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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Geosciences 2011

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

Field Trip 4
Tuesday 29 November 2011

Roding River ("Nelson Mineral Belt") copper mineralisation and Dun Mountain-Maitai terrane stratigraphy

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HEALTH AND SAFETY ISSUES

COMPULSORY READING

An average level of fitness and mobility is required for this trip as, after leaving the vehicles there is up to 12 km of walking, mostly on well-formed tracks or roads. There are 10 river or stream crossings as well as clambering for a short distance along stream beds. Lightweight boots or sturdy hiking shoes are required. Do not try to boulder hop as the exposed and water covered boulders are slippery and at the very least you will end up soaked and there is potential for significant damage to yourself. Crossings have good firm beds but are usually in deeper water (but unless there has been significant rain not over knee deep).

There are certain inherent hazards in participating in this fieldtrip, including river crossings and working close to large outcrops, which can be unstable and portions may collapse or shed debris without warning. Caution should therefore be exercised when examining rocks at the base of natural or man-made outcrops. Participants must heed and observe the warnings and time limitations imposed by the trip leaders. Times given are approximate only but are regarded as the latest if the trip is to remain on schedule.

There are also mining relicts, including old smelter equipment and other historic sites that could be hazardous. On no account are old mine workings, which are extremely dangerous, to be entered. Historical features (protected under the Historic Places Act) should be left undisturbed and as this is a public area please be discrete about hammering rocks. Also some rocks are extremely hard and vigorous hammering can result in lethal projectiles. Please ensure that no one is nearby when collecting samples from such rocks and safety glasses are to be worn.

The weather can be variable and participants need to be prepared for cold, warm, wet, and/or dry conditions. The expectation is that temperatures will be in the range 13–20°C. A sunhat, sun cream, sunglasses, waterproof and windproof raincoat, and warm clothing (layers) are essential. As river and stream crossings are involved a change of socks may be appreciated. Shorts, rather than long trousers such as jeans, are preferable.

There is an alternative route, via the Champion Mine, on the return to the vehicles but this will be decided at the time depending on weather and level of interest. There will be trip leaders for both options. However, on no account wander off on your own but discuss with the trip leaders if personal difficulties arise. As we will be in waterworks reserve Nelsonians do not want your remains polluting their water supply (there is no cell phone coverage). In this regard please observe bush code when using the facilities, which are convenient patches of bush – there is a single toilet at the United Creek smelter site, which we will pass by mid-morning and will return to the site for our lunch stop. Any discharges should be to land and never to water.

Participants should have a day pack to carry your supplied lunch, plus extra nibbles and personal items, such as spare clothing and medications, including those for allergic reactions (e.g. insect stings, pollen, food allergies and sandflies are active, particularly if the weather is overcast, and have an overriding thirst for new blood). A waterproof bag for cameras and other similar items is recommended. The water is safe to drink.

