Industrial Minerals in New Zealand

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Introduction

With a population of 3.8 million, New Zealand has a limited market for industrial minerals. However, New Zealand's developed economy demands relatively large quantities of building materials for new construction and fertilizer minerals for the high level of agricultural production. On a per capita basis, New Zealand is the world's largest consumer of phosphate rock, potash and sulphur (Martin, 1997).

In addition to construction aggregates, New Zealand produces a diverse range of industrial minerals including limestone, dolomite, marble, ironsand, clays, diatomite, perlite, pumice, zeolite, salt and serpentine (Figs 1 and 2). Output of most commodities is governed by domestic demand. Because of New Zealand's distance from markets, export products must have an inherent quality or composition which gives them a position in world markets either from their primary properties (e.g. halloysite) or through processing (e.g. ultrafine milling of calcium carbonate for use in paper-making). Some commodities or processes that have particular promise include microsilica, sulphur, pumice and the production of minerals from geothermal fluids.

Currently New Zealand's main industrial mineral exports are ironsand, clay, lime, limestone and cement (Fig. 3; Thompson and Christie, 1999). Minor items include peat, salt, sulphur and pumice. The main minerals imported into New Zealand are fertiliser minerals such as phosphate, potash and sulphur, gypsum for use in plaster and cement manufacture and refractory clays, magnesia, building stone, magnesite, talc, diatomite and cement (Fig. 4).

This review draws on previous descriptions of New Zealand's industrial minerals by Officers of New Zealand Geological Survey (1970), Williams (1974), Thompson (1982, 1989), Martin (1986, 1997), Benbow (1990), MacFarlan and Barry (1991), Thompson et al. (1995) and annual reviews in *Mineral resources of New Zealand* (e.g. Louthean, 1999).

Aggregates

Domestic production of aggregates is currently about 20.5 M tonnes per annum (tpa) of which 14.3 M tpa is consumed in the North Island. Almost 65% of this production comes from the medium scale operations (50,000-500,000 tpa) that make up only 20% of the total number of operations (Happy, 1993; Happy and Ashby, 1993). The small number of quarries with production capacities greater than 500,000 tpa account for about 20% of production, with the remaining 15% or so of production from numerous small scale operations (<50,000 tpa).

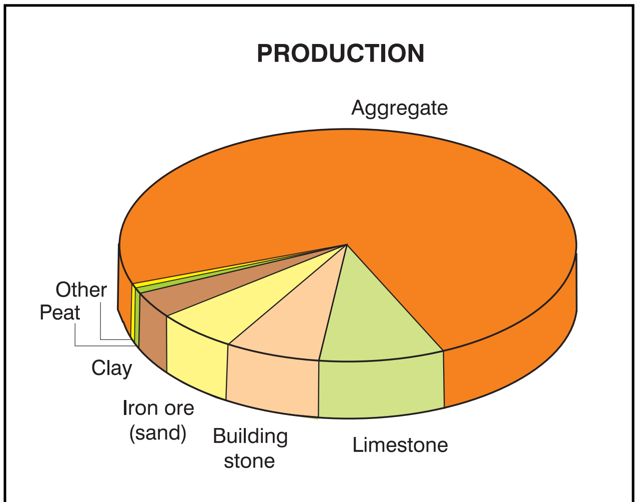

Figure 1: Relative production of industrial minerals and aggregate in New Zealand for 1996, ranked by dollar value and totalling NZ$540 M.

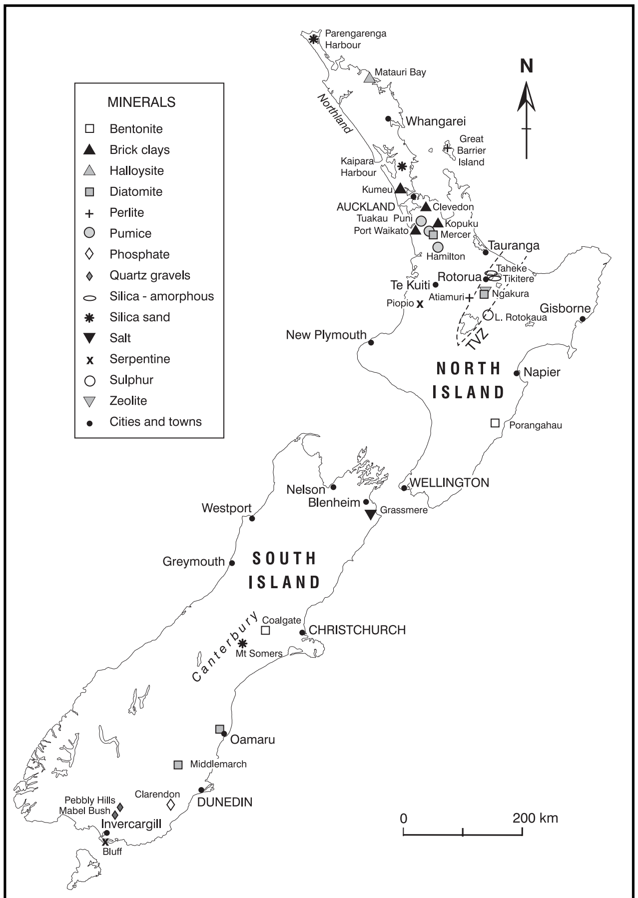

Figure 2: Locations of selected industrial mineral deposits in New Zealand.

The most important resource types used for high quality aggregate are greywacke sandstone, basalt and andesite (Fig. 5). Basalt and andesite are quarried, and greywacke is either quarried or won from alluvial gravels. Alluvial gravels are derived from the greywacke ranges in both the North Island and the South Island. Breakdown of softer materials during

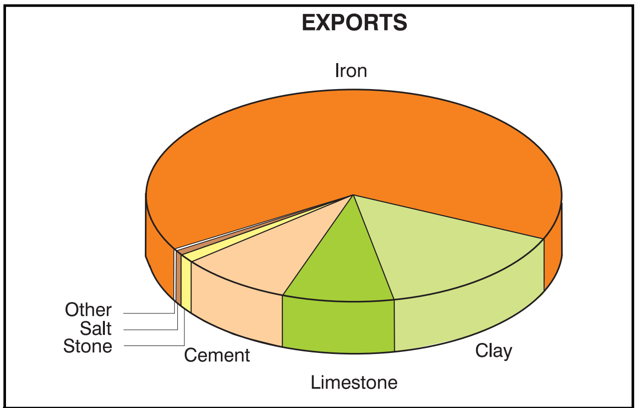

Figure 3: Exports of industrial minerals in 1998, ranked by dollar value and totalling NZ$89 M.

