since the early 1990s, activity has occurred in Lake Vui through a single vent area, with a series of heating-cooling cycles that culminated in a small one-day phreatic eruption in 1995. Historic eruptions on Ambae have been documented in 1575, 1670 and 1870. The 1870 event formed a small cone inside Lake Vui. Over the last four years an education program involving development of village-level volcanic emergency plans and a Province-level disaster plan have been carried out through UNESCO and Massey University initiatives.

The latest eruption broke through the surface of the acidic lake Vui on 28 November 2005. The ~ 10 000 inhabitants of the island were aware of its volcanic nature through oral tradition and at least two hazard-awareness programs since the 1995 unrest. Surtseyan-style eruptions began a few days later forming a tephra cone island in the lake within 8 days. Hazards due to lahars were feared, with origin either by displacement of water and/or ejection of surges onto the steep outer caldera slopes. Lahars never eventuated and the eruption only reached a maximum volcanic alert level of 2 (= confirmation of eruption threat and minor activity). Despite this low level of scientific concern, local authorities organised themselves rapidly and managed a 4-week evacuation of 3500 people. This was driven by public and local authority fear, along with a lack of recent experience in volcanism and perhaps also a strong and overbearing interest from international media wanting to sensationalise the events. On the plus side, this eruption sequence showed the effectiveness of locally developed plans for volcanic crisis response and the ability of a local-government authority (Penema Province) to manage a full evacuation without external help. On the negative side, the event demonstrated a strong disconnect between scientific advice/warning levels and the magnitude of community response. According to the highest level of alert reached and official advice from the National Disaster Management Office, only readiness activities should have been undertaken. Political forces (driven by Ambaens in high-ranking government positions) dictated, however, a much stronger reaction.

POSTER

INTRAVENT PEPERITES IN AN ERODED PHREATOMAGMATIC VOLCANO OF THE WESTERN SNAKE RIVER PLAIN VOLCANIC FIELD IDAHO (USA) AND THEIR IMPLICATION FOR FIELD-WIDE ERUPTIVE ENVIRONMENT RECONSTRUCTION

Károly Németh [1] & Craig White [2]
[1] Volcanic Risk Solutions, Institute of Natural Resources, Massey University, PO Box 11 222, Palmerston North, New Zealand.
[2] Department of Geosciences, Boise State University, Boise ID-83725, USA
(k.nemeth@massey.ac.nz; cwhite@boisestate.edu)

The western Snake River Plain volcanic field in SW-Idaho contains up to 400 basaltic vents and centers that produced lava shields, pahoehoe lava fields, scoria cones, and great variety of phreatomagmatic volcanoes between late Miocene and middle Pleistocene time. Tephra deposits produced by phreatomagmatic eruptions are particularly well exposed in the walls of the Snake River canyon, where thick accumulations of pyroclastic rocks indicate widespread and probably long lasting phreatomagmatic eruptive events throughout most of the volcanic history of the region. Previously, many of the phreatomagmatic deposits were considered to be the products of subaqueous eruptions that took place on the floor of one or more large freshwater intra-continental lakes. Recent field based observations confirm the presence of widespread phreatomagmatic pyroclastic rocks; however, some that had been interpreted as being subaqueous exhibit textural features that are more consistent with subaerial depositional environments. Intrusive and extrusive magmatic bodies with features associated with peperite formation have also been identified. Most of these peperites can be attributed to magma-sediment mixing in intra-crater/conduit or vent settings, and therefore they cannot be used as widespread paleoenvironmental indicators to demonstrate magma and surface water (e.g. lake) non-explosive interaction. One of the studied sites ("*71 Gulch Volcano"*) was previously used to indicate the presence of a shallow lake. At this site there is clear field evidence that peperitic feeder dykes contacted muddy, sandy siliciclastic sediments forming globular peperite. The peperitic feeder dykes transition to pillowed, ponded lava up section. The ponded lavas are partially surrounded by a ~5-m-thick unit composed of gently dipping, dune bedded, volcanic glass shard-rich, unsorted, tuff and lapilli tuff containing abundant impact sags caused by volcanic lithics. We suggest that the 3D architecture of the erosional remnant of "*71 Gulch Volcano"* does not require the presence of a lake at the time of its formation; it is equally possible that that it represents a subaerial phreatomagmatic upper conduit – crater filling succession. This interpretation opens up many questions about the Mio/Pliocene evolution of SW Idaho, the timing of the volcanism, and its association with the evolution of the lacustrine systems in the region. In addition, reevaluations of the volcanic features in SW Idaho have some general implication for the usage of phreatomagmatic pyroclastic rocks for paleoenvironmental reconstruction.

PAPER

THE NOUMEA BASIN AND MT CAMEL TERRANE: EVIDENCE FOR LARGE SCALE SUBDUCTION DURING THE LATE CRETACEOUS

K. Nicholson[1], P.M. Black[2], C. Picard[3], P.Maurizot[4] & D. Cluzel[5]
[1]Dept. of Geology, Ball State University, Muncie, IN 47306, USA.
[2] Dept. of Geology, University of Auckland, Private Bag 92019, Auckland, NZ.
[3] Lab. de Geologié, Université du Nouvelle Caledonie, BP4477, Noumea, New Caledonia.
[4] BRGM, BP 56, Noumea, New Caledonia.
[5]Institut des Sciences de la Terre, Université d'Orléans, Orléans, France
(k.nichols@bsu.edu)

Throughout the SW Pacific region Cretaceous sedimentary basin successions enclosing in-situ volcanic sequences are uncommon. Current theory suggests that the southeastern Gondwana margin experienced fluctuations between extension and compression throughout much of the Cretaceous. Yet, the timing and duration of the fluctuations remains uncertain due to a lack of on-land exposures. Fragments of late Cretaceous siliceous volcanism, associated with volumetrically minor basic and intermediate lavas, are preserved in a number of localities around the rim of the Tasman Sea: eastern Queensland; Mt Somers, New Zealand; Three Kings Ridge; Alexander Island, Antarctica; New

Caledonia and along the Lord Howe Rise. Bimodal volcanism found in the Noumea Basin of New Caledonia and in the Mt Camel terrane of New Zealand represents an exciting opportunity to unravel the tectonic evolution of the area north of New Zealand during the late Cretaceous.

The Noumea Basin and the Mt Camel terrane are in-situ, have associated sediments with preserved micro- and macro-faunas, contain a range from rhyolitic to basaltic lavas and have experienced little metamorphism. Current research suggests the autochthonous Mt Camel terrane represents the development of a continental arc system along the New Zealand sector of the southeastern Gondwana margin during the late Cretaceous. The majority of Mt Camel terrane lavas have continental arc signatures. Second minor suite of lavas have oceanic island (OIB) signatures interpreted as the result of rifting during the final phases of arc volcanism. Although limited data exist for the Noumea Basin, it appears that the mafic to intermediate lavas in the Noumea Basin also exhibit two distinct geochemical affinities. Most of the lavas have continental arc signature, though a second suite of mafic lavas have distinct OIB signatures. The Noumea Basin does appear to be more complicated than Mt Camel terrane, however, due to the presence of trachyrhyolites.

Preliminary geochemical analyses have identified continental arc signatures in the lavas, as supported by sedimentary petrography indicating continental detrital mineral assemblages in both units. These results suggest that there was a well-developed late Cretaceous continental arc system active in both New Zealand and New Caledonia, possibly extending through Australia into the Antarctic Peninsula, with major implications for tectonic modelling during Gondwana break-up. Understanding the formation of these units, the tectonic environment that contributed to their formation and the larger scale tectonic implications of their formation will yield invaluable information about the processes active during the break-up of the southeastern Gondwana margin.

PAPER

LARGE (>50 KM) POST OLIGOCENE STRIKE-SLIP DISPLACEMENTS IN THE NORTH ISLAND; FACT OR FICTION?

A. Nicol[1], C. Mazengarb[2], F.Chanier[3], G.Rait[4], Chris Uruski[1] & L. Wallace[1]
[1] GNS Science, PO Box 30 368, Lower Hutt.
[2]Mineral Resources Tasmania, PO Box 56, Rosny Park, Tasmania, Australia 7018
[3]Université des Sciences et Technologies de Lille 1, Bat. S.N.5, 59655 Villeneuve d'Ascq Cedex, France
[4]Talisman Energy, 3400, 888 3rd St SW, Calgary, Alberta, Canada T2P 5C5
(a.nicol@gns.cri.nz)

Ever since Harold Wellman demonstrated 480 km of strike separation along the Alpine Fault nearly 60 years ago (in Benson, 1952) workers have been searching for, and speculating about, strike-slip faults with large (e.g. 50-500 km) right-lateral displacements in the North Island. Displaced landforms provide clear evidence of Quaternary strike slip on the principal faults of the active North Island Fault System (e.g., Wellington, Wairarapa, Mohaka, Ruahine and Whakatane faults), however, geological data supporting significant (>50 km) strike-slip displacements prior to this time are equivocal. To estimate the maximum permissible strike slip on upper plate faults, we compare the margin-parallel plate motion taken up by clockwise vertical-axis rotations of the North Island with the total margin-parallel motion between the Australian and Pacific plates. We find that, due principally to clockwise rotations of the North Island of up to 3°/Myr, the relative plate motion vector was approximately orthogonal to the margin from 10-24 Ma. The rates of margin-parallel relative plate motion increased from 10 Ma to the present, with current rates at a maximum for the post Oligocene. Clockwise rotations could have taken up all of the margin-parallel component of relative plate motion prior to 1-2 Ma. During the Quaternary rotations accounted for ≥40% of the total margin-parallel motion, with most of the remainder (e.g. >70%) accommodated by strike-slip in the North Island Fault System. As high strike-slip rates (4-17 mm/yr) in this fault system were geologically short-lived (1-2 Ma), large unresolved strike-slip displacements (>50 km) in the upper plate are not a requirement of the post Oligocene relative plate motions. We suggest that post Oligocene tectonic models of the North Island that incorporate large displacement strike slip faults are more fiction than fact.

Benson, W.N. (1952), Meeting of the Geological Division of the Pacific Science congress in New Zealand, February, 1949, *Intern. Proceed. Geol. Soc. Am.*, *1950*, 11-13.

PAPER

RELATIVE AGE DATING OF THE WAHIANOA MORAINES, MT RUAPEHU

E. Nolan
Geography, School of People, Environment and Planning, Massey University
(erinnolan@hotmail.com)

This presentation will present results of dating the Wahianoa moraines, using lichenometry, and schmidt hammer relative age dating methods in order to determine which climatic period they formed in.

The Wahianoa moraines are situated on the eastern part of Mt Ruapehu and are approximately 400m in length. The morainic deposits are deposited on top of the Wahianoa Formation, which is about 60,000-15,000 years BP. Therefore these moraines are at least 60,000 years BP in age, which suggests that they formed during either the Otira Glaciation or possibly the Little Ice Age. However, there has been no study in detail on the age of the Wahianoa moraines or other glacial sites around Mt Ruapehu. This is possibly due to the fact that the glaciers on Mt Ruapehu are situated in an active volcanic environment, which tends to take precedence on any studies conducted. Although, the present day glaciers are less than 1km in length they do play an important role in the shaping of Ruapehu's landscape.

PAPER

THE ALPINE FAULT MYLONITES: A ZONE OF LOCALISED DUCTILE SHEAR WITHIN THE MID TO LOWER CRUST

Richard J. Norris & Alan F. Cooper
Department of Geology, University of Otago, PO Box 56, Dunedin

The Alpine Fault is rare among major active faults in that oblique convergence across it over the last c. 5 Ma has led to the uplift and exhumation of a deep-seated mylonite zone in the hanging wall of the fault. This allows direct observation of the deep parts of the fault zone. The mylonite zone is approximately 1 km wide for most of its 350 km extent and in the central section of the fault (Haast to Hokitika), grades from Alpine Schist in the southeast through protomylonite, mylonite and ultramylonite before being fractured and crushed to cataclasite, microbreccia and gouge within the damage zone of the present active brittle fault. Although gouge-filled shears occur sporadically throughout the mylonites, extensive fracturing is limited to c. 100m from the fault and the zone of extensive cataclasis is generally less than 50m thick. The mylonites thus exhibit continuous ductile shearing throughout most of their width. Shear sense indicators consistently show dextral-reverse shear within the zone consistent with the overall displacement on the Alpine Fault. Detailed mapping along the length of the Alpine Fault has shown that protoliths within the hangingwall are progressively incorporated within the mylonites and sheared out laterally within the zone for distances of up to 100 km. In the south, the Alpine Fault truncates the Dun Mountain Ophiolite Belt and other Mesozoic terranes, and these are sheared out northwards within the mylonites. North of the Livingstone Fault, Alpine Schist forms the hangingwall and is progressively incorporated into the mylonites. The schists range from biotite zone and garnet zone in the south to oligoclase zone north of Jackson Bay. In the Mataketake Range north of Haast, the hangingwall schists contain a swarm of pegmatite veins formed by partial melting at 65-70 Ma. The pegmatites are also incorporated into the mylonite zone and progressively stretched out by c. 90 km to near Franz Josef. Between Haast and Makawhio Rivers, mylonites close to the fault contain albitic plagioclase porphyroclasts which commonly have oligoclase rims, typical of feldspars from garnet zone rocks. We interpret these as being derived from the lower grade schists near Jackson River up to 90 km to the south. The most likely protoliths of a thick amphibolite sequence with kyanite-bearing ultramafic schist in the garnet zone of metamorphism at Makawhio River occur 95 km to the south in the Jackson River area. Thus the mylonite zone represents a highly attenuated sequence of hangingwall lithologies sheared out laterally over 70-100 km. The bulk of the mylonites are derived from a quartzofeldspathic schist protolith, although a more or less continuous unit of carbonate mylonite occurs between the Waitaha and Mikonui Rivers, and a pod of ultramafic mylonite near the Waitaha River. Measurements of thickness distributions of the pegmatite veins were used to estimate shear strains of 12-22 in the protomylonites, 120-200 in the mylonites and 180-300 in the ultramylonites. These are some of the highest strains reported in the literature and are consistent with the 70-100 km of shear displacement recorded by the attenuated lithological units. This shearing is similar to that estimated for the last 5 Ma. Thus the exposed mylonite zone represents a zone of continuous ductile shear within the mid-lower crust formed and exhumed since oblique convergence began on the Alpine Fault at c. 5 Ma.

POSTER

SEISMICITY OF THE CENTRAL ALPINE FAULT

B.C. O'Keefe, E. Smith, M. Savage
School of Geography, Environment and Earth Sciences, Victoria University of Wellington, PO Box 600, Wellington
(okeefebron@student.vuw.ac.nz)

The central Alpine Fault between Harihari and Karangarua is recognised as having a significantly lower seismicity level than the regions northeast and southwest. Several hypotheses of mechanisms said to contribute to the anomaly have been proposed over the years including slow slip, shallow creep, and external fluids affecting the thermal regime and brittle-ductile transition. We plan to test these hypotheses with data from a microseismicity in the region.

We recently deployed nine seismographs within the region encompassing a sharp break in seismicity immediately south of Harihari and a more gradual return in seismicity south of Franz Josef Glacier. They will be recording from late August for 4-7 months dependent on the timeframe required to record sufficient quantity and quality of earthquakes. We will show a detailed background seismicity study of Geonet data in the region, and we expect to be able to show some of the data from the first download, planned for November.

PAPER

COUPLED MODELLING OF HEAT FLOW, FLUID FLOW AND EXTENSION IN THE TAUPO VOLCANIC ZONE: THE ROLE OF BASEMENT FAULTS

N.H.S. Oliver[1], J.G. McLellan[1], B.E. Hobbs[2], J.V. Rowland[3], J.S. Cleverley[1,2], R.H.Sibson[4] & S.F. Simmons[3]
[1]Economic Geology Research Unit, School of Earth & Environmental Sciences, James Cook University, Townsville, Australia, 4811 (nick.oliver@jcu.edu.au)
[2] CSIRO Exploration and Mining, P.O. Box 1130, Bentley, 6102, Australia
[3] Geology Department, University of Auckland, Private Bag 92019, Auckland, NZ
[4] Department of Geology, University of Otago, PO Box 56, Dunedin, NZ

Upwelling zones of heated fluids in the Taupo Volcanic Zone have been exploited for geothermal power and host low grade epithermal gold resources, testimony to the likely effects of sustained convection of hydrous fluids. Using reasonable values for heat flow, fluid supply and rock properties derived from physical measurements in the TVZ, vigorous convection is predicted in recent models for coupled heat flow and fluid flow using static geometries, including ours. In some models, the initially regular spacing of convection cells is primarily a function of the overall model conditions including the width and depth of the TVZ (Kissling & Weir, 2005). However, if the permeability of the upper crust is as high as measured, then our model convection is unstable and convection cells should have moved laterally fairly rapidly with time, yet the current sites of geothermal upwelling have been stable over the last 200000 years. The apparently poor control of near surface rift faults on geothermal fluid flow, despite repeated earthquake activity on normal faults, does however suggest that the ignimbrite pile is very permeable, otherwise exposed rift faults should have had a stronger influence on fluid flow. Recent mapping of the detail of the rift fault segment tips (Rowland & Sibson, 2004) suggests the presence of deeper-seated transform faults in basement which may have controlled the localization of fault zone irregularities and possibly fluid flow. Insertion of model permeable fault structures that do not penetrate upwards into the permeable cover has the effect of "pinning" the overlying convection cells. This effect occurs even when a very short-lived burst of overpressured fluid is applied (e.g. released from intrusions or faults) – the perturbation of the hydraulic structure of the overlying convection cell continues well beyond the duration of the fluid pressure anomaly. Long-lived mid- to lower-crustal magma chambers that themselves are controlled by structural detail within the rift may also pin the overlying convection cells. Even if faults penetrate into the permeable upper crust and convection cells are periodically destroyed by seismic activity (as we can now model using the coupled code FLAC3D), the detail of the basement architecture or intrusions and its connection to the overlying structure has a first order control on maintaining convection cell position. Geophysical imaging of basement faults and intrusions in ancient and modern rift zones is crucial to develop concepts that will assist mineral and geothermal power explorers in the future.

