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Geoscience Society of New Zealand 2011 Conference

FIELD TRIP GUIDE


St Arnaud, Lake Rotoiti, Alpine Fault


Mt Owen marble massif


Marlborough Sounds


Awaroa Bay, Abel Tasman National Park

NELSON 27 November - 1 December 2011

Geoscience Society of New Zealand


Abel Tasman National Park

Geosciences 2011

Annual Conference of the Geoscience Society of New Zealand
Nelson, New Zealand

Field Trip Guide

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Annual Conference of the Geoscience Society of New Zealand,
Nelson, New Zealand

Field Trip 6
Tuesday 29 November 2011

The elusive Permian-Triassic boundary

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HEALTH AND SAFETY ISSUES

Please Read

We will be negotiating poorly-formed tracks on steep shaded bush-covered slopes and forested slopes adjacent to the Wairoa River. Conditions underfoot may be slippery and river conditions can be potentially dangerous. Caution should be exercised when examining rocks at the base of natural or man-made cliffs. Anticipate getting wet feet. Boots are essential.

Participants must heed and observe the warnings and time limitations imposed at certain stops by the trip leaders. We will be stopping on and crossing both public and private roads that are frequented by logging trucks and farm vehicles.

We will be negotiating farm land with fences, stock (sheep) and stream crossings. At times we will be walking on farm and sheep tracks across valley floors but also across steep hilly terrain. There is a potential to dislodge rock materials. At all times be mindful of this hazard and ensure that the ground below you is clear of other people.

Participants should carry any personal medications, including those for allergic reactions (e.g. insect stings, pollen allergies). Be prepared to encounter sand-flies, wasps and sheep.

Fossil and rock collection involves use of hammers and chisels. It is advisable to use safety goggles when using geological hardware. Use your own discretion.

The weather in November can be variable, although we hope for dry sunny conditions it can be wet and/or windy. Participants need to be prepared for cold, warm, wet, dry and/or windy conditions. Temperatures should be in the range 15–25°C. A sunhat, sun-cream, sunglasses, waterproof and windproof raincoat, and warm clothing (layers) are essential.

An average level of fitness and mobility is required for this trip. There is not much walking involved in terms of distance but we will be negotiating steep slopes and slippery surfaces. You should be fit enough to negotiate a wire fence in less than 20 seconds and fall gracefully when caught out by a juicy sheep dropping. You need to be sure-footed.

We will encounter several fine swimming holes on the Wairoa River so be prepared for a swim at our lunch spot should you feel inclined. Remember the sand-flies though. Trout and eel tickling will be encouraged.

Needless to say, we cannot guarantee that conditions will be exactly as we expect them. Conditions change frequently sometimes on a daily if not hourly basis.

It is a legal requirement that people working within a road reserve have the permission of the road owner (in our case the local district council and forestry operators) and implement a pre-approved Traffic Management Plan (TMP). We have organised the required TMP for fieldtrip. When visiting roadside stops, a traffic controller will have overall responsibility for the safety of the site and of the participants.


Moutere Bluff
Ruby Bay
Harakeke
Rabbit Island
Mapua
Bronte
Upper Moutere
Mahana
Port Nelson
Haulashore I
Atawhai
Boulder Bank
NELSON
Tahunanui
Nelson South
Bells Island
Bests Island
Waimea Inlet
Enner Glynn
Stoke
Redwood Valley
Eves Valley
Waimea R
Richmond
Hope
Brightwater
Spring Grove
Wakefield
Wai-iti
Foxhill
Roding River
Mt Malita
Mt Stewart
Mt Starveall
Mt Rintoul
Old Man
Ben Nevis
Mt Glennie
Mt Harvey
GORDON RANGE
Lake Chalice
Hut
1
2
3
4
5
6
7
8

Introduction

This aim of this trip is to visit a number of significant Permian and Triassic localities within Maitai Group (Dun Mountain – Maitai Terrane) and Richmond Group (Murihiku Supergroup; Murihiku Terrane) sequences exposed in the Wairoa River valley, Barnicoat and Gordon ranges located proximal to and southwest of Nelson city.

In particular, it is an opportunity to visit a Permian-Triassic boundary section within Maitai Group described by Krull *et al*. (2000). On the way, we will visit the richest Early Triassic (Nelsonian Stage; Campbell & Owen 2003) fossil locality known from New Zealand, documented by Owen (1991, 1995).

Key formations encountered within Maitai Group will include: Tramway Formation, Little Ben Sandstone, Greville Formation, Stephens Subgroup.

We may also observe mafic and ultramafic igneous lithologies in Wairoa River gravels (boulders, cobbles) that are derived from the Dun Mountain Ophiolite which underlies the Maitai Group (in primary depositional contact). Other sedimentary and metamorphic lithologies will be derived from Pelorus Group (Caples Terrane) rocks exposed within the Richmond Range and the catchment of the upper Wairoa River.

