Mineral resource assessment of the West Coast Region, New Zealand

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ABSTRACT

The West Coast region of the South Island is endowed with a wide variety of geological resources as a result of a complex geological history from early Paleozoic to Recent. Gold, coal, aggregate, limestone, and rip rap are the most important resources currently extracted. Additional commodities mined at present or in the past include antimony, clay, dimension stone, mica, greenstone (pounamu), silica sand, and silver. Other commodities of potential interest include feldspar, fluorite, garnet, molybdenum, monazite, serpentinite, titanium, tungsten, and zirconium. There are also occurrences of asbestos, barite, beryllium, chromium, copper, lead, nickel, talc-magnesite, tin, uranium, and zinc.

Gold production began with the gold rushes of the 1860s. Approximately 240,000 kg of gold have been mined from fluvioglacial and beach placer deposits, predominantly of Pleistocene age, and about 100,000 kg have been produced from auriferous quartz veins in Ordovician greywacke. Current mining of the placer deposits produces more than 300 kg (possibly >1000 kg) of gold annually from c. 35 small operations and the Grey River dredge, and hard rock mining at Globe-Progress near Reefton produces c. 2,700 kg of gold annually.

The West Coast coal region comprises the Greymouth, Buller, Pike River, Reefton and 10 other smaller coalfields that have produced more than 120 Mt to date. Coal mining began in 1864 (Greymouth Coalfield) and production has been continuous to the present, amounting to more than 55 Mt from Paparoa (Late Cretaceous-Paleocene) and Brunner (Late Eocene) coal measures. Buller and Greymouth coalfields produce all of New Zealand's bituminous coal, whereas production from other areas within the region is of sub-bituminous coal. Current annual production is around 2.5 Mt and estimated recoverable coal resources are more than 200 Mt.

Aggregate sources are abundant and most of the 0.2 Mt annual production is from pits working greywacke and granite gravels in Quaternary fluvioglacial deposits and modern river channels. A few hard rock quarries work greywacke, granite or limestone.

Large deposits of Oligocene limestone are present. Current annual production is about 0.93 Mt in 2006, the latest year for which detailed statistics are available: 840,000 t for cement making, 90,000 t for agricultural lime and 3000 t for industry and roading.

Extensive deposits of Holocene ilmenite-rich sand are present along the coast with resources of 175 Mt estimated for the Barrytown-Twelve Mile, Nine Mile, and Carters deposits. Accessory minerals include garnet, gold, zircon, monazite, rutile, and cassiterite. Barrytown is the most intensively explored deposit and has resources of 50 Mt of sand at an average grade of 13.8% ilmenite (equivalent to 6.9 Mt of ilmenite), 0.2% zircon, 100 mg/m^3 gold, and less than 0.1% each of monazite and rutile. Large deposits of ilmenite are also present at Westport.

Kaolinitic clay, for production of fire bricks and building bricks, has been worked in the past from deposits in coal measures, deeply weathered basement rocks, and Tertiary mudstone units (e.g. Blue Bottom Group). Sandstone with a high silica content (ganister) is present in coal measures of the Buller, Charleston, and Greymouth coalfields, and silica sand occurs at Little Totara River and Ross.

Granitoid intrusive rocks and their contact zones in the metasedimentary country rock contain mineral occurrences of fluorite, scheelite, barite, chalcopyrite, galena, molybdenite,

cassiterite, and sphalerite; pegmatite dikes at Charleston contain beryl, feldspar and mica; and ultramafic rocks have asbestos, chromite, greenstone, nickel, serpentinite, and talc.

Resources of rock aggregate, sand and limestone have not been quantified, but are estimated to be large and sufficient to meet foreseeable local demand. Previous estimates have been used for in-ground resources of sub-bituminous and bituminous coal (818.65 Mt) and for ilmenite beach sands (approximately 30 Mt of ilmenite). Other potential mineral resources have been estimated using a three step process involving mineral deposit models, a geographic information system (GIS) of spatial data sets, and a counting method of assessment. In total, estimates have been made for 28 metallic mineral deposit models and for 10 non-metallic mineral deposit models.

There has been detailed geological mapping over the region, but no detailed airborne geophysical surveys or regional geochemical surveys have been undertaken. These types of surveys would provide new data that may lead to the discovery of new mineral deposits.

Scenarios are proposed whereby the value of the West Coast's annual mineral and coal production could increase from the current estimated NZ$602 million to NZ$866 million, by increasing production of individual commodities to past annual maximums (between 2000 and 2009, except 1995 for placer gold). It could increase to NZ$1,409 million annually by:

- New exports of 500,000 t of high quality aggregate;
- Increasing coal production from 2.5 Mt to 4.5 Mt;
- Increasing hard rock gold production from 87,100 oz (2009) to 120,000 oz;
- Increasing onshore placer gold production to 1995 levels (70,000 oz Au) and by new mining of offshore placer gold (50,000 oz Au);
- Development of an ilmenite beach sand mine producing 250,000 t of ilmenite concentrate;
- New mining of non-specified metallic and/or non metallic mineral commodities to an annual value of $50 Ma;
- An increase in production of other currently producing commodities to past maximum annual levels.

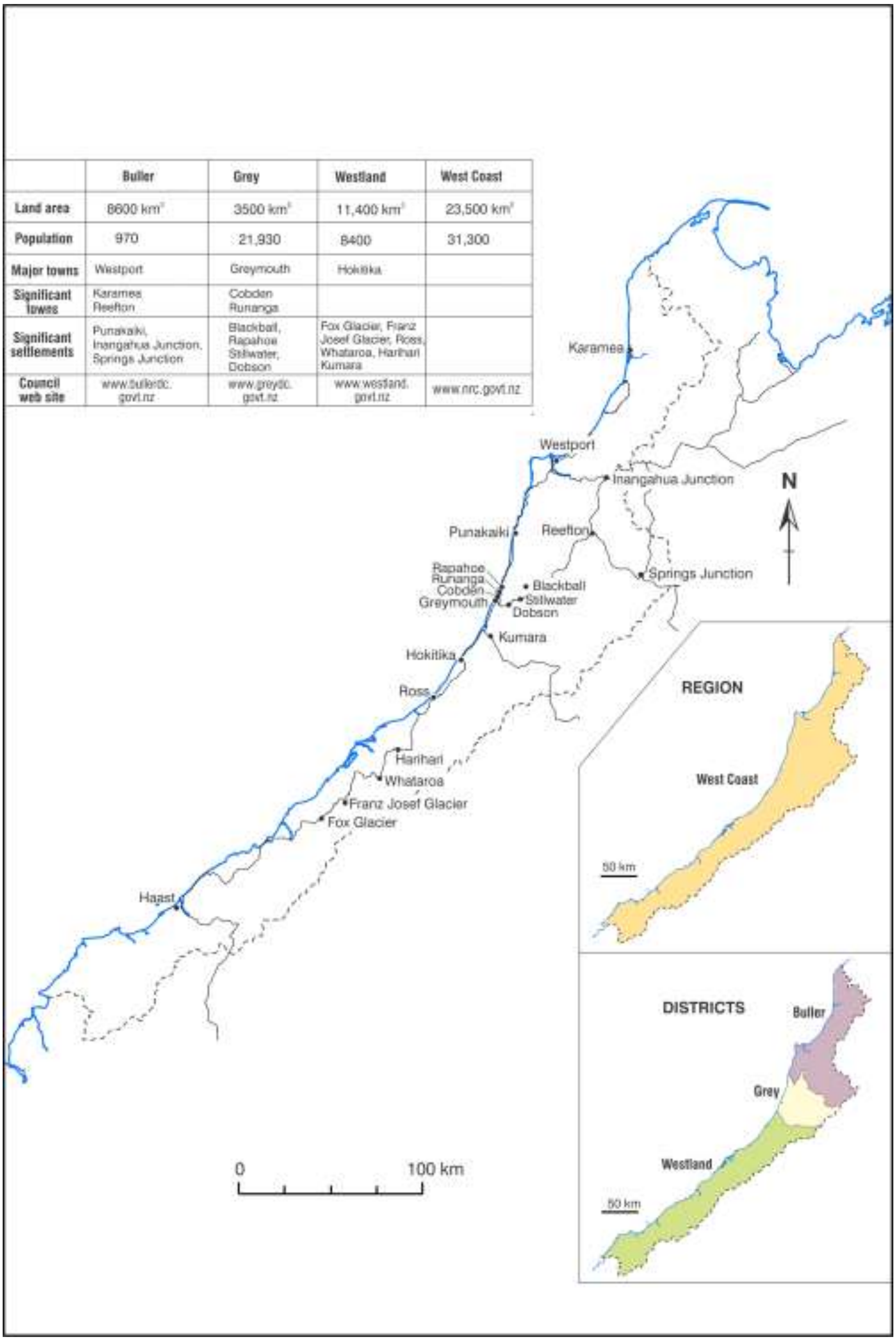
This scenario would be possible over a 15-20 year time-frame, provided that: 1) there is a sufficient level of exploration to define the new resources and 2) new discoveries can be developed. Attracting explorers to work in the region will require marketing the West Coast’s mineral potential to the international exploration community along with identifying and overcoming barriers to exploration and mineral development.

Keywords

Mineral resource assessment, West Coast, geographic information system, GIS, geology, mineral deposits, aggregate, antimony, asbestos, beryllium, chromium, clay, coal, copper; dimension stone, feldspar; fluorite, garnet; gold, greenstone, ilmenite, lead, limestone, mica, molybdenum, monazite, nickel, nephrite, platinum, rip rap; sand, serpentinite, silica, silver, talc, tin, titanium, tungsten, uranium, zinc, zircon.

1.0 INTRODUCTION

This report describes a mineral resource assessment of the West Coast region, comprising a land area of approximately 23,000 km^2 (Figure 1 and Figure 2), which amounts to about 9% of the land area of New Zealand. The land is administered by the West Coast Regional Council, and Buller, Grey and Westland district councils (Figure 1). A large area is land managed by the Department of Conservation (Figure 3).



	Buller	Grey	Westland	West Coast
Land area	8600 km^2	3500 km^2	11,400 km^2	23,500 km^2
Population	970	21,930	8400	31,300
Major towns	Westport	Greymouth	Hokitika	
Significant towns	Karamea Reefton	Cobden Runanga		
Significant settlements	Punakaiki, Inangahua Junction, Springs Junction	Blackball, Rapahoe Stillwater, Dobson	Fox Glacier, Franz Josef Glacier, Ross, Whataroa, Harihari Kumara	
Council web site	www.bullerdc.govt.nz	www.greydc.govt.nz	www.westland.govt.nz	www.nrc.govt.nz

Figure 1 Location map and division of the West Coast region into local authorities.

Figure 2 Topographic map of West Coast reproduced from LINZ 1:2 M map.

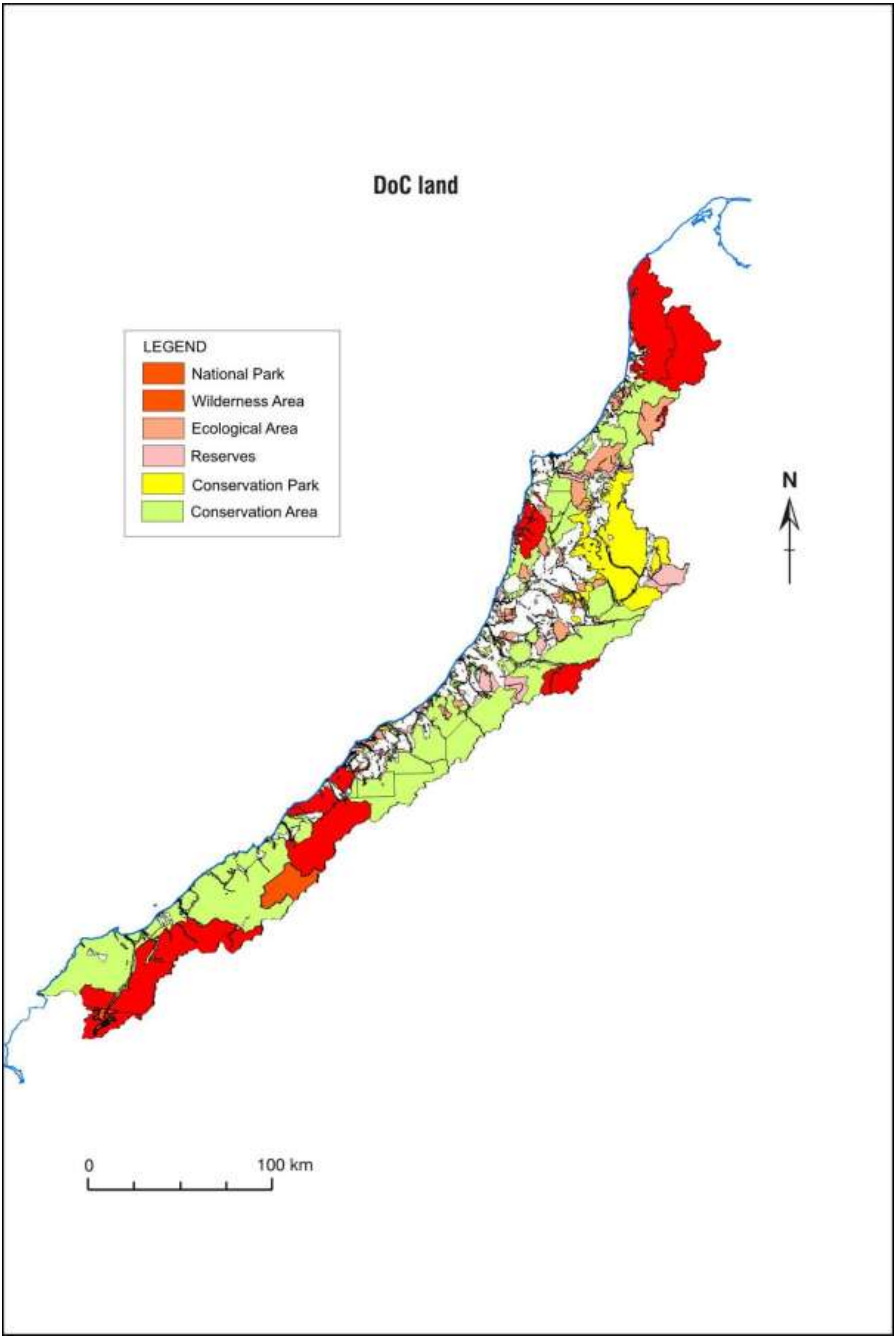


Figure 3 Areas of land administered by the Department of Conservation (DoC).

The West Coast region contains a wide variety of mineral commodities and currently produces coal, gold, limestone for cement and agriculture, rock and sand aggregates, decorative stone, and sand for industry (Table 1). Kaolinite clay, serpentine and mica have been mined in the past and there are prospects for other commodities including antimony, chrome, nickel, rare earth elements, tin, titanium, and tungsten.

Table 1 Annual mineral production for the West Coast region for 2005-2009.

Mineral commodity	2005	2006	2007	2008	2009
Bituminous coal	2,543,404 t	2,863,029 t	2,014,314 t	2,476,848 t	2,085,486 t
Sub bituminous coal	112,193 t	136,351 t	134,218 t	134,658 t	151,045 t
Gold, hard rock Reefton	-	-	1,179 kg (37,897 oz)	2,368 kg (76,132 oz)	2,710 kg (87,138 oz)
Gold, placer	168 kg (5401 oz)	454 kg (14,597 oz)	460.348 kg (14,801 oz)	284.273 kg (9140 oz)	326.682 kg (10,503 oz)
Building and Dimension stone	950 t	323 t	1,020 t	210 t	-
Decorative pebbles	8570 t	9490 t	75 t	16070 t	4393 t
Limestone and marl for cement	750,000 t	840,000 t	Withheld	Withheld	Withheld
Limestone for agriculture	96,860 t	77,278 t	96,836 t	96,724 t	86,296 t
Limestone for industry & roading	30 t	3120 t	3083 t	4249 t	597 t
Rock for reclamation & protection	30,950 t	103,295 t	63,633 t	88,445 t	51,230 t
Rock, sand and gravel for building	250,00 t	80,000 t	15,112 t	12,800 t	3200 t
Rock, sand and gravel for roading	281,080 t	362,743 t	294,252 t	99,112 t	71,715 t
Rock, sand, gravel & clay for fill	11,750 t	10,000 t	-	-	39,138 t
Sand for industry	50,300 t	5300 t	-	15,120 t	9450 t
Serpentine	20 t	-	-	-	-

Source: Crown Minerals (www.crownminerals.govt.nz/cms/minerals/facts-and-figures), except for the hard rock gold category which is production from the Globe Progress mine, sourced from www.oceanagold.com

Production values for placer gold and rock, sand and gravel for roading are anomalously low (especially for 2008 and 2009) and may represent incomplete reporting.

The minerals industry forms an essential part of the West Coast economy. Aggregate production underpins infrastructure and building development. Limestone used as fertiliser supports the agricultural industry. Although specific statistics are not available, in terms of end value, cement manufacture is one of the most important industries on the West Coast, worth more than $100 M per year. High quality coal is a significant export commodity. Additionally, small quantities of greenstone (pounamu) are produced for jewellery and ornaments.

The Ministry of Economic Development has been compiling and publishing mineral prospecting and exploration spending data since 1999 (Figure 4). Mineral prospecting and exploration spending on the West Coast increased dramatically from 2003 to 2008 and fell back in 2009 (note 2008 spending shown in Figure 4 is for only 9 months).