PAPER

NEARSHORE HABITAT MAPPING FROM MULTIBEAM BATHYMETRY

A. Pallentin[1], I.C. Wright[1], K. Mackay[1], J. Gardner[2], & T. Byfield[2]
[1]NIWA, PO Box 14-901, Wellington
[2]Victoria University of Wellington, PO Box 600, Wellington
(a.pallentin@niwa.co.nz)

Multibeam mapping can produce seafloor bathymetry of unprecedented quality and quantity for a range of purposes including hydrographic charting, seafloor engineering, and scientific research of seafloor processes. Increasingly multibeam mapping is also being applied to seafloor "habitat mapping", where in addition to bathymetry, seafloor "back-scatter" and derived map layers (e.g., slope analysis, slope aspect, artificial illuminated terrain models) are being used to understand causal relationships between the marine physical environment, marine habitats, and biodiversity.

In late 2005 NIWA completed a EM3000D multibeam survey of the Wellington South Coast in collaboration with the Department of Conservation, and School of Biological Sciences, Victoria University of Wellington, mapping some 46 km^2 of seafloor habitat between the harbour entrance and Cape Palliser including the area and immediate environs of the proposed Taputeranga marine reserve. The bathymetry grid, built from over 400 million individual beam soundings, has a 1 m^2 cell-size resolution, and a vertical resolution of 15 cm. The multibeam data provide the first complete base-line map of the proposed Taputeranga marine reserve. Ground-truthing of the multibeam mapping is currently underway via towed seafloor video analysis, biological sampling, and diver observations.

GIS analysis of the multibeam data has been used to produce various map layers to characterize seafloor morphology and associated habitats of the Wellington South coast. These layers include map products derived directly from the bathymetry grid (e.g., slope and aspect), but also more derived map layers like seafloor roughness (or rugosity), first derivative of the slope (seafloor complexity), and indices that integrate both seafloor backscatter and rugosity. Other GIS algorithms (e.g., Benthic Terrain Modeler) that are objective, seafloor classification schema have been used also. An overview of the project and examples of various map layers will be presented.

PAPER

EXPANSION OF THE GEONET SEISMOGRAPH NETWORKS

Nora Patterson and the GeoNet Team

New Zealand's seismograph networks are continuing to expand as the GeoNet project enters its sixth year. The seismic monitoring networks include the New Zealand National Seismograph Network (NZNSN), the Strong Motion Network, and regional networks above the Hikurangi subduction zone and near volcanic centres. The NZNSN provides a backbone of broadband seismometers and strong motion accelerometers at ~100 km spacing throughout the country. The Strong Motion Network provides additional strong motion instruments throughout densely populated areas. Regional network stations, which will ultimately have 30 km spacing above the Hikurangi subduction zone and be closer spaced near volcanic centres, are equipped with short period seismometers. Moreover, many seismographs are co-located or in proximity to continuous GPS stations.

The number of national and regional seismic monitoring stations has nearly doubled since the GeoNet project began and will continue to grow over the coming years. This year we plan on expanding the National Network by two stations and the regional networks by 11 stations. The strong motion network is complete and consists of nearly eight times more instruments than before GeoNet received funding. The seismic data collected from these networks enables real-time earthquake location, has utility in modelling earthquake hazards, and will inevitably enhance our understanding of New Zealand tectonics. All earthquake data collected by GeoNet is freely available for public research via the GeoNet website, www.geonet.org.nz.

POSTER

FENITISATION ON MOUNT MORNING, SOUTHERN VICTORIA LAND, ANTARCTICA

H. Paulsen[1]
[1]Department of geology, University of Otago, PO Box 56, Dunedin.
(hannekp@gmail.com)

Mt Morning is a 2723m high, undissected, predominantly basanitic volcano with minor trachytic and phonolitic assemblages. It is located 92km southwest of Scott Base, near the foothills of the Royal Society Range. Rocks of the Erebus Volcanic Province, part of the more extensive McMurdo Volcanic Group, are exposed on the western Riviera Ridge and eastern Hurricane Ridge on the northern flank of the mountain. A relatively small, but important, outcrop of a poorly bedded pyroclastic breccia occurs on the upper reaches of Mt Morning. A basement clast of granitic composition found within this breccia, consisting of orthoclase, plagioclase, quartz, and biotite, has been metasomatised. A carbonatite or an alkali intrusion was emplaced adjacent to the granite wall-rock, and sodium enriched volatiles from the intrusion have altered the mineralogy of the original granite. Along the edges of the feldspars and quartz, the original minerals, including biotite have altered into a green pyroxene, aegirine; blue amphibole, riebeckite; and the feldspar albite, all sodium-rich end members.

PAPER

CONSTRAINTS ON ANTISCARP FORMATION FROM PHYSICAL AND NUMERICAL MODELLING

Verne H. Pere, Tim Davies and Jarg R. Pettinga
Dept. Geological Sciences, University of Canterbury, Private Bag 4800, Christchurch.
(v.pere@geol.canterbury.ac.nz)

Antiscarps, or sackung, can form in response to gravity loading or from a major change to slope conditions, such as glacial loading or the large scale removal of material. Physical and numerical modelling has been undertaken to assess the significance of defect properties within a massif and to provide some constraints on the conditions under which antiscarps form.

A base friction table was employed to simulate a gravity load through a defect ridden massif. Elements used to construct the models were prefabricated pattern blocks, manufactured MDF blocks, M4 steel hex nuts, and coins. Defect geometry was limited by the relationship of the element interfaces and was altered by varying the aspect of the model relative to the frictional sliding surface.

2D finite element modelling was initially undertaken with Plaxis® v.6.1 and subsequently with FLAC® 2D v.3.40. Grids for both Plaxis and FLAC incorporated unidirectional and bidirectional defect sets to which a gravitational load was applied. Successive runs analysed incremental changes to defect orientations, and were coupled with tests using changing values for both the defect properties and the rock mass properties. Staged construction methods were used to emulate loading and unloading of the slope.

Graben-type collapse of the ridge into the model, toppling, and element rotation within translational slides occurred in the base friction table models where the modelled defects were steeper than 30º. Antiscarps were evident in many of the failures suggesting antiscarp formation can occur solely under gravity given the right conditions. Deformation of the grids used in the numerical analyses support the base friction results where interfaces have been incorporated into the model to represent defects. When no defects are built into the model the effective stress contours indicate zones of tensile stress that when coupled with the resultant displacement vectors, suggest zones conducive to antiscarp formation.

PAPER

DEFINING THE QUATERNARY

Brad Pillans
Research School of Earth Sciences, ANU, Canberra, 0200, Australia
(brad.pillans@anu.edu.au)

One can only agree with sentiments recently expressed by the eminent stratigrapher Amos Salvador, that a stable, standard geologic time scale is indispensable for clear and precise communication among geologists. Indeed, this is exactly the task of the International Commission on Stratigraphy (ICS), expressed through its most recent iteration of the international Geological Time Scale, GTS2004. However, as many of you know, the definition of the Quaternary is much debated, and remains anything but stable in the GTS.

In September 2005, the full ICS voting membership, after an intensive interval of consultations and working group efforts, made the following recommendations:

1. That the Quaternary be established as a formal chronostratigraphic (geochronologic) unit of the Cenozoic Erathem (Era).
2. That the Quaternary span the past 2.6 myr of the Cenozoic Erathem/Era, with its formal base at the GSSP of the Gelasian Stage/Age of the Pliocene Series/Epoch.
3. That the Quaternary have the rank of Sub-Erathem (and Sub-Era) in the geologic time scale, and be coeval with the uppermost portion of the Neogene System (Period).

The recommendations were submitted to the International Union of Quaternary Research (INQUA) for their formal acceptance. However, at an INQUA executive meeting in March 2006, following further polling of INQUA members and Quaternary national committees, INQUA rejected the ICS recommendation to define the Quaternary as a Sub-Era/Sub-Erathem. The stated reasons for rejecting the ICS recommendation included its non-hierarchical nature, the decoupling of the Quaternary from the base of the Pleistocene, and the extension of the Neogene to the present. In reply, INQUA proposed that the Quaternary be defined as a Period/System above the Neogene, and that the base of the Pleistocene be redefined at the Gelasian GSSP (to also correspond with the base of the Quaternary).

In August 2006, the International Union of Geological Sciences (IUGS), the parent body of ICS, also rejected the ICS proposal. In doing so, IUGS noted that the ICS recommendation was not in agreement with the long-standing protocol and procedural principles that have been accepted by the international geological community, and established by ICS itself in the International Stratigraphic Guide (Salvador 1994) and in the "Revised Guidelines for the Establishment of Global Chronostratigraphic Standards of the ICS" (Remane et al.1996, *Episodes 19(3)*, 77-81). In particular, IUGS stipulated that the formal definition of the Quaternary must be in accordance with the strictly hierarchical structure of the GTS (which the ICS proposal was not). As I will discuss, the most likely outcome could well be the reintroduction of Quaternary and Tertiary as the major subdivisions of the Cenozoic Era, with Neogene and Paleogene being subdivisions of the Tertiary (as in Salvador 1994). It would then remain to pin the bases of the Pleistocene and Quaternary at the Gelasian GSSP at 2.6 Ma, necessitating transfer of the Gelasian Stage from the Pliocene to the Pleistocene.

PAPER

FUTURE DIRECTIONS IN NEW ZEALAND GEOSCIENCE EDUCATION – THE PLACE OF EARTH SCIENCE IN THE SCIENCE CURRICULUM

Jenny Pollock[1], Daphne Lee[2], and Alan Munro[3]
[1]Nelson College for Girls, Trafalgar Street, Nelson & Junior Vice President of New Zealand Association of Science Educators
[2]Department of Geology, University of Otago, PO Box 56, Dunedin
[3]Southland Boys' High School, 181 Herbert St, Invercargill
(jenny.pollock@xtra.co.nz)

Planet Earth and Beyond has been part of the New Zealand Science curriculum since 1993. It is currently being revised and major changes are being proposed. The Science curriculum, both in its current and draft forms, has four major contexts that students are required to study at least to the end of Year 11 These are: Living World (Biology), Material World (Chemistry), Physical World (Physics), and Planet Earth and Beyond (Earth Science and Astronomy). Underpinning the new curriculum is the Nature of Science strand with four Achievement Aims (Understanding about Science, Investigating in Science, Communicating in Science, Participating and Contributing). This discussion is particularly concerned with the teaching of Earth Science at secondary school. However, the proposed changes will apply to all year levels.

At present, secondary school students study plate tectonics, including earthquakes and volcanoes, at years 9 or 10, the identification and formation of selected rocks and the rock cycle at year 11, the geological history of New Zealand at year 12, and a more detailed treatment of plate tectonics, volcanoes and earthquakes at year 13. However, students wishing to continue with either Earth Science or Astronomy after year 11 (the fifth form) can only do this by taking (General) Science at year 12 and year 13. Whereas most schools offer the specialist science subjects of Chemistry, Biology or Physics, only a small number of schools currently offer Science.

Also, under NCEA, each of the 4 contextual strands has an equal number of credits (out of a possible 24-26): 5 at Level One, and 4 at Levels Two and Three. The remainder of the credits are assigned to a research project and a practical investigation. This means that each of the Earth Science and Astronomy Achievement Standards are assigned only a small number of credits. Consequently, because of overcrowded timetables, the small credit ratings, and a desire to prepare students well for the specialist sciences, most schools are choosing not to teach and assess either Earth Science or Astronomy at year 11. Many students now study no Earth Science or Astronomy after year 10.

Earth Science needs to be made more relevant and hence more attractive to all students as citizens of Planet Earth. The proposal is that the teaching and learning of Earth Science should change to have a broader focus on Earth Systems Science. Students will consequently study selected aspects of the geosphere, hydrosphere, atmosphere and biosphere. This should also encourage an integrated approach towards science in general, and make a very important contribution towards developing a scientifically literate society.

PAPER

CONTROLS ON ACID MINE DRAINAGE CHEMISTRY, WEST COAST, SOUTH ISLAND.

J. Pope[1], N. Newman[1] and D. Craw[2]
[1] CRL Energy Ltd, 123 Blenheim Rd, Christchurch, j.pope@crl.co.nz
[2] Geology Department, University of Otago, Dunedin.

Acid mine drainage (AMD) is the largest environmental problem facing the mining industry because it can effect the environment many kilometres downstream of mine sites and if untreated, can persist decades to centuries after mining has ceased. AMD forms when sulphide minerals disturbed by mining oxidise, react with surrounding rocks and release acid, Fe, Al and trace elements. AMD chemistry is highly variable and therefore the nature and severity of environmental impacts and optimal mitigation or treatment methods are difficult to predict.

A suite of samples from coal mine drainages on the West Coast of the South Island has been collected to determine chemical variability. All samples have been collected as close to source as possible to avoid changes in chemistry due to downstream processes. Mine drainage chemistry on the West Coast can be related to several factors including regional geology, mine type, hydrogeology, and local rock types.

The impact of regional geology on mine drainage chemistry is best demonstrated by comparison between mine drainage from Paparoa Coal Measures and Brunner Coal Measures. Mines within Paparoa Coal Measures produce neutral mine drainage with low concentrations of Fe, Al and trace elements. Mines within Brunner Coal Measures produce acid mine drainage (AMD) with elevated Fe, Al and trace elements. Differences in mine drainage chemistry between mines hosted in Paparoa Coal Measures and Brunner Coal Measures can be correlated with differing mineralogy in coal and surrounding sediments related to depositional and diagenetic processes.

In Brunner Coal Measures AMD, mine type (open cut or underground) influences the ratio of Al to Fe. Open cut mines produce AMD with a higher Al:Fe ratio than underground mines because reaction between acid and aluminosilicate minerals can proceed more readily in subareal waste rock dumps compared to underground workings. At underground mines in Brunner Coal Measures, hydrogeology influences the total acidity of AMD. The pH and concentrations of acidic cations (Al + Fe) is lower in flooded underground mines (portal above the workings) compared to underground mines that are continually flushed by groundwater (portal lower than the workings). At active open cut mines in Brunner Coal Measures local rock type influences the total acidity of AMD. Mudstone rich waste rock produces AMD that has higher total acidity than sandstone rich waste because sulphides are typically more abundant and possibly more reactive in mudstones.

The influence of regional and local factors on mine drainage chemistry is supported by rock geochemistry data from active mine and exploration areas. These data and relationships can be used to construct a hazard model for mine drainage water quality. Prediction of mine drainage chemistry improves management of environmental risks from mining and optimises planning for mitigation or remediation strategies.

PAPER

GEOTECHNICAL ASSESSMENT OF FOUNDING CONDITIONS FOR LARGE WIND TURBINES, TARARUA RANGES, NEW ZEALAND

Steven Price
Riley Consultants Ltd, PO Box 100 253, North Shore Mail Centre
(sprice@riley.co.nz)

The Tararua windfarm is one of the world's top three wind farm sites. Its owner has committed to a stage 3 extension involving construction of 35 large wind turbines standing 65m, producing 3MW each.

The Tararua Ranges are located immediately adjacent to an active fault zone and have recently been up-thrusted. The ranges consist of shattered 'greywacke' sandstone with a complex capping of Tertiary and Quaternary marine deposits, along with reworked loess.

Proposed sites for the turbines are generally challenging as 'easier' sites are already occupied by in excess of 100 smaller turbines.

Though theoretically relatively low strength material is required to support the turbine weight resting on 15m diameter octagonal pads, cyclical rocking under wind and possibly seismic load, requires strong material of high stiffness. Thus, greywacke rock is the preferred founding material.

In January 2006 construction of the stage 3 extension commenced. Large earthworks are required to form foundations and adjacent crane platforms. Excavations to date have generally been consistent with conditions inferred from the geotechnical investigation, however, some sites have revealed geology more complex than envisaged, such as localised low strength gully fills on ridge crests. Thus, foundation designs have been adapted to the subsurface conditions encountered.

CONTRASTING RHEOLOGIES REPRESENTED BY VOLCANIC FLOW DEPOSITS WEST OF MT. TARANAKI, NEW ZEALAND

Jonathan Procter, Anke Zernack & Shane Cronin
Institute of Natural Resources, Massey University, Private Bag 11 222, Palmerston North, NZ
(J.N.Procter@massey.ac.nz)

The <130 ka ring plain deposits of Mt Taranaki in the western North Island, N.Z., have been mapped and categorised on the broad characteristics of their sedimentary character, to include: large-scale debris avalanche deposits, lahar units, block–and–ash flow deposits and fluvial beds. Individual units of debris avalanches or packages of other deposits of similar character were dated and chrono-stratigraphically grouped using interbedded soils and tephras. These mapped units are the basis for hazard assessments of the area as well the first units examined when attempting to develop scenario-based hazard modelling. On closer inspection of individual units however, the nature of these units is highly variable, not only between types of flow, but also within mapped units. An example is described of the the Warea Fm., which is represented as a group of breccias and sandy gravel units, interpreted to result from debris and hyperconcentrated flows (lahars), loosely dated between 13-23 ka. It is mapped in four separate lobes; NW, SW, SE, and N of the edifice. Concentrating on the western ringplain in more detail, debris flows and hyperconcentrated flows have originated from three discrete catchments. (1) The northernmost deposits (Stony River) are a sequence of (approx 3) coarse-grained, poorly sorted debris flows of dense andesite clasts. These deposits exhibit variations both longitudinally and laterally. Lateral variations show transitions from gravel-rich, clast-supported massive paleo-channel deposits to over-bank deposits, which vary considerably in sorting, texture and bedding. Longitudinal variations result from complex patterns of incorporation and deposition of sediment along the flow paths. This results in typical transformations of individual units from debris flows to hyperconcentrated flows, and in distal reaches fluvial and ponded sands in paleo-estuarine and delta environments. (2) Deposits originating from the Warea catchment further south differ by exhibiting homogenous texture and sorting. They have pronounced normal grading, a coarse sandy matrix, monolithologic clast and matrix compositions and greater cementing. Their most prominent feature are common angular jigsaw-jointed scoria clasts. (3) The southernmost of these western deposits exhibit a similar stratigraphy but with more defined time breaks between the flows represented by inter-bedded soils. These debris flow deposits exhibit better sorting, with sub-rounded smaller clasts and rapid lateral changes between channel and overbank facies. Longitudinally these deposits show very little evidence of transformation downstream.