We will also visit fossiliferous rocks of Middle and Late Triassic age within Richmond Group in the Eighty Eight Valley and Cat Hill area to the SW of Wakefield. Key formations encountered will include Wells, Garden and Pitfure formations.

Murihiku Supergroup rocks are enjoying a resurgence of interest at present, partly because of attention from the hydrocarbon exploration industry. The reason for this is partly that Jurassic-Cretaceous plant macerals have been detected in some oils from the Taranaki Basin, but also because Murihiku rocks have been interpreted in seismic surveys, especially in some of the deeper off-shore basins. The implication is that Jurassic Murihiku Supergroup rocks may be contributing as source rocks.

Whereas Murihiku Terrane is generally regarded as the most coherent New Zealand ‘basement entity’ (in terms of stratigraphy and structure), in the Nelson region, the Richmond Group is particularly ‘chopped up’ and well-exposed by virtue of deformation (folding and faulting) and topographic relief (erosion). Examination of Murihiku Supergroup rocks in Nelson therefore offers insight that is not so easy to acquire in Southland and Kawhia regions.

We will be following 1:50,000 geological map sheets: Red Hills (N28 BD; Johnston 1982a), Richmond (N27; Johnston 1982b), and Motupiko (N28 AC; Johnston 1983). For the immediate Nelson city area, we will be following the 1:25,000 geological map (Johnston 1979). Then of course there is the 1:250,000 geological map (Rattenbury *et al*. 1998) for the big picture.

We also plan to visit the Rutherford Memorial near Brightwater, and equally historic Magazine Point with good exposures of Early Oligocene fossiliferous marine rocks (Magazine Point Formation) close to Nelson city.

Stop 1 Panorama Heights: view over Waimea Plains

From the Rutherford Hotel, we will proceed along Waimea Road past Bishopdale to Enner Glynn, across Jenkins Creek, then up Ridgeway Road and on to Panorama Drive, a distance of about 6 km. This is a good vantage point (about 200 m a.s.l.) from which we can see over much of the Nelson landscape including Stoke, Waimea Inlet, Tasman Bay, the Waimea Plains, the Barnicoat Range and the higher Richmond Range that forms the backdrop to the Nelson region.

To the west across the extensive lowland of the Moutere Depression, are the mountain ranges of NW Nelson, dominated in the near distance by plutonic rocks of the Median Batholith and in particular the Early Cretaceous Separation Point Granite (121-109 Ma). In behind are higher ranges dominated by Early Paleozoic sedimentary and volcanic rocks of the Takaka Terrane (Western Province) and Late Devonian intrusives (Karamea Suite; 358-358 Ma).

The Moutere Depression is a broad half-graben that formed in early Pleistocene time along the Waimea-Flaxbourne Fault System prior to uplift of the adjacent eastern and western ranges of the Nelson region. The Moutere Gravel infilling the Moutere Depression is almost entirely comprised of greywacke and semi-schist lithologies derived from Torlesse Supergroup.

Stop 1 is located on the ridge crest between Jenkins Creek (to the N) and Poormans Valley Stream (to the S). Jenkins Farm was visited by 29 year old *Novara* geologist Dr Ferdinand Hochstetter (he was knighted by the King of Württemburg on 19 Feb 1860 to become Ferdinand von Hochstetter) and his party on Saturday 6 August 1859, specifically to examine the closest coal mine to Nelson.

Geologically, this stop is located on the W limb of the Marsden Syncline. Port Hill Gravel (named by James Park in 1910), within the Tadmor Group (of Johnston 1971), is up to 500 m thick and forms the core of this syncline. Poorly dated as Middle Miocene to Early Pliocene (Waiauan to Opoitian; 12.7 – 3.6 Ma) in age range on the basis of fossil pollen, it is clay-bound gravel derived from source rocks in the immediate Nelson region.

Major faults can be seen including the Flaxmore, Waimea, Eighty Eight and Grampian faults.

The Flaxmore Fault runs NE-SW and lies to the W of the Waimea Fault and proximal to Nelson City, separates Cenozoic rocks from basement Brook Street Volcanics.

The Waimea Fault runs NE-SW and is regarded as active (Rattenbury *et al*. 1998). It separates Cenozoic sedimentary rocks from older Permian-Triassic basement rocks (Richmond Group, Brook Street Volcanics, Maitai Group).

The Eighty Eight Fault runs sub-parallel to the E of the Waimea Fault and bounds the E margin of Richmond Group rocks against Maitai Group rocks. The Richmond Group rocks are neatly folded (best exemplified by the Heslington Syncline; Campbell 1974) and constrained between the Waimea and Eighty Eight Faults.

The Grampian Fault is oriented NW-SE and is up-thrown to the N, exposing Brook Street Volcanics in the lofty hill country immediately behind Nelson City.

