GEOLOGY AND MINERAL RESOURCES

Geological framework

The landmass of New Zealand is part of a larger submerged microcontinent that was originally formed on the eastern margin of the Gondwana supercontinent. New Zealand's complex geology and wide variety of mineral deposits are a function of its location at active plate boundary settings on the mobile margin of the Pacific Ocean over the past 600 million years.

The rocks of New Zealand can be grouped into:

- an Early to Mid Paleozoic Western Province
- a Late Paleozoic to Early Cretaceous Eastern Province
- Late Cretaceous to Cenozoic sedimentary and volcanic cover rocks

The first two comprise basement rocks, forming jigsaws of terranes produced by the interaction of various tectonic plates, and containing many mineral deposits. The Western and Eastern provinces were formed on or near the margin of Gondwana, and are separated by the Median Batholith. These basement units are displaced by 480 km of Late Cenozoic movement along the Alpine Fault, which forms part of the present plate boundary that runs through New Zealand separating the Pacific and Australian plates.

The basement rocks are overlain by Late Cretaceous to Cenozoic rocks in a number of onshore and offshore sedimentary basins. Many of these basins initially developed during the rifting of New Zealand from Gondwanaland in the Late Cretaceous. They contain New Zealand's economic petroleum, coal and limestone deposits. Volcanism since the Miocene has also produced extensive mineralisation. Erosion of some of these volcanic rocks and basement units has formed placer deposits.

Early to mid-Paleozoic - Western Province

The Western Province is confined to the western South Island and contains two major terranes, Takaka and Buller, that were sutured together in the mid-Devonian Tuhua orogeny. New Zealand's oldest known rocks (Middle Cambrian) are found in the Takaka Terrane and consist of volcanics, limestone, conglomerate and turbidites deposited in an island arc setting. The volcanic rocks contain volcanogenic massive sulphide deposits. A major change to a passive margin-type environment is shown by the transition into overlying basin and shelf sediments, including Ordovician carbonates, with economically important lenses of marble at Takaka Hill, dolomite at Mt Burnett, and Silurian quartzites.

The Buller Terrane records a different geological history. Extensive fans of quartz-rich greywacke sandstone (Greenland Group) were deposited along the margin of Gondwana during the Cambrian-Ordovician. This phase was followed by a transition to quartzitic sandstone and graptolitic black shales formed in starved offshore basins. The main associated mineral deposits are mesothermal gold-quartz lodes localised along shear zones in Greenland Group greywacke and argillite in west Nelson (Golden Blocks and Lyell), Westland (Reefton) and southwest Fiordland. They were formed in steeply dipping shear and fault structures.

Gold exploration in Ordovician Greenland Group rocks, Reefton

Mafic-to-ultramafic complexes which have associated copper-nickel-platinum mineralisation were intruded into the Western Province during the Late Cambrian (Cobb Igneous Complex) and Late Devonian (Riwaka Complex). The Cobb Igneous Complex also contains chrysotile asbestos, talc and magnesite deposits. Extensive granite batholiths of the Karamea Suite were intruded during the mid Devonian to Carboniferous and are the most conspicuous feature of the Tuhua Orogeny. The same granite suite in Westland has related vein tungsten and tin mineralisation.

During the Early Cretaceous, granitoid rocks were intruded. Small granodiorite stocks in west Nelson have associated porphyry molybdenum mineralisation and at Copperstain Creek there is a copper skarn. A granite dike at Sams Creek in west Nelson hosts gold in quartz vein stockworks.

Late Paleozoic to Early Cretaceous - Eastern Province

Permian to Early Cretaceous rocks of the New Zealand region form the Eastern Province, which is subdivided into the Brook Street, Murihiku, Maitai, Caples, Waipapa, and Torlesse terranes. These terranes were formed at some distance away from or along the Gondwana margin during the Mesozoic.

Island arc volcanics, mudstones and limestones

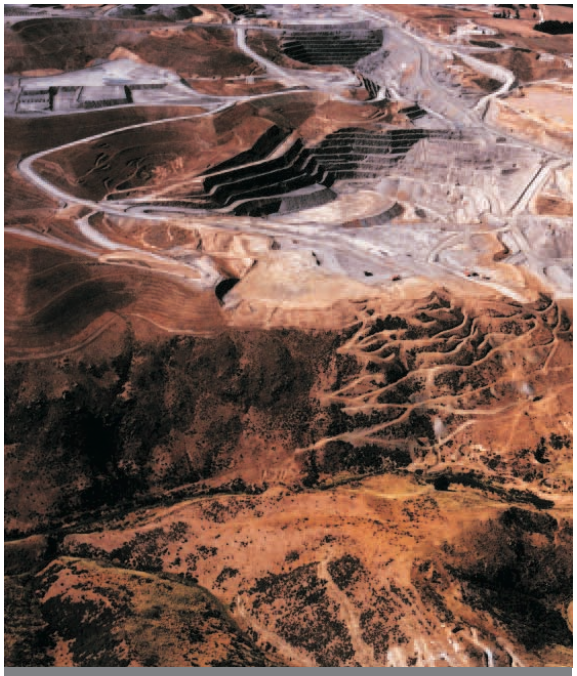
The Permian Brook Street Terrane is an island arc assemblage of volcaniclastic sediments and basaltic and andesitic volcanic rocks intruded by layered mafic to ultramafic intrusions (e.g. Longwood Complex) which are sources for alluvial platinum group metals and gold in Southland. Exploration has located platinum-palladium-gold values in several horizons within the layered series of the Longwood Complex, which shows many similarities to the Bushveld Complex in South Africa.