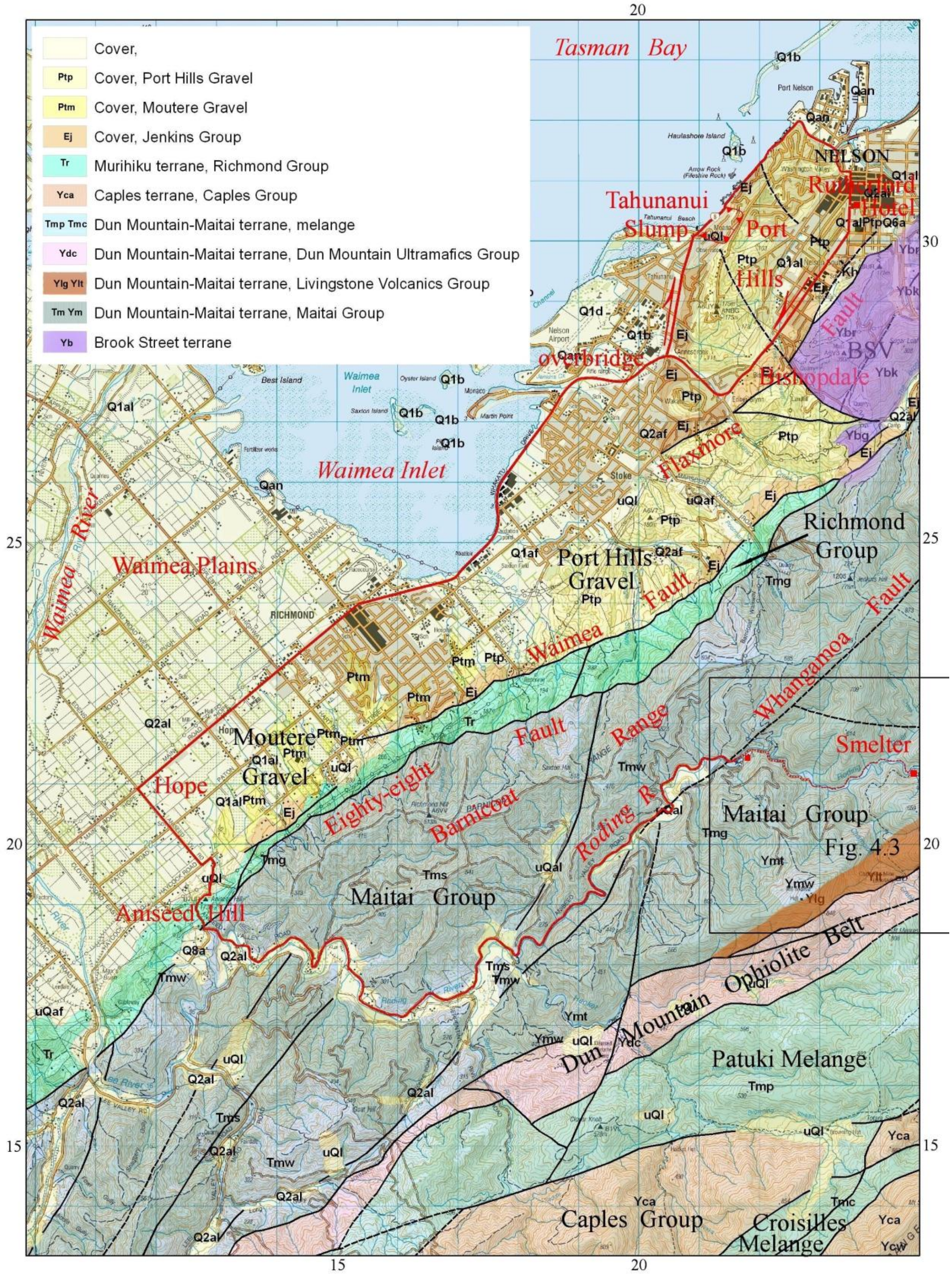

Figure 4.1 Route map from Nelson to upper Roding River (base geological map modified from Rattenbury et al. 1998.) See Fig. 4.2 for expanded geological legend and Fig 4.3 for Field Trip stops. The 1000 m grid is in terms of NZTM2000.

Introduction

This trip will visit part of one of the best sections through the Maitai Group and Dun Mountain Ophiolite Belt, which is well exposed in the Roding River to the east of the Waimea Plains southwest of Nelson city. The river rises on Dun Mountain in the eastern ranges and flows southwest to join the Lee and Wairoa rivers, which all contribute to the Waimea River. The rocks to be examined consist of the middle and lower parts of the Maitai Group, named from the Maitai River that flows through Nelson City, and the unconformably underlying upper part of the Dun Mountain Ophiolite Belt, which takes its name from Dun Mountain at the head of the Maitai and Roding rivers (see companion field trip guide by Rattenbury and Johnston 2011). Collectively all of these rocks constitute the Dun Mountain-Maitai terrane. Except for the middle and upper parts of the Maitai Group, which are Early Triassic age, all of the rocks in the terrane are Permian. The terrane is bounded to the northwest by the active Eighty-eight Fault, a reactivated Late Cretaceous feature and, on its southeast side, it is separated from the sedimentary rocks of the Caples terrane by the up to 6 km wide Patuki Melange. The ultramafic belt forms a distinctive landscape of stunted vegetation interspersed with reddish (dun) weathering rocks. The ultramafic rocks also contribute to the Junction Magnetic Anomaly, which marks the ophiolite belt under cover throughout and beyond New Zealand. The ophiolite belt and Maitai Group also played a key role in the recognition by Harold Wellman of the 480 km horizontal offset on the Alpine Fault.

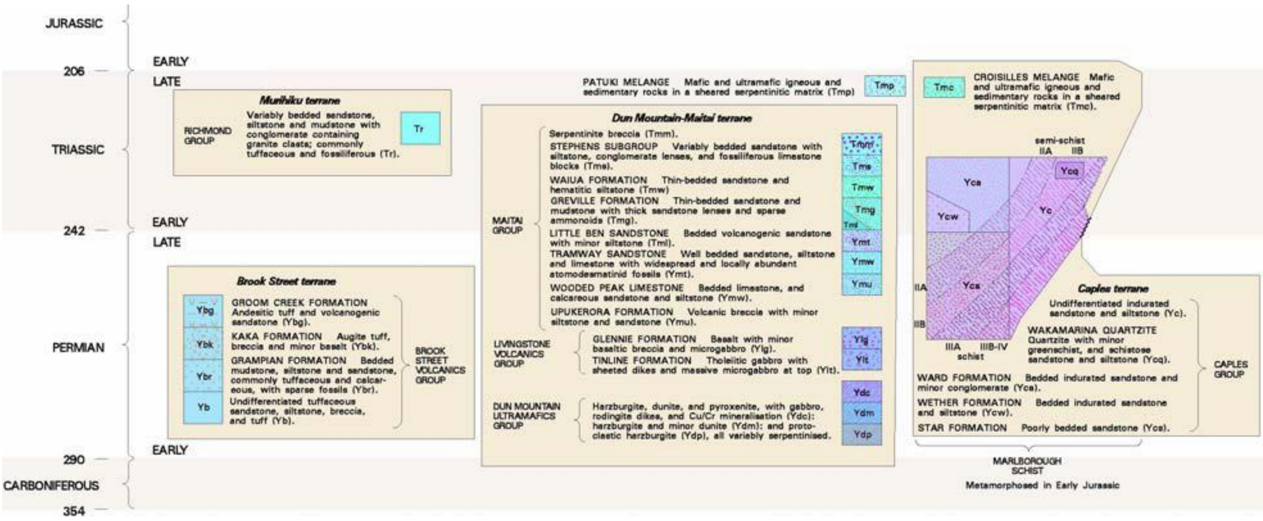

Figure 4.2 Legend for basement rocks of eastern Nelson (from Rattenbury et al. 1998).