We will descend the hill from Panorama Drive and head towards Brightwater via Stoke, Richmond and Hope, crossing the Waimea River just before Brightwater. Turn inland at Brightwater and head up River Terrace Road cossing the Waimea Fault and then the Eighty Eight Fault (the entire Richmond Group is traversed within a distance of less than 1.5 km), and then along the Wairoa Gorge Road, heading up the Wairoa River on the true LHS. The distance from Stop 1 to Brightwater is about 16 km; the distance from Brightwater to Stop 2 is c.10 km.

MAITAI GROUP (named by Hochstetter 1864)

The Maitai Group comprises a folded (Roding Syncline) sequence of weakly metamorphosed deep marine sedimentary rocks that are up to 6,000 metres thick, of Late Permian to Middle Triassic age. The basal units of this sequence are the Upukerora Breccia (<50 m thick) and Wooded Peak Limestone (<1,000 m) which lie in primary depositional contact upon igneous rocks of the Dun Mountain Ophiolite (hence the terrane has a double-barrelled name and is referred to as the Dun Mountain – Maitai Terrane). We will not see in situ Upukerora Breccia or Wooded Peak Limestone on this excursion, but we will see the overlying formations (older to younger): Tramway Formation (<1,000 m), Little Ben Sandstone (<600m), Greville Formation (>1,200 m), perhaps Waiua Formation (500-700 m), and Stephens Subgroup (c.2,000 m).

RICHMOND GROUP (named by Hochstetter, 1864)
The Richmond Group comprises a folded sequence (Heslington Syncline) of weakly metamorphosed, indurated shallow marine volcanogenic sedimentary rocks (conglomerate, sandstone, siltstone, tuffs and shellbeds) that are at least 1,500 metres thick. It can be traced in the Nelson region over a length of about 50 km and is nowhere wider than 2 km, and outcrops between the Waimea and Eighty Eight Faults. The age range of Richmond Group is Etalian to Otapirian (Anisian – Rhaetian; Middle to Late Triassic)

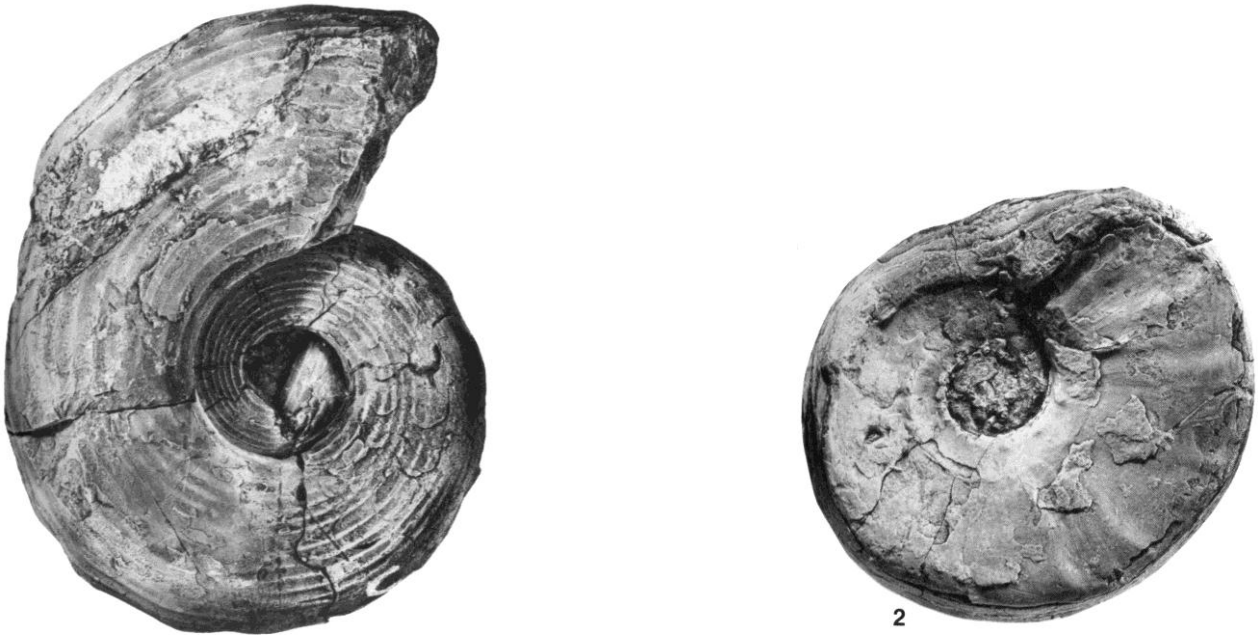
A number of formations have been described over the years by Campbell (1974) and Johnston (1981, 1982a,b, 1983) but on this excursion only the following will be encountered: Wells Formation (>1,200; Kaihikuan; Ladinian) Garden Formation (>250 m; Oretian; early Norian) and Pitfure Formation (Oretian-Otapirian; Norian-Rhaetian) and its constituent members: Problematica Shellbed (c.100 m; Otamitan; early Norian), Max Sandstone (c.50 m; Otamitan; early Norian), Heslington Conglomerate (c.70 m; Otamitan; early Norian), Richmondiana Shellbed (150 m; Warepan; middle to late Norian) and Cat Hill (>150 m; Warepan-Otapirian; late Norian - Rhaetian).