The Triassic to Jurassic Murihiku Terrane contains forearc basin volcanogenic strata with bedded zeolites, particularly in Southland.

The Permian to Triassic Maitai Terrane consists mainly of arc-derived volcanic sandstone, mudstone and limestone. The Dun Mountain Ophiolite Belt, located at the base of the Maitai Terrane, extends discontinuously in east Nelson and Otago as fault-bounded lenses of serpentinitised peridotite, gabbro, basalt and volcanic breccia with tectonic melange. Around Dun Mountain, podiform chromite is hosted in dunite at the top of a basal peridotite zone, and is the source of minor alluvial osmiridium and iridosmine. Small lenses of chalcopyrite and pyrrhotite occur in shear zones above the podiform chromite zone. Serpentine has been quarried at Lee River in Nelson and Mossburn in Southland as a source of magnesium in superphosphate fertiliser. At Pyke River in west Otago, a large deposit of chrysotile asbestos is localised in serpentinite at the margin of a large peridotite massif.

Greywacke sequence

The Caples, Waipapa and Torlesse terranes comprise greywacke and argillite sequences, locally with minor spilitic volcanic rocks and manganiferous chert. In the South Island, these terranes have been partially overprinted by Jurassic-Cretaceous metamorphism (Haast Schist), resulting from the collision of the Caples and Torlesse terranes. Chlorite zone schist in Otago and Marlborough contains widespread gold-bearing shear-zone quartz lodes. Some of the mineralised shear zones are laterally very extensive: 25 km in the case of the Hyde-Macraes Shear Zone. Quartz lodes at Glenorchy in Otago and Wakamarina in Marlborough were mined principally for tungsten (as scheelite).



Gold mining along the Hyde-Macraes shear zone, Central Otago

The Haast Schist of the Southern Alps, hosts lenses of serpentinite (Pounamu Ultramafics) with talc-magnesite and nephrite jade deposits.

Volcanogenic sulphide copper deposits occur in both the schist and greywacke, and have been mined historically on a small scale at Waitahuna (Otago), Maharahara (Ruahines) and Kawau Island (Northland). Volcanogenic sedimentary manganese oxide deposits are associated with chert and basaltic volcanics. The only deposits that have been mined are in Northland and South Auckland, where the manganiferous cherts show secondary enrichment. Torlesse Terrane greywacke is the main source of high quality aggregate in New Zealand.

Median Batholith

The Median Batholith, separating the Western and Eastern provinces, is a narrow belt of calc-alkaline, mafic-ultramafic, plutonic igneous complexes, with subsidiary units of terrestrial volcanic rocks and volcaniclastic sandstones. These rocks represent the remains of a number of Permian to Cretaceous subduction-related magmatic arcs. The mafic-ultramafic intrusions (e.g. Longwood Complex) have platinum group metal and gold deposits that are sources for placer deposits in Southland.

Separation of New Zealand from Australia and Antarctica

The convergent margin tectonic regime of the Eastern Province was supplanted at about 105 Ma by extension tectonics which led to the separation of New Zealand from Australia and Antarctica by the opening of the Tasman Sea at about 82 Ma. This extensional phase was reflected by a major regional angular unconformity and rifting and graben development in southern and western New Zealand. The majority of the basins formed during that phase are infilled with terrestrial clastics, whereas marine strata were deposited in the East Coast of the North Island, Marlborough and North Canterbury regions. Non-marine fan-glomerates host uranium mineralisation on the West Coasts and placer gold in Otago.

Extensional tectonics were also marked by the development of metamorphic core complexes in Westland. Ongoing igneous activity included emplacement of layered mafic to ultramafic intrusives containing minor copper-nickel sulphide and ilmenite-magnetite mineralisation in Marlborough, and high-potassium rhyolite that was locally weathered to produce economic kaolinite deposits in Canterbury.