Nelson to the Roding Dam (Departure time from Rutherford Hotel 08.00 sharp)

To reach the Roding River, Rutherford Street and then Waimea Road are followed southwest over Bishopdale Saddle to Stoke. The saddle is on the slightly overturned unconformity separating terrestrial Port Hills Gravel formation, of Miocene age, from a variety of Eocene-Oligocene rocks of the Jenkins Group on the eastern limb of the Port Hills Syncline. The high hills further east are of Brook Street terrane, comprising the dominantly sedimentary, but largely volcanic derived, Brook Street Volcanics Group of Permian age (Brook Street is on the other side of the higher hills). The group is separated from the Jenkins Group rocks by the Flaxmore Fault, a component of the Waimea-Flaxmore Fault System, which branches off the Alpine Fault near Lake Roto-iti in Nelson Lakes National Park and extends northeast to join the Taranaki Fault System. The Waimea-Flaxmore Fault System comprises steeply southeast-dipping reverse faults with a relatively minor dextral component. A number of the major faults, and several lesser faults, show rupture of Late Quaternary surfaces and deposits, although these are only intermittent north of the Wairoa River.

The fault system forms the southeastern boundary between the lowlands of the Moutere Depression (in part flooded by Tasman Bay), a complex fault angle depression some 25 km wide, between the eastern and western Nelson ranges. There are several faults that define the eastern range front. In northern Nelson city it is the Flaxmore Fault, in the central city it is an unnamed concealed fault west of the Port Hills, further south the Waimea and Heslington faults fulfil this role. However from about 25 km southwest of the Aniseed Hill to the Alpine Fault the major faults of the fault system are close together and the Waimea Fault forms the range front. Additional information on the fault system is in a companion field trip guide (Wopereis 2011).

On the south side of the saddle the route briefly crosses Holocene marine sediments and joins Whakatu Drive, part of State Highway 6. The over-bridge spanning SH6 here has its southern abutment on an abandoned cliff cut by the sea 6000 years ago. North of the cliff the marine sediments have been deposited by longshore drift currents flowing southwest into the head of Tasman Bay. Much of the sediment is derived from major landslides on the western limb of the Port Hills Syncline, including the active Tahunanui Slump that will be seen on our return to Nelson. To the west is the Waimea Inlet formed when a number of barrier islands, the largest being the pine tree covered Rabbit Island, and spits were deposited in the head of Tasman Bay following post-glacial sea level rise. The islands are composed largely of sand and gravel derived from the western Nelson ranges and carried southeast by longshore drift to the head of Tasman Bay. Between the inlet and the eastern ranges is the Stoke Fan Gravel, deposited by small creeks draining the nearby Barnicoat Range. At the toe of the range is the Waimea Fault, which separates Brook Street terrane (down faulted 1-2 km below the surface) and Triassic Richmond Group rocks of the Murihiku terrane. Higher up on the range the Eighty-eight Fault, marked by a line of saddles, separates Murihiku rocks from Maitai Group sediments of the Dun Mountain-Maitai terrane.

After passing through Richmond, SH6 passes over Last Glaciation outwash surface of the Hope Gravel deposited by the Waimea and Wairoa rivers. Below the surface two confined aquifers (buried interglacial or interstadial river channels) supply water to Richmond and, except in very dry summers, they meet much of the irrigation demand on the plains. The rolling hills, now becoming more obvious, in the Moutere Depression are composed of weathered greywacke-derived Moutere Gravel. The gravel is up to 2 km thick adjacent to the Waimea-Flaxmore Fault System. The distinctive rock types of the eastern and western Nelson ranges are rare and instead the greywacke clasts originated from Torlesse terrane rocks south of the Alpine Fault. The Moutere Gravel formed a series of coalescing fans, which would have been similar to the present day Canterbury Plains, and are the direct result of the uplift of the Spenser Mountains at the northern end of the Southern Alps during the Late Pliocene. The western and eastern Nelson ranges were subsequently uplifted and part of the greywacke gravel was preserved within the resulting intervening Moutere Depression.

Turning off the highway, at the horticulture centre of Hope, a side road heads east and climbs the Aniseed Hill. On the lower part of the hill the road has recently been strengthened to stabilise failing Eocene coal measures of the Jenkins Group. At the top of the remediated road, faint red staining in a road batter defines the Waimea Fault and from here to the top of the hill Late Triassic siltstone, sandstone and conglomerate of the Richmond Group are exposed. In contrast to many other rocks in eastern Nelson, fossils are widespread in the group and in places are so abundant that they are mapped as members, such as the Monotis Shellbed defining the Warepan Stage. Richmond Group rocks belong to the zeolite facies. On the other side of the hill, the Eighty-eight Fault separates the group from the Maitai Group belonging to the prehnite-pumpellyite facies, locally lawsonite-albite-chlorite assemblage (Landis & Coombs 1967). Immediately east of the fault is the Waiua Formation, one of New Zealand's most distinctive rock units, consisting of finely bedded alternating green sandstone and red mudstone, reflecting varying ferrous and ferric iron content in the sediments. Adjacent to the fault, high terrace gravel remnants now some 90 m above the Waimea Plains, attest to the early history of uplift of the eastern Nelson ranges.