Stop 2 Wairoa River: Maitai Group; Early Triassic olistostrome

Park bus on side road off Wairoa Gorge Road. Cut through private property and descend track to Wairoa River. At this stop we will examine olistoliths within the upper Stephens Subgroup (Maitai Group) c.1,000 metres above the Waiua Formation. The age of olistostrome emplacement is considered to be no older than early Olenekian (= Nelsonian Stage; Campbell & Owen 2003) and is probably late Olenekian (249.3 to 247.2 Ma). NB these absolute age values used herein are refinements of the timescale that post-date those used in Cooper (2004).

These rocks were mapped by Stuart Owen as part of his PhD research project (Otago University; Owen 1995). He discovered a number of fossil-bearing limestone blocks and with much careful preparation, established three different ammonoid faunas of Early Triassic age (Owen 1990, 1991, 1992) involving thirteen species of ammonoid. The material is so well preserved that he was able to describe eight new species (as yet unpublished). One single block has produced 26 ammonoid specimens.

Examples of two Early Triassic ammonoid genera from Canada that are typical of ammonoid morphologies preserved at Stop 2: *Euflemingites* (left), and *Arctoceras (right*). From Tozer (1994: p.399 & p.401).



The three faunas identified by Owen include:

Fauna 1: *Durvilleoceras woodmani* and *Episageceras* n.sp.
Age correlation: Nelsonian; Induan; 252.5 - 251.3 Ma.

Fauna 2: *Paranorites* n.sp., *Pseudoflemingites* n.sp., *Flemingites* n.sp. and *Clypeoceras* aff. *Besairiei.*
Age correlation: Nelsonian; late Induan to early Olenekian; 251.9 - 249.3 Ma.

Fauna 3: *Arctoceras* n.sp., *Anaxenapsis* n.sp., *Pseudoflemingites* n.sp., *Clypeoceras* sp.A*, Clypeoceras* sp.B*, Procarnites* n.sp. and cf.*Protychites* sp.
Age correlation: Nelsonian; early Olenekian; 251.3 - 249.3 Ma.

Other fossils recorded by Owen (1995) in association with these ammonoid faunas include foraminifera, fragmentary shelly fossils of other molluscs (bivalve, gastropod, nautiloid), echinoid and crinoid elements, as well as conodonts and fossil teeth.

From this locality, we will proceed up the Wairoa River as far as the junction of the two major tributaries: the Wairoa River Left Branch and Wairoa River Right Branch, and go up Old Mill Road and travel up the Wairoa River Left Branch as far as Andrews Road. The distance from Stop 2 to Stop 3 is about 8 km.

We will park the bus and descend to the Wairoa River, crossing the ford by foot, then head up the road for a distance of about 300 metres. While in the river, we will observe in situ Tramway Formation and also boulders of various lithologies that relate to the hinterland geology.