Post separation - Late Cretaceous to Cenozoic

Separation was followed by a prolonged period of subsidence and a very substantial reduction in land area as the New Zealand continental fragment moved away from Australia. This is recorded in a transgressive sequence of coal measures passing up into shallow-marine sediments consisting of mudstones, sandstones and limestones. These sequences are found in a number of sedimentary basins onshore and offshore of the North and South Islands and contain most of New Zealand's economic petroleum, coal and limestone deposits.

Basin depositional sequence

In the Greymouth, Ohai and Kaitangata coalfields, Late Cretaceous-Eocene coal measures were deposited as a basal unit of non-marine sequences filling fault-bounded basins. Coal measures of northwest Nelson are of similar age but are mainly located at depth offshore.

Coal measures at the base of an Eocene transgressive marine sequence are extensive in both islands, and contain major resources of sub-bituminous coal in the Waikato Coal Measures and bituminous coal in the Brunner Coal Measures of the West Coast. Much of the country's total coal production of about 3.7 Mtpa comes from these coal measures. Some contain economic kaolinite clay deposits.

Stockton opencast mine in Brunner Coal Measures

On the east coast of the North and South Islands, Late Cretaceous to Eocene marine sediments include siliceous limestone and smectite mudstone, locally with bentonite. Many of the onshore South Island basins contain basal quartzose gravel and sand which in Canterbury and Otago are important sources of gold and silica sand. In Southland large resources of lump silica have been appraised as a raw material for ferrosilicon.

The culmination of the marine transgression in the Oligocene to Early Miocene is represented by economically important crystalline limestones which occur mainly in eastern Northland, Waikato, Westland, Canterbury and Otago. On the crest of the Chatham Rise, a resource of about 100 Mt of phosphorite nodules lies in water depths of 300-500 m.

A marine regression during the Miocene resulted in erosion and either deposition of gold-bearing quartz gravels and lignite overlying basement (Otago and Southland), or deposition of coal measures overlying Tertiary marine beds in Taranaki, Westland and Southland. The Southland lignite deposits are a major potential energy resource containing over 9 billion tonnes of coal-in-ground.

The Miocene to Quaternary shelly limestones of Gisborne, Hawke's Bay, Wairarapa, Taranaki, and Southland are important local sources of agricultural lime.

The Oligocene-Miocene boundary (25 Ma) was marked by the emplacement of allochthonous rocks in Northland and East Cape, and the initiation of volcanic arcs in northern North Island. The allochtonous rocks consist of a dismembered sequence of Cretaceous to early Cenozoic marine sediments and ophiolite slabs that contain stratiform pyritic copper deposits in Northland and at East Cape. The abrupt change, which marked the beginning of the Kaikoura Orogeny, was probably caused by the propagation through New Zealand of the Australian-Pacific plate boundary forming a convergent margin similar to its present form.

Tertiary volcanics

The Northland Volcanic Arc consists of a western belt of predominantly basalt and andesite, and an eastern (Northland to Hauraki) belt of andesite and dacite. Volcanism in Northland ceased at about 15 Ma but continued in the Hauraki region until the Late Pliocene.

Activity then shifted to the Taupo Volcanic Zone where it is represented by voluminous rhyolites, with lesser andesites and dacites, and continues to the present. Back-arc volcanism was manifested by andesitic volcanoes on the west coast of the North Island.

Miocene and Pliocene intraplate volcanism is represented in the South Island by tholeiitic to alkaline basaltic rocks in Canterbury and Otago. Non-swelling bentonite at Coalgate in Canterbury was formed from glassy basaltic ash of Early Miocene age.

Miocene to Recent mineral deposits

Hydrothermal gold deposits

In the North Island, porphyry copper style mineralisation is associated with Miocene subvolcanic intrusive rocks in Northland, at Great Barrier Island and in the Coromandel Peninsula. Lead-zinc skarn is hosted by limestone in Northland. Epithermal gold-silver vein deposits in the Hauraki Goldfield are associated with Miocene-Pliocene andesite, dacite or rhyolite. The Hauraki deposits have been mined since the 1860s, with a total reported production of 303 t of gold and 1181 t of silver from about 50 quartz vein systems.

Martha mine, Waihi

In the Taupo Volcanic Zone, gold is present in geothermal systems associated with Quaternary volcanism. Gold-silver mineralisation is present in sinters at several active geothermal fields, and exploration has defined several gold prospects in inactive geothermal systems. Deposits of sulphur, perlite, pumice, zeolite, and amorphous silica have all been exploited.

In Northland and later in Auckland, basalt volcanism from about 10 Ma provided the main source of high quality aggregate for the Auckland area. Mercury deposits in Northland appear to be associated with alkaline rhyolites. Hydrothermal alteration and weathering of the rhyolite domes have given rise to halloysite clays that are exported for use in high quality ceramics. Several small deposits of bauxite have been formed by subtropical weathering of older basalt flows in Northland.

