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ABSTRACT VOLUME

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Abstracts are organised in alphabetical order by family name of the first author.

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AGE OF PROTOLITHS IN OTAGO AND MARLBOROUGH SCHIST

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Detrital zircon age patterns in metagreywackes in Otago and Marlborough Schist provide maximum depositional ages for their protolith and define terrane ancestry. In eastern Otago, south of the Hyde-Macraes Shear Zone (HMSZ) and Rise & Shine Shear Zone (RSSZ), a large proportion of the Otago Schist is Late Triassic with polymodal zircon age patterns resembling those in lower grade Rakaia Terrane in Canterbury and Wellington. North of the HMSZ, Late Triassic protoliths continue but are increasingly displaced by Late Permian protoliths of Rakaia Terrane ancestry. In a narrow strip (informally termed Hyde-Macraes Block) at the HMSZ, there is a possible Late Carboniferous protolith resembling that in the southernmost, Carboniferous, sector of the New England Orogen accretionary wedge in eastern New South Wales. In the western Otago Schist both Late Triassic and Early Jurassic protoliths are present within presently-mapped Aspiring Lithological Association and Torlesse Composite Terrane. However, their simpler zircon age patterns are very similar to those in the Waipapa Terrane, North Island and possible correlates along the east Otago coast. This pattern continues northwards across the Alpine Fault into the Marlborough Schist, where a Late Triassic to Early Jurassic, Waipapa Terrane protolith dominates. No examples of Jurassic, Kaweka Terrane or Early Cretaceous, Pahau Terrane protoliths were found.

ORAL

RESERVOIR CHARACTERISATION OF TIKORANGI FORMATION, WAIHAPA-NGAERE FIELD, TARANAKI BASIN, NEW ZEALAND.

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Over 60% of the world’s oil reserves lie in carbonate reservoirs, particularly in the Middle East oilfields. Carbonate depositional environments produce a diverse range of sedimentary facies which contain a wide variety of porosity types with varying degrees of connectivity, producing complex. Carbonates in geological point of view sensitive to post-depositional diagenesis, additionally most carbonate reservoirs contain natural faults and fractures, which influences the overall connectivity and porosity, and is a key uncertainty to understand when determining in-place volumes. Experts caution that relationships between facies and petrophysical properties in carbonate reservoirs cannot be determined without first understanding the basin sedimentary and structural history.

The Taranaki Basin is a proven and prolific hydrocarbon basin in New Zealand. Within the Basin, and in fact New Zealand, the Oligocene Tikorangi Formation is unique. It is a proven hydrocarbon producing formation comprised predominantly of carbonate reservoir, Waihapa-Ngaere field (early production 10,000 bopd).

Tikorangi Formation comprises a spectrum of interbedded limestone rock types ranging from calcareous mudstone into wackestone and packstone to grainstone. The Tikorangi Formation is distributed across the entire basin with fracture porosity and variable permeability.

In this paper, we examine methods to evaluate carbonate reservoirs at the core and well log scale using the available conventional well log and core data. The analysis includes a petrophysical evaluation to identify the primary role of heterogeneity and its effect on reservoir quality. This is then linked to the results of the proposed analysis to the facies of the studied formation across the field.

And identification of structural heterogeneities and main lithology features in order to evaluate the potential of possible hydrocarbon deposits in the area in addition to understand their effects on the reservoirs hydrocarbon prospect and oil productivity of the field.

ORAL
Paleoproductivity records from the central Gulf of Alaska can uncover the mechanisms that control biogeochemical cycling on glacial-interglacial timescales. Today, surface waters that overlie Site U1417 in the subpolar Pacific Ocean are characterised by high nutrients and low chlorophyll (HNLC), where primary production is controlled by micronutrient (iron) availability. A continuous 92 m sediment record that contains the last 600,000 years was used to reconstruct surface water productivity variations. A multi-proxy approach, comprising biogenic silica flux and concentration, as well as changes in the isotopic compositions of organic matter ($\delta^{13}C$ and $\delta^{15}N$), was used to evaluate relative changes in sediment constituents. We interpret intervals with elevated $\delta^{13}C$, $\delta^{15}N$, N/C, and wt. % BiSi to indicate periods of higher productivity combined with reduced influence of glaciogenic sediment delivered by ice rafting, meltwater plumes, and overflow from nearby Surveyor Fan channels. Based on comparison with regional records, we speculate that productivity increases during deglaciation due to the delivery of bioavailable Fe that is released from the adjacent continental shelves during post glacial sea level rise. At the same time, a decrease in ocean stratification allows for upwelling of nitrate and silica rich deep waters to the surface providing the conditions for an increase in macronutrient fertilisation and primary production. Small increases in productivity that occur during glacial periods may be the result of volcanic ash or an increase in the delivery of glacial dust and ice rafted detritus to the surface ocean. The relationship between deglaciation and productivity is strong in the central Gulf of Alaska, and we conclude that production is the result of increased nutrient abundance, transport, and upwelling that occurs in response to retreating continental ice.

3D MAPPING OF FLUID/ROCK INTERACTION USING STABLE ISOTOPES, MOUNT ISA, NORTHWEST QUEENSLAND, AUSTRALIA

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Carbonate-hosted mineral deposits represent globally significant mineral deposits, although they can be notoriously hard to target during exploration. The highly reactive nature of carbonate minerals mean they effectively neutralise acidic fluids, resulting in relatively narrow and poorly developed visible mineral alteration and lithgeochemical halos. However, interaction between hydrothermal fluids and carbonate rocks is recorded by changes in carbon and oxygen isotopes of host rock and carbonate veins. These cryptic alteration halos may be large and extended well beyond the limits of ore or visible alteration. The cost of isotope analysis by isotope ratio mass spectrometry (IRMS) and the long laboratory turn-around times has precluded the use of C and O stable isotopes in mineral exploration.

Mount Isa is a world-class base metal deposit hosted in a dolomite-rich Proterozoic sedimentary sequence, with good exposure as well as a long history of mining and research effort. Historical C and O stable isotope studies identified a large $\delta^{18}O$ depletion halo surrounding the Mount Isa deposits, which is 9 km long and reaches up to 2 km beyond visible mineral alteration halos. Reactive transport theory now provides a framework upon which to understand these observations and further develop these tools for vectoring towards mineralisation.

Historical exploration data and new isotopic analysis generated by off-axis integrated cavity output spectroscopy (OA-ICOS) have been combined to produce 3D model of wall-rock $\delta^{18}O$ composition at Mount Isa. This model identifies zones of alteration coincident with NNW trending faults and high strain zones in the folded basement contact. Combining this with a $\delta^{18}O$ gradient model reveals features such as fluid input zones and preferential fluid pathways. This is the first time high density isotopic data has been modelled alongside other indices of alteration and mineralisation in a data-rich mine environment.

ORAL
SECONDARY MINERALS IN VOLCANIC ROCKS – BASANITE LAVAS. ZEOLITES FROM BLACKHEAD QUARRY, (MAKEREATU), NEAR DUNEDIN, NEW ZEALAND

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Blackhead (Makereatu) a prominent volcanic headland 10 kilometres south of Dunedin city, once an isolated feature with spectacular basaltic rock formations, is now a major aggregate quarry. In the early stages of quarrying, the calcium-rich and sodium-rich zeolites, gonnardite and natrolite were abundant. Uncommon gismondine with phillipsite was found later in the deeper stages of quarrying. Phillipsite, chabazite and thomsonite were found in volcanic pyroclastic flow material in an upper sheltered part of the headland. Other secondary minerals present include aragonite, calcite, pyrite, goethite and siderite. An early pyroclastic eruption was followed by a main magma flow of basanite forming a lava lake. Groups of zeolites with different compositions have formed. A clear zonation in the layers reflects the distribution of temperature and hydrothermal conditions for zeolitisation in the two different eruptive basalts. The main eruption vent is considered to be a maar.

INVESTIGATING THE ROLE OF FLUIDS IN CONTROLLING HIKURANGI SUBDUCTION THRUST BEHAVIOUR USING THERMOMECHANICAL MODELS CONSTRAINED BY SEISMIC VELOCITY DERIVED POROSITY ESTIMATES

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Pacific-Australia plate convergence at the shallow subduction megathrust of the Hikurangi margin is characterised by inter-seismic slow slip behaviour along the northern Hikurangi margin and locked behaviour along the southern margin. We explore what role fluid production and overpressure may play in this change in observed behaviour, using porosity estimates derived from seismic velocities to constrain numerical models of fluid production in the shallow subduction zone.

The 05CM seismic reflection survey conducted offshore the east coast of North Island for Crown Minerals (now NZ Petroleum and Minerals) in 2005 utilised a large source and long-offset streamer (up to 12 km). This enabled good imaging of the subduction thrust and upper plate, with the long offsets also facilitating better velocity analysis. Using pre-stack depth migration coupled with a technique known as high density velocity analysis (HDVA) we obtain a reasonably robust, high resolution seismic velocity model along two margin-wide dip profiles at the northern and southern Hikurangi margin. These velocities are inverted for sediment porosity, which together with estimates of lithology and seismically-constrained structure can be used to predict “steady-state” fluid budgets in the accretionary wedge using numerical models. These models combine mechanical flow of sediments through the wedge, thermal modelling, and porosity profiles to calculate fluid release from compaction and dehydration reactions. Fluid source terms can then be used to estimate the degree of overpressure in wedge sediment.

We compare fluid release from sediment that is frontally accreted vs. subducted beneath the wedge for the northern vs. southern profiles.

MAPPING THERMAL GRADIENTS IN HYDROTHERMAL SYSTEMS USING CLUMPED ISOTOPES

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Thermal gradients within hydrothermal systems reflect a number of factors, including the temperature of the host rocks and hydrothermal fluid, distribution of fluid flow pathways and rate of fluid flow (i.e. host rock permeability and permeability distribution), and duration of hydrothermal fluid flow. Mapping the thermal structure of fossil and active hydrothermal systems is common practice for mineral and geothermal energy exploration (e.g. smectite – illite-smectite – illite transitions). However, resolving the thermal structure
is typically relatively difficult, as mineral transitions occur over a range of temperatures, and can be limited by kinetic factors.

Recent advanced in stable isotope instrumentation means it is now possible to measure very rare isotopologues of carbon dioxide, including the $^{13}$C$^{18}$O$^{16}$O isotopologue. It has been demonstrated that the relative abundance of the rare $^{13}$C$^{18}$O$^{16}$O isotopologue in carbonate minerals is directly related to the formation temperature of the carbonate minerals. This allows the precipitation temperature of carbonate minerals to be directly measured from the isotopic composition to ~5-10 °C precision in many cases, and allows the fluid composition to be solved for independently.

This approach may allow thermal gradients around hydrothermal ore systems to be elucidated (potentially offering direct thermal vectoring towards ore bodies in some ore deposit environments), as well as allowing models of hydrothermal fluid flow (e.g. free versus forced convection) to be tested. In addition, we will be able to, for the first time, directly determine the δ$^{18}$O signature from which carbonate minerals formed, potentially pointing to the source (meteoric vs magmatic vs metamorphic) of hydrothermal fluids. In this presentation we will provide background theory, and highlight case studies from preliminary data collected from the Taupo Volcanic Zone and Carlin Trend, Nevada.

**DUNEDIN’S LATE CENOZOIC TECTONIC DEFORMATION PATTERNS**

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Geological information is a component of a project looking for any as-yet-unknown active faults beneath Dunedin City (see Villamor et al., this conference). Existing geological maps, including the iconic 1:50,000-scale ‘Benson’ geological map of the Dunedin area, compiled by Noel Benson from field data collected during his long career as Professor of Geology at Otago University (1916 to 1949), were used together with topographic information to generate structure contours on distinctive stratigraphic markers, notably the Early Cenozoic Waipounamu Erosion Surface (WES) and the base of the early-mid Miocene Dunedin Volcanic Group (DVG).

The structure contours provide insights to Late Cenozoic tectonic deformation near Dunedin. The base of the DVG resting on progressively older strata towards the west implies a regional slight angular unconformity (Benson’s ‘Late Tertiary Peneplain’) and indicates that some regional uplift or tilting (up-to-the-west) and differential erosion had occurred by the early Miocene. The WES and DVG are deformed by a suite of northeast-striking faults, some with associated anticlines, and virtually all appear to be contractional. A change in fault pattern occurs at about Dunedin. To the northeast, an array of subparallel faults, spaced between 4 and 8 km apart, have lengths ranging from ~15 km to ~27 km and maximal vertical throw on the WES of ~50 m to ~250 m (larger on longer faults). Fewer, but relatively longer and larger, faults lie to the southwest, including the active Akatore and Titri faults.

Three NW-SE oriented cross-sections extending ~65 km inland from the coast, and using a nominal 40° net dip on each fault, indicate cumulative Late Cenozoic (section-parallel) shortening of ~2.2 km (i.e. ~3%). Shortening is similar on all transects, irrespective of fault array pattern. These results provide context for active tectonic research as well as improved geological interpretations on the new Dunedin Urban Geological Map.

ORAL
Slope instability is a widespread and significant geological hazard in the Dunedin area. As part of the GNS Science Urban Geology project, a 1:25,000-scale geological map has been compiled, with an accompanying generalised geomorphological map. However, the existing landslide database for the Dunedin City district, last updated by GNS in 2012 and currently a primary information resource on landslides for the Dunedin City Council (DCC) and Otago Regional Council (ORC), is a collation of data from various historical sources and at various disparate scales. Its limitations were recently highlighted during formulation of the DCC 2nd Generation District Plan, where the existing landslide database was translated into proposed activity restraints for property parcels coinciding with mapped landslides. Numerous submissions from the public pointed to substantial inaccuracies in landslide locations at the scale of cadastral boundaries, among other objections.

The existing landslide database is clearly an unsatisfactory adjunct to the new geological map. It was decided to produce a comprehensive new landslide map at detailed scale for the urban map area. Substantial co-funding from ORC enabled the extension of this map to all land in the Dunedin district zoned residential, commercial, industrial and rural-residential. Mapping was facilitated by DCC and ORC lidar coverage for much of the map area, extensive high-quality b&w stereoscopic airphotos (1940s-50s), full coverage by ORC 2013 colour orthophotos and Google Earth imagery.

The new landslide database, compiled at 1:10,000-scale or better, provides a resource that is an appropriate adjunct to the new urban geology map, and is more applicable at property-parcel scales. The area affected by landslides identified in the new comprehensive dataset is greater than in the previous dataset. The new map footprint (569 km²) contains 93 km² of landslide terrain (16% by area) compared with the original dataset’s 72 km² (13%) of landslide terrain.
The Oligocene is a key period in the Cenozoic geological history of New Zealand. It corresponds to a time of maximum landmass submersion and possibly also to the inception of the Cenozoic plate boundary. In the Canterbury Basin, Oligocene strata are dominated by limestones and glauconitic sandstones deposited in shelfal to lower bathyal water depths (50-1000 m). Offshore wells and seismic reflection data show a condensed Oligocene interval of up to 150m thick which can be eroded by mid-Oligocene (~30 Ma) channels 1-10km wide and up to ~100m deep. Onshore these channels may be responsible for the discontinuous preservation of Oligocene limestones. Mapping of the channels suggests that the first-order geometry of the Canterbury Basin was established by the mid-Oligocene. The channels formed by drainage flow towards the SE and E of the basin which transported sediment from a shallow, emerged carbonated shelf onshore to bathyal water depths in the distal offshore basin. Increased water depths in the early Oligocene and shallowing of water depths associated with channelization in the mid-Oligocene may exceed the predicted eustatic sea-level changes and are consistent with mild tectonic uplift of hundreds of metres (e.g., <500 m) in the Canterbury Basin. Maximum tectonic uplift at this time occurred west and northwest of the Canterbury Basin and was not high enough to supply significant terrigenous sediment to the basin. This study focuses on the characterisation of the channels present within the Oligocene interval and on defining their age in order to produce paleogeographic map at mid-Oligocene time.

ORAL

Radiative forcing by greenhouse gases is typically considered the most important driver of climate change, and the polar regions are consistently shown to be highly sensitive to anthropogenic greenhouse gas emissions. Fossil plants recovered from Paleogene deposits in the Canadian High Arctic, particularly those preserved in the Middle Eocene Buchanan Lake Formation on Axel Heiberg Island at approximately 78°N paleolatitude, provide an exceptional opportunity to investigate polar vegetation, environments, and climate during a period of global warmth. Mummified remains of forests, including in situ stumps and forest-floor litters, give evidence to a diverse rainforest ecosystem, with trees in excess of 2m diameter. Swamp forests were dominated by the deciduous taxodiaceous conifers dawn redwood and swamp cypress; lowland floodplains, by deciduous broad-leaved trees including alder, elm, sycamore, oak, walnut, dove-tree, katsura, and ginkgo. Conifers both deciduous (larch, yellow larch) and evergreen (pine, spruce, hemlock, cedar, taiwania) were locally abundant on the landscape. The flora, and associated vertebrate remains including alligators, indicate a mean annual temperature of approximately 15°C, and winters with little, if any frost. Yet seasonality would have been profound, with months of continuous darkness in winter and light in summer, and the warm, dark polar winter indicates a global heat engine substantially different from that of today. The flora combines elements now found in mesothermal mid-latitude semi-deciduous vegetation, to temperate deciduous and boreal mixed-deciduous vegetation, and represents a circum-boreal, remarkably widespread floristic zone that extended poleward from about 50°N. Displacement during Cenozoic climatic change has led to disjunction and relictual distributions as well as to a more complex vegetational zonation of the mid-northern latitudes. While predictive models for climate change are challenged to recreate low equator-to-pole temperature gradients of the Paleogene, Paleogene polar floras inform our understanding high-latitude sensitivity, and the biosphere’s response to elevated global temperatures.

ORAL
ENIGMATIC FITTED CLAST TEXTURES, CRETACEOUS PAPAROA FORMATION, GREYMOUTH BASIN

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Intricately jigsaw-fitted clasts can be seen in the Cretaceous-Paleocene conglomerates of the Paparoa Formation in the Greymouth Basin. The ~600 m thick section contains clast supported cobbles to cobble conglomerates with sandstone lenses and soft sediment deformation. Locally, lenses of pebble-cobble conglomerates are clast supported with little to no matrix present at all. Clasts show jigsaw-like fitted edges with sharp contacts and angular indentations on clast interfaces. The clasts are composed of Greenland Group metasandstones and siltstones with vein quartz and granite present in minor amounts. The metasedimentary clasts are fitted tightly together regardless of the relative hardness of argillite vs metasandstone with examples of either lithology indenting the other. The fitted clasts occur in lenses approximately 5-7 m wide and 1-2 m thick. The thick section of conglomerates contains abundant soft sediment deformation including load casts and convolute bedding indicating a subaqueous environment alternating with subaerial braided river deposits. The interpreted depositional setting for the intricately fitted clasts is one of a channel mouth bar in a fan delta into a deep fault-controlled lake.

Intricately fitted beach boulders have been recently described for a rocky shore platform by Nelson and Hood (2016). These occur on a modern cliff-backed rocky shoreline on a promontory with large waves. The in situ abrasion process suggested by the authors relies on microseisms from wave impacts on the cliffs causing jostling of the clasts until the intricately fitted contacts form. Much older studies of in situ abrasion in fluvial environments suggests the role of microvibrations from clast collisions and winnowing of fines (Schumm & Stevens 1973). The context of the intricately fitted clasts in the Paparoa Formation conglomerates in river mouth channels into low energy lakes suggests that microvibrations and winnowing by currents may both be necessary.

LIQUEFACTION IN WHAKATANE: GROUND TRUTHING GEOTECHNICAL TESTING WITH PALEO-LIQUEFACTION INVESTIGATIONS

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Liquefaction and associated lateral spreading during the 1987 M_6.3 Edgecumbe earthquake caused severe damage within parts of Whakatane, in the North Island of New Zealand. Liquefaction and lateral spreading was well documented proximal to the Whakatane River and along the modern coastline in areas underlain by recent fluvial and marine sediments. Previous studies utilizing extensive Cone Penetration Test (CPT) investigations indicate that much of the Whakatane Central Business District (CBD) is underlain by sediments with a low cyclic resistance to liquefaction, however no evidence of liquefaction was observed during the Edgecumbe earthquake. Paleo-liquefaction investigations were undertaken at selected sites within the CBD to determine whether sub-surface evidence of liquefaction is present and to characterize the sediment that was predicted to liquefy. Trenching exposed fine sand interbedded with medium to coarse sand with pumice granules. No liquefaction features were observed indicating that the sediment had most likely not liquefied since deposition. Additional paleo-liquefaction investigations at sites known to have liquefied during the Edgecumbe earthquake revealed lateral spreading fissures from the Edgecumbe earthquake that cross-cut loosely consolidated fine sand with rare and comparably thin layers of medium sand with pumice granules. No evidence of pre-1987 liquefaction was observed in the trenches indicating that these sediments had not liquefied since their deposition and prior to 1987. The interbedded medium to coarse sand with pumice granules exposed within the CBD results in high hydraulic conductivity between layers and thus may dissipate pore-water pressures during cyclic shearing and inhibit liquefaction. This thin layering is unlikely to be captured by the CPT and may account for some variability between the predicted manifestation of liquefaction and that observed during the Edgecumbe earthquake. It is anticipated that this work will help to adequately characterize the liquefaction hazard of the Whakatane region, and highlight potential reasoning for over-prediction of liquefaction hazards.

ORAL
GEOLOGIC AND GEOMORPHIC INFLUENCE ON THE SPATIAL EXTENT OF LATERAL SPREADING IN CHRISTCHURCH, NEW ZEALAND

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Liquefaction-induced lateral spreading during earthquakes poses a significant hazard to the built environment, as observed in Christchurch during the 2010 to 2011 Canterbury Earthquake Sequence (CES). Published empirical models commonly used to predict lateral spread displacements have been shown to vary by a factor of <0.5 to >2 from those measured in parts of Christchurch during the CES. Post-CES studies focusing on the Avon River in eastern Christchurch have clearly indicated that the spatial extent of lateral spreading and associated horizontal displacements were strongly influenced by geologic and topographic features. These effects are not explicitly accounted for in the models and likely account for some of the discrepancy between predicted and measured displacements. Extensive LiDAR and satellite derived horizontal displacement datasets for main CES earthquakes provide an indication of the maximum extent and magnitude of lateral spreading, however, each dataset has inherent limitations including the spatial resolution, accuracy, and acquisition errors (i.e. flight line offset). Additional datasets indicating the maximum extent of lateral spreading include the summation of measured crack widths along transects from field surveys, LiDAR derived ground surface subsidence, documented land damage, and details of cracking from post-event high resolution aerial photography. Using each of these datasets, the maximum extent and magnitudes of displacement were estimated along the Avon River. The zones of observed lateral spreads are spatially correlated with geologic and geomorphic maps to directly examine the influence of these factors on the extent of lateral spreading. Detailed geotechnical characterization of the subsurface sediments is compared with the surface manifestation (i.e. cracking or surface volcanoes), and the extent and direction of lateral spreading within Avonside. It is shown that local geomorphic, topographic, and sedimentologic variability within the inner-meander bend strongly influences the extent and severity of lateral spreading. This study aims to combine geomorphic mapping and geotechnical characterization with lateral spreading extents in an effort to enhance engineering evaluation of lateral spreading.

THE CLAY CREEK LIMESTONE: A DEPOSITIONAL MODEL FOR AN UNUSUAL DEEP-WATER COQUINA LIMESTONE

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The late Miocene Clay Creek Limestone is an unusual example of a Te Aute Lithofacies limestone, and is sometimes considered to be a forerunner to the classic Te Aute Lithofacies of the Pliocene and early Pleistocene. It is a coarse-grained, pebbly coquina limestone which variably overlies Torlesse basement and late Miocene sedimentary rocks with a highly irregular basal contact. Despite major differences in lithology, the Clay Creek Limestone is a partial lateral equivalent of the bathyal Bells Creek Mudstone, and lateral transitions from coarse-grained carbonate to fine-grained terrigenous sediment often occur over very short distances. New outcrop and biostratigraphic data from the Clay Creek Limestone show evidence for mass transportation of skeletal carbonate sediment and terrigenous gravel from shallow, high-energy coastal waters to the outer shelf. We propose a conceptual depositional model to explain key features of the Clay Creek Limestone, the Bells Creek Mudstone, and the lateral relationship between the two units. This stratigraphic relationship has proven useful in constraining an episode of accelerated tectonic shortening which occurred in the southern Wairarapa during the late Miocene.
An accurate, high-resolution topographic model is fundamental for detailed engineering geological mapping. However, high costs of topographic data collection are often exacerbated by the remoteness of many field sites, rendering cheaper, more portable surveying platforms (i.e. terrestrial laser scanning or GPS) impractical. An alternative is Structure-from-Motion (SfM) photogrammetry. This technique allows for rapid, high-resolution modelling of surface terrains comparable in resolution to that attained by LiDAR, but at a fraction of the cost. Utilising SfM in conjunction with an Unmanned Aerial Vehicle (UAV) as means of a low altitude survey platform, this allows the rapid collection of terrain imagery. These can then be used as a basis for construction of high-resolution engineering geological maps viewable in a 3D space. SfM generates high-resolution topography and coregistered texture (colour) from an unstructured set of overlapping photos taken from varying viewpoints and known camera orientations.

The technique was applied to the coastal landslide at Ohuka, near Port Waikato, New Zealand. The engineering geomorphology of the Ohuka slope failure is complex, with a steep, failed seaward face above the beach, while the landward face of the hill is lower angle, irregular with a paucity of scars and compressional features. The seaward side includes a prominent c. 500 m long arcuate head scarp rising to 195 m above sea level, flanked by two gullies which represent the lateral margins of the failure, formed within pull-apart basins. It would appear that slope failure at Ohuka occurred along saturated clay seams within a unit of the 1 Ma Kidnapper’s Tephra. The SfM imagery captured the above engineering geological features in a high degree of detail as a 3D model. Hence, the SfM application reported here represents an effective, financially viable alternative to traditional topographic surveying and photogrammetric techniques, particularly for practical application in remote or inaccessible regions.

POSTER

THE STRATIGRAPHIC RECORD OF VOLCANISM - EXAMPLES FROM NEW ZEALAND SEDIMENTARY BASINS

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Reconstruction of past geological events or environments close to submerged volcanic edifices requires a sequence stratigraphic approach. Modern sequence stratigraphy blends autogenic and alloogenic processes into a unified model to explain the evolution of sedimentary basins. This method focuses on the analysis of stratigraphic surfaces that mark shifts in depositional regimes through time, mainly controlled by mechanisms such as tectonics, eustasy and climate. When affected by volcanism, depositional trends are locally impacted by the construction and destruction of positive and negative volcanic forms.

The sequence stratigraphic approach uses the shoreline trajectory through time as the focal point of discussion to recognize the geometrical trends, stratigraphic surfaces, system tracks and sequence boundaries of a sedimentary succession. In volcanic terrains, the focal point of the analysis is the eruptive centre (e.g., volcanic vent), which is an important source of siliciclastic material, and locally influence sediment dispersal. The resulting genetically-related assemblages of lithofacies vary in space and time and are bounded by chronostratigraphic surfaces separating syn-eruptive and inter-eruptive time intervals. These bounding surfaces are scale dependent and separate stratigraphic sequences formed during magmatic and non-magmatic stages of volcanic edifice development and burial.

The present study uses seismic reflection data, wells and outcrop analogues to characterize stratigraphic sequences proximal to volcanic edifices within New Zealand sedimentary basins. Case studies show three main higher-order (larger) sequences: pre-magmatic, magmatic-sedimentary and post-magmatic. These sequences are mainly controlled by the inter-relationships between mechanisms such as magmatic intrusion and deformation, volcanic eruptions, erosion and edifice burial by basin sedimentation. The vertical extent of these sequences is dependent on the duration of the magmatic event together with the interplay between volcanism, tectonics and eustasy. Lower-order (smaller) sequences are also recognized from the geometric configuration of seismic reflectors and lithofacies, which vary dependent on their position relative to the volcanic edifice.

ORAL
Geophysical techniques allow investigation of the subsurface in 2- and 3-dimensions. These investigations are critical to the identification of deeply buried lithological and structural features, development of detailed geologic maps, structural reconstructions and regional tectonic models, particularly at regional and exploration scales. Alongside essential field-based structural analysis and petrophysical data, geophysics provides a tool for structural geologists to reduce uncertainty in maps and models.

Various types of potential field data are collected for exploration and research. Examples include airborne magnetics, radiometrics, gravity and seismic data. Combined with other analyses, these data may be used to characterise rock packages, whose inherited magnetic anisotropies and lithological distributions are revealed in magnetic anomalies or distinct radiometric signatures. When applied to minerals exploration, geophysical techniques can be used to identify and map hydrothermal alteration, potential fluid pathways and traps, and local and regional structural features important for ore formation. Kinematic indicators and fault networks can inform our understanding of boundary tectonic conditions during crust evolution.

Frequently, structures observed in potential field data are replicated at smaller scales in outcrop-scale examples and microstructures. Hence, it is possible to use geophysics to upscale local observations to terrane and regional scales, and extrapolate under cover. In particular, geophysical datasets prove critical for 3D investigations, through inversion and forward modelling techniques, ideally reducing model uncertainty and improving prediction.

Application of geophysical methods to structural geology, and structural geology methods to geophysics, provides a lens through which we can improve our understanding of the subsurface over large areas and under cover. Integrated interpretation techniques, high-resolution maps and predictive models can be constructed. We present various case studies illustrating the application of geophysical methods to geological problems and minerals exploration in the Mount Isa and Gawler Craton regions of Australia, and suggest possible similar applications in New Zealand.
The Southern Alps Microearthquake Borehole Array has been operating continuously since late-2008 along a 50 km-long section of the central Alpine Fault, where the uplift rate of the Southern Alps is highest. To date it has detected >40 small to moderate-sized upper-mantle events (1≤M≥3.9). The Central Otago Seismic Array has been in operation since late-2012 and detected ~15 such events along the sub-vertical southern Alpine Fault and its termination at the Puysegur subduction zone. Most of the upper-mantle earthquakes occur south of Mt Cook. To the north the mantle appears relatively aseismic until the Hikurangi subduction Benioff zone is reached beneath northern South Island. This south-to-north partition of the mantle- seismicity suggests the true collision zone for the mantle lithosphere of the Australian and Pacific plates occurs just south of Mt Cook, and that the rheological properties of mantle lithosphere for each plate are different. A large variety of focal mechanism solutions with a predominant component of reverse-faulting was obtained for the mantle earthquakes. Some events exhibit energetic secondary arrivals that are tentatively interpreted as converted phases from the base of the crust and can be used to infer more information about the earthquake’s location relative to the Moho. These phases are analysed for their characteristics (type, polarisation). The event location results are interpreted in conjunction with new information about crustal structure, Moho depth and low-frequency earthquakes in light of existing models of velocity, attenuation and resistivity structure.

**ORAL**

**SEDIMENTOLOGY AND PALEOGEOGRAPHY OF SYN-OBDUCTION TURBIDITES: THE EOCENE BOURAIL FLYSCH (NEW CALEDONIA)**

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In New Caledonia, during the Paleogene, a major change from extensional to compressive regime led to the obduction of oceanic mantle onto both autochthonous and allochthonous units. In the western coast, this event is recorded by a ca. 4 km-thick turbidite succession referred to as the “Bourail flysch”. The current study focuses on the detailed sedimentological and paleogeographical analysis of this succession and aims at bringing new constrains on the onset of ophiolitic nappes and their impact on sedimentary records.

New facies descriptions and stratigraphical interpretations, both from a fully cored onshore petroleum well named CADART-1 which recovered 1700m of rocks, and from outcrops of the Gouaro anticline area were performed. A new facies classification based on sedimentary processes has been established. This classification covers a wide spectrum of depositional environments, from proximal mass flow deposits to distal hemipelagic fall-out deposits. Their spatial distribution along with sedimentary structure orientations (cross beddings, sole marks, etc...) suggest a main westward polarity of the turbidite system. In terms of vertical organization, the overall succession is thickening and coarsening upward (with uppermost olistoliths) but, in details, turbidites are organized following ca. 200m-thick sequences highlighted by variations of bed thickness and relative proportions of clastic and carbonate components. These variations are also supported by Hylogger hyperspectral logging performed by CSIRO on the CADART-1 cores. Indeed, hyperspectral data reveal a correlation between source types and sedimentary facies and microfacies. The origins of such trends are still being discussed (eg. control of relative sea level variations on source availability, polyphased nappe emplacement, etc...).

These new results will bring new elements on the paleogeography and evolution of Paleogene turbidites in Bourail area. From an applied perspective, this study should enhance the knowledge of New Caledonia petroleum system(s).

**POSTER**
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The central Alpine Fault accommodates up to 75% of the total relative Australian-Pacific plate boundary motion and ruptures episodically in large magnitude (Mw 8) earthquakes. An aim of the Deep Fault Drilling Project (DFDP) is to understand the processes that govern earthquake rupture nucleation and propagation on the Alpine Fault. In January 2011, DFDP-1A at Gaunt Creek drilling recovered a c. 25 cm-thick principal slip zone (PSZ) from around 90.25 m depth. We document the physical, structural, mineralogical, and chemical attributes of an 8 cm x 8.5 cm cylindrical section of PSZ core containing the oblique thrust contact (055/29SE, lin. 23/109) between hanging wall gouges and footwall gravels. From oldest to youngest, lithological units within the PSZ core include a catalcasite, a chloritic-micaeous gouge, and a smectitic gouge. Smectitic gouges occur at the plate boundary contact and are also present as injection veins, lenses, recumbent folds, and clasts within the overlying chloritic-micaeous gouge, providing evidence for repeated slip within this unit. In the near surface, the entire Alpine Fault alteration zone lies within the smectite stability field. However, the low-temperature clay mineral smectite only occurs within a small portion of the principal slip zone. We posit that alteration reactions within the smectitic gouges were enhanced by coseismic slip processes that generated pore fluids far from equilibrium with fault zone minerals, a condition requisite for clay mineral formation. Coseismic slip can promote clay nucleation and growth by: (1) increasing reaction rates through frictional heating and grain size reduction; (2) mixing hanging wall and footwall protoliths; and (3) forming impermeable slip surface(s) hydrologically isolated from advecting, chemically equilibrated, hanging wall fluids. Smectite neoformation can weaken the Alpine Fault by reducing the coefficient of friction and by decreasing permeability, which leads to pore fluid overpressure development.

TOWARDS UNDERSTANDING EARTHQUAKE NUCLEATION ON A SEVERELY MISORIENTED PLATE BOUNDARY FAULT, ALPINE FAULT, NEW ZEALAND


New Zealand’s Alpine Fault has accommodated relative motion between the Australian and Pacific plates for over 23 million years: first as strike-slip fault, then as an oblique transpressional fault. Despite being driven by principal stresses whose orientations have changed with time, the Alpine Fault continues to accommodate up to 75% of the relative plate boundary motion. Between the Toaroha and Martyr Rivers, the central Alpine Fault is consistently oriented 055/45°SE at depths from around 2 km to 15 km; focal mechanisms indicate that the stress tensor is oriented $S_1=S_{\text{Hmax}}=0/117^\circ$, $S_2=S_{\text{v}}$, and $S_3=0/207^\circ$ (Boese et al. 2013, doi: 10.1016/j.epsl.2013.06.030). Using the seismologically determined stress tensor and average fault orientation, the central Alpine Fault at depth lies at an angle of ~51° to $S_2$. The Mohr-Coulomb failure criterion requires that, for reactivation of a fault to occur, sufficient shear stress must develop on the fault plane. Using a friction coefficient of 0.6, as measured for representative Alpine Fault rocks under in situ conditions (Neimeijer et al. 2016, doi:10.1002/2015JB012593), and an estimated stress shape ratio, a 3-D reactivation analysis was performed (Leclère and Fabbrì 2013, doi:10.1016/j.jsg.2012.11.004). Results show that the Alpine Fault is severely misoriented for failure, requiring pore fluid pressures greater than the least principal stress to initiate frictional sliding. However, abundant evidence suggests that earthquakes commonly nucleate and propagate along this major plate boundary fault. By assuming an increase in differential stress of 15 MPa/km, our analysis shows that reactivation may occur with superhydrostatic pore fluid pressures given a ≥10° counterclockwise rotation of $S_{\text{Hmax}}$. Using measured hydraulic data, we estimate the potential for pore fluid overpressure development within the Alpine Fault core. We also explore whether processes including foliation development and grain-size reduction enable stress rotations sufficient to explain earthquake nucleation in frictionally strong materials and, thus, continued strain localization.

ORAL
Terranes are widely accepted in New Zealand and have been incorporated into the lithostratigraphic hierarchy. From time to time, however, questions are raised about how exotic or how different terranes really are, with hints or suggestions that they are merely faulted-bounded bodies that are basically related. The question of scale was not been seriously discussed other than at the lower end where there was a general agreement that individual blocks and olistoliths were not terranes.

It is common to compare terranes with modern environmental or plate tectonic settings such as ‘island arc’ or ‘passive margin’. When compared with modern analogues, most terranes are conspicuously smaller. New Zealand has only two substantial terranes, the Buller Terrane and the Torlesse Superterrane. The others are clearly incomplete and lie on both sides of the Median Batholith, which is much narrower within ‘Middle New Zealand’ than to the north and south. Were these terranes narrow slices when they accreted or were they thinned later?

Review of recent literature shows how uncertain is our understanding of large scale tectonic displacements and the assumption that older terrane bounding faults are simple is unwarranted. Discovery of Late Cretaceous schists near the Alpine Fault shows that the terrane pattern was not finalised when subduction ended in southern Pacific portion of the Zealandia margin. These younger schists probably originated far to the north and relate to Late Cretaceous subduction, but are now found well to the south, adjacent to the Rakaia Terrane. They appear represent a major sinistral displacement, and possibly an aspect of early Alpine Fault history. Why are many terranes and the median Batholith conspicuously narrow in New Zealand? Are the narrow terranes and the reduced Median Batholith also aspects of Late Cretaceous reworking of the terranes and their boundaries?

NEW DATA FROM THE SILURIAN/DEVONIAN ROCKS OF THE BATON RIVER AREA, NORTHWEST NELSON

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Silurian and Devonian rocks crop out between the Wangapeka and Takaka valleys and comprise the Ellis Formation and Baton Formation. The middle to Late Silurian Ellis sandstones rest conformably on Wangapeka rocks in the south and are believed to be equivalent to the Hailes Quartzite in the north, although on Hailes Knob the latter is in tectonic contact with Arthur Marble. A conglomerate in Moran Creek was previously considered the base of the Baton Formation and interpreted as evidence for a Pre-Baton ‘event’. However, the conglomerate contains a granite clast with a U-Pb age of 375 Ma (Late Devonian), indicating it may be an infaulted slice of Permian Pupu Conglomerate. The Ellis-Baton contact is conformable with a significant limestone horizon at the top of the Ellis that has been offset by numerous faults. This may be the same as the limestone previously found in Baton River that contained Lochkovian conodonts (earliest Devonian). A further outcrop of limestone on the Mt Gomorrah-Wangapeka spur is being investigated. The limestone is overlain by mudstones that contain tabulate corals, including Pleurodictyum. Preliminary faunal studies of both the Ellis and Baton Formations indicate strong links with Victoria, Australia. The difference in brachiopod faunas between the Ellis sandstones of the Wangapeka valley (Notocochidium tasmaniense Late Silurian) and those on Hailes Knob (Conchidium sp. middle - Late Silurian) may be due to the latter specimens coming from a lower level. Trace fossils occur in the Ellis Formation (Zoophycus, Spirophyton, Chondrites) and fine sediments near the base of the Baton Formation contain hyolithids, tentaculitids, plated annelid worms (machaeridians), ostracods and the bivalve Praectenodonta, previously unknown in New Zealand. A possible link with the Devonian of Reefon is suggested by the discovery of the bivalve Nuculodonta in fine sandstone beds in the youngest part of the formation.

ORAL
THE GOOD OIL: A CANDID VIEWPOINT FROM A
RELIEVED EXPLORATION GEOLOGIST

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Two years ago Mike Isaac gave a presentation extolling the virtues of further exploration for oil and gas in New Zealand. The feeling at that time in New Plymouth was optimistic with regional prosperity riding on high oil and dairy prices. Since that time both commodities have suffered serious price reductions.

Oil fell to below US$100 per barrel in September 2015 and has languished below $50 for the past year. Most of us motorists (and air travellers) have benefitted from lower petrol and diesel prices. Major producers at OPEC set a spot oil price responding to demand driven by global economy and the amount of new oil. The addition of reserves from new discoveries (e.g. deepwater Brasil) plays a part but it has been the success of multilateral drilling and fracking in US oil shale that has triggered this sudden price shift.

So how does this transport ‘free-for-all’ stack up following the 2015 Paris Agreement to which New Zealand is a signatory?; one of the aims being to reach a peaking of greenhouse gas emissions as soon as possible.

The result of the oil price collapse has certainly been to put a halt to exploration with no rigs or seismic crews operating now or in the near future; resulting in loss of jobs in the Taranaki oil sector (4700 two years ago to c.800 now) and minimal investment.

The price of oil will increase sometime in the future as a response to an increased world energy demand and New Zealand’s extraordinarily large Exclusive Economic Zone will again become the focus for oil and gas exploration; though the constraints upon this (e.g. carbon tax) are largely unknown.

But what the oil industry needs to do now includes:

- Maximise recovery from existing fields.
- Seriously investigate gas storage /sequestration.
- Develop strategies for decommissioning wells/fields.
- Communicate with government, the public (including Greenpeace), academia and the press.

Maybe it was ‘industry/business’ that pushed governments into making a deal at the Paris talks. With the good oil and gas now constituting some 60% of global energy, the petroleum industry needs to be part of the solution to aspirationally keep the world average temperature within 2°C above pre-industrial levels.