On crossing and recrossing the Roding River at the Two Bridges Reserve the Waiua Formation grades upwards into the Stephens Formation, the uppermost Maitai unit. The Stephens Formation consists predominantly of well bedded, sandstone and weathered outcrops tend to take on a blocky appearance. Although the rocks are dominantly grey, green sandstone is common and can form massive beds, and green and red beds similar to the Waiua Formation are also present. Conglomerate is also widespread but is not a common lithology. The Stephens Formation is exposed in the core of the Roding Syncline.

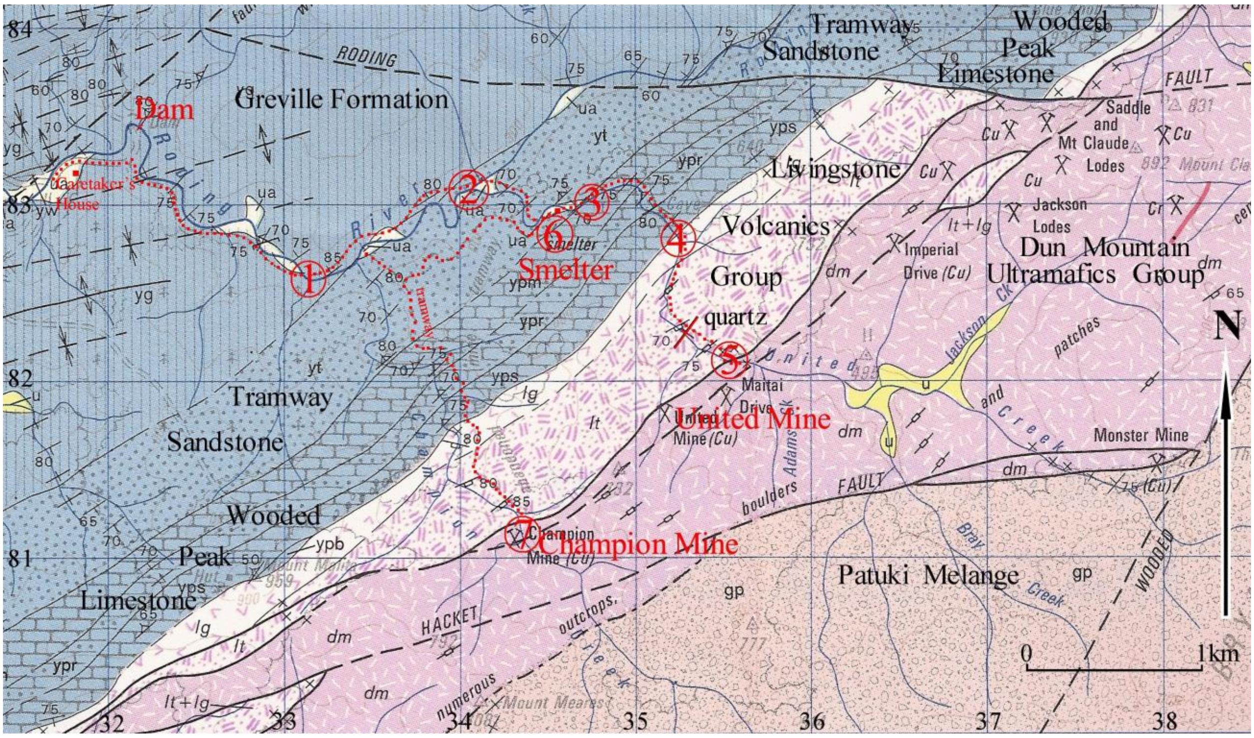

Figure 4.3 Geology (after Johnston 1981) and field trip stops in the Roding River, United Creek and Champion Creek. The map grid is in terms of Geodetic Datum 1949.

Maitai Group: Greville Formation yg, Tramway Sandstone formation yt, Wooded Peak Limestone formation = Malita Limestone Member ypm, Roding Green Sandstone member ypr, Sclanders Limestone Member yps
Livingstone Volcanics Group: Glennie Formation lg, Tinline Formation lt
Dun Mountain Ultramafics group: dm
Patuki Melange: gp

Beside the river are a series of narrow aggradation terraces deposited by the Roding River. The terrace gravels contain a large percentage of clasts derived from the Dun Mountain Ophiolite Belt or as it is locally known the "Nelson Mineral Belt". On the terrace edges the mountain carrot, *Anisotome montana*, was formerly widespread and from its smell the valley acquired the name of Aniseed Valley. *Anisotome* is now rare in the valley as it is a favourite food of sheep and rabbits. The terraces and valley sides were originally covered in forest, dominantly *Nothofagus* although podocarps were more abundant adjacent to the river. European settlement, and forest clearance, began in the late 1850s and one major landowner was Thomas Ridge Hacket (1837-1884), who was appointed mine manager to the Dun Mountain Copper Mining Company in 1857. Despite its name, the company ended up building the Dun Mountain Railway to mine chromite on Wooded Peak (Johnston 1987). Hacket left the company in 1861 when he opened up his own chromite mines in the Serpentine and Hacket rivers, eastern tributaries of the Roding. The Maitai Group, with its low volcanogenic content, has thin infertile skeletal soils and, as a consequence, the farms were converted commercial *Pinus radiata* plantations.