The characteristics of these deposits all depict a highly variable system of sediment-water interaction with the ratio of sediment to water increasing and decreasing by bulking and de-bulking during flow. The overall downstream flow transitions are further complicated by repeated variations over short distances in channel confinement/depth. This results in complex variations in fluid rheology and inter-granular forces. Current numerical models and related computer codes can potentially simulate simple steady-state flows down catchments, with relatively precise identification of inundation areas. However our sedimentology studies indicate that typical volcanic mass flows are anything but steady-state in nature. Through geomorphology and sedimentology analysis, can we systematically quantify these variations in rheology between and within catchments to constrain conditions for numerical simulations?

POSTER

PETROFABRICS AND SEISMIC WAVE SPEEDS OF THE RED MOUNTAIN OPHIOLITES, SOUTH ISLAND, NEW ZEALAND.

V.B.Rajasekhar[1], R.Davey[1], I.Das[1,2], M.Savage[1], T.Little[1], S.Greve[1] & J. Louie[3]
[1]Institute of Geophysics, Victoria University of Wellington, NZ
[2]Indian Institute of Technology, Kharagpur, India
[3]University of Nevada, Reno
(rajasekhar.vadlamannati@vuw.ac.nz)

To study scaling of seismic properties, we compare seismic and structural measurements of peridotite fabric at Red Mountain for cm, hectometre and larger scales. We determine the fabric foliation and lineation by field and petrographic observations. We measure seismic anisotropy with an active seismic experiment along two perpendicular lines.

As observed macroscopically in the field, the mean strike of the foliation derived from 148 readings, mostly defined by compositional layering and orthopyroxene (opx) shape fabrics is 068 whereas its mean dip is 79 NW. The finite stretching lineations in these rocks are defined by opx prisms alignment (observed both macro and microscopically) and the mean pitch derived from 50 readings plunges 49 SW. Brittle cracks, serpentinite veins, chromite, harzburgite and dunite bands, diorite, cpx and opx dykes are the next dominant features that are aligned obliquely to the observed field foliations. Their strikes range from 080-150 with dips ranging from 65-80 NW-NE. Microstructural analysis of three hand samples within 100m of the seismic lines yields approximately the same results for the foliation orientation (average strike at 061 and dips 73 NW) as defined by olivine and opx shape fabric and dimensional alignments. The younger brittle cracks cross cutting this foliation having a mean strike 123 and dip 64 NE.

We measure shallow seismic P-wave speed along perpendicular lines oriented parallel and perpendicular to regional fabric, with 4m spacing between geophones. Near surface weathered layer velocities were calculated as 1.4±0.15 km/s for Line 1 (180 m long, oriented at 60) and 1.82±0.12 km/s for Line 2 (147 m long, oriented at 150). Velocities at greater depths (5-10 m) are poorly constrained due to large noise (2.48±0.32 km/s for Line 1 and 2.14±0.51 km/s for Line 2). We find 23.4±9.5% (1σ) anisotropy for the surface, weathered layer (above 5m).

Surface wave analysis for radial components from Line 1 gave the S-wave velocity for the average top 30 m as 1.3 km/s, while Line 2 gave 1.5 km/s indicating Line 2 has higher velocity than Line 1 and the 14.3% anisotropy is consistent with the shallowest P-wave anisotropy. Shear wave splitting from hammer shots also yields fast orientations predominantly in the -30 to -60 degrees orientation range.

Low average and seismic fast orientations wave speeds that are parallel to cracks rather than to mineral orientations, suggest that they are controlled by near-surface cracks. Further analysis plans include EBSD and splitting of local and teleseismic earthquake phases.

PAPER

QMAP 2010 AND FUTURE GEOLOGICAL DATA NEEDS

M.S. Rattenbury
GNS Science, P.O. Box 30 368, Lower Hutt 5040
(m.rattenbury@gns.cri.nz)

The QMAP: Geological Map of New Zealand programme is delivering a new series of 21 1:250 000 scale geological maps covering the country and is scheduled for completion in 2010. At the conclusion of the programme, in addition to the maps and explanatory texts, there will be a seamless digital geological GIS dataset, available at low cost on CD or free via the Internet. The release of QMAP digital vector GIS data on CDs for individual map sheets over the last two years has been well received and there are increasing numbers of industry, government and academic applications of the data. This reflects the growing use and sophistication of GIS in the workplace and also a greater awareness of the QMAP dataset.

QMAP however has limitations and one of these is the design scale. The digital data have been acquired principally for portrayal at 1:250 000 and are unsuitable for use at suburb-level scale let alone site-specific investigations. Point (structural measurement) and line (fault, fold) data can be stored in more detail within the GIS, and for QMAP publication purposes these detailed features have been suppressed or "plot ranked" out. Polygon (geological unit) data are hard to portray at different scales because of the difficulties of changing the unit boundary complexity to suit. There are however locational accuracy and precision issues with all geometrical features at detailed scales.

A second limitation is that QMAP is deliberately a conventional geological map series where the mapped unit is the dominant rock type at or close to the surface. The published maps depict a compromise between surficial and basement rock types, designed to cater for a variety of end user purposes. Surficial veneers up to 5-10 m thick of alluvium, loess, volcanic ash etc are normally not shown. A third (related) limitation is that QMAP provides little information on what lies underneath the mapped geological units. Published cross sectins and the legend allude to this but only in very general terms.

There is an opportunity ahead to improve upon these limitations. Over the next couple of years the geological community and users of geological data can influence the direction and scope of systematic geological data acquisition in New Zealand. There is also an opportunity to influence how national "public good" geological data are managed, accessed and visualised. Improving geological data detail in areas of economic importance (where we live and where we produce) is one obvious direction to concentrate on. Detailed geological data could assist with engineering construction, land-use planning, and the identification of geological hazard susceptibility amongst others. Another direction is to undertake QMAP-like (low cost, accessible, spatially integrated, information-rich, uniform quality) data acquisition into the third dimension. A digital geological map GIS database equivalent in 3D would enable more robust decision-making in, for example, geological hazard assessment and the quantification of groundwater and mineral resources.

PAPER

THE ROLE OF FLUIDS IN THE EVOLUTION OF THE TAUPO VOLCANIC ZONE

Martin Reyners[1], Donna Eberhart-Phillips[1] & Graham Stuart[2]
[1]GNS Science, PO Box 30368, Lower Hutt 5040, New Zealand
[2]School of Earth Sciences, University of Leeds, Leeds LS2 9JT, UK
(m.reyners@gns.cri.nz)

Recent seismograph deployments in the central North Island with a station spacing of 15-20 km have allowed detailed 3-D tomographic imaging of both seismic velocities (*Vp* and *Vp/Vs*) and seismic attenuation (Qp^{-1}) throughout the crust and upper mantle. These images reveal that southwest of the termination of the Taupo Volcanic Zone (TVZ) at Mt Ruapehu, the crust thickens by *ca.* 10 km. In the mantle wedge, *Vp* is lowest (7.4 km/s) and *Vp/Vs* is highest (1.87) at 65 km depth, immediately west of the Taupo caldera. 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. There is no significant low *Vp* zone in the mantle wedge southwest of the TVZ, suggesting that the thicker crust there has choked off mantle corner flow. This lack of corner flow is a plausible explanation of the cessation of volcanism to the southwest.

Crustal earthquakes in the overlying plate form a continuous band along the strike of the underlying subduction zone, deepening from mostly <10 km in the central TVZ to ~30-40 km deep in the lower crust 30 km southwest of the termination of the TVZ. Earthquakes in the band often occur in swarms, suggesting fluid movement in critically loaded fault zones. Seismic velocities within the band are consistent with the presence of fluids, and the deepening seismicity parallels the boundary between high seismic attenuation (interpreted as partial melt) within the central TVZ and low seismic attenuation in the crust to the southwest. This linking of upper and lower crustal seismicity and crustal structure allows a common explanation for all the seismicity – weakening of faults within an otherwise cool and dry crust by hot fluids exsolved from underlying melt. Such weakening provides an explanation for the southwestwards propagation of the TVZ with time.

Numerical modelling experiments have demonstrated that in regions of well-developed mantle return flow, viscous decoupling occurs at shallow depth between the slab and the mantle wedge because hot material from the wedge is entrained close to the trench. We would thus expect a major change in the large-scale viscous coupling of the plates at the southwestern termination of the TVZ, from decoupled in the northeast to more strongly coupled to the southwest. Such a change in viscous coupling is likely to play a significant role in the long-term clockwise rotation of the forearc and extension within the TVZ.

Thus fluids and their effects can explain the evolution of the major features of the TVZ. Pre-existing zones of weakness, such as previously suggested large faults, are not required.

PAPER

DATING MYLONITIZATION IN THE PAPAROA CORE COMPLEX, WESTLAND

Uwe Ring[1], Michelle Herd[1], Robert Bolhar[1], Johannes Glodny[2], Mike Palin[3]
[1]Department of Geological Sciences, Canterbury University, Christchurch
[2]GeoForschungsZentrum Potsdam, Potsdam, Germany
[3]Department of Geology, Otago University, Dunedin

In order to better understand the tectonic relationship between the inception of mylonitic shearing in the Paparoa core complex (PCC) in Westland and the intrusion of the Buckland granite into the footwall of the core complex, we dated an ultramylonite at the southern end of the PCC, the granite from which the ultramylonite developed and a sample from the Buckland granite.

Sample PCC06-2 is a blackish ultramylonite from White Horse Creek at the southern end of the PCC. The ultramylonite derived from a granite and has a very fine-grained, dark matrix containing about 5% of coarser components that escaped from the otherwise extreme grain size reduction. The coarser components are feldspar, forming rotated clasts indicative of top-SSW shear, and muscovite, appearing as syn-folial crystals up to 500 µm in size. U-Pb zircon dating by LA-ICPMS yielded highly variable ages ranging from 330 to 1950 Ma. The youngest distinct zircon population defines an imprecise age of 347±27 Ma (N=4, MSWD=9.9), which may be taken as approximation to the timing of crystallisation of the granitoid protolith prior to ductile deformation. Isotopic dating by Rb-Sr analysis of the fine-grained matrix, of feldspar clasts and of three muscovite grain size fractions yields an age of 116.2±5.9 Ma (2σ error). The three muscovite grain size fractions essentially define this age but show largely and systematically different Rb, Sr trace element concentrations and Rb-Sr ratios, which is characteristic for progressive syn-kinematic recrystallization. Sr-isotopic inheritance from pre-Cretaceous events can be ruled out, both for feldspar clasts and muscovite. Feldspar recrystallised entirely indicating deformation well in amphibolite-facies conditions. Although there is some scatter of the data outside analytical uncertainty, reflecting the disequilibrium texture of the rock, we interpret the age of 116.2±5.9 Ma as dating a pre-ultramylonitic, early stage of deformation. U-Pb ages obtained by LA-ICPMS for zircons from the Buckland Granite define two distinct peaks at 102.4±0.7 (N=6, MSWD=0.2) and 110.3±0.9 Ma (N=9, MSWD=0.44). The older age is statistically identical to, albeit more precise than, a published SHRIMP U-Pb zircon age of 109.6±1.7 Ma (Muir et al., 1994), and is best interpreted as dating the crystallisation of the Buckland Granite. Inherited zircons range from ~240 to 1600 Ma, with a broad cluster at 240-640 Ma, consistent with derivation of the Buckland Granite from re-melting of Mesozoic and Palaeozoic sedimentary sources. The significance of the 102 Ma age is difficult to ascertain. In view of systematic differences in Th/U ratios and Ti concentrations for zircons from both age populations, we tentatively interpret the younger age to reflect an event that remobilised Zr and precipitated a second zircon generation, possibly in response to emplacement of the ~102 Ma Stitts tuff.

Our data suggest that extensional deformation was already under way at 116.2±5.9 Ma and thus probably started before the intrusion of the Buckland Granite at 110.3±0.9 Ma. The complete recrystallisation of potassium feldspar in the ultramylonite indicates temperatures >500°C and strongly suggests that the high-temperature metamorphism is related to extensional deformation.

POSTER

TOWARDS A LOCAL Mw SCALE FOR NEW ZEALAND

E. de J. Robertson[1,2], E. G. C. Smith[1] & R. Robinson[2]
[1]Institute of Geophysics, Victoria University of Wellington, P.O. Box 600, Wellington.
[2]GNS Science, P.O. Box 30368, Lower Hutt.
(roberteliz@student.vuw.ac.nz)

We aim to enable accurate earthquake magnitudes (moment magnitude, M_W) to be calculated routinely and in near real-time for New Zealand earthquakes. This will be done by inversion of GeoNet waveform data to obtain Centroid Moment Tensors (CMTs). CMTs will also provide information on fault-type and potentially better depth information.

Currently only local magnitude (M_L) can be calculated for New Zealand earthquakes, and M_L is known to significantly underestimate the size of earthquakes above M_W ~6.5, and may also overestimate the size of some earthquakes.

Accurate values of M_W will help scientists and emergency managers by providing accurate estimates of an earthquake's size, which, combined with accurate estimates of fault-type and depth, can lead to better estimation of its shaking potential, likely damage and the likelihood of tsunami generation.

We will apply a well established CMT inversion method, the Time-Domain [seismic] Moment Tensor Inversion algorithm (TDMT_INVC, Dreger, 2003). This software has been installed and tested. Some modifications to this software are needed, and these are being identified and implemented. This software will be applied to GeoNet broad-band waveform data. Appropriate seismic velocity models for New Zealand will be established from information available in the scientific literature, and will be used by the software. A number of seismic velocity models will be required due to the diversity of the New Zealand crustal structure.

Preliminary results from the example data suggest that although the full moment tensor solutions are sensitive to errors, the value of the moment magnitude is less sensitive. Further tests will be conducted to prove or disprove this hypothesis.

A test set of earthquakes from 2000-2005 has been compiled. Harvard (http://www.seismology.harvard.edu/CMTsearch.html, April 2006) have calculated seismic moment tensor solutions for these earthquakes and there are New Zealand (GeoNet) broad-band data for them. Earthquake and broad-band station locations have been mapped for each earthquake. This test data set will be used to compare seismic moment tensor solutions calculated with the TDMT_INVC code applied to GeoNet data and the Harvard moment tensor solutions, to test the accuracy of solutions obtained using the TDMT_INVC code, including how quality varies with faulting type, geographic location and magnitude.

We hope that the final algorithm will be able to be incorporated into GeoNet procedures so that it runs automatically after locations have been determined for earthquakes with adequate broad-band data.

POSTER

SEA-RAFTED PUMICE AT MILI ATOLL, MARSHALL ISLANDS: 3000 KM FROM SOURCE

M. D. Rosenberg[1], F. R. Thomas[2], and G. N. Kilgour[1]
[1]GNS Science, Private Bag 2000, Taupo.
[2]Pacific Studies Program, PIAS-DG,University of the South Pacific,Suva,Fiji.
(m.rosenberg@gns.cri.nz)

Several pumice pebbles were collected by staff of the Marshall Islands Historic Preservation Office during a 2005 archaeological survey of Jelbon Islet, Mili Atoll, Marshall Islands. GNS Science analysed the major and trace element chemistry of two pumice pebbles and found a close match with analyses of the alkali-rich rhyolite erupted in 1953 - 1957 from Tuluman Island, located in the Admiralty Islands, Bismarck Archipelago (northern PNG) some 3000 km from Mili Atoll. The same provenance was determined by Spennemann & Ambrose (*Antiquity* 71:271 (1997), pp.188-193) for a pumice-obsidian block collected from Nadikdik Atoll, close to Mili Atoll.

Although the atolls of the Marshall Islands are built on Cretaceous age basalt, they are entirely comprised of coralline gravel, sand, or limestone. Volcanic rock does not occur *in situ* anywhere in the Marshall Islands and its discovery immediately raises questions of origin and means of transport, whether by ocean current or by canoe. Our investigation of the Mili pumice was prompted by the anthropological implication of its presence. Pumice was a resource sought after by the Marshallese with traditional uses as a fertiliser, and more commonly as abraders or abrasive in wood working and shell ornament manufacture. Pumice finds have been recorded throughout the Marshall Islands; all are assumed to be drift material from various sources, perhaps subsequently traded between local islets or atolls. The Mili pumice was discovered ca.100 m inland and a few metres above high water level. The morphology of the pumice is not consistent with any human modification and its inland location while possibly due to human transport, is more likely attributable to the effect of storm waves. Dispersal of pumice rafts from the source region could have occurred within weeks to months of an eruption, or pumice could have been stranded and re-entrained any time thereafter.

Common pumice types reported throughout the Pacific are those erupted from Krakatau in 1883 and more recently from submarine volcanoes in the Tonga-Kermadec arc. These were considered most likely sources of the Mili pumice, but silica (70.3 %) and high total alkalis (Na_2O=5.28 %; K_2O=3.39 %) determined by whole-rock XRF, exclude both sources, and with other major oxide and trace element abundances instead point to the 1953-1957 eruptions of Tuluman Island.