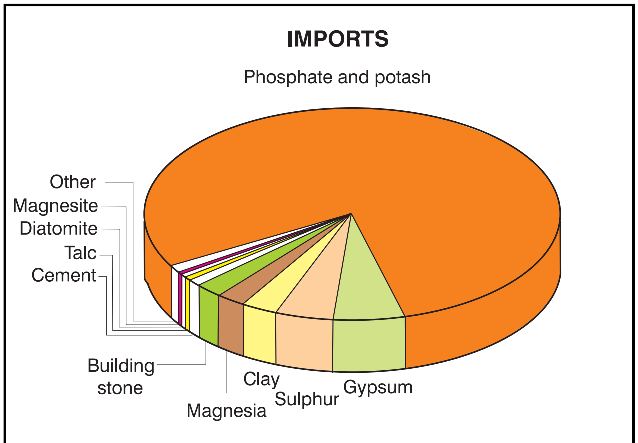

Figure 4: Imports of industrial minerals in 1998, ranked by dollar value and totalling NZ$297 M.

movement in river beds results in an easily won, high-grade aggregate.

In areas that are devoid of more suitable rock types, limestone is commonly used. Quartz sand and gravels are widely used for aggregates for concrete and masonry. In the Auckland area, sand for concrete is supplied from offshore dredging of marine sand and from river sand. Vesicular basalt and andesite scoria are widely used for drainage fill.

Although there are no detailed resource estimates on a national basis, there are extensive deposits of greywacke and volcanic rocks to meet future demand for aggregates. The quantity of rock available for any specific purpose varies from area to area and, because of the low total value per tonne, transport costs are a major factor in the economics of supply. Long-distance transport is uneconomic, apart from when small quantities of higher-quality rock are required. Therefore sources of supply are required close to demand. Generally there are adequate local sources of suitable aggregate, however, the Auckland area, with its large population and consequent high usage, is having to transport aggregate from farther afield as existing quarries are being worked out and nearer potential resources are sterilised by competing land uses.

New Zealand's domestic aggregates industry is dominated by the activities of a small number of major companies. There are a large number of smaller producers who cater primarily for very localised demand.

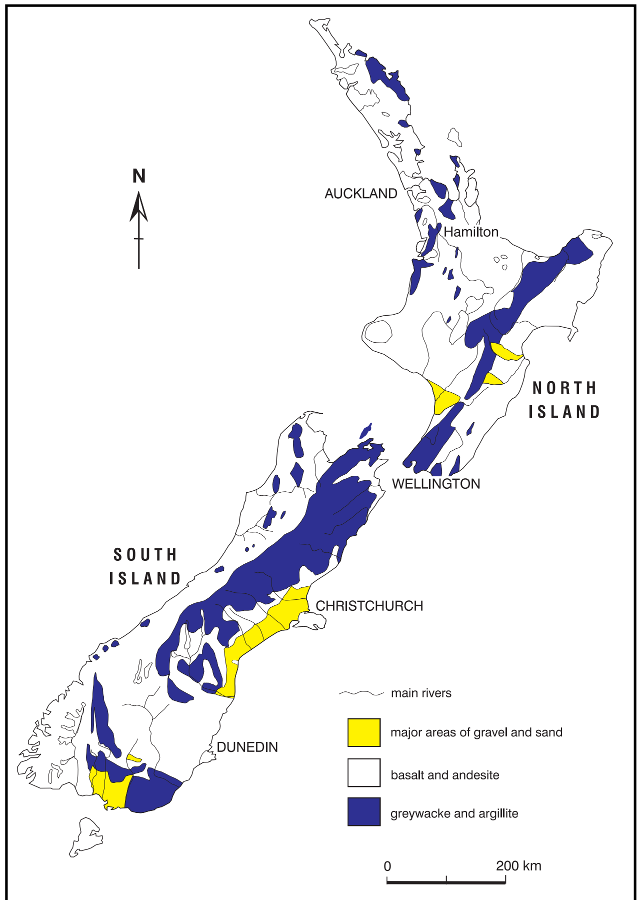

Figure 5: Map of major aggregate resource rock types in New Zealand.

Winstone Aggregates Limited operates 30 extractive facilities throughout the North Island. In addition to hard rock aggregates the company has several sand, gravel and scoria plants. Winstone's 2 Mtpa Lunn Avenue quarry in Auckland is the country's largest. Total output from Winstone's operations is currently around 6.5 Mtpa, equivalent to one-third of domestic annual aggregate output.

Fulton Hogan Limited is the South Island's largest aggregate producer and most of its extractive operations are concentrated there, although the company has a growing presence in the North Island. The company operates numerous quarries, with a current combined output of some 1 M tpa. In addition, the company also operates mobile units to supplement production from its quarries or for crushing and screening on contract to local authorities.

Two other large producers are W. Stevenson & Sons Limited, who operate several quarries in the Auckland area, and Milburn New Zealand Limited, one of New Zealand's two cement companies, who operate several aggregate quarries through its aggregate and concrete division.

Building stone

Although few buildings in New Zealand are constructed entirely of building stone, there is a widespread use of building stone for decorative walls, and general paving. Production was 360,000 t in 1996 with an average value of NZ$175 per tonne.

Limestone is widely used as a building stone throughout New Zealand, particularly at Oamaru in north Otago, where bricks and blocks of Oamaru Stone are cut. Other limestone resources used for building stone are present near Whangarei, Hanmer, Te Kuiti and various localities in Hawke's Bay, Canterbury and north Otago.

Prior to 1996, marble was quarried in the Nelson region from Mt Arthur Marble for building and monumental stone. Resources of marble in the Mt Arthur Range are very large.

Schist is widespread in Otago, and to a lesser extent in Marlborough and Canterbury. Schist from Otago is now used mainly as a decorative stone in walls and fireplaces and as flooring tiles.

Ignimbrite is widespread in the central North Island. The main source for building stone is in the Hinuera Valley in the Waikato region. Hinuera stone is easily worked and is widely used for wall cladding.

There are also deposits of basalt, dacite, sandstone, serpentine, tonalite, norite and various granites, which have all been worked for building stone in the past.

Clays

High alumina clays - halloysite

Halloysite clay, reputed to be "the world's whitest clay", is produced from deposits at Matauri Bay, 100 km north of Whangarei, in Northland (Fig. 2), by NZ China Clays Limited (Townsend, 1989; Harvey et al., 1990; Luke, 1997). Two pits are worked on the Matauri Bay and Mahimahi rhyolite domes respectively, located 2 km apart. The company also has deposits at Shepherds Hill to the west of Matauri Bay, and Maungaparerua, 8 km west of Kerikeri.

The clay is formed by hydrothermal alteration and subtropical weathering of Pliocene to Pleistocene age rhyolite to produce a raw material comprising approximately 50% halloysite, 50% silica and minor feldspar.