From the Hacket River, the Aniseed Valley is aligned along the Whangamoa Fault (the eastern most component of the Waimea-Flaxmore Fault System) until reaching the caretaker's house at the Roding Dam, where the river takes a more ENE course towards Dun Mountain. The dam, or more correctly weir, diverts water from the river by way of a tunnel through the Barnicoat Range to Nelson, The amount of water available from this run of the river system diminishes dramatically during summer and the city then becomes increasing reliant on storage from the Maitai Dam, which impounds water draining northwest from Dun Mountain.

Figure 4.4 Relics from the Roding smelters, including copper ingot mould (centre), at the Roding Waterworks caretaker's house.

Photo: Mike Johnston

Stop 1 Roding River (first ford above Roding Dam) O27/331827[1] 240 m (09.30)

From the caretaker's house near the Roding Dam to beyond the first ford above the dam, the Greville Formation of the middle Maitai Group is well exposed and consists of finely bedded grey sandstone and mudstone. The formation has an estimated thickness of 1000 m but this is very tentative due to widespread mesofolding. Ferdinand Hochstetter (1829-1884) on observing these rocks and the overlying Waiua Formation in the lower Roding and Maitai valleys named them in 1859 the "Maitai Slates". Sparsely in eastern Nelson the Greville Formation contains ammonites, including *Durvilleoceras woodmani* (Waterhouse), and is within the Nelsonian Stage, the lowest stage recognised in the New Zealand Triassic (Campbell & Owen 2003).

Figure 4.5 Finely bedded Greville Formation, Roding River just downstream of the caretaker's house.

Photo: Mike Johnston

[1] Grid references are in terms of Geodetic Datum 1949, which is the grid depicted on Fig. 4.3.

Stop 2 Tramway Sandstone, United Creek O27/341831 265 m (10.05)

Just prior to second ford (above the dam), across the Roding River at its junction with United Creek, the Greville Formation grades down into c.1000 m Tramway Sandstone. The formation (Waterhouse 1959) is a well bedded sandstone and siltstone, which becomes sandier towards its base. It is also more quartz rich (c. 10%) than the remainder of the Maitai Group (Waterhouse 1964). The formation, more particularly towards its base, contains abundant atomodesmatinid shell beds and tracks of worms and other soft bodied organisms. For many years the Tramway fossils were misidentified as *Inoceramus* leading to the "Maitai Problem". Also compounding the "problem" was that the Maitai and Richmond groups were regarded as a continuous sequence, despite Alexander McKay (1841-1917) discovering Permian fossils in the Stephens Formation in the Wairoa Gorge. It was not until 1917 that Charles Taylor Trechmann (1884-1964) identified the Tramway Sandstone fossils as belonging to the atomodesmatinid family, and that a major fault (Eighty-eight) separates the Maitai and Richmond groups, that the "Maitai Problem" approached resolution (Trechmann 1917). However, because of McKay's Wairoa fossils, the age of the Maitai Group was accepted as Permian. The discovery of the Triassic ammonites in the Greville Formation again placed the age of the upper Maitai Group in doubt. It was not until the recognition that many of the Stephens Formation fossils were in allocthonous blocks, plus the finding of the Triassic ammonites, that it was confirmed that the Maitai Group spans the Permian-Triassic boundary. The boundary has not been pinpointed within the group but is assumed to be at the base of the Greville Formation. Locally along base of the Greville is the lensoidal green Little Ben Sandstone, but this formation is not exposed in the Roding River.

Stop 3 Wooded Peak Limestone (copper smelter) O27/346830 (10.25)

Ascending United Creek to the remains of a copper smelter (which will be examined when we return here for lunch), the Tramway Sandstone grades down into the Wooded Peak Limestone and is also about 1000 m thick. The limestone, named by Hochstetter, is well exposed in the creek beside the smelter. It is now divided into three members: the flaggy Malita Limestone, the very calcareous Roding Green Sandstone and the less well bedded basal Sclanders Limestone. No fossils have been found in the Wooded Peak Limestone other than it is composed of a mass of atomodesmatinid prisms. Except for the Roding Green Sandstone, the limestone contains little clastic detritus although mafic igneous debris is common at the base and locally in eastern Nelson there is a thin breccia, conglomerate or siltstone (Upukerora Formation). Walking on up the old tramway beside United Creek, the lower part of the Tramway Sandstone is again initially encountered. Atomodesmatinid fossil fragments can be found in loose blocks on the track.