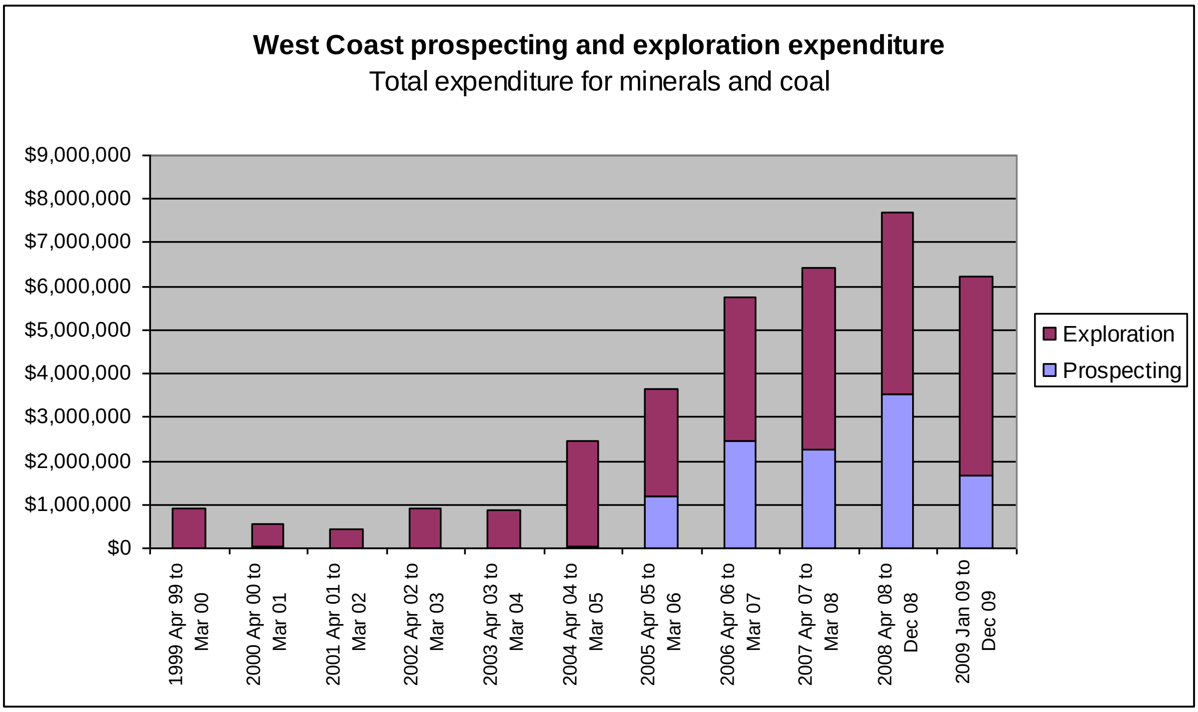


Figure 4 West Coast mineral prospecting and exploration expenditure (source: www.crownminerals.govt.nz).

2.0 MINERAL RESOURCE ASSESSMENT FACTORS AND LIMITATIONS

The mineral resource assessments in this report have been carried out with existing information and therefore the results must be considered in the light of the following factors:

Desk top study

This project is a desk top study that reviews available literature and data. There has been no field checking or new work on the geology of the deposits for this project.

In-ground resources

Mineral resource estimates are for gross, potential “in ground” resources. The estimates do not imply that the resources are recoverable, or that they can be mined at a profit.

These resource estimates are generally of potential resources and do not comply with Australasian JORC ore reserve reporting code of the Australasian Institute of Mining and Metallurgy (AusIMM) and related organisations. The AusIMM has adopted a code for valuing mining assets (the VALMIN code) that has been supported by the Australian and New Zealand stock exchanges. The application of the VALMIN code requires the assessment of technical and commercial factors that are outside the scope of the assessments in this report, which is designed for policy-making rather than for commercial purposes.

Value

Gross values have been calculated from the market price or sale price of the commodity and to realise this value, there will be costs in exploration, mining and processing that are not considered in the assessments in this report.

Constraints not considered

The mineral resource estimates have been made ignoring physical, topographical, political, environmental and other non-geological constraints, and are based solely on the probability of each environment containing a deposit of the specified type.

Undiscovered Deposits

The estimates of undiscovered deposits are the probability of a deposit being present, rather than of it being found. Also, the estimation process treats a prospective area as a single homogeneous unit. Estimated undiscovered deposits have no fixed position within the area, but also cannot be assumed to be evenly distributed throughout the area.

Changing technology

Advances in exploration, mining and processing technology may allow lower grade, smaller and or deeper deposits to be discovered and mined in the future.

Changing economics

Commodity prices fluctuate with time and market conditions.

New mineral deposit types

The future discovery of new mineral deposit types internationally and locally may greatly increase the prospectivity of some geological units and may make some of the estimates gross underestimates, particularly when relying on past history of production. For example, several commodities such as chromium and nickel may not be considered worth exploring at present. However, changes in price and technology in the future may make them worth investigating, and therefore they are included here as they represent resources that may have value in the future.

Studies of mineral potential based on existing data are inherently conservative because it is not possible to predict economic changes and technical advances. For example, in 1974 Gordon Williams, economic geologist and Dean of the Faculty of Technology at Otago University wrote (Williams 1974): “In the general area of the former Hauraki Goldfields, it is not likely that mines will be re-opened for their gold content, or that new vein deposits will be found.” Few would have disagreed with him at the time. Since then, the Martha mine at Waihi has been reopened for its gold content and new vein deposits have been discovered in the district at Golden Cross and Favona, together containing a total of several million ounces of gold. These have resulted from the development of new technology, changes in the economics of mining, and continuing exploration.

Data accuracy and precision

The GERM (Geological Resource Map) database is based around the point location of each mineral occurrence, recorded by geographical coordinates. These are typically compiled from existing geological maps, many of these unpublished e.g. in mineral exploration reports. These maps range in age, scale, accuracy and quality. The mineral occurrence locations in some cases are independently verified, but the database does not record an estimate of the spatial location error. The GERM database contains a large number of fields that can store diverse, but relevant information about each mineral occurrence. These fields are variably populated for each mineral occurrence and some contain rich information, others minimal information. Many of these data are unchecked and may contain errors. Virtually all the information was entered prior to the mid 1990s and since then, there has been considerable rationalisation of stratigraphic association and nomenclature as well as refinement of geochronological age, particularly through the QMAP 1:250,000 geological mapping programme. Some of the information on geological setting and host rocks in the GERM database is now superseded.

The QMAP 1:250,000 geological mapping is relatively small scale and generalised and not ideally suited for interpreting point-source information. Areally small and potentially significant geological map units commonly cannot be rendered at the published scale of 1:250,000.

3.0 PREVIOUS WORK

The West Coast mineral resource assessment project follows similar previous projects for the whole of New Zealand (Christie & Brathwaite 1999a), the Coromandel area (Christie et al. 2001a; 2008), Northland region (Christie & Barker 2007), and Kahurangi and Rakiura national parks (Christie et al. 2009a, 2009b). Preliminary results were presented by Christie & Barker (2010).

The geological resources of the West Coast region were described in the New Zealand Geological Survey bulletins by Bell & Fraser (1906), Morgan (1908, 1911), Morgan & Bartrum (1915), Henderson (1917), Suggate (1957) and McPherson (1978). A computerised national datafile of mineral occurrences, the Geological Resource Map (GERM), was compiled to produce a series of 1:250,000 maps (Nicol & Nathan 1987; Sewell et al. 1989; Eggers & Sewell 1990; McPherson et al. 1994; Roser et al. 1994). This data has recently been made available on the GNS Science web site (www.gns.cri.nz) via the MinMap interface. West Coast mineral resources are included in national reviews by Williams (1974), MacFarlan & Barry (1991) and Brathwaite & Pirajno (1993). Occurrences of specific minerals were noted in national reviews by Morgan (1927) and Railton & Watters (1990).

National reviews of individual mineral commodities that describe mineral resources in the West Coast region, include: building stones (Marshall 1929; Hayward 1987), clay (Schofield 1977), feldspar (Henderson 1950), greenstone (Beck 1984), limestone (Morgan 1919; Willett 1974a), and serpentine (Coleman 1966), and a series of mineral commodity reports published in New Zealand Mining (Christie & Brathwaite 1994 (copper), 1995a (lead and zinc), 1995b (molybdenum), 1995c (nickel), 1996a (tin), 1996b (tungsten), 1997 (gold), 1998a (titanium), 1999b (beryllium, uranium and zircon), Edbrooke 1999 (coal); Christie et al. 2000b (clay), 2001b (limestone), 2001c (aggregate)). The prospectivity for mesothermal (orogenic) gold was estimated by Partington & Smillie (2002) and Crown Minerals (2002), which included a compilation of geological and geochemical data in digital form.

Brief summaries of the geology and resources of the coalfields are respectively contained in national reviews by Willett (1974b), Sherwood (1986), Anckorn *et al.* (1988) and Barry et al. (1994); detailed reviews are given by Nathan (1972) and Gage (1952) for the Charleston and Greymouth coalfields respectively, and results of exploration by the National Coal Resources

Survey are contained in libraries of reports and a computerised data file (National Coal Resources Database) of mainly drill hole information, maintained by GNS Science and Crown Minerals of the Ministry of Economic Development. Sara (1972) listed the coal mines on the West Coast.

The results of mineral exploration since the late 1960s are described in reports submitted by explorers to Government as part of the conditions of their prospecting and exploration permits. These reports are held by Crown Minerals, Ministry of Economic Development, with many available for downloading from www.crownminerals.govt.nz. Reports for exploration from 2005 are currently mostly held on closed file, but some information has been released on company web sites and in the news media. Borehole logs for extensive alluvial gold drilling programmes during the 1930s-1940s are held by Crown Minerals.

Exploration geochemical data have been compiled in the REGCHEM (Regional Geochemistry) database (Warnes & Christie 1995) and a Crown Minerals geochemical database (Crown Minerals 2009).

The Ministry of Economic Development has been compiling and publishing exploration spending data since 2001. Exploration spending in New Zealand has risen from $1.3 million in 2001 to $25 million in 2006 (www.crownminerals.govt.nz), with a significant portion of the total spent in the West Coast region.

4.0 METHODS

The mineral commodities are examined in three groups because of the different level and type of information available:

Aggregate, sand, dimension stone and limestone

Resources of aggregate and limestone are large and poorly known, because they occur over large areas and their low value relative to many other mineral commodities precludes regional exploration and resource definition. Resources are usually investigated only in the vicinity of local markets, because transport over long distances is generally precluded by the low dollar value per tonne. Exceptions are dimension stone and high quality aggregate. Schist dimension stone is exported to other parts of New Zealand and small quantities of aggregate have been barged to Auckland.

Past production of aggregate, sand and dimension stone has fluctuated in relation to the state of the local and national economies, and with infrastructure development. Therefore, our assessment of these commodities is based on their annual production, plus a suggested increase in future demand.

Coal

Nationally, resources of coal are generally better known than most other mineral commodities, because of the government funded National Coal Resources Survey exploration programme during the 1980s and earlier surveys. Therefore, for this study, data is taken from the National Coal Resources Survey with some adjustments based on feedback from the coal industry.

Metallic and industrial minerals

These mineral commodities generally have a high value and there is potential for export out of the region (and New Zealand). In the case of most of the metals, there are large international markets, and any quantity of the metal that can be produced in the West Coast region could be readily sold. For most industrial minerals, markets must be sought and this may be a limitation to the potential quantity of production. Exploration has helped to broadly define resources of some specific metallic mineral and industrial mineral deposits as reported in the literature, and we have additionally used a process of mineral resource assessment to estimate undiscovered resources (see section 12.0).

5.0 DATA

Fundamental to the mineral resource assessment process is the collation of available information in a suitable form for analysis. The ArcMap GIS has been compiled with the inclusion of information from Crown Minerals (2002) and some other sources, and is included on the enclosed CD-ROM. Mineral occurrences in the GERM database are referenced by e-number, e.g. the former Arahura gold dredge is J33/e97, where J33 is the LINZ Infomap 260 map sheet number and e97 is the unique number within that sheet. The GERM database was mostly compiled prior to 1994, with production figures to 1993, the last year the Ministry of Energy (now Crown Minerals of Ministry of Economic Development) published annual production statistics for individual operations. Since then, production statistics have been amalgamated on a regional basis and figures for individual operations are not publicly available. Therefore, the post-1993 operational and production status of many of the mining operations (e.g. aggregate quarry and river gravel operations) may have changed and some new operations may have commenced. Few operations, new since 1994, are included in the GERM database.

Data on current aggregate and gold producers was provided from databases operated by the West Coast Regional Council and from information collated by the West Coast Commercial Gold Miners Association.

6.0 RESOURCE MAPS

The results of our analysis are presented as a series of maps for specific mineral commodities or mineral deposit types that generally include one or more of the following:

- Locations of mineral occurrences from the GERM database for the specific deposit type;
- Geological units prospective for the mineral deposit type, from the 1:1 M geological map;
- A table describing the mineral deposit type;
- A table of past estimates of resources; and
- A table of our estimates of resources based on known deposits and potential undiscovered deposits.

7.0 SETTING

7.1 POPULATION AND INFRASTRUCTURE

The West Coast region includes the Buller, Grey and Westland districts. Population centres, with a total population of about 31,000 include the towns of Greymouth (population 9702), Westport (3990), Hokitika (3384), Reefton (950), Karamea (420) and Ross (371) (Figure 1). State Highways link the main towns, reaching the area from the northeast and south (S.H. 6), from the southeast via Arthurs Pass (S.H. 73), from the east via Lewis Pass (S.H. 7), and from Karamea in the north (S.H. 67) (Figure 2). Secondary roads provide access up many of the river valleys to settlements and farms. Most of the mountainous areas, however, are accessible only on foot and there is a network of well maintained walking tracks in some of the national and forest parks. The railway line from Christchurch via Arthurs Pass branches at Stillwater, one line proceeding west to the coast at Greymouth and then south, to terminate at Hokitika, the other northeast to Reefton, Inangahua, Westport, and Ngakawau. Airports with regular domestic services are located at Westport and Hokitika, and there is also an airport at Greymouth. Westport and Greymouth have small ports servicing coastal shipping (Figure 5).

Figure 5 Buller River mouth (foreground) and Westport (middle distance) (GNS photo CN32368/5H, photographer Lloyd Homer).

Most of the land area is Crown Land covered by native forest and administered by the Department of Conservation. This includes Paparoa and Westland Tai Poutini national parks, parts of Kahurangi, Arthurs Pass, and Mount Aspiring national parks, forest parks, several scenic reserves, and large areas of unclassified forest (Figure 3 and Figure 6). Most of the coastal strip and terraced or gentle hilly areas in the river valleys are private farm land. The major commercial activities in the area are farming, mining (coal and gold), forestry and milling, tourism, and fishing.

Figure 6 Franz Joseph Glacier (GNS photo CN D0001016, photographer Lloyd Homer).

7.2 GEOMORPHOLOGY

Flat areas are mostly confined to narrow coastal plains (particularly in the vicinity of Westport and south of Greymouth) and to the large river valleys (e.g. Grey, Taramakau, and Hokitika rivers) (Figure 7). The remainder of the region mostly consists of densely forested hill country and steepland, with some areas of subalpine to alpine terrain distributed along the southeastern margin. The high country forms a series of broadly north to northeast trending belts with intervening valleys, the sequence from northwest to southeast consisting of:

- the flat coastal plain at Westport (Addisons Flat and Virgin Flat);
- the mountainous Paparoa Range (ridge elevations typically 1200-1400 m, with a maximum elevation of 1485 m at Mt Faraday) (Figure 8);
- the broad Grey River valley (part of the Grey-Inangahua Depression);
- a chain or belt of segmented, precipitous mountain blocks (Mt Greenland 905 m, Mt Graham 828 m, Mt Turiwhate 1369 m, Hohonu Range 1356 m, Paddock Hill 1135 m, Granite Hill 1156 m, and Bell Hill 839 m), each isolated from the other by entrenched, glacially carved valleys;
- a well-defined linear valley excavated by erosion along the trace of the Alpine Fault;
- the ranges of the Southern Alps (ridge elevations typically 1000-2000 m, with a maximum elevation of 2271 m at Mt Rolleston).

The area drains west to the Tasman Sea from the Main Divide (the Southern Alps). The major rivers are the Buller River and its tributaries (particularly the Inangahua River), and the Grey, Taramakau, Hokitika and Haast rivers. Several large moraine-dammed lakes also lie within the belt of segmented mountain blocks, e.g. Lake Kaniere, Lake Brunner, and Lake Hochstetter.

Figure 7 Shaded digital elevation model.

Figure 8 Paparoa Range (photo courtesy Pike River Coal Ltd).

8.0 GEOLOGY

The geology of the West Coast region is illustrated in Figure 9 and Figure 10.

8.1 PREVIOUS WORK

The geology of much of the West Coast region was mapped at 1:63,360 for the New Zealand Geological Survey bulletins by Bell & Fraser (1906), Morgan (1908, 1911), Morgan & Bartrum (1915), Henderson (1917), Suggate (1957) and McPherson (1978), and for the first edition of the 1:250,000 geological map series by Bowen (1964), Gregg (1964) and Warren (1967). The 1:250,000 map series was revised as the QMap project (Nathan 1994, 1998; Rattenbury & Heron 1997) and includes new map sheets by Rattenbury et al. (1998; 2010), Nathan et al. (2002), and Cox & Barrell (2007). Parts of the West Coast have been mapped at 1:25,000 by Nathan (1976), 1:50,000 by Suggate & Waight (1999), and 1:63,360 by Nathan (1975, 1978a, 1978b) and Laird (1988). Nathan et al. (1986) provided a detailed description of West Coast geology as part of the GNS Cretaceous Cenozoic project.

Maps have also been published for regional airborne magnetic surveys (Reilly 1970a, 1970b; Hunt & Nathan 1976) and ground based gravity surveys (Bennie & Ferry 1977; Hunt 1978; Whiteford 1978; Rose 1986). Smaller areas have been covered by low level aeromagnetic surveys in mineral and coal seam gas exploration programs (e.g. Kirkpatrick 2007; Grange Resources Ltd 2008; Vidanovich 2008; Blomfield et al. 2010). Nathan & Foster (1970) noted radiometric anomalies near Granity.

8.2 INTRODUCTION

At a national scale, onland New Zealand’s crystalline basement rocks have been subdivided into various major batholiths, terranes and structural and metamorphic overprints (Mortimer 2004; Figure 10). The batholiths generally have plutons of mixed ages, with distinct geochemistry and magma sources. In this report, we distinguish between plutons primarily on age.