About 80,000 tpa of raw clay is mined from the two deposits with 50% of plant feed from each. Plant capacity is about 25,000 tpa of processed halloysite, with clay products being exported to more than 20 countries.

The high purity halloysite possesses exceptional whiteness, and brightness, and an overall fine particle size. Iron oxides average 0.28% and titania averages 0.08%. The inherent brightness of the raw material, coupled with low iron and titania levels, imparts whiteness and translucency to the finished product. Halloysite is exported for the manufacture of high-quality ceramics, principally porcelain, but also fine bone china and technical ceramics. There are two main applications in the technical ceramics sector. The main market is for use in synthetic zeolite-based molecular sieves, while a lesser amount is used in the manufacture of honeycomb catalyst supports. Other uses are in catalyst absorption carriers and filters. A coarse by-product is sold on the local market as filler clay and a silica sand by-product is used in the local building industry and for golf course bunkers.

Clays for bricks, pottery and industry

Kaolinite clays are used widely for domestic brick, tile, pipe, ceramics and pottery manufacture. Some kaolinite is also used as a filler in rubber, bitumen and adhesives. High-purity kaolinite is used by the New Zealand paper industry for paper coating and filling.

In New Zealand, kaolinite clays are formed mainly by:

1. Surface weathering of clay-rich rocks such as argillite in several locations near Auckland.
2. Acid leaching of mudstone to produce fireclays associated with coal measures in both the North and South Islands.
3. Weathering of mudstone and siltstone at West Auckland and near Nelson.
4. Hydrothermal alteration of rhyolite in the Coromandel Peninsula and Canterbury.

The quantity of clay present in most areas is considered to be large but is poorly defined.

The largest brick making operation is the plant operated by CSR Building Materials (NZ) Limited (formerly Monier Brickmakers Ltd) in Auckland. Clay is sourced from four clay pits: Brigham's Creek, Clevedon, Kopuku and Port Waikato (Taylor, 1994). Brigham's Creek clay pit, Kumeu, 20 km north of Auckland, produces 12,000 tpa of clay (mainly halloysite) from weathered Taupo Alluvium. The halloysite can cause shrinkage and drying problems, which are controlled, if not eliminated, by the admixture of ironsand of a specific particle size. Pumiceous sand derived from the Waikato River may also be used to promote fluxing.

Clevedon clay pit, south of Auckland, produces 9,000 tpa of clay (halloysite with lesser kaolinite and illite) from weathered argillite. The clay is used as a filler material to improve the red body colour in bricks. Kopuku clay pit, 60 km southeast of Auckland, is in a former coal mine from which kaolinite is produced at about 14,000 tpa. Four different clays are derived from this site, all of them possessing light burning colours, good strength characteristics and relatively high shrinkage rates. Port Waikato, 90 km south of Auckland, produces about 14,000 tpa of clay (illite, smectite and vermiculite) from weathered argillite. The clay is extremely hard and possesses good weather resistant properties.

Some of the clay pits, particularly in the South Island, are small scale operations working small pockets of clay within larger areas of clay-bearing rocks.

Bentonite

Bentonite is mined by Omya (New Zealand) Limited in the Harper Hills near Coalgate, 65 km west of Christchurch (Fig. 2). Annual production peaked at 19,722 t in 1970, and was 7,000 t in 1996. Non-swelling calcium bentonite occurs in a main bed up to 62 m thick, separated from a lower, carbonaceous bentonite bed by 3 to 4 m of quartz sand and gravel. It is processed by treatment with soda ash to impart swelling properties. Measured resources total around 11 Mt, but inferred resources are much larger. Coalgate bentonite is used as a binder for foundry sand, in drilling muds, for sealing clay dams and diaphragm walls in construction projects, as a bitumen emulsifier, in fibrous cement and as pellet binder in stock food.

Marine bentonitic beds are widespread along the east coast of both the North and South Islands. They have been worked in the past at Mangatu, north of Gisborne and at Porangahau, where there is a resource of about 1 Mt.

Diatomite

Diatomite has been quarried from several deposits for use as a mild abrasive, insulation, filtration, and pozzolan material. Two types of deposits are known: lake bed and marine (Ritchie, 1962). Diatom-rich lake deposits are interbedded with young volcanic sediments in Northland, Auckland, South Auckland, Waikato and Rotorua. A deposit at Mercer, South Auckland, is estimated to contain about 180,000 t of extractable diatomite and pumicite (Waterhouse, 1967). In the Rotorua basin there are considerable quantities of diatomite between Ngongotaha and Hamurana.

At Ngakuru in the Waikite Valley, 20 km south of Rotorua, diatomite beds have an aggregate thickness of 30 m and contain medium to high grade diatomite, ranging from 50-90% diatom content, with pumicite as the other main mineral. Diatomite Products Limited, a subsidary of Rockfield Investments Limited, is currently developing the Ngakuru deposit with production expected at 20,000 m^3 pa (Louthean, 1999). Drilling in 1998 delineated about 3.5 M m^3 of diatomite in a central mining block.

At Middlemarch in Otago, diatomite lake beds are more than 35 m thick. Resources are estimated at about 5 Mt. These deposits are being developed by Featherston Resources Limited to provide high grade filtration products.

The marine deposits near Oamaru cover an area of about 26 km^2 and contain diatom-rich beds up to 9 m in thickness (Edwards, 1991). These extensive deposits are being mined by Rosebery Enterprises Limited, principally for use as pet litter.

Dolomite

Dolomite is present on Mt Burnett, in Northwest Nelson (Fig. 6). It occurs as discontinuous lenses in a folded dolomite-marble sequence. The dolomite is 60-70% $CaCO_3$, 28-39% $MgCO_3$, with up to 3% SiO_2 and up to 0.66% Fe_2O_3 (Bishop and Braithwaite, 1969). The main lens of dolomite contains about 70 Mt. Other lenses each contain up to 1 Mt.

Omya's plant at the Mt Burnett quarry has a capacity of around 100,000 tpa, although current output is of the order of 25,000-40,000 tpa. About 80% of the product is used as an additive to phosphatic fertilisers for spreading on magnesium-deficient soils and the balance is used for aggregate and rip rap. Physical and chemical analyses indicate that the Mt Burnett material would be suitable for refractories, insulation wool and magnesium metal production. The dolomite has formerly been used in glass manufacture and in the steel industry. Omya barges dolomite from nearby port facilities either direct to customers or to storage facilities at Wanganui in the North Island. Dolomite blocks have also been barged to Wellington for use in harbour breakwaters.