In addition to modern trash, drift material reported in the Marshall Islands includes driftwood, net floats (various sources), cut logs (North America), wooden canoes (Solomon Islands), pumice (Admiralty Islands, PNG; Krakatau, Indonesia), and people in canoes (e.g. Kiribati). These multiple sources both east and west attest to the influence, interaction, and variance by season and *El Niño* effect, of the westward-flowing Northern Equatorial Current, eastward North Equatorial Counter-Current, and westward South Equatorial Current.

POSTER

MAPPING THE DEEP-SEA: NEW ZEALAND'S DEEP-SEA FORAMINIFERA

Ashwaq Sabaa[1], Bruce Hayward[1], Hugh Grenfell[1], Helen Neil[2]
[1]Geomarine Research, 49 Swainston Rd, Auckland
[2]NIWA, Wellington
(a.sabaa@geomarine.org.nz)

We combine the results of our four major studies of the ecological distribution of deep-sea benthic foraminifera in regions north, south, east and west of New Zealand to produce a map covering half of the New Zealand Exclusive Economic Zone (EEZ). Our database consists of census counts (~60,000 specimens) of 510 species in 266 sea-floor samples (50-5000 m water depth). Twenty one mappable associations are recognised by Q-mode cluster analysis. Canonical correspondence analysis shows that factors related to water depth (especially the food supply from the surface waters) are the most significant in determining the overall foraminiferal distribution. Significant environmental drivers of the distribution pattern include phytoplankton productivity in the surface waters and its seasonality; bottom water ventilation; the energetic state of the benthic boundary layer and resulting substrate texture; and bottom water carbonate corrosiveness, particularly in lower Circum-Polar Deep Water.

The results of these studies have the potential to improve the resolution of paleodepth estimates based on fossil deep-sea benthic foraminiferal faunas in Neogene sedimentary strata around New Zealand.

PAPER

GEOPHYSICAL EVIDENCE FOR CONVECTIVELY REMOVED MANTLE AND LOWER CRUST BELOW THE NORTHWESTERN NORTH ISLAND

Michelle Salmon[1], Martha Savage[1], Tim Stern[1]
[1]Institute of Geophysics, Victoria University of Wellington.
(michelle.salmon@vuw.ac.nz)

Thickening of continental lithosphere followed by its convective removal provides a mechanism to explain a broad range of surface observations from the formation of deep sedimentary basins to uplift on a scale similar to that seen at hot spots. In New Zealand we see both geological and geophysical evidence for the convective removal of the lower lithosphere below the northwestern North Island. We use a combination of geophysical techniques to investigate large-scale crust/mantle structure behind the continental back-arc of New Zealand. The results paint a consistent picture of an abrupt change in crustal thickness in concert with missing mantle lithosphere.

Receiver function analysis and magnetotelluric data show the presence of a step in Moho depth from 25 km to 32 km across the Taranaki-Ruapehu line over a distance of less than 20 km. Seismic attenuation (Qp^{-1}) in the lithosphere also increases by a factor of 2 below the region of thinned crust in the north. Qp^{-1} values rise from less than $1x10^{-3}$ where the crust is 32 km in the south, to $2x10^{-3}$ below the thinned crust of the northwestern North Island. The high attenuation indicates that the mantle lithosphere is hot T ~ 0.97 melting temperature) and anomalously thin (< 50 km) below the region of thinned crust. These results are consistent with the steep gradient in isostatic gravity between the two regions, which requires the presence of a shallow positive density anomaly, counterbalanced by a deeper negative density anomaly. The replacement of crust with mantle provides the shallow density anomaly and the replacement of lithospheric mantle with asthenosphere provides the deep density anomaly. The exhumed sediments of the Taranaki and Wanganui basins give evidence of a sequence of subsidence followed by rapid uplift in the region of thinned lithosphere. Along with the short lateral distance over which the change in lithospheric properties occurs, this is indicative of a geologically fast process such as convective thinning.

PAPER

LANDSLIDE GUIDELINES FOR CONSENT & POLICY PLANNERS -BRIDGING THE GAP BETWEEN GEOLOGICAL HAZARDS & LAND USE PLANNING

W.S.A. Saunders[1] & P. Glassey[2]
[1]GNS Science, PO Box 30 368, Avalon, Lower Hutt, New Zealand
[2]GNS Science, Private Bag 1930, Dunedin, New Zealand
w.saunders@gns.cri.nz, p.glassey@gns.cri.nz

GNS Science has developed guidelines to assist planners with the landslide hazard as part of the FRST funded natural hazards program. The guidelines have been based on *Planning for the Development of Land on or Close to Active Faults* (also known as the Active Fault Guidelines), published by the Ministry of the Environment. The draft guidelines are currently being compiled, with a draft version due for release for consultation in early 2007, with the final version due for release by June 2007.

While not a prescriptive guideline, it does assist planners to determine if existing planning documents incorporate the landslide hazard appropriately, by providing examples of policies and assessment criteria at a regional and district level. It provides examples of issues, objectives, policies and rules, along with assessment criteria specifically to address landslide hazard concerns at consent stage. Basic concepts are introduced to assist planners in understanding landslide processes, triggers, mapping landslides, hazard and risk assessment. Various information boxes give examples of landslide policies, and provide guidance on technical aspects, such as ‘Who does what?’ (i.e. geologists, engineering geologists, geotechnical engineers) and what information should be included in a landslide hazard and risk assessment.

The guidelines present a risk-based planning approach, which requires the following steps to be undertaken:

Risk Analysis
1. Identify landslides in your district
2. Identify the nature of the landslide hazard
3. Identify the consequences of the landslide hazard
4. Estimate the risk to a subdivision or development

Risk Evaluation
5. Assess and evaluate the level of risk to a subdivision or development

Risk Management
6. Treat the risk
7. Monitor and review

While these guidelines are specifically aimed at land-use planners, they will also be of interest to geologists, geotechnical engineers and emergency managers. Drafted with geotechnical input, they provide an example of how geotechnical experts can contribute to planning issues.

PAPER

WEDGES AT THE TOP OF THE GAS HYDRATE STABILITY ZONE: AN EXAMPLE FROM THE CANTERBURY SLOPE, NEW ZEALAND

K. Senger & A.R. Gorman
Department of Geology, University of Otago, P.O. Box 56, Dunedin, 9054, New Zealand.
(senger.kim@gmail.com)

Gas hydrate deposits have been well established globally, occurring in specific pressure-temperature conditions on both active and passive continental margins provided that a sufficient supply of methane is present. In New Zealand, gas hydrates have been identified through the presence of bottom-simulating reflections (BSRs) on both the Hikurangi and Fiordland active margins. No direct evidence for gas hydrate has yet been found in New Zealand's offshore hydrocarbon systems, including the Canterbury Basin. This may be due to the fact that BSRs are masked by the generally flat-lying stratigraphy.

Strong evidence links the presence of gas hydrate with increased slope instability, due to the effect of hydrate dissociation on the physical properties of the host sediment. This is especially true in a shallow-water setting like the Canterbury continental slope, where eustatic fluctuations, rapid sedimentation, and temperature shifts will promote a dynamic behaviour of the hydrate stability zone (HSZ).

Here we present an alternative way of potentially predicting the occurrence of gas hydrates on the Canterbury slope. A model for the HSZ of the Canterbury slope is established using bottom-water temperatures and borehole data. The model predicts the intersection of the top of the HSZ and the seafloor at ~540 m water depth. This depth corresponds with a zone of increased slope instability, interpreted using an array of industrial and academic multichannel seismic reflection profiles and bathymetric data sets. Potentially, this zone of shallow-based slope instability could be linked to weakness planes at the top of the HSZ. The model also predicts the extent of the base of the HSZ, a prime location for finding BSRs.

An extension of the HSZ model to hypothetical scenarios, with differing geothermal gradients, hydrate phase boundaries and the nature of the seafloor, reveals that a wedge of suitable conditions for hydrate formation may form at the landward edge of the HSZ. This is particularly apparent in systems characterized by low geothermal gradients, such as the Canterbury slope. We consider some of the implications of the HSZ wedge, in terms of preventing the interaction of the BSR with the seafloor, and its consequence for modelling of hydrate-related slope failures.

PAPER

THERMAL AND MECHANICAL PROPERTIES OF THE UPPER MANTLE BENEATH THE CENTRAL NORTH ISLAND, NEW ZEALAND

A.M. Seward[1], E.G.C. Smith[1] & C.M. Henderson[1]
[1] Institute of Geophysics, Victoria University of Wellington, P.O. Box 600, Wellington
(anya.seward@vuw.ac.nz)

The central North Island represents a rare example of back-arc spreading impinging on a continental lithosphere. Earth Scientists largely concur that the driver of volcanism within back-arc basins is water (and other volatiles) driven off the subducted slab. Water hydrates the mantle rocks and lowers the melting temperatures. Typically, P- and S-wave speed drops with increasing temperature and partial melt. Thus, waves from shallow earthquakes that have travelled through the upper mantle, known as Pn and Sn phases, provide an ideal tool for studying the properties of the uppermost mantle.

To produce an independent Model, the method of Haines (1979) is adapted, whereby velocities are determined for the Pn and Sn phases from wave propagation times between pairs of seismograph stations. Data from up to 63 seismograph stations throughout the North Island, of magnitude >3.5 events between 1990 and 2000 (~10000 events, ~40000 ray-paths), were used to constrain lateral fluctuations in Pn speeds in the upper mantle. Temporary seismograph arrays were deployed to gather data that would increase ray coverage over regions of interest.

The resulting models show distinct lateral variations of low and higher mantle velocities. Along the western North Island, mantle velocities of 7.9+/-0.2km/s are detected, while along the east coast, velocities as high as 8.6+/-0.2 km/s are seen. Beneath the CVR, mantle velocities as low as 7.3+/-0.1 km/s can be seen across a 100km wide extension zone. The velocities detected in the west are similar to “Normal” mantle velocities, whereas those seen beneath the CVR are approximately 10% lower, suggesting about 2% of partial melt.

PAPER

MAGMATIC HISTORY OF THE TARAWERA VOLCANIC COMPLEX

Phil Shane[1], I.A. Nairn[2], V.C. Smith[3], & J. Cole[4]
[1] Dept. of Geology, The University of Auckland, Private Bag 92019, Auckland.
[2] 45 Summit Road, Rotorua RD5 & GNS Science, Wairakei Research Centre, Taupo.
[3] Dept. of Earth Sciences, University of Bristol, Queen’s Road, Bristol BS8 1 RJ, UK.
[4]Dept. of Geological Sciences, University of Canterbury, Christchurch
(pa.shane@auckland.ac.nz)

The Tarawera Volcanic Complex has been built over the last 22 ka from 4 rhyolitic eruptive episodes, each involving ~5-10 km^3 of magma. Three of these episodes (21.9 ka Okareka, 17.7 ka Rerewhakaaitu, and ~AD1315 Kaharoa) were primed and triggered by basaltic intrusion, and each involved the sequential or simultaneous eruption of multiple distinct rhyolite magmas. The 13.8 ka Waiohau episode differs in being compositionally homogeneous and not displaying evidence of mafic intrusion. Subtle differences between rhyolite batches within the other three eruption episodes can be recognised from variations in ferromagnesian mineralogy, whole-rock and glass chemistry, and temperature, oxygen fugacity, and pressure estimates. There are no temporal or spatial trends in chemical or physical parameters either within or between episodes, and thus no evidence for any common magmatic origin linked by fractional crystallisation. Instead, the different magmas within each eruption episode had separate migration and storage conditions prior to eruption. Some mingled clasts with disequilibrium mineral assemblages and bimodal compositional populations point to rapid and short-lived mingling occurring during individual eruptions, presumably in the conduit. Different magma dynamics in terms of number of magmas, their storage geometries and evacuation processes, is recognised for each eruption episode.

Despite these differences in magma compositions and ascent histories, two broad magma affinities can be recognised throughout the history of Tarawera. (1) Biotite-bearing magmas that were K_2O-rich, generally more crystal-rich and cooler (<750°C). (2) Crystal-poor orthopyroxene-hornblende magmas with lower K_2O contents and higher temperatures (~760-820°C). All Tarawera magmas plot on the same T-fO_2 buffer trend despite mineralogical differences, indicating a common source or formation processes. However, smaller chemical and physical differences are seen within these affinities.

The differences in eruption and magmatic dynamics for each Tarawera episode mean that attempts to assess the likely geophysical precursors and eruption style for a future rhyolite event will be problematic. However, the association with basaltic intrusion implies this is a common eruption driving mechanism at Tarawera. The 1886 eruption is now recognised as part of a long sequence of sporadic basalt intrusions, but in this latest event no rhyolite magma reservoir was encountered to be remobilised, hence a purely basaltic event occurred.

PAPER

SEISMIC VELOCITY STRUCTURE OF THE TAUPO VOLCANIC ZONE

Steven Sherburn[1], **Martin Reyners**[2], **Donna Eberhart-Phillips**[2], **Stephen Bannister**[2]
[1]GNS Science, Private Bag 2000, Taupo
[2]GNS Science, PO Box 30368, Lower Hutt
(s.sherburn_at_gns.cri.nz)

Previous attempts at earthquake tomography in the Taupo Volcanic Zone (TVZ) have been able to resolve only the upper 10 – 15 km because of a thin (6-7 km) seismogenic zone. We have used the velocity model of Reyners et al. (2006) to fix the deep velocity structure which permits us to use earthquakes originating in the Benioff zone and significantly extend the resolvable depth. Our goals are to obtain images of the depths at which partial melts are believed to interact with crustal rocks, and to look for any differences between andesitic and rhyolitic portions of the TVZ.

We have combined the Reyners et al. (2006) data set, with previous data sets used for earthquake tomography in the TVZ, and with new data from upgraded Geonet seismographs. More than 1,500 earthquakes and several active sources contributed in excess of 50,000 P-arrival times and 20,000 S-P observations, and we have determined Vp and Vp/Vs models for a 110 by 220 km area of the central North Island to a depth of 65 km.

Vp/Vs appears to be more effective than Vp at imaging shallow, poorly consolidated and possibly water saturated, volcanic sediments within the TVZ, while Vp can identify basement rocks bounding the TVZ. As has previously been reported, there is a strong similarity between shallow tomographic images and the residual gravity anomaly data.

We image a thin, but prominent, zone of low (1.65-1.7) Vp/Vs underlying much of the TVZ at a depth of ~10 km. This coincides with a high Vs region seen in velocity profiles derived from receiver function analysis (Bannister et al., submitted).

Using Vp/Vs we can image the partial melt zone at ~50 km depth observed by Reyners et al. (2006). This is particularly noticeable west of Lake Taupo where a tongue with a Vp/Vs of ~1.77 extends to within ~30 km of the surface. A Vp of 7.4 km/s, traditionally considered to represent low velocity mantle beneath the TVZ, is not reached until deeper than 30 km, in agreement with velocity models derived by Harrison and White (2004).

References

Bannister S.; Reyners M.; Stuart G.; Savage M. Imaging the Hikurangi subduction zone using teleseismic receiver functions; results from the CNIPSE experiment. Submitted to GJI.

Harrison AJ; White RS. 2004.Crustal structure of the Taupo Volcanic Zone, New Zealand: Stretching and igneous intrusion. Geophysical Research Letters 31, L13615.

Reyners M; Eberhart-Phillips D; Stuart G; Nishimura Y. 2006. Imaging subduction from trench to 300 km depth beneath the central North Island, New Zealand, with Vp and Vp/Vs. Geophysical Journal International 165: 565-583.

PAPER

DIMINISHING GLACIATIONS OF THE SOUTHERN HEMISPHERE MID-LATITUDES

J. Shulmeister[1], Henrik Rother[2], Glenn D. Thackray[3], Uwe Rieser[4], David J.A. Evans[5], David Fink[2], & Olivia Hyatt[1].

1. Dept. of Geological Sciences, University of Canterbury, Private Bag 4800, Christchurch.
2. Institute for Environmental Research, Australian Nuclear Science and Technology Organisation (ANSTO), PMB 1, Menai, NSW 2234, Australia
3. Department of Geosciences, Idaho State University, Pocatello, ID 83209-8072, USA
4. School of Earth Sciences, Victoria University of Wellington, Post Box 600, Wellington, New Zealand
5. Department of Geography, Durham University, South Road, Durham, DH1 3LE, UK

(James.shulmeister@canterbury.ac.nz)

This paper summarises the evidence from some Canterbury valleys of a significantly greater ice extent during the penultimate glaciation than occurred during the last glacial cycle. We present data from the middle reaches of the Hope and the Rakaia Valleys that demonstrate that extensive suites of glacial and paraglacial deposits relating to OIS 6 or older advances are preserved near the limits of the last glacial maximum ice in these valleys. In the Rangitata, we have no age control, but a similar geometry exists. The valleys appear to have been scoured to at least modern fluvial base-levels by OIS 6 or older advances. In the Rakaia, in particular, evidence exists for extensive lake beds in the base of these troughs. These lakes were over-run by glacial readvances with paraglacial sediments and outwash gravels capping the lake beds. The terminal moraines of the last ice age are perched on the outwash that caps the fill of these scours. The last glaciation advances were either of insufficient mass or duration (or both) to erode the pre-existing glacial sediments in these middle valley reaches.

Similar inferences about the diminishing scale of glaciations have been obtained from Tasmania where the so-called Last Glaciation Maximum (LGM) appears to be little more than a cirque readvance at many sites. It can also be interpreted from records in southern South America. This suggests that the glacial diminution was hemisphere wide, at least in the mid-latitudes.

We hypothesise that changes in orbital forcing (precession) may be responsible and present some insolation data to support this idea. Variation in precessional amplitude (seasonality) and precessional minima (insolation minima) have been invoked to explain New Zealand glaciations. Both models are supported by the available data and higher resolution dating would be required to resolve which, if either, forcer was responsible.