ORAL

ROLE OF LITHOSPHERIC HYDROUS
METASOMATIC PHASES ON ZEALANDIA
INTRAPLATE MAGMATISM

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The role of lithospheric mantle metasomatised by CO2-bearing melts in the genesis of HIMU-like alkaline intraplate basalts is investigated using partial melting models based on a suite of peridotite xenoliths from Otago. The xenoliths have Sr-Nd-Pb-Hf isotope compositions overlapping with the HIMU mantle reservoir. Two mantle metasomatic styles are distinguished from pyroxene trace element concentrations and are interpreted to be the result of reaction of peridotite with carbonatites or CO2-bearing magmas. Either way, the formation of the HIMU-like enriched lithospheric mantle was achieved by percolation of young volatile-rich melts, which likely rose from the asthenosphere. Partial melting modelling of representative depleted-and-then-enriched samples shows that low-degree melting of a CO2-bearing melt-metasomatised peridotite could yield a melt with a trace element composition very similar to that of the Zealandia HIMU-like alkaline basalts but only if small volumes (~5%) of amphibole participated in the melting process. Although not observed in our xenoliths, amphibole is associated with mantle metasomatism by carbonatitic/CO2-bearing melts elsewhere in the world and has been found as xenocrysts with HIMU-like isotope compositions in some Zealandia basalts. The melt modelling results also imply that amphibole buffers trace element budgets of a low-degree melt regardless of source peridotite composition; therefore, provided that hydrous metasomatised middle lithospheric mantle can be perturbed to melt, the contribution of amphibole could explain the chemical similarities of alkaline OIB-like magmas in continental and oceanic settings.

ORAL
TEMPERATURE ANOMALIES IN THE DFDP-2B BOREHOLE, SOUTH WESTLAND

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A detailed analysis of temperature logs measured during drilling of the DFDP-2B borehole in the Whataroa Valley, South Westland, reveals two distinct portions of the signal containing information on different processes. The long-wavelength portion of the temperature signal, i.e. the overall trend (hundreds of metres), reflects the response of the rock environment to the disturbance caused by drilling and permits an estimation of the thermal diffusivity of the rock in the hanging wall of the Alpine Fault. The short-wavelength (tens of metres to centimetres) signal represents the local anomalies caused by lithological variations or, more importantly, by fluid flow into or out of the borehole along fractures. By analysing these distinct features, we can identify anomalous zones that manifest in other wireline data (resistivity, BHTV). Here we document several examples of the short-wavelength temperature anomalies that are likely attributable to permeable fractures.

PIKE RIVER- AN INEVITABLE DISASTER

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Like all of us, I was shocked to hear about the explosion at Pike but regrettably not surprised. My involvement with Pike started in 2000 when I was asked to review the mining proposal for the Department of Conservation (DoC). What was supposed to be a month’s assignment occupied much of my time for 4 years. DoC’s concern was obviously about the unknown potential impacts on the environment.

I found that there was a profound lack of information supporting the mining proposal despite which a mining permit had been granted.

Over time I identified that the critical environmental issues were significant subsidence and acid mine drainage (AMD) and associated end of mine AMD containment. The geological issues were equally profound; particularly lack of understanding about geological structure, and significantly, the reliance on poor quality coalseam gas data which never changed.

Ultimately I considered the inadequacy of the proposal posed a significant economic risk to the Crown. The solution to the geological risks was the concept of trial mining panels at the NW limit of the mine with mining prior to that limited to the drivage necessary to reach the panel and which had the benefit of providing multiple emergency egress points.

In 2007 I was asked to advise potential investors. I identified the following geological risks; 2k drive through hard-rock; presence of an active fault presenting a zone of considerable in situ stress. A pit bottom with highly gassy coals and an associated risk of outburst, and finally uncertainty about the geological structure and the environmental damage.

My focus here is on geological structure and gas. I am constrained about what I can say about some matters canvassed by the Pike River Royal Commission.

EQRORRSCAN: OPEN-SOURCE PYTHON PACKAGE FOR DETECTION AND ANALYSIS OF NEAR-REPEATING SEISMICITY

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Recent developments in earthquake detection methods have allowed the detection of more events in with reduced effort. Notably, matched-filter detection has been used extensively to study a range of seismological phenomena, including the detection of low-frequency and repeating earthquakes, analysis of aftershock sequences and swarms, explosion detection, and tracking of induced seismicity. Despite the popularity of this method, few open-source implementations of the methodology exist. EQRrorrscan provides an open-source implementation of the matched-filter method, and other methods including subspace detection and so-called brightness detection methods, alongside functions for analysis of detected events. The package is distributed via the Python package index, PyPi, and stored on github. All functions are documented online, with examples for most functions, and tutorials for major functions. All code is tested via continuous integration software to reduce the number of bugs present and increase reproducibility. The core detection routines in EQRrorrscan are optimized for massively parallel
ENHANCING MINE DRAINAGE TREATMENT BY SULPHATE REDUCING BACTERIA USING NUTRIENT ADDITIVES

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Mine influenced water (MIW) enriched in sulphate and metals can pose an ecological threat to receiving environments. Treatment of mine water is often required prior to discharge in order to meet regulated conditions, which may limit pH, solute concentrations, suspended solids, and salinity. Passive treatment systems that utilise sulphate reducing bacteria (SRB) to generate alkalinity and remove contaminants have been used with varying degrees of success. SRB obtain energy by oxidizing organic compounds while reducing sulphate to hydrogen sulphide:

\[ \text{SO}_4^{2-} + 2\text{CH}_2\text{O} \xrightarrow{\text{SRB}} 2\text{HCO}_3^- + \text{H}_2\text{S} \]

This paper investigates lab trials of semi-passive SRB bioreactors. Influent MIW was dosed with two nutrient additives, to provide additional nourishment to the SRB to improve the efficiency of sulphate removal in the reactors.

The reactors neutralise the influent pH 3.2 MIW, and decrease the influent 1300 mg/L sulphate concentration. At a hydraulic retention time (HRT) of 5 days, the control reactors fed MIW removed nearly 10% of the influent sulphate, or 19 mg of SO42- per litre of MIW per day. The reactors that were fed nutrients with the MIW at a 5 day HRT removed an average of 50-60% of the sulphate, or 126 mg of SO42- per litre of MIW per day. At a 2.5 day HRT the nutrient dosed reactors removed up to 45% of the sulphate, corresponding to 356 mg of SO42- per litre of MIW per day.

Addition of nutrients enhances sulphate removal from MIW by SRB, with a six fold increase in the proportion of sulphate removed at a 5 day HRT, and a 10 fold increase in the net sulphate removed at a 2.5 day HRT. This creates opportunity for smaller, simpler, and more effective reactors for MIW treatment. Ongoing trials will optimise HRT, nutrient dose and nutrient composition, and a field trial is planned in 2017.

UNRAVELLING ‘OCEANIC ANOXIC EVENTS’ USING HIGH-RESOLUTION $\delta^{238}$U


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The Mesozoic ‘Oceanic Anoxic Events’ (OAEs) are some of the largest carbon-cycle perturbations of the Phanerozoic. These events are typified by the widespread accumulation of organic carbon (OC) as marine black shales. It is not clear, however, to what extent OAEs represent an increase in preservation potential through restricted circulation, or an increase in organic productivity, where the oxidative degradation of primary producers drives oxygen depletion.

The development of 238U/235U ($\delta^{238}$U) as a proxy for seawater oxygenation has the potential to address these questions because it gives an independent indicator of global redox changes that can be isolated from other processes. The isotope fractionation of U is strongly redox-dependent, whereby the heavier 238U isotope is sequestered into organic-rich sediments under anoxic conditions. Although the application of $\delta^{238}$U in deep-time is being increasingly utilized, published $\delta^{238}$U data for OAE-2 (Cenomanian-Turonian) [1] and the Permo-Triassic Mass Extinction [2] demonstrate high stratigraphic variability that makes it difficult to clearly resolve global-scale redox changes.

We present new $\delta^{238}$U data for OAE-2 carbonate sediments from the European shelf sea and Tethyan Ocean (Eastbourne Chalks and Raia del Pedale platform carbonates) at high temporal resolution (~5–10,000yr). We demonstrate that the high variability previously seen in $\delta^{238}$U resolves into clear systematic trends that show striking coherency between locations and correlation with other OAE-2 chemo-stratigraphic records.

These data show clear changes in global oxygenation on 50-100 kyr timescales, before and, repeatedly, during the OAE-2 positive carbon-isotope excursion (CIE). Comparison to other published records identifies distinct intervals where coupling occurs between silicate weathering and anoxia, demonstrating the link between nutrient flux and productivity as drivers of global anoxia. In other instances, however, no coupling is seen and
altive explanations are required. These datasets highlight an intra-OAE complexity that has not previously been recognized.


A HOT-COLD RELATIONSHIP: HOW VOLCANISM AND GLACIATION BUILT SOUTH CRATER, TONGARIRO VOLCANO

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Summit or flank glaciers are common features of many intermediate composite cones worldwide and, until recently, have been thought of as passive or erosional entities. However, because of a glacier’s contribution to positive topography, it plays an active role in the emplacement of eruptive products, for example, by confining or impounding lava flows. Production of glacial meltwater during an eruption, also influences the distribution and emplacement mechanisms of pyroclastic material.

Glaciovolcanic interactions at andesitic centres are poorly studied, but recent mapping and dating of ice-contact lavas and pyroclastic flows on Ruapehu Volcano, and moraine ridges on Ruapehu and Tongariro have shown that parts of these edifices grew during the last and penultimate glacial periods. Therefore, with no permanent glaciers remaining, Tongariro provides an ideal site for the study of past subglacial volcanic processes, of both explosive and effusive behaviour, on an andesitic cone.

Detailed mapping, logging and lithofacies analysis of Tongariro Volcano’s South Crater, presented here, was undertaken in order to understand the physical eruption and emplacement processes of individual eruptive units. Coarse lapilli tuffs bearing fluidal, glassy, pillowy bombs exhibit numerous sedimentary structures that suggest water-lain deposition and wet sediment deformation. These are unlikely to have been deposited from surges due to the absence of ash-draped dunes and accretionary lapilli. Pillow breccias also indicate eruption into accumulated water. At ~1700-1900 m above sea level, these deposits form or cap a steep-sided cirque with an open mouth at its southern end. To accumulate significant volumes of water on such topography, we infer that the volcano was glaciated during eruptive periods, with the ice forming at least a partial barrier to an englacial, probably eruption-formed, lake. The morphologies of intercalated and cross-cutting coherent bodies also indicate lava impoundment by ice and intrusion beneath a summit glacier, respectively.

ORAL

AMBER BIOTAS FROM ZEALANDIA


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New Zealand has an exceptionally long and continuous record of amber from the Late Cretaceous to the present-day, mainly in situ in carbonaceous deposits ranging from lignite to sub-bituminous coal, but also reworked into a variety of fluvial and marine sandstones and mudstones. The amber comes mainly from coniferous forests dominated by a range of Araucariaceae, for which there is evidence from fossilised wood, leaves and abundant pollen.

Since our initial discovery of an orbibatid mite in amber in 2010, the diversity of organisms has increased to include representatives of 10 orders of terrestrial arthropods including Acari (mites), Araneae (spiders), Pseudoscorpiones (pseudoscorpions), Coleoptera (beetles), Collembola (springtails), Diptera (flies), Hemiptera (bugs), Hymenoptera (bees, wasps and ants), Lepidoptera (moths and butterflies) and Psocoptera (psocids). Other taxa include minute, soft-bodied nematodes and a range of fungi, including sooty moulds. Almost all are new species and many represent the first fossil records at genus and/or family level. For example, the pseudoscorpions represent groups with an otherwise poor fossil record for the entire Southern Hemisphere.

The remarkable preservation also makes it possible to determine ecological interactions, including diet (fungal spores in mite guts); predation (prey in spider webs); parasitism (parasitic wasps); and the role of fungi (as parasites, pathogens, decomposers) and their antiquity. The systematic and ecological diversity of these fossils highlights the potential for amber inclusions to help reconstruct the ecosystems associated through time with Araucarian forests of Zealandia.
THE HAAST SCHIST – A POLYGENETIC, POLYMETAMORPHIC COMPOSITE

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Detrital zircon analysis has shown that the simple Caples-Rakaia protolith subdivision of the Haast Schist is no longer tenable. Cretaceous metasediments (~108 Ma) overlying the Pounamu Ultramafic Belt ophiolite in the Whitcombe River are in tectonic contact to the east with the Triassic Rakaia terrane. Cretaceous age metasediments (108-138 Ma) also extend 150 km southwestwards from Franz Josef Glacier to the Arawhata River. Volcanogenic Triassic metasediments in the Jackson River, west of Arawhata, may belong to the Caples terrane.

Jurassic-Cretaceous Aspiring terrane metasediments occur in the Rees (156 Ma) and Matukituki Rivers (126 Ma). At Haast River to the north, correlitive Aspiring assemblages have yielded Cretaceous-Jurassic detrital zircon ages, with Carboniferous-Triassic components (Rakaia terrane s.s.) to the east. In a multiply-deformed Haast Schist, the geometry of arrangement of different-aged components is likely to be irregular and more analyses are clearly required to refine the age pattern. However, the apparent westward younging and Cretaceous age of some Haast Schist components requires major revision either to the accretionary/deformational history of New Zealand’s Eastern Province or to its subsequent tectonic modification.

Zircons from the highest grade Alpine Schists have metamorphic overgrowths sufficiently coarse for LA-ICP-MS analysis. Samples analysed to date have metamorphic ages of 66-73 Ma, similar to metamorphic monazite and anatectic pegmatite ages previously documented, but post-dating the Otago Schist metamorphism by almost 100 Ma. The proposed amalgamation of Caples and Torlesse terranes, including intervening Aspiring (Waipapa?) metasediments, in the Jurassic cannot have taken place if some of these sediments are of Cretaceous age. Either the western Alpine Schist protoliths represent a separate Creataceous terrane accreted after Otago Schist metamorphism, or a significant late Cretaceous underthrusting of Pahau and Kaweka terranes has taken place, but leaving apparently no trace in contemporary Cretaceous sedimentation on the East Coast of the South Island.

ORAL

THE SIGNIFICANCE OF THE MAGMATIC PLUMBING SYSTEM, DEGASSING, AND MAGMA MINGLING ON THE PYROCLASTIC DENSITY CURRENT HAZARD AT MT RUAPEHU, NEW ZEALAND

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Pyroclastic density currents (PDCs) are a major volcanic hazard. Understanding the types of PDCs that have occurred at a volcano and the processes leading to their generation is essential for hazard assessment. At Mt. Ruapehu, 12 young deposits on the volcano’s eastern flanks show that PDCs have frequently occurred over the past ~13.6 ka. We present results from a new MELTS-based method for characterising the pressure-temperature regime of Ruapehu’s magma storage system, and combine these with textural studies to investigate the processes leading to PDC generation. Initial results show that PDCs have occurred across most of Ruapehu’s known eruptive styles, and that magma storage depths, temperatures, and the proportion of magma mingling have strongly influenced the PDC characteristics. These factors control the amount of pre-eruptive degassing, clast densities, and the bulk density of the erupting mixture. Large column collapse PDCs accompanied Ruapehu’s largest plinian eruptions from deep (3.7-5.5km) gas-rich magmas (Units 1-5), with PDC generation influenced by both vent widening (Unit 1) and also densification of the erupting mixture through mingling with denser secondary melts (Unit 4). Hazardous PDCs also occurred from smaller column collapse and ‘boiling over’ style eruptions (Units 8-10) of shallow (<2km) gas-poor magmas similar to Ruapehu’s modern-day magma system. A third kind of PDC (Units 6-7) was generated on ≥2 occasions where hot, slightly degassed material accumulated as spatter on steep slopes and then repeatedly collapsed to form PDCs. Magma mingling occurred during many of Ruapehu’s PDC-forming eruptions, and appears to have been a trigger for eruption of otherwise stagnant, degassed magma that consequently may have been more prone to generating PDCs due to the higher pyroclast densities. The ubiquity of magma mingling at Ruapehu, as well as the role of shallow magma degassing, are therefore important considerations when assessing the PDC hazard at this volcano.

ORAL
UNDERSTANDING THE RISK INFORMATION NEEDS FOR NEW ZEALAND’S CDEM SECTOR

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Recent shifts in thinking catalysed by both international and local factors, such as New Zealand signing the Sendai Framework for Disaster Risk Reduction 2015 - 2030, has seen a broader debate around the CDEM sector in New Zealand and an increased emphasis on CDEM’s role within natural hazard risk management. This poster presents initial results of work being undertaken as part of my PhD project. Five focus group sessions were facilitated with CDEM Groups across New Zealand aimed at better understanding the needs of the CDEM sector for natural hazard risk information, including earthquake risk. The focus group sessions were recorded, transcribed and thematically analysed with three main themes emerging: The role of CDEM within and across council; risk information and modelling drivers and needs; and risk information pathways and sources. Understanding the natural hazard risk information needs for New Zealand’s CDEM sector is significant because it can inform and improve CDEM policy and procedure and in turn, develop more resilient communities.

THE MANY USES OF GPS DATA IN NATURAL HAZARD MONITORING

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GPS data are becoming more and more important in natural hazard monitoring. From quick assessment of the static displacement caused by moderate to large earthquakes, to volcano and landslide monitoring, GPS data from ground networks are now widely used by the scientific community. Nevertheless, their potential as a monitoring tool is still not fully implemented at a routine level in natural hazard monitoring centres (see also C. Mueller et al.).

The GeoNet and PositioNZ networks, operated by GNS Science in collaboration with Land Information New Zealand (LINZ), comprise the New Zealand national continuous GNSS (Global Navigation Satellite System) network. GNSS is a relatively new acronym, used to describe the multi-constellation satellite system that includes the well know USA satellite constellation (GPS) and more recent constellations developed by other countries (Russia, Europe, Japan, India, China). “Full-GNSS tracking” has been recently enabled on all the LINZ sites, and there is now a core network of 40 ground receivers tracking 5 different satellite constellations across New Zealand. Full GNSS data are already increasing the accuracy of real time positioning, and will improve also daily positioning once scientific software will be ready to process them.

The 200 GeoNet/PositioNZ sites are continuously recording the numerous geologic events occurring in New Zealand. In this presentation we will give an overview of the most interesting ones from the past year, such as slow slip events, earthquakes and volcanic eruptions. At GeoNet, we are now providing an easy access to daily processed GPS data through a new web service named FITS (http://fits.geonet.org.nz), so anyone interested in studying present-day surface deformation in New Zealand will be able to do so without having the burden of processing raw GPS data.

OREAN SPREADING AND CONTINENTAL RIFTING IN ROSS SEA, WEST ANTARCTICA

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The initial process of rifting of continental lithosphere is not well understood and has been the focus of research for many years. Analysis of marine magnetic anomalies indicates relatively slow extension between East and West Antarctica from about 43 to 26 Ma that, in the Ross Sea, is focussed along the its western margin. Magnetic anomalies of this age associated with new ocean crust formation in the Adare Basin off north-western Ross Sea, can be traced directly into the Northern Basin that underlies the adjacent morphological continental shelf, implying a continuity in the emplacement of oceanic crust. Modelling of the steep gravity gradients along the margins of the Northern Basin, particularly in the east, suggests that little extension and thinning of continental crust occurred before it ruptured. Immediately south of this and offset to the west, the Victoria Land Basin has formed by stretching and thinning of continental crust, similar to that found elsewhere and in modelling studies. Under the Ross Ice Shelf, extension is small and may be of a
THE SOUTH CAMPBELL PLATEAU SUBDUCTION MARGIN – A NNE FACING LATE CRETACEOUS SUBDUCTION SYSTEM AND POTENTIAL BACKSTOP TO SSW DIRECTED HIKURANGI PLATEAU(LIP) SUBDUCTION.

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Satellite gravity data of the southern Campbell Plateau, offshore New Zealand, reveals a set of semi-parallel, WNW–ESE oriented ridges and troughs which when viewed in seismic profiles across the anomalies reveal a subduction interface, accretionary prism, forearc high, forearc basin and volcanic arc high.

Campbell Island sits astride the volcanic arc gravity high which extending across 75% of the southern Campbell Plateau intersects the western plateau margin 20 km south of Auckland Island.

Interpreted seismic horizons imply that the South Campbell margin was active in the Late Cretaceous. Late Cretaceous basement granites (>96 Ma), found on Auckland Island, support this age interpretation. Both Auckland and Campbell Islands have widespread Cenozoic volcanism exposed.

The paleo-South Campbell subduction margin parallels, but opposes, the pre 105 Ma Gondwana margin prior to jamming of Hikurangi Plateau Large Igneous Province subduction, rotation of the offshore Gondwana margin to an east-west orientation and subduction cessation ca. 100 Ma. Multiple fault zones, which terminate at the south Campbell subduction margin, are interpreted to have formed by transfer of transtensional motion from the Wishbone Ridge into the Gondwana interior prior to Antarctica/New Zealand sea-floor spreading c. 84 Ma.

The interpreted age of the South Campbell subduction, combined with interaction with the major transtensional faults which traversed the Campbell Plateau, implies the subduction margin was active synchronously with, and opposed to, Hikurangi Plateau subduction 110-100 Ma and potentially through to c. 85 ma when extension transferred into the Gondwana interior ceased. The extreme compressive forces associated with shallow subduction of the Hikurangi Plateau beneath the Gondwana super-continent will have been relieved by the development of an opposing subduction backstop within the super-continent.
The relationship between confidence and experience was evaluated and shown that prior experiences (overall) did not influence the students’ self-reported communication confidence. However, a closer look at the survey items indicated that professional experiences communicating (e.g., presenting at a conference) was a predictor of higher confidence. This research allows us to understand how communication training can be used to improve students’ skills and what factors influence their improvement. Further research will evaluate how students value different communication opportunities (curricular and extra-curricular).

ORAL

EVOLUTION OF THE MULTIPLY-METAMORPHOSED BROUGHTON ARM META-PERIDOTITE IN FIORDLAND

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The Broughton Arm Meta-peridotite occurs as a two dominantly dunitic pods, roughly 200*150 m and 150*50 enclosed in Deep Cove Gneiss amphibolites and quartzofeldspathic gneisses in the mountains above Broughton Arm and Vancouver Arm in western Fiordland. This unit was recognised by QMAP Fiordland mapping program but has not been studied until now. Petrographic and scanning electron microscope-EDS examination indicates that the ultramafic rocks have been metamorphosed at least twice, with the first phase forming olivine + Cr-bearing magnetite + orthopyroxene. Olivine Mg\# varies from 93 to 77 in different samples, and reflects heterogeneity in the protoliths. The age of this metamorphic assemblage is unknown but is tentatively correlated with the 330 Ma metamorphic event documented in nearby Vancouver Arm (Schwartz et al., 2016). The dry metamorphic assemblage has been subsequently partially overprinted by a metamorphic event that developed Mg-chlorite + tremolite + serpentinite and a second generation of magnetite. This hydrous event is tentatively attributed to deformation accompanying (or occurring just after) emplacement of the vast Western Fiordland Orthogneiss batholith in the Early Cretaceous. On the basis of whole rock chemistry (Mg\#, Mg/Si, moderate Fe content), the Broughton Arm Meta-peridotite protolith was most likely an ultramafic cumulate that was emplaced as a sill, rather than a slice of the Fiordland sub-continenal lithospheric mantle as per the Anita Peridotite in Northern Fiordland (Czertowicz et al., 2016). The presence of this metamorphosed ultramafic unit provides evidence for (probable) Paleozoic high-temperature melting of the Fiordland mantle.


PYRITE GEOCHEMISTRY AND TEXTURES IN THE EPITHERMAL AU-AG MINERALISATION AT WAIHI

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The Waihi epithermal system is a low sulphidation epithermal system that hosts one of the highest grade ore deposits in the Southern Hemisphere. Various sulphide minerals are present within the system, including pyrite (FeS\(_2\)), one of the most abundant sulphide minerals on Earth. Pyrite is unique due to its crystal structure enabling incorporation of other elements of similar mass and size to sulphur. The presence or absence of these elements reflects the changes in the hydrothermal fluid chemistry throughout the growth of the grain. The textural variations in the grains indicates growth, interruption, dissolution, then regrowth. The chemistry of each different zone, coupled with stages of growth, indicates the chemical influences on the pyrite in the Waihi system at that time.

The use of petrographic, EPMA and LA-ICPMS analyses demonstrates distinctive textural zones within pyrite grains, varying in chemistry and appearance. Some zones contain elevated concentrations of Au and Te, and varying concentrations of Fe, S, Cu, Pb or Zn. The textural observations indicate pyrite growth was interrupted by periods of dissolution before the grain continued growing. Grains begin growth with low trace element concentrations. The highest concentrations of trace elements occur in the middle phase. Inclusions are rich in Pb, Ca, Se, Zn, Au and Ni, and cause the ‘dirty’ texture observed in grains. The distinctive textural features are attributed to the varying concentrations in Au, As, Cu and Te. The presence of Te suggests a single source of magmatic fluid, released in pulses, or periodical dilution of the magmatic fluid by meteoric waters during the system’s evolution, at 5-7 Ma.
This research showcases the dynamics of hydrothermal fluid flow at Hikurangi, revealing whether gold-forming hydrothermal systems are “normal”, reflecting typical hydrothermal fluid flow, or whether they are the result of gold “supercharged” hydrothermal fluid rising from depth. ORAL

FEEDBACK BETWEEN FLUID FLOW AND MECHANICS IN THE HIKURANGI SUBDUCTION ZONE

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Elevated fluid pressures in subduction zones affect mechanics by lowering effective stresses, and thus reducing brittle yield strength. Because elevated fluid pressure results from the inability of fluids to escape in response to mechanical loading and/or dehydration reactions, fluid flow mediates both porosity loss and the evolution of fault and sediment strength. Transient permeability changes from fault slip or creep at depth can also affect fluid flow and pressure on or near the subduction interface. We explore these complex feedbacks for the Hikurangi subduction margin, where the interface behaviour varies substantially along-strike. In the north, a steep wedge taper formed by episodic seamount subduction lies above an interface that creeps interseismically to depths of <15 km, while in the south, the wedge is wider, with a lower taper, and the subduction interface is interseismically locked to depths of 30-40 km. Using a numerical model coupling fluid flow and deformation, we relate transient changes in fluid overpressure to interactions between effective stress, fault slip, porosity reduction, fluid generation and flow. Maintenance of high porosity in the subduction channel provides a mechanism for fluids to be transported to depth. If faults are permeable pathways, drainage leads to fluid pressures in the wedge interior that are near hydrostatic, while higher fluid pressures persist in front of the wedge where permeable faults have not yet formed. However, if creep seals off permeability at depth, some regions of the wedge and subducting sediment channel remain overpressured. Seamount subduction generates a splay fault that releases fluid transiently during wedge evolution. ORAL

DETECTING HAZARDOUS NEW ZEALAND FAULTS AT DEPTH USING SEISMIC VELOCITY GRADIENTS

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Many large damaging earthquakes occur along previously unmapped faults, because it is difficult to locate faults that have slow average slip rates and weak surface expression. We test whether recently collected seismic wave velocity data from New Zealand can be used to map unknown faults at seismogenic depths. We show that there is a strong statistical correlation between seismic velocity gradients deep in the earth’s crust and known active faults. Most significantly, in the region of good data coverage, all seven of the post-1840 M_w>7 upper crustal earthquakes in New Zealand occurred along mid-crustal seismic velocity gradients. We interpret these as rheological discontinuities that act as preferred sites for fault reactivation because strength contrasts are enhanced there. Many of the seismic velocity gradients coincide with the faulted edges of strong blocks within basement rocks, correlating with active- and in some cases unmapped- faults that may reactivate and rupture in infrequent earthquakes. We propose that seismic velocity gradients provide a means to map potentially hazardous undiscovered faults at mid-crustal depths, in advance of their activation in future damaging earthquakes. ORAL

POSTER
DEEPWATER CANYON INCEPTION AND CENOZOIC DEFORMATION IN THE SOUTHERN NEW CALEDONIA TROUGH (TASMAN FRONTIER AREA, SW PACIFIC)

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The New Caledonia Trough (NCT) is a deepwater basin that extends >2000 km from New Zealand to New Caledonia. Originally thought to originate from Cretaceous extension with little or no Cenozoic deformation, recent studies have shown that it underwent a significant Eocene tectonic phase. Along with subsidence, this phase includes contractual deformation, uplift/erosion of ridges and syntectonic depocenter creation. The timing of these processes and hence their stratigraphic implications remain poorly constrained.

This study is based on multibeam data, seismic profiles and rock samples from the TAN1312 and TAN1409 voyages conducted onboard R/V Tangaroa. We focused on the southern NCT, on its western margin, where these new data underpin a direct link between deformation of Paleocene units, their erosion and deposition within the NCT. Indeed, Paleocene strata are affected by clear reverse faulting associated with prominent folds cropping out on the seafloor and diverting a submarine canyon. This deformed unit is significantly eroded and is overlain by an interval containing cliniform or chaotic high-amplitude reflectors, localised below the basinal onlap. This unit has a fan-shaped geometry and is thickest at the mouth of the present day canyon. This suggests that the canyon was initiated and active during and after deformation. This unit, interpreted as a syntectonic turbidite fan, is overlain by an interval of high-amplitude continuous reflectors interpreted as axial turbidites and hemipelagites that onlap low-amplitude semi-continuous wavy reflectors interpreted as slope bedforms alternating with pelagic sediments. Axial turbidites are mainly sourced from the Taranaki region >500 km distant. Slope bedforms likely originate from supercritical downslope gravity flows, potentially sourced from intraplate volcanoes and/or local slope failures.

These data provide new insights into the sedimentary processes involved in a deepwater basin remote from terrigenous sources, and into the Cenozoic tectonic phase that led to erosion and deposition in the NCT.

ORAL

THE GEOTECHNICAL CHARACTERISTICS OF THE EAST COAST BAYS FORMATION, AUCKLAND

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The engineering geology of the Auckland urban area is of increasing importance due to planned transportation routes and residential subdivision. The area is mainly underlain by Miocene East Coast Bays Formation (ECBF) of the Waitemata Group, often overlain by the Quaternary Tauranga Group deposits. Coastal cliff exposures of the ECBF provide an excellent opportunity to understand and develop models of the geotechnical characteristics of the formation. This has been attempted in part in the past, but the present study seeks to develop a more complete understanding by evaluating the engineering geological properties of the ECBF over a wider area.

The sites chosen for the investigation are all in the northern east coast beaches of the Auckland region. These included: Army Bay, Stanmore Bay, Waiaku Beach and Churchill Reserve, and the approach included a range of laboratory-based and field-based investigations. The latter included the application of several rock mass classification systems. The former involved a range of strength and rock indices, such as porosity, p-wave and s-wave, point load strength, slake durability, and Shore Hardness tests. Following this, kinematic analyses of likely failure mechanisms was undertaken using Rocscience Dips software.

Specific issues identified important for engineering geology include conglomerate lenses such as the Parnell Volcanoclastic Conglomerate, and marked strength contrasts within the East Coast Bays Formation including strongly cemented bands and poorly-cemented sand units. Hence, the variable rock mass conditions identified will present future challenges for certain tunnelling methods and excavation projects. The variability outlined is important because at present, rock strength values are often extrapolated across different rock units, when the geotechnical and geomechanical picture is much more complex.

POSTER
The highly specialised, living, South Asian River Dolphin *Platanista* is of long-uncertain affinities. Related long-jawed fossil marine dolphins (*Platanistidae* - *Zarhachis, Pomatodelphis*) range back to the middle Miocene, but older origins are problematic. A dolphin skull from Awamoa Creek, North Otago, now helps to link younger *Platanista*-like forms with more-archaic Oligocene taxa from New Zealand.

Dolphin OU 22670 is from a float concretion of Mount Harris Formation, probably Altonian (early Miocene) and marine outer shelf-slope. Its skull is reminiscent of *Squalodelphis* and *Notocetus* from the east-equatorial Pacific and Atlantic: high, with a narrow frontal on the vertex and a medially projecting nasal. Each maxilla has a raised protuberance, possibly equivalent to the pneumatic acoustic crests of later Platanistidae. A small bony orbital fossa may mark a lobe of acoustic sinuses. The roof of the temporal fossa for jaw muscles has a frontal window. No teeth are preserved.

We included OU 22670 and local Oligocene dolphins (*Waipatia, Otekaikea, Awamokoa*) in a large-matrix morphological cladistic analysis of modern and fossil odontocetes. Results show this base-to-top succession: *Awamokoa, Waipatia*, and *Otekaikea*, then OU 22670, and finally *Squalodelphinidae-Platanistidae*; all comprise the major group Platanistoidea. However, other researchers have produced different phylogenies (judging by the position of *Waipatia*), reflecting choice of taxa and characters, phylogenetic software, character weighting and ordering, inclusion of molecular data, and imposition of constraints. Results may also reflect the pull-of-the-Recent, and limited sampling of an explosive mid-Cenozoic radiation.

The Awamoa fossil is the first New Zealand dolphin recognised with specialised maxillary protuberances similar to *Squalodelphis* and relatives. More specimens might be expected; other concretions of Mount Harris Formation from Awamoa include unprepared dolphin remains. New Zealand’s earliest named fossil dolphin, *Phocaenopsis mantelli*, is also from Awamoa, but comprises only a humerus, not comparable with OU 22670.
AZIMUTHAL ANISOTROPY OF THE HIKURANGI MEGATHRUST IN THE REGION OF SHALLOW SLOW SLIP

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In 2014, ocean bottom seismometers (OBS) and absolute pressure gauges (APG) from the HOBITSS deployment captured a relatively large and shallow slow slip event (SSE) offshore of the North Island, New Zealand. The event is one of the best recorded shallow SSE to date. Because the SSE occurred only kilometers (~2-15) from the seafloor instrumentation, the dataset represents one of the best chances to date for observing changes in seismicity and physical parameters that govern seismic wave propagation before, during, and after the SSE. In this work, we focus on polarization anisotropy of surface waves. We have retrieved 9-component daily Green's Functions from ambient noise correlograms of 3-component OBS throughout the recording period. The daily cross-correlation functions show high signal to noise ratios and remarkable mutual consistency, providing a promising approach to temporal monitoring. We will present results of an analysis of the complex phase of these signals that suggests the ambient noise wavefield between 0.2 and 1 Hz changes during a SSE. Possible mechanisms for this change are the disestablishment of a coherent wavefield due to radiation from tectonic tremor or a change in stresses along the megathrust or in the overriding plate.

RAPID ACCELERATION OF A SLOW RUPTURE CONTRIBUTED TO STRONG GROUND MOTIONS IN THE 2011 CHRISTCHURCH EARTHQUAKE

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Many destructive earthquakes occur in slowly deforming regions away from plate boundaries. As these earthquakes occur less frequently than those located near to plate boundaries, relatively few observations have been made in the deadly ‘near-field’, or the nearest tens of kms from the epicenter. Earthquakes in areas of the crust which rarely experience earthquakes are thought to be strong, with fast ruptures, high amounts of released stress, and stronger than average ground shaking. Here we show that this model is at least sometimes, not correct. The Mw=6.2 Christchurch earthquake of February 22, 2011 occurred in a low-strain rate region approximately 140km from the plate boundary and produced at least 2.2g accelerations in the near-field. Previous work has suggested that aftershocks in the sequence have higher static stress drops than those measured elsewhere. Numerical experiments have shown that stress drop is proportional to rupture velocity (Vr). In this study, we use a back projection approach to show that the rupture velocity of the event was variable, starting slowly before reaching a maximum of ~0.9 * shear-wave velocity (Vs) near the end of the rupture process, when the rupture was within about 2km of the ground surface and Vs is substantially less than at the origin depth. This result has implications for estimates of source parameters, including the rapidly developing field of dynamic rupture modeling. The effect also provides a dynamic example of the rupture process of shallow buried thrust faults, in which overlying sediments halt the rupture within a few km of the surface.

SYSTEMATICS AND PALEOECOLOGY OF OLIGOCENE CORALS FROM SOUTHERN NEW ZEALAND

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Corals are important components of many marine ecosystems, both modern and ancient. Fossil corals from New Zealand have been reported in Squires’s important monograph, and more recently by Cairns and others. This research considers the taxonomy and diversity of Oligocene corals from the southern South Island. Fossils were collected from 3 localities: Hakataramea Quarry and Lake Aviemore in South Canterbury, and Cosy Dell farm in Southland. Corals represent 10 families of alcyonarians and scleractinians: Pennatulidae, Melithaeidae, Oculinidae, Rhizangiidae, Caryophylliidae, Turbinoliidae, Flabellidae, Dendrophylliidae, Poritidae and Astrocoeniidae. In total, the assemblages contain 17 species in 15 genera; they include 6 previously undescribed species of Melithaea, Peponocyathus,Notocyathus, Astrangia, Goniopora and Astrocoenia. Goniopora and Astrocoenia are the first probable hermatypic (reef-forming) coral species of Oligocene age from southern New Zealand. Corals from Hakataramea Valley occur in a glauconitic packstone (Otekaike Limestone), particularly in a high-diversity mid-shelf shellbed (“Pratula horizon”). The presence of Stephanocyathus mantelli and Trochocyathus papakurensis suggest average bottom temperatures of 10°C, although warmer temperatures are possible (as indicated by e.g. the
brachiopod Lingula and the bivalve Spondylus). Corals from Lake Aviemore, from the richly glaucositic Kokoamu Greensand, are congeneric with those of Hakataramea, despite the different facies. Corals from the Cosy Dell locality are also from highly diverse molluscan-rich strata. The presence of hermatypic coral species at this locality indicates that water temperatures were at minimum 18°C, several degrees warmer than current mean annual sea surface temperatures in southern New Zealand. These hermatypic species must also have lived in the photic zone, and likely lived in waters down to 20-40m depth. This, and the facies and wider assemblage, indicates that the Cosy Dell locality was a shallow inner shelf setting, in comparison to the deeper-water Hakataramea and Aviemore localities.

ORAL

HIGH-RESOLUTION δ¹³Corg AND TOC RECORDS FOR THE PALAEO-PACIFIC OCEAN DURING ‘OAE-2’: INSIGHTS INTO THE GLOBAL EXTENT OF OCEAN ANOXIA

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In contrast to the generally oxygenated conditions in the oceans today, the Oceanic Anoxic Events (OAEs) of the Mesozoic Era caused extreme perturbations to ocean chemistry and are commonly associated with biological turnover. OAE-2 (~94 Ma) represents the most severe and spatially extended of the OAEs. In particular, a number of studies indicate oceans deficient in oxygen in the Northern Hemisphere, although very few investigations address the extent of anoxia in the palaeo-Pacific Ocean. Here, we present the first high-resolution δ¹³Corg and total organic carbon (TOC) datasets for part of the palaeo-Pacific Ocean during OAE-2, sampled at two sites in New Zealand.

The δ¹³C record reveals a broad positive carbon-isotope excursion through OAE-2, allowing detailed correlation with sections from the Northern Hemisphere. The new records provide clear evidence of the onset of OAE-2 as well as the first documentation from the Southern Hemisphere of the carbon-isotope expression of the ‘Pleus Cold Event’ (PCE), widely inferred to represent a short-term return to globally oxygenated bottom-water conditions during OAE-2. Moreover, the occurrence of black-shale facies, typical for the Tethyan, proto-North Atlantic and equatorial palaeo-Pacific Oceans, are absent in New Zealand where, instead, marine Fe-oxide-rich ‘red beds’ were locally deposited. The generally low TOC values in the New Zealand sections is indicative, for this sector of the proto-Pacific Rim, of water masses whose degree of oxygenation intensified into the PCE, coincident with a stepwise decrease in TOC. Relatively oxygenated conditions at the sea floor were maintained throughout the OAE, suggesting an early recovery to pre-event conditions. Despite these findings, the New Zealand sections also reveal the partial collapse of benthic ecosystems during OAE-2, an observation that remains unexplained.

ORAL

MOLLUSCAN PALEOECOLOGY OF THE SHALLOW MARINE CHATTON FORMATION, SOUTHERN NEW ZEALAND

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Chatton Formation is a late Oligocene unit comprising fossiliferous shallow marine sandstones, sandy siltstones, greensands, grainstones and conglomerates. The Formation was studied at twelve localities in Southland and southwest Otago: Thompson’s Farm and Muddy Terrace (Freshford), Coalbrook, Wendon Valley School, Wendon Creek, Wendon Valley, Chatton, Charters Road Slump, Copelands Pit, Cosy Dell Pit, Hedgehope Stream and Brydone. Exposures are discontinuous and thin, with one to two facies exposed, hampering correlation. Molluscs are exceptionally diverse with >100 described and >300 undescribed species. Molluscan assemblages include life and death components (autochthonous, para- autochthonous). Assemblages are somewhat localised and facies-controlled, although some mollusc taxa are widespread: families Glycymerididae, Pectinidae, Carditidae, Veneridae, Turritellidae, Calyptraeidae, and Naticidae, and the genera Limopsis, Austrofusus and Amalda. Shellbeds represent a variety of depositional environments from storm or transgressive lag deposits for conglomerates to quiet shelf environments for greensands. The formation was probably deposited during a transgressive systems tract. Auctecology of fossils suggests water depths between intertidal and
mid shelf (100 m). The shallow water taxa (including the brackish potamid *Terebralia*) and the presence of abundant plant debris indicate that basement terranes (Murihiku, Maitai and Caples) were variably emergent in the field area throughout the late Oligocene. Dating with foraminifera and molluscs reveals that the Chatton Formation is Duntroonian in the north and Waitakian in the south of the field area. This evidence, coupled with dating of the underlying lower Gore Lignite Measures and Pomahaka Formation, indicates that there was a rapid, short-lived transgression which formed a shallow Chatton seaway during the Duntroonian. This seaway rapidly regressed in the Waitakian, possibly due to falling global sea levels coupled with rapid influx of sediment caused by the prograding river system that deposited the overlying upper Gore Lignite Measures.