Feldspar

Plagioclase feldspar-rich dune, beach and marine sands of Quaternary age found at Ruakaka Flat and Mangawhai, south of Whangarei and near Kaipara Harbour (Thompson,

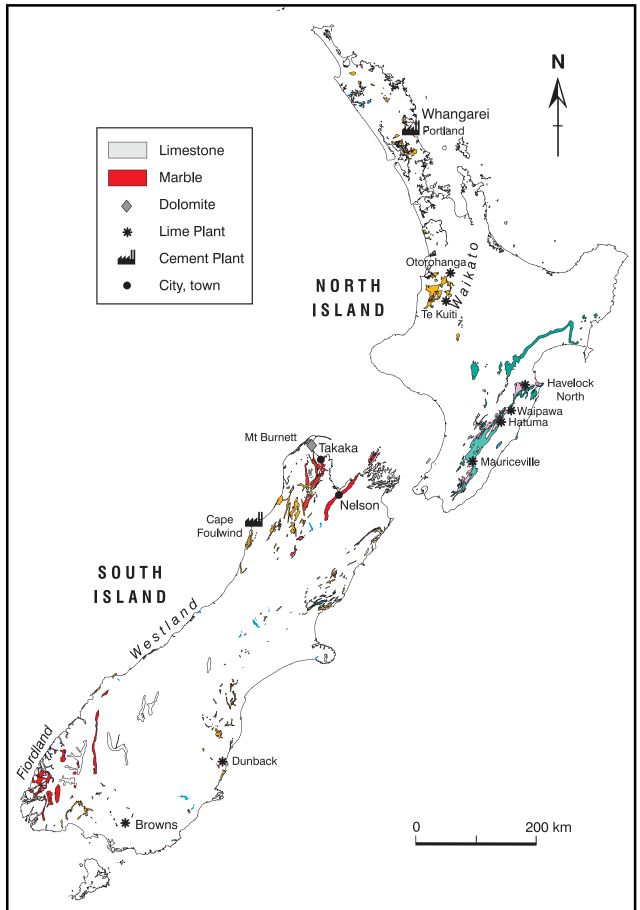

Figure 6: Locations of limestone, marble and dolomite deposits in New Zealand.

1989). The Ruakaka deposit consists of andesine (67%), quartz (25%), iron-rich minerals (4%) and rock fragments (4%). The northern end of Ruakaka Flats is estimated to contain 50 Mt of sand, which would yield, at 60% recovery, 30 Mt of saleable minerals. At the southern end there is probably in excess of 350 Mt of sand.

Ilmenite beach sands

Ilmenite rich black sands, with locally economic concentrations of gold, are present at intervals along 320 km of the west coast of the South Island (Christie and Brathwaite, 1998; Fig. 7). The black sands are contained in narrow (less than 1.6 km wide), elongate beach and dune sand deposits. The black sand contains 5-15% ilmenite. The titanium dioxide content (45-47% TiO_2) of the ilmenite is low by world standards (e.g. 52-57% TiO_2 for Western Australian ilmenite) due to inclusions of garnet and other silicate minerals. In addition to ilmenite, the sand also contains significant garnet and magnetite and minor zircon, gold, uranothorite and monazite. There are also trace quantities of scheelite, rutile, cassiterite, xenotime and beryl in places along the coast.

Barrytown, the largest deposit, extends over a distance of 16 km along the coast (Mann and James, 1989). Westland Ilmenite Limited estimated resources of 50 Mt of potentially mineable sand at an average grade of 13.8% ilmenite (6.9 Mt), 0.2% zircon and 100 mg/m^3 gold. Recent exploration at Westport by Austpac Titanium Limited has indicated a resource of 17-30 Mt of ilmenite. Austpac has successfully treated Westport ilmenite using the patented ERMS process to produce synthetic rutile with a grade exceeding 99% TiO_2.

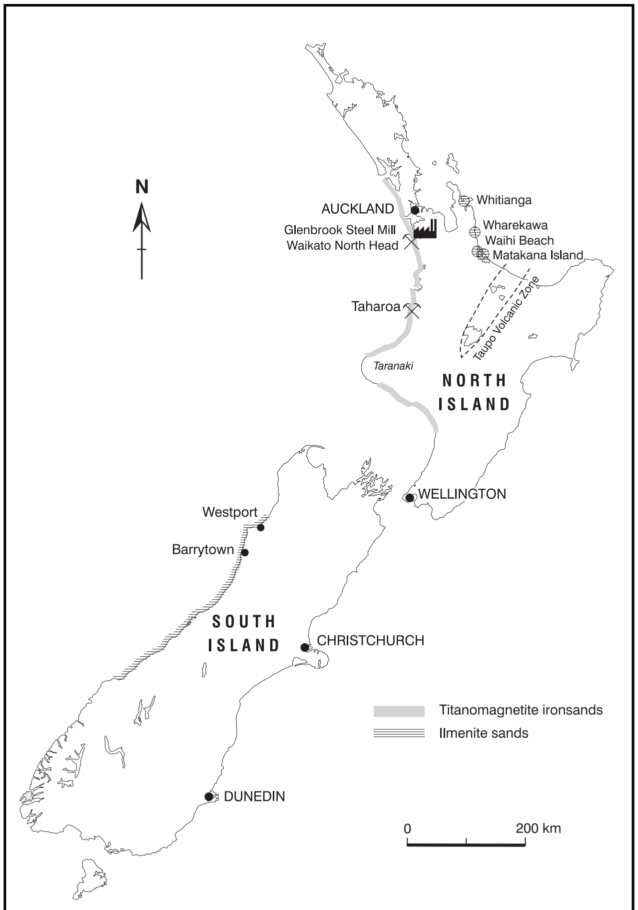

Figure 7: Locations of titanomagnetite ironsand and ilmenite sand deposits in New Zealand.

Ilmenite beach sand deposits are also present on the east coast of the Coromandel Peninsula in the North Island. The main deposits are Whitianga (Wharekaho Bay), Wharekawa (Opoutere Beach), Waihi Beach and Matakana Island.

Limestone

Limestone deposits are widespread throughout New Zealand (Fig. 6). Limestone containing more than 70% $CaCO_3$ is used for agricultural fertilizer and for roading aggregate. High grade limestone and marble suitable for domestic and export industrial use are widespread. The best quality large tonnage deposits, containing 97.4-99.5% $CaCO_3$, are present in the south Waikato where limestone is produced for fertilizer, roading aggregate and hydrated lime manufacture. Limestones in Canterbury, and marble from west Nelson are used by the major producer Omya (NZ) Limited for manufacture of industrial grade lime. Cement works near Whangarei and Westport use local high grade limestones mixed with marl for their feed.