PAPER

PRINCIPAL COMPONENT ANALYSIS AND MODELING OF THE SUBSIDENCE OF THE SHORELINE OF LAKE TAUPO, NEW ZEALAND, 1983-1999: EVIDENCE FOR DE-WATERING OF A MAGMATIC INTRUSION?

Euan G. C. Smith,[1] Timothy D. Williams[1,2], Desmond J. Darby[3]

[1]Institute of Geophysics, Victoria University of Wellington
[2]now at Dept Mathematics and Statistics, University of Otago
[3]GNS Science, Lower Hutt
(euan.smith@vuw.ac.nz)

Principal Component Analysis was applied to a set of relative water level measurements made at 22 sites around Lake Taupo, New Zealand, in 37 surveys during 1986-96. Only a single mode was significantly above noise levels. This mode showed a subsidence of the Lake shore that decayed exponentially with time, with a time constant of about 12 years. The mode was well modelled by a Mogi point dilatation at a depth of 8 ± 1 km located beneath the point with the greatest rate of subsidence, which was about 8.5 ± 1 mm/yr, in the centre of the northern Lake shore. The model implies that the source contracted by 0.02 ± 0.002 km^3 during 1986-96.

Three model parameters, the time constant, the depth and the volume contraction, place constraints on the physical process or processes that caused the contraction and resulting Lake shore subsidence. We infer that magma was intruded into the crust beneath the north shore of the Lake at some time prior to

the start of the Lake shore observations in 1979 and that the contraction was due to water leaving the melt because of decompression. For this to work the water must diffuse quickly away from the source, and we accordingly infer that the permeability of the overlying crust must be 10^{-15} m^2 or greater. To match the observed source contraction, and assuming a 1% by weight fluid loss, the magma would have to have contained about 2.5 km^3 or more of melt.

POSTER

PRELIMINARY HAZARD IMPACT ZONES FOR THE NEXT NGAURUHOE ERUPTION

RT Smith[1], **BJ Scott**[2a], **BJ Hobden**[1], **G Leonard**[2b]
[1]Department of Earth and Ocean Sciences, University of Waikato, Hamilton 3240
[2]GNS Science Wairakei[a] and Lower Hutt[b]
(rtsmith@waikato.ac.nz)

The recent seismic unrest at Ngauruhoe highlights the importance of addressing hazard scenarios for renewed volcanic activity at Ngauruhoe. Historically, Ngauruhoe has been New Zealand's most regularly active volcano (c. 60 events since 1839). Significant eruptions in 1870, 1949, 1954, 1974 and 1975 involved multiple lava flows, summit scoria cone construction, low energy pyroclastic flows, ballistic projectiles and widespread ash fall. The interval since February 1975 is the longest repose period on record for Ngauruhoe. There was minor seismic activity in 1983, 1991, 1994 and 1995, but no associated surface changes or eruptions. Given the relatively short historical observation period (only 6% of Ngauruhoe's 2500 year lifespan), and poorly resolved geological record of frequent low magnitude events, data are insufficient to establish the significance of the current unrest.

In addressing this issue, we are developing preliminary hazard maps and impact scenarios for Ngauruhoe based on the magnitude and style of historic activity as well as the recent geological record, in an attempt to define zones that have an objective and geologically reasonable basis. For instance, to quantify lava flow and pyroclastic flow hazards we have calculated the length dimensions of all individual flows with a surface expression. The highest lava hazard zone (within 2 km of vent) corresponds to the area impacted by 80% of all lava flows (81 historic and prehistoric).

Maximum direct impacts from pyroclastic flows (from fountain collapse and spatter/scoria rampart collapse) are likely to be similar to the inner lava flow hazard zone. However, transport directions of pyroclastic flows may be more variable than lava flows, due to the influence of plume dynamics and wind direction. More widespread hazards are associated with ash clouds generated by pyroclastic flows and avalanches.

Distal ash fall is expected to have the greatest social and economic impacts during the next explosive Ngauruhoe eruption. In the 1975 Ngauruhoe eruptions several cm of ash accumulated within a few km of vent, and light falls were experienced throughout much of the central North Island, as far away as Hamilton and Tauranga (165 km from vent).

The hazard impact maps presented are preliminary only, and feedback and contributions are encouraged.

The next Ngauruhoe eruption will be a significant media event due to: 1) considerable curiosity from people who have never witnessed Ngauruhoe in eruption; 2) ease of volcano access enabling potentially close observation of hazardous activity (creating access management issues for DOC); and 3) the high likelihood of eruption of lava flows, a spectacle not seen in New Zealand in the last 50 years.

POSTER

FURTHER INSIGHTS INTO PRE-ERUPTION PROCESSES AT TARAWERA, OKATAINA VOLCANIC CENTRE, USING MELT INCLUSIONS

V.C. Smith[1], **I.A. Nairn**[2] **&** **P. Shane**[3]
[1] Dept. of Earth Sciences, Univeristy of Bristol, Queen's Road, Bristol BS8 1 RJ, UK.
[2] 45 Summit Road, Rotorua RD5 & GNS Science, Wairakei Research Centre, Taupo.
[3] Dept. of Geology, The University of Auckland, Private Bag 92019, Auckland.
(pa.shane@auckland.ac.nz)

Tarawera is a fairly unique rhyolite volcano with eruptions from a linear chain of vents. Three of the four eruption episodes (21.4 ka Okareka, 17.7 ka Rerewhakaaitu, 13.8 ka Waiohau, & ~AD1315 Kaharoa) have tapped multiple distinct rhyolite batches and were primed by basalt intrusion. The distinct rhyolite magmas were generally erupted sequentially from multiple vents; however, some were erupted simultaneously. Mingled clasts are observed in some of the deposits, but there is very little hybrid ejecta, suggesting that any contact between the magmas was mostly short-lived.

New trace element and volatile data from quartz-hosted melt inclusions provides new insights to pre-eruption rhyolite magma processes and storage at Tarawera. Previously, little was known about volatile abundances in these magmas. In general, H_2O contents range from 0.7 to 5.4 wt% and CO_2 concentrations range from 50-660 ppm. Some of the magmas appear to have been water saturated at deep levels with crystallisation occurring in response to ascent driven decompression. Whereas, others appear to have mostly crystallised under isobaric conditions in the shallow crust. Average saturation pressures of 100 MPa (~4 km) were estimated using H_2O and CO_2 content. These pressures agree with crystallisation closure pressures, estimated by projecting major matrix glass compositions onto a synthetic Qz-Al-Or- H_2O system, using the method of Blundy & Cashman (2001).

Most differences between the trace element composition of the melt inclusions and the associated matrix glass are associated with crystallisation of the phases present. However, some variations do not appear to be associated with crystallisation, and most likely reflect different processes (e.g., magma mixing). The different trace element compositions and trends of the magmas produced during each eruption episode provide evidence against deriving all the compositions via fractional crystallisation. However, the trace element compositions are broadly similar between the magmas suggesting that they were produced from the same large silicic mush. It is likely that each melt was generated separately from the mush, which at different times had experienced differing degrees of melting or crystallisation.

Blundy, J., & Cashman, K.V. 2001. Contrib Mineral Petrol, 140: 631-650.

PAPER

PUPUKE; ONE VOLCANO OR THREE?

S.R.W. Spargo, I.E.M. Smith and C.J.N Wilson
[1]Department of Geology, University of Auckland, PB 92019, Auckland, 1142
s.spargo@auckland.ac.nz

Pupuke is the northern most volcano within the Auckland Volcanic Field (AVF). The explosive basaltic centre consists of a 1.1 km^2 maar, created through the eruption of ~0.043 km^3 of pyroclastic deposits and lava flows. Pupuke is thought to be one of the oldest centres in the AVF. Sparse exposures reveal a sequence of lower lavas (LL), lower pyroclastics (LP), upper lavas (UL) and upper pyroclastics (UP) (Fig. 1). Geochemical analyses show there to be three distinct compositions erupted from Pupuke. Correlations can be made between these three magma types (groups 1 to 3) and their location in space and time within the Pupuke volcanic centre.

The lower lavas belong to group 1 (Fig. 2) where they outcrop on the SW side of Lake Pupuke, and to group 2 where they are exposed on the SE side of the lake. In contrast, the upper lavas belong to group 3, where present in lake shoreline and coastal platform exposures and drill cores on the SE, E and N sides of the volcano (Fig. 1). There is no evidence of any hiatus, suggesting that these three magma compositions were erupted in quick succession from the volcano. The identification of multiple batches of magma being deposited from a single volcanic centre is very rare within AVF. The geochemistry of Pupuke offers further unique insights into the petrological evolution of intraplate volcanism with the identification and interpretation of distinct geochemical trends within the individual lava groups. For example, group 1 lavas form distinct clusters of samples with consistent Mg#, but have three distinct zirconium abundances. In contrast, group 2 and 3 lavas form a negative linear trend of reducing Mg# with increasing zirconium (Fig 2). The discovery that multiple magma batches have erupted in such close spatial and temporal proximity, and the recognition that these individual magma batches show distinct evolutionary trends provides valuable new insights into the intricate nature of the AVF and challenges the simplified monogenetic model for the field.

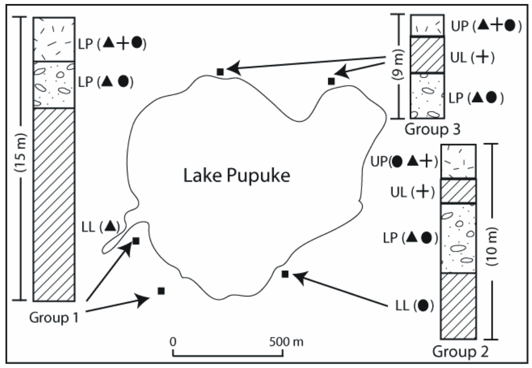


Figure 1

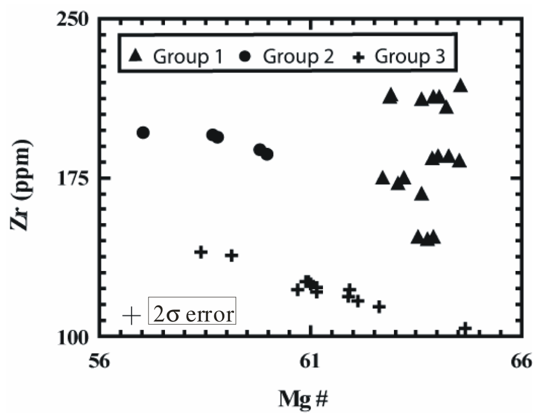


Figure 2

POSTER

UPPER CRUSTAL STRUCTURE OF THE TARANAKI FAULT IMAGED BY A MAGNETOTELLURIC SURVEY

V.M. Stagpoole[1] S.L. Bennie[1], H.M. Bibby[1], M.R. Ingham[2], S Dravitzki[2]
[1]GNS Sciences, Lower Hutt, New Zealand
[2]Victoria University, Wellington, New Zealand.
(v.stagpoole@gns.cri.nz)

The Taranaki Fault, located along the west coast of New Zealand's North Island, is one of the largest known thrust faults in New Zealand. Although the fault has no surface exposure, interpretations of seismic reflection data suggest that along most of its length there is typically more than 6 km of vertical displacement. Activity on the fault (mostly prior to the Pliocene) has resulted in Mesozoic metamorphic greywacke being thusted westward over Cretaceous and Cenozoic sediments in the Taranaki basin. Most of our knowledge of the faults structure has come from petroleum exploration seismic and gravity surveys, but there is considerable uncertainty about the structure beneath the hanging wall and at greater depths. To provide new information about the fault, particularly it's deeper structure, a pilot magnetotelluric (MT) consisting of 13 broadband soundings was made across the Taranaki Fault in a east-west oriented line. The line was chosen to pass close to drill holes that provided estimates of both basement depths and electrical properties from down-hole logs. In this area extensive use is made of electric fences, so the survey also tested the viability of the method in the presence of coherent electrical noise.

Phase tensor analysis of the MT data shows that upper 1 – 2 km of sediment are characterised by 1D resistivity structure and overly a 2D section with one principal axis parallel to the strike of the fault. 2D models successfully track the change in resistivity associated with the basement rocks and show an increase in thickness of the low resistivity sediments from 2-3 km on the east to more than 5 km on the west of the fault.

When bore-hole resistivity data are used as constraints in modelling the structure of the fault becomes more apparent, with models predicting sediments extend eastward beneath the tip of the fault. At depth the resistivity contrast in basement rocks between east and west outlines a discontinuity that when projected to the surface matches the near surface fault location and dip defined by seismic and well data. The resistivity contrast in basement rocks suggests there is a fundamental change in basement rock types at the fault and that it probably marks a terrane boundary.

POSTER

CRUST AND UPPER MANTLE STRUCTURE RESEARCH, CENTRAL NORTH ISLAND: A SUMMARY OF RECENT RESULTS FROM THE INSTITUTE OF GEOPHYSICS(VUW)

Staff and students of the Institute of Geophysics, Victoria University.

The Institute of Geophysics at Victoria University has had a strong focus on the central North Island since the inception of the Institute in 1967. Initial work was focussed around the geothermal fields and included heat flow measurements in lakes, the first micro-earthquake surveys to be carried out in New Zealand and some of the first measurements of geodetic strain in the North Island. More recent work includes seismic anisotropy of the crust and upper mantle, and both passive and active source studies of crustal structure. As well as the Taupo region members of the Institute have carried out work in the Wanganui, Taranaki and Galatea Basins, and just recently have put together a geophysical profile from Raurimu south to Wanganui down the Para Para Rd. Highlights of this research include:

- Strong contrasts in seismic anisotropy across the central North Island.
- Mapping of unusually thin crust (~ 20 km) underlain by low wave-speed upper mantle beneath the wedge shaped Central Volcanic Region.
- Documentation of thin (25-27 km) crust over much of the western North Island and right up into Northland.
- Confirmation of a pervasive low Pn wave-speeds beneath the central North Island.
- A sharp change in crustal and mantle-lithosphere thickness at the west-east Taranaki-Ruapehu line.
- Evidence for viscous thickening of the crust beneath Wanganui basin to form some of the thickest crust in New Zealand.
- Geophysical evidence for missing mantle lithosphere for much of the central and western North Island, and as far south as the Taranaki-Ruapehu line.
- Evidence for changes in crustal seismic anisotropy and attenuation associated with the 1995 eruption of Mt Ruapehu.
- Development of kinematic and dynamic models to describe the evolution of the central North Island through time.

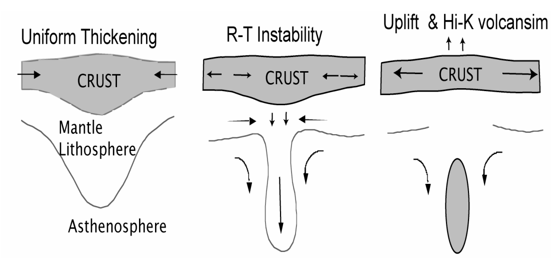
PAPER

UPLIFT OF THE WESTERN-CENTRAL NORTH ISLAND DUE TO CONVECTIVE REMOVAL OF UPPER MANTLE AND LOWER CRUST.

T.A. Stern, W.R. Stratford, M.L. Salmon
Institute of Geophysics, Victoria University of Wellington.
tim.stern@vuw.ac.nz

Rapid and regional rock uplift of up to 2.5 km started at ~ 5 Ma within central and western North Island. Associated with the uplifted region are geophysical evidence for removed mantle lithosphere and lower crust, onshore (Pliocene) high-K volcanism, offshore (Miocene) extension and volcanism, and ~ 600 km-deep earthquakes. An abrupt termination of these phenomena at the west-east Taranaki-Ruapehu (T-R) line is marked by ~ 5-10 km step in the Moho, a jump in seismic attenuation (Qp^{-1}) values from 500 to >1000, and a steep 1 mgal/km ramp in the isostatic gravity field. These seemingly unrelated observations can be accounted for by a time-progressive, north to south, growth then detachment of thickened mantle lithosphere and lower crust, beneath western North Island. As continental lithosphere shortens mantle lithosphere must also thicken and, providing some boundary conditions are met, form a Rayleigh-Taylor instability (see figure). The requisite thickening for a Rayleigh-Taylor instability occurred during the Miocene beneath the Taranaki Fault Zone; 70 ± 30 km of shortening is estimated on the basis of restored deep seismic reflection sections. For the convergence rate and lithospheric thickness appropriate for New Zealand in the Miocene we use finite element models to show that a viscous Rayleigh-Taylor instability could have formed and detached within 15-20 My. If tectonics of the western North Island in the Pliocene are controlled by Miocene Rayleigh-Taylor instabilities there are several important predictions:

1. Lack of back-arc extension south of the T-R line is ascribed to the time delay (10-20 My) inherent in the full development then detachment of a mantle instability.
2. Pliocene down-warping in Wanganui Basin through to the Marlborough Sounds is driven, at least in part, by thickening of the mantle lithosphere.
3. Hi-K, Pliocene, volcanism of the Waikato and Taranaki may be unrelated to present subduction, but rather due to the rapid removal of a Rayleigh-Taylor instability then remelting of metasomatised mantle that had been trapped in the upper mantle or lower crust (as argued for Western USA and elsewhere).