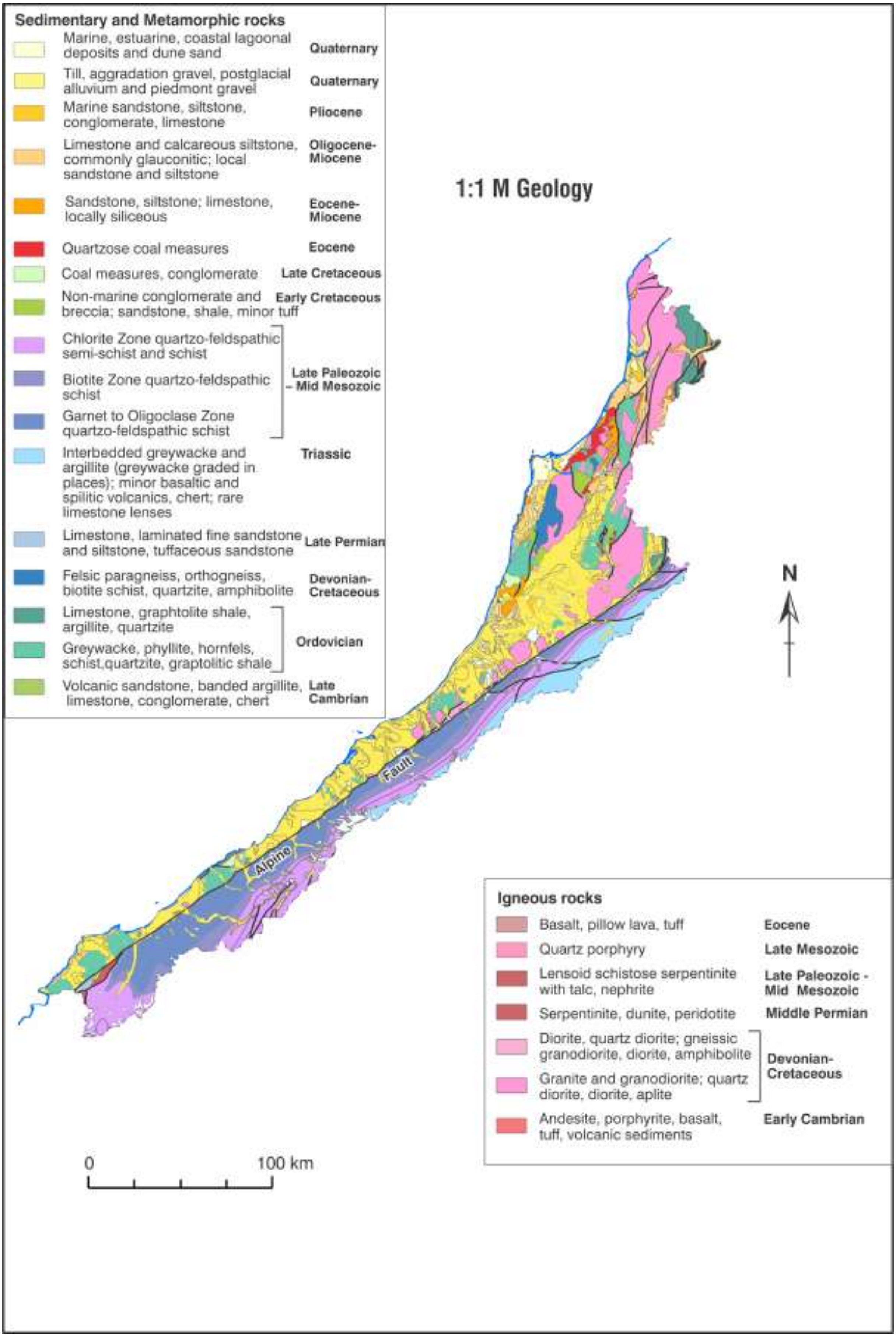


Figure 9 Geology of the West Coast region from the GNS Science 1:1 M digital geological map.

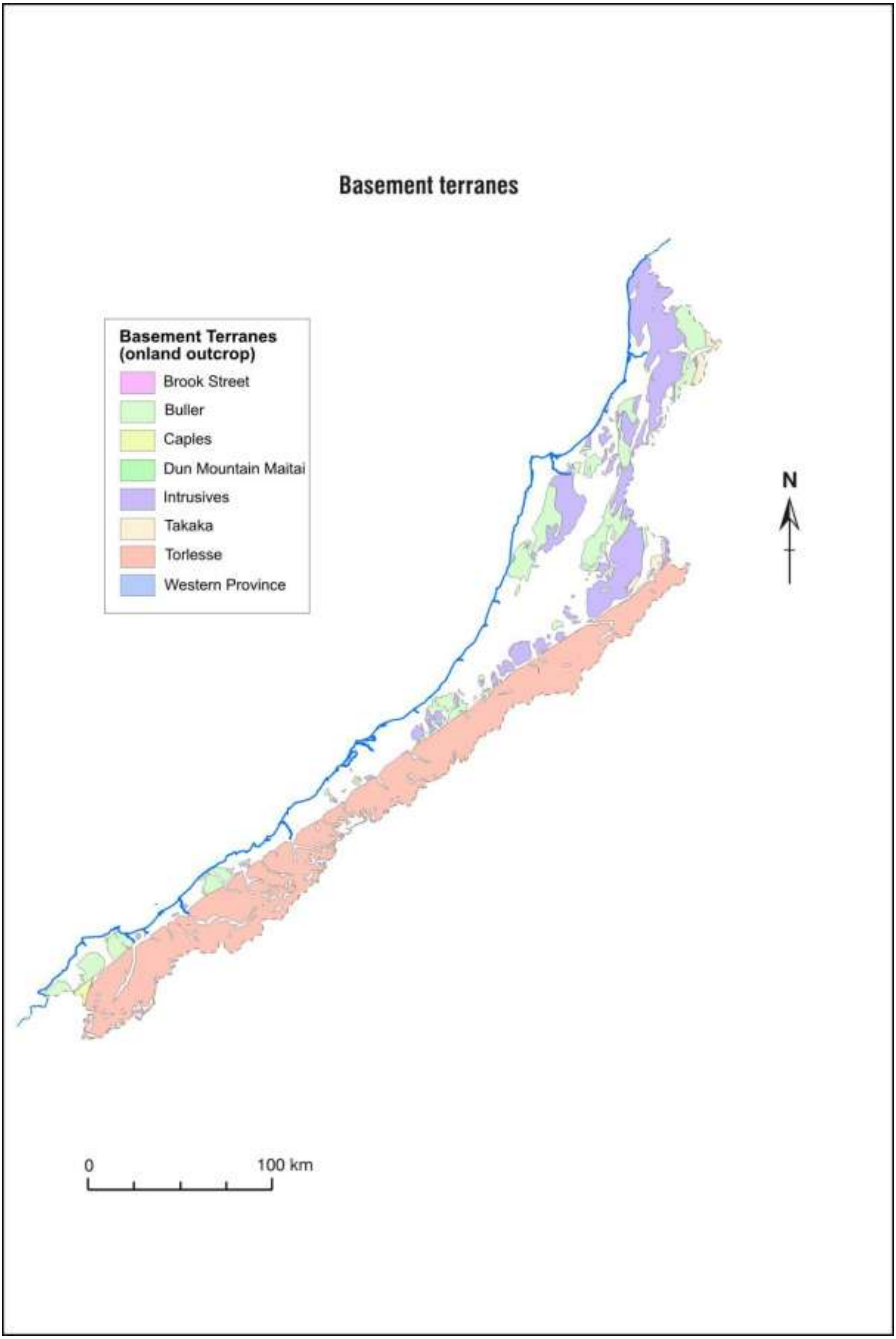


Figure 10 Basement terranes.

8.3 PALEOZOIC TO JURASSIC GONDWANA ROCKS

Before the Late Cretaceous, New Zealand was joined to Australia and Antarctica as part of the Gondwana supercontinent. Pre-Cretaceous rocks west of the Alpine Fault (Figure 11) were formed on the margin of Gondwana and make up part of a region termed the Western (or Foreland Western) Province. Pre-Cretaceous rocks east of the Alpine Fault are exotic terranes grafted onto the Western Province during the Rangitata Orogeny in the Late Jurassic to Early Cretaceous and make up the Eastern (or Rangitata) Province.

Western (Foreland) Province rocks are subdivided into three major units: gneiss of Charleston Metamorphic Group (formerly Constant Gneiss), Greenland Group metasedimentary rocks, and granites of the Karamea and Rahu suites (formerly Tuhua Group). The gneiss consists of Paleozoic paragneiss, typically banded and representing highly metamorphosed alternating beds of sandstone and shale, intruded by mid Paleozoic and Early Cretaceous granitic rocks that, along with the gneiss, were all subjected to metamorphism and deformation during the Early to Mid Cretaceous (Adams 1975; Kimborough & Tulloch 1989). Greenland Group metasedimentary rocks are alternating greywacke/shale sequences, of Lower Paleozoic age, metamorphosed to lower greenschist facies. Granites occur as isolated plutons of Mid Paleozoic Karamea Suite at Cape Foulwind, Maybille Bay, Barrytown, Nelson Creek, Doctor Hill and Mt Greenland.

Eastern (Rangitata) Province rocks consist of two northeast-trending belts: the western belt, immediately east of the Alpine Fault, comprises zoned chlorite, biotite, garnet, and oligoclase quartzo-feldspathic schists of the Haast Schist Group; the eastern belt comprises quartzo-feldspathic greywacke and argillite turbidite sequences of the Torlesse Supergroup (locally of Triassic to Jurassic age). The schists are metamorphic equivalents of the Torlesse Supergroup, but also include a belt which contains lenses of serpentinite and talc-serpentinite (Pounamu Ultramafics) representing metamorphosed slices of tectonically emplaced ultrabasic rocks.

Figure 11 The Alpine fault trace in the area of Jerry River and Pyke River looking south. Here the fault juxtaposes ultramafic rocks on the east (left) against Greenland Group metasedimentary rocks on the west (right) (GNS photo CN6281/17H, photographer Lloyd Homer).

8.4 EARLY TO MID CRETACEOUS ROCKS AND THE MID TO LATE CRETACEOUS GONDWANA BREAK-UP

The Early-Mid Cretaceous spans the main period of the Rangitata Orogeny, a time of major tectonic activity which included a phase of regional extension that culminated in the separation of New Zealand from Gondwana at around 84 Ma. Widespread plutonic activity occurred during this period, represented by Early Cretaceous Rahu Suite granites of the Paparoa and Hohonu batholiths (Tulloch 1983, 1988a), and orthogneiss of the Charleston Metamorphic Group (see above). No sedimentary record is present for the lower part of the Early Cretaceous, but during the late Early Cretaceous, non-marine sediments of the Pororari Group were deposited in half-grabens adjacent to rapidly rising mountains. These sediments consist of carbonaceous mudstone, vitric tuff, and sandstone, overlain by thick sequences of alluvial fan breccia and breccia-conglomerate of the Hawks Crag Breccia, followed by fluviatile conglomerate and lacustrine mudstone.

During the Mid to Late Cretaceous Gondwana breakup, north-northeast directed regional extension caused detachment and deformation along low-angle faults, juxtaposing the high grade metamorphic rocks of the Charleston Metamorphic Group (lower plate) against low grade metamorphic rocks of the Greenland Group, Pororari Group, and various granitic intrusives (upper or cover plate) in the northern part of the sheet, to form the Paparoa Metamorphic Core Complex (Tulloch & Kimborough 1989).

8.5 LATE CRETACEOUS-PLIOCENE SEDIMENTARY BASINS

Late Cretaceous to Pliocene sediments were deposited in a number of tectonic basins in two main tectonic regions, the Western Platform to the west (offshore) and the West Coast 'Basin and Range' province to the east (onshore), separated by the Cape Foulwind Fault which trends parallel to the coastline.

Fault-controlled basins, parallel to the present coastline, developed in the Western Platform and Paparoa Trough as a result of west-northwest directed extension during the Late Cretaceous. The Western Platform contains a flat-lying to gently dipping, little deformed Cretaceous-Cenozoic sedimentary sequence, 2000-2500 m thick. Outcrops and many drill holes in the Paparoa Trough have provided good geological control for interpretation of the sedimentary sequence. As the Paparoa Trough subsided in the Late Cretaceous, it was filled with a sequence of terrestrial Paparoa Coal Measures (sandstone, conglomerate, coal, and carbonaceous mudstone) accompanied by the eruption and intercalations of alkali basalt flows. The deposition of increasingly mature, quartz-rich sediment accompanied slowing of subsidence during the Paleocene, leading to non-deposition in the Early Eocene. Renewed subsidence during the middle to Late Eocene was associated with further deposition of quartz-rich (Brunner) coal measures in the Paparoa Trough, including quartz conglomerate and sandstone, carbonaceous shale, and coal. A Late Eocene marine transgression commenced with deposition of the Island Sandstone followed by increasingly calcareous siltstone of the Kaiata Formation, with which is interbedded a thick wedge of coarse clastic rocks of the Omotumotu Formation. The maximum thickness of Late Cretaceous to Early Oligocene rocks was over 4 km.

In the Middle Oligocene, tectonism decreased and carbonates were deposited (Cobden Limestone, Waitakere Limestone, Tiropahi Limestone, and Potikohua Limestone; Nile Group). Close to the Oligocene-Miocene boundary, renewed tectonism caused basin eversion, with cessation of sedimentation in the Paparoa Trough, but downwarping in the developing Grey Valley Trough to the east. Marine mudstone of the Blue Bottom Group was deposited over wide areas of the Grey Valley Trough and Western Platform throughout the Miocene and the Early and Mid Pliocene. The Blue Bottom Group was succeeded near the end of the Pliocene by the terrestrial Old Man Group, consisting of conglomerate, sand, glacial till (Ross Glaciation), and lignite. The Old Man Group sequence is interpreted as piedmont gravel deposited in a coastal plain environment, and derived from the rising Alpine chain. The Late Pliocene (Ross) glaciation caused deposition of outwash gravel, till and glacial silt, which were followed by a warming period and a further succession of piedmont gravel. The maximum thickness of Miocene and Pliocene sediments was greater than 3 km. The rate of tectonism increased in the Pliocene, with the development of the ranges that represent the major anticlinal features, and fault bounded troughs that represent the synclinal features. Folds within the troughs increase near the trough margins.

8.6 MIDDLE AND LATE QUATERNARY

Accelerated erosion through uplift along the Alpine Fault and in the Paparoa Ranges since the Pliocene, has supplied large quantities of fluviatile gravel to the area; this was modified and reworked during successive glacial and interglacial periods throughout the Pleistocene. Tills from a recognised sequence of glaciations (Nemona, Waimaunga, Waimea, Otira), representing lateral or terminal moraines, together with glacial outwash gravel, filled the southern valleys almost to the coast, and the upper parts of valleys in the Paparoa Ranges. Progressive uplift assisted fluvial erosion and reworking during subsequent interglacial periods, resulting in a succession of terrace deposits in the river valleys. In the southern parts of the region these are the Cockeye (oldest and preserved at highest elevation), Tansey, Waimea, Loopline, and Moana formation gravels. In the northern part of the region, there are only minor representatives of the corresponding glacial formations of the Buller catchment.

During the intervening interglacial periods, sea level was similar to its present height. Wave-cut benches were formed along the coast and covered with marine gravel and sand. These were subsequently tectonically uplifted and preserved, forming a succession of terraces (formations) along the coast. The Caledonian, Candlelight, and Whisky formations are the older, higher units, whereas the younger units at lower altitudes are the Addison, Waites, and Virgin Flat formations in the north, and Sealmaria, Karoro, Awatuna, and Rutherglen formations in the south. Finally, the Recent postglacial coastal and alluvial deposits are included in the Nine Mile Formation.

8.7 GEOLOGICAL CORRELATION WITH AUSTRALIA

The Cambrian-Cretaceous crystalline basement rocks of New Zealand have counterparts in Australia and Antarctica. With the Tasman Sea closed, Zealandia (Mortimer 2008) spatially restores to a position close to Tasmania and Antarctica (Figure 12). Geologically, the best matches of New Zealand's terranes and batholiths are with similar rocks in Tasmania, Victoria and Queensland, all mineral rich states. Of particular note are the Victoria mesothermal orogenic gold deposits in the deformed and metamorphosed Ordovician-Devonian siliciclastics of Victoria (e.g. Bendigo, Ballarat), and the Devonian-Carboniferous granites that intrude the Lachlan Orogen that are the host to Sn-W deposits.