Cement

New Zealand has two cement manufacturing plants, one at Portland, near Whangarei, operated by Golden Bay Cement Company Limited, and the other at Cape Foulwind, near Westport, operated by Milburn New Zealand Limited, a subsidiary of the Holderbank group (Fig. 6). The domestic market is the principal consumer of the cement products, although some is exported to the Pacific Islands.

The Portland plant produces about 490,000 tpa. The main raw material feed consists of 75% argillaceous marl (approx

Figure 8: Limestone quarry and cement plant at Portland, near Whangarei, Northland. Photo: Lloyd Homer.

75% $CaCO_3$) and 25% crystalline limestone (South et al., 1999). Imported gypsum is used as a setting retardant. The argillaceous marl is quarried near the Portland cement plant at a rate of 600,000 tpa (Miller, 1999). The crystalline limestone is sourced from the company's Wilsonville Quarry, 20 km north of Whangerei. Bulk and bagged cement from the Portland plant is distributed locally by road while the company's coastal supply ship transports cement further afield.

Milburn's Cape Foulwind plant is located 10 km west of Westport and produces 470,000 tpa (Fig. 8). Limestone and marl quarrying operations are centred on a crusher facility near the cement plant. The thick, gently dipping limestone is overlain by a similar thickness of marl (Pettinga, 1993). Bulk cement is transported by ship, road and rail to cement supply centres throughout New Zealand.

Lime and limestone for industry and agriculture

Omya (NZ) Limited is a major producer of limestone for industry. Its main operation is located 5 km north of Te Kuiti, in the south Waikato. It produces high grade limestone (98-99% $CaCO_3$) with a current output of about 50,000 tpa. This material is used domestically as a filler in paper, plastics, paint and rubber, for paper surface coatings, and in glass. High grade limestone for industry is also produced by Robert Hall from the Te Kumi Quarry, located 5 km north of Te Kuiti. Production is about 9,000 tpa.

Milburn New Zealand Limited is a major producer of burnt lime, with the company's lime division having a strong presence in both the North and South Islands via its subsidiary companies McDonalds Lime Limited and Taylors Lime Company Limited.

At Otorohanga, 60 km south of Hamilton, McDonalds quarries high grade crystalline limestone producing about 124,000 tpa of burnt lime, 120,000 tpa of high grade limestone and 247,000 tpa of ground limestone for agriculture. The principal industrial uses are in steelmaking at the Glenbrook mill operated by BHP New Zealand Steel (Fig. 7), in processing gold ore at the Martha Hill gold mine at Waihi, and offshore at Lihir (Papua New Guinea) and Gold Ridge (Solomon Islands), in paper pulp manufacture at the Tasman and Carter Holt Harvey paper mills, in the sugar industry, in soil stabilisation, and in sewage sludge and waste water treatment.

In the South Island, Taylors Lime operates a plant at Dunback, 60 km north of Dunedin. The plant quarries a lens of crystalline limestone (96-98% $CaCO_3$) in Triassic age greywacke. This quarry used to supply the former Burnside Cement Works in Dunedin. Taylors now supply burnt lime and ground limestone mainly for use in processing gold ore at the Macraes Flat gold mine. Other markets include water treatment, soil stabilisation, sewage sludge and waste water treatment, agriculture, plus an expanding market for finely ground limestone for the plastic, rubber and glass industries.

A significant producer of agricultural or non-burnt lime is Hatuma Lime Company Limited which operates three quarries - Hatuma (51,000 tpa), Waipawa (9,000 tpa) and Mauriceville (20,000 tpa) in the central Hawke's Bay and Wairarapa areas. All three quarries mine selectively to produce limestone with a purity ranging from 90% up to 95% $CaCO_3$. The Hatuma limestone is notably low in iron - 185 ppm. All output is sold solely for agricultural use within the domestic market.

Awarua Browns Lime Limited is producing agricultural lime from its main operation north of Invercargill in Southland, as well as from other sites. Output from the operation is approximately 100,000 tpa. Limestone extracted from the quarry is crushed, dried, pulverised and classified. Milburn Lime Limited is working the resource at Milburn in South Otago, which is the site of the original Milburn Lime Company Limited.

Other lime producers include Webster Hydrated Lime Limited, near Havelock North and Mata Lime near Whangarei. Websters works shelly limestone, producing about 8,000 tpa of hydrated lime. Other smaller producers, include Austin Chalk Company Limited, Redvale Lime Limited, Valley Lime Limited, Firth Industries Limited and Springfield Lime Company Limited.

Recently, some overseas companies have been interested in purchasing large quantities of limestone for use in industrial chemical applications. Several suitable limestone resources in the south Waikato, Nelson and Westland regions are close to transport links.

Marble

Large resources of marble are present in Northwest Nelson and Fiordland (Fig. 6). The main production has been from quarries on Takaka Hill in Northwest Nelson, for use as building stone, and in industry and agriculture.

The Ngarua quarry, located 15 km northwest of Motueka, Northwest Nelson, is owned by Omya (NZ) Limited and quarries 15,000-20,000 tpa of white marble with a calcium carbonate content greater than 98.6%. The product is used as a filler and for the surface coating industry, although about half of the production is used for agricultural lime.

Magnesite

Magnesite occurs along with talc in ultramafic rocks in Northwest Nelson, Westland, north Otago and Southland (Williams, 1974). The main occurrences are in the Cobb-Upper Takaka district, where magnesite occurs in lenses derived from serpentinite of the Cobb Igneous Complex. At Cobb, 21,802 t of magnesite were produced up to the cessation of mining in 1981. L&M Mining Ltd are currently investigating the magnesite deposit at Cobb as a potential source of raw material for magnesium metal production.

Perlite

Large resources of perlitic rhyolite occur as near surface layers on rhyolite domes and as flows of perlitic, glassy rhyolite lava in the Rotorua-Taupo area and on Great Barrier Island. About 2,000 tpa are quarried at Atiamuri, southwest of Rotorua by Industrial Processors Limited. The material is processed in Auckland by crushing, screening and heating to 900°C, to expand the perlite by 7-20 times. It is used in the domestic market as an inert insulator and filler, and for horticultural/pot plant mixes.

The high expansion capacity of perlite from the Taupo Volcanic Zone, which results partly from its young age, makes it particularly good for filtration applications. There is potential for developing this market.

Phosphate

Phosphate has been mined at Clarendon, southwest of Dunedin (Fig. 2), where phosphate-rich beds are found near the top and bottom of the 40 m thick Clarendon Sand. Remaining resources are about 5 Mt grading 11% P_2O_5 (Douglas, 1989). There is potential for a combined phosphate and glauconite operation provided suitable processes and markets can be developed.