**INVESTIGATING GROUNDWATER-INDUCED SETTLEMENT AT THE WATerview CONNECTION PROJECT, AUCKLAND**

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The construction of tunnels often results in ground settlement in the area above and adjacent to the tunnel alignment. The NZ Transport Agency’s Waterview Connection project involves the construction of 4.8 km of motorway to complete Auckland’s Western Ring Route. The project includes 2.1 km of ‘undrained’ driven tunnels as well as drained cut-and-cover tunnel and tunnel portals, including the 0.4 km long Southern Approach Trench (SAT), a temporary excavation up to 29 m deep. Ground settlement associated with the tunnel development is typically generated by three separate sources: (1) mechanical settlement of the ground due to the physical excavation of the material for the driven tunnel; (2) mechanical settlement of the ground due to the physical movement of the cut-and-cover and the portal retaining walls; and, (3) consolidation of the ground due to the extraction of groundwater. This study focuses on groundwater-induced settlement in the vicinity of the SAT, which is within the Oakley Creek paleo-valley, with complex topography, geology and hydrogeology. The SAT is excavated through basalt lava flows, Quaternary alluvium, residual soils and Tertiary-age interbedded sandstones and siltstones of Waiomata Group East Coast Bays Formation (ECBF). The low storativity of the geological units, combined with structural controls (paleo-valleys and faults), have resulted in drawdown effects up to 230 m from the SAT in some areas. Nevertheless, despite more than 3 years of groundwater drawdown, there has been negligible consolidation settlement or stream depletion that could be attributed to construction. This project investigates groundwater level and settlement monitoring prior to, throughout, and following construction, to explore why settlement effects have been minor.

**DIVERSE PliocENe MACROFossil PLANT AND Fungal ASsEMBLAGES FROM AUCKLAND**

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Estuarine sediments from Auckland, thought to be Pliocene in age, are yielding rich and diverse assemblages of fossil plants and fungi. Fossils include fruits (and stones, seeds and cones), leaves with cuticle, wood, amber, pollen, spores and rarely preserved bracketfungi basidiocarps. Many macrofossils retain a three-dimensional structure with organic preservation ideal for investigating using macro- and micro-morphological methods. Fossil fruits are a taxonomically diverse component of these assemblages. Fruit morphotypes sharing affinities with locally extinct groups include Vitaceae, Menispermaceae, Casuarinaceae, *Brassospora*-type *Nothofagus* and an uncertain genus of Cupressaceae. Fruit morphotypes that may share affinities with extant NZ taxa include *Prumnopitys*, *Passiflora* and *Elaeocarpus*. The leaf flora includes *Nothofagus* (*Brassospora*-type?), *Sapindaceae*, *Laureaceae*, *Myrtaceae*, *Podocarpaceae*, possibly *Agathis* and other conifers, ferns and monocots. Fossil wood includes tree ferns, common *Nothofagus* and possible *Agathis* with associated amber. Macrofossil fungi include basidiocarps of Ganodermataceae which sometimes retain portions of host wood. The microfossil floras are dominated by pollen of *Nothofagus cranwelliae* (locally extinct *Brassospora*-type) and *Cyathaea* spores.

The sediments yielding these fossils include terrestrial (fluvial, muddy river), estuarine and near-shore depositional environments. The depositional age of the fossiliferous sediments is not well constrained using palynological methods. However, some
MODELLING UNCERTAINTY IN EARTHQUAKE SOURCES AND IMPLICATIONS FOR USES OF THE NATIONAL SEISMIC HAZARD MODEL

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Since the mid-1980s, the National Seismic Hazard Model (NSHM) has been developed using probabilistic seismic hazard assessment (PSHA) techniques. PSHA is an algorithmic technique and recent models have been constructed by developing an earthquake source model by combining component models based on earthquake catalogue data and active fault data; these models forecast the size, location and magnitude of future earthquakes. These sources are generally assumed to be random and independent. To forecast the hazard (e.g., ground shaking), the source model is coupled with ground-motion prediction equations (GMPEs). In recent years, the international community has had considerable progress and improvement in understanding of the uncertainties inherent to GMPEs, but less attention has been given to uncertainties in modelling of the earthquake sources. In our current work, we are investigating how uncertainties in some of the fundamental assumptions in the NSHM propagate through to the end uses of the model. One major end-use is in the national building design standards. Some of the uncertainties we are exploring are those resulting from a paucity of earthquake occurrence data (e.g., in the Auckland region) and from different methods that can be used to model the seismic sources. Additionally, seismic sources are generally assumed to be a stationary Poisson process and earthquake clustering is ignored. A key component of our work is to understand how the uncertainties affect the spatial resolution of the model and how we may optimise this spatial resolution for the downstream applications of the model. For example, current design standards are directly coupled to the output of the NSHM without a buffer inbetween. It is likely that including these uncertainties and determining an optimal risk-based spatial resolution of the model will lead to more robust estimates of the design standard and also more robust estimates of risk for use by industry.

ORAL

PETROLOGY AND GEOCHEMISTRY OF TWO GROUPS FORMING THE SWINBURN VOLCANIC COMPLEX, WAIPIATA VOLCANIC FIELD, CENTRAL OTAGO, NEW ZEALAND

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The Miocene Waiapita Volcanic Field, South Island, New Zealand, is an eroded Miocene volcanic field (c. 25 – 10 Ma), belonging to the Dunedin Volcanic Group. The largest Waiapiata volcano is represented by the little-known Swinburn Volcanic Complex, in Central Otago. Here we present new petrographic and geochemical analyses of two groups of rocks forming the Swinburn complex: an older Swinburn Plateau group (15.6 +/- 0.6 Ma) and a younger Northern Flows group (13.4 +/- 0.3 Ma). Plateau rocks are basalts (45.2 < SiO₂ wt % < 47.8), with relatively low total alkalis (Na₂O + K₂O = 2.0 – 3.7 wt%); Northern group rocks are basanites (42.5 < SiO₂ wt % < 44.2) with high total alkalis (Na₂O + K₂O= 5.2 – 6.9 wt%). Plateau lavas present a peculiar ophitic texture. The mineralogy of the Northern lavas is like that of the Plateau rocks, but texturally they are holocrystalline, porphyritic rocks consisting of microphenocrysts of olivine, clinopyroxene in a microcrystalline groundmass. Major element compositions show that fractionation didn’t play a significant role for either the Plateau or the Northern group. Incompatible trace elements display different trends. Plateau lavas have significantly lower HFSE, REE and LILE concentrations than do the younger Northern group ones. These different trends suggest that mantle-source compositions were probably the same for both Swinburn groups but with different degrees of partial melting. Nb, K, Sr, P, Zr, Eu and Y anomalies are similar to those of peridotite-bearing lavas collected from volcanoes elsewhere in the Waiapita Volcanic Field and from Dunedin Volcano. This supports a mantle source with a single broadly similar composition as the source for all volcanoes belonging to the wider Dunedin Volcanic Group, which extends over an area of more than 5000 km², at distances of about 200 km to immediately east from the plate-bounding Alpine Fault.

ORAL
LIQUEFACTION INVESTIGATION IN A DUNE SETTING OF THE CANTERBURY PLAINS

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The coastal dune setting of Christchurch was affected by liquefaction during every major earthquake of the 2010-2011 sequence and the 2016 Valentine’s Day earthquake. Our study contributes to understand the effects of liquefaction in the coastal dune environment. Three study sites were considered: Wainoni and QEII parks on the Christchurch Formation Dunes and Featherston Avenue Reserve on the Kairaki dune complex in North Canterbury (~25 km north of Christchurch). Our method involved: 1) detailed liquefaction mapping using DEMs derived from LIDAR, and post-earthquake ortho-photos; 2) Bidimensional and 3D GPR surveys; 3) trenches to expose the stratigraphy and investigate the liquefaction features; 4) piston cores and Vibrocores to investigate deeper liquefaction and stratigraphy; 5) samples for radiocarbon dating, grain-size analysis and thin-section analysis.

Our results show that the coastal environment is more prone to severe liquefaction of near-surface deposits than the alluvial setting, owing to a shallower water table and lack of fines. In general, liquefaction features at the coastal sites were characterized by sand dikes up to 1 m wide and sand blows up to 20 m in diameter. Near-surface B or C soil horizons commonly provide the liquefaction source. Liquefaction in near-surface sediment in which B and C soil horizons have formed, resulted in closely spaced features that disrupted, split and delaminated the A horizon.

The liquefaction investigations at the three sites in the Canterbury Region will improve the understanding of the liquefaction process and its surficial manifestation in coastal settings. Our results will inform susceptibility maps and help interpret prehistoric liquefaction features during future studies in New Zealand and abroad.

SEISMIC ANISOTROPY ANALYSIS ON A SCALE OF 10S OF METERS NEAR THE ALPINE FAULT, NEW ZEALAND, FROM SHEAR WAVE SPLITTING

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The Alpine Fault is a transpressional plate boundary fault which traverses the length of New Zealand’s South Island. From paleoseismicity studies, it is inferred to be late in its earthquake cycle. Measuring the stress around the fault region will contribute immensely to the study of the faulting process. Seismic anisotropy, which is sensitive to stress-controlled cracks in the shallow crust, may provide a means to infer the stresses in the region. We employ Shear Wave Splitting (SWS) measurements, an ubiquitous means to estimate seismic anisotropy, to infer strength of anisotropic fabric around the Alpine fault. For preliminary analysis, SWS measurements were performed on five local events, which were recorded on 160, 3C seismometers surrounding the Deep Fault Drilling Project (DFDP-2) site with spacing of 10 m perpendicular and 20 m parallel to the main strike of the Alpine Fault. We envisage that this dense deployment will assist in mapping the lateral changes and constrain the depth of the anisotropy around the region. SWS results revealed that, the fast azimuths exhibit two predominant inclinations: one sub-parallel E-W direction and the other almost perpendicular to the E-W direction. These orientations may be attributed to a combination of factors including: of stress-controlled anisotropy, crack-induced anisotropy, and possibly, mis-orientations of the seismometers. Delay times ranged between 0 and 180 ms with an average of 79.4 ±13.7 ms, indicative of a weak anisotropy. To resolve the possible contribution of mis-orientated seismometers on our results, a detailed reorientation analysis is planned. We also intend to surpass the traditional means of presenting SWS result by using modelling and inversion tools like MSAT (MATLAB toolbox for the analysis and modelling of seismic anisotropy) and TESSA (Tomography Estimation and Shear-wave-splitting Spatial Average) to aid in providing explanations for its physical origin, spatial pattern and to yield useful geological or geophysical information.

ORAL
MID PLIOCENE (3.3-3 MA) SEA-LEVEL RECONSTRUCTIONS FROM THE WANGANUI BASIN, NEW ZEALAND

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The Mid-Pliocene Warm Period (MPWP; 3.3 – 3.0 Ma) was characterised by CO₂ levels of 400 ppm and global average temperatures 2-3°C above present. This period has been identified as one of the most accessible times in the geological past relevant to future warming scenarios. A global compilation of geological evidence for Pliocene global mean sea-level, which includes previous estimates from Wanganui Basin, New Zealand, suggests peak values of 22 m ± 10 m above present day. Two new ~350 m-long sediment cores (Siberia-1 and Tiriraukawa-1) recovered from the Wanganui Basin, containing continuous coeval sedimentary sequences from the inner to mid-shelf provide sea-level amplitude estimates for glacial cycles of the MPWP. Paleowater-depth has been reconstructed through a combination of facies analysis, foraminiferal depth paleoecology using the Modern Analogue Technique with extant benthic taxa and a sediment grain-size wave-water depth. A two-dimensional backstripping approach, removing the regional effects of loading (sediment and water), compaction and tectonic subsidence, has been applied to obtain eustatic sea-level change. The sea-level cycles have been constrained by an integrated age model constructed using magneto-, tephro- and biostratigraphy. Which allows the frequency of fluctuations to be identified and will facilitate a correlation with the insolation record to evaluate the role of orbital forcing on global sea-level.

ORAL

A NEW PALAEO MAGNETIC SECULAR VARIATION RECORD FOR THE LAST 15 KA FROM VOLCANIC MATERIALS IN NEW ZEALAND

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Global datasets of paleomagnetic secular variation (PSV) are required to understand the origins and behaviour of Earth’s magnetic field and to predict its future behaviour. Global databases suffer from a paucity of data from the SW Pacific region and are often affected by inconsistencies in data quality, or available age control of the sampled units.

Here we present a new PSV record obtained from volcanic materials (primarily lavas) from New Zealand. The dataset incorporates a compilation and critical assessment of all discrete PSV data previously available and their age controls, and the results of detailed sampling campaigns within the Taupo Volcanic Zone. The overall dataset includes 24 directional and 10 absolute palaeointensity records. Directional swings, ranging from 326.5°W to 26.0°E declination and -81.4 to -46.3° inclination and intensity variations from 37.0 to 70.6 µT, fall well into the range of PSV expected for the time-frame in New Zealand and reproduce features of continuous sediment records.

In this presentation I will explore the significance and implications of the new dataset for global and regional studies of palaeomagnetic secular variation.

ORAL

THE STRENGTH OF EARTH’S MAGNETIC FIELD DURING THE HOLOCENE FROM NEW ZEALAND LAVAS

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Absolute palaeointensity data are crucial to understand fluctuations in the global dipole field strength through time and to constrain relative palaeointensity records from lake sediments. This presentation will focus on the methods and results of comprehensive palaeointensity and rock magnetic studies on lavas from the Taupo Volcanic Zone. Palaeointensity experiments were conducted on 42 sites from 12 units, using the traditional double-heating and microwave palaeointensity methods. Success rates varied somewhat with the location within the lava flows sampled and corresponding differences in the rock magnetic properties. High quality palaeointensity results were obtained from 10 units with values ranging from 37.0 ± 5.7µT to 70.6 ± 4.1 µT.

POSTER
CHARACTERIZING ALPINE FAULT SLIP AT DEPTH AND ACTIVE DEFORMATION IN CENTRAL SOUTH ISLAND, NEW ZEALAND, USING A NOVEL METHOD OF ANALYSING GPS DATA

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Understanding the mechanisms and dynamics of continental deformation at plate boundaries requires high-resolution images of strain rates and deformation sources. Current methods for analysing GPS data are limited by the data they fit and by non-physical and/or subjective, prescriptive choices. Haines et al. (2015) have presented a novel non-prescriptive physics-based approach to inversion of GPS data for the vertical derivatives of horizontal stress (VDoHS) and strain rates that has none of these limitations. The VDoHS rates are the horizontal-component surface manifestation of all subsurface deformation sources, and are substantially higher-resolution surface expressions of the subsurface deformation sources than GPS velocities or strain rates.

We apply this method to GPS data in the Central South Island, New Zealand, which straddles the obliquely converging Pacific-Australia plate boundary. We estimate along-strike variations in the Alpine Fault locking depth, dip angle and slip-rate. Alpine Fault dip-slip occurs only when the dip angle shallows enough to make dip-slip mechanically feasible. The remaining plate motion is accommodated by numerous small faults for which we observe high contractional strain. Our slip rates are often higher than those recorded in the New Zealand Active Fault Database, suggesting that deformation rates on some smaller faults may be underestimated. Principal contraction directions agree well with stress indicators from earthquakes. Importantly, VDoHS rates can provide detailed variations of fault properties of high-rate faults such as the Alpine Fault; produce slip rates for lower rate, poorly-characterized faults; and reveal deformation due to previously unknown, hidden faults.


A ROCK AVALANCHE BESIDE THE TOWN OF WANAKA

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A fan-shaped deposit of rock avalanche debris (est. volume $1 \times 10^6 \text{m}^3$), lies at the foot of a mountain range 3km south-east of the Wanaka town centre. Evidence of past rock avalanche activity so close to the town (pop. 10,000) is significant for geological hazard assessments in the area. The rock avalanche follows a steep narrow valley on the north-facing slopes of the range. The source area is an irregular arcuate depression in schist bedrock, lying immediately below the ridge-line at the head of the valley. Debris infills the lower valley floor, and spreads out at the entrance to form a fan shaped lobe. The lobe has an undulating hummocky surface, and overlies an alluvial fan developed on an outwash surface of the Mt Iron Glacial Advance age, dating the failure to the last 23,000 years. Road exposures in the toe region suggest an internal structure comprising a thin ‘carapace facies’ of boulders overlying a ‘body facies’ of highly fragmented schist. Run-out distance is 1.0 km, and the ratio of H/L is 0.4, indicative of a relatively low mobility rock avalanche. The source area lies in a zone of north-striking, 60 ° dipping TZ IV quartzo-feldspathic schist, 1km west of the active NW Cardrona Fault. Paleo-seismic studies in the adjacent Cardrona Valley indicate post-glacial earthquakes of about Mw7 on the fault. The source area topography has been steepened by multiple glacial events and gully erosion. Shaking from earthquakes on the NW Cardrona, Alpine, and other regional faults may have caused progressive loss of rock quality and pre-conditioned the slope for failure. The shaking intensity in the ridge-top source area from a NW Cardrona Fault earthquake, amplified by topography, may have been up to MM9. Therefore a co-seismic failure from a NW Cardrona Fault earthquake is considered likely.

POSTER
Volcanic landscapes reflect the volcanic processes that created them. In the erosion of a volcano, intrusive features are exposed, the height of the volcano greatly reduced, and the interior extensively eroded, as observed in the Miocene volcanics of Banks Peninsula. Recent studies on Banks Peninsula have focussed on detailed mapping of the Akaroa Volcanic Complex (AVC) and the systematic sampling via transects through the now eroded flanks, which indicates cyclic volcanic activity driven by magma recharge. Accompanying geological mapping is geomorphological and GIS based investigations of the AVC. “Volcanic benches” have been recognised on the outer flanks and inner harbour regions. Benches appear in valley cross section like large-scale steps, comprised of stacked lava flows. Along-valley profile benches form dipping surfaces that can be correlated from the valley head to floor, and dip away from the central region of the volcano.

Considering the origin of benches, two possible sources are posed: volcanic or loess. Loess forms a surficial veneer on the eroded volcanics, and deposition did not create large-scale topographic features, rather mantling and enhancing existing features. Therefore correlated dipping surfaces from the central vent regions suggest benches are related to inherited volcanic features. Questions then arise: 1) What is the erosional control on forming these bench surfaces? 2) How are benches related to stacked sequences of lava flows? 3) Are benches purely erosional landscape features unrelated to volcanic structure(s)? 4) Are benches erosional features that reflect a remnant volcanic surface – i.e. a stage of quiescence in the development of the AVC?

To start answering these questions we investigate the relationship between bench features and volcanic stratigraphy through the correlation of geochemical transects across multiple benches. Paradoxically, initial results indicate that geomorphic erosional landscape features might provide important clues into how the AVC was volcanically constructed in the Miocene.

Oral

Freshwater Diatoms in Miocene Sediments in Otago


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Fine-grained mudstone and siltstone sediments from several different lake systems of early to mid Miocene age in southern New Zealand were examined for diatom (microalgae) paleofloras. Diatoms were only preserved in some samples from the extensive paleolake Manuherikia formed during a period of basin subsidence in the early Miocene (c. 20–15 Ma). The Nevis samples are from an oil shale in a sub-basin with restricted circulation, while Bannockburn floras represent a lake margin paleoenvironment. The second set of samples are from two small maar lakes of early Miocene age, Foulden and Hindon Maars. The third, paleolake Double Hill, is a small lake associated with the mid–late Miocene Dunedin Volcano. The maar sites have well preserved diatoms but the diversity of their floras varies. Foulden and Hindon Maars have few taxa (<10) and the floras are dominated by different species of Encyonema. In contrast, the well-laminated diatomaceous siltstone from Double Hill has many more taxa (>30), indicating that this site included a wider range of habitats. We consider ecological implications of the floras.

Poster
COMPILATION OF GSNZ’S NZ GEOPRESERVATION INVENTORY NOW INTERACTIVE ON WEB

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Compilation of GSNZ’s NZ Geopreservation Inventory began 33 years ago as a proactive project to help address the society’s objective “to seek the preservation of important geological sites”. Since then it has received periodic grants from NZ Lottery and DoC and been supported in kind by NZ’s geoscientific community and their host institutions. Sites have been nominated by geoscientists with fields for the sites’ significance, brief description, location, informants, references and an assessment of each site’s international, national or regional significance and perceived vulnerability to human actions.

The Inventory was initially compiled in subdiscipline categories which were later combined into twelve regional inventories. These were published and made available to land management agencies and planners. Maps for larger sites were prepared and made available as hard copy in the late 1990s. In the last 20 years many additional sites have been added and a few sites deleted or combined. Caves, karst and coastal landforms entries have been reviewed nationally to ensure comprehensive coverage in these critically threatened categories.

The NZ Geopreservation Inventory has had its own web page (http://www.geomarine.org.nz/NZGI/) for the last ten years, in which the inventory and its purpose is described and all the sites are listed within their regions and map sheets, but did not provide most information nor site maps. Through a more recent Lottery grant, all the sites have now been digitally mapped on GIS and the interactive map is viewable on the web at http://services.main.net.nz/geopreservation/. This new addition now allows all sites in the inventory to be found on a map of New Zealand with either LINZ topo or aerial photography base maps. All information about each site is now also available with one click of the mouse. Photographs for most of the 3200 sites are being added progressively.

THE ERUPTION TRIGGERS, MECHANISMS, DEPOSITION AND HAZARDS OF THE LARGEST SCALE EXPLOSIVE ERUPTIONS OF TONGARIRO VOLCANO

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Mt. Tongariro is an unusual composite volcanic complex in being made up of many vents, normally associated along fault-zone lineaments within the Tongariro graben. New Zealand’s most popular hiking trail, the Tongariro Crossing, passes across the active central parts of this volcanic system. The high ballistic, gas, surge and ashfall hazards from several historically active vent sites were exhibited most recently during the 2012 explosive eruptions from Upper Te Maari Crater. The volcano has also produced a number of very large eruptions, as evidenced in the tephra record, with several well documented episodes including the Mangamate set of eruptions from ~10.9-11.2 cal. ka B.P., and the ~16.6 cal. ka B.P. Rotoaira Tephra. However, the established stratigraphic record around Tongariro Volcano implies a very sporadic eruption history, with short, rare pulses of large-magnitude and volume pyroclastic eruptions. This new study will examine the eruption record of Tongariro in two ways: 1) A new composite eruption record will be built for the volcano, in particular by investigating a number of “mystery” tephra layers seen that have distributions and appearance consistent with Tongariro and 2) the physical, textural, sedimentological and chemical properties of several of the largest scale pyroclastic eruptions will be examined to interpret eruption durations, steadiness, and size, along with the use of chemical and petrological indicators to understand the magma source, rise and eruption triggering mechanisms. Key features that we expect to shed light on are the durations of eruptions and the reasons for the unusually widely dispersed tephra from the large-scale Tongariro eruptive episodes, including identification of multiple vents. From this multicomponent study we anticipate developing a series of new eruptive scenarios for hazard management planning at this volcano, as well as to compare and contrast its magmatic processes to the neighbouring Ruapehu volcano, which has very different styles of eruption and a more typical stratovolcano shape.

ORAL

POSTER
CALCULATION OF DEVIATORIC STRESS IN NEW ZEALAND

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We determine the stress field in the New Zealand plate-boundary zone in the context of the thin sheet model of lithospheric deformation, using the fields of vertically averaged gravitational potential energy (GPE) and strain rates. Two methods of calculating deviatoric stresses and viscosities were tested: one that solved first for gravitational stresses from GPE and then for total deviatoric stresses (Flesch et al., 2001); and one that solved directly for viscosity (Lamb, 2015). Both methods were tested on synthetic data with velocities and GPE calculated from known stress and viscosity fields. The methods were tested using on sinusoidal stress and viscosity fields and fields with values realistic for the New Zealand region. The methods were tested on their ability to recover the known stresses and viscosities, both with and without noise added to the velocities. The Flesch (2001) method solving directly for stresses possessed edge effects but handled noise well, whereas, the Lamb (2015) method solving directly for viscosity had no edge effects but did not handle noise as well, requiring collocated velocities. Both methods were able to recover the known stresses and viscosities within 20%. The Flesch (2001) method was applied to the New Zealand region using two sets of strain rates: one derived from Quaternary fault motions and one derived from contemporary GPS measurements. Both strain rate fields indicated deviatoric stress magnitudes of 10-20 MPa across much of New Zealand, rising to ~40 MPa near the subduction zones. Effective viscosities were found to be 1021-1022 Pas in the regions of most active deformation, with the lowest viscosities along the Alpine Fault. These values are generally consistent with those found for other subduction zones around the world.

ORAL

CAPTURING VARIABILITY IN BROADBAND GROUND MOTION MODELLING OF A MAJOR ALPINE FAULT EARTHQUAKE (NEW ZEALAND)

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The large September 2010 and the tragic February 2011 Canterbury earthquakes caused widespread damage by ground shaking and sand liquefaction in the Canterbury region. Both earthquakes were less than 50 km from the Christchurch central business area and had a magnitude that is much smaller than that expected from the Alpine Fault (Mw=8.2). Recent advances in earthquake mechanics allow us to compute seismograms for realistic earthquake scenarios, at specific locations, and with specific site conditions. Such simulations can provide very useful alternative estimates of possible ground motions from large faults for major population centres in the South Island (NZ).

Synthetic broadband strong-motion records are produced for a possible large Alpine Fault earthquake (Mw8.2). Following Holden and Kaiser (2016) we compute seismograms using a hybrid approach combining a simple discrete wavenumber approach and a stochastic method. To define the earthquake sources, we test a broad spectrum of source models ranging from simple validated recipe based on a characterised source model for large crustal earthquakes developed by Irikura and Miyake (2011) to heterogeneous models developed by Mai et al. (2000&2002). The synthetic rock site motions are then used as the input motion for a frequency-dependant site amplification function. We are not only interested in capturing regional ground motion characteristics but also uncertainties inherent to the various components of our modelling approach.

ORAL
Despite being well researched and understood in the science community, sea level rise and its effects on coastal communities are often poorly understood or considered ‘alarmist’ by people who live in the communities in question. Before making decisions about where to target research and development of new infrastructure, or discussing managed retreat, local and regional councils need to engage with their communities about why issues surrounding sea level rise, and associated groundwater rise, are important. Severe flooding that occurred in the low-lying suburbs of South Dunedin in June 2015 has angered and confused residents over whether flooding was due to ‘climate change’ or poorly maintained stormwater infrastructure. It was decided that engaging with the community on why South Dunedin is prone to flooding and groundwater ponding would smooth the road for future discussion around the risk posed to this community by rising sea levels. One communication initiative was a series of short videos that sum up key findings of the report ‘the natural hazards of South Dunedin’, which is otherwise inaccessible to many people. Associated educational material for locals and schools, as well as public drop in sessions facilitated discussion of the natural environment that the city is built upon. This was achieved primarily through the use of historical images, stories and local anecdotes of groundwater pooling in back yards at high tide, etc. With a greater appreciation of the connectivity of sea level and groundwater residents were much more appreciative of risks posed by sea level rise. It is hoped that better engagement with the community will be helpful going forward as Dunedin and other coastal settlements around New Zealand plan for expected sea level rise.

POSTER
QUANTIFYING THE INITIAL VOLATILE BUDGET OF BASALTIC ARC VOLCANOES

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Volatiles, especially H2O and CO2, play a critical role in the eruption dynamics of volcanoes, providing the driving force for eruptions, and controlling crystallisation. Therefore, it is important to accurately quantify the initial volatile budget of eruptions if we aim to understand volcanic processes. For historic eruptions, the only way to estimate the magmatic volatile content is to use melt inclusions (MIs). MIs are tiny pockets of melt trapped inside crystals, which provide a useful window into the conditions of the magma before it erupted. For volatiles (S, Cl and F) that exsolve at shallow depths, the concentration in MIs should represent the concentration in the initial magma. Other volatiles (H2O and, particularly, CO2) exsolve at higher pressures than MI formation and therefore the initial concentration is more difficult to quantify.

The 1886 A.D. Tarawera eruption is the largest historic eruption in New Zealand, occurring over a 17 km fissure and lasting for five hours. It was entirely basaltic which is rare for the Taupo Volcanic Zone and for Plinian eruptions especially. To explain the violence of the eruption, it has been proposed that the magma was particularly rich in volatiles (specifically CO2). Unfortunately, scoria from the Tarawera eruption are crystal-poor and therefore MIs are rare and, when present, very small (< 30 μm). CO2 may have played an important role in the eruption intensity but the initial content is unlikely to have been recorded in the MIs.

Many micro-analytical techniques (e.g., EPMA, SIMS, Raman) have been used to measure the composition and volatile content of MIs. However, previously unrecognised issues can cause spurious results, which have implications for EPMA analyses of glasses more generally. We use and develop a variety of techniques to quantify the volatile budget of Tarawera, which are more widely applicable to basaltic arc volcanoes.

PORTABLE XRF FOR THE EXPLORATION OF LOW-SULFIDATION EPITHERMAL AU-AG VEINS

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Portable x-ray fluorescence (pXRF) is a low cost, simple analytical technique that can be used to detect pathfinder elements and potassic alteration around low-sulfidation gold-silver veins. This study was conducted on samples obtained from the Waihi area, New Zealand, which hosts multiple low-sulfidation epithermal veins. All analyses were undertaken with an Olympus 40kV Delta Premium analyser. The samples were analysed alongside standards with a similar matrix to monitor drift and to assess accuracy, precision and reproducibility. The results from pXRF were compared to lab analyses on the same samples, and demonstrate that elements of potential utility to exploration (i.e. arsenic, potassium, and rubidium) can be measured accurately by pXRF. However, light elements such as Mg, Si and Al, and elements in low-concentrations (<30 ppm) will not be measured as precisely and some elements of significant interest as pathfinder elements (e.g. mercury, selenium and antimony) are below detection limits. Comparison of analyses on core in comparison to crushed samples generally yield poor reproducibility. However, comparison of K/Al results from drill core yield results that are comparable to K/Al ratios obtained from crushed samples, suggesting that the presence of potassic alteration as adularia and/or illite in andesites could be determined directly on core samples.

TRACKING VOLCANIC RESPONSES TO FAR-FIELD SLOW SLIP IN THE TAUPO VOLCANIC ZONE, NEW ZEALAND

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Volcanic and geothermal areas have been shown to be more susceptible to dynamic triggering from large earthquakes than purely tectonic regions. We here examine the strain induced by slow slip events (SSEs)
of variable size and duration on the Taupo Volcanic Zone (TVZ), particularly around Taupo caldera volcano. We use continuous GPS data from GeoNet to analyze changes in strain and strain-rate for the two small deep SSEs (2006, 2008) that are the closest to Taupo caldera to date, and a series of larger long duration “Manawatu” SSEs at Taupo and Ruapehu. Due to their proximity, the strains from Manawatu SSEs are expected to be nearly an order of magnitude larger at Ruapehu than at Taupo. The observed strains are compared to those predicted from slip distributions of the individual SSEs in finite element models with varying material properties. Monitoring suggested that seismicity and gas changes at Taupo volcano accompanied the deep (>20 km) SSE in 2008. Despite good evidence of a correlation in the timing of the 2008 deep SSE and Taupo unrest, there was no equivalent unrest or seismicity observed during a similar deep SSE in 2006. Our initial results show that the 2008 SSE-induced dilational strain changes at Taupo were larger than the mostly contractional strain produced by the 2006 SSE, suggesting dilatation may be an important factor controlling the volcano’s response. We also show analysis of seismic velocity through ambient noise results from 2005-2016 at the Taupo and Ruapehu networks. Initial results for Taupo do not show large changes associated with the nearby local SSEs, but potential seasonal variations in seismic velocity will also be addressed. Comparing the two volcanoes may allow us to test whether there are levels or directions of strains necessary to trigger local volcanic unrest.

Poster

**IMPROVING FIELD EDUCATION THROUGH STUDENT CONNECTIONS WITH LANDSCAPE**

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Improving our understanding of the undergraduate field experience has wide implications for enhancing geoscience education and the quality of our graduates, yet the emotions and perceptions that drive why and how students learn in the field are less studied. Places are an integral component of field education and students may develop connections with field sites as they move throughout the landscape, uncovering its geological history. ‘Place attachment’ refers to a person’s degree of identification with and dependence upon a place. This is a useful means to characterise and understand some aspects of how students engage with field landscapes, and hence, the geology that shapes those landscapes.

This work considers the influence of several field trip variables on place attachment: trip structure, instructor, weather and student nationality. Field trips were observed and students were surveyed on their background and place attachment before and after each field trip (n=17-31/trip). A subsample of students was interviewed to understand their experiences and perceptions in more detail (n=3-5/trip). Instructors were interviewed to understand their backgrounds, attachment to the field places and intended learning outcomes for each field trip (n=1-4/trip). Findings suggest that the field trip experience is best understood as a set of interacting characteristics: the individual student, their peer group, the instructor and the landscape. Key recommendations include: (1) the need to link roadside field trip sites with each other through a larger theme or assessment and spatial information, (2) the opportunity to leverage the novelty factor for students from out of country/region, and (3) the ability to create comparable experiences despite variable weather and instructors. Future work will focus on additional field trip variables including past student field experiences, trips with an independent research component, or the involvement of intentional place-based content.

**SEISMIC GAS CHIMNEYS SURROUNDING WELL TOROA-1 IN GREAT SOUTH BASIN**

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The present seismic profiles of total 500 seismic lines representing the 2D seismic surveys recorded in the Great South Basin were examined for predicting the seismic gas chimneys. To enhance the analysis and interpretation processes. The sea bed horizon was mapped in all seismic lines and the continental slope was built. The study is emphasizing on the area around Toroa-1 which had already expelled Gas and Oil from Palaeocene and Maastrichtian sandstones. The dominant of the seismic chimneys is located in the continental slope whereas 52 seismic chimneys/mud volcanoes were determined surrounding the well Toroa-1.
Chimneys are vertical to semi vertical body intersects the seismic strata reflectors and their horizontal continuity. They take the shape of the cigar/tree with roots. The majority with mounds on the sea bed but some ended below the sea floor. The methodology is focusing on both chaotic amplitudes and pulls up features to identify the dimension of the chimney and their sources. The deepest pull up feature depth was determined using TWTs in the 2D view seismic profiles for each chimney to indicate the entry level depth at which the gas/liquid fluid invaded into the adjacent/overlain sediments. Structural and stratigraphic correlation of the seismic chimneys strata with seismic lines DUN06-23 and OMV08-64 intersect the well Toroa-1 in the dip and strike directions were performed to master the estimation of the source rock and ages at seismic chimney location.

Findings show that 52 seismic chimneys were surrounding Toroa-1. The majority of which reached the sea bed. All chimneys are ended with mounds with different shapes, height and width. The correlation of the seismic strata shows that the source rock for these chimneys are mainly Maastrichtian and possible deeper as that shown by some of the chimneys originated in/near synrift sediments, and rare are from lower Palaeocene. The gas/liquid fluid migration in these chimneys are vertical to semi vertical partially lateral but for short distance.

SEISMIC CHIMNEYS DISTRIBUTION IN THE GREAT SOUTH BASIN

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The objective of the study is to identify the seismic gas chimneys/mud volcanoes in the Great South Basin and to identify their flow of pathways from the source sediments in the subsurface to the sea bed. The study will assess their sources with comparing to the current petroleum system discovered in the 8 exploratory wells in the basin.
To predict there location that required a set of special criteria characterised these chimneys, these are the amplitude reflectors strata within the interior part of chimneys which are random and discontinuous and chaotic compared with strata outside the border of chimney which are well preserved, and stratified with high amplitude and coherent. Dip and pull up features of reflectors are important benchmarks to discover the chimneys location. The mound is direct indicator pointing to chimney location.

Chimneys have different shape and size of mounds. Their sources were predicted based on the pull up features of their reflectors amplitudes such that the deepest pull up is taken as reference depth using TWTs where the gas/liquid fluid invading the sediments of the chimney from nearby/underneath the source rock.

Seismic lines bearing the gas chimneys are correlated with the nearby seismic lines crossing the drilled wells, in order to identify the age of the source rock at the chimneys location and compare it with the gas bearing and oil shows units discovered in the those drilled wells.

The result of the study shows that there are three main groups of gas/liquid fluid/mud chimneys in Basin. Their distribution is 34 over the continental shelf and 52 on the continental slope and the rest is 22 located in the ocean floor. Majority of the continental shelf chimneys are not reached the sea floor and their mounds ended within the overburden sediments meanwhile continental slope chimney mounds are ended above sea floor. The third group could be associated with polygonal faults and there is potential to be classified as pockmarks.

ORAL

SIMPLE MODELS TO PREDICT REGIONAL GROUND MOTION CHARACTERISTICS BASED ON RECENT EARTHQUAKE SEQUENCES

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The 2010 – 2011 Canterbury earthquake sequence produced some of the strongest ground motions recorded globally (exceeding 2 g) leading to extensive structural damage, landslides and liquefaction in the city of Christchurch. Ground motions in Canterbury are thought to have been strongly influenced by several regional factors, including high stress drop sources and strong and variable site effects. Much of Canterbury is situated on flat-lying plains formed by braided river systems, and is underlain by thick sedimentary sequences (~1km deep) and locally variable near-surface Quaternary stratigraphy. By contrast, the Wellington region is characterized by shallower, spatially complex bedrock topography and subsurface soil structure, and is also inferred to exhibit lower average stress drop more typical of tectonically active regions. Quantifying how these regional
factors influence ground motion is important for future hazard assessment and mitigation.

We use strong motion data from recent earthquake sequences in Canterbury and Wellington to separate and quantify the source, path and site characteristics of each region using generalized spectral inversion. Using Canterbury as an example, we propose a simple regional Fourier Amplitude Spectra (FAS) model to approximate S-wave spectra at any given location and any scenario event in the region. We also use this model to show how site amplification varies at selected Christchurch stations under increasing levels of peak ground acceleration (PGA).

In general, reduction in site amplification is observed down to a frequency of 1Hz at Christchurch soil sites for PGA values approximately 0.3 g or greater. This effect is particularly pronounced at known soft soil and liquefiable sites. Finally, we employ regional and local ground motion parameters in stochastic ground motion simulations in order to better capture local ground motion characteristics. When compared against observed data, the use of regional parameters leads to better prediction of PGA amplitudes and acceleration characteristics.

ORAL

NUCLEATION PROCESS OF M~2 EARTHQUAKES ON THE SAN ANDREAS FAULT PREDICTED BY RATE-AND-STATE FAULT MODELS WITH SAFOD DRILL-CORE DATA

Y. Kaneko

Recent laboratory shear-slip experiments conducted on a nominally flat frictional interface, reported the intriguing details of a two-phase nucleation of stick-slip motion that precedes the dynamic rupture propagation. This behaviour was subsequently reproduced by a physics-based model incorporating laboratory-derived rate-and-state friction laws. However, applying the laboratory and theoretical results to the nucleation of crustal earthquakes remains challenging due to problems related to scaling and poorly-constrained physical and friction properties of fault-zone rocks at seismogenic depths. Here we examine the scaling of laboratory results to crustal conditions using the same physics-based model. We find that both the time and length scales of nucleation processes are proportional to the critical nucleation length derived from previous theoretical studies. Applying this model of rupture onset to data acquired during the San Andreas Fault Observatory at Depth (SAFOD) experiment, we predict what the nucleation phase will look like for magnitude-2 repeating earthquakes at a 3-km depth. Our results suggest that precursory slow slip associated with the earthquake nucleation phase may be observable in the hours before the occurrence of the magnitude-2 earthquakes by strain measurements close (a few hundreds meters) to the hypocenter, in a position reached by the existing borehole.

ORAL

DEVORA 2021: A NEW OUTCOME-BASED FOCUS TO DETERMINING VOLCANIC RISK IN AUCKLAND

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The Determining Volcanic Risk in Auckland (DEVORA) research program is a multi-agency, multi-disciplinary effort with a mandate to investigate the Auckland Volcanic Field (AVF), a monogenetic volcanic field located beneath the city of Auckland. The DEVORA project, which began in 2008, includes >65 researchers who cooperatively have produced >130 published papers. Originally funded for 7 years, the project focused on understanding the geological context of the AVF, its volcanic hazards, and the risk posed to Auckland. Now revamped as DEVORA 2021, the project endeavours to look forward and focus on the application of scientific findings to risk assessment, risk management, and science communication. Specifically, DEVORA will continue to work with civil defence and emergency managers and ensure that fundamental science forms the basis for key decision-making in the preparation for and response to a future AVF eruption. The project has ten major intended outcomes, which align with local and national response and resilience objectives. Continuing work focuses on developing planning resources such as RiskScape, New Zealand’s multi-hazard risk assessment tool, creating probabilistic hazard models, and working with various scientific and governmental advisory groups in order to ensure a coordinated response in the event of an AVF eruption. The new DEVORA 2021 is a model for an integrative approach for understanding, mitigating, and managing natural hazards in an urban environment.

ORAL
EARLY MIOCENE PLANT FOSSILS FROM THE PUUKORUKORU FORMATION, HOKIANGA, NORTHLAND

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We have identified rare low temperature (<30°C) arsenic sulfide forming in arsenic-rich processing wastes at three separate sites at the historic Blackwater gold mine (1906-1951) in the South Island of New Zealand. Roasting wastes and tailings from the mine were stored within several man-made dams. Samples were collected from the drying room foundations at Snowy Battery and a low lying area as well as the tailings impoundment at the Prohibition Mill site. These sites provide three different settings; weathered sulfide concentrates, iron-rich quartzose tailings mixed with abundant arsenolite and organic matter, and iron-rich quartzose tailings, Sediments within the dams contain up to 10 wt% As, and up to 330 mg/L As and 20 mg/L SO₄ in pore water. Water pH in the waste material ranges from acid to neutral (pH 2.8-7). Bright yellow, macroscopic arsenic sulfide occurs in patchy horizons, 15-45cm below the surface. It is associated with organic matter within the sediments in suboxic to anoxic conditions. Scanning electron microscope (SEM) imaging of the arsenic sulfide shows a dense network of filamentous As-S nanotubes (100 nm to 2 µm diameter) and poorly-developed nano-crystalline aggregates (< 1 µm). X-ray diffraction (XRD) and Energy-dispersive X-ray spectroscopy (EDS) analysis confirms realgar (As₄S₄) as the most likely As-S mineral present. Secondary arsenolite and scorodite are well documented on site, but arsenic sulfide has not previously been identified. This study provides quantification of this naturally-occurring sulfate reduction and provides insights into the environmental conditions necessary to drive the process. Our findings also have implications for the management of mine wastes and development of novel wastewater treatment systems.