PAPER

ACTIVE RIFTING IN THE CENTRAL VOLCANIC REGION, NORTH ISLAND, NEW ZEALAND

W.R. Stratford & T. A. Stern
School of Earth Sciences, Victoria University of Wellington, PO Box 600, Wellington.
(wanda.stratford@vuw.ac.nz)

Active back-arc rifting in the Central Volcanic Region (CVR) of North Island, New Zealand has thinned the crust and perturbed the upper mantle. This perturbation is manifest at the surface in extreme heat output, high rates of extension and rhyolite eruptions rates that are some of the highest in the world. The CVR provides a rare opportunity to study back-arc extension in continental crust and to make comparisons to other regions, and tectonic settings, of crustal extension. High effective heat

flow, ~13 times the continental average, suggests a significant portion of the crust in the CVR consists of intrusions in various states of cooling. Overall, the extension rates and heat output are up to an order of magnitude higher than for continental rifts (such as Kenya Rift) and the underlying process is clearly more than just a passive stretching of pre-existing continental crust. Key to understanding the extreme thermal and kinematic observations of the CVR is knowledge of the structure of the lithosphere in the back-arc. Interpretations from refraction and wide-angle reflection seismic data provide evidence for a magmatic underplate, with 6.8 km/s velocities, starting at ~15 km depth. Velocities then increase with depth to mantle Pn velocities of 7.4 ± 0.2 km/s at 20 ± 2 km depth. These 7.4 km/s velocities are interpreted as anomalous upper mantle as beneath this level passive seismic studies show similar Pn velocities that increase slowly to ~7.8 km/s at ~80 km depth. Despite the extremely thin crust of the CVR, the region is elevated above sea level. Buoyant support for the thin crust from a mantle density anomaly of -66 kg/m^3, with respect to a normal mantle lid, is inferred from rock-uplift studies. This density anomaly, combined with Pn velocities that are 8% less than regular mantle, implies the mantle lid here may have been completely removed. Likewise, lower Pn wave speeds are observed, and partly missing mantle lid is required, west of the CVR in the Waikato and eastern Taranaki. Thus a key factor in explaining high heat output, and extension rates, at least in the CVR, is that the mantle lithosphere is absent and the hot (~1000^{o}C), (wet) asthenosphere could be at depths as shallow as 20 km. Some of this heat will be transferred to the surface via a magmatic plumbing system. Crustal magma bodies, however, have yet to be found. Direct evidence for melt bodies in the upper mantle comes from strong reflections at ~34 km depth, from an interface directly beneath the volcanically, and geothermally, active eastern side of the CVR. On the basis of reflection amplitudes, the mantle reflections are most readily explained by an interface with a 30-70% drop in S-wave speed compared to the surrounding mantle. A ~16 km wide layer of ~4-9% partial melt is inferred to be the source of the reflections. These interpretations highlight the degree the CVR's crust and upper mantle have been altered by extension and volcanism and point towards possible reasons for the high heat flow and volcanic activity of the back-arc.

PAPER

DO GREAT EARTHQUAKES OCCUR ON THE ALPINE FAULT IN CENTRAL SOUTH ISLAND, NEW ZEALAND?

<u>R. Sutherland</u>[1], D. Eberhart-Phillips[2], R.A. Harris[3], T. Stern[4], J. Beavan[1], S. Ellis[1], S. Henrys[1], S. Cox[2], R.J. Norris[5], K.R. Berryman[1], J. Townend[4], S. Bannister[1], J. Pettinga[6], B. Leitner[1], L. Wallace[1], T.A. Little[4], A.F. Cooper[5], M. Yetton[7], M. Stirling[1].

[1.] GNS Science, 1 Fairway Drive, PO Box 30-368, Lower Hutt, NZ.
[2.] GNS Science, Private Bag 1930, Dunedin, NZ.
[3.] U.S. Geological Survey, Menlo Park, CA 94025-3591, USA.
[4.] Victoria University of Wellington, PO Box 600, Wellington, NZ.
[5.] University of Otago, PO Box 56, Dunedin, NZ.
[6.] University of Canterbury, Private Bag 4800, Christchurch 8020, NZ.
[7.] Geotech Consulting, RD1 Charteris Bay, Lyttelton R.D., NZ.

Geological observations require that episodic slip on the Alpine fault averages to a long-term displacement rate of 2-3 cm/yr. Patterns of seismicity and geodetic strain suggest the fault is locked above a depth of 6-12 km and will probably fail during an earthquake. High pore-fluid pressures in the deeper fault zone are inferred from low seismic P-wave velocity and high electrical conductivity in central South Island, and may limit the seismogenic zone east of the Alpine fault to depths as shallow as 6 km. A simplified dynamic rupture model suggests an episode of aseismic slip at depth may not inhibit later propagation of a fully developed earthquake rupture. Although it is difficult to resolve surface displacement during an ancient earthquake from displacements that occurred in the months and years that immediately surround the event, sufficient data exist to evaluate the extent of the last three Alpine fault ruptures: the 1717 AD event is inferred to have ruptured a 300-500 km length of fault; the 1620 AD event ruptured 200-300 km; and the 1430 AD event ruptured 350-600 km. The geologically estimated moment magnitudes are 7.9 ± 0.3, 7.6 ± 0.3, and 7.9 ± 0.4, respectively. We conclude that large earthquakes (M_w >7) on the Alpine fault will almost certainly occur in future, and it is realistic to expect some great earthquakes ($M_w \geq 8$).

(Full paper accepted for publication in a forthcoming AGU *Geophysical Monograph* about South Island).

POSTER

Nd-Sr ISOTOPIC AND TRACE ELEMENT CONSTRAINTS ON THE ORIGIN OF LATE PLEISTOCENE BARAMBAH BASALTS, NORTHERN NEW ENGLAND FOLD BELT, AUSTRALIA

Reddy V. R. Talusani
Division of Earth Sciences, The University of New England, NSW 2351, Australia.
(vtalusan@hotmail.com)

Post-subduction intraplate basic volcanism is widespread in the New England Fold Belt forming basalt plateaus associated with extensional rifts. Although widely dispersed the activity shares common source isotopic characteristics (Sun et al., 1989; O'Reilly and Zhang, 1995). In southeast Queensland, the Late Pleistocene Barambah basalts occur east and northeast of Gayndah. These basalts are classified into alkali basalts, basanites and Hawaiites. A detailed study of petrogeneses of these late Pleistocene basalts may increase our understanding of the closing stage in the evolution of the New England Fold Belt.

The geochemistry of Barambah basalts provides important constraints on the petrogenesis of continental alkali basalts. The Barambah basalts have a large range of initial $^{87}Sr/^{86}Sr$ (0.703764 – 0.705465) and $^{143}Nd/^{144}Nd$ (0.512921 – 0.512683) ratios and are characterized by OIB-type trace element patterns with significant enrichment in incompatible elements. An enriched mantle component is required to explain the enriched character. A strong light vs heavy rare earth element enrichment is indicative of relatively low percent of partial melting of mantle source.

The Barambah basalts were likely derived from an enriched and heterogeneous mantle source, having a dominant OIB-type component. The isotopic and trace element ratios of these basalts are best explained by modification of a OIB-type source by a fluid and partial melt of subducted continental material.

References

Sun, S.-s., McDonough, W. F. and Ewart, A. (1989). Four component dynamic model for East Australian basalts. In: Johnson, R. W. (ed.) Intraplate Volcanism in Eastern Australia and New Zealand. Cambridge: Cambridge University Press, pp. 333-347.

O'Reilly, S. Y. and Zhang, M. (1995). Geochemical characteristics of lava-field basalts from eastern Australia and inferred sources: connections with the subcontinental lithospheric mantle. Contributions to Mineralogy and Petrology 121, 148-170.

POSTER

MAGNETOSTRATIGRAPHY OF PLIOCENE MARINE CYCLICITY, PENINSULA OF MEJILLONES, NORTHERN CHILE

C. Tapia[1], G. Wilson[1], S. Ishman[2] & H. Wilke[3]
[1]Department of Geology, University of Otago, PO Box 56, Dunedin, New Zealand
[2] Department of Geology, Southern Illinois University, Carbondale, IL, USA
[3] Departamento de Ciencias Geológicas, Universidad Católica del Norte, Chile
(tapcl295@student.otago.ac.nz)

We report paleomagnetic results for 18 sites from a 36 m, Pliocene section of marine cyclothems exposed in the Tiburon Basin, central part of Mejillones Peninsula, II Region of northern Chile. Remanent magnetization consists of three components: (1) a low (<150ºC) blocking temperature (Tb) component that is interpreted to be a recent thermo viscous component, usually close to the present day field in direction; (2) an intermediate (150-290ºC) Tb component, which is thought to be all that remains of the primary detrital magnetization; and (3) a high (>290ºC) Tb component that is considered to be diagenetic in origin. Paleomagnetic directions define 6 polarity intervals in the Tiburon basin succession. ^{40}Ar-^{39}Ar dating of two ash layers supports the correlation of this magnetostratigraphy with chrons C2An.3n, C2An.2n and C2An.1n of the geomagnetic polarity timescale [1]. Combined with cyclostratigraphic analysis, this new age model identifies a temporal switch of periodicity in sea level controlled sedimentary cycles, from ~24 ky to ~41 ky at 3 Ma ago.

[1] Cande, S. C., and D. V. Kent (1995), Revised calibration of the geomagnetic polarity timescale for the Late Cretaceous and Cenozoic, J. Geophys. Res., 100(B4), 6093–6096.

PAPER

THE WHANGAEHU FORMATION: A MASSIVE DEBRIS-AVALANCHE FROM ANCESTRAL RUAPEHU?

J.-C. Thouret*, J.A. Lecointre, V.E. Neall**, S.J. Cronin**, R.C. Wallace****
*Laboratoire Magmas et Volcans, UMR 6524 CNRS, OPGC et IRD,
Université Blaise Pascal, Clermont-Ferrand, France (thouret@opgc.univ-bpclermont.fr)
** Soil and Earth Sciences Group, Institute of Natural Resources,
Massey University, Palmerston North, New Zealand (J.A.Lecointre@massey.ac.nz)

A new collaborative research project between Massey University and Université Blaise Pascal has been initiated on the late Pleistocene volcaniclastic deposits covering parts of Mt. Ruapehu's southern ring plain. Since deposits associated with early periods of volcanic activity are not exposed on the volcanic cone, the Whangaehu Formation, a succession of andesitic lahar and debris-avalanche deposits interbedded with fluvial deposits, provides a critical record, preserved in the middle reaches of the Whangaehu River valley.

The stratigraphy consists of three principal units totalling 20 to 70 m in thickness: (1) a lower massive unit of un-graded, indurated breccia, 10 to 30 m thick, containing coarse subangular cobble and outsized boulders; (2) a 5 to 20 m-thick middle unit comprising crudely stratified beds of clast-supported debris-flow and hyperconcentrated-flow deposits; (3) a 5 to 20 m-thick sequence of fluvial gravel, hyperconcentrated-flow deposits, and some debris-flow deposits intercalated with layers of reworked sand, silt, and pumices. The Formation is capped by 5 to 8 m-thick, weathered hyperconcentrated-flow deposits and soils in ash and loess. The basal surface of the Formation shows an erosive and often sheared contact.

Initially, the "Whangaehu valley-fill" was interpreted as the result of a climate-driven process of aggradation during a glacial period (Fleming, 1953). Following work conducted by Hodgson (1993), we argue that at least the lower unit of the Whangaehu Formation was emplaced as a catastrophic volcanic debris avalanche at distances > 40 km from a Ruapehu source. The lowermost un-graded, megaclast-rich breccia shows large-scale sedimentary features suggesting the deposit was stacking against ramp-like structures from NNE to SSW. Oblique to sub-horizontal fractures indicate that shearing occurred at the base of the coarse, clast-supported breccia, which contains abundant rip-up clasts from the underlying Tertiary siltstones. An indurated and sheared clast mixture of angular to subangular cobbles and pebbles supports large boulders; the densely crushed material mimics a fine grained, indurated matrix surrounding boulders at the base of the breccia, where the fracture pattern is concentrated. Gravel and small clasts have been segregated to form vertical pipe-like features. Pockets of densely fragmented clasts and boulders showing jigsaw fractures suggest collision effects during transportation from source.

Pumice deposits found in and near the base of the debris avalanche deposits, within the middle reaches of the Whangaehu River, will be used for ^{40}Ar-^{39}Ar dating. These pumices have no known correlative closer to source. An age range of c. 140 to 180 ka is expected for the emplacement of the ≤ 1 km^3 Whangaehu Formation (Hodgson, 1993), based on dated uplifted marine terraces exposed in the coastal region 160 km from source (Fleming, 1953; Pillans, 1988) and cover beds identified at key sections in the middle reaches of the valley.

In summary, the debris-avalanche deposit points to the instability of the south flank of Ruapehu in late Pleistocene times, followed by a massive aggradation on the adjacent southern ring plain. The middle sequence suggests reworking of the debris-avalanche deposits interspersed with lahar deposits, which may represent the effects of eruptions on the ringplain of ancestral Ruapehu. Only the upper unit reflects an aggradation phase on the volcaniclastic ringplain, interspersed with minor volcanic activity on the cone, as shown by reworked tephra deposits. Deposits contemporary with this Formation also crop out in catchments located east-southeast and northwest of the Whangaehu River c.60 km away from Ruapehu's summit. In the current context, such large magnitude, catastrophic sector collapses would represent a significant hazard to the populated Ohakune-Waiouru areas.

POSTER

MAGNETIC BEHAVIOUR OF PALEOGENE SEDIMENTS IN THE CANTERBURY BASIN

K. Tinto & G.S. Wilson
Geology Department, University of Otago, PO Box 56, Dunedin, NZ
(kirsty.tinto@stonebow.otago.ac.nz)

Results are presented from two paleomagnetic studies from Canterbury basin, at Otaio Gorge and the mouth of the Kakanui River. Samples were collected in order to establish an age model for the sections that can be used in an investigation of the mid-Oligocene unconformity known as the Marshall Paraconformity.

A wide variation in lithology and magnetic behaviour is observed both within and between the studied sections. The aim of the analyses has been to identify the orientation of the characteristic magnetisation of the sediments and to explain the origin of other components of magnetisation observed in the demagnetisation data.

In the Kakanui River section this has involved remagnetisation great circle analyses and investigation into displaced origins of characteristic remanance directions on orthogonal component plots. This is due to the presence of high temperature, secondary components of magnetisation that are not removed during heating.

The Otaio Gorge section shows wider lithological variation and this study attempts to correlate the variation in magnetic behaviour with variations in lithology. Lithological variables (grainsize and mineral content) have been plotted against magnetic variables (susceptibility, intensity and behavioural group) on a log of the section. Observed correlations are discussed in terms of the depositional conditions associated with behavioural groups.

These analyses show some of the magnetic behaviour to be found in the Canterbury Basin and indicate the appropriateness of different techniques for their interpretation.

PAPER

DEVELOPING AN ON-LINE ATLAS OF NEW ZEALAND FOSSIL POLLEN TYPES, WITH AN INTEGRATED POLLEN IDENTIFICATION GUIDE TO ASSIST NOVICE PALYNOLOGISTS.

Arthur Todd[1], Kevin Butler [1], Elisabeth Todd[2], Elizabeth Kemp[2] and John R. Flenley[1]
[1] School of People, Environment and Planning, Massey University.
[2] Institute of Information Sciences and Technology, Massey University.
(A.Todd@massey.ac.nz, and K.Butler@massey.ac.nz)

Fossil pollen and spores have been used extensively in New Zealand as an indicator of temporal change in the structure and composition of vegetation, and by inference environmental change. Pre-historic indigenous vegetation patterns, Holocene climate change, the date of Maori colonisation, Maori and European forest clearance, Maori and takahe dietary patterns, the origins of New Zealand coal measures and the destruction of forest vegetation at the Cretaceous-Tertiary boundary are some of the areas that have been investigated in New Zealand using fossil pollen.

Identifying and counting pollen and spores from samples taken from lake, swamp and marine cores is a time-consuming and exacting process, requiring considerable domain expertise. Fossil pollen grains may be damaged or altered during transport, preservation in sediments, or by preparation processes, e.g. acetolysis, in the pollen lab. Novice palynologists require extensive assistance while developing their own skills at recognising palynomorphs. The majority of published pollen identification aids and most existing on-line pollen databases classify pollen types by plant families and genera rather than visible pollen grain features, making them unsuitable for use by novice palynologists without extensive botanical knowledge. Many of the images in published and on-line aids are from scanning electron microscopes, whereas our students use only light microscopes.

We recognised that a web-based atlas of common New Zealand indigenous pollen types, containing both polar and equatorial views of each taxon, and accompanied by a simple interactive pollen identification tool based on the classification keys commonly used in New Zealand, would be a particularly useful teaching aid. A prototype has been developed using the open-source software tools XHTML, PHP and the MySQL database, and is served from an Apache web server accessible from within the Massey University LAN. High resolution light microscope images and data are currently being loaded into the system to enable it to be evaluated as a teaching aid by both staff and students working in the palynology lab of the Geography Programme at Massey University.

In this paper we report our experiences in developing and evaluating this system, and indicate possible future developments, including possible extensions to the system to enhance student learning.

PAPER

TIME, DISTANCE AND MAGNITUDE DEPENDENCE OF FORESHOCKS IN NEW ZEALAND

T. Tormann[1,2], M. K. Savage[1], M. W. Stirling[3], A. Christophersen[2], and J. Zhuang[4]
1. Institute of Geophysics, Victoria University of Wellington, Box 600
2. ETH, Zurich, Switzerland
3 GNS Science, PO Box 30368, Lower Hutt
4. Department of Earth and Space Science, University of California, Los Angeles., USA
Martha.Savage@vuw.ac.nz

The possibility that a moderate earthquake may be followed by a larger one (termed the foreshock probability) can increase the hazard in its immediate vicinity for a short time by an order of magnitude or more. Thus, foreshock probabilities are of increasing interest for the development of time dependent seismic hazard forecasts. We examine how the probabilities for future larger events vary with increasing time and distance from the potential foreshock and with the magnitudes of the potential foreshock and mainshock, separating the NZ earthquake catalogue into events within and outside of the Taupo Volcanic Zone (TVZ). We use events with magnitude ≥3.8 and shallower than 40 km that are not aftershocks and that occurred between 1964 and 2003. We find that (1) foreshock probabilities are independent of the foreshock magnitude but depend on the difference δm between the foreshock and mainshock magnitudes, (2) foreshock probabilities decrease with increasing inter event time t as $1/t^p$ (modified Omori's law) with p significantly larger than one (p is 2.4±0.5 in the TVZ and 1.6±0.2 elsewhere), (3) foreshock probabilities decrease with increasing epicentral distance as $1/r^{rexp}$ with rexp of 2.7±0.2 (non-TVZ) and 3.6±0.2 (TVZ) and (4) the mainshock magnitude distribution follows the Gutenberg-Richter relationship, $M \sim 10^{-b}$, with b = 1.3 ±0.2 (all regions), slightly higher than normal b-value. Thus, the probability that a mainshock with magnitude Mfs+δm will occur at time t after and distance r from a potential foreshock of magnitude Mfs is $P * 10^{(-b*\delta m)} * 1/(t+c)^p * 10^{rexp}/r^{rexp}$. P is 0.0375 (TVZ), 0.0049 (non-TVZ), and c is 0.001 to 0.005.