Extensive phosphate resources are present in submarine deposits along 400 km of the crest of the Chatham Rise, in water depths of about 400 m, east of the South Island (Cullen, 1989). They consist of nodules, typically 10-40 mm in diameter, in a layer up to 70 cm thick, within a glauconitic sandy mud matrix. The areal distribution of the nodules is very patchy, the highest concentration averaging 66 kg/m^2. Dredge sampling has outlined an estimated provisional resource of 100 Mt of nodules averaging 21% P_2O_5. Test trials have demonstrated that the material is suitable for use as a direct application, slow-release phosphate fertilizer.

Pumice

Pumice is quarried from very large pyroclastic deposits in the Taupo Volcanic Zone and dredged with sand from alluvium in the lower reaches of the Waikato River. Annual production is estimated at 500,000 t. The main uses of pumice are as fill in road construction, for sand in concrete block manufacture, and for foundations and drainage. It is also used in horticultural soil mixes and is exported for use in the stone washing of denim clothing.

The major deposits of primary ash-flow pumice are all in the Taupo-Bay of Plenty area. Alluvial deposits of pumice are present near Hamilton, on the Hauraki Plains and along the Waikato and Wanganui rivers.

Winstone Aggregates Limited is a major pumice producer. The company operates two sand plants south of Auckland extracting material from the Waikato River at Tuakau and Puni. The raw materials dredged consist of a mixture of sand and gravelly pumice in roughly equal proportions. During 1998, the Puni sand plant recovered approximately 150,000 t of dredged aggregate, while the Tuakau operations produced 126,000 t.

Salt

Although there are no natural bedded salt deposits in New Zealand, salt is produced by Dominion Salt Limited at

Figure 9: Solar evaporation salt works at Lake Grassmere, Marlborough. Photo: Dominion Salt Ltd.

Grassmere, south of Blenheim, by solar evaporation of sea water (Fig. 9). The evaporation ponds are constructed in a low-lying area close to the sea. They are separated into paddocks with gates to admit and retain sea water. Low rainfall, high sunshine hours and adequate wind assist in the evaporation of the sea water with a resulting salt production of about 60,000 tpa. Apart from the Grassmere facility the company owns associated refineries on the same site and at Mount Maunganui, Tauranga, in the North Island, supplying raw solar and vacuum dried salt to the domestic market. The markets for the company's salt are in chlorine manufacture, edible salt, water treatment, tanning, dairy and agricultural usage.

Serpentine

Small quantities of serpentinite are mined and crushed for use as an additive to superphosphate fertilizer to supply magnesium and to assist in the free-running properties of fertiliser required for aerial topdressing. At Piopio, 100 km south of Hamilton (Fig. 2), diapiric serpentinite bodies, up to 1 km in length and 60 m in width, are emplaced vertically along the Waipa Fault. Rorison Mineral Developments Limited produces 19,000 tpa at Aria, near Piopio (Louthean, 1999). The serpentine is used as an additive in the manufacture of magnesium superphosphate fertiliser. Some serpentine is also used as ornamental stone.

At Greenhills, near Bluff, in Southland, layered bodies of serpentinised gabbro and peridotite are present in the Bluff Complex. Greenhills Quarrys Limited produces 12,000 tpa for use in the manufacture of magnesium superphosphate fertiliser. Resources are estimated at about 18 Mt (Louthean, 1999).

Silica - sand and lump

Silica sand

Silica sand of Quaternary age is found in dune, beach and shallow offshore marine sand deposits along the present day coastline. The principal localities are all in Northland, at Parengarenga Harbour on the east coast and around Kaipara Harbour on the west coast (Fig. 2). These deposits have been derived from intense chemical weathering of sedimentary rocks. The quantity of silica sand is not well defined. There are probably more than 80 Mt at Parengarenga Harbour, and possibly 10 Mt in the Kaipara Harbour area. Until recently, about 40,000 tpa of sand were dredged from Parengarenga Harbour by ACI NZ Glass Manufacturers and processed into glass in its Auckland factory. This operation is likely to resume shortly. The sand is quartz-rich, with SiO_2 ranging between 95.7-97.7%, Fe_2O_3 between 0.05% and 0.42%, and Cr_2O_3 between 0.004 and 0.013%.

Silica sands are also concentrated on erosional land surfaces associated with coal measures in the South Island. The main occurrences are at Mt Somers in Canterbury and at Charleston in Westland. There are other deposits in East Otago and Southland.

Large quantities of sand are available at Mt Somers and its high silica content can be upgraded to 99.6% SiO_2 by washing. Webb Transport Limited mine silica sand at Mt Somers for the glass, foundry and building industries. The several million tonnes of sand at Charleston contain mica (10%) and feldspar (30%), which make it unsuitable for glassware, but it has been used locally in cement making.

Figure 10: Sampling in the amorphous silica pit at Tikitere. Photo: New Zealand China Clays Ltd.

Lump silica

Quartzite

Quartzites formed by metamorphism of quartz sandstones occur as chert beds in greywacke in eastern Northland, where there are extensive deposits containing 90-93.7% SiO_2, and in Northwest Nelson, about 1 Mt of ferrosilicon quality quartzite containing 97-97.6% SiO_2 is associated with schist at Aorere (Fig. 2).

Quartz gravels

Quartz gravels in Southland are widespread and have potential for use in the production of ferrosilicon or silicon metal (Williams, 1974). The quartz gravels around Pebbly Hills-Mabel Bush, in central Southland, were prospected in the early 1970s and further evaluated in 1990-91. The deposits are inferred to contain more than 350 Mt averaging 98% SiO_2. Of this amount, 30 to 40% is suitable for use in ferrosilicon production. Preliminary tests conducted on the raw silica from Pebbly Hills by a ferrosilicon producer have indicated the suitability of this material for that purpose. The availability of abundant low ash coal and hydro-electricity are other factors favourable to a ferrosilicon industry in Southland. Material from Pebbly Hills is presently being investigated by Silicon Metal Industries (NZ) Ltd as a raw material for silicon metal production. Elsewhere in Otago and northern Southland there are smaller deposits of similar material.

Amorphous silica

Amorphous silica is deposited by hot springs as silica sinter and by hydrothermal alteration of nearby rocks in volcanically active areas. In the Taupo Volcanic Zone, acid sulphate alteration in the near surface parts of active geothermal systems has resulted in the conversion of all minerals, except primary quartz, to an assemblage of amorphous silica + cristobolite ± native sulphur, alunite, cinnabar and barite (Roberts, 1997). The end result is a low density, white, porous rock composed primarily of amorphous silica and residual quartz phenocrysts. Three amorphous silica deposits have been explored recently, Tikitere and Taheke, near Rotorua, and Lake Rotokaua, near Taupo (Fig. 2). The Tikitere deposit is currently being mined by Microsilica New Zealand Limited.