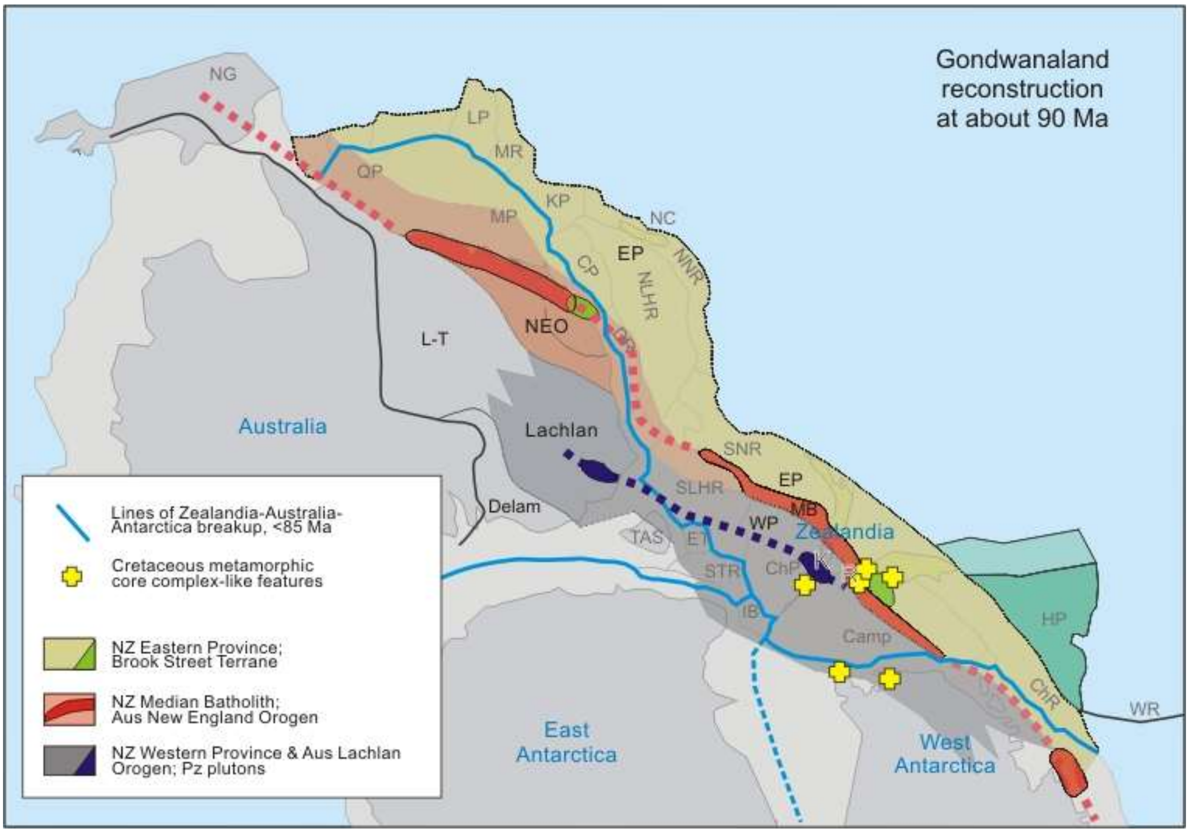


Figure 12 An "untightened" Gondwanaland reconstruction of Australia, Zealandia and Antarctica after Mortimer (2008). Note along-strike continuation of continental geology from eastern Australia and Tasmania into Zealandia and beneath Kahurangi National Park. Geographic/bathymetric features in grey type: NG=New Guinea, NC=New Caledonia, QP=Queensland Plateau, MP=Marion Plateau, LP=Louisiade Plateau, MR=Mellish Rise, KP=Kenn Plateau, CP=Chesterfield Plateau, DR=Dampier Ridge, NLHR, SLHR=Northern and Southern Lord Howe Rise, NNR, SNR=Northern and Southern Norfolk Ridge, TAS=Tasmania, ET=East Tasman Rise, STR=South Tasman Rise, ChP=Challenger Plateau, Camp=Campbell Plateau, ChR=Chatham Rise, HP=Hikurangi Plateau (pale green part now subducted beneath Kermadec Trench), WR=Wishbone Ridge. Geological features in black type: Delam=Delamerian Orogen, L-T=Lachlan-Thomson Orogen, NEO=New England Orogen, EP=Eastern Province, WP=Western Province, MB=Median Batholith.

9.0 GEOCHEMISTRY

9.1 GIS DATA SETS (FIG. 13-17)

Stream sediment geochemical surveys have been one of the major reconnaissance prospecting techniques used in the West Coast area by mining companies during their exploration for mineral deposits. Results of geochemical analyses for 8328 stream sediments and 300 pan concentrate samples have been collated in the REGCHEM (REGional exploration geoCHEMistry) database (Christie & Mitchell 1992; Warnes & Christie 1995) from open-file mining company exploration reports and described by Christie & Carver (in prep.). Each sample has been analysed for one or more elements, typically Cu, Pb, Zn, Mo, W and Ag, and less commonly for elements such as As, Au, Ni, Sn and Sb The database may contain information on the sample location (grid reference), sample type, laboratory, analytical method, and detection limits for each element analysed.

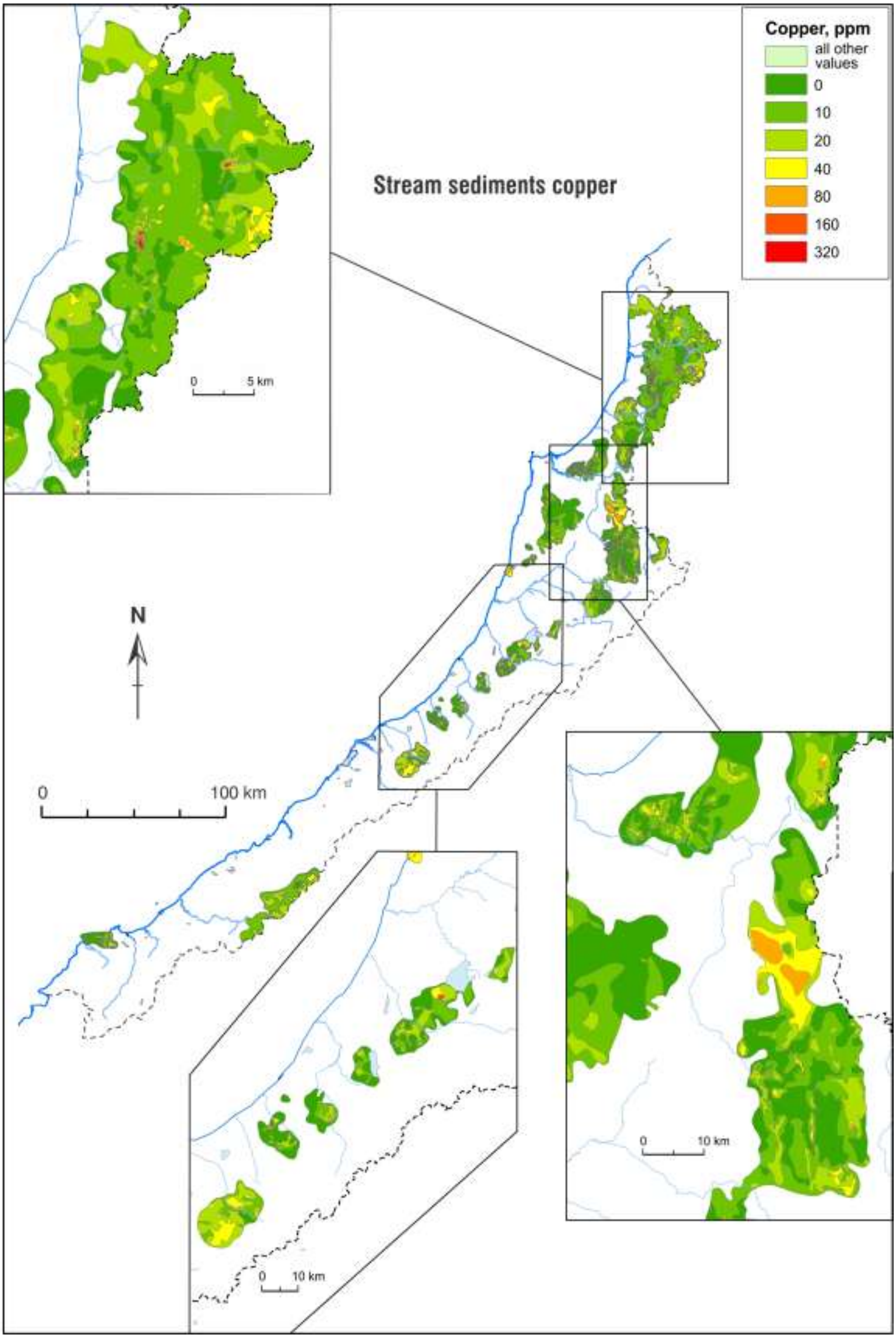


Figure 13 Contoured Cu anomalies in stream sediments from open file mining company data compiled in the REGCHEM database (after Christie & Carver in prep.).

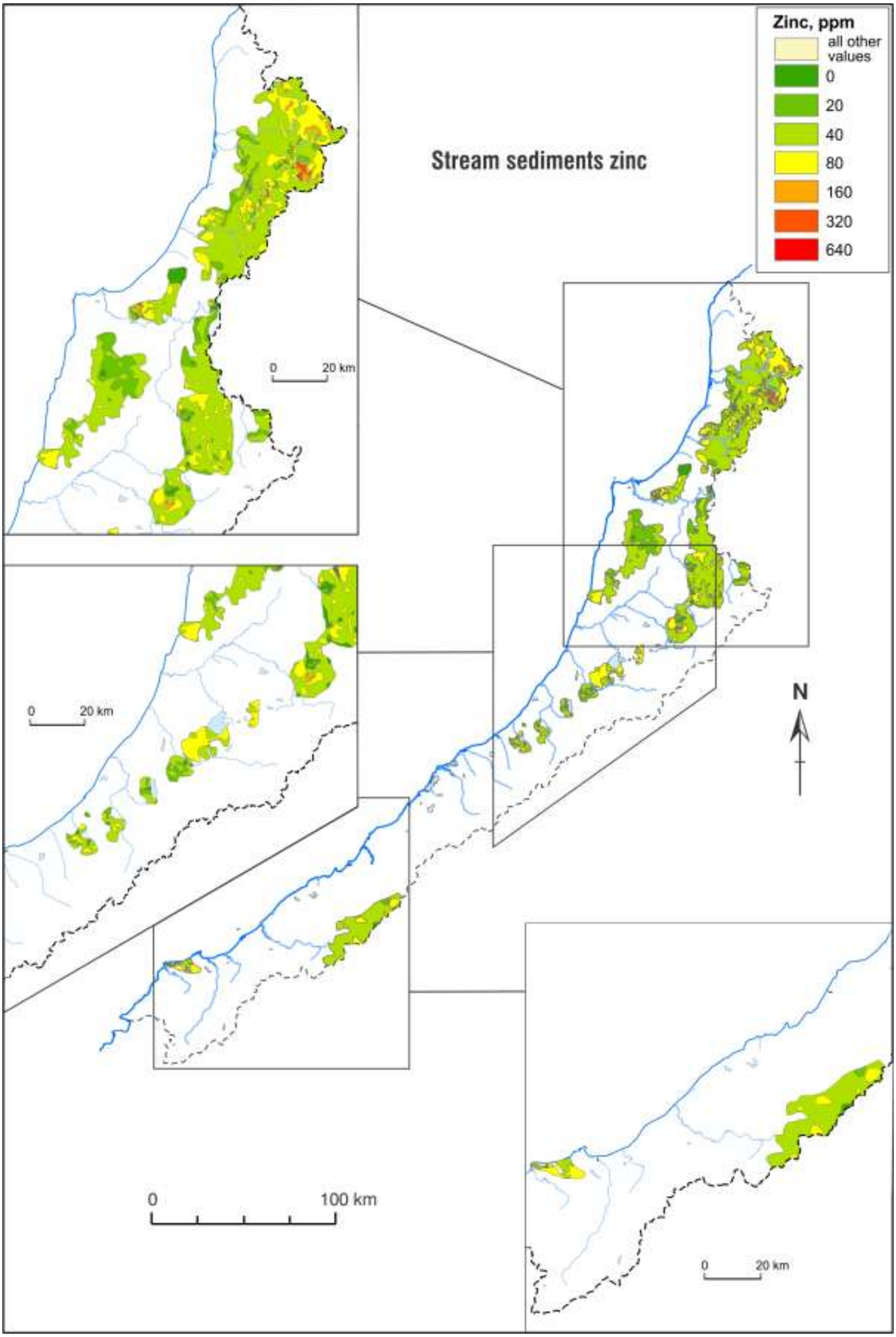


Figure 14 Contoured Zn anomalies in stream sediments from open file mining company data compiled in the REGCHEM database (after Christies & Carver in prep.).

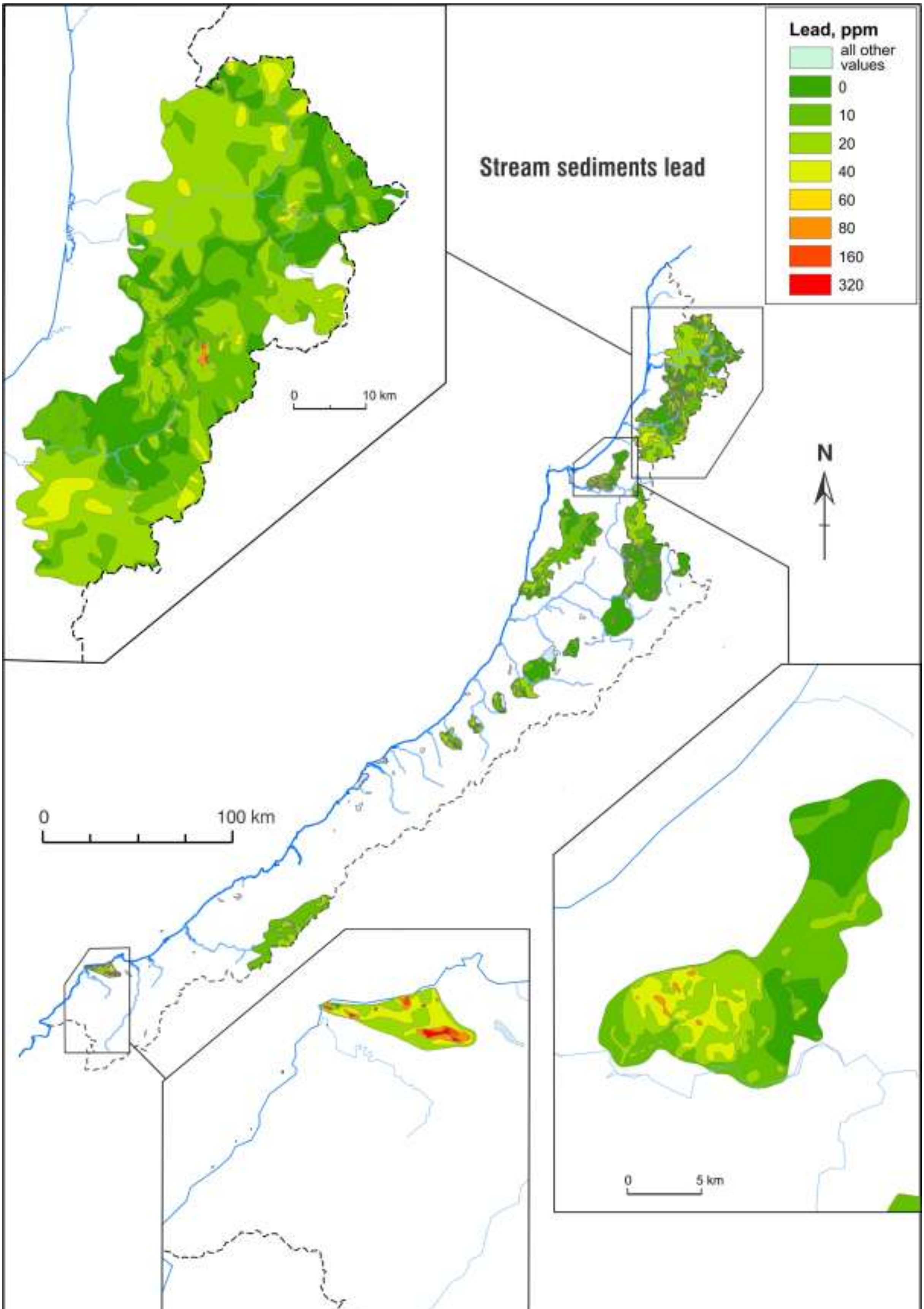


Figure 15 Contoured Pb anomalies in stream sediments from open file mining company data compiled in the REGCHEM database (after Christie & Carver in prep.).

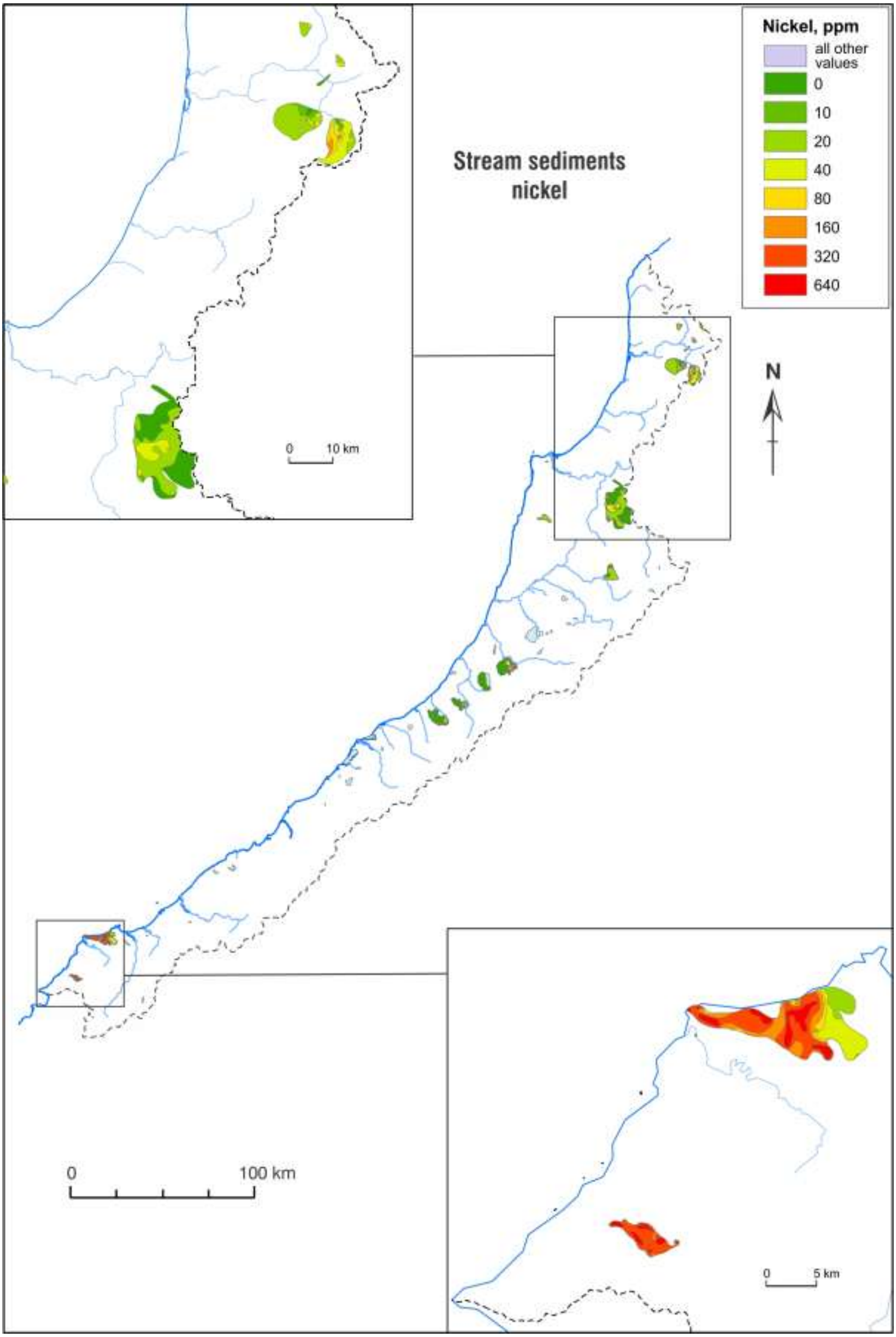


Figure 16 Contoured Ni anomalies in stream sediments from open file mining company data compiled in the REGCHEM database (after Christie & Carver in prep.).