FORMATION OF ARSENIC SULFIDE IN GOLD MINE PROCESSING WASTES, WEST COAST, NEW ZEALAND

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Sediments of the Puukoruku Formation outcrop in low cliffs and beach platforms along c. 3 km of coastline north of Waimamaku River, Northland. Sandstones and conglomerates dominate the formation with fine sediments, including lignite, also present. Plant remains occur at several localities and include in situ tree trunks, leaves, seeds, inflorescences, wood, pollen and spores.

The Puukoruku Formation sits on basalt flows of the Waipoua shield volcano, constraining the maximum age to 19–18 Ma. The contact with the basalt is exposed at both the northern extent of the Puukoruku Formation and at Waimamaku River mouth. Palynological assemblages are consistent with the previously determined Altonian age, but also include recycled elements from the Cretaceous and Paleogene, including dinoflagellate cysts. A notable feature of the palynological assemblages to date is the rarity of the common Miocene elements Notothofagus and Casuarina. Overall, the assemblages suggest a coastal depositional environment, with vegetation dominated by angiosperms (likely shrubs and small trees) and ferns, with occasional podocarps.

A dicotyledonous angiosperm-dominated leaf assemblage was collected from laminated siltstone and sandstone at one locality and will be used to estimate paleoclimate using leaf morphology-based methods. The angiosperm leaves include many simple broad-leaved forms (affinities not yet determined). Other distinctive leaves include a well-preserved compound leaf (likely belonging to the Fabaceae family), a leafy monocot shoot with an inflorescence which bears a strong resemblance to the modern genus Arthropodium (family Asparagaceae) and a palm frond. Angiosperm leaves were noted at other localities in low abundance. Two of the macrofossil localities are dominated by ferns. Conifer remains are rare in the leaf assemblages.

ORAL

ORAL
LATE QUATERNARY SLIP RATE ALONG THE WESTERN HOPE FAULT, NEW ZEALAND, AND IMPLICATIONS FOR PALEOEARTHQUAKES

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The Hope Fault accommodates between one third and three-quarters of the relative plate motion in the northern South Island. The fault last ruptured the ground surface during the 1888 Mw ~7.1 North Canterbury earthquake and will produce future large magnitude earthquakes. Displacements of geomorphic markers and associated slip rates provide a means of determining the size and recurrence intervals of these earthquakes. Here we use high resolution airborne LiDAR to measure 477 dextral displacements and scarp heights from the Hurunui segment of the Hope Fault. Dextral displacements for the 59 highest quality geomorphic markers including alluvial fans, debris deposits, terrace risers, and abandoned channels range from 2.6 to 189 m. Analysis of geomorphic piercing points with large horizontal displacements (≥ 80 m) shows that the scarp heights are only ~1% of the horizontal displacements and confirms that the fault is predominantly strike-slip. Calibrated radiocarbon ages ranging from 500 to ~16000 yr B.P. obtained from seven sites along the Hurunui segment in this and previous studies have been used to calculate a dextral slip rate. Average slip rate ranges from 9.3 to 14.9 mm/yr with a mean of 12.2 ± 2.4 mm/yr. Slip rates were approximately uniform for different sites along the Hurunui segment of the fault during the Late Quaternary. A mean single event displacement (SED) of 3.6 ± 0.7 m for the Hurunui segment is estimated from interpretation of ‘grouped’ displacements of ≤ 25 m. For the mean slip rate and mean SED, a mean recurrence interval of ~200 to 440 yr is estimated. This recurrence interval is consistent with the mean recurrence interval (i.e., ~210-386) obtained from previous paleoseismic studies. Based on the SED and approximate fault segment lengths these surface-rupturing events are inferred to have magnitudes of Mw ~7–7.5.

PRELIMINARY RESULTS FROM THE 27TH APRIL, 2016 ERUPTION OF WHITE ISLAND: PROCESSES AND ENERGETICS

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White Island erupted on the 27th April, 2016 during a period of heightened volcanic tremor and moderately elevated gas flux. Furthermore, the level of Crater Lake had dropped significantly over the two weeks prior to the eruption. The eruption itself took place at around 9:30 pm (NZT) without any visual observations possible. Subsequent analysis of the acoustic and seismic signals indicates that there were at least 5 pulses of ejections over the ~ 1.5 hr period of the eruption.

The volcanic gas flux did not increase significantly before the eruption, which implies that the trigger of the event was most likely related to hydrothermal rather than magmatic processes - consistent with the analysis of the eruption deposit. The eruption deposit contains variably altered rock fragments, sulphur-infused breccia and minor lake sediments with no juvenile material.

Ground visits to the island were made within days of the eruption to assess the resulting deposit. Thickness measurements, grain size analysis and image analysis have been used to determine the volume of ejecta, the relative timing of phases and the components present. Based on these data, the eruption generated a dilute pyroclastic density current (DPDC) that reached ~ 800 m from the vent. Soon after the current was initiated, a jet of ballistics was ejected onto the tail of the DPDC. These ballistics landed up to 450 m from the vent. This eruption reinforces both the difficulty in forecasting small phreatic eruptions and the dangers they pose to the general public.

ORAL
STRUCTURAL DISORDER OF GRAPHITE AND IMPLICATIONS FOR GRAPHITE THERMOMETRY

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Graphitization, or the transformation of organic matter into crystalline graphite, is induced by compositional and structural changes during diageneric metamorphism. The irreversible nature of this process has allowed the degree of graphite crystallinity to be calibrated as an indicator of the peak temperatures reached during progressive metamorphism. However, discrepancies between temperatures indicated by the graphite crystallinity vs. other thermometers have been documented in numerous fault zones, such as the Alpine Fault rocks, New Zealand (Kirilova et al., in review) and the Hidaka metamorphic belt, Japan (Nakamura et al., 2015). We hypothesise this is because the calibrated graphite thermometers disregard the effects of mechanical modifications of the graphite structure. To examine this possibility, we have carried out laboratory deformation experiments, combined with Raman microspectroscopy to investigate the impacts of structural disordering of graphite on the graphite ‘thermometry’.

Our experiments were performed in the Brittle Rock Deformation Versatile Apparatus (BRAVA) at INGV, Rome. We systematically sheared highly crystalline graphite powder at room temperature, normal stresses of 5 MPa and 25 MPa and sliding velocities of 1 µm/s, 10 µm/s and 100 µm/s to total displacements of 20 mm, 10 mm and 5 mm. We then analyzed the degree of graphite crystallinity in the resulting material by Raman microspectroscopy. Our results show consistent decrease of graphite crystallinity with increasing shear strain; spectra area ratios (R3) drop from ~0.1 in the initial material to ~0.5 in the deformed powder. We infer this is due to mechanical modification and thus conclude that graphite thermometers are unreliable in brittely deformed rocks. Temperatures derived from the thermometer in deformed rocks should be treated as minimum estimates of temperatures experienced by them.

ORAL

STRUCTURAL AND PETROLEUM SYSTEM MODELING FOR THE OFFSHORE NORTHERN TARANAKI BASIN, NEW ZEALAND

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The Taranaki Basin is the most explored sedimentary basin in New Zealand and contains all the producing petroleum fields in the country. Despite over 70 exploration wells and extensive seismic data coverage, many aspects of the offshore basin’s petroleum systems are still poorly understood. In the northern Taranaki Basin there are few petroleum discoveries, and to date none have been commercially viable. Off these, the Kora field stands out as it has black oil sourced by the Late Paleocene organic-rich marine mudstone of the Waipawa Formation. The thickness of this potential source rock is below seismic resolution and therefore its thickness and distribution are uncertain. In the present study several 1D petroleum systems models were built to reconstruct the burial history, temperature distribution and the corresponding expulsion timing from a Waipawa Formation source rock in the Kora field area. Predicted Miocene expulsion at several Kora wells is driven by the increased temperature in the area due to the volcanic activity.

Petroleum system model is going to be constructed for the study area based on the available seismic and geochemical data to understand petroleum generation and migration from the source rock in 3D.

POSTER
KAPITI ISLAND AND SURROUNDING SEAFLOOR MORPHOLOGY - OUTREACH POSTER LAUNCH

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Following a seafloor mapping survey in 2015 and 2016 using shallow water multibeam technology, we have integrated high resolution bathymetric data with low resolution, land, and satellite derived data to produce an integrated map of Kapiti Island within its submarine surrounding. The data highlight fine morphological details such as sand waves, rock outcrops, current scours, sediment flats and rocky beaches. This framable poster brings together knowledge from NIWA, the Department of Conservation, Victoria University of Wellington and Land Information New Zealand, and provides the most up to date baseline information on seafloor morphology around Kapiti.

POSTER

SCALE-DEPENDENT PREDICTIVE SEAFLOOR HABITAT MAPPING IN THE BAY OF PLENTY

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Detailed knowledge of the physical and biological conditions of the seafloor is key to the development of economic, environmental and cultural activities in the marine environment. Full coverage information on substrate and benthic habitat relies almost exclusively on acoustic remote-sensed data provided by multibeam echosounders, subsequently ground-truthed using visual observations and physical sampling. Predictive habitat mapping provides a means to develop models of seafloor habitat in regions where only acoustic data are available. The diverse geomorphology and benthic ecology in the Bay of Plenty makes the area a useful case study for developing regional and local models of benthic habitat: water depths range 0 - 3300 m with geomorphological features including channel, canyons, seamounts and ridges at a variety of scales. Active geology is demonstrated by the intense seismicity, dense fault network, and ubiquitous submarine volcanic activity that results in venting hydrothermal fluids like at the Calypso vent fields. This environment provides habitat for benthic communities, whose structure and distribution can be expressed at a variety of scales. We integrated marine geological and oceanographic information in Benthic Terrain Models of the Bay of Plenty and the Calypso vent fields, i.e. at regional and local scales. Classification of the geomorphology was based on a number of morphometric parameters (e.g., slope, Bathymetric Positioning Index, curvature, rugosity) derived from the bathymetry gridded at 25 m for the region, and 5 m for the Calypso vent fields. A 13 geomorphological class catalogue was used that differentiate large (broad slopes, basins) and local (knolls, narrow ridges/valleys) scale features. 77% of the 25,000 km² area are broad flat, the remainder is dominated by local ridges and narrow depressions. Ground-truthing data will enable us to associate biological observations to each class and predict benthic habitat in regions where no observations exist.

POSTER

EARTHQUAKE SLIP, SLIP RATE AND PALEOSEISMICITY OF THE ALPINE FAULT AT CALF PADDOCK, BULLER DISTRICT

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Recent studies at the Calf Paddock site adjacent to the Maruia River have focused on the well-known record of degradational terraces offset by the Alpine Fault. Field studies in 2010 focused on surveying the terrace riser and channel sequence and logging pits to date terrace surfaces. These yield late Holocene dextral and reverse slip rates of 10 ± 2 mm/yr, and 1.3 ± 0.2 mm/yr, respectively, for the northern section of the Alpine Fault covering the last 1200 years. The distribution of slip across the site is complex with greater slip across the 2nd-youngest faulted terrace (T2) versus older terraces (T3-T5). We have inferred that terraces T2-T5 have all experienced the same number of earthquake rupture events, i.e., that degradation has occurred rapidly across the Maruia valley. Phase 2 in 2016 involved the excavation of trenches across T2 and T3 to date the timing of past earthquakes and match these to the slip record and a well dated record of shaking events preserved as turbidites from nearby Lake Christabel. Paleoseismic events in both trenches were recognised on the basis of faulted and unfaulted scarp-derived colluvial wedges and by progressive deformation within the terrace gravel deposits. Both show evidence for at least 3 events whose timings will be discussed once
radiocarbon dates are available. These data add to the understanding of the earthquake rupture record on the northern section of the Alpine Fault. The river capture and degradation history of the Maruia River terraces and its bearing on the earthquake history will be described by Ries et al. at this meeting.

ONSHORE SUBSURFACE ANALOGUE STUDY, NORTHERN HAWKE’S BAY, NEW ZEALAND

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The aim of this project is analyse onshore well data and use the interpretations as analogues for offshore deposits identified from seismic data in East Coast basins. Data for the study are from a series of wells of varying vintage that were drilled in onshore northern Hawke’s Bay, from near Mahia Peninsula to about 15 km north-west of Wairoa. The wells penetrate as deep as the Oligocene Weber Formation. A full suite of conventional wireline logs (gamma, density, neutron porosity, resistivity etc.) was run in most of the wells, and resistivity borehole image data were acquired in three wells. Structural analysis of borehole images in all lithologies show the structural dip and consistent dominant NE—SW fracture strike match mapped outcrop trends. It was noted that fracture characteristics in carbonates differ from siliciclastic sediments in that fractures are commonly confined within a single bed suggesting a lithological control on fracture generation. Mudstones display very similar image characteristics between formations and between wells so conventional wireline log properties have proved useful in differentiating them. Sediment dispersal orientations obtained from sandstone bedding surfaces are highly variable, which is consistent with shallow-dipping distal turbidite sandstone lobes. However, this means that identification of regionally significant sediment dispersal trends (i.e. channels etc.) cannot be achieved directly from these wells. Despite this, observed bed-scale turbidite characteristics compare well with nearby outcrops. Borehole image analysis has identified six distinct limestone image facies, which display differences in conventional log responses that suggest they can be correlated to wells where borehole images have not been acquired. Cuttings indicate that these limestones share characteristics with limestones further south, such as the Te Aute lithofacies. At this stage, despite some minor issues, the use of these results to aid seismic interpretations in adjacent offshore areas where there are no dredge data or well control, such as Hawke Bay, looks promising.

PALEONTOLOGICAL AND CLIMATIC SIGNIFICANCE OF THE EARLY MIocene HINDON MAAR COMPLEX, OTAGO


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Geological mapping of four subcircular basins associated with high magnetic intensity near Hindon, east Otago combined with further geophysical and sedimentological investigation confirms that all four are partly eroded maar-diatreme volcanoes associated with the Waipaita Volcanic Field. Palynostratigraphy suggests an early Miocene age and radiometric dating ($^{40}$Ar/$^{39}$Ar) of associated basals is underway.

Preliminary excavations in two craters have exposed finely-laminated diatomite and/or extremely fossiliferous laminated sponge-rich carbonaceous mudstone and yielded a wealth of animal and plant fossils. The most common macrofossils are leaves (mainly Nothofagus), but the flora also includes cycads, palms, conifers including small cones, Lauraceae, Myrtaceae and leaves and flowers of several Araliaceae species. These indicate that the maar lakes were surrounded by Nothofagus/podocarp/mixed broadleaf forest growing under humid, warm temperate to subtropical conditions.

Fish fossils are abundant at Hindon and an eel resembling Anguilla is a key record for the Southern Hemisphere. Larval to adult stages of Galaxiidae are present, some with skin and mouthparts preserved. Also abundant in terms of numbers and diversity are insects, which currently comprise ~140 specimens belonging to the orders Hemiptera, Hymenoptera, Trichoptera, Thysanoptera and Coleoptera, with weevils particularly diverse. The first record of fossil feathers supports the idea that common, but allochthonous quartz-sand-rich coprolites were derived from volant birds, presumably waterfowl. The remarkable preservation of soft-bodied fossils makes this a Konservat-Lagerstätte of potentially global significance.

Ground-based magnetic, microgravity and seismic surveys carried out to characterise the size, depth and sediment infill suggest that ~200m of laminated sediment is present and preliminary coring has
retrieved >10m of laminated sediments. Further coring in all four maars could yield a high resolution (seasonal to decadal) record of changing climate and ecosystems for Southern Hemisphere mid-latitudes which would complement the Foulden Maar record to produce an unparalleled understanding of early Miocene climate and environment.

ROSSELIA SOCIALIS DAHMER 1937 AND OTHER TRACE FOSSILS IN TIDALLY MODULATED BEDS OF THE LOWER WHAKAPOHAI FORMATION, LATE CRETAceans, SOUTH WESTLAND BASIN, NEW ZEALAND

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Steeply dipping transgressive marine sediments of the Late Cretaceous Whakapohai Formation examined along the coast between Moeraki River and Otomotu Point, ~25 km northeast of Haast, form part of the uplifted eastern margin of South Westland Basin. Whakapohai Formation overlies quartzose pebbly sandstone, siltstone, shaley coal, and rare tuff of the Tauperikaka Coal Measures.

A tidal heterolithic association of cross-stratified glauconitic sandstone and thinly bedded sandstone and mudstone represents the lower ~50 m of Whakapohai Formation. This is overlain by a 40+ m thick shoreface association of heavily bioturbated muddy fine-grained sandstone. The shoreface sands include abundant deep-tier robust *Ophiomorpha irregulare* burrows, of likely decapod origin, that display characteristic meandering maze structures.

The lower tidal section includes a diverse assemblage of dwelling burrows, feeding/locomotory trails, and invertebrate resting traces. Among the dwelling burrows, *Rosselia socialis* crowds at least six beds exposed near Whakapohai River outlet. Thought to have been produced by anemones or terebellid polychaetes (e.g. Nara, Lethaia 28:171-178), the cone-shaped *Rosselia* burrows of 1-3 cm maximum diameter show evidence of re-colonisation of the substrate following minor short-lived sedimentation events. Like the makers of vertical U-shaped *Diplocraterion yoyo* and *D. parallellum*; trace fossils that are also present in the lower heterolithic association, the occupiers of *Rosselia socialis* either escaped or perished when buried by thicker sands, or succumbed to more gradual change in estuarine sub-environment represented by lenticular bedded sand and mudstone.

An additional trace fossil recently found in the lower association of Whakapohai Formation, *Sinusichnus sinuosus* comprises horizontal winding and branching galleries that were likely made by another decapod crustacean. Also present are radial chevron trails, individually comparable to *Protovirgularia*, that possibly represent surficial siphon feeding activities of tellinid bivalves. A further deposit or filter feeding bivalve is represented by deep vertical *Siphonichnus* burrows that are elliptical in cross-section.

USING ELEMENTAL CONCENTRATIONS AND STABLE METAL ISOTOPES TO IDENTIFY THE CONTROLS ON ORGANIC MATTER ACCUMULATION AND PRESERVATION IN THE WAIPAWA FORMATION

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The Waipawa Formation is a late Paleocene organic-rich marine mudstone that has long attracted significant economic and environmental interest. Previous studies have shown that the Waipawa Formation, which is widespread throughout NZ basins, not only acts as an important source rock for oil and gas deposits but also records unique environmental conditions related to global climatic events.

However, more work is needed to refine current paleoenvironmental interpretations of the Waipawa Formation. In this study, we will apply non-traditional metal stable isotope systems to constrain the controls on marine source rock deposition in three primary sections within the East Coast Basin that represent an onshore-offshore transect: Te Hoe River, Taylor White (adjacent to Angora Rd section), and Mead Stream. In particular, this study utilizes novel proxies of oceanic anoxia (U, Mo, and Fe isotopes), primary productivity (Zn and Cd isotopes) and terrigenous input, to unravel their relative importance in controlling marine source rock deposition.
SEISMIC AND TSUNAMI HAZARD CONSTRAINTS FROM A TRENCH ACROSS MARINE TERRACES AT PUATAI BEACH, NORTHERN HIKURANGI MARGIN

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Marine terraces along the Gisborne east coast are inferred to be uplifted by nearshore submarine faults and so can place constraints on seismic and tsunami hazard. Puatai Beach, 30 km north of Gisborne, is landward of the Gable End Fault, and previous work showed relatively young ages for three Holocene marine terraces.

We excavated a 90-m-long trench across the terraces, which exposed three shore platforms overlain by 1-2 m of beach deposits and 0.8-2 m of colluvium. Tephra and 22 radiocarbon ages indicate uplift events occurred at 1920–1713, 1270–1030, and 520–320 cal. yr BP. Surveyed altitudes of the strandlines indicate uplift-per-event of 3.4 ± 1 m and an uplift rate of 5.6 ± 1 mm/yr. These are slightly higher than calculated from Pakarae River mouth, and so there may be another fault as well as the Gable End Fault causing uplift at Puatai Beach. Puatai Beach records the highest uplift rates along the Hikurangi margin.

Discontinuous 0.1-0.2 m thick layers of silt and sand within the colluvium are interpreted as paleotsunami deposits; three are dated at 1190–930, 400–100, and 450–150 cal. yr BP. The ages are younger than the marine terrace uplift ages, and this, along with their position in the colluvium, suggests they were not necessarily triggered by the Gable End Fault. Minimum run-up heights of 9.3 ± 0.5 m and 12.6 ± 0.5 m, and are within, but at the upper end of, estimates in the National Tsunami Hazard Model. Further work is required to determine whether the tsunami were from a local or regional source.

This study demonstrates the value of marine terrace sequences as repositories of paleoearthquake and paleotsunami data; we aim to carry out similar studies at other locations along the Hikurangi margin.

LATE HOLOCENE SURFACE RUPTURING HISTORY OF THE KEKERENGU FAULT, MARLBOROUGH FAULT SYSTEM, NEW ZEALAND

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In central New Zealand, the locus of plate boundary deformation transfers from the Alpine Fault onto the Hope Fault, but beyond Kaikoura, its route eastward to link with Hikurangi subduction is less certain. Van Dissen et al. (this volume) present data supporting a slip rate on the Kekerengu Fault of 20-26 mm/yr since ~34 ka, indicating that most slip on the Hope Fault transfers northward via the onland Jordan Thrust onto the Kekerengu Fault before entering Cook Strait. If true, the Kekerengu Fault poses a significant seismic hazard to NE South Island, and strike-slip faults in Cook Strait linking into the Kekerengu Fault, such as the Boo Boo Fault, pose one to nearby Wellington. A testable prediction is that the Kekerengu Fault has ruptured frequently in large earthquakes. To test this, we excavated three trenches. At the surface, the Kekerengu fault zone transitions eastward from being chiefly dextral-reverse to dextral-normal near the coast. We cut our trenches across several fault strands near the coast where slightly extensional fault furrows are locally infilled with ponded sediments. Earthquakes were recorded in these by: 1) upward truncation of faults against un faulted clays and peats; 2) downward incremental deepening of axial sags; and 3) infilling of fissures with peat. Based on 14 radiocarbon ages, we date three earthquakes (range quoted at 95%): 1) 249-108 cal. yrs. B.P.; 2) 528-356 cal. yrs. B.P.; and 3) 1248-903 cal. yrs. B.P. Because we may have missed earthquake(s), these data provide a maximum estimate of the mean recurrence interval—which is 444 ±180 yrs (±1 s). The Hope Fault has also ruptured ~3 times since ~1250 B.P., and our data support the inference that most plate boundary deformation steps northward from the Hope Fault onto the Jordan Thrust and Kekerengu Fault before extending offshore into Cook Strait.

ORAL
Tuaheni Canyon is located (38°53′55.49″S 178°29′42.42″E) on the mid-slope of the tectonically active Hikurangi margin, off the east coast of the North Island, New Zealand. The Tuaheni Canyon is bound at its head by the Tuaheni South landslide, along its eastern flank by the dissected Tuaheni Ridge, and exits onto the margins of the Poverty Bay Debris Avalanche in the Paritu Trough. Tuaheni South landslide has been described as a slow-moving submarine earthflow.

The phenomena of earthflow-type failures is familiar in landslide classifications in subaerial settings, but has more recently been used for classification of submarine failures. The aim of this project is to do sedimentological characterization of three gravity cores. The cores were acquired at 1163 m, 1192 m and 1247 m water depth from the Tuaheni Canyon during the RV Sonne SLAMZ research voyage (SO247). The current study aims to characterise the sedimentary gravity flow deposits and depositional behaviour near the base of a submarine slow-moving earthflow, by assessing if recent failure history was catastrophic, cyclic, gradual and or episodic. Lithological properties and provenance may suggest varied sediment sources, which includes: remobilized material calving from the toe of the Tuaheni South Landslide, gravity flows from the upper slopes, volcanic tephra from the Taupo Volcanic Zone?, and/or hemipelagite.

Onboard core description showed that these cores contain mud-dominated massive hemipelagic units interbedded with sandy, ash-rich turbidites and tephra layers. There is evidence for a range of grading and textures, suggesting a spectrum of depositional processes. Sedimentological characterization of the gravity cores will incorporate standard laboratory analyses and radiocarbon AMS dating. Sedimentary characterization will be coupled with a quantitative marine geomorphic analyses using 14 - 8m grids of high resolution bathymetry of Tuaheni Landslide Complex acquired during SO247 using a Kongsberg EM122 multibeam echo-sounder.
A detailed sedimentary facies analysis of the Paparoa Coal Measures is used to develop a sequence stratigraphic model of the Greymouth basin based on lacustrine lake and shoreline facies. Whereas deep lacustrine facies are easily recognized by the presence of thick mudstones with interbedded turbidite sandstones, shoreline facies are more difficult to categorize and map. The western side of the basin is dominated by alluvial fan deltas alternating with braided rivers draining off steep slopes. High gradient delta slope facies contain interbedded conglomerates, sandstones and mudstones with common convolute bedding and load casts. The associated delta front facies comprise conglomerate channels with enigmatic clast fabrics present. The southern and eastern sides of the basin are dominated by meandering rivers and floodplains to muddy low gradient deltas. Low gradient delta slope facies comprise mudstone with abundant turbidite sandstone and siltstone beds with organic material and load casts present. Associated thick mouth bar facies show coarsening upward sequences in gamma ray logs. Marshy shore line facies are thinly interbedded siltstone, sandstone, carbonaceous mudstone and silty coal with abundant leaf matter and vertical rootlets. Coal facies deposited along the lake edge and in abandoned channels are thin and high in ash. Thick, low ash coal facies are interpreted as raised mire complexes and commonly replace the organic rich, thick lacustrine mudstones at the centre of the basin. Better mapping of shoreline facies has led to revised isopach maps and cross-sections allowing interpretation of a sequence stratigraphy. Lake highstands likely record episodes of moderate to fast subsidence which increased accommodation space. These are replaced by the raised mire complexes during lowstands. The increasing thickness, paleogeographic extent and lake depths through time from the oldest to the youngest lacustrine mudstones suggest an expansion and maturing of the basin.

MINERALOGY OF MINE WASTES FROM HISTORIC GOLD PROCESSING

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Historic gold processing sites are places of significant toxicity as the methods used to extract the gold were less efficient than today’s methods, and regulations were not in place. These sites were abandoned after the mines closed, with no site remediation. Elevated metals and metalloids on these sites are the result of the geology of the deposits (As, Sb) and the metals added (Pb, Zn and Hg) to aid in the recovery of the gold. This study examines three historic gold processing sites in the Reefton Goldfield, New Zealand, that are used as case studies to understand the geochemical processes that occur on abandoned processing sites. The sites were processing similar ore, so any differences in tailings mineralogy and geochemistry are the result of different processing techniques used.

The highest As value at the sites has resulted from ore roasting used to extract refractory gold from sulphides. Roasting has produced toxic and bioavailable arsenolite (As5+) and the calcium arsenate minerals pharmacolite and yukonite. Vapours released during roasting have been absorbed by the Edwards roaster structure forming As-bearing gypsum crystalline efflorescences. Roasting has also concentrated other metals. Roasted tailings contain porous hematite derived from sulphide oxidation with As incorporated into its structure. High As levels also result from the ageing and weathering of sulphide concentrates that have formed amorphous hydrous iron arsenate and As-bearing iron oxide minerals.

Arsenic dispersal from the three sites is low and largely attenuated by secondary mineral formation. Any dissolved metals or metalloids that leave the sites are diluted by the high rainfall. There were no elevated dissolved metals leaving the sites with all dissolved metals below the New Zealand drinking water guidelines.

ORAL
COMBINED AIRBORNE GEOPHYSICS AND FIELD MAPPING IN CENTRAL OTAGO

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Onshore, airborne geophysical surveys flown in the past decade are transforming the geological knowledge of New Zealand. Using Central Otago as an example, we show that new geophysical interpretations, new stratigraphic interpretations and new structural interpretations are possible from combined study of aero-geophysics and traditional fieldwork. In the Central Otago survey area (c. 13 000 km²), similarities in structural style, lithology and geophysical response are noted in the northern half of the survey, which approximately equates with the Rakaia Terrane. The southern half of the survey area roughly equates to the Caples Terrane, and the boundary between these terranes is approximately traced in the geophysical data. Linear, geophysical anomalies in Central Otago are interpreted to reflect primary lithological differences; however, field mapping shows that multiple foliation surfaces generated from polyphase ductile deformation are not always parallel to that lithology.

The first products based around these new interpretations include a GIS data package of the Middlemarch area providing a detailed 1:50 000 geological map and accompanying 66 page text, available from GNS Science. The Middlemarch map data package includes reprocessed geophysical images (magnetic, electromagnetic, gravity), geophysical interpretations and models; a summary of historical mineral production figures, geology, mineralisation and modern exploration history at Barewood and Nenthorn gold deposits; a detailed overview of mineral, aggregate and groundwater resources; lithology and updated geological interpretations (e.g. a surface geology map, cross section); updated resource locations; magnetic susceptibility and whole-rock chemistry measurements; sub-division of the Dunedin Volcanic Group; classification using the new high level stratigraphic nomenclature for New Zealand; a digital elevation model; cultural features; structural measurements and interpretations; and a schist outcrop map showing 250 000 outcrops. Combining airborne geophysics and field mapping into geological models will become more common in New Zealand as new surveys are flown around the country.

SOIL MAGNETIC SUSCEPTIBILITY AS A SEDIMENT PROVENANCE TOOL: AN EXAMPLE FROM SOUTHERN NEW ZEALAND

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Magnetic susceptibility values have been measured at two soil depths across c. 20,000 km² of southern New Zealand in a systematic study of samples on an 8 km grid. Measurements were made using both laboratory and field methods, with the data from both being strongly, positively correlated. There is a minimal anthropogenic input detectable by magnetic susceptibility methods, and by proxy, a minimum of heavy metal contamination in southern New Zealand soils, making them relatively pristine. The absolute difference between magnetic susceptibility between the two depths is also minimal. The nature of the samples in this study means they represent natural magnetic susceptibility variation to which other, similar soils can be referenced. The source of most studied samples is proximal and within the same rock type, terrane or supergroup that the soil was sampled above (a distance ≤ 80 km and frequently < 1 km). Relative magnetic susceptibility highs in the dataset have geogenic sources (typically igneous) related to the soil type they were sampled in or to the magnetic mineralogy of the soil parent material. A well-documented library of rock magnetic susceptibilities in New Zealand has allowed the provenance of soil and sediment in the study area to be mapped and understood, that is a key step when mapping element or isotopic distribution, vectoring to mineralisation or studying soil for agricultural suitability, water quality or environmental regulation. Measuring soil magnetic susceptibility is a useful, quick and inexpensive approach to provenance studies that has wide applicability.

POSTER
IN-SITU PERMEABILITY OF FAULT ZONES ESTIMATED BY HYDRAULIC TESTS AND CONTINUOUS GROUNDWATER-LEVEL OBSERVATION

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The permeability structure of fault core and damage zone has an important role in fault hydrogeology and slip behaviour. Although there are many studies about laboratory measurements of permeability of natural and synthetic fault products, in-situ observation of permeability within the fault zone is a few.

GSJ, AIST constructed an integrated groundwater observatory at Matsusaka-litaka (ITA) as a part of the groundwater and crustal deformation observation network for the prediction research of the Nankai and Tonankai earthquakes. Hole 1 (total depth 600m) was penetrated MTL at a depth of 473.9m. Total depth of Hole 2 is 208m. Screened depth of Hole 1 is 547.6-558.5 m and is located in the lower fracture zone of the MTL fault zone developed in the Sanbagawa metamorphic rocks. Screened depth of Hole 2 is 145.5-156.4 m and is located at a branch fault in the Ryoke granitoids.

Slug tests in Hole 1 at ITA performed six times by filling the water up to the top of the well head. After January 2010, well head of the Hole 1 was closed and then groundwater pressure have been observed. Groundwater-pressure recovery could observed in Aug. 2011 and Feb. 2012 because of opening and closing of the well head. Hydraulic diffusivities of slug test Nos. 1-6 and two well water-pressure recoveries are analysed, and range 1.8 - 8.5 x 10⁻¹⁶ m².

At Hole 2, ITA, we firstly analysed data of well pressure recovery in Oct. 2008. After that we obtained hydraulic diffusivity T = 1.8 x 10⁻¹³ m² as a result of pump test by assuming S = 1.0 x 10⁻³ and screened length = 17 m.

In-situ permeabilities are basically consistent with detailed permeability structure in and around fault core sampled from Tsukide outcrop about 15 km away from ITA (Wibberley and Shimamoto, 2003).

RESPONSE OF GROUNDWATER-LEVEL TO LARGE STRAIN CHANGE ASSOCIATED WITH HIGH EMBANKMENT NEAR THE WELL

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Precise groundwater level has been observed at the Haibara well, Shizuoka, Japan since 1981 (Matsumoto et al., 2003; Matsumoto and Roeloffs, 2003). During 2002-2006, high embankment was done to raise the ground level about 27 m at the location of the well to construct the Shizuoka airport. The groundwater level raised immediately after the embankment, but groundwater level decreased when the embankment stopped more than several days. These increase and decrease in groundwater level might be explained by poroelastic response associated with the embankment and by groundwater flow from the aquifer, respectively.

WHAT DO DFDP-1 CORE SAMPLES FROM THE ALPINE FAULT ZONE, NEW ZEALAND TELL US ABOUT THE MINERALOGY AND MICROSTRUCTURE OF MAJOR FAULT ZONES?

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It is important to characterize the internal structure of major fault zones to understand their gross physical attributes, including their mechanical, seismic and hydraulic properties. Previous studies and preliminary analyses indicate that there are a variety of types of cataclasites within the damage zone of the Alpine Fault – in terms of structure, composition, and protolith (Woodcock and Mort, 2008; Toy et al., 2015).

Deep Fault Drilling Project (DFDP)-1 core samples, collected from ~50 – 150 m depth in the Alpine Fault zone were analysed by SEM-EDS methods to characterise their microscopic structure and mineralogy. We obtained information on mineral compositions, microstructural setting and paragenetic sequence. Because this is a dip-slip fault, these exhumed rocks have accommodated the cumulative effects of deformation occurring at a
range of depths and thus under different pressure and temperature conditions.
The cataclasites consist of quartzofeldspathic clasts, calcite and clay minerals (e.g. chlorite, mica, illite).
The discrete cataclasite particles and the matrix contain less than 5 μm grains of these clay minerals.
We have focussed on quantitative compositional analyses of clorites and other clay minerals, because these are common authigenic phases in the cataclasites, and from them we can constrain pressure and temperature during formation of the various cataclasite microstructures. We will present a preliminary result for how distributed cataclas is within this fault structure at a range of depths (or pseudodepths).

POSTER

CHARACTERISATION OF THE PROHIBITION GOLD MINE TAILINGS, WAIUTA, WESTLAND, NEW ZEALAND

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The Prohibition Mill gold mine, located in the Birthday Reef of the Reefton goldfield, was operational from 1938 until 1951. It is situated near the town of Waiuta in the Victoria Forest Park, Westland and is now administered by the Department of Conservation. An exclusion zone is in place on the processing site where extremely high arsenic values (up to 40 wt%) have been identified due to the historic processing and roasting of ore rich in arsenopyrite. Cleanup of the site within the exclusion zone has commenced. This paper reports on a field portable XRF survey and mineralogical study of the tailings impoundment outside of the exclusion zone. The FP-XRF survey found that elements of environmental concern, in particular: As, Cu, Pb and Zn are elevated. Further mineralogical study using XRD and SEM as well as leaching experiments have been used to characterise the tailings and soil in the tailings impoundment area. The tailings are predominantly composed of hematite and quartz with relatively uniform As levels ranging from 4000-9000 ppm at the field level. SEM analysis of the tailings shows that the distribution of the As is not uniform on the microscopic scale and is closely associated with iron oxides and minor sulphides which have not been completely roasted. Arsenic was found to be relatively stable under the current conditions of the site and shrubs and grasses collected from the tailings area show limited As uptake into the biosphere.

POSTER

EVOLUTION OF A MIOCENE ALKALINE MAGMATIC BODY AT THE NORTHERN PERIPHERY OF DUNEDIN VOLCANO, KARITANE, EAST OTAGO.

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Dunedin Volcano (16-10.1 Ma) is the most volumetrically significant expression of the Dunedin Volcanic Group (24.8 – 8.9 Ma), which comprises a compositionally wide range of alkaline lavas erupted in the Miocene.

This study presents 8 new XRF whole-rock analyses, EDS-SEM phenocryst analyses, and detailed petrography for representative lavas from an unstudied northern satellite of Dunedin Volcano, on the coast between Sealiff and Karitane.

Five distinct lava compositions are now recognised on the basis of total alkali – silica (TAS) concentrations: basanite, hawaiiite, benmoreite, tephri-phonolite and phonolite. Major element trends show a systematic depletion of Fe, Ca, Mg and Ti, and enrichment of Si, Na, K, Al and P from basanite to phonolite. Similarly, trace elements show variable depletion of Ni, Cr, V, Cu, and enrichment of Rb, Pb, Th, U, Zr, Nb. The low silica end-members (basanite – hawaiiite) are typically rich in calcic plagioclase, Ti-augite and olivine, whereas more silica rich members (benmoreite – tephri-phonolite) contain sodic plagioclase and zoned augite. Phonolite appears vitrophyric with alkali feldspar and nepheline phenocrysts. Kaersutite-rich, globular mafic inclusions with quench textures and kaersutite megacrysts are commonly found in tephri-phonolite.

A fractionation model is proposed which genetically links the basanite – phonolite lineage to a common basanitic parent magma. Magmatic evolution was induced by preferential crystallisation of mafic minerals in crustal magma chambers related to Dunedin Volcano. Mafic inclusions in evolved members are strong evidence for the repeated injection and mingling of basanitic magma with phonolitic differentiates, and such injection may have been a triggering mechanism for the eruption.

The eruptive products at Karitane are geochemically consistent with those of the main Dunedin Volcano and the area probably represents a number of satellite volcanic vents connected with its magma system.

ORAL
AMBIENT NOISE TOMOGRAPHY OF THE ALPINE FAULT HANGWALL IN THE WHATAROA VALLEY, WESTLAND, NEW ZEALAND

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As part of the Deep Fault Drilling Project (DFDP), an active-source seismic experiment was conducted in January 2016 to capitalise on downhole infrastructure and further investigate the structure of the central Alpine Fault. The DFDP-2 drill site sits adjacent to a seismically quiet portion of the Alpine Fault, the major continental transform fault separating the Australian and Pacific plates in southern New Zealand. As part of the experiment, 159 three-component geophones covering ~2 km² recorded continuously for four days, providing an opportunity to undertake high-density seismic noise tomography in conjunction with more traditional active-source methods. The dense deployment of three-component geophones provides >12,500 station pairs for noise cross-correlation analysis. Cross-correlations obtained for ambient noise produce a robust estimate of the Green’s function at frequencies above 0.5 Hz in the Whataroa Valley, allowing us to probe to depths of approximately 1 km. Using these Green’s functions, surface wave dispersion curves show a Rayleigh group velocity of 600 m/s at 2 Hz with velocity increasing at lower frequencies. We are working to construct a high-resolution velocity model by performing tomography on group and phase velocity dispersion curves and then inverting for shear wave velocity with depth.

POSTER

APPLYING LASER SPECTROSCOPY FOR STABLE ISOTOPE ASSESSMENT OF HYDROGEN AND OXYGEN IN HYDROUS MINERALS

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In the study of ancient systems, hydrous minerals provide important constraints on fluid history and the hydrologic cycle. Such information has application potential in a variety of disciplines, ranging from understanding the role of meteoric water circulation in hydrothermal ore formation to defining the balance between precipitation and evaporation in paleoclimatic reconstructions. However, because traditional IRMS analyses of hydrous minerals are time consuming and costly, use of this important archive has been relatively limited. The recent advent of commercially available laser spectroscopy units overcomes this barrier by providing a new avenue to rapidly measure hydrogen and oxygen isotopic abundances in molecular water extracted from hydrous minerals. Here, a hardware configuration and data processing protocol are described for determining the isotopic signatures in hydrous minerals using an LGR OA-ICOS water vapour analyser. Results are reported for measurements of both liquid waters and hydrous minerals, including gypsum, kaolinite, and muscovite. The instrument and sample preparation line were operated in two configurations, using both dry air and nitrogen as carrier gases. Dry air allows for assessment of hydrogen only, while the nitrogen mode facilitates simultaneous measurement of δD and δ18O. Preliminary results indicate that precision for hydrogen and oxygen are slightly lower than analyses carried out using traditional IRMS. Ultimately this method will be useful in applications where large sample sets are required, and uncertainties of up to 4‰ for δD and 0.5‰ for δ18O are acceptable.

ORAL
The Alpine Fault is one of the most prominent tectonic features in the South Island, New Zealand, and based on paleoseismological evidence is inferred to be late in its seismic cycle of M7-8 earthquakes. Despite this, the Alpine Fault displays low levels of contemporary seismic activity, with little documented on-fault seismicity. This low magnitude seismicity, often below the completeness level of the GeoNet national seismic catalogue, may inform us of changes in fault character along-strike and might be used for rupture simulations and hazard planning. Thus, compiling a micro-earthquake catalogue for the Southern Alps prior to an expected major earthquake is of great interest.

Areas of low seismic activity, like the central part of the Alpine Fault, require data recorded over a long duration to reveal temporal and spatial seismicity patterns and provide a better understanding for the processes controlling seismogenesis. The continuity and density of the Southern Alps Microearthquake Borehole Array (SAMBA; deployed in late 2008) allows us to study seismicity in the Southern Alps over an extended time period, in greater detail than afforded by New Zealand’s national network. Furthermore, by using data from other temporary networks (e.g. WIZARD, ALFA08, DFDP-10) we are able to extend the region covered.

To generate a spatially and temporally continuous catalogue of seismicity in New Zealand’s central Southern Alps, we will use automatic detection and phase-picking methods. We utilise an automatic phase-picking method for both P- and S-wave arrivals proposed by Rawles and Thurber [2015]. Preliminary results obtained from three months of data show that the automatic picker routine is capable of locating micro-earthquakes, with the lowest magnitude calculated thus far equal to $M_s \sim 1.7$. Moreover, the phase picks obtained are reasonably accurate: comparison with analyst picks yields differences of less than 0.2 seconds for 95 per cent of the data.