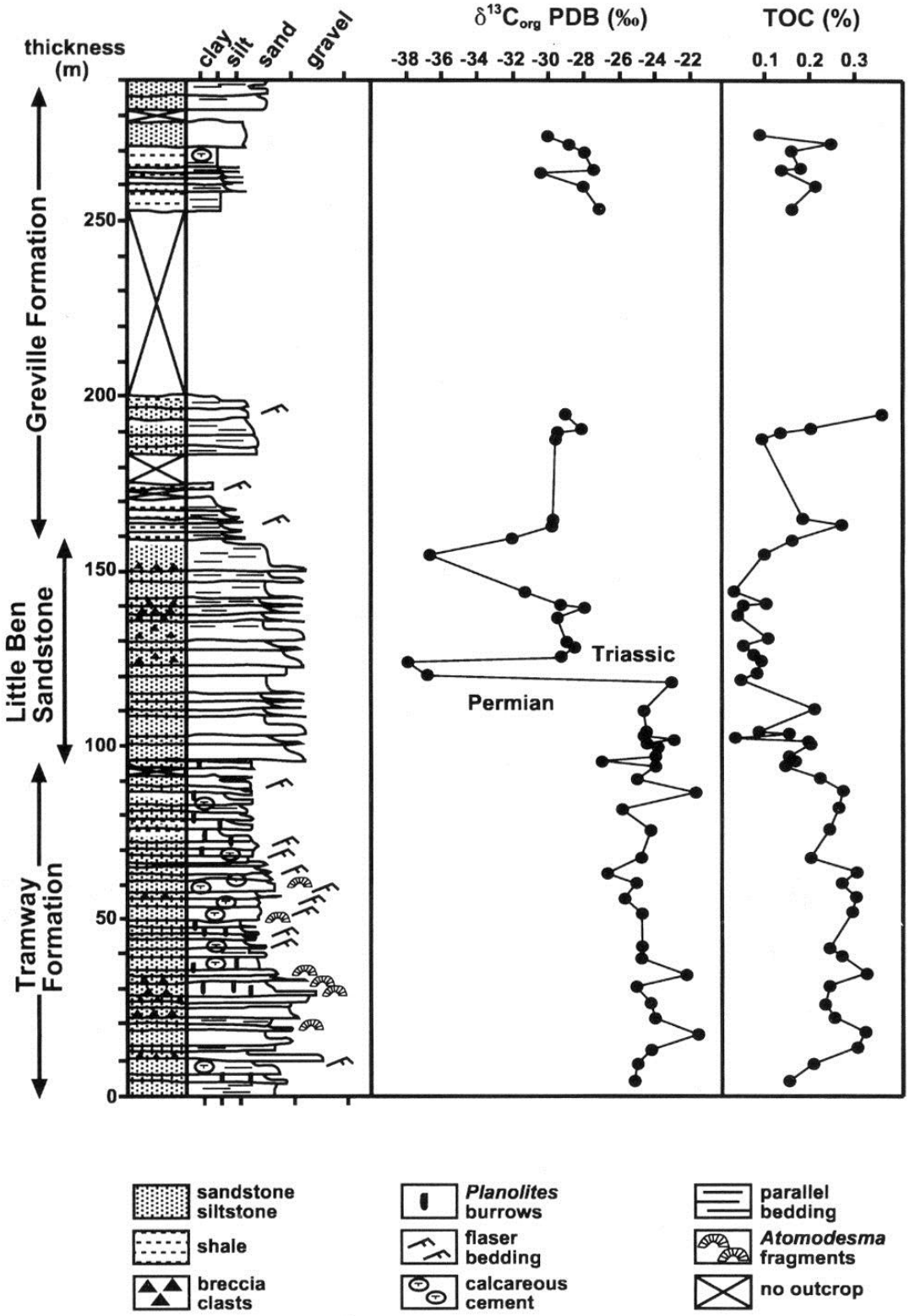
This is a forestry road that heads up the SW leading ridge of Little Ben (884 m), a prominent mountain between the Wairoa River and Lee River to the NE.

Stop 3 Wairoa River (Left Branch) Andrews Road: Maitai Group; P-Tr boundary sequence

As we proceed up the road, we are walking up-section through well-bedded grey calcareous siltstones of the Tramway Formation; fossils are conspicuous in places and include trace fossils and bivalve molluscs. These are atomodesmatinids, mainly fragmental, with distinctive prismatic calcite shell. At the top of the formation there is an obvious lithological change as we pass into the Little Ben Sandstone which is very distinctive due to its coarser grain-size and green colour. Apart from fossil plant fragments it is unfossiliferous.

This change in lithology is regarded as a proxy for the Permian-Triassic boundary. This section in the Wairoa River valley was sampled and studied by Krull *et al*. (2000) for stable isotopes of carbon. The results support the idea that the Permian-Triassic boundary is proximal to the base of the Little Ben Sandstone.

LITTLE BEN SANDSTONE (named by Waterhouse, 1959)
Landis (1980) states that: 'Little Ben Sandstone comprises those rocks that overlie the thin-bedded to laminated, fossiliferous grey sediments of Tramway Formation and that underlie the thin-bedded to laminated, unfossilifeous grey siltstones and sandstones of Greville Formation. The formation consists of unfossiliferous, massive to thin-bedded, green volcanogenic sandstones with lesser amounts of laminated siltstones and mudstone and local conglomerate lenses.' This formation is interpreted as a massive event deposit from a submarine slide within to a submarine fan system marginal to a volcanic arc, and is markedly different in character from the underlying quartzofeldspathic Tramway Formation and overlying Greville Formation.



Stratigraphic section from Krull *et al*. (2000: Fig. 4; p. 25) of lower Maitai Group showing $\delta^{13}C_{org}$ values and TOC (total organic carbon) contents for the Tramway, Little Ben Sandstone and Greville Formations. A distinct excursion toward ^{13}C-depleted and highly fluctuating $\delta^{13}C_{org}$ values occurs at or above the contact between the Tramway Formation and Little Ben Sandstone, which marks the Permian-Triassic boundary. Isotopic values return toward less ^{13}C-depleted values in the Greville Formation.

Stop 4 Lunch stop: junction of Wairoa River Left Branch and Right Branch: Maitai Group

This stop is within Greville Formation (Nelsonian; Induan; Early Triassic). Fossil ammonoids of Induan age (Nelsonian; Early Triassic) have been recorded from Greville Formation (*Durvilleoceras woodmani*). Though rare, and none are recorded from this particular locality, they are usually found within calcareous concretions.

Stop 5 Highfield: Richmond Group; Middle – Late Triassic

Drive down Wairoa River and turn L at Pig Valley Road, over a saddle and down Church Valley Road, and drive out to Wakefield (about 14 km from Stop 4) and onto Hwy 6 for a kilometre. Turn L onto Eighty Eight Valley Road and drive for about 8 km to 'Highfield'. Park bus and walk up Eighty Eight Stream and its tributaries. We will be walking…not more than 5 kilometres. Many fossil localities and collections have been recorded from the Eighty Eight Valley – Cat Hill area (Campbell & Johnston 1984).