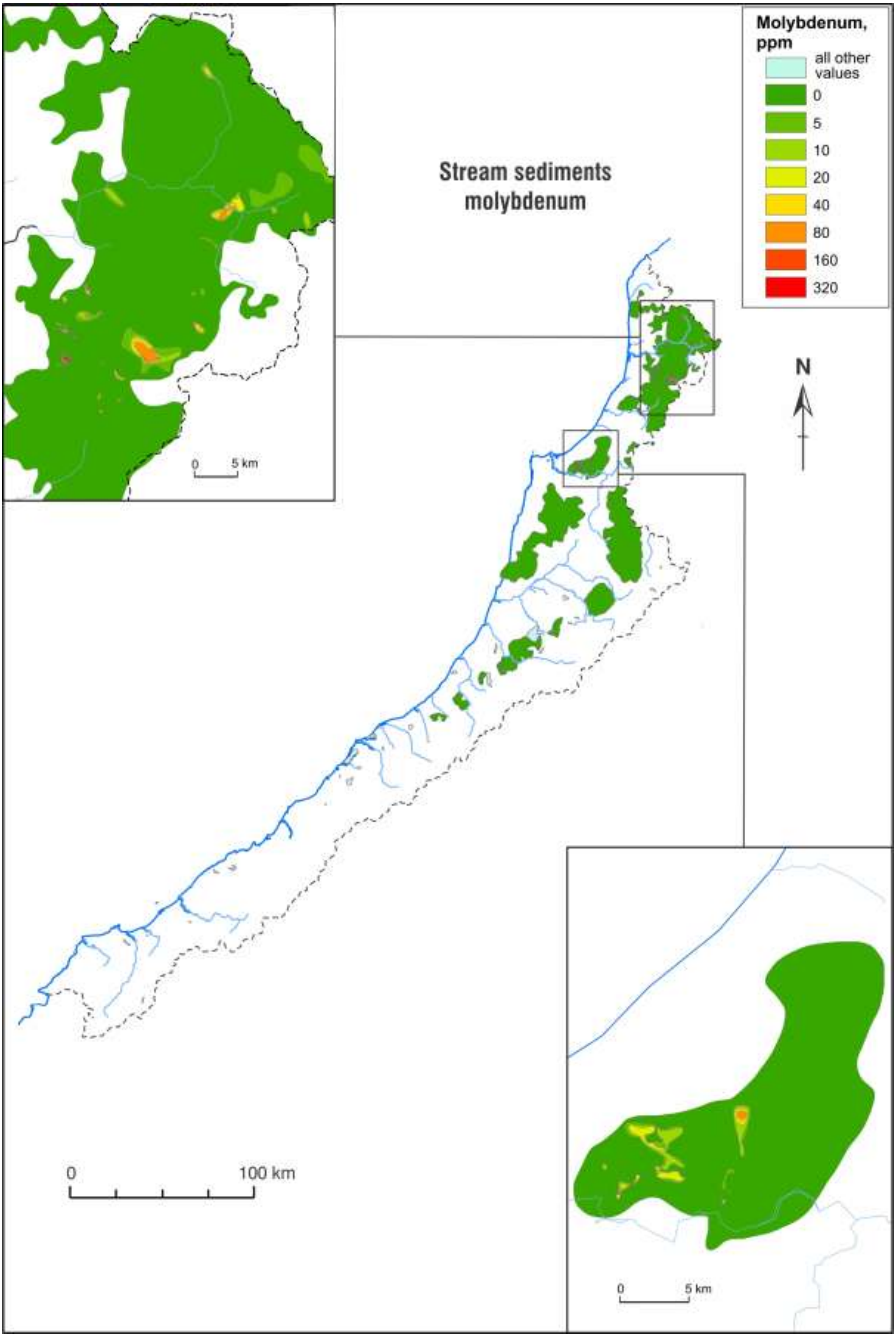


Figure 17 Contoured Mo anomalies in stream sediments from open file mining company data complied in the REGCHEM database (after Christie & Carver in prep.).

Most stream sediment sampling programmes in the West Coast region have used conventional sampling techniques and analysed the -80 mesh fraction. However, many companies have also used panned concentrate samples, particularly for heavy minerals such as the tin mineral cassiterite and the tungsten mineral scheelite. Because scheelite fluoresces under UV light, a few surveys have additionally utilised UV lamping.

Differences in the sampling and analytical methods, the number of elements analysed and their detection limits causes complications in combining the data for a regional study. Christie & Carver (in prep.) contoured data for eight elements, Cu, Zn, Pb, Mo, W, As, Au and Ni, five reproduced here in Figure 13 – Figure 17. Data is absent in uncoloured areas of these maps. Limited geographic coverage or problems with different analytical methods and detection limits preclude this type of synthesis for other elements.

The variability between the different surveys, patchy coverage for some elements, and the possibility of buried mineral deposits means that the data should be used only for positive indications of mineralisation. Elevated concentrations of elements are indicative of some nearby source, probably a mineral deposit, but the absence of elevated concentrations does not preclude the presence of a mineral deposit.

9.2 GEOCHEMICAL INTERPRETATION

Christie & Carver (in prep.) identified 15 anomalies or clusters of anomalies based on the combination of element associations and anomaly size.

The contoured data for Cu are shown in Figure 13. Copper is dominantly at background levels. High background values of 80-160 ppm Cu and the few anomalous areas are concentrated in the north eastern part of the region and most copper anomalies are closely spatially related to porphyry molybdenum deposits.

Background levels for Zn are significantly higher than Cu (4x). The contrast is lower than Cu and the anomalous values (>160 ppm) are concentrated in the northern part of the studied area (Figure 14).

The background levels for Pb are similar to those of Cu. The areas of high background to anomalous Pb are more restricted than those of Cu and Zn (Figure 15). Again some lie in the northern part of the region, but there is some Pb anomalism in the southern part of the region coincident with an area of anomalous Ni.

The Ni coverage is quite restricted (Figure 16). Areas of >80 ppm Ni represent mafic or possibly fine grained sediments. Values >320 ppm indicate ultramafic rocks. Ni of this magnitude occurs in two areas in the south of the area (Figure 16). In both areas the geology is till or quaternary cover, but this must be thin with ultramafic rocks beneath. The anomalism is supported by elevated values in limited reconnaissance soils collected in this area which have up to 680 ppm Ni (Christie & Carver in prep.). The streams in this area also have Cu, Pb and Zn assays. None of the Cu values are high enough to indicate Ni-Cu sulphides, but it is extremely uncommon to see Ni sulphide signatures in stream sediments. As indicated above, the other anomalous element in this area is Pb. This Ni and Pb association is unusual.

Molybdenum has a very high contrast. The anomalies, which are restricted in extent, are concentrated in the northern part of the area related to porphyry molybdenum deposits (Figure 17).

Tungsten has a similar contour pattern to Mo, but the contrast is higher (Christie & Carver in prep.). The As data is limited in extent and is dominated by the high background to anomalous response in the Reefton Goldfield (Christie & Carver in prep.). The As contrast is high with a threshold of 40 ppm As. The Au contrast is very high, but there is a very limited ability to resolve variations in the background, because the detection limit of most of the data is 0.05 ppm or 50 ppb Au. Gold broadly correlates with As although in detail the Au highs are not coincident with the peak As values (Christie & Carver in prep.).

10.0 BULK COMMODITIES: ROCK AGGREGATE, SAND, BUILDING STONE AND LIMESTONE

10.1 CURRENT PRODUCTION

Table 1 in the Introduction shows non-metallic mineral production for 2005 to 2009 as reported by Crown Minerals. Regional mineral output is dominated by "limestone for industry" that consists almost entirely of limestone for cement making at Westport. Aggregate is produced mainly for roading and reclamation and protection, with building (concrete-making) accounting for a small component. Limestone for agricultural use accounts for about 10% of total non-metallic mineral production.

10.2 AGGREGATE

The annual production of aggregate on the West Coast for use in roading and building are shown for 2000 to 2009 in Figure 18 and Figure 19. The main aggregate, gravel and sand producing operations are listed in Table 3, Table 4 and Table 5, which are based on information provided by the West Coast Regional and district councils from their databases of current consents. Table 2 summarises the information from Table 3 on river gravel extraction, which is the main source of supply in the region. The locations of the operations are shown in Figure 20 - Figure 23.

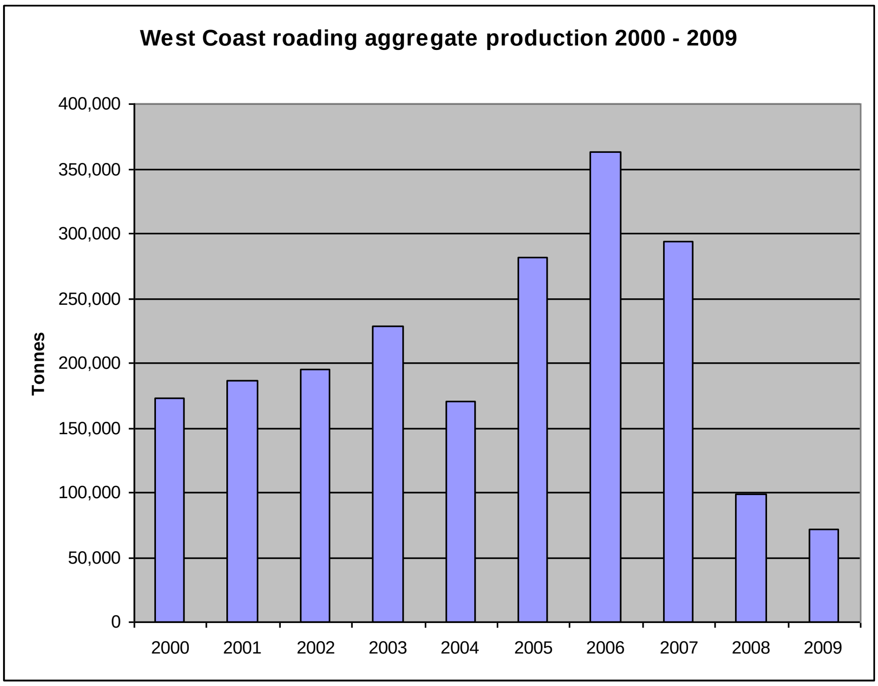


Figure 18 West Coast roading aggregate production 2000 – 2009.

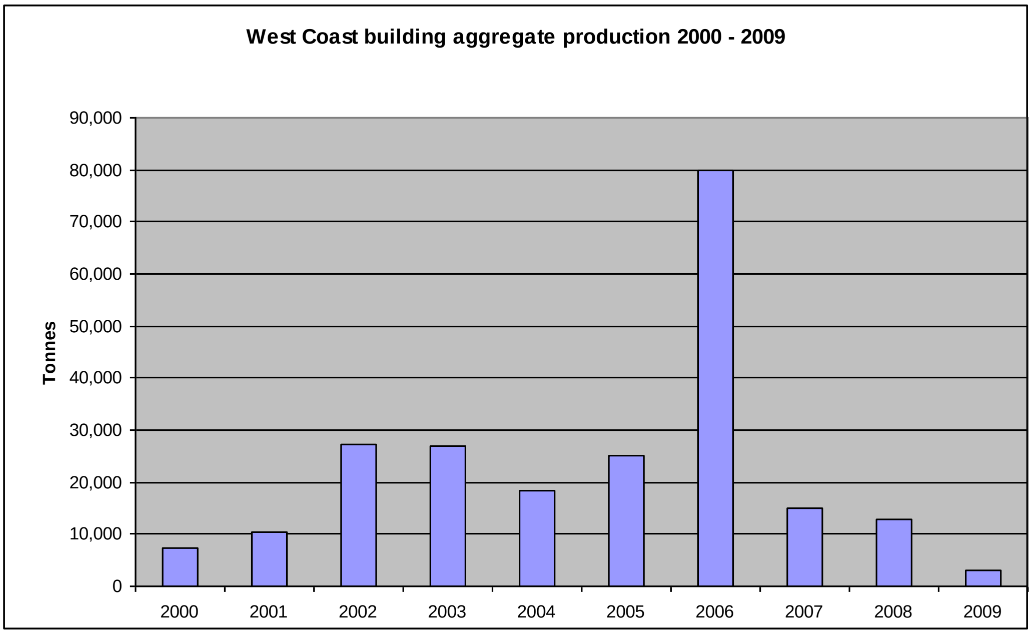


Figure 19 West Coast building aggregate production 2000 – 2009.

The production statistics for building aggregate (and to a lesser extent roading aggregate) show a dramatic decline since 2006. Notes with the statistics that are included in the footnotes to Table 1 indicate that incomplete reporting may be the cause. The statistics are compiled by sending questionnaires to producers and where operations are not located on a mining permit or licence, production reporting is voluntary. Major producers that account for most of the production near the main centres of New Zealand are not active on the West Coast, which is dominated by small producers, working deposits intermittently. For concrete aggregate our enquiries of West Coast producers indicate that about 2000 m^3 of concrete per month was produced during 2009, equivalent to about 20,000 m^3 per year. This is broadly consistent with Statistics NZ data that 146,000 m^3 of concrete was produced in the West Coast, Tasman, Nelson and Marlborough regions in 2009. This aggregated value for the four regions is the only data available for the West Coast for reasons of commercial sensitivity. The region's total of 20,000 m^3 of concrete requires about 36,000 t of sand and aggregate, whereas the statistics (Table 1) report that only 3200 t of aggregate was produced in 2009.

Production statistics for limestone for agriculture listed in Table 1 appear to be realistic based on our enquiries. The main commodities of value (coal and gold) are dominated by large producers that produce reliable statistics.

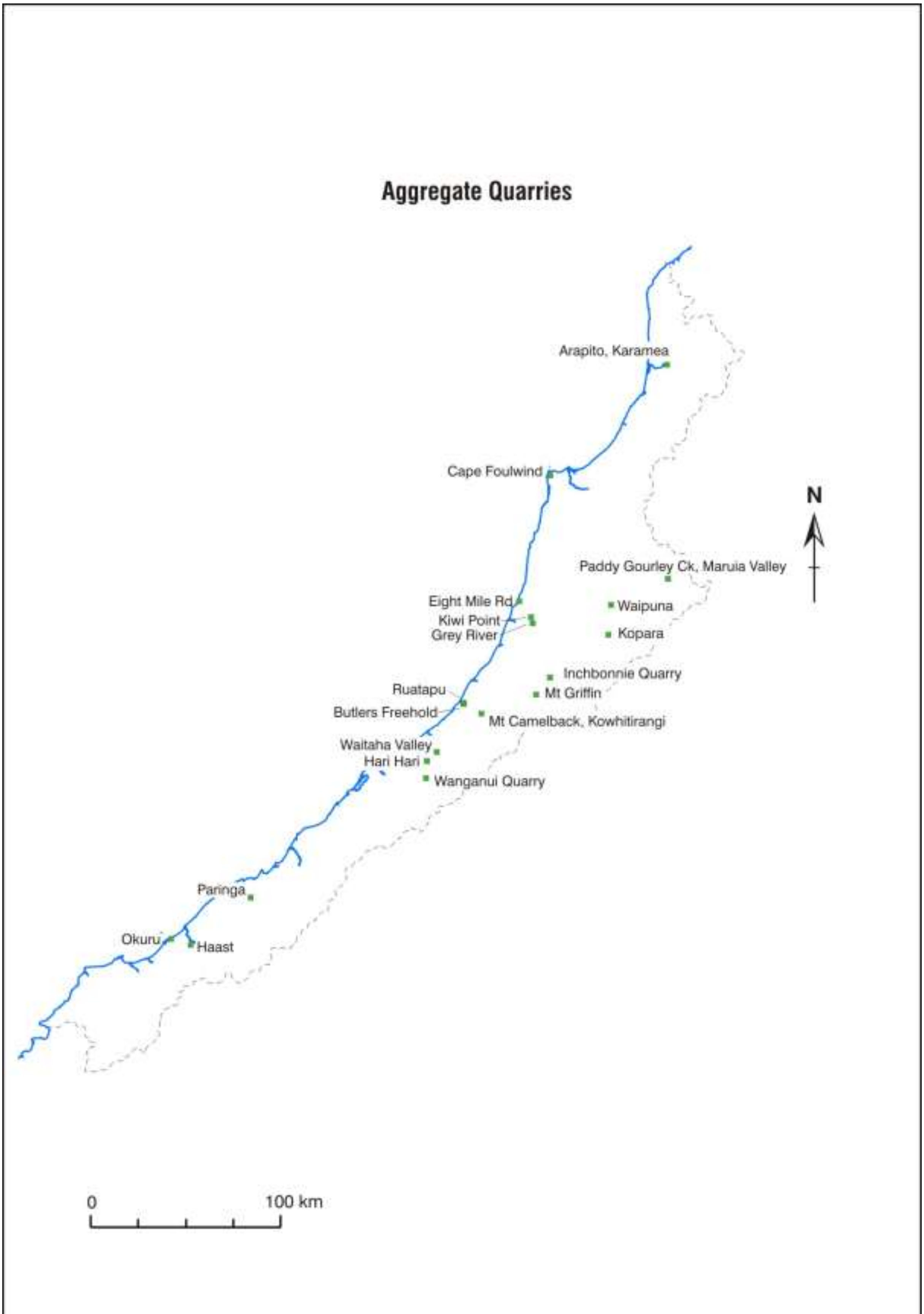


Figure 20 Location of aggregate quarries.