Characterising the structural network in geothermal resources is essential, as faults and fractures play an important role as fluid pathways in the reservoir rocks. The properties of such structural networks feed into reservoir models, field operation and development planning. Recent studies of the Wairakei Geothermal Field utilise micro-earthquake analysis, borehole logging, and active fault mapping to determine the structural character of the geothermal system, how the structural observations from these studies inform and relate to each other, and how it contributes to fluid flow. Initial phases of the study have found a dominant NE-SW structure strike orientation, with minor populations of N-S, E-W, and NW-SE striking fractures, consistent with the broad Taupo Volcanic Zone observed trend.

High-temperature borehole televiewer (BHTV) logging has been used to acquire acoustic images of wells in the Te Mihi sector of the Wairakei Geothermal Field. BHTV logging yields two different images; the travel time image which can inform us on the shape and potential open nature of natural fractures in the reservoir, and the amplitude image which relates to the acoustic impedance of the borehole wall (i.e., variable geology, structure, alteration).

The 166 MW$_e$ capacity Te Mihi power station, opened in 2014, utilises the geothermal resource in the Te Mihi sector. Here we present new interpretation of four BHTV logs in the Te Mihi sector of the Wairakei Geothermal Field. By characterising subsurface structure from this data, as well as determining the orientation of the horizontal stress field from induced features, it is possible to resolve any structural and stress heterogeneities across the field. By combining this data with indications of fluid flow in these wells we gain insight into the structures directly contributing to the transport of geothermal fluids in the Te Mihi subsurface.

ORAL
DEFORMATION STYLE, ROUGHNESS AND MECHANICS OF AN ACTIVE LOW-ANGLE NORMAL FAULT, MAI’IU FAULT, WOODLARK RIFT, SE PAPUA NEW GUINEA

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The Mai’iu Fault, Woodlark Rift, SE Papua New Guinea, is globally one of the best-exposed, fastest slipping (6.4-9.6 mm/yr dip-slip) active low-angle normal faults (LANFs). We analysed structural field data from this fault’s exhumed slip surface and footwall, together with geomorphic data interpreted from aerial photographs and GeoSAR-derived digital elevation models (5-30 m spacing), to evaluate deformational processes affecting the rapidly exhuming, domal-shaped detachment fault. Emerging at a dip of ~21°N near sea level the fault flattens over the crest of the dome to dip S at ~15° with some fault remnants extending up to 29 km in slip direction. Windgaps perched on the crest of the dome indicate up-dip tectonic advection and progressive back-tilting of the exhuming fault surface. We infer that slip on a serial array of m-to-km scale up-to-the-north, steeply S-dipping (~75°) antithetic-sense normal faults accommodated some of the exhumation-related, inelastic bending of the footwall. These geomorphically well-expressed faults strike parallel to the Mai’iu Fault at 110.9±5°, have a mean cross-strike spacing of ~1520 m, and slip with a consistent up-to-the-north sense of throw (<5 m to 120 m). The footwall is also cut by other smaller offset (<1.5 m) brittle faults, including down-to-the-north-synthetic normal faults, and near-vertical conjugate strike-slip faults. Inversion of fault slip data for stress suggest Andersonian principal stresses with a subhorizontal σ3 (183.4/1.7) and σ1 and σ2 directions (83.7/80.0) of subequal magnitude that have temporally flipped with respect to one another. Apparently the Mai’iu Fault was able to continue slipping despite differential stress being locally high-enough to initiate new-well oriented faults. Roughness analysis of the Mai’iu Fault indicates a progressively rougher fault topography at smaller spatial scales, reflected in a Hurst exponent of ζ=0.6 on slip-parallel profiles. This is consistent with a shear strength that scales with the observation scale (L) as L^{-0.4}.

ORAL

ROCK STRENGTH, PERMEABILITY, AND JOINTING AROUND SHALLOW INTRUSIONS, MT. RUAPHEU

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Magmatic intrusions alter host-rock strength and permeability by inducing fracturing and alteration mineralogy in the host rock. At Mt. Ruapehu, we mapped fractures and alteration mineralization in 3D space with respect to proximity of intrusions. Our aim is to compare these field analyses with laboratory measurements of strength and permeability.

Mt. Ruapehu is an active andesitic stratovolcano with rockfall, landslide, and eruptive hazards. Our study focuses on the fossil hydrothermal system of Pinnacle Ridge in the Te Herenga formation (~170 ka), the oldest known formation of Mt. Ruapehu, exposed in a nearly vertical sequence by glaciation (~10 ka). Pinnacle Ridge is composed three distinct facies, variably altered coherent andesite lavas and sills, variably altered andesite breccias, and several generations of microdiorite dyke and stock intrusions.

We used several methods to observe a wide array of physical properties. These methods included photogrammetry from UAV photography with scanline fracture ground truthing, field permeability and Schmidt Hammer measurements, in-field rock mass classification. Sample core data included porosity, permeability, Vp, Vs, uniaxial compression strength, and triaxial compression strength data. We completed mineralogical assessment through use of optical thin-section, TerraSpec, and SEM Analysis.

Our data suggest that primary lithology and distance to fractures controls rock properties more than the relative distance to the intrusion. Alteration affects rock strength and failure behaviour under uniaxial and triaxial conditions. The contrasting rock properties have implications for controlling fluid flow, and thus heat flow, in volcanic and geothermal systems. We suggest this type of detailed field study can provide important context to laboratory-based rock mechanical studies.

ORAL
ROCK DREDGE SAMPLING OF THE FAIRWAY RIDGE, NORTHERN ZEALANDIA: R/V INVESTIGATOR CRUISE IN2016T01 (ECOSAT II), JUNE-JULY 2016


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ECOSAT II (Eastern Coral Sea Tectonics II) was a Lautoka to Hobart transit voyage conducted on the Australian ship R/V Investigator from 30th June to 14th July 2016. Seven rock dredge deployments were made on three parts of the steep, NE-facing scarp of the NW-SE striking Fairway Ridge, west of New Caledonia: DR1 and 2 (c. 162.4°E, -21.0°S), DR3, 4 and 5 (Landsdowne canyon: c. 161.6°E, 20.4°S) and DR6 and 7 (c. 160.8°E, 20.1°S). An estimated 900 kg of igneous and sedimentary rock was dredged off the seabed of which 102 kg was retained for study and archiving. Underway gravity and multibeam bathymetry data were also collected.

Soft foram limestones were obtained in all seven dredges and attest to the Neogene carbonate cover that blankets most of submarine northern Zealandia. Orange hyaloclastite breccias were obtained at DR1, 2 and 6 and probably represent Neogene intraplate volcanic rocks. Between them, the three Landsdowne canyon dredges (DR3, 4, 5) contain a wide and potentially very informative range of igneous and sedimentary rocks that can be sorted into the following provisional and speculative lithostratigraphic order: black basalt and dolerite may be syn-rift igneous rocks from seismic basement; carbonaceous mudstones and pebbly and gritty sandstones may be from a Late Cretaceous clastic sequence; indurated algal limestones may be from a Paleogene maximum flooding sequence. No in situ Austral Superprovince basement was dredged but pebbles of granite and very hard lithic volcanenite greywacke in DR3 sandstones may represent locally recycled Median Batholith and Téremba Terrane basement.

When dating and analysis of rocks is complete, we hope that the results of the IN2016T01 voyage will test competing models for the continuity of Mesozoic igneous belts and terranes across northern Zealandia, and improve our knowledge of New Caledonia Basin stratigraphy and tectonic development.

NEW AEROMAGNETIC DATASET REVELATIONS: SOUTHLAND

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A high resolution airborne geophysical survey dataset covering a large part of Southland has been acquired for New Zealand Petroleum & Minerals and was publicly released in September 2016. The survey was flown at 200 m line spacing at a target ground clearance of 50 m, and collected magnetic and radiometric measurements. These data have been processed into gridded images that are available, with the original line data, from http://www.nzpam.govt.nz/cms as mineral report MR5400.

The survey reveals a greater continuity of geology than previously realised. Magnetic intensities over the Triassic and Jurassic sandstone-dominated sequences of the Murihiku Terrane are moderate, with bedding prominent. Murihiku units show large-scale continuity about the regional-scale Southland Syncline but, in detail, are cross-cut by numerous low-displacement fault-fractures at km-scale spacing. Magnetic intensity of Murihiku and Brook Street terranes is subdued where they are buried beneath Maui and Pakihi Supergroup cover sediments, but units of the Brook Street Terrane can be traced beneath Southland Plains. A small (<1 km) Brook Street inlier in Oreti River is part of a much larger, mostly buried, 15 km-long feature, and there are a number of long-wavelength anomalies suggesting the presence of other buried magnetic bodies that are yet to be explained.

Magnetic intensities over rocks of the Median Batholith for the most part very high, particularly the Hekeia Gabbro (Longwood Range) and Bluff Intrusives, and these rocks are clearly continuous offshore from Riverton to Bluff. While the overall strike is broadly NW-SE across the survey, a change to NNW-SSE in the west marks the subtle effect of oroclinal bending. Some revision of mapped faults, both exposed and concealed beneath the Southland Plains, and assessment of displacement sense and scale of offset may now be warranted.

POSTER
ASSESSING TSUNAMI HAZARD IN LAKES PART 1: 
LAKE TEKAPO SEDIMENTARY PROCESSES, 
LANDSLIDE DISTRIBUTION AND TIMING

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In February 2016 NIWA used the newly modified vessel Rukuwai to map Lake Tekapo using a Kongsberg EM2040 multibeam and a Geometrics multichannel boomer seismic reflection system. These data are central to a 2-year Natural Hazards Research Platform project focussed on assessing the tsunami hazard from mass movements into and within lakes.

Multibeam data achieved a 1 m-resolution – making the data comparable to LiDAR – and reveal fine scale details of lake floor processes. The surface geomorphology of the lake floor is highly complex reflecting an active and dynamic sedimentary environment. Sediment bedforms, fans and channels record sediment input from primary river sources since glacial retreat. The large delta at the mouth of Godley River at the northern end of the lake, along with several other river mouths along the eastern and western margins, define the key locations for riverine sediment input. These deltas and the steep lake margins are subject to erosive gullying processes and larger scale mass failure. Landslides have a broad range in sizes up to 1 km² and show highly varied morphology from intact block slides to disaggregated flows. Seismic-reflection data show that the sedimentary fill in the lake basin is up to 200 m thick, all of which is interpreted to post-date glacial retreat since the LGM. Seismic profiles indicate that landslide deposits occur throughout the sedimentary succession and provide valuable information on the location of repeated versus one off failures, along with the approximate volume and relative timing of the events. We analyse these datasets to derive magnitude-frequency relationships for mass failure within the lake.

Landslide geometry, mechanical behaviour and magnitude frequency relationships will be used to determine the landslide tsunami hazard from mass failure for this lake. This process-based understanding of tsunami sources preserved on the lake floor and in strata of Lake Tekapo is being developed as a working template for application to other New Zealand lakes.

GEOCHEMICAL EVIDENCE FOR LATE PLEISTOCENE AND HOLOCENE HYDROCLIMATIC CHANGE IN SOUTHERN NEW ZEALAND

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The strength and position of the Southern Hemisphere westerly winds play a fundamental role in regulating New Zealand’s climate. Strong westerlies not only promote the generation of mid-latitude precipitation-bearing storms over the Southern Ocean, but the mean position of the strongest winds dictate if these systems pass over and deliver rainfall to the South Island. To provide insight into how the westerlies impact New Zealand’s precipitation regime, and the broader Southern Hemisphere climate system, we evaluate past hydrologic change using sediment cores collected from lakes, fjords, and peatlands on the SW portion of the South Island and the subantarctic Auckland Islands. These localities are situated either in the core (50°S) or the northern margin (45°S) of the modern wind belt and local catchment hydrology has demonstrated links to the westerly winds. We apply stable isotope, including compound-specific (n-alkane) H isotopes, and elemental concentration data to these records to evaluate: 1) changes in carbon cycling and delivery pathways related to organic matter provenance and water column stratification, 2) changes in the dD of plant water related to precipitation origin and atmospheric temperature, and 3) changes in the isotopic composition of closed-basin lake water driven by evaporative processes. During the Late Glacial and early Holocene (15 to 9 ka), multiple periods of lower lake level, elevated long-chain n-alkane dD values, and water column stratification coincide with periods of rapid deglacial warming identified in Antarctic Ice cores and signal weakened westerly winds system and/or a southward-shifted core. Since 5.5 ka, we interpret the decline in long-chain n-alkane dD observed in peatlands (50°S) and lake sediments (45°S) to indicate enhanced SW flow over the South Island combined with cooler temperatures. We will further evaluate these interpretations, and place them in a broader context, through comparison of established records throughout the Pacific Basin.

ORAL
Forecasting of distant tsunami has become an almost routine task internationally. Catalogues of pre-calculated scenarios and the DART buoy network have made the process reasonably robust. However, if the tsunami is generated regionally or locally, the latter being defined by travel times of less than one hour, forecasting and warning become time critical and uncertainty around the forecasts is high. The situation becomes even more critical if the source of the tsunami is on a close subduction zone as it was the case, for example, in Japan, Tohoku 2011 and could be the case in New Zealand. In this situation, assessments of tsunamigenic potential and impact need to be accomplished in minutes or better even seconds.

Several fast inversion algorithms to assess local subduction tsunami sources have been developed and documented in the past few years and are capable of characterising a source within minutes. In this computational study we have tested performance of machine learning algorithms from the linear model family for this task. Machine learning offers a promising approach to this problem because once a machine learning system is trained the assessment of a scenario takes only several seconds. We discuss how precise this assessment can be and what potential extensions to the GeoNet network would help to improve this assessment.

We have generated hundreds of subduction tsunami sources located on a Hikurangi subduction zone interface model (Williams et al., 2013). Part of this data set is used as a training data set for a machine learning algorithm, while the rest is used for performance testing. The source scenarios vary randomly in location across the interface and for each location a given set of moment magnitudes is assumed. We use a traditional scaling relationship after Abe, 1975 and assume a simple rectangular shape tangential to the interface model.

The 2010 and 2011 Christchurch earthquakes demonstrated that concealed active faults pose a significant hazard to infrastructure and human life in New Zealand. Geological mapping suggests that active faults pass beneath, or within many urban areas in New Zealand, including Auckland, Blenheim, Christchurch, Hastings/Napier, Nelson, Rotorua, Taupo, Wellington, and Whakatane. No established methodology for routinely locating and assessing the earthquake hazard posed by concealed faults in these settings is available. The principal objective of the presented study was to evaluate the usefulness of high-resolution shear wave seismic reflection profiling with a land streamer to locate buried faults in urban areas of New Zealand. A secondary objective was to locate the Whakatane Fault. In a calibration survey the method was first tested over a surface trace of the Edgecumbe Fault 30 km south-west of Whakatane township, that ruptured during the 1987 Mw 6.3 Edgecumbe Earthquake. This survey helped gain an understanding of the shear wave propagation characteristics across an active fault in the sediments of the area. These comprise pumiceous material from the Taupo Volcanic Zone re-deposited in a Holocene marine and fluvial environment. Having established the characteristics of shear wave seismic images in a green field location, the main survey was conducted within the Whakatane township.

In total, 11 high quality profiles of 5.7 km total length were acquired, showing concealed displacements in sediments to a depth of 100 m. Normal fault displacements of up to 15 m are visible in depths from 20 to 40 m and deeper structures show displacements of up to 20 m. The technique proved useful for accurately defining the location of the Whakatane Fault beneath the township of Whakatane on several East/West profiles. Corroborative evidence for the location of the fault requires a drilling programme.

**Performance of Machine Learning to Classify Local Subduction Zone Tsunami Sources**

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**Imaging the Concealed Section of the Whakatane Fault Below Whakatane, Using a Shear Wave Land Streamer System**

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In explosive volcanic eruptions there is an abrupt transition from an ascending continuous column of magma with entrained bubbles to an expanding cloud of gas with entrained juvenile fragments. This change occurs across a fragmentation front. The process of fragmentation controls the characteristics of the particles produced (e.g. grain-size distribution, morphology etc.) and strongly influences the dynamics and potential impacts of the eruption. Understanding the relationship between magma properties, ascent, degassing dynamics and different fragmentation processes is thus vital in assessing the dynamics of and possible hazards associated with eruptions.

Magma is a chain silicate and can behave in both a brittle and ductile manner. The transition point between these two behaviours is dependent on the temperature, composition (e.g. silica and volatile contents) and the rate at which strain is applied. The manner of a magma’s behaviour when stressed will dictate style of fragmentation during an explosive eruption, and thus the characteristics of the resulting fragments. The high strain rate applied during explosive eruptions of silicic magma means that fragmentation in such events is almost always brittle.

There are fluidal ash grains in deposits of the 2012 submarine silicic explosive eruption of Havre volcano, Kermadec Arc, NZ, and among particles formed in explosive fragmentation experiments using remelted material from the same eruption. Unlike previously documented coarse fluidal fragments in rare rhyolite spatter deposits, we find evidence of fluidal/ductile grains in the fine-ash size range (10-250 microns). The natural grains formed at 900-1400 m water depth either during an eruptive phase forming lavas and domes, or during the intense explosive eruption. Experimentally produced fragments formed at surface pressures during both wet MFCl experiments and in dry-blowout experiments. Such fragments are atypical for rhyolite magmas, and indicate that surprisingly small particles could be shaped by surface tension during a fully submarine eruption.

**ASH GENERATION DURING AN EXPLOSIVE DEEP MARINE ERUPTION**

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Despite water’s encompassing presence at submarine eruptions, there remain many questions about the degree and nature of water’s interaction with magma during explosive submarine eruptions. We are analysing microtextural and morphological characteristics of ash sampled from the 2012 rhyolitic submarine eruption at Havre seamount. This eruption occurred at 700-1300 m depth, producing a 400 km$^2$ sea surface pumice raft along with effusive and explosive deposits on the sea floor. The fully submarine eruption site, rhyolitic composition, known explosive and effusive phases, and extensive post-eruption “ground truthing” and in situ sampling during a 2015 research cruise make Havre an ideal laboratory to study the processes and products of interaction between silicic magma and water.

We have defined three distinct volcaniclastic units on the seafloor from different sources that record a complex eruption history. A seafloor-draping deposit, called the Eruption Fallout Unit forms the lowest volcanoclastic unit of the eruption succession, composed of glassy vesicular clasts from >5m to <10microns in size. The ash of this unit is blocky, angular and tube pumice in shape. Overlying this is the Western Rim Unit, it is closely distributed around lava dome E, and composed of fine lapilli to ash-sized glassy elongate tube-pumice clasts. The Bulge Unit caps the sequence; it is composed of morphologically variable dark microvesicular clasts distributed around the caldera floor lava flows.

The Eruption Fallout Unit is inferred to have formed during an explosive eruption, however also shows extensive evidence for thermal quench fragmentation. The Western Rim Unit is somewhat of a mystery, inferred to be sourced from dome E’s vent, the elongated vesicles and clasts indicate extensive shearing during eruption. The Bulge Unit formed by fine scale fragmentation of the lava flows either during eruption or later due to quenching or strain during flow, a plume then dispersed the clasts.

**ORAL**
The Mount Irene Shear Zone in Fiordland is exposed as a low-angle mylonite zone that was active at mid-lower crustal conditions (T ~ 600°C, P ~ 6 kbar) during Cretaceous extension. The (ultra)mylonitic part of the shear zone is restricted to a calcite marble layer typically 3-5 m thick containing hundreds of thin (mm-cm) calc-silicate bands that are now parallel to the shear zone boundaries. The lower boundary of the shear zone preserves meter-scale undulations that cause the calcite marble layer to be squeezed in to regions <1.5 m thick. The calc-silicate bands act as “flow markers” and allow individual marble layers to be traced continuously through thick and thin regions, implying that the mylonites experienced cyclic variations in stress and strain rate. Microstructural analysis (SEM, EBSD) on samples collected along the same calc-silicate band indicates that shear zone thinning was accompanied by a progressive increase in the degree of recrystallization. Relict, large (d~350 μm) calcite porphyroclasts became progressively stretched and flattened, as well as internally strained, leading to the development of subgrains (d~20 μm). With increasing strain, interconnected networks of recrystallized grains (d~20 μm) formed along porphyroclast boundaries. The recrystallized grains have straight to slightly curved boundaries, polygonal shapes, low internal lattice distortion, and grain boundaries that frequently meet at triple or quadruple junctions. Our current observations suggest that shear zone thinning was initially accommodated by dislocation creep and subgrain-rotation recrystallization in calcite porphyroclasts, but subsequent deformation in the recrystallized matrix involved grain boundary sliding.

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Monogenetic volcanoes are commonly defined as volcanoes that erupt only once during their eruptive history through distinct eruptive phases. Systematically or randomly changing magma discharge rates, fluctuation of external versus internal influences on the eruption styles by magmatic vs phreatomagmatic fragmentation can produce a great range of volcano types. Such volcanic processes make monogenetic volcanoes unique but still human-scale volcanic features relatively easy to utilize to demonstrate volcanic processes and hazards.

Short-lived and small monogenetic volcanoes are easy to access; their eruptive products are on a “human scale” and, therefore, they can be used to demonstrate volcanic processes without major challenges for educators or visitors.

Monogenetic volcanic fields in can carry high geoheritage value if a) their eruptions influenced human societies, b) they have high aesthetic value, or c) they are used as reference areas to describe unique volcanic processes. This tripartite reference to geoheritage values reflects the current geosite evaluation methodology (GAM) applied to evaluate geoheritage values. The difficulty is however to demonstrate the outstanding universal values (OUV) of monogenetic volcanoes as they are the most common volcano types on Earth. In addition there are “simple” low geodiversity and “complex” high geodiversity volcanic fields. Hence geodiversity could be used as a strong argument to define monogenetic volcanic field’s OUV.

Here we present examples of monogenetic fields from Saudi Arabia, Central Europe, Argentina, Miyakejima (Japan) and Samoa to exemplify simple and complex fields in various scales. This global framework will then serve a reference to put Auckland, South Auckland, Waipiata and Chatham Island in place. Some ideas will be highlighted to show pedagogical methods (Montessori Method) to utilize these geosites for geoeeducation.

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Microstructural Adaptations to Shear Zone Thinning: Examples from the Mount Irene Detachment Zone, Fiordland, New Zealand

Volcanic Geoheritage Values of Monogenetic Volcanic Fields in the Global Scale and from New Zealand Perspective

Poster
Monogenetic volcanic fields carry great geoheritage values, especially if their historic eruptions influenced human societies and are reflected in oral and written history, and artefactual historical remains of such event(s).

The Auckland Volcanic Field (AVF) in the North Island of New Zealand is one of the youngest basaltic volcanic fields in New Zealand, active since about 250 ka BP. In particular, the Ihumātao Peninsula, and the wider Mangere area, is a region where periods of alkaline basaltic volcanic activity have produced numerous volcanic features over the Quaternary Period. These features include tuff deposits, maar craters, lava flows, and scoria cones. In several areas the results of interacting eruptive processes may still be viewed in an area well served by infrastructure due to its proximity to an urban centre.

While the volcanic field has been the subject of intense scientific research in recent years, especially in relation to volcanic hazard and risk management and forecasting, relatively little has been done so far to document and evaluate the geoheritage values of the region, especially with the goal of developing successful geoeducational and geotouristic programs.

Recently an application has been lodged for adding AVF to the UNESCO World Heritage List, in spite limited evaluation of their geosites throughout the AVF as a whole. Even with a well-established geosite inventory of the AVF volcanic field demonstrating its **outstanding universal values (OUV)** based on its natural phenomena, establishing validity as a World Heritage site may prove a difficult task, as monogenetic volcanic fields contain the most common types of volcanoes on Earth.

Here we discuss a more conservative approach to promoting the volcanic geoheritage of the AVF (Fig. 1), by using the Ihumātao region in South Auckland as a case study, with a goal towards establishing a geotrail, geopark, or heritage reserve as a community-driven initiative, based on well-documented geological, cultural, and heritage values of the area.
The Alpine Fault is New Zealand’s longest (~900 km long) and fastest moving active fault exposed on land with horizontal slip rates of up to ~32 mm/yr. The fault accrues slip during large surface-rupturing earthquakes which pose an important seismic hazard, particularly in the South Island. During the past ~30 years a growing body of evidence from on-fault and off-fault sources indicates that these earthquakes can exceed magnitude 8 with recurrence intervals of hundreds of years. Despite the world-class paleoseismic datasets available for the Alpine Fault, uncertainties remain about the range of surface-rupturing earthquake magnitudes and recurrence intervals (and how they vary along the fault), and the most likely rupture scenarios for future events. To quantify these parameters and their uncertainties we have collated existing data on the geometry, slip rates and paleoearthquake histories of the fault from the literature, unpublished information and elicited expert opinion during a workshop. The results highlight variability in the geometry and rupture dimensions along strike for well-characterised events over the last ~1400 years. These surface-rupturing events have estimated moment magnitudes of ~7.8-2 and rupture fault lengths of ~30-450 km (lower bounds estimated from offshore sections of the fault), with events beyond these ranges also possible. The average recurrence interval for these earthquakes varies by up to a factor of three (~140 years vs ~360 years), being dependent on the location of the measurement, the time interval recorded and uncertainties in the estimated event ages. Collectively these data and their uncertainties will be used to help quantify the next generation of seismic hazard models for the fault.


THE UPS AND DOWNS OF TECTONICS, SEA-LEVEL AND SEDIMENT SUPPLY IN THE RECENT GEOLOGICAL HISTORY OF WELLINGTON HARBOUR (TE WHANGANUI A TARA)

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Wellington Harbour is located at the southern end of the North Island, New Zealand, and is an 80 km-diameter, near-circular depression with one prominent arm (Evans Bay) and a narrow harbour entrance. The harbour lies within a series of tectonically uplifted and tilted structural blocks that comprise greywacke basement rocks, with major bounding strike-slip faults. The present-day harbour sediment-fill are marine silt muds that overlie coarse fluvial and colluvial clastic materials deposited during the last glacial period when sea-level was ~120 m lower than today. At the harbour entrance, marine sands and gravels, pushed into the harbour by southerly storms, interferes with the muds. Since human habitation, extensive areas of the harbour have been reclaimed and harbour sedimentation rates have increased substantially due to widespread land vegetation clearances in the hinterland caused by natural earthquake events and human activities. Recently collected marine geophysical and sediment core data have further elucidated the effects of tectonics, climate/sea-level and sediment supply on the recent geological formation and evolution of Wellington Harbour. These data have led to an improved appreciation of known tectonic structures and the discovery of new faults in the harbour, better definition of sea-floor depressions and pockmarks, caused by freshwater and/or biogenic gas expulsion, and an enhanced understanding of the distribution of near-surface groundwater aquifers and aquicludes that are important for water supply to Wellington City and its environs. These new data offer the potential to build further resilience into geological hazard and resource exploitation plans for the benefit of the Wellington region.

ORAL
Recent devastating tsunami have heightened awareness of the consequences and vulnerabilities of low-lying Pacific islands and coastal regions. Our appraisal of the potential tsunami hazard for the atolls of Tokelau is based on a non-deterministic tsunami source–propagation–inundation model using Gerris Flow Solver. We assess the potential for tsunami flooding from 14 tsunamiic earthquake sources in terms of magnitude, orientation, and distance. For the purposes of informing a civil evacuation strategy, a relationship was established between an earthquake warning and potential tsunami risk.

Wave fields are channelled by the Pacific basin bathymetry with swaths of the highest waves sweeping northeast of Tokelau. From our limited series of simulations, great earthquakes from the Kuril Trench created the highest maximum wave heights of >1 m, lasting a few hours and may include several wave trains. Other sources affect specific sectors of the atolls, particularly distant earthquakes from Chile and Peru, and regional earthquake sources to the south. Dry areas remain around the villages in nearly all our simulations. Consistent with the oral history of little or no perceived tsunami threat, simulations from the recent Tohoku and Chile earthquakes infer only limited flooding. Where potential tsunami flooding was identified, evacuation heights above local sea level were recommended relative to directional quadrants around the atolls. But complex wave behaviours around islets, tidal channels and within lagoons were also observed in our simulations. Wave amplitudes within the lagoons may exceed 50 cm, increasing any inundation and risks on the inner shoreline of the atolls, and may influence evacuation strategies. Our study shows that indicative tsunami simulations can be achieved even with only basic field information, due to the spatially and vertically limited topography of the atoll, short reef flat and steep seaward bathymetry, and the simple depth profile of the lagoon bathymetry.

Oral

SEA ICE AND DIATOM PRODUCTIVITY IN THE ROSS SEA, ANTARCTICA: THE RESPONSE TO POST-GLACIAL WARMING

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The Holocene, the period from 11,700 calendar years BP to present, is characterised by millennial-scale climate fluctuations superimposed on an orbitally paced warming trend. Geographic heterogeneity in these fluctuations appears to result from local variations in climate and oceanography associated with deglaciation. The timing of ice retreat within the Ross Sea is somewhat constrained [1]. In comparison, there are fewer constraints on oceanographic and climatic conditions during the progression of Holocene warming following ice retreat, and the subsequent impacts on sea ice extent and primary productivity. The Ross Sea coastal margins have high sedimentation rates with excellent potential to preserve continuous high-resolution sedimentary records, which are essential for Holocene reconstructions of climate and oceanography.

We present geochemical proxies for gross diatom abundance, nutrient utilization and water stratification (wt.% BSi, d13C, d15N, C and N concentrations), and early results of diatom assemblages from four marine sediment cores. These cores are located along the Sw margin of the Ross Sea; offshore of Mawson Glacier, Granite Harbour, east and northeast of Ross Island, and were collected during the 2015 KOPRI Antarctic Cruise ANA05B. All cores contain basal ice-associated facies and overlying diatomaceous ooze. This multiproxy approach enables us to reconstruct sea ice extent and primary production during the Holocene and to compare our results to proximal ice core reconstructions.

Obtaining precise and accurate chronology of sediment is critical to spatially correlate the timing and pace of deglaciation and subsequent Holocene changes. We are currently developing a core-to-core correlation through 210Pb-corrected 14C chronology. However, Antarctic sediments are challenging to date accurately due to old carbon contamination. To overcome this, we are employing the recently
developed ramped pyrolysis method [2]. This multiproxy analysis, combined with robust chronology, allows us to constrain the nature of Holocene warming within the SW Ross Sea with greater accuracy than previously possible.

AN UPDATED STRAIN RATE MAP OF NEW ZEALAND: EVIDENCE FOR STRAIN PARTITIONING ON PART OF THE PACIFIC-AUSTRALIAN PLATE BOUNDARY

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This poster presents an updated strain rate map for New Zealand based on the velocity field from Beavan et al. (2016). Elevated maximum shear strain rates define a broad corridor across the central and northern South Island following the Alpine fault and Marlborough fault system (MFS) and extending onto the lower North Island. Strain rate tensors are generally consistent with transpression with a principal axis of contraction trending 145°. The largest values, of about 4·10^-8 PPB/yr, are located in the central Southern Alps near Mt Cook, an area that is also characterized by significant dilatation. Farther north, high shear strain rates are restricted to the Hikurangi margin and the Taupo volcanic zone (TVZ) and the strain rate tensors indicate strain partitioning with significant extensional dilatation signal associated with the TVZ contrasting with contraction in the axial ranges. In general our results are similar to previous studies however, in the southern South Island our study reveals a region located just east of the Waitaki Valley where the principal axes of contraction trends at 80°, in contrast to 120° in adjacent parts of Canterbury and Otago. This change, combined with slightly elevated strain rates in costal Otago, may support modelling studies of Upton et al. (2009) who predicted a similar change in orientation in the stress field due to the along strike transition from a thin, stronger, crust for the Canterbury strain regime and a thicker weaker crust in the Otago strain regime.

CHARACTERISATION OF COASTAL FJORDS AND BURIED GLACIAL VALLEYS AT THE SUB-ANTARCTIC AUCKLAND ISLANDS USING HIGH FREQUENCY SEISMIC DATA

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The leeward side of the sub-Antarctic Auckland Islands (51° S, 166° E) is dominated by Quaternary glacial landforms extending offshore to the shelf break. These offshore glacial landforms, as a part of the wider glacial history at the Auckland Islands are currently poorly resolved. Over 1200 km of high-frequency seismic data from the previously unsurveyed fjords, harbours and eastern shelf are presented here with corresponding multibeam bathymetric surveys. Using a suite of high-resolution geophysical and geologic surveying techniques, this project constrains the infill stratigraphy and morphology of drowned valleys and coastal fjords. Specifically, we will (i) examine glacial extent and sedimentary regimes in fjords and drowned valleys to further understand the local glaciation and sedimentation history, (ii) identify potential submarine lacustrine deposits as future coring targets for high-resolution climate proxies, (iii) use paleo sea levels to constrain paleo-shorelines during the last glacial maximum (c. 26 – 19 ka), (iv) characterise the eroded eastern shelf platform during the last glacial maximum and sea level lowstand.

First-order observations and interpretations from the data show sedimentary deposits and widespread buried topography consistent with coastal glaciation. Analysis of the processed seismic data through the evaluation of seismic velocities in combination with new sea floor bathymetry data, provide high-resolution inputs into specific geologic modelling packages. This refines spatial constraints on sedimentary lithologies, valley morphologies and valley formation. These reconstructions of offshore Auckland Islands topography and stratigraphy at glacioeustatic lowstands help to identify localities where lacustrine deposits may occur separate from marine influences. Lacustrine deposits are to be targeted for coring for high-resolution Southern Hemisphere paleo-climate proxies as a wider research objective. These methods and approaches advance understanding of glacial extent, climate parameters and the emergent Auckland Islands landmass during the last glacial maximum at mid-high southern latitudes where geologic archives are sparse.

ORAL
THE MT FYFE AND SEAWARD SECTIONS OF THE HOPE FAULT, EASTERN MARLBOROUGH, SOUTH ISLAND

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Onshore-to-offshore tectonic geomorphology mapping using high resolution LiDAR data and marine EM2040 multi-beam bathymetry and seismic reflection data are providing new insights into the structural complexity, segmentation, and possible slip-rate of the Mt Fyfe and Seaward sections of the Hope Fault, eastern Marlborough.

The predominantly dextral, high slip rate (>20 mm/yr) strike-slip Conway segment of the Hope Fault inland and SW of Mt Fyfe, abruptly transitions to a wide and complex transpressive deformation zone along the Mt Fyfe range front. Shallow-level fault slip partitions into strike-slip, thrust and normal splays. Prominent thrust “flaps”, driven by the topographic loading of the overriding Mt Fyfe block, have propagated and widened the fault zone by up to 1 km into the SE footwall block, deforming alluvial fans and unstable slopes. The distributed deformation here is also associated with transfer of dextral shear onto the north-trending Jordan Thrust Fault (JTF). Surface traces of the partially over-ridden Hope Fault “re-appear” NE of the JTF intersection, as braided dextral-slip strands broadly arranged in a left-stepping en echelon pattern approaching the coast.

On the north Kaikoura Plain an E-W trending splay off the Hope Fault projects offshore to possibly link with the Kaikoura Fault, forming a right step-over with associated basin. The main Seaward section of the Hope Fault extends to the NE across the shelf as a series of splays linking to the Te Rapa section 30 km east of Kekerengu. Here the structural style of active deformation is strongly transpressive with multiple (>10) dextral-slip fault splays associated with folding and uplift. The length of the combined Seaward and Te Rapa sections NE of the JTF reaches 80 km, with total left step-over width of 10-15 km. On-going analysis of dextral offsets captured in the high resolution (2 m DEM) EM2040 multi-beam data will lead to improved assessments of slip-rates.

NEW GEODETIC RESULTS FROM THE HAURAKI RIFT: SLOW CONTINENTAL RIFTING OBLIQUE TO SUBDUCTION, NORTH ISLAND

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The Hauraki Rift, an active but slow-deforming narrow intra-continental rift in northern New Zealand paradoxically strikes nearly normal to the Pacific-Australian oblique subduction boundary 300+ km to the southeast. Both the driving mechanism and quantitative details of the rift’s current activity are unknown. Past GPS/GNSS geodetic surveying in the area has been coarse and erratic (e.g. single 8-hour surveys in 1995). In 2015 and again in 2016 a ~37 station network of existing benchmarks around the rift was measured with the aim of gaining better insight into deformation in the region. We find that it is primarily extensional (~0.9 mm/yr) with a small portion of right-lateral shearing (~0.1 mm/yr) relative to a fixed Australian plate in ITRF2008. Closer to the plate boundary, the oblique westward subduction of the Pacific plate generates a strong clockwise angular strain signature in the over-riding plate; this same angular stress field is the simplest explanation for the Hauraki Rift’s axis-perpendicular strain and in consistent with previous geophysical observations. Additionally, several short wavelength dislocations between our velocity solutions hint at the existence of undocumented active faults which will have implications to the seismic hazard to Auckland, New Zealand’s largest city, located just ~50km west of the rift.

POSTER
NEW (U-Th)/He AND U-Pb ZIRCON AGES ACROSS THE TAURANGA AND KAIMAI VOLCANIC CENTRES: STRENGTHENING THE AGE FRAMEWORK OF THE COROMANDEL-TAUPO VOLCANIC TRANSITION

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The final phase of silicic volcanism attributed to the Coromandel Volcanic Zone (CVZ), and immediately preceding the onset of activity along the modern Taupo Volcanic Zone occurred around the Tauranga and Kaimai areas. Briggs et al. (2005, N.Z. J. Geol. Geophys. 48, 459-469) determined 40Ar/39Ar ages on feldspar separates of a suite of rhyolite and dacite lava domes/flows and ignimbrites from both the Tauranga (2.69 – 1.90 Ma) and Kaimai (2.87 – 2.09 Ma) volcanic centres. Six of these rhyolites/dacites (Kaimai, Minden Peak, Upuhue, Kopukairua, Papamoa and Mangatawa) and one ignimbrite (Waiteuriki Ignimbrite) were re-sampled, in addition to two previously undated rhyolite domes (Waitoa, Waikete), for zircon dating by (U-Th)/He and U-Pb methods. The purpose of this approach was three-fold: (a) to establish a benchmark for (U-Th)/He and U-Pb dating in the CVZ against the established 40Ar/39Ar ages; (b) to strengthen and broaden the age constraints of the Tauranga and Kaimai volcanic centre eruptives; and (c) to extend an earlier (U-Th)/He and U-Pb dating campaign across the central and northern CVZ (Vincent, 2012, MSc Thesis, Univ. Waikato; Vincent et al. unpublished data) to the southern CVZ. Preliminary (U-Th)/He age data for several rhyolites/dacites are consistent with the earlier 40Ar/39Ar ages, although the Kopukairua and, previously undated, Waitoa domes occur close to, possibly older than, the previous upper age limit of volcanism for the Tauranga Volcanic Centre. This presentation will report on the final (U-Th)/He and U-Pb ages and their implications for the timing of volcanic activity at the Tauranga and Kaimai volcanic centres.

POSTER

MINE PIT WALL WASH GEOCHEMISTRY – BRUNNER COAL MEASURES.


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Wall wash samples were collected from coal mine pit walls with ages spanning 3 days to 18 years to measure differences in the amount of acid and trace elements released as the rocks of the pit wall weather. Changes in wall wash chemistry with the age of the pit wall can be used to predict the long term patterns in acid and trace elements release from these rocks under conditions where oxygen availability for pyrite oxidation is unlimited.

For the first year or so the concentration of acid released in wall wash is relatively high and constant, but subsequently the concentration of acid decreases rapidly and can be fitted with a power function. After 18 years of weathering the concentrations of acid and trace elements released in wall wash remains substantially higher than the concentrations that occur in small streams draining only coal measures without mining impacts.

Extrapolation of the decreasing trend in acid release from pit walls to concentrations that occur in natural coal measures streams indicates that the period of enriched acid lasts for between 10 and 165y. If these data are averaged and a regression is applied, then the time for which AMD released from pit walls is more enriched than streams is between 55 and 105 years.

Trace element concentrations in wall wash are often higher than concentrations measured in BCM leaching experiments or in AMD analyses and do not decrease in the same manner as acid release from pit walls.

ORAL
WHAT CAN THE BOULDER BRECCIAS OF THE MOMOTU SUPERGROUP TELL US ABOUT CRETACEOUS HIGH LATITUDE PALEOENVIRONMENTS? ARE THEY GLACIAL LAKE OUTBURST FLOOD (GLOF) DEPOSITS?

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Momotu Supergroup sediments include the Cretaceous Matakea Group of Otago and the coeval Pororari Group of Westland. Thick non-marine boulder breccias are prominent within these units, which rest unconformably on basement and are truncated above by a regional heterolithic unconformity, the Waipounamu Erosion Surface.

The origin of the bouldery sediments is currently obscure, and the mode of formation of the Waipounamu Erosion Surface is controversial.

The Momotu Supergroup is a rift infill sequence. Breccias were previously interpreted as talus shed from nearby fault scarp with finer fluvial and lacustrine material representing distal equivalents. This interpretation is problematic because distal units have a different provenance to their putative proximal equivalents. Geological relations within the Matakea and Pororari Groups can alternatively and preferably be interpreted in terms of sandstones and conglomerates low in the sequences giving way up-section to laterally extensive boulder breccias.

The temporal transition from fluvial and lacustrine sedimentation to boulder breccia deposition is expressed regionally and suggests that a pluvial climatic regime was superseded by an episode of semi-aridity. This marked Cretaceous climatic change accompanied Gondwana breakup and took place at high paleolatitude soon before the brief destructional event that formed the enigmatic Waipounamu Erosion Surface. These events can be explained coherently with a model involving a change from continuous fluvial sedimentation to episodic non-precipitation driven deposition from hyperconcentrated debris flows. Aridification can be accounted for by windy periglacial conditions, and coarse breccias may represent jökulhlaup or glacial lake outburst flood debris deposited into the proglacial environment soon before regional glacial erosion.