We will traverse Pitfure Formation (Oretian-Otamitan) and cross Highfield Fault into Wells Formation (Kaihikuan).

Within Pitfure Formation, Otamitan fossil bivalves (clams) are conspicuous in the Problematica Shellbed Member, especially *Manticula problematica*. Other fossils present include the bivalves *Mysidioptera riceae, Hokonuia trechmanni, Maoritrigonia, Triaphorus, Halobia* and paleotaxodonts *(Phaenodesmia, Nuculana);* brachiopods *Psioidiella otamitensis* (spiriferinid), *Oxycolpella wreyi* (athyrid; previously referred to the genus *Athyris*) and other brachiopods (terebratulids, reziids, rhynchonellids; see MacFarlan 1992); gastropods such as *Pleurotomaria hectori* (see Begg & Grant-Mackie 2003), tabulate corals (previously thought to be bryozoans; *Eoheteropora maorica;* see Schäfer & Grant-Mackie 1998), and echinoid fragments.

For the most 'recent' taxonomic consideration of *Manticula see* Waterhouse (1960) in which he introduced the name *Manticula,* and also described *Mysidioptera riceae.*

Within Wells Formation, Kaihikuan fossil brachiopods are conspicuous: *Oxycolpella kaihikuana, Alipunctifera kaihikuana, Mentzeliopsis spinosa, Sakawairhynchia zealandica.* The gastropod *Patella nelsonensis* may be present too.

From here, we will either walk up to Cat Hill or travel there by bus. If people are not up to walking, they will have the option of being taken by vehicle.

Stop 6 Cat Hill: Richmond Group; Late Triassic

Within some 23 km of Richmond Group exposure, there are only six key areas in the Heslington Syncline where *Monotis* beds are exposed (Grant-Mackie 1984). Cat Hill is one and is significant because it also has younger fossil-bearing Otapirian beds.

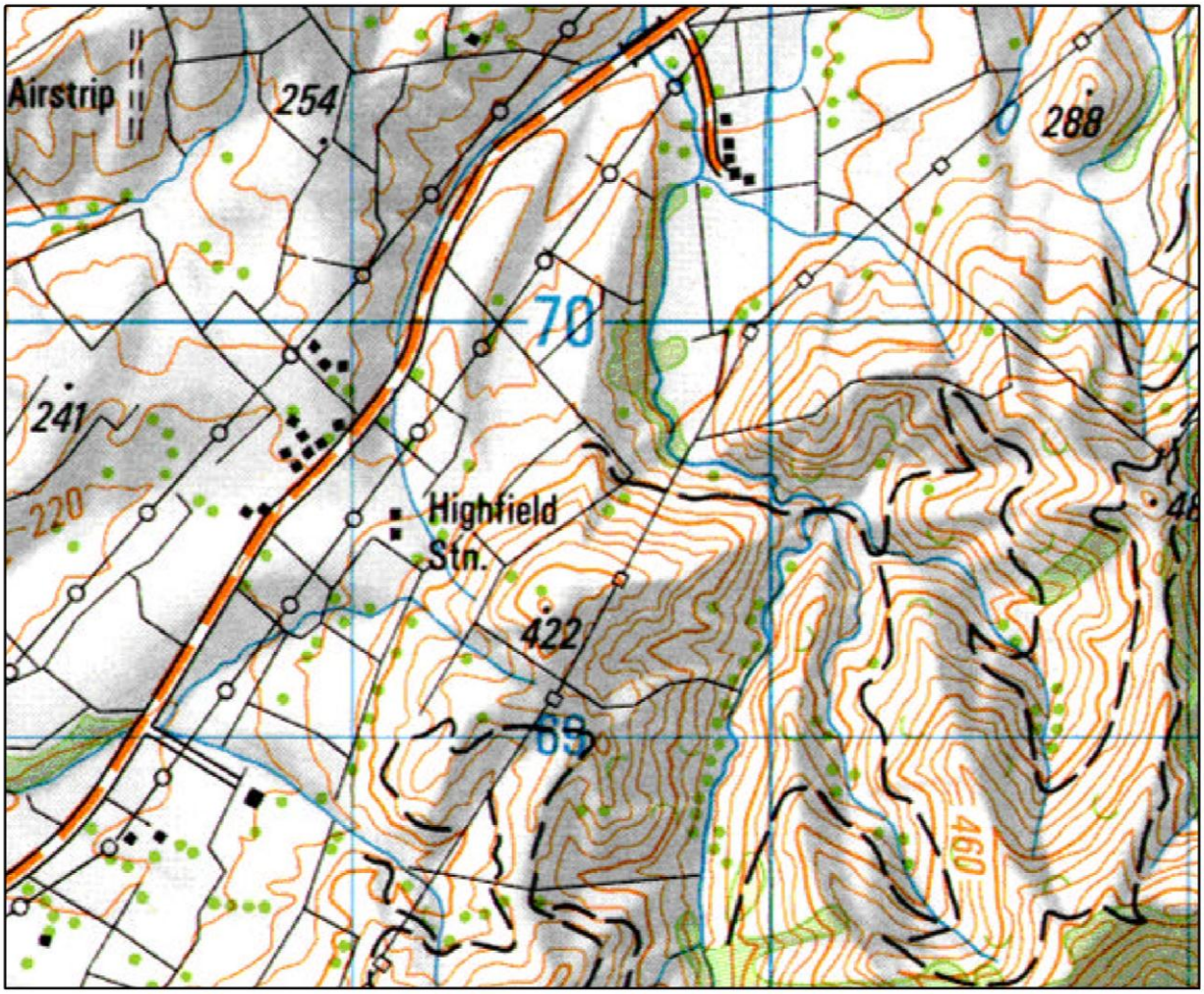
The Richmondiana Shellbed sequence exposed at Cat Hill is less than 80 m thick and represents only the lower *Monotis* biostratigraphic zones recorded by Grant-Mackie (1984). There must therefore be a local unconformity between Richmondiana Shellbed and Cat Hill members. In New Zealand, *Monotis* beds do not exceed 150 m in thickness, whereas in New Caledonia they are up to 500 m thick.