The behaviour of these foreshock probabilities with time and distance differs from the behaviour of aftershocks, suggesting that there may be a different triggering mechanism for foreshocks than for aftershocks.

Preliminary probabilities determined with the same computer codes but on a synthetic catalogue matched to the New Zealand catalogue under the assumption that aftershocks and foreshocks obey the same triggering mechanisms are much larger. They also decay at different rates as a function of magnitude, distance and time, consistent with the suggestion that aftershocks behave differently than foreshocks.

PAPER

THE GEOPHYSICAL EXPLORATION OF A TRANSTENSIONAL BASIN: GALATEA BASIN, EASTERN NORTH ISLAND

S.J. Toulmin[1,2] & T.A. Stern[1]
[1]Institute of Geophysics, Victoria University of Wellington, PO Box 600, Wellington.
[2]now at GNS Science, PO Box 30-368, Lower Hutt, Wellington.
(s.toulmin@gns.cri.nz)

Regions subjected to transtension or transpression often develop complex geological structures. Such regions can evolve at a global scale (triple junctions, microplates), regional scale (transitional zones between different tectonic regimes, for example, between the strike-slip zone of the North Island Dextral Fault Belt, and the extensional Central Volcanic Region of the North Island, New Zealand) or local scale (on releasing or restraining bends or steps on strike-slip faults).

The Bouguer gravity anomaly map of the North Island, New Zealand, depicts a -20 mGal anomaly located over the Galatea Basin, which is in the transitional tectonic zone between the strike-slip North Island Dextral Fault Belt (NIDFB) and the extensional Central Volcanic Region (CVR). The anomaly is also located at a releasing bend on the Te Whaiti strike-slip fault .

New seismic reflection, seismic refraction and gravity measurements across the Bouguer anomalyhave revealed a basin reaching depths greater than 3000 m. Basin infill is interpreted to be 900 m of interbedded Pleistocene volcanic and lacustrine sediments mantling 2000 ± 200 m of Tertiary sediments. Displacement on the Te Whaiti Fault Zone is interpreted to be partitioned on to at least two strands. Te Whaiti A, coincident with the prominent fault scarp and Ikawhenua range front, dips 45° W and is dominantly normal. The subsurface Te Whaiti B fault dips 80 ± 10° W and is interpreted to have behaved as both a dip-slip and strike-slip fault throughout its history. Basin structure is similar to that of pull-apart basins such as the Dead Sea pull-apart and Hamner Basin (New Zealand), suggesting a transtensional evolution in the Galatea Basin.

A thick sequence of sediments preserved in the transitional tectonic region of the North Island is significant for several reasons. It potentially records the extensional deformation of the surrounding region – possibly the key to unravelling the extensional history of the CVR. It also records the relationship between rifting and strike-slip, leading to a better understanding of how the tectonic environments have interacted through time.

POSTER

QMAP TARANAKI PROGRESS -2006

Dougal Townsend
GNS Science, Box 30368 Lower Hutt
d.townsend@gns.cri.nz

The 1:250 000 scale geological map 7 (QMAP Taranaki) spans the region between Urenui in the north, Whakapapa Village in the east, and Feilding in the south. It includes the western half of Mt Ruapehu in the east, Mt Taranaki/Egmont in the west and the Wanganui/southern King Country basins in between.

The variable nature of the topography and geology within this area requires a varied approach to field mapping. However, the mainstay of the mapping approach is the interpretation of aerial photographs, of varying scales, as a basis for the assessment and classification of landscapes. Photographs are interpreted using a stereoscope, are scaled and compiled at 1:50 000 scale onto transparent overlays printed with topographic data. Where possible, aerial photograph interpretation sheets are compared and incorporated with existing field mapping. In areas with no extant mapping, QMAP staff undertake fieldwork and “fill in the gaps” to create a “record sheet” with all of the available geology for the region. Line-work on record sheets is then simplified for reduction to 1: 250 000 scale and digitised at 1:50 000 scale.

Several improvements have resulted from the interpretation and mapping process so far. In the south of the Taranaki QMAP sheet, a region which is dominated by variably deformed Late Quaternary marine and fluvial terraces, some new unit boundaries have been resolved. This has improved our understanding of Quaternary landscape evolution in this area, in particular the interplay between marine-dominated and fluvial-dominated coastal systems (See Palmer et al. this issue; fieldtrip guide).

Linkage of some stratigraphic units across the central part of the Taranaki basin has been achieved by the mapping of shellbed/sandstone marker horizons within thick Neogene siltstone and mudstone units. This has required a large amount of ground-truthing and correlation with existing mapping.

New active faults have been recognised in western Taranaki and the traces of other known faults have been extended (e.g. the Oaonui Fault now has a mapped length of over 13 km, c. 3.5 km longer than previously mapped). This has important implications for Taranaki lifelines such as roading, power and gas pipelines. Other hazard implications arise for these NE-SW striking faults: do they join with structures mapped offshore and are they big enough to generate severe ground-shaking conditions that may conceivably result in catastrophic sector collapse of Mt Taranaki/Egmont?

More detailed work is required to address specific questions, but the usefulness of aerial photograph interpretation as the basis for regional geological mapping is demonstrated.

POSTER

EFFECTS OF PRE-EXISTING FABRIC, HIGH STRAIN AND KINEMATIC VORTICITY NUMBER ON LINEATION DEVELOPMENT IN THE ALPINE FAULT ZONE

V.G. Toy & R.J. Norris
Geology Department, University of Otago, PO Box 56, Dunedin 9054
(virginia@geology.co.nz)

Lineations are formed by a variety of mechanisms in the mylonite zone that is exhumed in the hanging wall of the Alpine fault zone. In the distal protomylonites, remnant Alpine Schist quartz rodding lineations are progressively reoriented from a SW to an E trend by action of discrete mylonitic C'-shear bands. Because this deformation is progressive a variety of intermediate lineation orientations are present, giving a mean of ~43/134° within the central section of the fault zone. This fabric does not reflect a steady state strain during mylonitic deformation.

Lineations in the higher strain mylonites and ultramylonites are frequently poorly developed as deformation has produced a relatively homogeneous aggregate lacking the bimodal grain size distribution between different minerals that is necessary to form a lineation (Piazolo and Passchier, 2002; *JSG* **24,** 25-44). Where these lineations are present they have a mean trend that is c. 40° oblique to the trace of the ~071°-trending plate convergence vector in the shear plane. Shear directions determined from quartz CPO fabrics, multiple sectioning and brittle wear lineations are successively less oblique to the convergence vector, but still not parallel to it.

We have modelled the development of a lineation that parallels the maximum finite extensional strain axis (S_1) using the deformation gradient tensor presented by Lin et al. (1998; *Geol. Soc. Spec. Pub.* **135**, 41-57) for an oblique transpressional shear zone. We calculated total pure and simple shear components that produce lineations trending towards 102° in the (ultra-)mylonites and 108°in the protomylonites to match our measured data. These strain amounts were also fit to the distribution of thicknesses of sheared pegmatite veins within the fault zone measured by Norris and Cooper (2003; *JSG* **20**, 2141-2157). We found that the lineation orientation is insensitive to the total simple shear strain provided it exceeds ~30. However, the orientation is critically dependent on the total pure shear strain, which cannot exceed 1.75 for the observed lineation orientations.

These values of strain are entirely consistent with, and support the strain estimates of Norris and Cooper (2003), and show that the total pure shear strain within the mylonite zone is no greater than in the adjacent Alpine Schists. The absence of lineations in the high strain mylonites therefore cannot be attributed to a high ratio of pure:simple shear strain. This result also suggests that the pure:simple shear ratios required to form a significantly oblique lineation in any shear zone are small (kinematic vorticity number W_k>0.97; i.e. within measurement error of many current methods used to determine this parameter) and may be easily realised in nature. This is an important consideration for the many studies of older exhumed fault zones where original tectonic transport directions are inferred from fabric orientations.

POSTER

MINGLING AND MIXING ON STEWART ISLAND

R. E. Turnbull[1], S.D. Weaver[1] & A.J. Tulloch[2]
[1]Department of Geological Sciences, University of Canterbury, Christchurch
[2]GNS Science, Private Bag 1930, Dunedin
(ret26@student.canterbury.ac.nz)

The mid Jurassic-Early Cretaceous, gabbro-diorite-granite Bungaree Intrusives are characterized by a sequence of mafic sheet-like units and mafic enclave swarms within a more felsic host. This mafic material represents multiple mafic replenishment events onto the floor of an aggrading crystal-rich felsic chamber. Field, petrological and geochemical evidence indicates varying degrees of mafic-felsic mingling and mixing. The analysis and interpretation of mafic/felsic magma interactions within the Bungaree Intrusives has the potential to provide new insights into physical and chemical processes operating within high level magma chambers, and provides an important link to volcanic processes occurring at the surface.

The type of interaction that occurs between the mafic and felsic magmas is dependent upon temperature and viscosity contrasts between the two magmas at the time of emplacement. Other factors which may also have an influence include relative volumes of the mafic and felsic magmas, compositions of the magmas, and the degree of crystallization. Interaction between the mafic and felsic magmas within the Bungaree Intrusives ranges from the formation of thick (1-10m+) mafic sheets and mafic enclaves with sharp, chilled contacts formed by quenching of the mafic magma in the cooler felsic host magma, to localized mixing of the two magma around the edges of the mafic sheets/enclaves, to almost complete homogenization of the two magmas to create a hybrid rock.

Detailed observations of these magma mixing and mingling structures suggest that several processes were operating within the magma chamber, and include:

1. Magmatic flow/convection; evidenced by strongly aligned plagioclase crystals within both the felsic host and the mafic enclaves, and flow aligned mafic enclaves. This process is also largely responsible for the breaking apart of mafic intrusions into enclave swarms, and is much stronger towards the inferred top of the chamber
2. Compaction; consistent with a N/S shortening direction throughout the pluton, as shown by elongate enclaves, and on interfaces between mafic enclaves and the host that are perpendicular to this shortening which are highly cuspate. There are localized areas of high-strain where the enclaves are highly elongate and have high aspect ratios
3. Vertical construction of the pluton; several “way-up” indicators permit the construction of a magmatic “stratigraphy” within the chamber
4. Mafic sheets behaving like lava flows; mafic sheets towards the bottom of the chamber often retain a thick core which magma continued to flow through
5. Escape of volatiles from the felsic host; in the form of amphibole accumulations at the base of mafic enclaves/sheets, and felsic-rich veins within the mafic intrusions

Magma mixing and mingling structures vary throughout the chamber, indicating that processes operating within the evolving magma chamber varied in intensity and relative importance through time.

PAPER

IDENTIFYING ERUPTION TYPES AND IMPLICIT HAZARDS FROM DISTAL TEPHRA DEPOSITS

M.B.Turner[1], S.J.Cronin[1] & I.E.Smith[2]
[1] Volcanic Risk Solutions - Institute of Natural Resources, Massey University, Private Bag 11 222, Palmerston North.
[2] Department of Geology, University of Auckland, Private Bag 92019, Auckland
(m.b.turner@massey.ac.nz)

Hazard assessments of andesite volcanoes rely on knowing and understanding the suite of potential eruption styles and magnitudes. This can be complex when compiling an array of events that span large ranges in magnitude, explosivity and composition. Full characterisation of eruption styles is also rarely possible from single sites – especially those in lake cores where eruption frequency records are best.

As a way forward, we demonstrate a petrological method that allows us to group individual eruption deposits (mostly fall units) into two end-member categories: open- or closed-vent degassing systems. Open systems involve generally rapid magma rise and eruption, commonly resulting in sub-plinian eruptions and pumice deposits. Characteristics of the resulting deposits include vesicular glass, homogenous titanomagnetite compositions and angular particles. Closed systems involve the relatively slower ascent of magma which results in lava effusion, including dome building and destruction. Tephras of closed system eruptions primarily result from elutriated ash clouds above pyroclastic flows (or Block and Ash Flows). The resulting particles can be sub-angular or partly rounded from transportation within the granular flows. Slower cooling rates coupled with degassing result in microlite growth within the melt glass. Also, due to variable oxidation, pressure and temperature conditions within extruded lava (e.g., within different parts/depths of domes), titanomageite phenocrysts undergo different degrees of 'exsolution'. The resulting 'exsolved' titanomagnetite grain is composed of two or more compositional phases including titanohematite-ilmenite lamellae and the remaining Ti-poor (<2/3 the original Ti content) titanomagnetite.

These petrological observations have been used to characterise the distal tephra-fall deposits from Mt Taranaki, New Zealand. The distal deposits within lacustrine sediments provide a continuous temporal eruption record which, due to poor-preservation conditions at proximal locations, is otherwise unattainable. By using the methods demonstrated, the record details can be expanded to include analysis of the frequency of the implicit hazards of open- and closed-vent eruption events.

PAPER

VENT ALIGNMENTS IN THE AUCKLAND VOLCANIC FIELD AND THEIR SIGNIFICANCE FOR VOLCANIC RISK ASSESSMENT

M.W. von Veh
School of Natural Sciences, Unitec New Zealand, Private Bag 92025, Auckland (mvonveh@unitec.ac.nz)

Emergency planning to manage risk associated with a future eruption in the active Auckland Volcanic Field (AVF) is hampered by the difficulty in predicting eruption locations because of the monogenetic character of the field. The alignments of volcanic centers parallel to the regional faulting (Kermode, 1992) indicate that hidden zones of crustal fracturing provide pathways for the upward movement of magma. Knowledge of the orientations and locations of these zones of weakness can provide important constraints for predictive modelling of future event locations.

The preferred orientations of the fracture zones are assessed using the nearest-neighbour azimuth method (Wadge & Cross, 1988), selecting only nearest neighbours that are closer together than would be expected by chance. This method is based on the assumption that that a volcanic body associated with a fracture is likely to have a neighbour in close proximity to it that lies along the same structure. The joins between nearest neighbours trend towards the ENE, NNE and NNW, parallel to the regional faults.

The fracture zones that acted as magma conduits are assumed to be megascopic in scale, extending across the AVF. Their locations are estimated from the alignments of multiple vents using the Hough Transform method (Dudani & Luk, 1978). A number of Hough 'lines' oriented towards the ENE, NNE and NNW are identified. The density of vents is higher along the ENE and NNE directions. A line passing through the Rangitoto and Motukorea vents to the northwestern extension of the active Wairoa North fault may represent a locus for future eruptions in the AVF.

Dudani, S.A., and Luk, A.L., 1978. Locating straight-line edge segments on outdoor scenes. Pattern Recognition, 10, 145-147.

Kermode, L.O., 1992. Geology of the Auckl;and urban area. Scale 1: 50 000. *Institute of Geological & Nuclear Sciences geological map* 2. 1 sheet + 63 p. Lower Hutt, New Zealand. Institute of Geological & Nuclear Sciences.

Wadge, G. and Cross, A. 1988. Quantitative methods for detecting aligned points: an application to the volcanic vents of the Michoacan-Guanajuato Volcanic Field, Mexico. Geology, 16, 815-818.

POSTER

SEISMIC ANISOTROPY MONITORING AT MT. RUAPEHU VOLCANO

A. Wessel[1], M. Savage[1], T. Hurst[2] & S. Sherburn[2]
[1]Victoria University of Wellington, PO Box 600, New Zealand
[2]GNS Science, Lower Hutt, New Zealand
(awbochum@gmail.com)

The aim of this study is to develop a new tool for near-real-time monitoring of stress related to volcanic activity and possibly forecasting of future eruptions. The last eruption of Mt. Ruapehu was in 1995/96, but crater lake temperatures show cycles of heating and cooling with a period of several months, giving a reminder of Ruapehu being an active volcano. We will examine temporal changes of anisotropy in the crust around the summit of Mt. Ruapehu volcano.

Previous studies (Miller and Savage, 2001; Gerst and Savage, 2004) found temporal changes in anisotropy at Mt. Ruapehu and proposed a relation to volcanic activity, especially to the 1995 eruption. A pressurised magma dike system is capable of overprinting the regional stress field – this affects anisotropy and can be measured with shear wave splitting.

We investigate further changes in anisotropy since 2002 at Mt. Ruapehu. Compared to previous studies, we have a larger dataset from numerous three-component Geonet stations. The data gathered from these stations will be analysed with automatic processing techniques to determine the best parameters and methodology to measure shear wave splitting rapidly and reliably, with the goal of developing a near-automatic method for routine monitoring. Preliminary comparisons of the automatic technique show agreement with the manual results of Gerst and Savage (2004).

PAPER

GEOLOGICAL MODELS OF THE TAUPO VOLCANIC ZONE

P. A. White, A. Bou, G. Kilgour & C. Meilhac
GNS Science, Wairakei Research Centre, Private Bag 2000, Taupo
(p.white@gns.cri.nz)

Three-dimensional computer modelling has been developed at GNS Sciences over the past 10 years with the long-term aims of understanding the geometry, fluid flows and layer properties of geological units in the Taupo Volcanic Zone (TVZ).