The amorphous silica at Tikitere (Fig 10) is hosted in hydrothermally altered rhyolitic ignimbrite and overlying pumice breccia within the Tikitere hydrothermal field (Taylor and Thorpe, 1999). Resources are in excess of 1 Mm^3. The amorphous silica product, marketed as Microsilica 600, is used as a pozzolanic cement additive to produce high quality, strong and durable concrete, sprayed tunnel linings, mortars and grouts. Microsilica 600 is used locally and exported. The natural amorphous silica product, having no carbon contamination, has a colour advantage over condensed silica fume. Microsilica 600 significantly reduces damage to concrete from chemical attack in seawater environments.

Microsilica New Zealand Limited also has a mining permit over the Taheke deposit, where shallow drilling is understood to have outlined in excess of 2 Mt of high-grade amorphous silica.

The amorphous silica deposit at Lake Rotokaua was discovered in 1995 by Resource Developments Limited (Roberts, 1997). Past drilling for sulphur exploration shows that the hydrothermal alteration of various rock types extends up to 75 m below the surface, over an area in excess of 2 km^2. Amorphous silica is concentrated in a succession of rhyolitic rock units. The oldest unit consists of rhyolitic and accretionary lapilli tuffs, up to 50 m thick. This is locally overlain by up to 40 m of hydrothermal eruption deposits, lake sediments, sulphur ore and thin interbedded ashes. The youngest unit mantles the area and is represented by up to 50 m of pumice breccias, pumice sands and vitric tuffs. In places, intense acid leaching has converted the breccias to fine-grained amorphous silica and residual phenocrystic quartz, typically with 99% SiO_2 and less than 0.6% combined Al, Mg, Ca, K and Na. Resources are estimated to be about 4.5 Mt.

Sulphur

Deposits of native sulphur are associated with present-day and fossil geothermal areas at Ngawha in Northland and in the Bay of Plenty and Rotorua-Taupo areas. Main areas of past production are White Island, Tikitere, Lake Rotorua and Lake Rotokaua. There is currently no significant production.

Lake Rotokaua, 12 km northeast of Taupo, offers the best potential for large scale sulphur mining, although the location of this resource within an active geothermal system poses some mining problems. Two types of deposits are present - lacustrine sulphur present within a buried lake bed and surface mineralisation where crystalline sulphur impregnates a brecciated pumice horizon (Sinclair, 1989).

In the lacustrine type of mineralisation, the sulphur occurs in a colloidal state disseminated throughout the lake mud. The mineralisation is buried some 25-75 m below the present land surface and extends under Lake Rotokaua. These lake sediments, amounting to an estimated 57 Mt, are estimated to contain 4.9 Mt of elemental sulphur. Although the overall grade for the lacustrine mineralisation is estimated at 10% sulphur, there are several layers within the bed where it is concentrated to 60-80% sulphur.

The surface deposit is much smaller with resources of approximately 100,000 tonnes of pumice breccia containing 10-15% sulphur. These surface deposits were intermittently mined up to 1991, but are now considered too small for further commercial development.

There is potential for pelletising the sulphur and using it as a direct application fertiliser in specialised agricultural markets, replacing imported granular products.

A sulphide form of sulphur deposit is found in the Kauaeranga Valley, near Thames, where about 15-20 Mt of mineralised rock averaging 7-8% sulphur as pyrite is associated with hydrothermally altered andesitic lava and breccia and silty sediments of Miocene age. Pyrite is also found in a skarn deposit adjacent to a granite intrusion of Early Cretaceous age at Copperstain Creek near Takaka. The granite intrudes marble and biotite schist. Drilling at Copperstain Creek found resources of 10.5 Mt of 7.5% sulphur, with associated copper and molybdenum (Williams, 1974).

Titanomagnesite ironsand

BHP New Zealand Steel Limited produces about 2.4 Mtpa of titanomagnetite concentrate for export and for domestic steel manufacture, from two mines south of Auckland (Fig. 7). The material is mined from extensive titanomagnetite "ironsand" deposits which are present at intervals over 480 km along the coastline of the North Island (Kear, 1979; Christie and Brathwaite, 1997). Estimated resources are in excess of 1,400 Mt of concentrate (Stokes et al., 1989). The ironsand is mainly in dunes, with lesser amounts in beach sands. The titanomagnetite is derived from erosion of andesite volcanoes of Taranaki and rhyolite volcanic rocks of the Taupo Volcanic Zone, and has been concentrated by longshore currents, and wave and wind action.

At Waikato North Head, south of Auckland, BHP mines 6 Mtpa of ironsand using bucket wheel excavators. The ironsand is concentrated on site to produce 1.2 Mtpa of titanomagnetite concentrate (Waterhouse and MacArthur, 1989; M. O'Connell, pers. comm., 1999). The concentrate is slurried 18 km to the steel mill at Glenbrook. Measured ironsand resources at Waikato North Head are estimated at 200 Mt averaging 25% titanomagnetite (M. O'Connell, pers. comm., 1999).

The Glenbrook mill produces a vanadium rich slag during steel manufacture. Currently 12,000 t/yr is produced and exported to China, representing 1% of the World's vanadium production. The slag is processed to increase the concentration of V_2O_5. The enriched product is used to make ferrovanadium, which is used as an additive in steel. The recovery of titanium from the slag is not economic with currently available technology, however BHP New Zealand Steel is investigating methods of producing a 30-40% TiO_2 concentrate byproduct by separating the titanium minerals ilmenite, leucoxene and rutile from ironsand at the Waikato North Head mine. The concentrate would be exported for use in the manufacture of TiO_2 pigment.

At Taharoa, 150 km south of Auckland, ironsand is mined by dredging beach and dune sand to produce 1.2 Mtpa of concentrate averaging 40% titanomagnetite (Stokes et al., 1989). The concentrate is slurried through a 3 km long pipeline from the shore onto a ship for export. The product is used by steelmakers in Japan and China for preserving blast furnace liners and for blending to produce low nitrogen steel (Maré, 1997). Indicated resources of ironsand at Taharoa are more than 200 Mt.

Waikato North Head production is limited by the capacity of the Glenbrook steel mill to 1.2 Mt of concentrate annually. Taharoa has previously produced up to 2 Mt in a year. Assuming expanding markets, future ironsand production could increase from the current operations. In addition to currently produced byproduct vanadium-rich slag, there is potential to produce an ilmenite-rich concentrate from the ironsand mining.

Zeolite

The Taupo Volcanic Zone hosts a number of zeolite deposits formed by hydrothermal alteration of suitable precursors such as vitric tuffs (Roberts, 1997). A large occurrence is at Ohakuri, where glass within the Ohakuri ignimbrite and younger pyroclastics has been hydrothermally altered to the zeolites mordenite and clinoptilolite, as well as smectite and opal.