Figure 4.6 Well-bedded Wooded Peak Limestone (Malita Limestone Member), United Creek immediately upstream of the smelter.

Photo: Mike Johnston

Stop 4 Basal Maitai Group Unconformity O27/353828 (11.00)

The tramway besides United Creek connected the smelter with the United Mine in the Mineral Belt. Although it will not be visited, the mine, comprising seven levels, is visible from the track. The main ore mined was pyrrhotite, with patches of chalcopyrite, and close to the surface secondary copper minerals, mostly malachite and a little native copper. Just beyond the view point, a short descent will be made to United Creek where the slightly overturned unconformity between the Wooded Peak Limestone and the mafic rocks of the ophiolite belt is rather poorly exposed. The mafic rocks are gradational between basalt and gabbro, mapped as the Glennie and Tinline formations of the Livingstone Volcanics Group (formerly Lee River Group) respectively. Primary minerals include plagioclase, augite, hypersthene, magnetite and very rare olivine. Some hornblende in the upper part of the group may be primary rather than secondary. The group shows three stages of metamorphism (Davis *et al*. 1980). Initially hornblende partially or totally replaced augite to form a uralite gabbro. This was followed by greenschist metamorphism with widespread replacement of plagioclase and hypersthene by albite and chlorite respectively. Finally plagioclase was replaced by hydrogrossular, epidote, prehnite and vesuvianite. In Champion Creek the mafic rocks contain sparse lenses of plagiogranite, from which U/Pb zircons are dated at 285 Ma (Early Permian age, Kimbrough *et al*. 1992).

Figure 4.7 Slightly overturned Wooded Peak Limestone (Sclanders Limestone Member), at the base of the Maitai Group, unconformably overlying mafic rocks of the Livingstone Volcanics Group (left), United Creek.

Photo: Mike Johnston

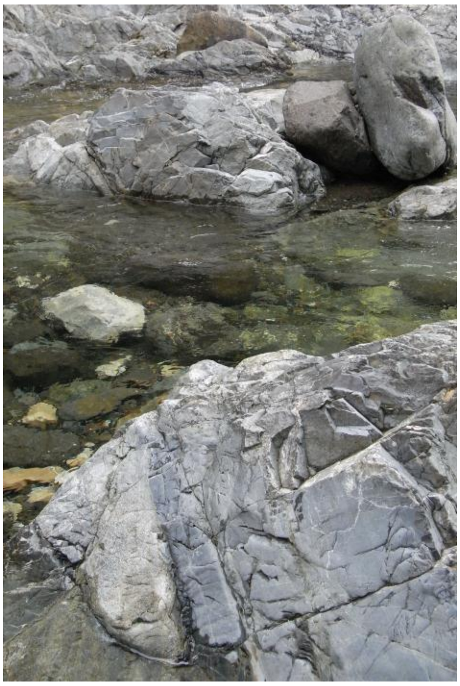

Figure 4.8 Coarse and fine grained gabbro constituting a dike complex in the Tinline Formation, Livingstone Volcanics Group, United Creek.

Photo: Mike Johnston

A little further up United Creek (O27/353823) a quartz vein intrudes Tinline Formation gabbro. While quartz veining is not unusual, quartz veins are very rare in eastern Nelson and this vein is an exceptional 1.4 m wide. It contains pyrite and minute traces of gold and silver (Bell *et al*. 1911). Small amounts of quartz were apparently used in the smelting process. At the tramway crossing of United Creek (only a few parts of the bridge remain) to an incline leading to the mine, the gabbro is well exposed and comprises a swarm of coarse and fine grained dikes (O27/355822). However, because of widespread jointing and other planes of weakness, individual dikes are not all that conspicuous. Be warned that the rocks leading down to the creek bed can be exceedingly slippery.

Stop 5 Mafic-ultramafic contact O27/355821 370 m (12.20)

From the tramway crossing a short walk up the bed of United Creek leads to a well exposed contact between the mafic and the ultramafic (cumulate zone) components of the Dun Mountain Ophiolite Belt. The lower depleted mantle part of the ophiolite is excised so that only the Patuki Melange crops out in the head of United Creek. The mafic-ultramafic contact is sharply defined and dips 75° northwest. Adjacent to the contact the serpentinite is initially sheared and a few metres upstream it is cut by fine-grained rodingite dikes. In the creek bed there is a striking variety of boulders derived from the ultramafics and the Patuki Melange and include rodingite, diopside, serpentinised harzburgite, serpentinised pyroxenite, basalt (some with pillow structures), basaltic breccia and pakohe.