Paleoenvironmental and paleoclimatic changes archived by Cretaceous terrestrial sediments of New Zealand’s Momotu Supergroup are explicable in terms of nucleation of small ice caps that periodically generated GLOFs before coalescing to form the voluminous wet-based or polythermal Cretaceous ice sheet beneath which the Waipounamu Erosion Surface developed.

ORAL

ASSESSING TSUNAMI HAZARDS OF LAKES, PART 2: MODELLING OF SCENARIOS FOR LAKE TEKAPO, AND DEVELOPMENT OF METHODS FOR PROBABILISTIC HAZARD ESTIMATION.

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We are working to assess the tsunami hazard posed by landslides in Lake Tekapo, building on the geophysical survey and subsequent analysis performed earlier this year by NIWA. A specialised version of the COMCOT tsunami model is being used to model the coupled process of landslide descent and tsunami wave generation – this represents a significant step forward from the traditional approach of modelling the landslide and tsunami independently. For calibration of the landslide-tsunami model, scenarios were developed based on identified pairings of landslide scar and lakebed deposit. A further set of scenarios was developed based on events found in the geophysical dataset, and is being used to identify the types of tsunami sources that are most likely to pose a risk to the township and infrastructure sites. Work is on-going to find a suitable process for estimating probabilistic tsunami hazard at sites around the lake: this process needs to consider that while some landslides appear to be repeating events – such as failure of deltas – others are ‘one-off’ events that are unlikely to repeat in the same form. Different approaches that are being considered for tackling this problem will be presented.

ORAL
NEW PERSPECTIVES ON THE VOLCANIC HISTORY
OF THE ANDESITIC-DACITIC 1.8 Ma
MAUNGATAUTARI COMPOSITE CONE, CENTRAL
WAIKATO REGION

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Maungatautari is an extinct andesitic-dacitic composite cone volcano that rises prominently in the Waikato region. A single radiometric age date of 1.8 Ma, activity here was synonymous with subduction-related volcanism of the nearby Alexandra Volcanics and the early Taupo Volcanic Zone. Maungatautari volcanism was previously addressed (1970s-80s) in context of the broader volcanic geology of the Waikato region, and the only dedicated volcanic study of Maungatautari (Briggs 1986. N.Z.J Geol. Geophys. 29, 273-289) provided insight to the chemical composition and origin of the magmas. Since then, track development by Maungatautari Ecological Island Trust (MEIT) has exposed many new study sites. Furthermore, previous studies have not attempted to determine the range of eruption styles associated with the volcano.

This talk will overview preliminary findings from geomorphic analysis and field observations and demonstrates the complex landscape evolution and various volcanic styles which have occurred. The mountain is highly eroded and incised by deep gullies with prominent peaks located on the NW and S slopes. It is proposed that these peaks are fragments which have broken away from a central point during large landslide events. The mountain is buttressed by a greywacke range and an onlapping ignimbrite plateau to the west and south respectively, preventing catastrophic collapse in these sectors. However, complete collapse has occurred in the NE, characterised by an amphitheatre-shaped scarp and hummocky deposits of a rock avalanche. Rock types consist of highly jointed, porphyritic andesite-dacite lavas and pyroclastic deposits - two of which are of particular interest. Quarry #34 reveals a succession of massive pyroclastic breccia to stratified lapilli tuff which may represent an eruption through a silicic lava dome and a potential vent site has also been located near the summit by deposits consistent with diatreme breccia facies and tilted blocks of spatter. Hydrothermal altered andesitic lavas were also found at a site previously explored for gold mining in the late 1800s.

ORAL

GEOLOGICAL REVELATIONS FROM NEW
AEROMAGNETIC DATASETS

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By mid-2017 approximately a third of New Zealand’s land area will have been covered by freely accessible, modern, high resolution aeromagnetic data. The surveys have been undertaken for industry and government, principally to support mineral exploration but have side benefits for petroleum and groundwater exploration as well as general geological understanding.

One of the newly released surveys acquired for New Zealand Petroleum & Minerals covers much of the East Nelson-Marlborough area and most of the highest amplitude magnetic anomalies there correlate well with known igneous rock. The Red Hills area of ultramafic rock has a striking concentric anomaly around its rim that may be intrusion related. Another high amplitude magnetic anomaly northeast of Nelson City correlates with surface-mapped Cable Bay Granodiorite but its subsurface extent appears to persist southwards beneath mapped Drumduan Group. Brook Street Volcanic Group rocks are the probable source of some strong linear anomalies due to the city and from an area west of Tophouse. Anomalies south of Wakefield correlate with mapped Murihiku Group rocks. Buried strongly magnetic rocks beneath Matai Group rocks, possibly in fault contact, are interpreted east of Golden Downs.

Preliminary results from the partially completed Southland-Otago aeromagnetic survey reveal several previously unrecognised features and structures. The Murihiku Terrane shows large-scale folding about the regional-scale Southland Syncline, and in detail are cross-cut by numerous low-displacement fault-fractures at km-scale spacing. The Brook Street Terrane can be traced beneath Southland Plains and there are a number of long-wavelength features suggesting the presence of buried magnetic intrusions that are yet to be explained. The Median Batholith is clearly continuous offshore from Colac Bay to Bluff. While the overall strike is broadly NW-SE across the survey, a change to NNW-SSE in the west to interpreted as the subtle effect of oroclinal bending. ORAL
A high resolution airborne geophysical survey dataset covering much of East Nelson and Marlborough has been acquired for New Zealand Petroleum & Minerals and was publicly released in September 2016. The survey was flown at 200 m line spacing at a target ground clearance of 50 m and collected magnetic and radiometric measurements. These data have been processed into gridded images that are available, with the original line data, from http://www.nzpam.govt.nz/cms as mineral report MR5400.

Most of the highest amplitude magnetic anomalies correlate well with known igneous rock, notably the Dun Mountain Ultramafic Group and the Croisilles and Patuki melanges in the Richmond and Bryant Ranges. The Red Hills area of ultramafic rock has a striking concentric anomaly around its rim that may be intrusion related. The anomaly is truncated at the Alpine (Wairau) Fault in a dextral drag with entrained ultramafic rock interpreted in the fault zone to the southeast. Another high amplitude magnetic anomaly northeast of Nelson City correlates with surface-mapped Cable Bay Granodiorite but its subsurface extent appears to persist southwards beneath mapped Drumduan Group. The area of Brook Street Volcanic Group rocks east of the city show some strong linear anomalies as do Brook Street rocks west of Tophouse. Anomalies south of Wakefield correlate with mapped Murihiku Group rocks. Buried strongly magnetic rocks are interpreted east of Golden Downs beneath, possibly fault-overlain, by Matai Group rocks. Torlesse Terrane rocks have very subdued magnetic anomalies in general. Moderate amplitude anomalies south of Blenheim are attributed to volcanogenic units in the Pahau Terrane.

**NEW AEROMAGNETIC DATASET REVELATIONS: NELSON-MARLBOROUGH**

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**MAGMA DYNAMICS AND ASCENT RATE BENEATH A MONOGENETIC VOLCANIC COMPLEX (THE JAGGED ROCKS COMPLEX, HOPI BUTTES VOLCANIC FIELD, AZ, USA)**

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The Jagged Rocks complex is the shallow (~300 m below the paleosurface) eroded remnant of the plumbing system of a monogenetic alkaline volcanic centre within the southern Hopi Buttes. It preserves coherent intrusive sheets and fragmental conduit deposits. These deposits reveal different clinopyroxene populations with specific textures and geochemical patterns. In the NW part of the complex crops out an en echelon dike along which are aligned five conduits. They bear i) coarse clinopyroxene with a homogeneous core overgrown by euhedral rims (types 1-2), ii) small greenish pleochroic moderately-resorbed clinopyroxene cores with the same rim overgrowth (type 4), and iii) accessory phlogopite and oxides. By contrast, the rest of the complex bears small euhedral clinopyroxenes with oscillatory zonation (type 3; sparsely present within the NW system as well), and a few small euhedral olivines and oxides. Major- and trace-element geochemistry distinguishes three groups of clinopyroxene. Types 1 and 2 cores are the most primitive and contain the lowest abundance of incompatible elements (Ti, Al, Fe, REE), whereas their overgrown rims and the type 3 are progressively more evolved (decreasing SiO2 and Mg#) and enriched in incompatibles toward the edges. The green cores are xenocrysts that reveal different geochemical patterns as low Mg# paired with high abundance of incompatible elements. The discrepancy between these mineralogical assemblages indicates a composite history of crystallization and magmatic evolution governed by different styles of magma ascent from a single source at ~50 km depth (~14 kbar). The NW system preserves a high-pressure assemblage that chilled rapidly from near-liquidus conditions, suggesting direct ascent at moderate rates (average velocity ~1.3 m/s). By contrast, the southern system was emplaced from a magma body that rose upward at much lower transport rates, allowing re-equilibration and crystallization of a mineralogical assemblage in equilibrium at shallower depths (~20 km; ~7 kbar).

POSTER

ORAL
CONDUIT INITIATION AT SHALLOW CRUSTAL LEVEL WITHIN A MONOGENETIC VOLCANIC COMPLEX (JAGGED ROCKS COMPLEX, HOPI BUTTES, AZ, USA)

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Small-volume, monogenetic, mafic volcanoes range in form and size from simple eruptive fissures and scoria cones to more-complex small shields and maar-diatremes, reflecting the broad spectrum of possible eruptive processes. They have limited magma supply and lack long-lived sustained magma plumbing systems, thus the location, style and duration of any eruption is affected by processes in the magmatic feeder system at shallow crustal depths (< 1 km), where the transition from dikes to conduits develop. The Jagged Rocks Complex in the late Miocene Hopi Buttes Volcanic field exposes intrusive and volcaniclastic deposits, holding information on how a shallow magmatic plumbing system evolved within a stable non-marine sedimentary basin, and on the processes by which magma flowing through dikes fragmented and conduits were formed beneath monogenetic volcanoes. Three types of fragmental deposits [buds (emerging from dikes), pyroclastic massifs (tabular or sub-circular), and diatremes] represent three different styles and intensities of shallow-depth magma fragmentation. They may develop successively and at different sites during the evolution of a monogenetic volcano. The deposits consist of a mixture of pyroclasts with varying degrees of welding, and country rock debris in various proportions. Pyroclasts are commonly welded together, but also reveal features consistent with phreatomagmatism. Development of elongate massif structures requires processes different to those forming sub-circular diatremes as the extent of fragmentation and the formation of subterranean open space controlled the nature of the particles and the architecture and geometry of these conduit structures and their deposits. Subterranean emplacement of bedded spatter in tabular vertical pyroclastic massifs accompanied magma retreat at depth when the superficial activity of an initial fissure eruption waned. Sub-circular massif reveals some sort of short-lived and more energetic fragmentation below exposure depth, with emplacement of lapilli tuff deposits that truncate the bedded spatter.

INVESTIGATING THE 3D GEOLOGICAL ARCHITECTURE OF THE LOWER POHANGINA VALLEY, NEW ZEALAND.

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The geology and stratigraphic architecture of the Lower Pohangina Valley, Manawatu has been documented recently by Rees (2015). A geological map has been compiled at 1:30,000 scale, allowing east-west trending cross sections to be constructed across the Pohangina valley. Data gathered from this study are used together with GIS and Leapfrog Geo modelling software to build a 3D geological model.

The geology of the Lower Pohangina Valley is dominated by regional structures including the Pohangina Faulted Monocline and underlying shallow reverse faults which bound the western margin of the Ruahine Range. Basement rock is composed of highly shattered and sheared Torlesse terrane greywacke. Overlying Plio-Pleistocene sediments up to 700 m thick record marginal to shallow marine deposition within the eastern Whanganui Basin. Regional uplift and drag tilting of the overlying Plio-Pleistocene sediments has resulted in an active, young landscape with steep stream gradients, deeply incised stream channels and high erosion rates.

Modelling software is a powerful tool which can be used in combination with traditional 2D mapping techniques to help visualise and refine geological interpretation. 3D geological models also create important frameworks which allow for the integration of a wide variety of datasets. A combination of stratigraphic logging, mapping and 3D modelling is used in this study to help visualise and understand the spatio-temporal distribution of geological units and structures.

POSTER
GALTERENTAL, SWITZERLAND: HAZARDOUS ROCK AVALANCHE OF 24 APRIL 2016 AND ITS MITIGATION

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During the collapse of an instable rock slope, a hazardous rock avalanche with a volume of more than 2,500 m³ of sandstone occurred in the Galterental Valley in Switzerland (coordinates (lat/lon) 46.80609, 7.19256) on 24 April 2016. A 300 year old building situated in proximity to the rock slope was destroyed. Fortunately, there were no casualties thanks to a telejoointmeter-based online surveillance. The instable rock slope had been monitored since 2012 when a smaller rockfall had occurred. Prior to the event, acceleration of displacement velocities were observed along a valley-parallel chasm. Data based prognosis of the collapse allowed to evacuate the house in the week prior to the event. For mitigation purposes and evaluation of secondary processes such as landslides, volume differences were calculated using 3D-surface models based on UAV imagery before and after the event. A safety blasting in the detachment zone was necessary to secure the area for further remediation works. The safety blasting was captured by a UAV in order to evaluate further damage or necessity of emergency intervention. GEOTEST was assigned by the local authorities to carry out the hazard mitigation from the event analysis to the expert monitoring of the safety blasting.

ORAL

COMPOSITIONS AND FLOW RATES OF SPRINGS IN THE HIKURANGI FOREARC, NEW ZEALAND

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More than 250 sources of saline waters (2000 to 2572000 mg/kg Cl), CH₄-rich gases and occasional oil seeps are discharged along a 500 km length of the subaerial accretionary prism in the East Coast of the North Island, from about -37.5⁰ to -41.3⁰ latitude, 80 to 100 km from the subduction margin. All fluid discharges are cold except for three hot spring systems in the central and northern blocks where surface temperatures vary from warm to 69°C. Based on chemical and isotopic compositions, the discharges consist of subducted waters derived mainly from clay water of hydration (<50%), seawater that had interacted at varying degrees with organic-rich marine sediments/formations at depth and/or volcanic material over a wide range of temperatures and water of hydration from basalt mixed with recent groundwater. Only the northernmost springs are affected by fluids from shallow serpentinization. Fluids at depth have equilibrated at 100°C + 25°C (median values). Fluid components can be correlated with differences in mass flow and structural grain across the accretionary prism. There is a general increase in estimated deep temperatures with flow rates but a decrease with excess Cl relative to seawater. The mantle component in gases generally increases with the amount of clay water of hydration in the aqueous solutions. Changes in the after earthquakes of magnitude 5.0 have been recorded since 1855 earthquakes. Indications include mud blow-outs (especially in the northern sector), expansion of the area covered by manifestations, increased water and gas discharges by up to >10x relative to baseline data, increased expulsion of oil, increased groundwater chemical signatures in the waters and increased CH₄ relative to CO₂ and heavier dD (CH₄) in the gases.

ORAL

3-D IMAGING OF HIKURANGI PLATEAU SUBDUCTION IN THE SOUTHERN SOUTH ISLAND

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The Hikurangi Plateau was originally part of Ontong Java – the largest large igneous province on Earth. At ca. 105 Ma, the ca. 35 km-thick plateau jammed the Gondwana subduction zone in what is now the southern South Island. Here we use data from a dense seismograph deployment to investigate the causes and consequences of this jamming. With detailed 3-D Vp and Vp/Vs structure determined from local earthquake tomography, we track a region of Vp ca. 8.5 km/s (which has previously been associated with an eclogite layer at the base of the Hikurangi Plateau) across most of the southwestern South Island. Its southeastern edge runs diagonally from near Christchurch to northern Fiordland. It dips both to the northwest and the southwest, and impacts the subducted Australian plate in northern Fiordland, where it currently bends the subducted Australian.
slab to vertical. The plateau and its leading oceanic crust are distinguished by low Vp/Vs, consistent with extensive dehydration during ca. 500 km of flat subduction at the Gondwana margin. The plateau is also revealed by dipping zones of relocated earthquakes. The backstop of Gondwana subduction appears to have been the Maitai terrane, which extends through the crust and forms the trench-ward boundary of the ca. 70 km-thick Median Batholith. Ahead of the plateau, crustal-scale duplexing caused a schistose crustal root in Otago which is still ca. 25 km thick today. Following plateau jamming, the Gondwana margin began extending, with extension and volcanism limited to those areas where the strong plateau was not present at shallow depth. The plateau has also controlled the shape and orientation of the crustal root underlying the currently uplifting Southern Alps. Our study underlines the on-going havoc that impact of a large igneous province with a subduction zone can cause.

FOSSIL PENGUIN FROM KAKANUI ADDS TO A SPARSE GLOBAL EARLY OLIGOCENE RECORD

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Zealandia has a long record of fossil penguins, from Paleocene to Pleistocene, including specimens that help to fill the early Oligocene gap in the global history of penguins. Of note are fossil penguins from a bryozoan grainstone, the Ototara Limestone, of North Otago (southern Canterbury Basin), spanning Runangan to lower Whaingaroa (latest Eocene to early Oligocene).

Current research involves an undescribed penguin, OU 22106, from the upper Ototara Limestone, Kakanui (Globigerina angiporoides zone, lower Whaingaroan). OU 22106 comprises a partly articulated incomplete skeleton, including the main wing bones (humeri, ulna, radius, carpometacarpus, etc.), and associated pectoral girdle (furcula, coracoid, scapula). The mid to posterior of the trunk is articulated (vertebrae, ribs, pelvis, femora, patella). The distal leg is lost, including the taxonomically important ankle bone (tarsometatarsus). The loss of the tarsometatarsus prevents comparison with the historically important but taxonomically perplexing Palaeeeudyptes antarcticus, acquired at Kakanui by Walter Mantell, and named by T.H. Huxley in 1859. Some bones of 22106 show apparent post-mortem bioerosion, and there is minor post-depositional compression damage. The naturally associated skeleton implies limited traction currents and/or rapid burial.

Other notable undescribed Ototara Limestone penguins include 2 from Parkside Quarry (one cluster of leg bones, one partial pectoral girdle) and rare material of the massive Pachydyptes. The Ototara assemblage is the richest for the early Oligocene globally.

The Ototara penguins, like others from the Eo-Oligocene of Zealandia, were larger than living species. The humerus in OU 22106 is 145 mm long, smaller than that of Kairuku grebenifzi (upper Whaingaroan-Duntroonian) at 176.1 mm. Kairuku stood about 1.28 m, implying about 1.05 m for 22106 – about the height of an emperor penguin, but with different proportions. Large body size may have aided long-distance swimming from rookeries on the Zealandia archipelago to presumed productive upwelling regions at the distant shelf edge.

RHEOLOGICAL CONTROLS ON FOLDING IN CROMWELL GORGE, CENTRAL OTAGO, NEW ZEALAND

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Rakaia Terrane schist bedrock is a product of a complex geological history comprising multiple phases of deformation. Five phases of metamorphic deformation are represented in the structural features of Rakaia Terrane bedrock in Cromwell Gorge. The five phases comprise: D1 mineralogical recrystallization and segregation into leucocratic (quartz-albite-rich) and micaceous-rich laminae; D2 broad scale folding in the form of Leaning Rock antiform and pervasive schistosity; D3 macro-tomesoscopic parasitic folds and crenulated cleavage; D4 kink banding; and D5 fractures, en echelon quartz veins and carbonate veins.

Analysis of deformation features along the Dunstan Flank of Cromwell Gorge suggests lithological variations within the Rakaia Terrane sedimentary sequence induced a rheological control on the development of metamorphic structures during deformation events. Rakaia Terrane is composed of greyschist, ranging from pelitic (mica-rich) to psammitic (quartzofeldspathic) end members with subordinate greenschist. Laboratory analysis indicates
psammitic greyschist and greenschist units are characterised by approximately 30% higher intact rock strength than the pelitic greyschist units. This competency contrast appears to have governed the rheological deformation response of the bedrock to strain.

Leaning Rock Antiform has a prominent south-east trend along the Dunstan Mountain Range, however at the southern limb the antiform trend swings towards the west in the vicinity of the Caples-Rakaia Terrane boundary in Cromwell Gorge. Review of extensive borehole and tunnel logs from the Dunstan Flank of Cromwell Gorge suggests that the Leaning Rock Antiform fold axis (D1) and parasitic mesoscopic antiform fold axes (D2) identified along the Leaning Rock Antiform south facing limb developed in zones of thick accumulations of greenschist and psammitic greyschist. It appears the competent “stiffer” greenschist and psammitic greyschist units accommodated strain and resisted displacement through layer shortening and development of buckled hinge zones (antiforms), whilst the surrounding less competent pelitic schist yielded via strain-slip along the fold limbs.

PULLING THE PLUG: ALPINE FAULT TRIGGERED RIVER CAPTURE AND DEGRADATION HISTORY AT THE MARUIA-ALFRED RIVER JUNCTION, BULLER DISTRICT

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The flight of terraces at Calf Paddock near the Maruia-Alfred River junction has long been an important site for Alpine Fault research. Downstream of this site, the Maruia River is confined to a narrow gorge cut through Sluice Box limestone of the Mount Arthur group. A digital terrain model of the terrace sequence produced from GPS-RTK surveys collected in 2009, clearly identified paleo-drainage on the oldest terraces suggesting that, prior to the formation of the current terrace sequence, the Maruia River was diverted from the Sluice Box to the south-west around Marble Hill. Recent slip rate calculations have identified that when the Maruia River switched back to the Sluice Box, degradation occurred rapidly across the Maruia valley forming a majority of the terrace sequence. A recent airborne lidar survey has revealed geomorphological features that could explain a mechanism for the diversion of the Maruia River and the subsequent formation of the river terraces. This study presents preliminary geomorphic interpretation of the lidar data in relation to the terrace sequence and Alpine Fault rupture history. The slip rate and paleoseismic history of this site will also be presented by Langridge et al. at this meeting.

SEA ICE AND SEASONALITY ON THE EAST ANTARCTIC MARGIN: A HIGH-RESOLUTION HOLOCENE GEOCHEMICAL RECONSTRUCTION FROM THE ADÉLIE DRIFT

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At Site U1357, IODP Exp. 318 recovered ~185 meters of Holocene diatom ooze in regularly alternating light/dark couplets, underlain by glacial diamict. Radiocarbon chronology suggests that the core, collected from the Adélie Drift, Wilkes Land Margin, East Antarctica, has near-annual lamination with accumulation rates comparable to coastal ice cores. Discrete sampling of the light and dark members of each couplet, respectively interpreted to preserve spring and summer/autumn diatom bloom and export, allows us to examine the influence of seasonality on primary production throughout the Holocene. Wt% BSi in paired light and dark samples is a reflection of fossil diatom accumulation: this parameter is high (mean = 48%) throughout the 11,800-year record, and the light member of each couplet is generally characterized by a silica concentration 3-10% higher than the dark member. This result is consistent with an interpretation in which each light member represents a “clean” and nearly instantaneous export of the spring bloom into the sediments, while each dark member represents continued diatom growth throughout the summer and fall, with more incorporation of wind- and ice-blown terrigenous material.

Bulk sedimentary δ13C is interpreted using a model wherein positive values reflect the replenishment of dissolved organic carbon (DIC) from water column mixing, while negative values reflect DIC utilization in a water column stratified by sea-ice melt or other
being actively eroded from the Southern Alps. From the Alpine Schist, these outcrop along, and are heavy mineral potential. It is generally accepted that the interglacial garnet bearing placer deposits of New Zealand. However, the West Coast garnet is poorly understood geologically. The West Coast of the South Island hosts a number of interglacial garnet bearing placer deposits of economic significance, known historically for their Ilmenite potential. It is generally accepted that the heavy mineral suite of these placers is largely sourced from the Alpine Schist, these outcrop along, and are being actively eroded from the Southern Alps.

This project aims to:

• Characterise the physical and geochemical variation of the garnet within these placer deposits and the active coastal sediment system from Haast to Westport. The physical and chemical properties of garnet affect its end use value as an abrasive.
• Characterise the garnet bearing source rocks of Westland and determine their influence on these placer deposits
• Access the economic potential of other heavy minerals within these garnet deposits.
• Describe the structure and grade of the Ruatapu Garnet Deposit using drill hole data and ground based magnetics

Approximately 600 m of Late Miocene (Tongaporutuan) interbedded rhyolitic tephra and hemipelagic mudstone are exposed on shore platforms of the Mahia Peninsula. Previous work (Shane et al. 1998 NZJGG 41: 165-178) reported glass fission-track ages for tephra beds ranging from 8.90 ± 0.52 Ma near the base of the section to 7.47 ± 0.46 Ma near the top, which together with glass geochemistry, are interpreted as evidence for at least 67 discrete rhyolitic eruptive episodes in the Coromandel Volcanic Zone (CVZ). We revise this chronology using U-Pb zircon ages of five tephras recently acquired by the laser ablation inductively-coupled plasma mass spectrometry (LA-ICP-MS) method at Victoria University of Wellington.

Single crystal U-Pb dates range from 4 Ma to 1780 Ma but early Late Miocene zircons dominate (n = 70/120). Early Miocene, mid-Cretaceous, Early Jurassic, Triassic and Late Permian dates form subordinate age groups. Three samples from the middle section yielded error-weighted mean ages of 9.51 ± 0.68 Ma, 8.51 ± 0.17 Ma and 8.27 ± 0.22 Ma. A linear sedimentation rate of ~200 m/Ma ($r^2 = 0.97$) estimated using these ages predicts that the base and top of the section are ~10.4 Ma and ~7.3 Ma, respectively. Thus, the Mahia section spans ~3 Ma of the early Late Miocene during which time one CVZ rhyolitic eruptive episode occurred on average every ~45 ka. Measured and predicted ages for the upper and middle section are the same within uncertainty as glass fission-track ages. However, the lower part of the section is predicted to be ~1.3 Ma older than dated by the glass fission-track method. The revised ages also suggest correlation with the CVZ Whitianga Group. Preliminary assessment of Mahia tephra and Whitianga Group incompatible trace element geochemistry (e.g. Rb) shows that they are broadly comparable, supporting their correlation.

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U-PB ZIRCON GEOCHRONOLOGY OF LATE MIocene RHYOLITIC TEPHRA, MAHIA PENINSULA

WEST COAST GARNET

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Recently there has been significant interest and exploration for garnet on the West Coast of the South Island. Garnet is primarily used as an industrial abrasive and increasingly for water jet cutting of steel. The global demand for garnet has increased over recent decades due to the phasing out and banning of silica sand abrasives. Silica sand tends to break up rapidly when used as an abrasive and exposure can cause silicosis which is a debilitating lung disease. Initial prospecting and exploration for garnet on the West Coast has been very encouraging. Within the next few years it is likely there will be a sustainable garnet mining industry set up in New Zealand. However the West Coast garnet is poorly understood geologically.

The West Coast of the South Island hosts a number of interglacial garnet bearing placer deposits of economic significance, known historically for their Ilmenite potential. It is generally accepted that the heavy mineral suite of these placers is largely sourced from the Alpine Schist, these outcrop along, and are being actively eroded from the Southern Alps.

This project aims to:

• Characterise the physical and geochemical variation of the garnet within these placer deposits and the active coastal sediment system from Haast to Westport. The physical and chemical properties of garnet affect its end use value as an abrasive.
• Characterise the garnet bearing source rocks of Westland and determine their influence on these placer deposits
• Access the economic potential of other heavy minerals within these garnet deposits.
• Describe the structure and grade of the Ruatapu Garnet Deposit using drill hole data and ground based magnetics

PUBLICATION
PHASE MIXING AND THE SPATIAL DISTRIBUTION OF GRAIN-BOUNDARY PORES IN THE ALPINE FAULT

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Large-scale continental faults represent zones of inherent weakness and focussed deformation in the crust. Heterogeneities in fault zone rocks, such as grain-boundary pores, fine-grained secondary phases, and fluid inclusions can provide nucleation points for deformation instabilities, which are required for strain localisation. However, these heterogeneities are not uniformly distributed at any scale within fault zones. Therefore, a systematic characterisation of the nature and distribution of fault rock heterogeneities will improve our understanding of the mechanisms of strain localisation and fault zone dynamics.

The Alpine Fault is the main Pacific-Australian plate-boundary structure on the South Island of New Zealand, with rapidly exhumed hangingwall mylonite and cataclasite sequences that are equivalent to the fault rocks currently deforming at depth. We have sampled across the ductile strain gradient of the Alpine Fault zone to examine how microstructures and material heterogeneities evolve with increasing strain. Synchrotron micro-computed x-ray tomography (µ-CT) and scanning electron microscopy (SEM) imaging reveal that at lower strains, grain-boundary pores are concentrated on monophasic quartz boundaries, while with increasing strain pores are progressively found on boundaries between different phases. Electron backscatter diffraction (EBSD) shows a decrease in the intensity of fabric anisotropy, such as crystallographic preferred orientations (CPO), with increasing strain in polyphase rocks. We infer this is due to a switch in the dominant deformation mechanism associated with increased phase mixing. Here we explore the relationship between phase mixing, microstructural evolution, and the spatial distribution of material heterogeneities with increasing strain, and the overall affect this has on strain localisation in the Alpine Fault.

SANIDINITE FACIES REACTIONS AND TEXTURES DEVELOPED IN OTAGO SCHIST

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Pyrometamorphism of Otago Schist that has been entrained as xenoliths within the Miocene Ram Rock basanite near Dunedin has resulted in a remarkable near complete change in mineralogy from greenschist facies (T = < 400°C) to sanidinite facies (T = > 900°C) assemblages at low pressure (< 1 kbar). Extensive analysis of the xenoliths by scanning electron microscope, due to the extremely fine grain-size, and chemical analysis by electron dispersal spectrometry reveal that the Otago Schist quartz-albite segregations have recrystallized to quartz (inverted tridymite?) with orthopyroxene coronas within rhyolitic glass. The micaceous segregations (muscovite, chlorite, garnet), on the other hand, have been completely replaced by olivine, spinel, plagioclase, cordierite, ilmenite, orthopyroxene and an alkali-rich mafic glass. Replacement textures indicate that the sanidinite facies minerals crystallised through two mechanisms: as the result of mineral reactions from the former greenschist facies minerals, or they nucleated within a melt and developed quench textures. Inferred mineral reactions allow constraints on temperatures reached, with chlorite breakdown occurring at 870°C and complete muscovite breakdown at 950°C. Glass geothermometry gives temperatures of ~960-1030°C, while olivine-glass geothermometry gives 950-1050°C. Within xenoliths the compositional segregations of the Otago Schist protolith are behaving as isolated blocks during pyrometamorphism, producing separate chemical domains of ultramafic and dacitic composition.

ORAL
WELL PRESERVED QUATERNARY TEPHRA HORIZON, EASTERN BANKS PENINSULA

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Young tephra in the South Island are rare and therefore important stratigraphic markers for constraining quaternary landscape-forming processes and paleoclimate. Tephra research can also shed light into eruption plume dynamics and pyroclast transport. At Pa Bay, eastern Banks Peninsula, a cream-coloured 10cm thick tephra horizon has been discovered within a 8m-high coastal exposure of interbedded very fine to coarse sandstone with sporadic volcanic and mudstone clasts. The tephra is well sorted, fine-grained, finely bedded and contains burrows along its upper contact. Directly beneath the tephra is a 12cm-thick mottled yellowish grey, moderately sorted, highly burrowed, massive, very fine sandstone. Overlying and infilling the burrows into the tephra is a 17cm-thick, mottled yellowish gray and pale orange crenulated, clast rich very fine sandstone unit.

The light colour of the tephra and its thickness correlate well with the 10cm isopach contour for the 25.5ka Oruanui super-eruption (Kawakawa Tephra). Its location within a sedimentary sequence provides a unique opportunity to decipher the paleoenvironment during the last glacial maximum period in this part of the South Island. In addition, the well-preserved layering within the tephra could be a primary depositional feature, providing an opportunity to investigate discrete airfall events from an on-going eruption. As such, the tephra and the bounding sedimentary layers have been systematically logged and sampled for grain size, componentry and geochemical analysis. Initial observations of the tephra under binocular microscope have revealed an abundance of clear, cuspat e-shaped glass shards. We will present key findings as to the nature and origin of this tephra horizon and implications of this within the distribution of airfall tephra in the South Island and discuss the depositional-environment for the sedimentary sequence.

ORAL

HIGH-T TO UHT METAMORPHISM OF THE OTAGO LOWER CRUST DURING CRETACEOUS SLAB ROLLBACK AND EXTENSION

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Granulite xenoliths in the Kakanui Mineral Breccia, New Zealand, reveal the stunning result that the lower crust under at least one portion of Otago reached ultra-high-temperatures (UHT, > 9000°C) in the Cretaceous. The granulites, which are mainly metamorphosed felsic sediments, comprise assemblages of garnet, orthopyroxene, biotite, plagioclase, K-feldspar and quartz with or without sillimanite, spinel, ilmenite and rutile. Quantitative P-T estimates indicate that these assemblages, when corrected for Fe-Mg diffusion after peak metamorphism, equilibrated at ~800-900°C at 0.8 GPa. Temperatures calculated from re-integration of exsolution in perthite and antiperthite, and temperatures and pressures determined from thermodynamic modelling, provide supporting evidence for the attainment of UHT conditions. Diffusion calculations demonstrate that the formation of extreme temperatures predate entrainment by the host melt.

The discovery of ~100-90 Ma UHT granulites in the lower crust of Otago is puzzling because this area was located in the accretionary prism above the shallowly subducting middle Cretaceous (~110-105 Ma) slab. Such a position cannot attain UHT via typically appealing to mechanisms (long-live crustal thickening + radioactive heating, or emplacement of large volumes of magma) because the subducting slab forms an insulating layer from the lithospheric mantle. We suggest that the sudden cessation of subduction along the Gondwana margin at 110-105 Ma caused the dense slab to rollback towards the trench position, which then permitted hot lithospheric mantle to interact with the base of the crust. The result of this process, coupled with contemporaneous regional extension, would be a rapid rise in the crustal geotherm that promoted re-equilibration. The effect of this Late Cretaceous event would be to dehydrate the middle and lower crust, and therefore strengthening it, whilst leaving the shallow crust unaffected and preserving older Otago Schist prehnite-pumpellyite to greenschist facies assemblages.

ORAL
THE MANTLE BENEATH THE DUNEDIN VOLCANIC GROUP AND IMPLICATIONS FOR INTRAPLATE BASALT SOURCES

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The peridotitic lithospheric mantle beneath the Dunedin Volcanic Group in East Otago is isotopically heterogeneous. Unmetasomatised xenoliths have distinctly radiogenic Nd (εNd > +15.5) and extend to unradiogenic 87Sr/86Sr (0.7021). However, many xenoliths were fertilised by a LREE-rich metasomatic agent that imparted a HIMU-like isotopic composition (87Sr/86Sr = 0.7028; εNd = +5.0; 206Pb/204Pb = 19.9, 207Pb/204Pb = 15.5 and 208Pb/204Pb = 39.6) that overlaps with that of the host basalts. The cores of pyroxenes in different xenoliths equilibrated at 800 to 1100°C and therefore indicate that the xenoliths represent extraction from the upper to middle portions of the lithospheric mantle beneath this volcanic province. All pyroxenes are zoned in temperature-sensitive elements (Al, Cr, Mg and Ca), with trends typically indicating element exchange occurred during cooling and diffusion calculations indicating that element exchange required hundreds of thousands to millions of years. These results indicate that (1) mantle metasomatism, which formed the metasomatic pyroxenes, cannot be due to infiltration of host magma during xenolith ascent, and (2) heating of middle to upper lithospheric mantle did not precede the magmatism. The Dunedin Volcanic Group basalt source must therefore be a zone located either close to the base of the lithosphere and well below the area represented by the studied xenoliths, or from an enriched zone within the asthenosphere. Either conclusion is problematic for models invoking amphibole in the magma source since the common mantle amphibole (F-poor fergusonite) has a maximum thermal stability of ~ 1100°C, which restricts it to only the middle and/or upper portions of lithospheric mantle. Therefore, portions of the middle or upper lithospheric mantle have the same isotopic composition as the alkaline Dunedin Volcanic Group but there is no evidence for it being involved in basalt genesis.

POSTER

SULFUR SPECIES IN THE EARTH’S CRUST: NEW INSIGHT INTO INTERMEDIATE OXIDATION STATE AND THEIR ROLE IN GOLD AND OTHER ELEMENT TRANSPORT BY HYDROTHERMAL FLUIDS

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Sulfur occurs ubiquitously in hydrothermal fluids throughout the Earth’s crust and plays a fundamental role in element transport and transition metal precipitation (i.e. ore deposition). At ambient temperature and pressure and with increasing oxidation, reduced sulfur (i.e. H2S and HS−) in aqueous solution transforms to univalent and divalent polysulfides, polythionites and polythionates, thiosulfate, sulfite/SO3 and sulfate. However, the stabilities of many of these species at elevated temperatures and pressures have been little studied and hence their potential importance in hydrothermal ore formation has been largely ignored.

The intermediate oxidation state polysulfide species, S2nS2−, contain zero valent sulfur(s) bound to an S2− moiety and these species have been shown to disproportionate at temperatures >250°C. In addition, unidentified sulfide radical ions have been known to occur in high temperature water for 150 years (Geitner, 1864; Lewis et al. 1918; Giggenbach, 1971) but have otherwise, been scarcely studied in hydrothermal solutions. Of particular current interest is the univalent trisulfide radical, the thiozonide ion, S32−, which was shown to be stable in high temperature aqueous solutions up to at least 260°C by Giggenbach(1971) and then more recently up to 450°C and at elevated pressures by Pokrovski and Dubrovinsky(2011). The role of the thiozonide radical in hydrothermal ore formation as well as its thermodynamic stability are still poorly known. We present new Raman spectroscopic data on its stability in hydrothermal fluids up to 500°C and 10kbar pressure and discuss its possible importance in hydrothermal ore formation in the Earth’s crust.

ORAL
TECTONIC STRESS AND FAULT ROCK FABRICS IN THE VICINITY OF THE ALPINE FAULT INFERRED FROM DFPD-2 BOREHOLE TELEVIEWER (BHTV) IMAGERY

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The analysis of BHTV logs collected during DFPD-2B drilling provides an opportunity to examine stresses in the hanging-wall of the Alpine Fault. 2244 planar structures were detected and 1680 of them are classified as fractures. We compute stress parameters using the Hough transform method using incomplete fault slip data. We assume that all fractures used in the calculation are representing reverse fault motion in response to a single homogeneous stress tensor, and that fractures with similar geometries to the Alpine Fault accommodated similar top to the west shear.

The analysis of the dataset as a whole yields orientations (trend/plunge) for the maximum compressive stress axis S1 of 124/30 and a stress ratio of (S2–S3)/(S1–S3)=0.288. The axis S1 is slightly different from that estimated by focal mechanism analysis. The orientations are compatible with geologically determined horizontal shortening from analysis of small fractures within a few km of the fault trace.

Stress tensors were also determined for groups of fractures within 20 m depth intervals. In most of these groups, the results are similar to the solution for all depths. However, in depth intervals 720-740 m and 780-860 m, the calculated S1 and S3 orientations and stress ratios are different from those for all depths.

A thermal gradient changes at ~730 m depth. This depth corresponds to that where results of stress analysis are changed. In depth intervals 720-740 m and 780-860 m, many fractures oriented such that low shear stresses would be resolved on them for the stress calculated from fractures across the entire depth range. There is a possibility that high fluid pressure causes the changing of the distribution pattern of fractures. To confirm the hypothesis, we need to acquire complete fault slip data from drill core samples.

ORAL

INTERNAL STRUCTURE OF THE MEDIAN TECTONIC LINE FAULT ZONE, SW JAPAN, REVEALED BY BOREHOLE ANALYSIS

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The internal structure of the Median Tectonic Line (MTL) fault zone and the processes that prevailed at depths are described based on an analysis of a borehole. The fault plane which defines the boundary between the Ryoke- and Sanbagawa-derived rocks dips at 56° to the north. Immediately beneath the boundary, approximately 40 m thick fractured rocks form the major strand of the MTL fault zone. The hanging wall above the boundary comprises variably deformed Ryoke granitoids, including several mylonite zones and cataclasite zones. The fault zone has evolved through a series of faulting events under temperatures ranging from 400 to 200 °C. The mineral assemblages of the mylonites and cataclasites immediately above the boundary indicate that these fault rocks were formed at temperatures of about 300 °C. These mylonites and cataclasites represent, therefore, fault rocks that formed immediately below and above the brittle–plastic transition, respectively. Development of dissolution seams in these cataclasites suggests that the cataclase has low strength. The presence of pseudotachylytes in the cataclasite indicates the occurrence of seismicity immediately above the brittle–plastic transition. On the other hand, the very fine grain size of recrystallised quartz in the mylonites indicates high differential stress immediately below the brittle–plastic transition. It is therefore likely that the differential stresses immediately below the brittle–plastic transition are much higher than those immediately above the transition. Formation of laumontite in the major strand of the MTL fault zone occurred at temperatures of around 200 °C. The central slip zone of the major strand is about 30-cm thick, and is surrounded by thick gouge zones. This situation is favourable for thermal pressurisation during earthquake slips.

POSTER
FILLING IN THE GAP:
A PREVIOUSLY UNIDENTIFIED AND POTENTIALLY CATALYTIC SEISMIC HAZARD WEST OF THE ALPINE FAULT

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Through the interpretation of geomorphology, aeromagnetic data, seismic profiles, fieldwork observations and GeoNet earthquake data, I have identified a seismically active, northwest striking sinistral strike-slip fault (the Taramakau Settlement Fault) that directly intersects the Alpine Fault footwall. This currently self-funded project has evolved from a Masters thesis that broadly looked at the Neogene tectonic evolution of the Greymouth-Hokitika area, west of the Alpine Fault, and how that has been influenced by inherited structural elements.

It is proposed here that the Taramakau Settlement Fault is part of a system of conjugate strike-slip faults (NW-SE striking sinistral and E-W striking dextral faults) that have formed during the Neogene compressional regime as a mechanism to tectonically ‘infill’ a WNW striking, approximately 25km wide band of crust that is very weak and has very low flexural rigidity (the “Gap”). It is also proposed here that the “Gap” is a failed insipient rift that formed in association with continued movement on the Pike Detachment of the Paparoa Core Complex as Zealandia began to break away from Gondwana c. 83 Ma.