NZ Natural Zeolite Limited, a subsidary of Resource Refineries Limited of Matamata, produces 5,000 tpa of zeolite from three deposits discovered over the last seven years at Ngakuru, about 20 km south of Rotorua. A further five large deposits have been identified in the area.

At Ngakuru (Fig. 11), hydrothermally altered tuffaceous lacustrine sediments are exposed intermittently along several faults within a 6 x 3 km area and have a thickness in excess of 40 m. The alteration has produced a zeolite + smectite + cristobolite + amorphous silica assemblage, locally containing between 25 and 90% zeolites, mainly clinoptilolite and mordenite (Roberts, 1997; C. Mowatt, pers. comm., 1999). There is some evidence of zoning with respect to the zeolite varieties. Mordenite increases with depth at the expense of clinoptilolite, presumably reflecting increasing temperature of alteration. The open-pittable resource of deposits identified to date exceeds 10 M t. When compared with zeolite deposits mined in other parts of the world, those from Ngakuru are young in geological terms (250,000 years) and have exceptional properties of adsorption.

The channel-like, 3-D crystal structure of zeolites provides a large surface area for chemical exchange reactions and adsorption of various materials. Because the channels are all the same size and shape, they can be used as molecular sieves, as well as ion exchangers and adsorbents. Each of the zeolite deposits quarried at Ngakuru has unique characteristics. They are specifically suitable as:

1. adsorbents for soaking up oil/chemical spills, as cat and animal litters, and as a stockfeed additive;
2. water softening, waste and potable water treatment, sports turf and potting mix amendment; and
3. odour adsorbents and as cosmetic additives.

Other occurrences of zeolite in New Zealand are known from Southland (Coombs et al., 1959), and in Northland and Auckland (Sameshima, 1975).

Recent developments

Several investigations have been made into the feasibility of artificially precipitating minerals from geothermal water presently used in geothermal electricity generation (Martin, 1986, 1997). Geochemistry Research Limited, in conjunction with Industrial Research Limited, has developed a patented extraction technology for the removal of silica from geothermal water. Fletcher Challenge is investigating using high grade silica sourced from geothermal water for filler and coating applications in high quality inkjet and laser printing paper (Waterman, 1998). The silica, which has a medium particle size in the order of 0.4 microns, has advantages in its light scattering and oil adsorption properties and is used as a flatting agent in paints.

Pacific Lithium Limited, an Auckland company, has experimented with the extraction of lithium from seawater at Thames on a pilot plant scale (Waterman, 1998). At present Pacific Lithium imports 1,500 tpa of lithium hydroxide and refines it into 1,200 tpa of high purity lithium carbonate for export.

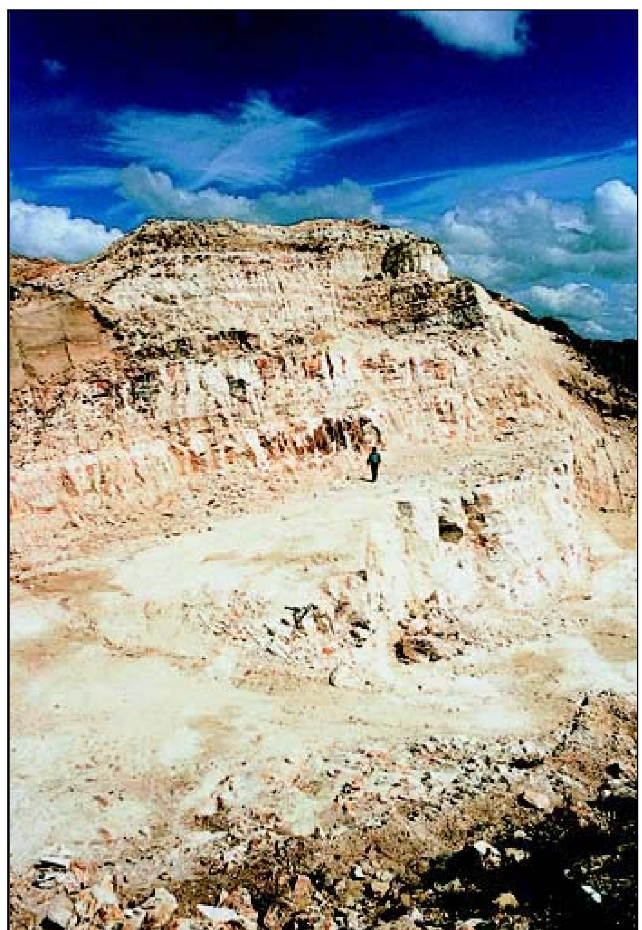

Figure 11: Zeolite quarry at Ngakuru. Photo: NZ Natural Zeolite.

Conclusions

New Zealand has a surprising number of industrial minerals including high grade silica sand, amorphous silica, bentonite, diatomite, dolomite, halloysite, limestone and lime, perlite, pumice, zeolite and a variety of brick clays. Most production is consumed locally with the exception of halloysite, which is exported to worldwide ceramics markets. Over the last few years there has been increasing production of amorphous silica, zeolite and, more recently, diatomite. There are large resources of amorphous silica, pumice and zeolite in the central North Island and of diatomite in the central North Island and Otago. These products have considerable export potential. High grade limestone is widely quarried for cement manufacture, agricultural lime and for hydrated lime and recently there has been interest from overseas in purchasing large amounts of limestone for industrial chemical applications.

A major constraint on the domestic industrial minerals sector is New Zealand's small population (3.8 million) and its location far from major industrial markets. Any significant increase in production clearly lies in the development of value added products and the placement of unique high-quality products into niche markets. Clay producers have shown that high quality clay can be exported profitably into Asian, Australian, North American and European markets where it is used to make ceramic and bone china products. Those same markets have experienced high levels of economic growth and high quality packaged filtration and absorption products, and pet litters, should find ready acceptance. Likewise, New Zealand amorphous silica is truly amorphous compared with many overseas tripolite products and has excellent pozzolanic properties.

The west coast beaches of the South Island have very large resources of ilmenite and garnet sand. Ilmenite resources have been thoroughly appraised but have still to be recognised internationally as a raw material for titanium dioxide manufacture. Garnet and zircon are typically discarded from placer gold mining operations although at least one miner is stockpiling these products in case a market can be identified in future.

In summary there are numerous industrial mineral products present in New Zealand. Many are being used in domestic industrial minerals markets and there are growing numbers of specialty products finding niche overseas markets. There are still mineral products which have not yet been adequately marketed but, with more development they could be made into value added products for export to expanding Asian, Australian, North American and European markets.

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