Alluvial gold

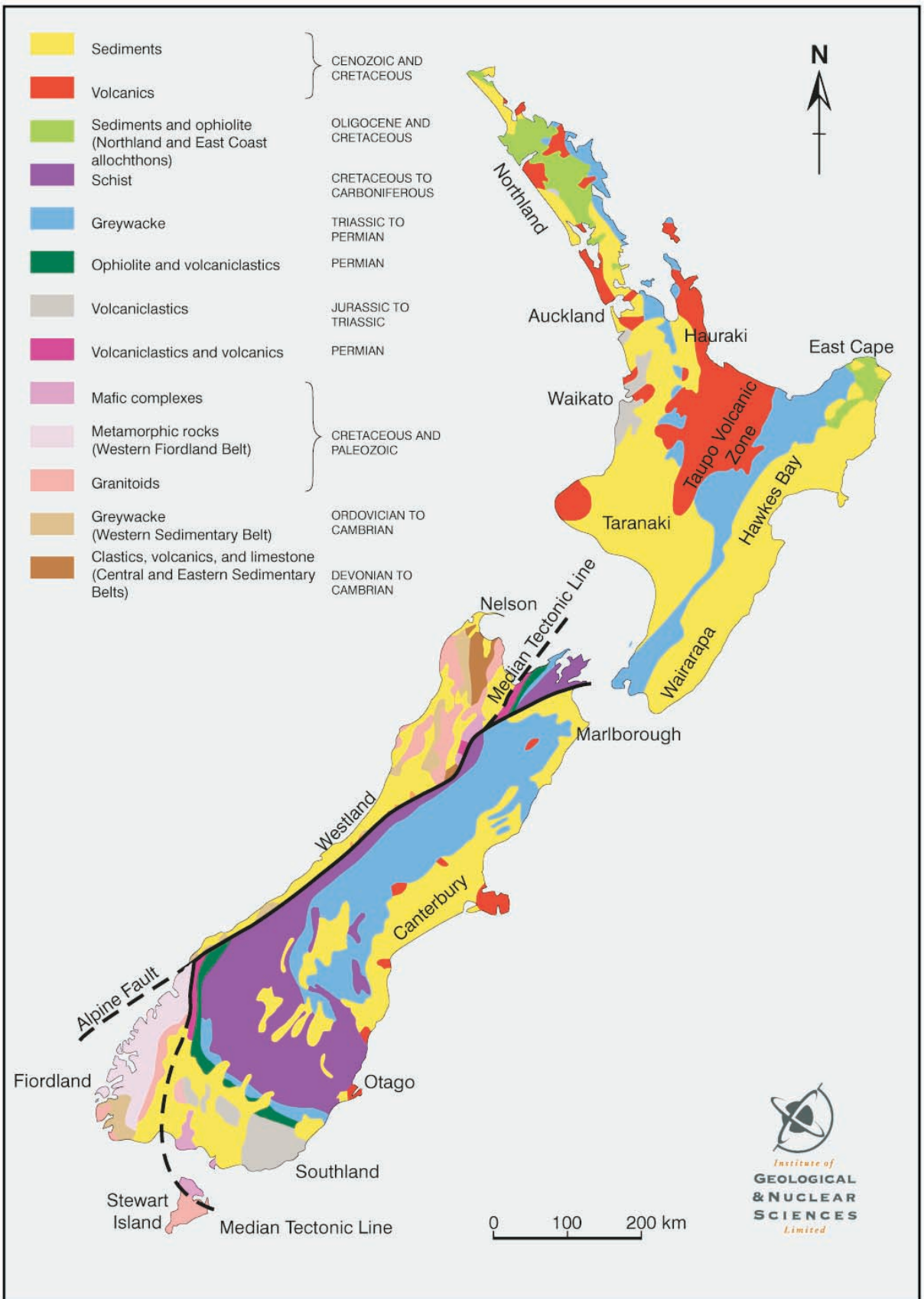
From the Late Miocene to the present day, regional uplift along the Alpine and related fault systems formed the axial mountain ranges of the North and South Islands. Erosion of the mountain ranges during the Plio-Pleistocene has produced extensive fluvioglacial and fluvial gravels which are hosts to important gold placers in Westland and Otago. Past gold production is estimated to exceed 600 t while present production from more than 70 open pits and river gravel operations is about 2 tpa.

Mining titanomagnetite sands, Waikato North Head

Mineral sands

Erosion of volcanic rocks in the North Island shed titanomagnetite onto the west coast where it formed late Cenozoic coastal placer ironsand deposits. Over 3 Mtpa of titanomagnetite concentrate are mined from deposits at Waikato North Head and Taharoa for domestic steel manufacture and export respectively.

Erosion of the Haast Schist in the South Island has resulted in the formation of shoreline placer ilmenite deposits along the coast of Westland.



New Zealand Geology