Evidence for the existence of the “Gap” includes: The presence of the A-type French Creek Granite and co-genetic Hohonu Dyke Swarm; the presence of a broad magnetic high centred on Kumara (assumed to be revealing the extent of the source magma body for the French Creek Granite) which is closely traced by an isostatic gravity low (showing it to be an area of basement down-warp); and the presence of the WNW striking Takutai Half Graben, situated directly offshore of Greymouth.

POSTER

THE VOLATILE LIFE OF AUCKLAND MAGMAS:
INSIGHTS INTO MANTLE SOURCES & PRE-ERUPTIVE PROCESSES IN THE AUCKLAND VOLCANIC FIELD FROM MELT INCLUSIONS

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Lavas erupted in intraplate basaltic volcanic fields, wherein single magma batches ascend quickly to the surface, are widely regarded as comparatively simple ‘windows’ into mantle compositions and magmatic behaviour. Recent studies, however, have revealed complex geochemical trends, both within individual volcanic sequences and across whole volcanic fields, with much of this heterogeneity attributed to multiple mantle sources.

The Auckland Volcanic Field (AVF), New Zealand, is a dormant monogenetic field containing 53 volcanic centres with compositions ranging from subalkalic basalt to nephelinite. Recent interpretations of extensive isotopic and major and trace element data from bulk rock seek to explain this geochemical range through the melting of three source endmembers: metasomatised lithosphere, carbonated components, and fertile asthenospheric mantle.

Evidence for these postulated sources should be seen in their corresponding magmatic volatile contents, normally lost during eruption. However, pockets of magma encapsulated in growing crystals (“melt inclusions”) can preserve this valuable information. In this study, glassy, olivine-hosted melt inclusions (MIs) from ‘endmember’ bulk rock compositions are being used to investigate mantle sources and pre-eruptive melt compositions and processes in the AVF, including, for the first time, magmatic H2O and CO2 contents.

Major, trace, and volatile data from endmember MIs provide a unique picture of the inner workings of the field, from source to surface. They reveal: (1) AVF lavas are most similar to ocean island basalts in comparison with other tectonic settings; (2) olivine crystallisation occurs over a range of depths, at least to 25 km; (3) bulk rock compositions for the field are not necessarily representative of pre-eruptive melt compositions; and (4) while limited volatile enrichment and evidence for at least two mantle sources can be seen in the MI data, they do not necessarily support a metasomatised lithospheric mantle source, as previous investigations have suggested.

ORAL
The >200 km long Moonlight Fault Zone (MFZ) in southern New Zealand was an Oligocene basin-bounding normal fault zone that reactivated in the Miocene as a high-angle reverse fault (present dip angle 65°-75°). Regional exhumation in the last c. 5 Ma has resulted in deep exposures of the MFZ that present a rare opportunity to study the structure and deformation processes that were active in a basinscale reverse fault at basement depths. The hanging wall and footwall of the MFZ are mainly greenschist facies quartzofeldspathic schists that have a steeply-dipping (55°-75°) foliation subparallel to the main fault trace. Where the hanging-wall contains relatively competent lithologies (e.g. greenschist facies metabasite) it is laced with networks of pseudotachylyte (dip 55°-75°) that formed subparallel to the host rock foliation in a damage zone extending up to 500 m from the main fault trace. The fault core contains an up to 20 metre thick sequence of cataclasites and foliated cataclasites preserving evidence for the progressive development of interconnected networks of (partly authigenic) chlorite and muscovite. Deformation in the fault core occurred by cataclasis of quartz and albite, frictional sliding of chlorite and muscovite grains, and dissolution-precipitation. We combine our field observations with the results of new friction experiments performed on the phyllosilicate-rich foliated cataclasites to suggest that: 1) host rock lithology and anisotropy were the primary controls on the structure of the MFZ at basement depths and 2) high-angle reverse slip was facilitated by the low frictional strength of fault core materials. Restriction of pseudotachylyte networks to the hanging-wall of the MFZ further suggests that the wide, phyllosilicate-rich fault core acted as an efficient hydrological barrier, resulting in a relatively hydrous footwall and fault core but a relatively dry hanging-wall.

FAULT ZONE STRUCTURE AND WEAKENING PROCESSES IN BASIN-SCALE REVERSE FAULTS: THE MOONLIGHT FAULT ZONE, NEW ZEALAND

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A high resolution, seismic reflection profile (SAHKE02) shows a localized region of relatively bright reflectors at ~30 km-depth, where the Australian plate Moho abuts the subducted Pacific plate beneath Wanganui Basin. These migrated, bright reflections define an arched interface resembling a ductile flow structure, rather than a flexed or faulted feature. We interpret this interface to be the top of a serpentinized mantle wedge, because: (1) beneath the interface reflections are of lower frequency indicating strong attenuation of seismic energy (Q ~20±10); (2) the interface is a polarity/impedance contrast reversal; and (3) reflections from the Moho are weak or absent in the overriding plate adjacent to the zone of bright reflective mantle. These seismic observations are consistent with the mantle wedge in the southern portion of the Hikurangi margin being cold enough for peridotite to be hydrated and altered to antigorite causing the change in seismic reflection characteristics and lowering the viscosity of the mantle wedge. Over the past 4 my, the region has subsided and a ~4 km deep, roughly circular sedimentary basin associated with a large negative gravity anomaly, has developed. We propose that serpentinisation of the mantle wedge is implicated in both the subsidence, via a corner flow mechanism, and the development of the gravity anomaly through a density change. Serpentinisation of the mantle wedge by ~50% will lower the density of peridotite by ~300 kg/m³, and this could account for up to ~80 mGal of the observed -150 mGal anomaly. The proximity of recently documented slow-slip events to the proposed zone of serpentinisation supports a possible causal link between the two phenomena.

GEOPHYSICAL EVIDENCE FOR SERPENTINISATION OF THE UPPER MANTLE BENEATH WANGANUI BASIN: IMPLICATIONS FOR SLOW SLIP EVENTS, SEDIMENTARY BASIN FORMATION AND LARGE NEGATIVE GRAVITY ANOMALIES

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POSTER
MANTLE EARTHQUAKES BENEATH THE TARANAKI-RUAPEHU LINE: DEPTH DISTRIBUTION, FOCAL MECHANISMS AND GEODYNAMIC INTERPRETATION

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A cluster of 30–52 km-deep earthquakes, and a 7–10 km Moho step beneath western North Island, are both interpreted as manifestations of active delamination of the continental lower crust and mantle lithosphere. These phenomena occur in the back-arc region beneath the east-west oriented Taranaki–Ruapehu line (TR-line), which strikes at a high angle to the present day plate boundary. Across the line there is an abrupt change in mantle lid thickness, and in upper mantle seismic attenuation ($Q_m$), which show the mantle lithosphere has been highly attenuated on the north side. An accompanying 100 mGal step in gravity anomalies across the TR-line can be accounted for with the observed change in crust and lithospheric thickness. Moho depths interpreted from a receiver function profile indicate that nearly all of the deep earthquakes reside in the uppermost mantle on the northern side of the TR-line. A sum of earthquake moment tensors suggests strike-slip motion either parallel, or orthogonal, to the TR line, resulting in NW–SE orientated, horizontal, extension. Active normal faults, orientated NW–SE and N–S, are seen at the surface, each side of the TR-line, but the surface is uplifting here at ~0.4 mm/y. This requires the mantle lithosphere to be thinning at a higher rate than the overlying crust, which is consistent with the delamination process. A finite element model incorporating a Rayleigh-Taylor type of instability suggests that a migrating delamination of both mantle lid and the lower crust could have occurred from the Waikato to the Wanganui basin in ~12 my if the viscosity of the mantle lid is ~5x10^20 Pa s. If so, then such a migrating delamination provides alternative explanations for the high-K volcanism of the western North Island, and for the unusual normal faulting signature in offshore regions of Taranaki basin.

ORAL

STUDIES OF FRAGILE GEOLOGIC FEATURES IN NEW ZEALAND AND WESTERN USA

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I provide a precis of collaborative studies on the use of fragile geologic features to constrain probabilistic seismic hazard models in New Zealand and western USA. The seismic hazard re-evaluation of the Clyde Dam in Central Otago has required an extensive program of paleoseismology on the local major fault (Dunstan Fault), and a subsequent analysis of the age and fragility of nearby precarious-balanced rocks (PBRs) to constrain near-field ground motions from the fault. Work at the Diablo Canyon nuclear power plant in coastal central California has thus far identified several PBRs on uplifted paleoseastacks, and quantified the fragility and age of the features. Both studies indicate that the PBRs could only have survived repeated large earthquakes on the local faults if the resulting ground motions did not exceed the median motions estimated from various ground motion prediction equations. The studies collectively represent the first application of fragile geologic features to major industry-funded projects.

ORAL

A FLEXURAL ANALYSIS OF OPHIOLITE LOADING AT AND ADJACENT TO NEW CALEDONIA

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Loading and subsequent unloading of New Caledonia by obduction then erosion of ophiolite nappes is recorded in the offshore stratigraphic record. The ~500 km long and 60 km wide island of New Caledonia was the location of a foreland basin in the Eocene when ophiolite nappes sourced from the Loyalty basin were obducted from the north east. The island is flanked to the east and west by sedimentary basins filled with ~7 km of post obduction sediment but with differing formation histories. To the east the Loyalty basin is floored by loyalty basin oceanic crust, and is filled with sediments that dip westward towards New Caledonia, with a central depocentre. Fanning sediments indicate progressive subsidence of the basin. To the west flexural loading of the New Caledonia Basin by nappe emplacement is evident in the eastward dip of Eocene-Oligocene unconformity horizon. The post nappe obduction sediments are, however, almost flat indicating only small flexural subsidence during the nappe erosion and basin fill

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phase. We use flexural loading models for nappe obduction, and subsequent erosion and basin fill to constrain formation histories for the New Caledonia and Loyalty Basins. We model the flexed Eocene-Oligocene unconformity with a nappe load on New Caledonia. The erosion of the nappes produces a redistribution of this initial load. That this redistributed load did not induce significant flexure in the New Caledonia Trough sediments is attributed to the plate being elastically strong. Values of Te ~40 are inferred and are in line with those predicted by process oriented gravity models for the New Caledonia Trough. If this Te value is about right then some upward flexural displacement is anticipated to have occurred on the eastern margin of the Lord Howe Rise.

Initial results show that similar facies occur in all sections, including channelised deposits. Foraminifera-based biostratigraphic and paleoenvironental analyses indicate Waitakian–Otaian and late Otaian ages, and middle-lower and lower bathyal water depths. There is also evidence for reworking of sediment derived from Cretaceous–Paleocene rocks. The petrography of sandstones is also being assessed in thin section, to expand existing reservoir quality datasets and assess the likely provenance of potential reservoirs.

FACIES, DISTRIBUTION AND RESERVOIR QUALITY OF EARLY MIOCENE RESERVOIRS FROM SOUTHERN NORTH ISLAND, ONSHORE EAST COAST BASIN

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Early Miocene rocks assigned to the Whakataki Formation are exposed in coastal and near-coastal localities, from southern Hawke’s Bay to central Wairarapa. They form a potential reservoir target in the adjacent offshore East Coast Basin, the target of current exploration efforts.

They are dominated by flysch-like alternating thin- to thick-beded sandstone-mudstone facies, with minor coarser-grained channelised deposits. Early Miocene strata appear to represent a relatively large sedimentary system, which is exposed over a distance of ~90 km along strike. These onshore outcrops may represent more proximal parts of offshore reservoir targets, rather than merely acting as analogues. The formation reflects a major early input of coarse clastic material into the East Coast Basin following the inception of the modern plate boundary. It contrasts with subsequent Mid–Late Miocene systems, which appear to be restricted to smaller ponded basins (e.g. Makara Sub-basin) formed during more intense deformation.

This unit has been extensively studied at classic exposures near Castlepoint between Mataikon and Whakataki, but significantly less so elsewhere. This study focuses on exposures well away from the “type area” to better constrain variations in facies, depositional paleoenvironment, and the size of the depositional system. This includes detailed investigations at the southernmost (Flat Point) and northernmost (Herbertville Beach) exposures of the formation, as well as more fragmentary inland exposures.

SHEAR WAVE ANISOTROPY IN THE VICINITY OF THE ALPINE FAULT INFERRED FROM VERTICAL SEISMIC ARRAY OBSERVATION

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Shear wave anisotropy in shallow crust in the vicinity of the Alpine fault is estimated by analyzing seismograms observed at four vertical seismic arrays. The vertical seismic arrays consist of borehole seismometers and additional surface sensors deployed above each borehole. We used two boreholes of the Deep Fault Drilling Project (DFDP) at Gaunt Creek and Whataroa Valley in the hanging wall side, and the other two boreholes in the footwall side. Cross-correlating rotated horizontal seismograms observed by the borehole and surface sensors, we extracted polarized shear waves propagating from the bottom to the surface of each borehole. We then estimated shear wave anisotropy using polarization angle dependence of travel times from the bottom of the borehole to surface. In the hanging wall side, the fast shear wave directions are parallel to the strike of the Alpine fault. An acoustic borehole imaging reveals fractures parallel to the Alpine fault. The fault parallel anisotropy suggests structural anisotropy is predominant in the hanging wall. Strong anisotropy of 20% was observed within the damaged zone of the Alpine fault. In addition, the anisotropy amplitude decreases as frequency
increases. The frequency dependent anisotropy may relate to fracture size within the damage zone. In the footwall side, on the other hand, the angle between the fast direction and the strike of the Alpine fault is 35-40 degrees. Since the footwall is composed of granitoid that may not have planar structure, stress induced anisotropy is possibly predominant. The direction of maximum horizontal stress (SHmax) estimated by focal mechanisms of regional earthquakes is 60 degrees of the Alpine fault. Possible interpretation of the difference between the fast direction and SHmax direction is depth rotation of stress field near the Alpine fault.

THE INFLUENCE OF METASOMATISM ON FAULT DYNAMICS IN ULTRAMAFIC ROCKS: THE LIVINGSTONE FAULT, NEW ZEALAND

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The Livingstone Fault is a >1000 km long terrane boundary in the South and North Islands of New Zealand that juxtaposes ultramafic rocks (peridotite and serpentinite) of the Dun Mountain Ophiolite Belt against quartzofeldspathic lithologies (schist, volcanics, sandstone and siltstone) of the continental Caples Terrane.

The superbly exposed fault zone is characterized by a sheared serpentinite mélangé tens to several hundreds of meters wide that contains a well-defined scaly fabric entraining pods of massive serpentinite and quartzofeldspathic schist. Talc- and tremolite-forming metasomatic reactions occurred along the margins of the mélangé and at the edges of pods as the result of interaction between serpentinite and fluids derived from the siliceous quartzofeldspathic schist. Layers of tremolite up to 1 m thick are characterized by a highly indurated microstructure consisting of networks of tightly interwoven acicular crystals. In these regions, discrete cataclastic slip zones and well-polished slickenlined surfaces occur at the interfaces of the serpentinite and schist. ‘Crackle-breccias’ with veined, multi-generational stockworks of tremolite provide evidence for repeated attainment of fluid overpressure during metasomatism. Our field observations suggest that tremolite-forming metasomatic reactions, combined with episodic fluid-driven brecciation events, promoted localized and unstable fault slip within a mélangé shear zone that was otherwise deforming by (pressure-solution modulated) creep. In support of this hypothesis, SEM-EDS and micro-Raman mapping of discrete magnetite-bearing slip surfaces reveals the presence of small (10-50 μm) inclusions of nanocrystalline olivine, enstatite and a talc-like phase consistent with localized serpentinite dehydration driven by frictional heating during episodes of coseismic slip. As such, the geometry and reaction sequences preserved in the Livingstone Fault mélangé provide insight into the nature of episodic, shallow seismic activity at the slab–mantle interface of subduction zones.

ORAL

THE CENOZOIC FOSSIL RECORD OF RĀTĀ (METROSIDEROS, MYRTACEAE) IN AUSTRALIA: AN AUSTRALIAN ORIGIN FOR THE GENUS?

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The iconic flowering genus Metrosideros (Myrtaceae), more commonly known by its Maori name as Rātā, has long proven a biogeographic anomaly for Southern Hemisphere phytogeographers. It grows throughout the Pacific, from the sub-Antarctic islands of New Zealand, to the Bonin Islands near Japan, from Africa to Hawaii, and on many other smaller pacific islands in-between. However, Metrosideros does not grow in Australia, and has never been found in the Australian fossil record, despite a clear disposition towards long distance dispersal. Previously it has been speculated that it may have evolved in, and subsequently dispersed throughout the Pacific from, New Zealand, since it’s highest species diversity is there, as well as the oldest fossil record of the genus from the Miocene. However, new fossil fruits, flowers and leaves described by the authors, from Eocene, Oligocene and Miocene deposits in Tasmania and New South Wales, show that Metrosideros was not only present on the Australian mainland, but potentially persisted from the Eocene to the Oligo-Miocene. The oldest of these fossils beat the oldest described fossil record in New Zealand by ~10 million years, and may indicate an Australian origin of the genus.

ORAL
The basal sliding of glaciers is a diverse and complicated process. When large influxes of water enter a sub-glacial drainage system they can be responsible for accelerations in basal sliding of between a few percent and a few thousand percent of the background rate. This acceleration manifests as an initial surge in velocity as the glacier sole rides up and over constraining bedrock bumps, but decays quickly to a week(s)-long enhanced sliding rate suggestive of a lubricating water film distributed across the glacier base.

Tasman Glacier, New Zealand’s largest glacier, sits at the extreme end of responses to episodes of sub-glacial flooding. Here accelerations of the lower glacier following heavy rainfall have been observed at 36 times the background velocity over three-hour intervals and 15 times the background velocity over 24-hour intervals. A network of 11 seismic sensors and five GNSS receivers was established over the lower glacier and its moraines between April and August of 2016. RISSIN, the Rain Induced Seismogenic Sliding of Ice Network, was designed to locate and characterise the seismicity of Tasman Glacier over the onset and duration of winter. Here we present preliminary results of both background seismicity in the region and the seismicity observed during and associated with transient rain-induced accelerations over this period.

The Akatore fault is the easternmost of a series of northeast-striking, active reverse faults which comprise the Otago fault-fold belt. The ~ 60 km long Akatore fault is located south of Dunedin, and has long been regarded as the source of greatest local seismic hazard for the city. In 1974 a M~5 earthquake was centred 10 km offshore from Dunedin, and is believed to have occurred on the Akatore Fault or a parallel offshore fault. The majority of damage occurred in South Dunedin where the unconsolidated alluvial soils amplified the earthquake shaking (felt intensity of MMVII).

This year we trenched two sites along the Akatore Fault where swamps have developed due to earthquake displacements on the fault. Our work follows earlier soil-augering studies of swamp deposits which suggested that the Akatore fault produced two earthquakes in the Holocene. One trench contained evidence of colluvial wedges adjacent to the scarp, one of which is faulted, confirming at least two earthquakes. It also confirmed the presence of a faulted distinctive woody peat layer, which was previously sampled in multiple soil augers. Radiocarbon and optically stimulated luminescence dating show that the two earthquakes occurred in the time period 760-1350 yrs BP, which is consistent with the earlier soil augering results.

We are currently examining the Taieri Mouth area where the Akatore Fault appears to have offset the local marine terraces (age ~ 125 ka) by less than 2 m, suggesting that the fault has been recently active after a long period of quiescence. Resolution of the degree of aperiodicity of Akatore Fault earthquakes will be very important for assessing the seismic hazard of Dunedin, and in understanding the mechanics of Otago faults in general.
A SUMMARY OF THE EXTINCT SPECIES OF BIRDS RECENTLY DESCRIBED FROM NEW ZEALAND

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Since 2006, 26 new species of bird have been described from New Zealand on the basis of fossil remains. These species were found in deposits of the following epochs: Paleocene (1), Eocene (1), Oligocene (2), Miocene (19), Holocene (3). The richest areas for discovering new species were the lacustrine deposits of the St Bathans region of Central Otago; all 19 Miocene records come from here. The Paleocene, Eocene and Oligocene species are from marine sediments in Canterbury and Otago. All 3 Holocene species come from the Chatham Islands. A diverse range of species has been described: 1 kiwi, 7 ducks, 1 palaeolodid, 3 penguins, 2 petrels, 2 herons, 1 adzebill, 2 wading birds, 1 pigeon, 4 parrots, 1 songbird, and 1 seabird of uncertain affinities. The new fossil species records are the first for several orders of birds in New Zealand: Apterygiformes (kiwi), Phoenicopteiformes (palaeolodids), Ciconiformes (herons), Charadriiformes (waders), Columbiformes (pigeons), Psittaciformes (parrots), and Passeriformes (perching birds). The current rate of discovery of extinct New Zealand bird species is unprecedented, with 23 pre-Late Pleistocene species described in the last 10 years and only 19 described before 2007.

ORAL

RAPI D POST-GLACIAL SEDIMENTATION IN THE DFDP-2 DRILLHOLES: A RECORD OF MASS WASTING AND DEGLACIATION IN SOUTH WESTLAND

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Drilling in the Whataroa Valley, as part of the Deep Fault Drilling Project 2 (DFDP-2) intercepted a significantly thicker than expected sedimentary sequence of late glacial ice retreat and pro-glacial lake sedimentation. Samples from the ~240m thick sequence were predominantly drilled using the dual rotary method, returning cuttings bagged at 1-2 m intervals, with intact sediment core retrieved from 125-160 m. Sedimentary facies analysis suggests a conformable sequence of basal diamictite (206-240 m), overlain by finely laminated lake muds and silts with rare pebble-cobble diamictite (~81-206 m), transitioning to sandy deltaic sequence (59-81 m). Radiocarbon dating throughout the succession indicates 172m of sediment accumulation in 650 ± 200 yrs, suggesting an extreme sediment flux of ~0.26m/yr into the lake following ice retreat. Grainsize and pXRF analysis revealed systematic changes in chemistry and grain-size throughout the entire lacustrine succession, together with smaller-scale changes associated with numerous upward fining, 1-10cm scale, sedimentary packets. Sedimentation appears too rapid to preserve an extended record of seismicity on the Alpine Fault, rather preserving a high resolution record of meteorological events. We interpret cm-scale sedimentary packets, termed “eventites”, as turbidity currents triggered by storm events, melt water pulses, and/or mass wasting, collectively representing the dominant mode of sediment influx into the proglacial lake environment. Future work will aim to utilise exposures of analogous sedimentary successions to delineate whether the high volume sediment flux observed at DFDP-2 represents a local anomaly, or indicates regionally extensive mass wasting. This will be complemented by detrital provenance analysis using Raman Spectroscopy of carbonaceous material, to constrain source rocks and patterns of catchment erosion during deglaciation.

ORAL

GEOTRIPS – A NEW ZEALAND FIELD TRIPS WEBSITE

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GeoTrips is the new field trips website for teachers, students, and the general public who are interested in visiting geological sites, landforms or displays in New Zealand. Hosted by GNS Science, the GeoTrips website content is created by the New Zealand geoscience community.

By providing map-based earth science content, we aim to encourage hands-on exploration, observation, inquiry and discovery in urban, rural and wilderness settings. GeoTrips is an expandable platform which allows geographically disparate earth-science enthusiasts and teachers to source local information, comment, rate locations, and interact with other users.

A new individual location (‘GeoTrip’) can be added by anyone in the New Zealand geoscience community
who applies to be an author. A simple online template includes guidelines for assistance and aids editorial consistency. Each location includes an introduction to the geological context and suggestions for what to look for, as well as images, directions and safety information. Links to further relevant information can be included for any GeoTrip. Quality assurance is via a peer review process that applies before new content is made public, and the originator is able to have their name and/or institution associated with a particular GeoTrip. All information provided on the site will be available under a Creative Commons license.

This presentation will include an update on the website design, co-created content and potential further development of this outreach initiative.

ORAL

VOLUME CHANGE OF A SMALL MARITIME GLACIER 1967-2016. BREWSTER GLACIER, NEW ZEALAND

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Maritime glaciers are highly sensitive to climate as a result of their high mass turnover. One such glacier, Brewster Glacier, has the longest continuous glaciological volume record of any New Zealand glacier, dating back to 2004. Such long volume records of maritime glaciers are important for understanding glacier processes and climate interactions, as well as for making accurate predictions into the future. This project aims to create a longer volume record by using geodetic methods. This is done by exploiting a comprehensive database of oblique aerial photographs as acquired through the End of Summer Snowline Surveys, processing numerous kinematic Global Positioning System datasets acquired between 1997-2016, as well as analysing a number of topographic datasets dating back to 1967. Bed elevation is inferred from prominent ground penetrating radar reflections and interpolated between survey lines. Volume estimates are then made by subtracting the bed elevation from the time varying surface elevation datasets. Results obtained from this project will then be used as a case study for a wider glacier monitoring programme within New Zealand. Here we present surface elevation changes over the period 1967 to 2016.

POSTER

SENSITIVITY TO REGIONAL EARTHQUAKE TRIGGERING AND MAGNITUDE-FREQUENCY CHARACTERISTICS OF MICROSEISMICITY DETECTED VIA MATCHED-FILTER ANALYSIS, CENTRAL SOUTHERN ALPS, NEW ZEALAND

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Microseismicity recorded since 2008 by the Southern Alps Microseismicity Borehole Array (SAMBA) and other predominantly short-period seismic networks deployed in the central Southern Alps reveals distinctive patterns of triggering in response to regional seismicity (magnitudes larger than ~5, epicentral distances of ~100-500 km). Using matched-filter detection methods implemented in the EQcorrscan package (Chamberlain et al., in prep.), we analyse microseismicity occurring in several geographically distinct swarms in order to examine the response of specific microearthquake sources to earthquakes of different sizes occurring in different locations. The swarms exhibit complex responses to regional seismicity which suggest that microearthquake triggering in these cases involves a combination of extrinsic factors (related to the seismic energy density of the regional earthquake, and the frequency content of the wave train) and intrinsic factors (controlled by the local state of stress, the dynamic stress change, and possibly by hydrogeological processes). We find also that the microearthquakes detected by individual templates have Gutenberg-Richter magnitude-frequency characteristics. Since the detected events, by design, have very similar hypocentres and focal mechanisms, the observed scaling pertains to a restricted set of fault planes.

POSTER

SEISMOMETERS IN ECUADORIAN SCHOOLS

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On 16 April 2016, Ecuador experienced a magnitude 7.8 earthquake, that caused substantial damage to the provinces of Esmeraldas and Manabi. There were
673 deaths, and the cost to this nation’s economy has so far been of order of US$3 billion. This impact was partly a result of building collapses - Ecuador’s regulations that guide construction of earthquake resistant buildings are not strictly adhered to.

We are starting an education and outreach program that aims to enhance societal understanding of earthquake hazard in this seismically active country. We hope to increase awareness of risk and stimulate resilient behaviours as simple as having household earthquake preparedness kits. Furthermore, we hope education will increase the desire of the population to adhere to existing construction regulations so that buildings are earthquake resistant in future, and might stimulate the scientific community and the legislative authorities to make plans for their response to future events.

We plan to install 10 cheap, robust, easy to build, and critically – very easy to understand – TC1 seismometers (https://tc1seismometer.wordpress.com/) in the (limited number of) schools with internet connections, initially in our local Ibarra area. These will continually record ground shaking during the regular earthquakes in this area and stream it to the Ecuadorian seismic monitoring network (through the USA’s IRIS Data Management Centre). We will develop a Spanish version of the IRIS app for smartphones that will allow children in other schools throughout the region to follow the live-streamed data (most Ecuadorian children have a cell phone and we hope that CNT, the national telecommunications company, sponsor one ‘smartphone’ in each classroom).

This project is just beginning (Sept 2016). By the time of the Geosciences meeting we expect the Yachay Geoclub will have managed to build our first seismometer, and we look forward to providing a status report.

ORAL

COMPOSITIONAL AND TEXTURAL CONTROLS ON THE ELASTIC PROPERTIES OF THE WHANGAI AND WAIPAWA FORMATION MUDSTONES, EAST COAST BASIN, NEW ZEALAND

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The Waipawa and Whangai Formation mudstones have garnered considerable interest as petroleum source rocks, and in the case of the Waipawa, as a potential unconventional reservoir. However, at present there is a paucity of information on the petrophysical and geomechanical properties of the Whangai and Waipawa Formation mudstones. Understanding how the rock properties control the elastic behaviour of these mudstones is essential for accurate geophysical interpretation and reservoir characterization. Six preserved cores from the Orui-1A and Te Mai-2 wells in the East Coast Basin have been analyzed in order to understand the compositional and textural controls on the elastic wave velocities, the dynamic elastic parameters and their use in interpreting the geomechanical properties of the rocks. In addition, we are investigating the scale dependence of velocity anisotropy in these samples, from decimeters to millimeters. High density and directional P-wave velocity scans on large cores and subsampled plugs were undertaken using non-contacting laser-based ultrasonics. S-wave data were acquired on core plugs using contacting ultrasonic transducers. Composition was determined with X-ray diffraction, X-ray fluorescence and source rock analysis, and rock texture is characterized via thin section petrography. Preliminary data show that wave propagation normal to bedding is 5–15% slower than bedding parallel, and is dependent on lithology and organic content. Rocks of similar composition with higher organic content have slower overall wave velocities and exhibit greater elastic wave anisotropy. We also find that rocks with significantly higher proportions of calcite relative to quartz show faster wave velocities.

ORAL
The last phase of exhumation of the Dun Mountain Ophiolite Belt (DMOB) in New Zealand was achieved by movements along the Livingstone Fault. At Mt Raddle in the Olivine Range, near-pristine DMOB harzburgite shows a complete transition through a series of hydration reactions to serpentinite. Serpentinite is the dominant lithology within the Livingstone Fault Zone, where it develops a pervasive scaly fabric that defines a tectonic melange c. 80 m wide containing pods of massive serpentinite. Juxtaposition of the serpentinite melange with the predominantly quartzofeldspathic Caples Terrane produced a metasomatic talc-tremolite-diopside reaction zone at the Caples Terrane-melange boundary.

Petrographic observations, trace element analyses and 143Nd/144Nd and 87Sr/86Sr isotope ratios from samples collected along a fault-perpendicular transect at Mt. Raddle show that hydrous fluids interacting with the Caples Terrane significantly enhanced metasomatic reactions within the serpentinite melange, but did not penetrate very far into the DMOB. At Mt Richards, 2 km further south, the melange narrows (<20 m wide) and fresh harzburgite is exposed adjacent to the Caples Terrane. This change in fault zone structure implies that serpentinisation and fluid flow within the DMOB were spatially and temporally variable and likely occurred prior to a later stage of serpentinisation within the Livingstone Fault melange itself.

Infiltration of fluid along the Livingstone Fault melange promoted hydration reactions and metasomatic reactions that contributed to slip localization along the DMOB-Caples Terrane boundary, and may also have contributed to Permian obduction of the ophiolite belt. In particular, we suspect that the initial formation of frictionally-weak talc helped to localise deformation within the metasomatic reaction zone. In this regard, the Livingstone Fault provides a superbly exposed analogue for processes that are thought to be important along major serpentinite-bearing structures including the San Andreas Fault and subduction zone interfaces.

RARE EARTH ELEMENT MINERALISATION IN THE FRENCH CREEK GRANITE

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Rare earth elements (REEs) are unique metals that are becoming increasingly important to the advanced technology and renewable energy sectors. The dominant economic source of REE is from igneous complexes and carbonatites where REE are concentrated by magmatic differentiation processes and/or hydrothermal alteration. Anomalous REE concentrations have been documented in the c. 82 Ma peralkaline French Creek Granite (FCG), cogenetic Hohonu Dyke Swarm, and panned concentrates from streams draining the area. However, no detailed studies on the type of REE minerals present, or the processes responsible for potential REE-mineralisation, have been undertaken. As a result, the REE economic potential of the FCG remains unknown.

We present new detailed field, petrographical, geochemical and geochronological data that highlights: 1. the REE-bearing mineral phases; 2. the petrogenetic history of the FCG and its relationship to the Hohonu Dyke Swarm; and 3. the processes responsible for REE-enrichment.

Field mapping has revealed that the FCG is lithologically heterogeneous. The dominant lithology is an alkali-feldspar granite with subordinate varieties of syenogranite, quartz alkali-feldspar syenite and a mafic-rich variety. Multiple generations of hydrothermal alteration are present, resulting in variable sericite, chlorite, carbonate, kaolinite and sulphide (pyrite, chalcopyrite) alteration. The most intense alteration occurs in the Eastern Hohonu River, which also correlates with the highest REE concentrations (ΣREEs ≥800 ppm). Detailed SEM-EDS analysis reveals that REE-Y-Nb-Zr are partitioned into carbonate-fluorite minerals (bastnäsite, synchysite, parisite), zircon, xenotime, apatite, brookite and Ti-oxides. Enrichment in REE is likely related to solid-liquid phase separation, and subsequent late-stage hydrothermal fluid circulation that remobilised and concentrated the REE. Carbonates from the French Creek Granite have δ13C and δ18O isotopic compositions that overlap those from mantle-derived Western Province alkaline lamprophyric dikes, indicating they may come from a similar magmatic-related source.
TOPOGRAPHIC CONTROLS ON THE STRESS STATE, SHALLOW FAULT STRUCTURE AND STRAIN PARTITIONING, APLINE FAULT, WHATAROA

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Although remarkably linear at scales greater than 20 km, in detail the Alpine Fault is broken into a large number of segments including more northerly-striking, oblique thrusting sections and more easterly-striking dextral strike-slip sections. We use 3D modelling to show that high relief adjacent to the fault perturbs the 3D stress state and controls near surface displacement. We also explain the role of evolving fault strength on partitioning of deformation. Our 3D models were based on a DEM smoothed to 200 m. All models had a pre-existing weakness representing the Alpine Fault and we varied both its frictional strength and the depth to the top of the pre-existing weakness in order to investigate the locus deformation. A weak (f = 10°) structure penetrating the surface precludes any partitioning; both fault-parallel and fault-normal components of deformation were taken up entirely along this structure. A strong (f = 25°) dipping structure accommodated almost none of the fault-parallel displacement, instead it was partitioned onto vertical structures within the hanging wall, some parallel to the Alpine Fault, others at high angle to it which utilize larger valleys as the Whataroa. If the weak Alpine Fault is not defined all the way to the surface, the fault-parallel displacement was taken up on a vertical structure that developed from the top of the weak model fault. The fault-normal displacement occurred on structures that developed close to or at the range front. As the depth to the top of the pre-defined weakness increased from 500 to 2000 m, the vertical structures developed further from the range front and the individual strand become more elongate. The lack of near vertical structures taking up strike-slip displacement at distances further than ~1 km from the range front suggests that the Alpine Fault is a very weak structure at shallows depths.

3-D MODELLING OF CURRENT DEFORMATION ACROSS OTAGO AND ITS RELATIONSHIP TO CRETACEOUS SUBDUCTION OF THE HIKURANGI PLATEAU

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The distribution of strain in an orogen reflects the imposed tectonic and surficial boundary conditions as transmitted via the rheological structure of the deforming lithosphere. Otago stands out as a distinct strain region within the southern South Island. Unlike the central Southern Alps north of the Waitaki River, the Otago Southern Alps and central Otago Ranges extend to the east coast with a distinctive basin and range type morphology. Previous modelling studies (Upton et al. 2009; Upton et al., 2014) relied on geological and geophysical arguments to constrain the crustal rheology of the Otago region. We have now determined a detailed 3-D Vp and Vs structure of this region using 3-D imaging of the southern South Island from a dense seismograph deployment. The new velocity structure confirms the original rheological model of Otago as schistose to a depth of ca. 25 km and hence quite weak compared with the thinned crust of Canterbury to the north. It also reveals deeper structure of the region that is impacting distribution of strain across the Southern Alps today. Updated, high resolution 3-D models of the southern South Island will reveal how the ca. 35 km-thick Hikurangi Plateau, subducted beneath the Gondwana Margin in the Cretaceous, continues to impact the style of deformation across Otago.

ORAL

From Hector to Rū: A history of the Milne #16 and the development of the Rū seismometers for schools programme.

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This talk briefly describes a history of the 1897 Milne #16 horizontal pendulum seismograph, traces the development of the seismometers for schools programmes and describes how seismology can be integrated and used within the current NCEA assessment regime. The earliest public record of the existence of a seismograph in New Zealand was found in the Evening Post of June 8, 1883 (Vol. XXV Issue
Earthquakes, as a ‘natural hazard’, has been part of the school curriculum since the introduction of the 1968 science and geography syllabi but very little of the science in terms of ‘seismology’ was taught. The focus in geography was on landscape and social effects rather than seismic wave processes. The notion of having ‘seismographs for schools’ as a vehicle to ‘teach’ geo science and physics has been operating in the US and UK since the early 1990s. In New Zealand, the introduction of the “Quake Trackers” programme began in 1998 by Warwick Smith and John Taber at VUW (and supported by GNS, VUW and EQC). There were nine stations in 1998. This programme closed due to maintenance, materials, seismometer failures, costs and changing personnel in 2003. But, all was not lost as the current incarnation, supported strongly in principle by GSNZ, is the Rū school seismometers network. This network began in 2013 with its introduction by Kasper Van Wijk and his team from Boise State University where the TC1 vertical seismometer overcame many of the cost issues and software issues. The whole package was developed by Ted Channel, Martin Smith, Kasper Van Wijk and others, and financially supported by SEG, EQC, Auckland University and IRIS.

Today, this programme is developing materials for teachers to present to their students for summative NCEA assessment tasks and develop greater awareness of the science of seismology across all age ranges. Having 23 seismographs in primary and secondary schools as well as museums reaches a wide spectrum of learners.

This talk shows how seismology has evolved in New Zealand and how it is implemented in our national science curriculum.

http://wildland.owdjim.gen.nz/?p=351

ORAL

LATE QUATERNARY DEXTRAL SLIP RATE OF THE KEKERENGU FAULT: NEW ZEALAND’S THIRD FASTEST ON-LAND FAULT


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This investigation establishes a lateral slip rate for the Kekerengu Fault, and tests the hypothesis that the chief locus of plate boundary deformation in northern South Island steps northeastward from the eastern Hope Fault to follow the Jordan Thrust and Kekerengu Fault before extending offshore into Cook Strait.

Alluvial terraces in the Kekerengu area have been mapped as five distinct units based on soil profile development, number of loess deposits, degree of gravel weathering and clay plugging, and relative elevation. Ages of the younger two terraces – Winterholme (younger) and Kulnine (older) – are constrained by seven OSL and two 14C dates, and by the presence of disseminated Kawakawa tephra in loess that caps the Kulnine terrace. The Kekerengu Fault truncates a prominent riser between the Winterholme and Kulnine terraces. The distance between the riser and its source, Glencoe Stream, is ~600±50 m. We infer that the riser was cut during the peak of Kulnine degradation, prior to the onset of extensive Winterholme aggradation, during ~25-30 ka. Because subsequent Winterholme aggradation may have caused some further trimming of the riser, this measured distance provides a maximum estimate of lateral offset. These data imply a maximum dextral slip rate of ~18-26 mm/yr. The Kekerengu Fault also truncates, and dextrally displaces, a beheaded channel on a Kulnine surface by ~800±100 m. Our dating suggests abandonment of this Kulnine channel at ~25-34 ka, yielding a slip rate of ~20-36 mm/yr.

The above two dated offsets provide a combined dextral slip rate of ~20-26 mm/yr, making the Kekerengu Fault the third fastest on-land fault in New Zealand (behind the Alpine and Hope faults), and demonstrating that most slip on the Hope Fault is...
transferred northeastward via the Jordan Thrust onto the Kekerengu Fault.

CENOZOIC FOSSIL WOOD OF SOUTH CANTERBURY, OTAGO AND SOUTHLAND

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An investigation of Cenozoic fossil wood (branches, logs and in situ stumps) present in lignite, conglomerate and sandstone deposits at 12 localities in the southern South Island has revealed Araucariaceae, Podocarpaceae, Nothofagus and two other unknown angiosperm woods. Samples were collected from field sites in south Canterbury (Aviemore), Otago (Galloway, Idaburn, Pomahaka and Roxburgh) and Southland (Bennett’s Pit, Cosy Dell Coal Pit, Cosy Dell Lime Pit, Gold Sandpit, Mataura Coal Mine, Newvale Coal Mine and Pikopiko). With the exception of the late Eocene Pikopiko and the Pliocene Gold Sandpit, all sites are Late Oligocene to Early Miocene in age.

Samples were collected based on two traits – how well preserved the cellular structure seemed in the field and how compressed they were. Cellular preservation ranges from excellent to very poor, and samples ranged from extremely compressed to uncompressed. A number of preservation types have been categorised, ranging from non-petrified to highly silicified. Rock thin sectioning can be used for the silicified wood, but is unsuitable for softer wood types and experiments have been carried out to determine the best methods of preparation for the latter. Sectioning of the wood used the traditional orientations for wood anatomy, and cellular structure was used to identify the modern equivalent family for each sample.

Araucariaceae wood has been recognised from Newwale, Pomahaka and Roxburgh and Nothofagus wood is present at Aviemore and Roxburgh. The most common wood identified to date is Podocarpaceae (probably Podocarpus) which is found at Bennett’s Pit Cosy Dell Coal Pit, Cosy Dell Lime Pit, Gold Sandpit, Idaburn, Mataura Coal Mine and Roxburgh. In addition, other angiosperm wood is present at Pikopiko and Galloway. Identification of wood from forest trees adds to our current knowledge of the composition of the paleoforests of southern New Zealand acquired from pollen and leaves.

SURTSEYAN VOLCANIC ERUPTIONS: AN EXPERIMENTAL PERSPECTIVE

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Surtseyan volcanic eruptions are submarine or sublacustrine eruptions initiated beneath relatively shallow water. They can endanger shoreline communities including highly populated areas (e.g. in Auckland volcanic field). These eruptions result from explosive interactions between magma and external water, and, if strong enough, can breach the water surface before emergence of a tuff cone. The few studies to have addressed questions about the submerged Surtseyan activity are based on study of their deposits.