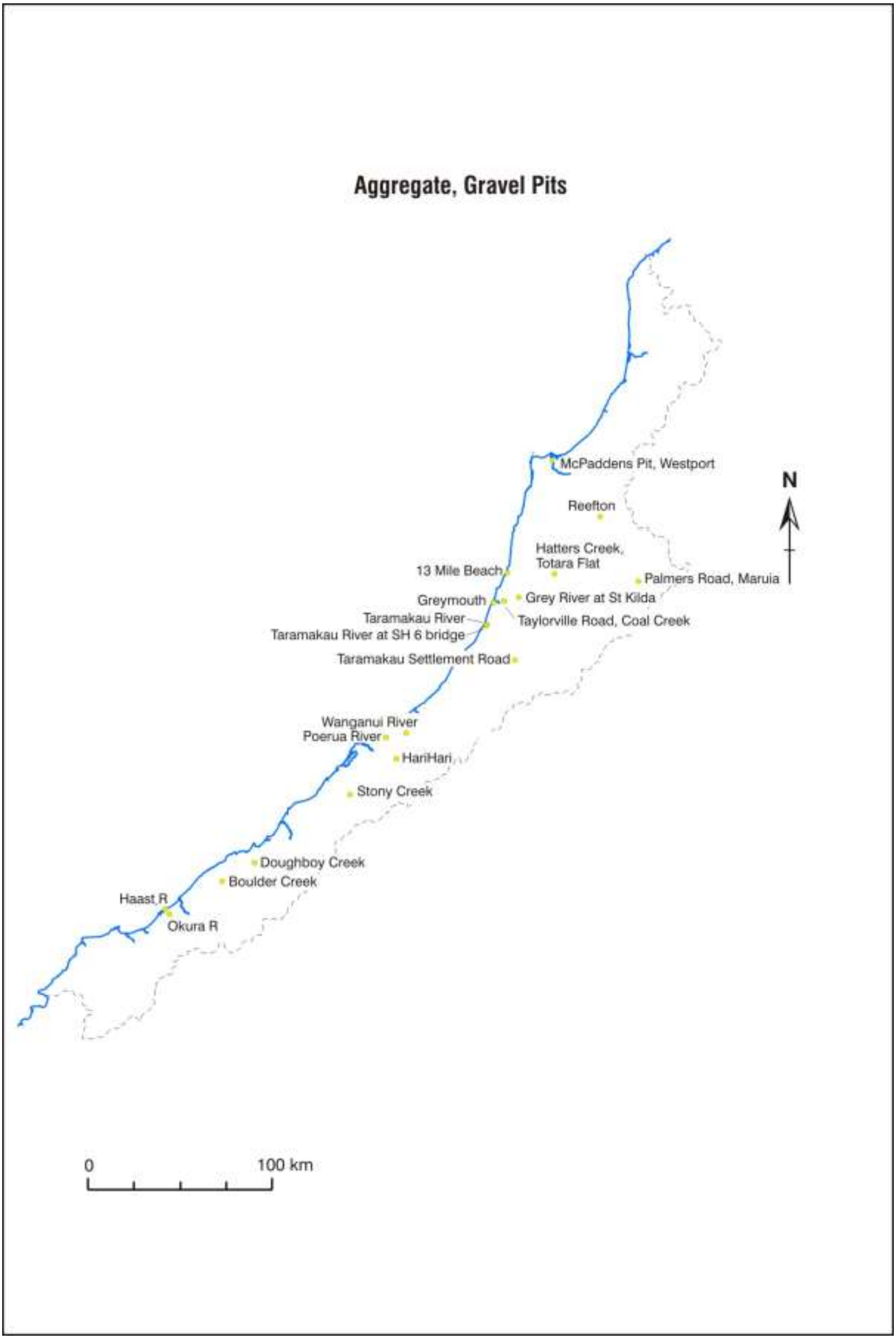


Figure 21 Location of aggregate gravel pits.

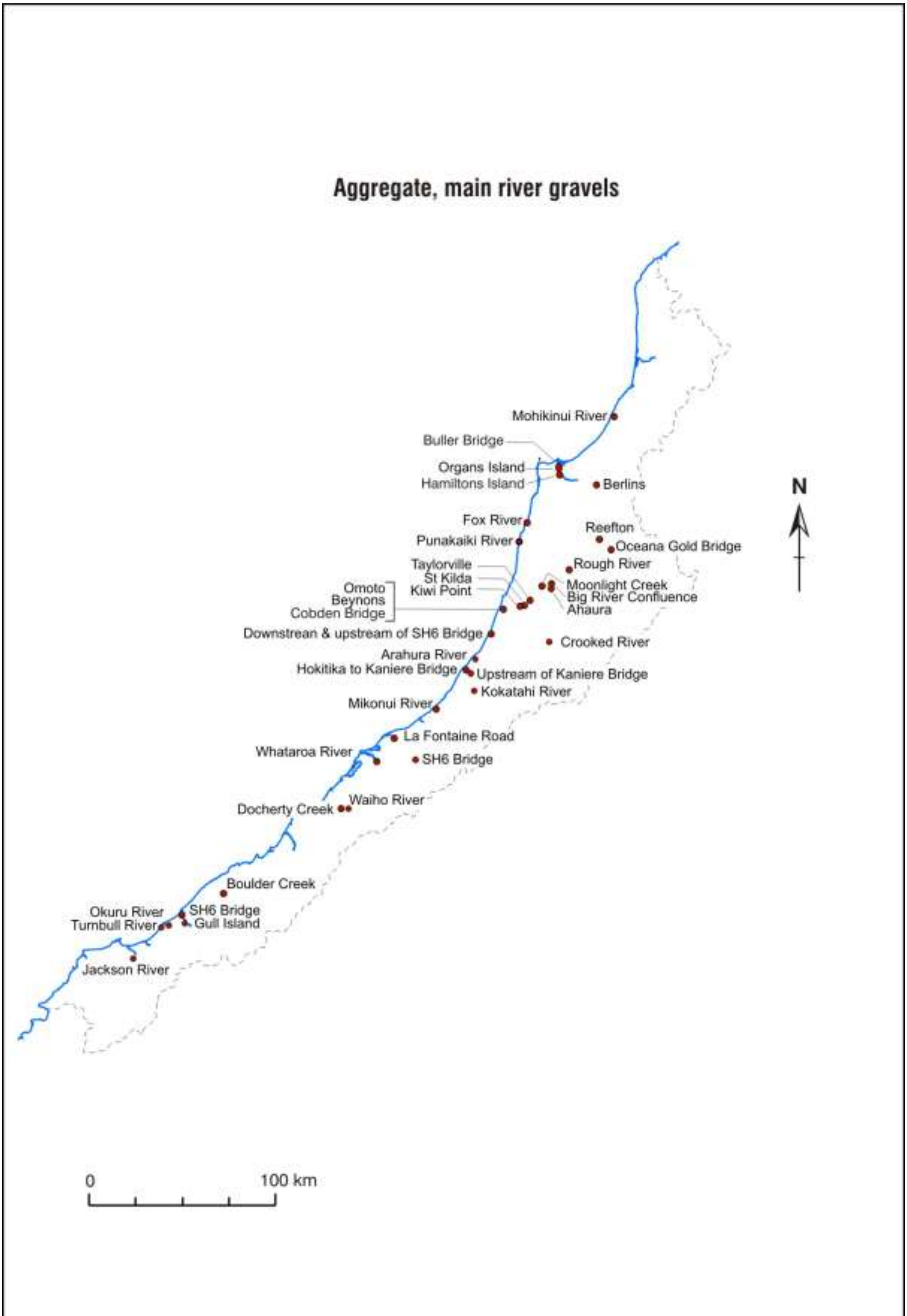


Figure 22 Location of main aggregate river gravel extraction sites.

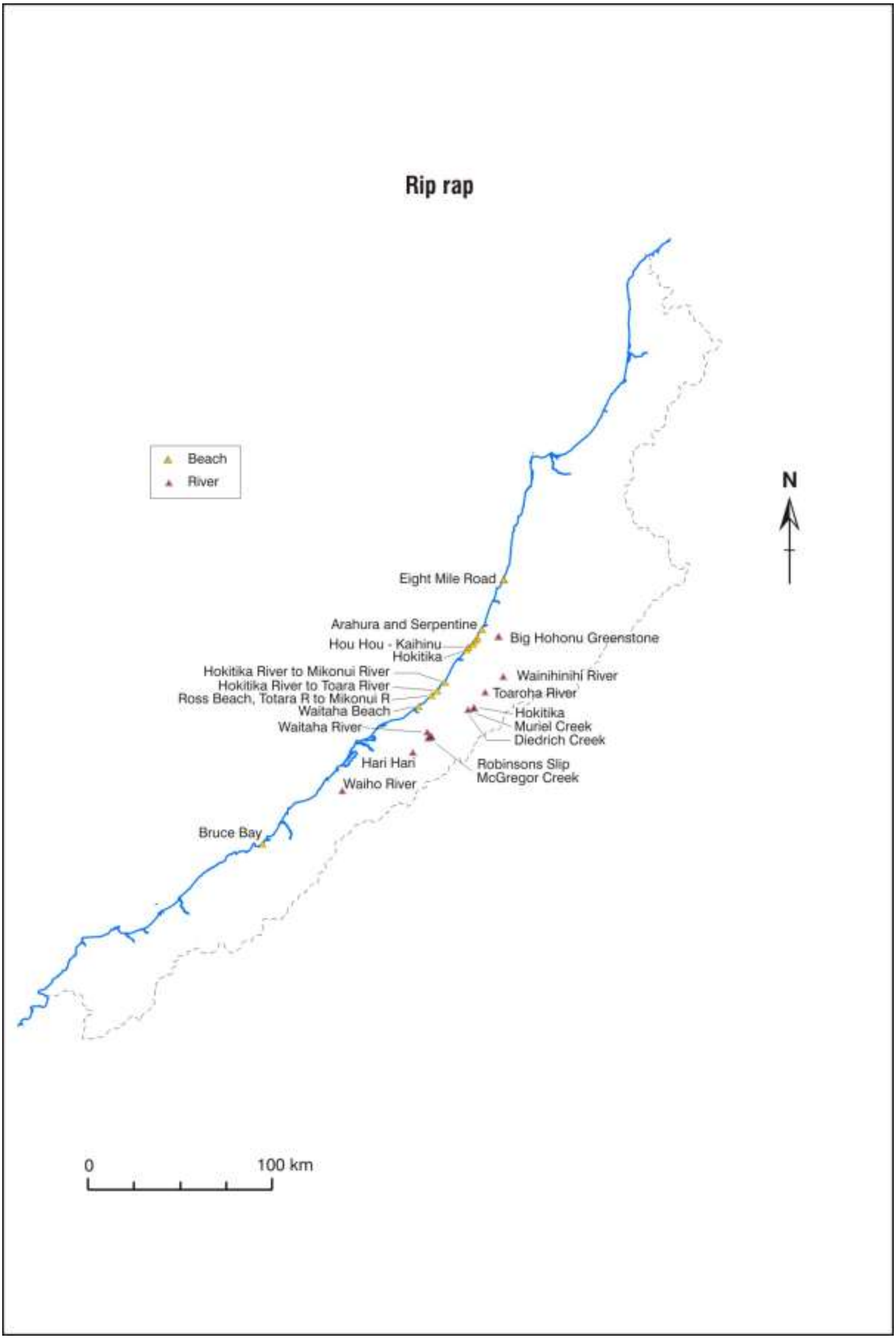


Figure 23 Location of rip rap sites from the GERM and West Coast Regional Council databases.

10.2.1 West Coast Deposits

Abundant resources of aggregate are present in the West Coast region, particularly as easily worked gravel deposits in the following settings: (a) modern river and stream channels and banks, (b) Quaternary interglacial aggradational river terrace deposits (e.g. along the Buller, Grey, Arnold, Taramakau, and Hokitika rivers), (c) Pleistocene glacial outwash and till deposits, (d) Pleistocene raised interglacial beach deposits along the coastline, and (e) tailings from placer gold workings.

The gravel commonly exploited is predominantly composed of greywacke and granite, with locally derived, variable quantities of gneiss and schist. Generally, in the north of the region the Greenland group is the major source of greywacke, whereas in the central and southern parts, Torlesse and Haast Schist terrane detritus is supplied by rivers flowing from the Southern Alps. Gravel in the Grey and Buller river systems contains a high proportion of granitoid rocks because of the close proximity of the granites of the Karamea and Paparoa batholiths. At Charleston, deposits consist mostly of gneiss, which rapidly diminishes in importance southwards. Near Ahaura, gravels consist of greater than 80% greywacke, derived from the Torlesse Supergroup, and less than 20% granitoid. Limestone is rarely used for aggregate (although commonly used for rip rap).

The abundant supplies of river gravel, and its proximity to points of use, means that transport of aggregate over large distances is usually unnecessary. Gravel for roading is obtained from many river and pit localities, and is normally taken from the most convenient point close to forestry and county roads. Several pits are commonly opened at a single locality. They operate intermittently and production can vary widely from year to year.

Riverbed and beach deposits are generally extracted by loader (Figure 24 - Figure 26). Terrace deposits, however, usually require stripping and may need ripping with a bulldozer before removal with a loader. Large material is screened and various sizes produced for basecourse and topcourse. Crushing is normally required for shaping and sizing of concrete and road-building aggregates.

Natural large river boulders and large quarried blocks are used as rip rap for river protection, breakwaters, harbour moles, and in reclamation fill. Quarries can produce angular blocks of rock that are more effective for erosion control than rounded river boulders.

River Gravel Deposits

The supply of rock for roading and construction is dominated by gravel produced from the beds of rivers and adjacent river banks and terraces. The West Coast Regional Council grants consents for gravel extraction that set maximum annual rates. Most production is from 40 sites that have been approved for the extraction of more than 5,000 m^3 per year. These are distributed throughout the region extending from the Mohikinui River in the north to Jackson River (a tributary of Arawhata River) in the south. Consent information for these sites for late 2009 is summarised in Table 2. Extraction of up to 500 and 1,000 m^3 of riverbed gravel per year is a permitted activity in a schedule of catchments listed in the Proposed Regional Land and Riverbed Management Plan.

The total available volume of more than 700,000 m^3 of river gravel per year authorised by the consents is equivalent to about 1.5 Mt of material annually (assuming a density of 2 t / m^3). However, Table 1 above shows that total recorded aggregate production for roading and building was well below this total, at 309,585 t in 2007 and 111,912 t in 2008. River extraction sites are generally worked intermittently for particular roading or construction projects using mobile plants. Having a potential supply available allows the resource to be worked when required, reducing transport costs. The sustainability of continuing gravel extraction is described in the following "future potential" section of this report.

Figure 24 Mining river gravel for aggregate (photo courtesy of Minerals West Coast).

Figure 25 Mining river gravel for aggregate (photo courtesy of Minerals West Coast).

Figure 26 Gravel stockpiles near Greymouth (GNS photo CN36126/18, photographer Lloyd Homer).

Table 2 Gravel extraction sites with greater than 5,000 m³ allocated per year

River Name	**Total allocated** (m³ per year)
Buller District	
Buller River	100,500
Mohikinui River	9000
Fox River	5,300
Grey District	
Grey River	260,850
Taramakau River	125,000
Punakaiki River	9200
Westland District	
Hokitika River	62,000
Haast River	16,000
Wanganui River	21,000
Mikonui River	6000
Arawhata River	6000
Waiho River	49,500
Okuru River	30,100
Moeraki River	52,000
Whataroa River	6000
Arahura River	17,000
Total	775,450

Table 3 Gravel extraction sites with greater than 5000 m³ allocated per year

River Name	Location	Easting	Northing	Current Consent Holders (as of 08/10/09)	Total Allocated at Site (m³ per year)
Buller District					
Buller	Buller Bridge	2393361	5936871	GP Contracting Ltd, Avery Brothers Ltd, Coastal Constructors	10,000
	Organs Island	2393818	5932349	Avery Bros Ltd, GC Smith Contracting Ltd, Ferguson Brothers Ltd, Pearson Contracting Ltd, Westreef Services Ltd, R Belcher, GP Contracting Ltd, Fulton Hogan Ltd	46,000
	Berlins	2413619	5927077	R Belcher	10,000
	Hamiltons Island	2393481	5935923	GP Contracting Ltd	7500
	Inangahua River, Reefton	2415074	5898120	Westreef Services Ltd, Tai Poutini Polytechnic, Rosco Contracting Ltd	17,000
	Inangahua River Oceana Gold Bridge	2421377	5892464	Rosco Contracting Ltd	10,000
Mohikinui		2422976	5963354	Pearson Contracting Ltd, Avery Bros Ltd, Westreef Services Ltd	9000
Fox		2376390	5906919	Fulton Hogan Ltd, MBD Contracting Ltd, R Reedy, Kelvin Douglas Contracting (2004) Ltd, NK Oates	5300
Grey District					
Grey	Cobden Bridge	2363961	5860728	Works Infrastructure Ltd, Westroads Ltd, Ferguson Brothers Ltd, Coastal Constructors	25,000
	St Kilda	2374749	5862800	Fulton Hogan Ltd, T Croft Ltd, Ferguson Brothers Ltd, Grey District Council, Westroads Ltd	22,500
	Kiwi Point	2372754	5862352	Ferguson Brothers Ltd, Westroads Ltd, T Croft Ltd	7350
	Atarau	2388400	5872100	Grey District Council	10,000
	Ahaura	2389369	5871841	PF&LE Berry	14,000
	Beynons	2364949	5859753	Fulton Hogan Ltd	30,000
	Craigieburn	2394400	5879200	Grey District Council	5000
	Omoto	2365996	5860687	Fulton Hogan Ltd, Coastal Constructors, Westroads Ltd	57,000
	Big River Confluence	2389537	5874449	PF&LE Berry	6000
	Taylorville	2378066	5865560	Grey District Council	5000
	Rough River	2399069	5881731	Ferguson Brothers Ltd, Grey District Council	35,000
	Moonlight Creek	2384451	5873178	G&G O'Connor, Grey District Council	11,000
	Crooked River	2388241	5843470	Paul Steegh Contracting Ltd, Ferguson Brothers Ltd, MBD Contracting Ltd, Fulton Hogan Ltd, Westroads Ltd	33,000