The mapping and modelling process uses ARCMAP geographic information system (GIS) software and EarthVision geospatial modelling software (Dynamic Graphics Inc.). The GIS is used to generate geological maps, compile well data and create isopach maps using lithologic and elevation data. EarthVision is used to construct contour maps of layer surfaces and model layer properties such as temperature and thickness of subsurface lithologies. EarthVision is also used to generate and visualise three-dimensional models and cross-sections.

Modelling in the TVZ area started in 1996 with development of geological and temperature models of the Broadlands - Ohaaki Geothermal Field. Three-dimensional geological models are currently developed for: the Tauranga region between the Kaimai Range and the coast from Waihi Beach to Te Puke; the Lake Rotorua catchment; the area between Taupo and Waiotapu including the Reporoa Basin; and the Lake Taupo catchment including the Tongariro Power Development catchment.

These models have applications to assessments of groundwater resources. For example restoration of Lake Rotorua water quality requires a good understanding of the groundwater system because groundwater plays a key role in the transport of nutrients from the land to Lake Rotorua. The 3D geological model of the Lake Rotorua catchment includes the formations that are important for groundwater flow and is used in the development of a groundwater flow model of the catchment.

These models also have applications to assessments of geothermal resources. For example 3D models of geology data and temperature data from drill holes within the Ohaaki-Broadlands Geothermal Field are used to generate cross-sections and to show the geometry of the geothermal production zone.

Future developments aim to complete coverage of the TVZ with 3D geological models and include geophysical information such as earthquake locations. Future uses of these models include: improved understanding of the links between land use, groundwater quality and surface water quality; development of geological models as a framework for assessing groundwater allocation; and improved understanding of large-scale geothermal flow systems.

PAPER

RELATIONSHIPS BETWEEN LATE QUATERNARY COASTAL GEOMORPHOLOGY AND SUBDUCTION ZONE GEODYNAMICS OF THE RAUKUMARA SECTOR OF THE HIKURANGI MARGIN.

K. Wilson[1], K. Berryman[1], T. Little[2], N. Litchfield[1], U. Cochran[1].

[1] GNS Science, PO Box 30-368, Lower Hutt.

[2] School of Earth Sciences, Victoria University of Wellington, Wellington.

The northeastern coastline of the Raukumara Peninsula is one of the few subduction zone locations globally where changes in tectonic uplift mechanisms can be documented across a margin-normal width of greater than 100 km. Evidence obtained from detailed studies of Holocene and Pleistocene marine terraces and transgressive marine sequences at three coastal regions on the Raukumara Peninsula show that late Quaternary coastal uplift mechanisms of the Raukumara sector vary between localised zones of coseismic uplift and broader zones of aseismic uplift. The main parameter controlling the spatial distribution of uplift mechanisms is most likely to be the margin-normal proximity of the forearc to the Hikurangi trench, and by inference, the depth to the plate interface below. Three zones of forearc uplift mechanisms are identified: (1) a zone of coseismic uplift on upper plate contractional faults located within 20 – 80 km of the trench, (2) a passive inner forearc zone at ~80-120 km from the trench, vertical tectonic movement within this zone is controlled by distal upper plate structures or plate interface events, and (3) a zone of aseismic uplift driven by sediment underplating located at a distance of ~120 – 180 km of the trench. All three zones appear to continue southwestward along the margin. Changes along the strike of the Raukumara sector include the thickness of the upper plate crust and the strength of plate coupling but these are inferred to be of lesser importance in controlling uplift mechanism distribution than changes normal to the margin. Important implications of this model include the ability to identify parts of the coastline more favourable to the preservation of great subduction earthquake records and that an aseismic process has evidently been capable of building the significant topography of the Raukumara Peninsula's axial ranges. This latter point suggests that, although there are active faults within the axial ranges of the central and southern Hikurangi margin, uplift of these ranges may also be in part aseismic and therefore more closely linked with deep-seated subduction processes than previously appreciated.

POSTER

EXPOSURE OF THE NEW ZEALAND DAIRY INDUSTRY TO TEPHRA FALL USING PROBABILISTIC AND SCENARIO BASED MODELS

Tom Wilson[1], Grant Kaye[1], Jim Cole[1], Andre Dantas[1], David Johnston[2], and Shane Cronin[3]
[1]Natural Hazards Research Centre, University of Canterbury, Private Bag 4800, Christchurch, New Zealand
[2]GNS Science, 1 Fairway Drive, Lower Hutt, New Zealand
[3]Volcanic Risk Solutions, Massey University, Private Bag 11 222,
Palmerston North, New Zealand
Email: tmw42@student.canterbury.ac.nz

Defining the exposure to a vulnerable industry or sector is becoming easier with greater access to land use data and the successful application of Geographic Information Systems within natural hazard analysis. As part of the development of Riskscape-Volcano one of the challenges has been defining what impact tephra fall (a spatially extensive hazard) will have to agriculture (a spatially extensive land-use activity). This poster illustrates some of the development steps currently being undertaken as part of research efforts at GNS Science and the University of Canterbury.

Probabilistic volcanic tephra fall data and several eruption scenarios have been used to determine the physical exposure of farms in the central North Island. The probabilistic ash fall model (based on data developed by other research at GNS Science) gives an impression of the tephra fall hazard for individual farms in the central North Island. Three scenario models illustrate what may occur during a future eruption. These are based on previously studied eruptions from different eruptive centres in the North Island.

Agribase, a GIS farm database, has been used to examine the exposure of farms from the various models. The exposure can be quantified by number of farms impacted by how much tephra, total farm area impacted by how much tephra, and impacts to transport systems.

Volcanic agricultural fragility functions have been developed from an extensive review of tephra damage to agriculture (literature review, expert opinion and field work). Such functions have been used here to estimate the economic damage to production and capital assets on dairy farms. When linked with probable production and asset valuations, economic loss can be estimated providing a valuable and comparable insight into the economic loss a future volcanic eruption may cost New Zealand.

POSTER

LORD OF THE FLIES: WHAT CAN THE WORLD'S MOST COMMON FLY TELL US ABOUT LONG-TERM ENVIRONMENTAL CHANGE.

Craig Woodward, Jamie Shulmeister
Department of Geological Sciences, University of Canterbury, Christchurch, New Zealand.

Chironomids (non-biting midges) are the most widely distributed and frequently the most abundant group of insects in freshwater. The chitinous remains of the larvae are frequently encountered preserved in sediments deposited in a wide range of aquatic environments. Consequently, many studies have investigated the environmental tolerances of modern species in order to use them as an analog for species found in the fossil record. By defining the numerical relationship between modern chironomid species and environmental parameters (transfer-functions) it is then possible to reconstruct unknown environmental parameters from quantitative counts of fossil chironomid larvae taken from sediment cores. Chironomid based transfer-functions for temperature, and a variety of water quality indicators have been developed in the Northern Hemisphere, and have provided valuable contributions to paleoclimate research and the study and management of aquatic ecosystems. Research exploring the potential for the use of southern latitude chironomid fauna and other biological groups in quantitative paleoenvironmental reconstructions is extremely limited.

This poster outlines the methodology and the results from research that has resulted in the development of two New Zealand chironomid-based transfer functions: one for air temperature (February mean), and another for the trophic status (total nitrogen (TN) concentration) of New Zealand freshwater bodies. These models have since been applied to several lake records from New Zealand. Two records have provided new insights into climate change in this region during the last 30,000 years including the last glacial interglacial transition (LGIT). A third record from a flooded sinkhole (doline) in northwest Nelson traces the response of this waterbody to recent human induced deforestation and intensive agriculture.

PAPER

NEW RECORDS OF CLIMATE CHANGE FROM NEW ZEALAND DURING THE LAST 30,000 YEARS: A FLY'S EYE VIEW

Craig Woodward, Jamie Shulmeister
Department of Geological Sciences, University of Canterbury, Christchurch, New Zealand.

A recently developed chironomid (non-biting midge) based temperature inference model (Woodward and Shulmeister, 2006) enables the reconstruction of past summer air temperatures over the New Zealand landmass. We present the results from two chironomid-based temperature reconstructions that provide information on climate variability in this region during the last 30,000 years.

Lake sediments exposed in Lyndon Stream in the South Island span 26.6-24.5 ka BP (the MIS 2/3 transition). A long-standing paradigm in New Zealand paleoclimatology argues for a major (4–7 ºC below modern), monotonic cooling that spanned the period between ca 30 and 18 ka BP. Chironomid-inferred summer (February mean) temperatures between 26.6 and 24.5 ka BP averaged 1 ^{o}C cooler than the modern mean, with a maximum inferred cooling of 3.7 ^{o}C (Woodward and Shulmeister, In press). Other records that are emerging from the New Zealand region also show a large degree of climate variability between ca 30 and 18 ka BP, including a phase of warming at the MIS 2/3 transition and a maximum cooling that did not occur until the global last glacial maximum (LGM) (ca 20 ka BP).

The recovery of the Earth's climate from the grip of the last ice-age between 18 and 10 ka BP was interrupted by a series of millennial scale climatic variations. The most significant and widely studied of these variations is a period of cooling between 12.7 and 11.6 ka BP that is referred to as the Younger Dryas Stadial (YDS). The YDS has been reported from many Northern Hemisphere climate records based on numerous proxies, including pollen, chironomids, Coleoptera, stable isotope records, and Foraminifera. Conversely, temperature records from Antarctica show a cooling event known as the Antarctic Cold Reversal (ACR) that occurs between 14 and 12.5 ka BP. This cooling event begins approximately 1500 years before the beginning of the YDS in the Northern Hemisphere. Furthermore, the YDS corresponds to a period of rapid warming in the Antarctic records, suggesting that the climates of the Northern and Southern Hemispheres are out of phase.

There are still a limited number of climate records that span this period in the southern mid-latitudes – particularly terrestrial records of air temperature. We present the results from a multiproxy study (pollen, macrofossils and chironomids) from a record spanning ca 17–10 ka BP from Lake Hawdon in the South Island, New Zealand. Chironomid-based temperature reconstructions infer a maximum cooling of 3 ºC occurring between 14 and 12.4 ka that interrupts the warming trend between ca 17 and 14 ka BP. This climate reversal corresponds to the Antarctic Cold Reversal, not the Younger Dryas Stadial.

Woodward C.A. and Shulmeister J. New Zealand chironomids as proxies for human-induced and natural environmental change. Transfer functions for temperature and lake productivity (chlorophyll *a*). *Journal of Paleolimnology*. Available online May 2006. DOI 10.1007/s10933-006-9009-6

Woodward C.A. and Shulmeister J. (In press) Chironomid-based reconstructions of summer air temperature from lake deposits in Lyndon Stream, New Zealand spanning the MIS 3/2 transition. Accepted to *Quaternary Science Reviews*, March 2006.

POSTER

A HIGH-RESOLUTION 200 K.Y. PALEOMAGNETIC RECORD FROM OFFSHORE EAST CAPE, NEW ZEALAND

C. Zeeden[1] & G.S. Wilson[1]
[1]Department of Geology, University of Otago, P.O. Box 56, Dunedin, New Zealand
(christianzeeden@yahoo.de)

Paleomagnetic data from a calypso core off the East Cape, North Island, New Zealand, reveal a continuous record of the earth's magnetic field for the last ca. 200 ka. This record is used to help constrain the age of the Matakaoa Debris Avalanche. We have established the pattern the pattern of geomagnetic reversals, geomagnetic excursions, the relative paleointensity and the magnetic susceptibility for the 27.68 m "MD06-3010" core, acquired by the French RV Marion Dufresne in February 2006. Measurements were carried out in the Paleomagnetic Research Facility of the University of Otago, mainly on a 2G enterprises cryogenic magnetometer. The data acquired from geomagnetic excursions and the relative paleointensity can be combined with tephra correlations to form a consistent age model for the "MD06-3010" core.

Furthermore, we have been able to identify, the "Mono Lake", "Laschamp", "Blake" and "Albuquerque" geomagnetic excursions. This is the first time such a complete excursion record is reported for the SW Pacific and an important step towards a high-resolution record of the relative paleointensity and paleosecular variation for the New Zealand region. The relative paleointensity was acquired using the ARM method. Below ca. 11 m depth the relative paleointensity loses both intensity and amplitude, related to the formation of greigite, which is clearly identifiable by GRM development during static AF demagnetisation. But above ca. 11 m the relative paleointensity is consistent with the results from other studies, including the GLOPIS-75 stack.

The combined excursion and relative paleointensity records indicate that the Matakaoa Debris Avalanche predates 200 k.y. and an age older than the Mamaku Ignimbrite (ca. 230 ka) is suggested.

POSTER

CYCLIC VOLCANICLASTIC SEDIMENTATION AT MT. TARANAKI, NZ – A HISTORY OF GROWTH AND DESTRUCTION

A.V. Zernack[1], J.N. Procter[1] & S.J. Cronin[1]
[1]INR, Massey University, Private Bag 11 222, Palmerston North, NZ.
(A.V.Zernack@massey.ac.nz)

The last 190,000 years of volcanic activity at Mt. Taranaki are characterised by alternating phases of edifice construction and large collapse events which accumulated a thick apron of volcaniclastic material around the cone; the so-called ring-plain. Distal ring-plain sequences along the Southern Taranaki coast represent a cross-section through diverse sedimentological settings and volcaniclastic lithofacies. Differences in sedimentary characteristics between stratigraphic layers as well as lateral and longitudinal contrasts within individual units were used to interpret their diverse origin and depositional conditions. At least six volcaniclastic flow facies were recognised: debris-avalanche deposits (DA), debris-flow deposits (DF), hyperconcentrated-flow deposits (HF), channel-fill deposits related to HF (CH), floodplain deposits related to HF (FP), and localised stream deposits (SF). These facies appear to be related to specific periods within a repeating pattern of deposition, which was used to develop a model of cyclic volcaniclastic sedimentation in distal areas of stratovolcanoes.

A generalised volcanic cycle at Mt. Taranaki begins after the destruction of large portions of the edifice by collapse. The subsequent edifice re-growth is characterised by small-scale pyroclastic eruptions and localised lava flows. Distal areas accumulate thick paleosols of medial ash and/or lignite with interbedded tephra layers reflecting the proximal activity. Ring-plain locations show three types of sequences: (1) Areas where DA deposition is followed by a period of distal quiescence, marked by the onset of paleosol or lignite formation and their preservation. (2) Areas which are repeatedly buried by DAs with little (preserved) accumulation between collapse events. (3) Areas that are frequently inundated by DF, HF and CH deposits. Erosive and transitional contacts to the underlying DA deposit imply that its surface was rapidly reworked.

Once the cone has grown to a size at which pyroclastic activity starts generating long-runout mass-flows, distal accumulation is characterised by massive sequences of pebbly sand-dominated, mainly monolithologic DF and HF deposits that intercalate with tephra beds, paleosols, dune sands, and local fluvial sediments. Pumice/scoria-rich flows were possibly generated from pyroclastic tephra fans, while those containing predominantly dense clasts represent the runout of dome-collapse block-and-ash-flows. The coarse body of these flows seems to be confined to pre-existing channels forming CH deposits which grade into more wide-spread, unconfined overbank-type (FP) deposits. The cycle is closed when the edifice reaches a critical point at which it fails, in distal areas represented by coarse, very poorly sorted, matrix-supported DF and DA deposits.

Large collapse events generating catastrophic DAs represent the greatest hazard at Mt. Taranaki but are far less frequent than long-runout mass-flows during growth phases. In order to forecast future hazards from these types of volcanoes, it is extremely important to understand their cyclic behaviour, which seems to represent a natural frequency in their growth dynamics, as well as the point of the cycle which they are currently in.

POSTER

SLAB OR CRUST - K_2O ENRICHMENT AT MT TARANAKI, NEW ZEALAND

<u>A.V. Zernack</u>[1], R.B. Stewart[1] & R.C. Price[2]
[1]INR, Massey University, Private Bag 11 222, Palmerston North, NZ.
[2]Faculty of Science, Waikato University, Private Bag 3105, Hamilton, NZ.
(A.V.Zernack@massey.ac.nz)

Mount Taranaki is the largest andesitic stratovolcano in New Zealand and represents the most westerly expression of subduction-related volcanism on the North Island. It is located 140 km west of the Taupo Volcanic Zone and lies 180 km above the Wadati-Benioff-Zone. Mt. Taranaki is recognised as a high-K arc volcano and was used to construct the Hatherton and Dickenson model of increasing K_2O with increasing depth to the slab (K-*h* relationship). More recent studies, however, show that K_2O behaviour in the Taranaki volcanics is time- rather than slab depth-dependent.

The last 190,000 years of volcanic activity on Taranaki are characterised by a series of alternating episodes of edifice construction and destruction. In this study, eleven debris avalanches generated by large collapse events have been sampled from ring-plain successions around the volcano. These deposits primarily contain fragments that built up the previous volcanic edifice and clasts represent the diversity of rock types produced by the volcano before it collapsed. Lithologies range between basalt and evolved andesite with most samples being of basaltic andesite composition. The oldest suites display the broadest range of compositions (48.65-58.81% SiO_2) and include more primitive rocks that have not been found in younger suites; the latter comprise predominantly andesite.

The evolution to less primitive compositions is accompanied by increasing K_2O with decreasing age. K_{55} values increase from 1.65% K_2O for the oldest rocks (> 130 ka) to 2.65% for the latest (< 1 ka) eruptives. The most dramatic rise in K_2O occurs in the youngest (< 10 ka) rocks and only these are classed as high-K andesites. Low field strength elements (LFSE) are coupled with K_2O while some high field strength elements (HSFE) show similar trends to K_2O only within samples younger than 70 ka. The oldest, more primitive rocks do not show a clear subduction signature which seems to get more distinct with increasing maturity of the volcano. Either the slab component of the melts becomes more dominant with time or there is increasing interaction with underplated crust.