Figure 4.9 Sharp contact between mafic (left) and ultramafic components of the Dun Mountain Ophiolite Belt, United Creek. *Photo: Mike Johnston*

Rodingite is dominated by grossular and hydrogrossular and varies from massive fine grained off white to green translucent varieties with Ca-Mg-Fe clinopyroxene (“diallage”) crystals up to 25 mm in length. The dikes are altered gabbro veins intruding the cumulate zone of the ultramafics. It was first described by Patrick Marshall, one of the authors of the Dun Mountain bulletin (Bell at al 1911); the other well-known rock he named from New Zealand was ignimbrite. Small chromite pebbles are relatively common in the creek bed and there was intermittent mining of deposits on the spur between United Creek and the upper Roding River. However, the main mining was on Wooded Peak and to which the Dun Mountain Railway was constructed in 1861, making it New Zealand’s first. Nearly 6000 tonnes of ore in total was mined from eastern Nelson and shipped to Britain for manufacture into dyes (Johnston 1987). The chromite can occur as layers and at a few localities as nodular or podiform deposits. Chromite values range from 40-60% Cr_2O_3 although most deposits err towards the lower end of these figures; Al_2O_3 and Fe are relatively high at 21-23% and 16-24% respectively. Fresh dunite is not known in United Creek.

Figure 4.10 Coarse and fine grained varieties of rodingite. The white to pale green is grossular and hydrogrossular with, in the boulder on the left, darker coloured clinopyroxene. United Creek.

Photo: Mike Johnston

Figure 4.11 Fine grained rodingite dikes in serpentinite of the Dun Mountain Ultramafics Group, United Creek. *Photo: Mike Johnston*

As shown by the boulders in the creek, pakohe is a tough metasomatic rock that has been commonly referred to as "baked argillite". Most pakohe was mudstone that has been incorporated as blocks in the Croisilles and, more particularly, Patuki melanges and altered through the formation of albite and tremolite. Although this alteration has resulted in an extremely durable rock, it has a pronounced propensity to fracture conchoidally. It is these properties that allowed Maori to shape the rock into adzes and other implements. Commonly used as hammer stones were boulders of rodingite and, in the larger quarries in eastern Nelson, Cable Granodiorite from the Nelson Boulder Bank, Although quarries are known from the Maitai and Serpentine valleys, as well as further afield, none have been reported from United Creek although Maori would have sourced pakohe boulders from the stream.

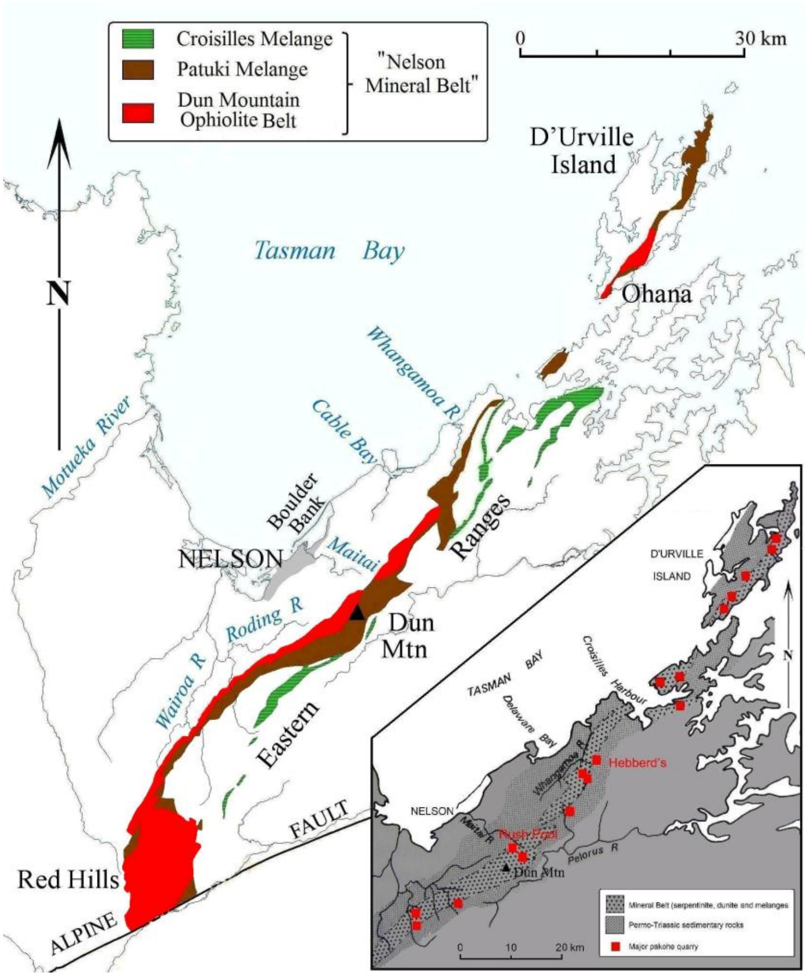

Figure 4.12 Dun Mountain Ophiolite Belt and Patuki and Croisilles melanges, eastern Nelson. The insert map shows the major pakohe quarries worked by Maori (Johnston 2011)

Stop 6 Copper Smelter O27/345829 280 m (13.20-13.50)