River Name	Location	Easting	Northing	Current Consent Holders (as of 08/10/09)	Total Allocated at Site
Taramakau	Downstream of SH6 Bridge	2357272	5847713	Ferguson Brothers Ltd, Westroads Ltd	75,000
	Upstream of SH6 Bridge	2358306	5847578	AG Cochrane, Ferguson Brothers Ltd	50,000
Punakaiki		2372220	5896691	NJ Mouat	9200
Westland District					
Hokitka	Hokitika to Kaniere Bridge	2344011	5828551	Scott Sandrey Contracting Ltd, John Dimmick Contracting Ltd, Westroads Ltd, AJ Cameron Contracting	32,000
	Upstream of Kaniere Bridge	2346498	5826615	Scott Sandrey Contracting Ltd, John Dimmick Contracting Ltd, Westroads Ltd, AJ Cameron Contracting	24,000
	Kokatahi River	2348213	5817319	Westroads Ltd, John Dimmick Contracting Ltd	6000
Haast	SH6 Bridge	2192498	5698045	Ferguson Brothers Ltd, Wanaka Digger Services Ltd, MTP Ltd, JJ Nolan Ltd, Westroads Ltd	6000
	Gull Island	2193829	5693514	Wanaka Digger Services Ltd	10,000
Wanganui	SH6 Bridge	2316879	5780590	Westroads Ltd, Amethyst Hydro Ltd	14,000
	La Fontaine Road	2305525	5792110	TA Arnold Transport Ltd, Westroads Ltd, Specks Trust	7000
Mikonui		2328114	5807620	P Cornish	6000
Arawhata	Jackson River	2166410	5674658	AT Wedding, Westroads Ltd	6000
Waiho		2281145	5754588	Transit NZ, Scenic Circle hotels, TA Arnold Transport Ltd, G Molloy, Westroads Ltd	40,000
	Dochertys Creek	2277352	5754656	Ferguson Brothers Ltd, Fulton Hogan Ltd, Wild West Adventures Ltd, Westroads Ltd, Ferguson Brothers Ltd	9500
Okuru		2185510	5692450	JJ Nolan Ltd, IL Rasmussen, AT Wedding	13,100
	Turnbull River	2181350	5691298	E&H Johnson, k Eggeling, N Gray, JJ Nolan Ltd, Westroads Ltd	17,000
Moeraki	Boulder Creek	2214634	5709414	Ferguson Brothers Ltd,Fulton Hogan Ltd, Transit NZ, Road Metals Co Ltd	52,000
Whataroa		2296282	5779791	TA Arnold Contracting, Arnold Contracting, Westroads Ltd	6000
Arahura		2348874	5834220	Te Runanga o Ngati Waewae Inc, John Dimmick Contracting Ltd, GC Smith Contracting Ltd	17,000
				Grand total	**775,450**

Terrace Gravel Deposits (Table 4)

Extensive deposits of Quaternary river and glacier deposited gravels are widespread along the West Coast Region. These gravels tend to be weathered and contain silt, unlike the gravels that occur in, and adjacent to rivers. The current resource consent database lists more than 30 active gravel pits that are distributed throughout the region. These produce lower grade material than the river bed gravel deposits. It is used as sub-base material for making roads, and for fill. These pits are worked intermittently.

Table 4 Aggregate gravel pits

Owner	Name	Location
Grey District Council	Donaldsons	K31:806-646
Private	Birchfields	K32:999-498
Grey District Council	Bell Hill	K32:934-482
Private	State Farm	K32:930-522
Grey District Council	Ahaura Kopara	K31:083-634
Grey District Council	Deep Creek	K32:919-520
Grey District Council	Eastern Hohonu	K32:752-386
Department of Conservation	Black Creek	K31:990-689
Private	State Forest	K32:721-493
Grey District Council	Dunganville	K32:719-494
	Kongahu	L27:363-882
	Karamea landfill gravel pit	L27:375-968
	Mawheraiti River, Ikamatua	K31:005-810
	Big Totara River	K29:853-249
M S Sullivan	Haast River	F37:834-942
I L Rasmussen	Okuru River	F37:858-915
Fulton Hogan Limited Central	Doughboy Creek	G36:318-193
Road Metals Co Ltd	Boulder Creek	G37:144-093
Molloy G & C	Stony Creek	H35:835-562
FH Simpson	Poerua River	I34:028-870
BD Mining Ltd	Hari Hari	I34:084-755
A&Q Henderson	Wanganui River	I34:138-894
G And J Powell trading as Coastal Constructors	Taylorville road, Coal Creek	J31:667-608
D Oates	13 Mile	J31:686-762
Ferguson Brothers Ltd	Taramakau River	J32:575-480
Westroads Greymouth Ltd	Greymouth	J32:611-599
T Croft Ltd	Grey River at St Kilda	K31:746-628
West Coast Regional Council	Taramakau Settlement Road	K33:725-288
PA & D Russell	Reefton	L30:186-064
John Dimmick Contracting Ltd	Taramakau River at SH 6 Bridge	J32:571-476
C J Hannah	Hatters Creek, Totara Flat	K31:939-755
Maruia Enterprises Ltd	Palmers Road, Maruia.	L31:394-715
Westreef Services Ltd	McPaddens Pit, Westport	K29:927-367

Hard Rock Quarries (Table 5)

Because of its abundance and widespread occurrence, river gravel deposits are the main source of aggregate for building and roading purposes, whereas quarries are used to supply blocks of rock (rip rap) for river and coastal protection. Their angular shape makes them less likely to move than rounded river-deposited material. The consent register maintained by the West Coast Regional Council shows 16 hard rock quarries in the region.

Table 5 Quarries – aggregate

Owner	Name	Location
West Coast Regional Council	Okuru Quarry	F37:839-937
Ferguson Brothers Ltd	Haast	F37:942-907
Ferguson Brothers Ltd	Paringa	G36:256-154
West Coast Regional Council	Wanganui Quarry	I34:175-779
S B McGrath	Hari Hari	I34:181-869
West Coast Accounting Ltd	Waitaha Valley	I34:232-916
Management and Processing Limited (Maori Gully)	Eight Mile Road	J31:664-706
West Coast Regional Council	Ruatapu	J33:370-175
West Coast Regional Council	Butlers Freehold Quarry	J33:374-168
West Coast Regional Council	Mt Camelback, Kowhitirangi	J33:466-117
West Coast Regional Council	Kiwi Point	K31:725-623
Ferguson Brothers Ltd	Grey River	K32:735-590
West Coast Regional Council	Inchbonnie Quarry	K32:826-306
	Turiwhate Quarry	K33:710-277
C Miedema	Arapito, Karamea	L27:439-945
West Coast Regional Council	Paddy Gourley Creek, Maruia Valley	L31:443-823
B A Rogatski	Kopara	L32:131-530

10.2.2 Future Potential

The future potential of gravel extraction depends on the issue of sustainability of the resources. The total quantity of sediment transported to the continental shelf by the main rivers throughout New Zealand has been calculated at about 105 Mt per year for the North Island and 284 Mt per year for the South Island (Griffiths & Glasby 1985). This rate of more than 1800 t / km^2 / yr for the South Island (284 Mt from an area of 153,000 square km) is much higher than the world average of about 182 t / km^2 / yr. The West Coast South Island (NW Nelson to Fiordland) rates are particularly high at more than 200 Mt per year, and account for most of the South Island total. The rapid erosion rate is attributed to rapid uplift, geological youth, high rainfall, and to a much lesser extent, possible effects of deforestation and the introduction of European farming practices.

Table 6 Input of river derived sediment to continental shelf – West Coast rivers

River	Annual load Mt/year	Bedload Kt/year
Karamea	0.404	8 – 20
Mokihinui	2.88	58 – 144
Buller	1.75	35 - 88
Grey	3.11	62 – 156
Taramakau	9.93	200 – 500
Hokitika	12.0	240 – 600
Kapitea to McKenzie	80.1	1,600 – 4,000
Haast	17.2	340 - 860
Total	125.62	2,510 – 6,281

Bedload is defined in practice as material too coarse to be sampled by a suspended sediment sampler (i.e. with a particle diameter greater than 2 mm which is within the gravel class range of the international standard Wentworth scale) and is estimated to range from 2% to 5% of the suspended load. The bedload will comprise a significant proportion of the sediment suitable for aggregate. Applying these percentages to the total load gives an annual bedload ranging from 8000–20,000 t/year for the Karamea river to 340,000-860,000 t/year for the Haast River. The Buller, Grey and Taramakau rivers are the main source of aggregate and have a total estimated bedload of between 300,000 and 744,000 t/year. In 2008, total aggregate production on the West Coast was estimated at 200,000 t, including material produced from pits working fluvioglacial terrace deposits and hard rock quarries. The total estimated bedload of 2.5 to 6.3 Mt/year for rivers in the West Coast Region is very large in relation to the current annual production rate.

This issue has been investigated in more detail by the West Coast Regional Council (Hudson 1988), who noted that many West Coast rivers have an abundant sediment supply, but there are considerable differences apparent in time and space. For example the Waiho River which drains the Franz Josef glacier has aggraded significantly in recent years following a period of degradation. In addition to cycles of aggradation and degradation for particular rivers, there are major differences in river behaviour along the coast.

In general terms, preliminary investigation suggests that southern rivers (e.g. Taramakau, Hokitika and Haast) have coarse aggregate loads that considerably exceed rates of extraction. Northern rivers, such as the Punakaiki and Karamea, are widely acknowledged to have limited aggregate supplies.

Extraction rates may exceed rates of replenishment on the Buller and Grey rivers, which are two of the largest sources of aggregate. Approximately 120,000 t was allocated in the Grey River in 1995. Coarse aggregate load is in the order of 60,000 to 120,000 t based on Griffiths & Glasby (1985). Approximately 80,000 t was allocated in the Buller, which has an estimated coarse aggregate load of ~40,000 to 80,000 t. Hudson (1988) recognised these bedload transport figures are only rough estimates, and may be low estimates although affected parties may question the assumption of sustainable harvest of aggregate from these rivers.

Hudson (1988) recommended that the rate of extraction and estimates of coarse aggregate supply are evaluated to identify possible supply problems. If major resource development is planned (e.g. river aggregate export), more comprehensive evaluation will be required.

An investigation into the management of aggregate (gravel) resources of the West Coast was carried out by Temple (2001) who studied the Inangahua, Grey and Whataroa Rivers. The study included sediment sources, changes in riverbeds and banks based on analysing airphotos and riverbed profile measurements, and testing the suitability of the material for a range of aggregate uses. The volume of sediment transported determined by this study is much less than that indicated by the work of Griffiths & Glasby (1985) though additional research would be needed to confirm these differences.

More recent calculations of sediment load based on an empirical model and sediment measurements at 200 sites throughout NZ (Hicks & Shankar 2003) have produced estimated yields of river-deposited sediment of 209 Mt/year for the North Island and 91 Mt/year for the South Island. The West Coast region accounts for about 68.5 Mt of total South Island sediment yield, considerably lower than the estimates of Griffiths & Glasby. However, Hicks (2003) estimated the bedload of the Hokitika River to be equivalent to about 5-10% of its suspended load when both the coarse sand and gravel are included based on bedload to suspended load ratios in other rivers.

The estimates of rates of sediment transport vary widely, as do estimates of the proportion that is represented by bedload. Differences in bedload estimates are due partly to how bed load is defined. The estimates of Griffiths & Glasby (1985) define bedload as gravel, with a particle size greater than 2mm, while if medium and coarse sand is included (with a particle size between 0.25 and 2mm), the bedload accounts for a much greater proportion of total sediment load. River gradient is a significant factor also. Hicks & Griffiths (1992) noted that in New Zealand mountain streams, the bedload can be about 90% of the suspended load.

Aggregate demand will increase as a result of increased infrastructure development and building.

10.2.3 Aggregate Exports

The West Coast region has an abundant supply of alluvial and fluvioglacial gravels and extensive, accessible resources of hard rock suitable for use as aggregate. Other regions in New Zealand, Auckland and Gisborne particularly, have to transport aggregate over long distances as local supplies are inadequate. In Auckland aggregate demand has been growing due to population and economic growth, while supplies of basalt, the traditional source of supply, have diminished as existing quarries are worked out and the development of new quarries is constrained by urban development above and close to potential resources. Several million tonnes were being transported to Auckland each year from adjacent regions (O'Brien 2006), but that has diminished significantly due to the effects of the recession on building activity. In the future, demand will increase along with the level of construction activity.

The feasibility of exporting both alluvial and hard rock aggregate from the West Coat has been investigated by the Port of Greymouth (Temple 2000) and in student research (Brockett 2004). The Port of Greymouth study involved field and laboratory investigation of aggregate resources within 80 km by road from the port of Greymouth. It evaluated potential for rip rap (armour stone) and aggregate for roading, concrete-making and railway ballast. Tuhua granite was found to be the most suitable rock type for rip rap stone. It is available from 3 quarries (Inchbonnie, Taramakau and Turiwhate). Camelback Limestone was also suitable, but its potential is limited by the small available resource at the Camelback quarry and the distance of the quarry from Greymouth. Fine grained Cobden limestone was found to have potential also, and is more abundant, but has lesser durability.

Coastal beach material from Blaketown near the mouth of the Grey River was found to be very suitable for use as aggregate and the study concluded that similar deposits of coastal beach material that are being actively abraded by the sea will be of good quality. Young fluvioglacial gravels were also found to be suitable for use as aggregates though their quality is more variable.

Brockett (2004) investigated the feasibility of transporting West Coast aggregate to Auckland. The study reviewed supply, transport options, economic feasibility, regulatory issues, environmental factors and comparable bulk transport operations in New Zealand and overseas. It concluded that the transport of aggregate from the West Coast to Auckland was not feasible at that time, but only by a narrow margin. Rising prices in Auckland and improved transport efficiency could make aggregate transport to Auckland feasible in the future. If transport issues are solved for export to Auckland, this may also increase the potential for export to other North Island regions that have an inadequate local supply of high quality aggregate (e.g. Taranaki and Hawkes Bay).

Based on our enquiries, West Coast aggregate producers are not generally optimistic about the potential for large scale aggregate exports from the region in the near future. Small quantities of high value decorative materials are being exported and this is likely to continue. Large scale exports of river transported gravel are impeded by uncertainties about the sustainable extraction rate, which depends on the occurrence of major floods in the main river catchments. As noted above, published estimates vary widely.

Rock quality varies. The northern catchments, where granite and greywacke are dominant, tend to produce the best quality material, but aggregate from the more southerly rivers, where schist is the predominant rock type, is generally unsuitable for concrete aggregate and sealing chip. As noted above, there is disagreement about the availability of supplies of high quality aggregate that are sustainable over the long term.

Transport constraints affect low value exports and the ports are unsuitable for large vessels. Rail freight across the Southern Alps is at present prohibitively expensive for comparatively low value materials such as aggregate.

Hard rock quarries could be developed to supply external markets if the transport constraints can be overcome, and rising demand increases prices significantly.

10.3 BUILDING AND DIMENSION STONE

10.3.1 West Coast Deposits (Table 7)

A wide variety of rock types present in West Coast region are potentially suitable for use as dimension stone (building and facing stone), particular schist, granite, sandstone, and serpentinite. Production has been significant in the past, but utilisation is currently low because of high labour costs, difficulties of access and transportation, and changing construction practice and preferences. A significant limiting factor in finding new resources is the almost ubiquitous presence of irregular jointing in rocks of the region, caused by the complex Cenozoic tectonic activity.

Schist suitable for dimension stone is found as boulders in river deposits in the gorges of the Hokitika[1] (J33/e25-27, e29, e35, e36, e61, e62), Kokatahi (J33/e56, e57, e59), and Arahura (J33/e50) rivers, and at Wainihinihi on the Taramakau River (K33/e4, e5, e18, e19). All these sites are immediately west of the Alpine Fault. Schist is an attractive stone because of variations in appearance caused by varying abundance of chlorite (green), stilpnomelane (brown) and piemontite (pink). Main uses of the rock have been non-structural, as facing slabs, and for monumental work. Production from the sites listed is small, with the largest (J33/e25) yielding just over 500 t of rock over five years.

Between Cape Foulwind and Tauranga Bay, there is a resource of Foulwind Granite estimated at 85 Mt (K29/e1, e53). This granite is grey in colour, and contains large crystals of feldspar, which give it an attractive appearance and suitability as a facing stone (Marshall 1929). The major use, however, has been for rip rap in harbour works.

1 The sheet number and location references are for the GERM digital mineral occurrence database http://data.gns.cri.nz/minerals/germ/index.jsp

Railway Quartz Diorite is also suitable for building purposes, although it has not been utilised to date. A large supply of attractive stone is available in the lower Buller Gorge (K29/e54-56).