This is an opportunity to observe and collect *Monotis* shellbeds (Warepan; middle to late Norian) within the Richmondiana Shellbed Member of the Pitfure Formation.

The following *Monotis* species/subspecies have been recorded from Cat Hill: five species/subspecies of *Monotis (Eomonotis)* namely *kiritehereensis, rauparaha mokaui, rauparaha aries, murihikuensis;* two species/subspecies of *Monotis (Entomonotis)* namely *richmondiana acutecostata* and *subcircularis discordans*; and one species of *Monotis (Maorimonotis)* namely *maniapotoi.* (See Grant-Mackie, 1984 fig.4 for a stratigraphic column). There are other molluscan fossils preserved within the *Monotis* beds, along with brachiopods, plant and trace fossils.

Still higher in the sequence is the Cat Hill Member with distinctive brachiopod (*Clavigera bisulcata, Rastelligera diomedea, Mentzelia kawhiana, Sakawairhynchia, Fissirhynchia, Zeilleria, Zugmayerella, Pseudocytina*) and molluscan (*'Lima', Kalentera marwicki, Maoritrigonia trechmanni, Minetrigonia otapiriensis, Torasatarte bensoni, 'Ochotomya'*) faunas characteristic of the Otapirian Stage (latest Norian to Rhaetian). There are other brachiopod and molluscan fossils including gastropods and ammonoids, as well as plant and trace fossils. These are the youngest rocks preserved within Richmond Group.

From Cat Hill we will drive back to Wakefield (about 12 km) and on to Brightwater (about 5 km).



Detail from N28 1:50,000 map sheet showing the 'Highfield' area with Eighty Eight Stream valley draining to the NW and Ram Creek draining to the SW. Cat Hill is the high point (422 m).

Stop 7 Brightwater: Rutherford Memorial

Lord Rutherford Memorial Reserve is located on Lord Rutherford Road at the junction of the Brightwater Deviation (State Highway 6). The memorial commemorates the famous physicist, Lord Ernest Rutherford, who was born nearby. He is probably Nelson's most famous 'son'.

It is interesting to note that he went to study at Cambridge with an 1851 Scholarship, and was the first research (post-graduate) student at Cambridge University with an under-graduate degree from another university (University of Canterbury). He commenced in September 1895.

The concept of this memorial was conceived and developed by Professor John Campbell (Department of Physics, University of Canterbury; see Campbell 1999).

Rutherford is an immensely significant figure in the history and philosophy of earth science and in particular geochronology. His research on radioactivity led to the realisation that it should be possible to date minerals and hence rocks, that contain radioactive elements such as uranium (Soddy and Rutherford 1902). Armed with numbers (absolute ages), earth science gained immensely in respectability and stature during the 20th century. This has led to our modern understanding of geological time and its sophisticated calibration, hence the New Zealand Geological Timescale (Cooper 2004).

From Brightwater, time and weather permitting, we shall proceed back to Nelson and visit one last locality on the shore platform at Magazine Point. The tide is favourable (low tide at 6:20 pm). The distance from Stop 7 to Stop 8 is about 18 km.