Here we present a reconnaissance experimental study that first addresses behaviour of particles during the initial stage of the subaqueous explosion process, then the subsequent evolution of the gas “column” generated by the blast. The blasts are charged with particles in our experiments, which is a novel extension of previous work on subaqueous explosions.

The experimental system is a tank (32x32 cm), filled with water for most runs, into which different types of particles were driven by blasts of compressed argon gas. We adopted three settings: 1) water-saturated particles forced into water, analogous to motion of slurry particles driven by an adjacent explosion; 2) dry particles driven into water, analogous to motion of particles created and entrained in a gas/vapor explosion; 3) dry particles released into air [=subaerial]. For most runs, a clear sequence through the explosion was observed: (i) initial doming; (ii) gas-bubble expansion, and (iii) gas-bubble collapse.

Water-saturated particles remain well-coupled with water into the column, whereas dry particles of different sizes/densities show significant differences in relative motion while entrained in the gas jet. Secondary variations, such as column shape, reflect features of the material (particle mass, particle density, and particle-population homogeneity). Many runs also showed column behaviours such as particle shedding (with generation of gravity flows), and particle assimilation (particles re-entering the plume).
ROCK AVALANCHES ON THE WESTERN RANGE FRONT OF THE SOUTHERN ALPS, NEW ZEALAND AS A RECORD OF PEAK GROUND ACCELERATIONS DURING ALPINE FAULT EARTHQUAKES

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We describe preliminary results of a study designed to quantify the peak ground acceleration (PGA) experienced on the West Coast of the South Island in past earthquakes, by analysing large rock avalanches that have occurred on the Western Range Front. We are analysing parameters of historical landslides such as volume, runout length, affected area, rock mass properties and landslide spatial density. The parameters of runout length and affected area tend to have large values, and landslide density displays high, linear correlation with PGA. We draw on published data about these parameters for the coseismic Round Top debris avalanche, Mount Harry and the Cascade rock avalanche. We will also carry out field investigations of rock mass properties, so that realistic strengths can be estimated. It is hoped this study will improve understanding of the hazard posed by co-seismic landslides in the West Coast region.

ARE THERE HIDDEN ACTIVE FAULTS UNDER DUNEDIN CITY?

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The Canterbury Earthquakes Royal Commission (CERC) recommended that “Research continues into the location of active faults near Christchurch and other population centres in New Zealand, to build as complete a picture as possible for cities and major towns”. In Dunedin, two northeast-trending structural lineaments have been identified as possibly active tectonic features: 1) along Kaikorai Estuary and Kaikorai valley and into Waitati valley; and 2) into South Dunedin and along Otago Harbour. Our research aims to assess whether these are active and, if so, their possible deformation rates. We are integrating geology, gravity, onshore and offshore seismic reflection, microseismicity, InSAR and GNSS observations in order to evaluate these potential earthquake sources.

Geological mapping and structural contouring of surfaces of established age suggest there are clear geological faults along each lineament, but whether they are still active and/or have played a major role in the late Quaternary tectonic history of Dunedin is yet to be established. Gravity data (62 new stations) currently being processed may shed light as to the deeper tectonic significance of the lineaments. Onshore seismic reflection data have refined the location of the active Akatore Fault southwest of Dunedin. Planned onshore seismic reflection at Kaikorai Estuary will investigate whether a northward extension of the Akatore Fault extends onshore. InSAR analysis has not identified any definitive fault-related contemporary surface tectonic deformation in Dunedin, but nor has it shown any ongoing deformation across the active Akatore and Titri faults to the south, indicating that it is not diagnostic of the presence or otherwise of hidden active faults under Dunedin. On-going observations from one new continuous and 11 semi-continuous GNSS stations may help constrain deformation rates. A microseismicity study is expected to define the presence and nature of any stress release that may be occurring along the two lineaments.

SPATIAL AND TEMPORAL VARIATIONS IN NON-VOLCANIC TREMORS IN THE NANKAI SUBDUCTION ZONE, SOUTHWEST JAPAN

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Since the first discovery of non-volcanic tremors in the Nankai subduction zone, southwest Japan in 2002, more tremor activities have been identified in various tectonic areas worldwide. Tremors themselves do not cause catastrophic damage, but a better understanding of their characteristics will aid with the investigation of interplate slip. The tremor
activity is observed to be spatially segmented and temporally recurrent. We developed a class of statistical models to classify the tremor source regions in the Kii region in the Nankai subduction zone. Fourteen distinct segments in 2D space were identified. The 14 segments form two major subsystems, one containing two segments at the southwest tip, and the other containing 12 segments to the northeast part of this region. The major subsystem to the northeast part can be further subdivided into three subsystems, the boundaries of which run along the 40km isodepth contour of the oceanic Moho discontinuity. The models also provide the spatiotemporal migration patterns among these subsystems.

CONSTRAINING THE FORESHOCK AND AFTERSHOCK SEQUENCE OF THE 2016 M7.1 EAST CAPE EARTHQUAKE: INSIGHTS FROM MATCHED-FILTER DETECTION

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The 2nd September 2016 M7.1 East Cape earthquake was preceded notably by a M5.7 foreshock 18.5 hours prior to the main event. However, understanding the processes linking these events and mapping the temporal and spatial evolution of the sequence is hampered predominantly by the limitations of the onshore network location relative to the offshore events. Specifically, the c. 100 km epicentral distance of the sequence from the nearest onshore station limits the ability to detect many small magnitude events, and the small c. 20 degree aperture restricts the ability to accurately determine hypocentre locations. As an added complication, the effectiveness of routine detection algorithms based on short and long-term amplitude variations is limited due to the emergent nature of many of the waveforms.

In this study, a template matching method is utilised to generate an improved microseismic catalogue and examine the sequence propagation. By using 383 GeoNet events as template waveforms, a matched filter cross-correlation routine is performed to detect events with similar source properties (i.e. similar waveforms, occurring in a similar location). This way, many smaller foreshocks and aftershocks are detected, particularly those which may be obscured in the coda of preceding overlapping events, leading to a lower magnitude of completeness. The spatial pattern of the sequence is examined by computing high precision relative locations through generation of lagged single channel cross-correlation derived phase picks. This method produces automatic phase picks to sub-sample accuracy, and allows for variation of detection location from that of the template event. Double-difference relative relocation of detected events allows for an improved spatial evolution of the sequence to be constrained.

GENERATION OF FAULT ROCK IN A WEAKLY LITHIFIED TURBIDITE, TARANAKI, NEW ZEALAND

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In weakly lithified sequences fault rock is typically generated by flow and mixing of the host material. Increasingly, cataclastic fault rocks are being inferred to form in weakly lithified rocks and at shallow depths (e.g., < 1 km), yet the processes that result in grain comminution are not always clear. Here we examine fault-rock generation for normal faults in the Late Miocene Mount Messenger Formation turbidites from the North Island of New Zealand. The tectonic normal faults studied have displacements of 0.001 to 1.1 m, are exposed in coastal cliffs up to 20 m high and probably formed at burial depths of ~1-1.5 km. Fault rock has been analysed using thin sections, SEM images, particle size distribution measurements and outcrops of faults mainly in cross section. Cataclasism associated with particle size and porosity reduction of protolith sandstones commences at low fault shear strains (<1) and continues as fault displacement accrues. Cataclasism was accompanied by smearing or drag of mudstone beds, which appears to have been mainly achieved by intergrain slip and associated micro-faulting with little grain-size reduction. In sandstone dominated parts of the sequence cataclasism is the primary mechanism responsible fault-rock formation. The relationship between particle-size reduction and displacement is non-linear with initial rapid cataclasis facilitated by disaggregation of weak lithic and altered feldspar grains along pre-existing grain defects (e.g., grain boundaries, fractures and altered cleavage planes). Continued fracturing of relatively strong quartz and feldspar grains set in a clay-rich matrix may arise due to impacts between these grains during high-energy slip events.
THE EFFECT OF EARTHQUAKE-INDUCED STRESSES ON HYDROGEOLOGICAL SYSTEMS

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In recent decades, earthquakes have been demonstrated to cause groundwater level-changes. We study these hydrological phenomena to provide internationally significant examples of crustal hydromechanics, which will inform infrastructural decision-making in seismically active regions. Our approach focuses on distinguishing the roles of extrinsic (earthquake-related) and intrinsic (local geological and hydrogeological) factors in earthquake-induced hydrogeological responses.

Using >670 monitoring wells throughout New Zealand in seven hydrogeological settings with varying geology (schist, volcanic, sandstone, limestone, gravel), we are currently quantifying different groundwater responses (transient [<2 hours], persistent [<days] and long-term [<years]) following earthquakes along the Australian-Pacific plate boundary, in a 12 year period (2003-2014). Once that phase is completed, we will approximate dynamic stresses by recorded peak ground velocity and phase velocity. We will estimate volumetric static stress by an elastic half-space model (Coulomb 3.3). We will attempt to classify aquifer compliance by assigning boreholes a geological classification based on the 1:250,000 Geological Map of New Zealand (QMAP, GNS Science).

We have developed one of the most extensive multiple-well/multiple-earthquake hydrogeological datasets internationally available. Presently, we infer a geological control on groundwater responses based on the threshold levels of shaking needed to produce a response. This suggests that, as the rock strength increases, so does the ability of the aquifer to resist earthquake-induced hydrogeological change. The intrinsic properties of the system are essential, as they partially control the magnitude and type of response, which aids in the understanding of the hydromechanics involved.

ORAL

SYN-EXTENSIONAL CONSTRICNTIONAL FOLDING OF THE GWOIRA RIDER BLOCK, A LARGE FAULT-BOUNDED SLICE ATOP THE MA'I'IU LOW-ANGLE NORMAL FAULT, WOODLARK RIFT.

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The Mai’iu Fault is an active and corrugated low-angle normal fault (LANF), located in the Woodlark Rift, SE Papua New Guinea, which dips ~21° NNE, accommodating rapid N-S extension. The Gwoira rider block is a large fault-bounded sedimentary slice comprising the Gwoira Conglomerate, located within a large synformal megamallion in the Mai’iu Fault surface. The Gwoira Conglomerate was originally deposited on the Mai’iu Fault hanging wall concurrent with extension, and has since been buried to a maximum depth of 1600-2100 m (evidenced by vitrinite reflectance data), back-tilted, and synformally folded.

I employ structural field mapping and cosmogenic nuclide dating to investigate the tectonic evolution of the Gwoira rider block. Both the Gwoira Conglomerate (former hanging wall) and mylonitic foliation (footwall) of the Mai’iu Fault have been shortened ~E-W, perpendicular to the regional extension direction. We show that E-W synformal folding of the Gwoira Conglomerate was concurrent with ongoing sedimentation, and with extension on the Mai’iu Fault. Structurally shallower Gwoira Conglomerate strata are folded less than deeper strata, indicating that folding was progressively accrued concurrent with ~N-S extension. We also show that the abandonment of the inactive strand of the Mai’iu Fault in favour of the younger Gwoira Fault, which resulted in formation of the Gwoira rider block, occurred in response to progressive megamallion amplification and resultant misorientation of the inactive strand of the Mai’iu Fault. We attribute E-W folding to extension-perpendicular constriction. This is consistent with numerous observations of outcrop-scale conjugate strike-slip faults that deform the footwall and hanging wall of the Mai’iu Fault, which accommodate E-W shortening. Constrictional folding remains active in the near-surface as evidenced by synformal tilting of inferred Late Quaternary fluvial terraces atop the Gwoira rider block. This sequence of progressive constrictional folding is dated using 26Al/10Be terrestrial cosmogenic nuclide burial dating of the Gwoira Conglomerate.

ORAL
DEVELOPMENT OF A CONCEPTUAL GEOCHEMICAL MODEL FOR THE ESCARPMENT COAL MINE

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The Escarpment Coal Mine is located on the Denniston Plateau north east of Westport within an area of historic coal mining dominated by underground mining activities within the Brunner Coal Measures. Bathurst Resources Limited (BRL) has been granted approval to develop the Escarpment Coal Mine, which is currently under care and maintenance due to low commodity prices. Mining is expected to commence again in the near future.

As part of the mine development, a small amount of mining was undertaken resulting in the construction of the Barren Valley Engineered Landform (ELF) and the development of Pit 3. These disturbances have provided the opportunity to determine acidity loads derived from a waste rock dump constructed in 2m lifts and the acidity generated from an acid pit lake within the Brunner Coal Measures.

A conceptual model has been developed for the site where the acidity load reporting from the toe of the ELF (140 mg/L CaCO₃ equiv. acidity; flow 2.5 L/s) is apportioned back to the waste rock within the ELF. This load is allocated to both oxic and anoxic portions of the ELF after deduction of the acidity load from drainage associated with underground workings.

Modelling has been undertaken to determine acidity generation rates for the pit lake, which suggest at the point of the pit lake overflowing (18 month fill time) there will be ~ 7 tonnes of acidity in the pit lake, with ~0.700 tonnes of acidity being produced annually from the remaining exposed highwall (0.3 ha).

It is anticipated that the installation of a passive treatment system to treat the AMD impacted drainage from the ELF will also generate an effluent stream having ~ 100 mg/L alkalinity at 2.5 L/s, which if diverted into the pit lake will generate ~7.8 tonnes of alkalinity being sufficient to neutralise the acidity generated by the pit lake highwalls.

NEW PRE-COMPETITIVE GEOPHYSICAL DATA ACQUISITION AND GEOCHEMICAL PROGRAMMES IN NEW ZEALAND: EXPANDING THE KNOWLEDGE BASE THROUGH GOVERNMENT FUNDED DATA INVESTMENTS

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Government-funded aeromagnetic and radiometric surveys acquired over New Zealand in the last five years have provided ground breaking insights into the country’s geology and mineral prospectivity. Newly acquired surveys (Northland - 2011, West Coast - 2013 and most recently, Nelson-Marlborough - 2015/16 and Otago-Southland - 2015/17) complement industry-funded acquisition. The result of this complementary data is that ~35% of New Zealand’s land area will now be covered by high quality geophysical data, and almost complete coverage of its mineral provinces outside of national parks. The aeromagnetic data is expanding our understanding of surface and subsurface geology in these areas.

In addition to the airborne acquisition, a regional government-funded geochemical survey in Otago, Southland, Nelson and Marlborough complements some of these geophysical datasets and there are plans to extend the survey nationally. The completed survey involves sampling of soils at two depths and analysing for 67 elements with ICPMS and XRF methods at a default grid spacing of 8 km, with some areas being addressed at a grid spacing of 2 km. This and future surveys will highlight background and anomalous concentrations of many ore pathfinder elements. The government funded geophysical and geochemical acquisition programmes have provided industry and researchers with free to use, modern, high-resolution data that are being used to de-risk the exploration of the sub-surface geology.

Broad uptake and use of government data by industry, research and academic institutions is encouraged. The aim is to assist industry in making future discoveries of ore bodies and deposits and to inform future government data investment programmes. The government funded data acquisition projects will be presented with a focus on their impact on our geological understanding of those areas, alongside an update on the current programme of regional geophysical and geochemical surveys.

ORAL
Throughout the Southern Alps of New Zealand, evidence for fluid flow during the orogen's history is ubiquitous. Such evidence are for example veins, silicified fault breccias and zones of hydrothermal alteration in the rock adjacent to these structures. In this study, the alteration of Otago Schist caused by infiltration of hot CO$_2$-rich fluids in Western Otago were studied on macro-to microscopic level. Various metamorphic phases (epidote, chlorite, actinolite) are replaced by Fe-bearing carbonate and phyllosilicates. Textural and chemical data of the individual metamorphic and hydrothermal minerals were obtained using SEM, microprobe and LAICPMS. The breakdown reactions form a diverse array of textures and give insight into relative solubility of the different mineral phases. The replacement reactions also attest for mobility and immobility of the different major and trace elements. For example, in the breakdown of epidote in rocks which contain metamorphic muscovite, Al is mobilised potentially in F-OH complexes and transported away from the original epidote site, where carbonate grows. In cases where there is no muscovite in the rock, epidote is replaced by muscovite, meaning that the Ca leaves the replacement site. At the same time, the REE of the epidote are also mobilised on microscopic scale as the muscovite cannot accommodate the REE in their crystal structure. These REE are then incorporated in the ankerite replacing the chlorite. On a macroscopic scale, Sr, Ba, Rb, K and Cs show the biggest mobility during the hydrothermal alteration (sometimes up to 20 times enrichment) and are often brought into the rock by the hydrothermal fluid. The REE and Al, on the other hand, do not show any signs of mobility on macroscopic scale, though it has been shown that they can be mobile on a microscopic level.

**MINERALOGICAL, TEXTURAL AND CHEMICAL CHANGES IN OTAGO SCHIST AS A REACTION TO INFILTRATION OF HOT CO$_2$-RICH FLUIDS**

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A 1955 maar-forming eruption in Chile, called Nilahue after the adjacent river, produced an elliptical crater 800 by 1400 m in diameter and 350 m deep. The eruption lasted less than a week, with the first 2 days of eruption from a fissure, after which separate small craters formed and then merged to form the final single crater. Activity on the whole "...consisted of explosive eruptions of remarkably uniform strength, each throwing up material to a height of 5 to 8 km. At the beginning, these eruptions of some 20 to 30 minutes duration followed each other every 30 minutes or so, but later on the duration of the individual eruptions tended to increase to about one hour, and their frequency decreased." After the eruption the crater was quickly filled with water to form a lake (summary & quote from Müller G and G Veyl, 1957, The birth of Nilahue, a new maar type volcano at Rilihahue, Chile, in Proc 20th Int'l Geol Congress, Mexico, 1957, v 1, pt 2, p. 375-396.). We examined and sampled deposits from this eruption, which temporarily dammed the river during eruption, drape tributary valley walls, and overlie lavas and pyroclastic deposit of a 1908 eruption that produced ash beds and formed an edifice 1 km away on the other side of the river. Both the 1908 and 1955 eruptions modified and overbuilt or cut into slightly older small volcanoes, and many deposits are very similar. Future work will focus on within-deposit textural and chemical changes through the eruptions, but we must also consider whether these small, closely spaced volcanoes that repeatedly erupt and/or physically overlap, are products of 1, 2 or four magma systems.

**REPEATEDLY MONOGENETIC MAARS AND A RIVER: CERRO CARRAN AND ITS NEIGHBORS, CHILE**

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Much of New Zealand’s population (e.g., Blenheim, Christchurch City and Hastings City) occupies coastal plains, like the Wairau Plain. These plains are primarily formed from Pleistocene sedimentary units deposited in terrestrial environments and marine-estuarine sediments at the coast that have been extensively drained.

This paper describes three-dimensional (3D) models of the Wairau Plain (i.e., lithology and groundwater pressure derived from observations made in approximately 1,500 wells) with a focus on the use of these models to describe the hydrogeological conditions that led to the requirements for drainage. In a sense, this paper is in footsteps of William Smith, who famously mapped surface geology in early 19th century Britain, and was integral to the dawn of modern hydrogeological science with the design and construction of agricultural drainage systems. Now, we are at the cusp of the wholesale application of 3D models to the characterisation of geological and groundwater systems and the solution of hydrogeological and geotechnical problems such as drainage.

The paper will summarise developments in hydrogeology related to drainage in the early 19th century, by Smith, and others. Then, Wairau Plain drainage works, completed over the last 150 years, will be outlined. For example, Blenheim’s flood risk was reduced with extensive drainage (e.g., through swamps at the base of the Taylor River gravel fan) and river works (e.g., realignment of the Omaka and Fairhall rivers, located to the west of the town).

Hydrogeological conditions that led to drainage and river works are clearly identified by 3D models. For example, the base of the Taylor River gravel fan was characterised by shallow gravels (deposited by the Omaka and Fairhall rivers), sands, silts and clays; confining conditions; and vertically-upwards groundwater gradients. In addition, the models provide important insights into the catchment hydrogeology of spring- and drain-fed streams in the Plain.

Geological formations in the Upper Waikato River catchment (i.e., the area between Lake Taupo and Karapiro dam) were represented with a 3D model in six main structural elements that are bounded by major faults and groupings of faults:
1. Permian to Jurassic basement greywacke and Pliocene-Pleistocene volcanoes that crop out in the west;
2. the Hauraki Rift extension southeast of the Hauraki Plains that has been filled largely with ignimbrites sourced from the Mangakino Caldera and from the Whakamaru Caldera;
3. the Mangakino Caldera in the western TVZ;
4. the TVZ rift, including ignimbrites sourced from: Mangakino caldera; Whakamaru caldera; calderas outside the catchment (Rotorua, Okataina and Taupo); rhyolite domes; Taupo rhyolites; and Tauranga Group sediment in valleys;
5. the Taupo-Reporoa Depression, including the Reporoa Caldera, rhyolite domes, lake sediments, Taupo rhyolites; and

This model uses Earth Vision software to map surfaces of 20 formations that are important for groundwater flow, including aquifers and aquicludes, on a 100 m by 100 m grid. Therefore, the model is particularly relevant to hydrogeological and geothermal studies that require an understanding of large-scale flow fields.

The model has been used to assess groundwater flow with: characterisation of surface-groundwater interaction for water allocation policy development, an assessment of land use and water quality in the Reporoa Basin and calculation of water flow paths in the Pokaiwhenua catchment. Applications of the model relevant to geothermal studies have included an assessment of the flow fields (i.e., cold- and hot-water components) of the Wairakei geothermal field catchment and the distributions of groundwater catchments of all high-temperature geothermal fields in the model area. In addition, the model has been used for public information (e.g., a museum display) and education with talks to school children and university-level course development.
A COMPARISON OF THE USE OF X-RAY AND NEUTRON TOMOGRAPHIC CORE SCANNING FOR DRILLING PROJECTS: INSIGHTS FROM SCANNING CORE RECOVERED DURING THE ALPINE FAULT DEEP FAULT DRILLING PROJECT

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It is now commonplace for non-destructive X-ray computed tomography (CT) scans to be taken of core recovered during a drilling project. However, other forms of tomographic scanning are available, and these may be particularly useful for core that does not possess significant contrasts in density and/or atomic number to which X-rays are sensitive to. Here, we compare CT and Neutron Tomography (NT) scans of core recovered during the first phase of the Deep Fault Drilling Project (DFDP-1) through New Zealand’s Alpine Fault. The higher resolution of the NT scans allows clearer imaging of some core features than in the CT scans, however, we observe that the highly neutron absorbing properties of DFDP-1 core diminishes the quality of images towards the interior of the core. We also compare the suitability of these two scanning techniques for a drilling project. We conclude CT scanning is far more favourable in most circumstances. Nevertheless it could still be beneficial to take NT scans over limited intervals of suitable core, where higher resolution and varying contrast is desired.

WHAT'S TO BLAME FOR THE DAMAGE? FRACTURE ORIENTATIONS AROUND NEW ZEALAND'S ALPINE FAULT

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The orientation of structures that define fault damage zones may provide information about the way they were generated, as well as allowing calculation of the fault’s permeability. We have determined the true orientation of 637 damage zone structures in the hanging wall of New Zealand’s Alpine Fault by correlating ‘unrolled’ X-ray computed tomography (CT) scans of drill-core collected during the first phase

DETAILED INVERSION OF A SHALLOW SLOW SLIP EVENT AT THE HIKURANGI SUBDUCTION ZONE, USING NUMERICAL GREEN’S FUNCTIONS AND ABSOLUTE PRESSURE GAUGE DATA

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Slow slip events (SSEs) have been observed throughout the world, and the existence of these events has fundamentally altered our understanding of the possible ranges of slip behavior at subduction plate boundaries. SSEs are typically observed via continuous GPS (cGPS) observations. Although much has been learned in recent years, the slip distributions for shallow SSEs are still poorly understood due to the lack of offshore data to constrain the slip estimates. Most importantly, it has been difficult to determine whether shallow SSEs extend to the trench, or whether they terminate at some distance inboard of the trench. Constraining the slip distribution is critical to our understanding of the physics underlying SSEs.

Recently, absolute pressure gauges (APGs) were deployed offshore near Gisborne, as part of the HOBITSS experiment, capturing a SSE event during September and October 2014. The APGs provide a record of vertical deformation during the event, allowing much better constraints on the offshore slip distribution. Initial inversions using an elastic half-space model based on these observations indicate that slip occurred within 2 km of the trench. We here describe a more detailed inversion procedure where we include the effects of detailed fault geometry, bathymetry/topography, and material property variations to provide a more accurate estimate of the slip distribution during this event. We use the PyLith finite element code to generate Green’s functions for use in our inversions. By going beyond an elastic half-space model we should be able to place much tighter constraints on the slip distribution, and thus improve our understanding of shallow SSEs.

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of the Deep Fault Drilling Project (DFDP-1), to geographically referenced borehole televiewer images of the DFDP-1 boreholes. These structures exhibit a broad range of orientations, rather than being systematically oriented with respect to a mylonitic foliation. By comparison, in CT scans of drill-core collected 1-2 km from the Alpine Fault during the Amethyst Hydro Project, brittle structures are predominantly parallel to the regional foliation. We therefore conclude that foliation-parallel fractures are representative of the regional fracture network, and are generated by long-term processes such as removal of elastic load during uplift. Conversely, in close proximity to the Alpine Fault, the foliation is apparently capable of exerting only a small influence on orientation. The wide range of orientations of co-seismic structures may instead be generated through a combination of slip occurring along a fault that is non-planar in the near surface (<4 km), and that at depth is poorly oriented with respect to the regional stress state for slip. If this is true, the presence of a wide range of structure orientations is diagnostic of the Alpine Fault damage zone. Field data show variable structure orientations are restricted to the hanging wall within 73-154m of the fault trace in the central section of the Alpine Fault, and this is the best estimate of true damage zone width.

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INFERRING LARGE EARTHQUAKES AT THE TONGA-KERMADEC TRENCH VIA TSUNAMI DEPOSITIONAL EVIDENCE

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The seismic and tsunamigenic potential along the entire Tonga-Kermaec Trench is not well understood, particularly in terms of whether the historic record is representative of the largest events or whether periodic strain build-up can synchronize allowing much larger events to occur. Recent studies of the 2009 South Pacific Tsunami in Samoa, as well as investigations of older tsunami deposits in these and surrounding islands that are likely linked to the same source region, provide a means to help answer this question. In this talk, we draw on available geological and ethnoarchaeological evidence of past tsunamis from Samoa, Uvea and Futuna, Tonga, Fiji, and Aotearoa-New Zealand to consider the potential for large to great earthquakes and subsequent tsunamis occurring at the Tonga-Kermaec Trench. Given the short seismic record in this region of 100 years or so, we propose that geological and ethnoarchaeological records over the last several millennia can help to better understand the potential for such events occurring in future.

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INTRODUCING NEW ZEALAND VERTICAL DATUM 2016 (NZVD2016)

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In June 2016 Land Information New Zealand released (LINZ) a new national datum NZVD2016. This geoid based datum, replaces the ageing tide gauge based datums, providing an easily accessible, seamless and more relevant reference surface for heights on land. This new datum supports the conversion of ellipsoidal heights from a GPS receiver, directly to the NZVD2016 thought the application of a geoid correction.

LINZ has published NZVD2016 elevations on all heightened marks in the Geodetic Database, providing a greater density of height control points throughout the country.

In order to allow the conversion of existing data collected in terms of one of the 13 local vertical datums to NZVD2016, LINZ has developed local vertical datum relationship grids. The datum relationship grids model the offset, which varies with horizontal position, between these datums and NZVD2016, which. The offset variation can be as much as 25 cm within the area contained by a local vertical datum.

POSTER

THE NATIONAL AIRBORNE GRAVITY DATASET

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Between August 2013 and June 2014 Land Information New Zealand, in collaboration with GNS Science and Victoria University of Wellington, conducted a national airborne gravity survey. The survey is made up of 120 flight lines over the three main islands of New Zealand, and up to 10km offshore. The flight lines are at 10km spacing, providing uniform and seamless coverage of the entire country, including the Southern Alps, Taranaki bight, and the littoral zone.
The data has been post processed, removing gross errors and flight lines biases. The resulting accuracy of this dataset is approximately 3 mGal.

Land Information New Zealand has made this data available to the public under a CC-BY licence.

**NEW SEISMIC AND ACOUSTIC INSIGHTS INTO LAKE TEKAPO**

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Large glacier-formed Lake Tekapo in the South Island is surrounded by mountainous terrain and receives high sediment input from glacially-fed rivers. The surroundings are riddled with faults which continue throughout the lake. Geological records document landslide activity into the lake that inevitably must have led to landslide generated tsunami in the past. Information on landslide recurrence and potential tsunami hazard is important for the Tekapo Township which is nestled into the southern part of the lake and also for the Tekapo power station.

In order to map Lake Tekapo bathymetrically and seismically a field campaign was completed in February 2016 using NIWA's vessel Rukuwai. The vessel was equipped with a retractable EM2040 multibeam system, DGPS and a seismic Boomer system.

Next to the ~80 km² high-resolution bathymetry, backscatter and water column data, we successfully acquired 130 line-km of multi-channel Boomer seismic data. The high-resolution seismic reflection (Boomer) system consisted of a 300 Joule boomer plate, towed behind Rukuwai. The receiver array was a 16-channel digital GeoEel streamer. We also trialled the University of Otago Pinger. A following field campaign by Otago University acquired additional Chirp data and collected sediment cores. The combined use of different imaging systems created one of the most advanced seismo-acoustic datasets ever collected in the New Zealand's glacial lakes.

The 1 m resolution bathymetry reveals river delta deposits, steep eroded margins, flat lying central lake floor and numerous landslide deposits. The high-resolution Boomer and Chirp seismic data show sediment penetration of up to 200 m even in 120 m water depth. Large areas are affected by gas. Seismic images reveal numerous superimposed landslide features and a rich structure of tectonic features. Both seismic imaging systems did not produce any useable images at steep lake skirts.

**SPATIAL VARIABILITY OF LOW PERMEABILITY FAULT ROCK AND ITS IMPLICATIONS FOR FAULT SEAL PREDICTION**

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A number of factors can influence the hydraulic behaviour of faults and these include the rheology and permeability of host and fault rock as well as bulk stress conditions, structural anisotropy, differences in pressure across the fault and viscosity of the fluids of which are interacting with the fault zone. These factors ultimately control whether a fault acts as a barrier to lateral fluid flow and/or a conduit for along fault flow (or possibly both within the same fault zone). In this study we examine the architecture of normal fault zones to improve understanding of how these faults impact fluid flow. We analyse seven normal faults with displacements of 0.01-0.40m from within the Late Miocene (~6.5-11 Ma) Mount Messenger Formation exposed along coastal cliffs in north Taranaki, New Zealand. For each fault the fault zone and fault rock thicknesses have been measured and are combined with grain-size analysis of displaced beds and fault rock. Data have been used to help constrain fault processes, fault permeability structure and the resulting implications for fault-seal prediction. Preliminary results indicate that both fault zone and fault rock thicknesses can vary by more than an order of magnitude over distances of <1 m. The wavelength of these changes may be partly controlled by bed thicknesses and associated fault segmentation. The thickness of fault rock is positively related to the number of deformation bands, which form by cataclasism of host-rock sandstone. Cataclasism is accompanied by smearing of mudstone beds, although these smears often do not significantly increase fault-rock thickness. Therefore, fault-rock thicknesses are not strongly correlated with the locations of mudstone beds. These data suggest that the utility of algorithms widely used to predict fault seal may require re-examination.
Successful forecasting of volcanic eruptions requires further work to understand the processes that precede them. One method used investigates the stress field surrounding a volcano, with the intrusion of magma likely to put pressure on adjacent rock. This study applies automated stress-monitoring techniques at White Island Volcano, in the form of shear-wave splitting analysis and ambient noise cross-correlation. Specifically sought are observable temporal variations in seismic properties of the surrounding medium that can be related to the 2012-2013 eruption sequence. Initial findings from shear-wave splitting reveal a new north-south population of crack orientations (166-15°) measured in 2011-2012 at both White Island and a mainland station (OPRZ). However, sample size issues render it difficult to suggest whether such variations represent a change in crack orientation or a different pathway of shear-waves. Similarly, the resolution of temporal variations is currently too low to link additional changes in crack orientation to the eruptive events. The future focus for shear-wave splitting at White Island therefore involves expanding the current dataset. Cross-correlating ambient noise provided more promising results, with the medium velocity between OPRZ station and White Island dropping by 0.2 ± 0.1% in the proximity of both volcanic eruptions. The timing of these events however, in relation to the velocity decrease, are inconsistent. Additionally, fluctuations of equal magnitude occur without an eruption. A stronger knowledge of the volcano’s background stress state is required to determine the regularity of velocity drops of this size. Furthermore, increasing the number of station pairs used will provide greater coverage of the region, enabling more accurate determination of whether observed changes are originating near the volcano. Later research will attempt to build on these initial results to provide a comprehensive analysis into the sources of stress variations at White Island and the capability of automated techniques to detect them.

A GEOETRIC STUDY OF STRAIN DISTRIBUTION ON THE SUNDALAND PLATE

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We use continuous GPS data from 1999 to 2014 to examine interseismic strain rate, of the 2004 M_9.1 Aceh, 2005 M_8.6 Nias and 2007 M_8.5 Bengkulu and 2012 M_8.6 and 8.2 northern Sumatra, in the Sundaland plate. These data have captured the process of pre-, inter- and postseismic deformation of the series of great earthquakes, which are mainly concentrated on its western margin of the Sundaland plate. Our analysis suggests that a 100 km long segment of the Sunda megathrust (1.43°N–2.15°N) has a fairly low rate of shear strain accumulation after the 2012 northern Sumatra strike-slip earthquakes compared to the pre-earthquake period. This segment is approximately one-third of 2005 Nias northern rupture segment, which also produced earthquakes M_8.5 in 1861 and ~M7.8 in 1907. The comparison of shear strain rate before and after 2012 earthquake suggest that this segment, which was freely creeping in the past, is now largely locked. This study also identified non-tectonic deformation in the Malaysia hinterland, particularly in Kuala Krai, Tanah Merah, and Sri Aman, that are subjected to localised land subsidence. Thus, the interseismic strain rate in this study is indicated the spatiotemporal of strain distribution of Sundaland plate that vary in space and time.

TEXTURAL ANALYSIS OF THE ONGATITI IGNIMBRITE MATRIX TO ASSESS THE PARTICLE FRAMEWORK AND MECHANISM OF PYROCLASTIC FLOWS

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The 1.23 Ma Ongatiti Ignimbrite is a widespread rhyolitic to rhyolitic ignimbrite that is exposed mostly in the western part of the central North Island, and correlates distally to the Oparau Tephra and (informal) unit K12 of the Kauroa Ash sequence. The ignimbrite contains zones of well-preserved, primary matrix and matrix that has been modified by chemical alteration, welding and compaction. This presentation will characterise the texture and componentry of the Ongatiti ignimbrite matrix to further understand magma fragmentation processes.
the physics of the ash-gas fluid and also post-
emplacement processes, and their role in modifying
ignimbrite rock properties.

Ignimbrite samples have been collected from
different locations (e.g. Hiuera Quarry, Waipari
Gorge and Tauranga). Conventional 2D methods,
optical petrography, scanning electron microscopy
(SEM), back scattered electron imaging (BSEI), and
elemental analyses (EDS) have been used to evaluate
the microtexture.

The poorly sorted Ongatiti ignimbrite has a complex
and variable framework of pumice, glass shards,
crystals and lithic clasts. Microscopically, the
vitriclastic matrix is also poorly sorted and largely
comprises glass shards ranging from a few microns to
approximately 900 microns in size and of various
shapes (e.g. platy, cuspate, and Y shapes). Glass
shards range from colourless to dark brown, showing
changes in the degree of devitrification and chemical
alteration. The eutaxitic texture, deformed glass
shards around rigid particles, and crystal-crystal
contacts occurring in parts of the ignimbrite are key
indicators of welding. The glass shards transition into
complex pumice fragments at larger sizes. Several
types of pumice have been recognized on the basis of
vesicularity, vesicle size and shape. The matrix is
crystal-enriched; primary volcanic crystals range from
less than 100 microns to a few 1000 microns in size
and include plagioclase, quartz, pyroxene, hornblende, and Fe-Ti oxides. The preliminary
observations highlight the complexity of ignimbrite
matrices which has direct implications for fine-scale
fragmentation, transport and depositional dynamics
of the ash-gas fluid and also post-emplacement
processes.

SWS analyses produce fast polarization directions and
a delay time (controlled by strength of anisotropy).
The SWS fast polarization is often inferred to
represent the maximum horizontal stress directions
(Shmax) in crustal studies and has been shown to vary
temporally at volcanoes and in association with large
earthquakes. SSEs may produce stress and fluid
changes that are detectable with the SWS technique.
We use Multiple Filter Automatic Splitting Technique
(MFAST) to analyse more than 3000 local earthquakes
from the Geonet catalogue between May 2014 and
July 2015 to look for temporal changes in SWS fast
polarization directions during the Gisborne 2014 SSE.

Because SWS results are sensitive to variations in
discrete earthquake locations, we also analyse results from
individual spatial earthquake clusters to test the
robustness of temporal changes and to better
indicate where the measured anisotropy originates.

Preliminary SWS results at Geonet stations MHGZ and
KNZ prior to the 2014 Gisborne SSE show a NE-SW
trending fast polarization direction similar to the local
Shmax direction mapped by previous studies and to
local fault trends.

INVESTIGATING CRUSTAL STRESS CHANGES
DURING 2014 GISBORNE SLOW SLIP EVENT

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In October 2014 a 2-month long Gisborne slow slip
event (SSE) occurred and for the first time was
recorded by offshore instruments. The instruments
were deployed by the Hikurangi Ocean Bottom
Investigation of Tremor and Slow Slip (HOBITSS)
project specifically to record an SSE. In this study we
use seismic data from the HOBITSS deployment as
well as local GeoNet stations to examine shear wave
splitting (SWS) around the time of this uniquely
recorded SSE.

PETROGENESIS OF ANTECRYST-BEARING
MEXICAN ARC BASALTS: INSIGHTS INTO ALONG-
ARC VARIATIONS IN MAGMA PONDING DEPTHS
AND SURFACE HEAT FLUX

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The Trans-Mexican Volcanic Belt (TMVB) is known for
the chemical diversity in its erupted products. We have analyzed the olivine, pyroxene and plagioclase
mineral chemistry of 30 geochemically well-
characterized mafic eruptives from Isla Maria at the
western end of the arc to Palma Sola in the East. The
mineral major oxide data indicate the dominance of
open system processes such as antecryst uptake, and
the scarcity of mineral-mineral and mineral-melt
equilibria suggest that erupted melts do not significantly crystallize during ascent. A combination
of plagioclase antecryst chemistry and MELTS thermodynamic modeling of H2O-saturated isobaric fractional crystallization is employed to develop a pressure sensor that allows determination of ponding depths of the co-genetic magmas from which the erupted plagioclase crystal assemblage originates. We show that the depth of magma-mush reservoirs increase eastwards along the TMVB. We suggest that magma ponding is triggered by degassing-induced crystallization during magma ascent, and that the pressure sensor can also be regarded as a degassing sensor, with more hydrous melts beginning to degas at greater depths. Magma ponding depth variations fully explain the observed westward increase of average surface heat flux along the TMVB, in line with global data that suggest heat flux variations between arcs are principally controlled by magma ponding depths (Zellimer et al., 2015).

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**GEOCHEMISTRY AND GROUNDMASS CRISTALLINITY CONTROLS ON THE PHYSICAL PROPERTIES AND STABILITY OF THE MOUNT TARANAKI LAVA DOME**

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The study of lava domes and their properties is inherently important as their collapses pose a significant hazard to infrastructure, human lives and the environment. Mount Taranaki on the west coast of the North Island of New Zealand provides an excellent case study as a large part of the summit lava dome is currently exposed due to a partial collapse. Here we describe a detailed investigation into the groundmass crystallinity and chemical composition of the Taranaki lava dome, taken both from the current summit dome as well as material found in block-and-ash flows in the surrounding riverbeds. We further relate these properties to the compressive and tensile strength of the respective material in rock deformation experiments on drill cores, simulating low temperature and low confining pressure conditions.

Our results suggest that the crystallisation of the groundmass significantly impacts both porosity and skeletal density of the rock material depending on the resultant groundmass crystal content. Higher crystal content results in less pores, likely reflecting a slow cooled dome deeper down the conduit due to higher pressure conditions. On the other hand, a less crystallised rock is more porous and cooled faster under lower pressures, closer to or at the surface. Furthermore, as the crystallinity increases, the density of the rock also increases (up to 10%) which must go along with a correlating reduction in volume, potentially reducing pore space further. Porosity is determined to be the main control of the peak rock strength and mode of failure. Thus groundmass crystallization could impact the strength and stability of the lava dome depending on the depth at which the dome crystallized. These findings may have important implications regarding the hazard associated with collapsing domes as the stability of the dome might shift significantly as the groundmass crystallises upon degassing and cooling.

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**BRITTLE FAULT ZONE DATING**

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Neotectonic brittle faults are associated with near-surface deformation. Displacement on the fault planes can result in fault gouge composed of rock fragments and authigenic illite. Recent studies [1 to 6] have demonstrated the potential to determine the absolute timing of brittle fault history using isotopic dating techniques of clay minerals. The understanding of the timing of clay-rich fault gouge formation is important for: (1) hydrocarbon exploration as faults may act as either a conduit or a seal for fluids and/or hydrocarbons; (2) civil engineering in the evaluation of earthquake hazards and (3) ascertaining the suitability for waste storage.

K-Ar data of authigenic illite from gouge developed in different geological settings comprising magmatic, metamorphic and sedimentary rocks in Europe (Alps), Japan (Nojima fault), Korea (Deokpuri thrust), Australia (Sydney basin) and New Zealand (Alpine fault) will be presented. The Ar dating results are consistent with well-defined field constraints and bracketed by AFTA and ZFTA ages from adjacent localities. The data provide absolute time constraints on the youngest, retrograde, neotectonic movements.