On this site are the remains of two smelters. The first was built by the Champion Copper Mining Company following the discovery of copper firstly in Champion Creek and then in United Creek. The smelter comprised a series of impressive brick roasting stalls, the fumes from which were fed into a high brick chimney. The reduced ore was then fed into a water jacket furnace, which still remains on site. Smelting commenced in 1886 but the company failed within a few months as a result of increased mining costs, difficulties in smelting the ores and a collapse in the price of copper metal. The company was on the basis of its nominal capital, one of the largest in New Zealand, and its demise led to severe financial hardship for its many, mostly Nelson, shareholders. A reverberatory furnace was built on the same site by the Maoriland Copper Company, a Christchurch based concern that was registered in 1906. Ore was roasted in two pots, which with their now detached hoods, are still present. The base of the smelter is clearly visible and nearby is an area of slag. An inclined flue leads up to a small brick chimney, with interesting external reinforcing rods, on the hillside above the smelter. The second smelter was a sham in that money was raised from shareholders and only some went into reopening the mines and building the new smelter and the remainder to purchase the interests of the promoters. After smelting thirty tonnes of ore, the company ceased work in 1908 on the flimsy excuse that the road to the smelter was so poor it could not get coke and other supplies on site (Johnston 1987). An evaluation of the mines soon after by the Geological Survey (Bell *et al*. 1911) showed that little ore remained and that it was mostly pyrrhotite.

Figure 4.13 The second smelter, built by the Maoriland Copper Company, ceased operations in 1908 (Bell et al. 1911).

Figure 4.14 Smelter site in 2011. On the left are two roasting pots used to reduce the amount of sulphur in the ore before smelting. The hood of one of the roasting pots rests on the base of the smelter. The cylindrical structure on the right is the water jacket furnace used by the Champion Copper Company in 1886. Malita Limestone was used extensively to build both smelters. Photo: Mike Johnston

The copper mineralisation occurs along shear zones within the cumulate zone and generally close to the contact with the mafic rocks of the ophiolite belt. The podoform chromite deposits are generally lower in the cumulate zone. The origin of the Cu-Ni-Co-Fe mineralisation is uncertain and possible explanations include remobilisation of magmatic sulphide segregations or hydrothermal extraction and deposition of metals during serpentinisation (Brathwaite and Piranjno 1993). The proximity to the mafic rocks, which are locally sulphide rich, may suggest that these could be the source of some of the sulphides.

Stop 7 Champion Mine O27/344811 465 m (15.00-15.25)

An alternative, optional, return to the vehicles can be made by way of the tramway that connects the smelter site to the Champion Mine. The tramway follows the contour above United Creek and the Roding River into the valley of Champion Creek. It initially crosses fossiliferous Tramway Sandstone and then is cut unto the Wooded Peak Limestone (watch out for nettle) and the mafic Livingstone Volcanics Group rocks. The Champion Mine, distinguished by blocks of native copper up to 1 m across lying on the ground was discovered in 1881. It received its name because it was believed to be main lode that had eluded the Dun Mountain Copper Mining Company and others. There are two zones of mineralisation, the Champion and Doctor's lodes, which trend northeast and are about 35 m apart. The ore is a weakly cupriferous pyrrhotite at depth with secondary minerals close to the surface. An appreciation of the mineralisation can be seen in mullock heaps and in the *in situ* serpentinite on the west side of the creek between the Doctors No 1 and 2 levels. Small pieces of native copper, malachite coated serpentinite and pyrrhotite are readily found. Do not enter the underground workings as the roofs are unstable and there are vertical shafts connecting the various levels, including the flooded workings up to 65 m below the creek.

Figure 4.15 Champion Mine ore consisting of malachite coating serpentinite, weakly cupriferous pyrrhotite and sparse small fragments of native copper.

Photo: Mike Johnston

Figure 4.16 Champion Mine beside Champion Creek and showing stunted vegetation typical of the "Mineral Belt". Mullock dumps from the Doctor's and Champion lodes are on the south (right) side of the creek whereas ore dumps dominate on the opposite bank. *Photo: Mike Johnston*

The return is back along the tramway to above the junction of Champion Creek and the Roding River before descending through manuka and gorse to the valley floor by way of a well-defined route down a spur. After crossing the Roding River at the toe of the spur the road is followed to the vehicles.

Stop 1 Roding River (first ford above Roding Dam) and return to Nelson (17.00)

On reaching the vehicles we will return to Nelson by this morning's route except that instead of going over Bishopdale Saddle we will go via the port so as to view the active Tahunanui Slump. This active complex rotational landslide, on which are sited about 120 houses, is slowly settling towards Tahunanui Beach. Periodically after prolonged wet weather and, in two instances (1929, 1962) coinciding with earthquakes, more rapid movement has locally occurred causing severe structural damage to several houses. Areas of higher risk are the margins of the landslide, the boundaries between subsidiary blocks within it and along the toe where sea erosion was active up until the construction of Rocks Road in the 1890s. Erosion of the toe of the landslide provided much of the sand and gravel deposited during the Holocene seaward of the 6000 year old sea cliff seen in the morning. The rocks involved in the landslide are southeast dipping (and younging) Oligocene graded beds of the Magazine Point Formation unconformably overlain by Miocene Port Hills Gravel formation. Further rotation of the rocks since the Miocene, as part of the development of the Port Hills Syncline, has resulted in the tilting of the unconformity to 40° southeast and the Magazine Point Formation to 70°. As the rocks dip into the hill, it is likely that the landslide was initiated by severe seismic shaking arising from rupture on one of the faults in the nearby Waimea-Flaxmore Fault System.

Rutherford Hotel (18.00)

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