Stop 8 Magazine Point, Nelson: Jenkins Group; Oligocene

Magazine Point is famous for its rocky shore platform located between Tahunanui Beach and Port Nelson. The sequence exposed here is the Magazine Point Formation (named by Johnston in 1979; within Jenkins Group named by McKay in 1878) of Early Oligocene age (Whaingaroan; 34.3-27.3 Ma) and is 300 m thick. This formation underlies the Port Hills Gravel and is probably about 1,500 m in total thickness. It has no base. In terms of structure, it is on the west limb of the Port Hills Syncline between two NW-SE trending faults, the Grampian Fault to the W and the Stafford Fault to the E (Johnston 1979). The strata are dipping steeply (70°) to the SE and comprised of well-bedded (10-80 cm) often graded beds of muddy sandstone, sandstone and conglomerate. This unit is of particular interest for various reasons, not least because it is fossiliferous, but also because of its age and its interpretation in terms of depositional environment.

This locality is famous for historical reasons. It is considered to be 'The Cliffs' locality from which notable geologists such as Walter Mantell (1850), Ferdinand von Hochstetter (Zittel, 1864) and Paul Vella (1962) collected. This locality was visited during the previous GSNZ Nelson conference held in 1979. Doug Lewis (Geology Department, Canterbury University) led a trip that is remembered for its heated debate about the interpretation of depositional environment, and all because he was convinced (wrongly) that he had in situ fossil tree stumps. Magazine Point is also one of 27 fossil localities that are described in 'The Kiwi Fossil Hunter's Handbook' by Crampton & Terezow (2010). It is one of very few fossil localities in New Zealand that is easily accessible to the public within a major urban area.

Fossils at this locality include wood (often bored), abundant molluscs (bivalves, gastropods, scaphopods, chitons, nautiloids), barnacles, solitary corals (*Truncatoflabellum*), shark teeth, echinoids, bryozoans, calcareous algae, foraminifera and trace fossils (*Ophiomorpha*). The common molluscs include cockles such as *Cyclocardia,* and oysters but also the following

genera: *Nucula, Nuculana, Glycymerita, Cucullaea (Latiarca), Spondylus, Megacardita, Dosinia, Haliotis, Polinices, Magnatica (Spelaenacca), Tanea, Sigapatella, Crepidula, Echinophoria, Falsicolus, Austrofusus (Austrofusus), Ficus, Galeodea, Amalda (Baryspira), Austrotoma* and *Zeacuminia*. (see Beu & Maxwell 1990, p.129, and Crampton & Terezow 2010.

This is the type locality for six species of mollusc that were collected by Hochstetter in August 1859, and subsequently described by Zittel in 1864: *Neiilo funiculata, Limopsis zitteli, Austrofusus (Neocola) zitteli, Zelandiella robinsoni, Austrotoma gracilicostata, Dentalium mantelli.*

Fossils are largely of shallow marine species. Many are deformed and/or broken and there is abundant fragmental shell debris and shell hash. The sediments are interpreted to be flood-related redeposited submarine debris flows that have brought shallow water assemblages down-slope into much deeper bathyal water. This interpretation is supported by the occurrence of microfossil assemblages (foraminifera) that are restricted to bathyal environments.

The following is a quotation from Hochstetter's diary entry for the morning of 6 August 1859 (translated by Sascha Nolden and Tom Darragh): 'At Fossil Point, as we called the corner, we found a reef submerged at high tide quite full of molluscs, a veritable nest of the most diverse species: *Serpula, Ostrea, Trochus, Natica*, sharks' teeth, *Fusus*, *Pyrula* [*Ficus*]*, Murex, Phasianella*, bryozoa, small corals, oysters'.

Hochstetter (in Hochstetter & Fleming 1959, pp. 150-151) published the following account of the same locality: 'The "Cliffs," near Nelson. On the Port Hills … at right angles from the road onto the beach, one arrives at The "Cliffs", opposite the harbour entrance. … At "Fossil Point" there are odd rocks submerged at high tide consisting of a glauconitic conglomerate, packed full of fossils; the soft limy shells are, however, exceedingly brittle and only with much difficulty did I succeed in collecting a great number of shells well enough preserved to be determinable. Dr Zittel has described the following genera and species: Anthozoa: *Oculina, Trochosmilia*; Bryozoa: *Selenaria, Celleporaria*; Acephala: *Cardium, Solenella australis* Quoy, *Pectunculus laticostata* Quoy, *Limopsis insolita* Sowerby, *Ostrea*; Gastropoda: *Dentalium mantelli* Zitt., *Bulla, Capulus, Natica denisoni* Zitt., *Cerithium, Voluta gracilicostata* Zitt., *Murex, Buccinum robinsoni* Zitt., *Buccinum* sp. ind. Zitt., shark's teeth'.

Johnston & Nolden (2011, pp. 144-148) give an account of Hochstetter's visit to this locality and the nearby area, with a photograph of bedding at Magazine Point. Johnston (1979, p. 19) noted that the largest fossiliferous lens, 20 m long and 1.5 m thick, towards the south end of Magazine Point, is probably where Hochstetter's fossils were collected, although other lenses possibly were buried during the subsequent building of Rocks Road around the point, and sparse, well preserved macrofossils occur throughout the formation (M.R. Johnston Nelson pers. comm. 7 Jan. 2011).

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