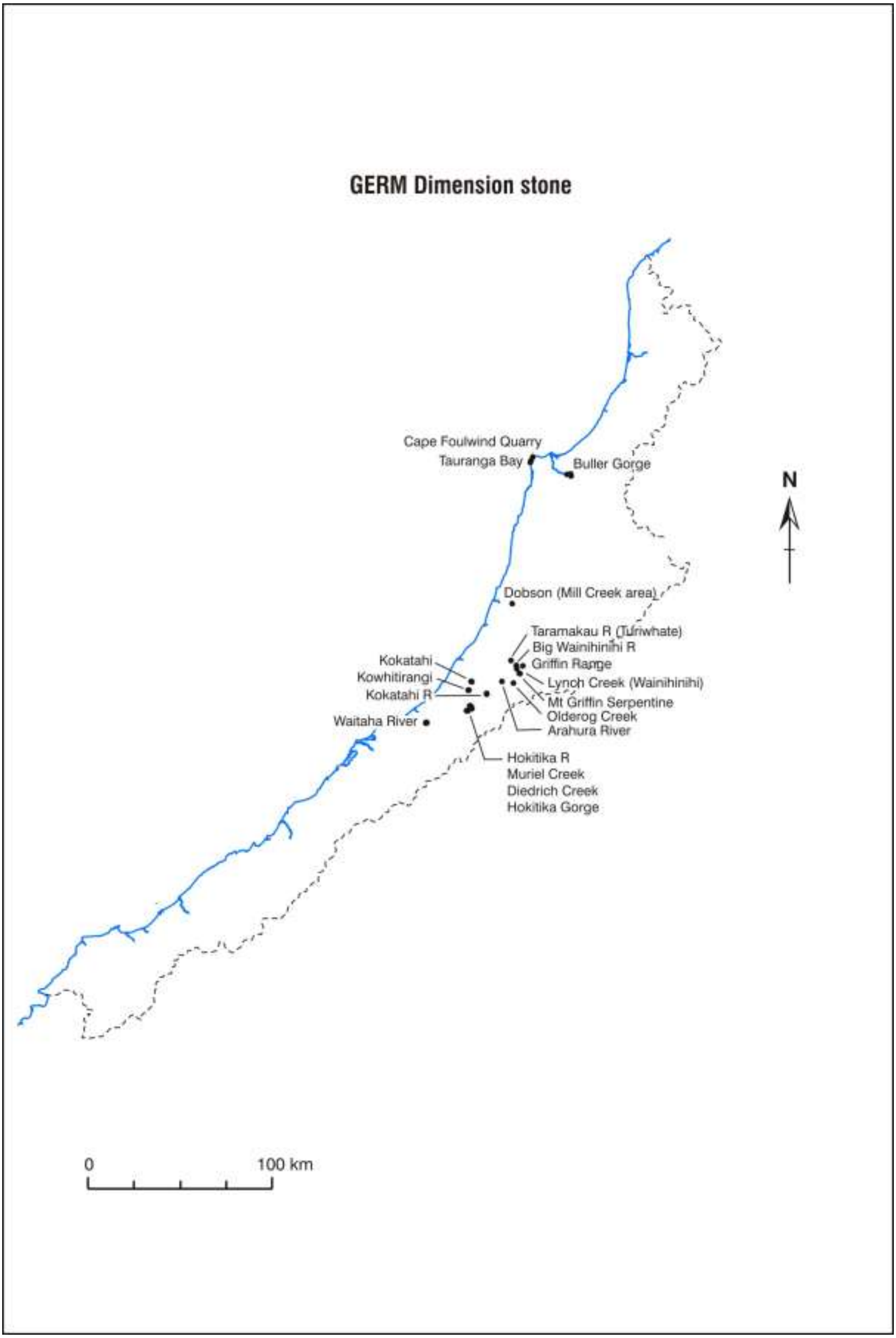


Figure 27 Location of building and dimension stone sites from the GERM and West Coast Regional Council databases.

The Island Sandstone from Dobson (K32/e87), near Greymouth, was used unsuccessfully for the basement course of the Government Building in Christchurch, and the now demolished General Post Office in Wellington (Marshall 1929). The sandstone is medium grained, consisting predominantly of brown quartz with some blebs of pyrite and marcasite. High values of absorption (2%) and porosity (5.1%) resulted in the disintegration of the basal areas of the buildings where the sandstone was in contact with the ground. Shearing resistance and compressional strength are also low, leading to fracturing. Weathering of pyrite and marcasite to iron oxide also spoils the appearance of the stone. These factors preclude further use of the Dobson sandstone for building purposes.

Boulders of serpentine occur within river deposits at Nephrite Creek (K33/e59) in the Griffin Range, the Hokitika River, and Muriel Creek (J33/e114), but production has been small. In the early 1900s, a serpentine quarry operated above the Taramakau Valley in the Griffin Range (K33/e28). The rock (Taramakau Serpentinite) was sawn into slabs for facing stone, and utilised in several major buildings such as the D.I.C. Building, Dunedin, and the National Insurance Building in Christchurch (Marshall 1929). The quarry closed in 1915, but was re-opened in 1991 by South Pacific Resources Ltd to produce tiles. Production during 1992 was 5 t.

At present, it is more economic to import stone for building purposes than to utilise West Coast material. This and the comparative isolation of the West Coast suggest that production of dimension stone in north Westland in the foreseeable future will be limited.

10.3.2 Future Potential

There is potential for extraction of rock for building and dimension stone for export from the region, but in terms of value, in relation to other commodities such as coal and gold, any new operations are likely to make only a very small contribution to the total value of mineral production from the West Coast region.

10.4 LIMESTONE

10.4.1 West Coast Deposits (Table 8 and Figure 28)

The locations of limestone and limestone quarries are shown in Figure 28. About 920,398 t of limestone were produced from the West Coast region in 2006: 77,278 t were used for agriculture, 840,000 t for cement making, and 3,120 t for industry and roading. Statistics for 2009 (Table 1) are available only for agricultural lime (86,296 t) and for industry and roading (597 t), because the production for marl and cement is withheld for commercial reasons (Table 1). Production of agricultural lime between 2000 and 2009 is shown in Figure 29.

Table 7 Dimension stone

River bed dimension stone		
Consent holder	**Name**	**Location**
A&Q Henderson	Waiho River	H35:789-582
BD Mining Ltd	Hari Hari	I34:170-789
AD Martin	Waitaha River	I34:248-900
West Stone West Coast NZ Ltd	MacGregor Creek & Waitaha River	I34:254-868
West Stone West Coast NZ Ltd	MacGregor Creek	I34:265-875
Whitcombe Veneer Ltd (Stone Direct)	Robinsons Slip	I34:265-876
Lindis Schist Supplies Ltd	MacGregor Creek	I34:273-873
A&Q Henderson	Big Hohonu Greenstone	J32:634-415
West Stone West Coast NZ Ltd	Toaroha River	J33:560-115
A&Q Henderson	Wainihinihi River	J33:659-199
Schist New Zealand Ltd	Hokitika	J33:468-020
A&Q Henderson	Diedrich Creek	J33:498-027
A&Q Henderson	Muriel Creek	J33:502-031
Beach Dimension Stone		
Consent holder	**Name**	**Location**
West Stone West Coast NZ Ltd	Arahura and Serpentine	J32:498-374
West Stone West Coast NZ Ltd	Arahura and Serpentine	J32:512-393
West Stone West Coast NZ Ltd	Arahura and Serpentine	J32:524-407
West Stone West Coast NZ Ltd	Arahura and Serpentine	J32:548-454
Waitaha Schist Mining Ltd	Bruce Bay	G36:362-294
KL & G Handisides & Oswald	Waitaha Beach	I33:205-038
M Dove	Ross Beach, Totara River to Mikonui River	I33:275-097
RO Chittenden	9 Mile Beach	J31:665-722
C A Leywood	Hokitika	J32:464-345
C A Leywood	Hou Hou - Kaihinu	J32:475-358
West Stone West Coast NZ Ltd	Hokitika River to Totara River	J33:306-122
Westland Schist Ltd	Hokitika River to Mikonui River	J33:347-168

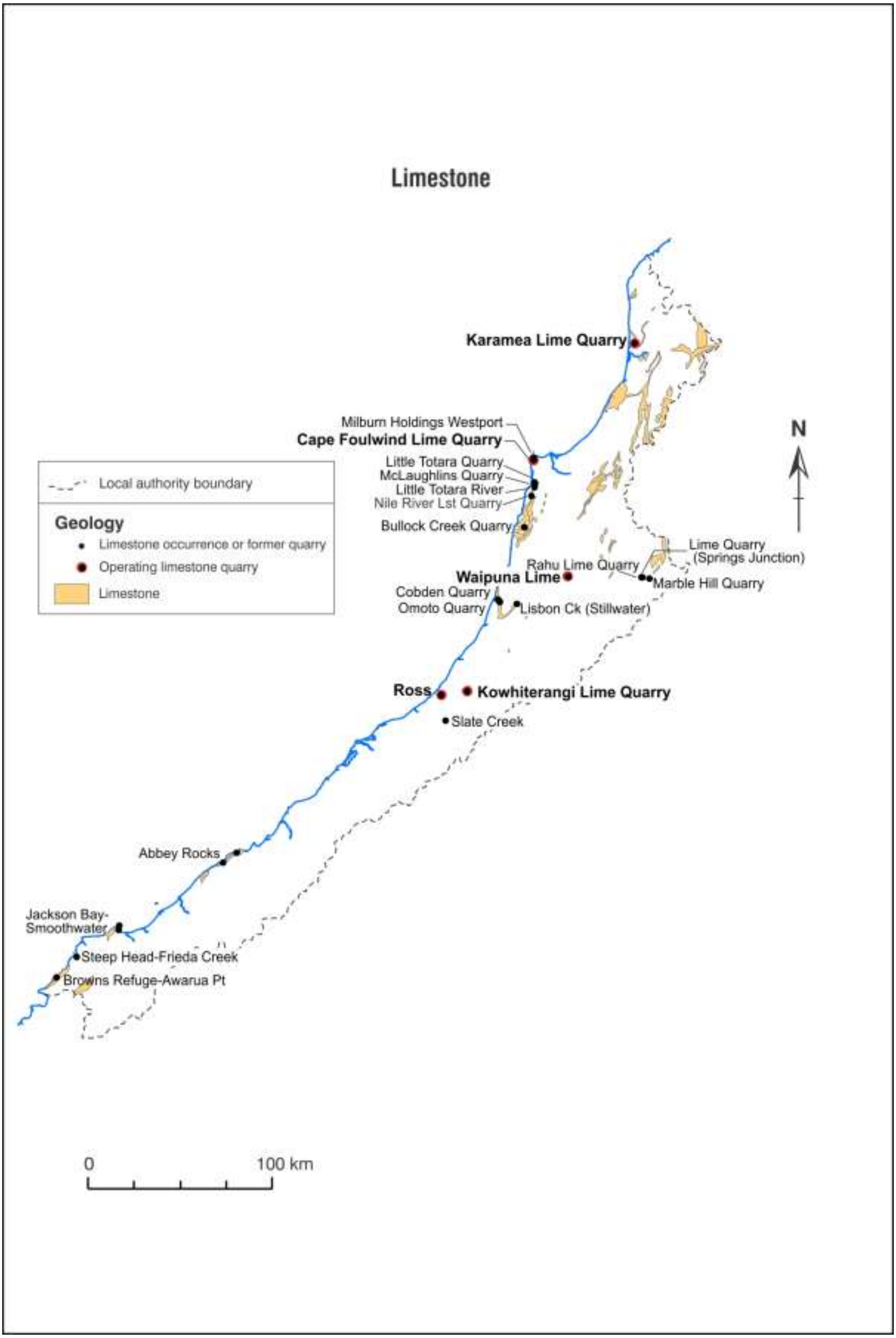


Figure 28 Location of limestone sites from the GERM database. The areas of limestone are from Turnbull & Smith Lyttle (1999).

More than 90% of the limestone produced in the region in recent years has supplied the Cape Foulwind cement plant near Westport operated by Holcim NZ Ltd (see Figure 30 and Figure 31). This operation is currently under review, and the company has obtained approvals to establish a new plant near Oamaru near the east coast of the South Island.

The other main use of limestone is for agriculture where several small operations supply the local market. (Figure 32 and Figure 33).

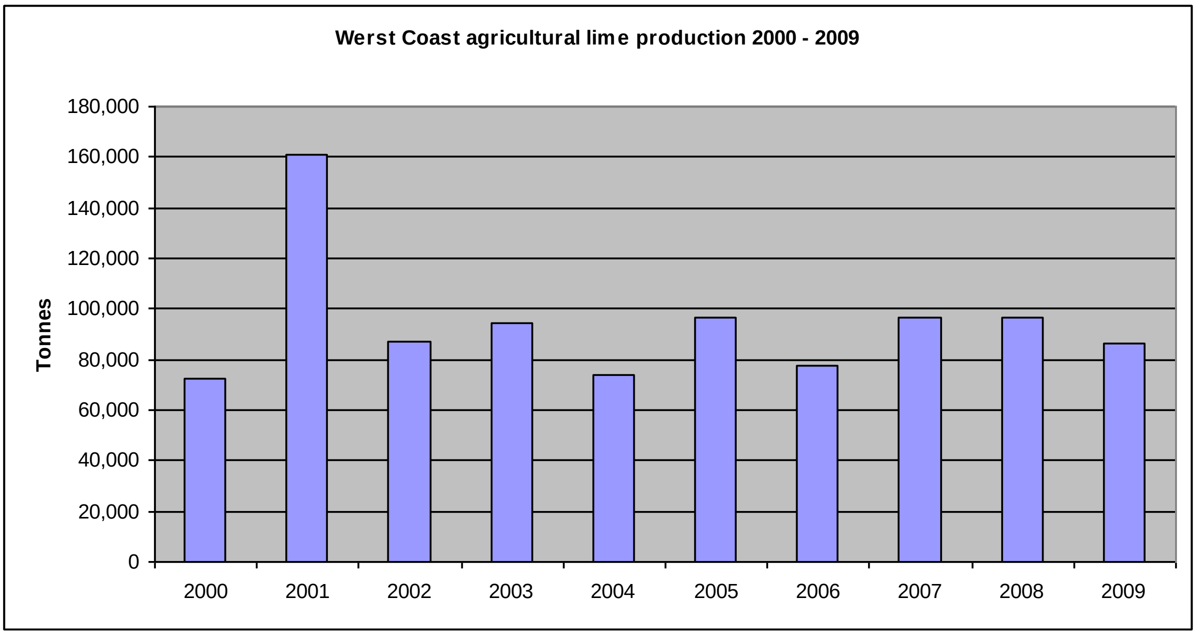


Figure 29 Coast agricultural lime production 2000 – 2009.

The belt of limestones between Charleston and Punakaiki (containing the Waitakere, Tiropahi, and Potikohua limestones) and the Cobden Limestone near Greymouth are the most extensive and accessible limestone formations in north Westland, and account for the major part of production. The Waitakere Limestone is a hard, light-grey algal limestone, and has been quarried at Cape Foulwind (K29/e2, e52; Figure 30 and Figure 31) for the past century. The high $CaCO_3$ content (92-98%) has led to a predominant use for cement manufacture. Nathan (1975) noted resources of about 5 Mt. Marl in the lower part of the Late Eocene Kaiata Siltstone at Cape Foulwind (10-20% $CaCO_3$), is also quarried locally as a component in cement manufacture. Additional resources of cement-quality Waitakere Limestone are present in the area between the Little Totara and Nile rivers. Utilisation of the Waitakere Limestone for agricultural purposes and as rip rap is also important in the region. Smaller quarries have been or are active at Little Totara River (K29/e23, e57), near Charleston, and Nile River (K29/e60). Large resources of Potikohua Limestone are also suitable for uses requiring high grade limestone (Nathan 1975).

The Cobden Limestone is well developed in the Brunner-Greymouth area where it is a hard, massive, muddy limestone. It forms a steep west-facing dip slope east of Greymouth where it defines the western limb of the Brunner-Mt Davy anticline. The resistant nature of the rock has led to extensive use as rip rap and dimension stone in harbour and river protection works (J31/e9, J32/e1). $CaCO_3$ content is generally between 70 and 75%, but may be as low as 44%. It is therefore not utilised for cement manufacture and has limited value in agriculture (Willett 1974a).

Nathan (1978a, p. 30) noted that "Bands of foraminiferal and polyzoan limestone near the base of the Stillwater Mudstone have a much higher carbonate content than the Cobden Limestone. A chip sample taken across the Tindall Limestone Member near the top of Tindall Hill contained 87% $CaCO_3$. This deposit contains easily worked reserves of only 25-40 000 t, but this could be sufficient to fulfil the needs of local farmers for several years."

Other less important limestones include the Oligocene Potikohua Limestone, Tiropahi Limestone, and Kowhitirangi Limestone. Substantial resources of Potikohoa Limestone are found at Bullock Creek (K30/e16) and north of Punakaiki (Figure 34). The rock is a hard, locally sandy, flaggy limestone, with 84-96% $CaCO_3$ (weighted average 92.4% $CaCO_3$) and has potential for agricultural lime. Predominant use has been for rip rap in river protection works. In the Charleston area, Tiropahi Limestone (excluding the Madmans Siltstone Member) has 61-77% $CaCO_3$ (weighted average 68.0%). In the vicinity of Kowhitirangi (J33/e22, e24) and Ross (J33/e16; Figure 32 and Figure 33), white crystalline Kowhitirangi Limestone and similar limestones exceed 80% $CaCO_3$, and are utilised for agriculture and rip rap. Other sites could be developed in this area.

Weathering and solution of limestone has developed several features used for recreational purposes. Caves and underground streams are present at a few locations, particularly Fox River (Fox River cave; K30/791061) and Bullock Creek (Xanadu; K30/773000). Pancake rocks and their associated blowholes, are famous tourist attractions situated at Dolomite Point, Punakaiki (K30/716978) (Figure 35). Laird (1988) noted that "They are developed in Potikohua Limestone, underlying the 34 to 36 m terrace formed on Waites Formation, which is being stripped of its cover of marine gravels by salt spray thrown up by the breakers pounding against the foot of the cliffs, and by the heavy regional rainfall. The solution-sculptured rocks, etched by acidic soil waters from a flax bog developed on the terrace gravels, form a landscape of striking towers and minarets." Weathering has emphasised the flaggy nature of the limestone, forming the "pancakes".

Table 8 Quarries – limestone for industry and agriculture

Owner	Name	Location
Karamea Lime Co	Karamea	Oparara Rd, Karamea
Holcim (New Zealand) Ltd	Cape Foulwind	K29:827-365
Grey Valley Lime Co. Ltd	Waipuna	L31:145-686
Kioteranangi Lime Co.	Kioteranangi or Kowhitirangi	2 Camel Back Rd, Kowhitirangi
West Coast Farmers Lime Co. Ltd	Ross	22 Donnelly’s Creek Rd, Ross

10.4.2 Future Potential

The main use of West Coast limestone has been for cement manufacture at Cape Foulwind by Holcim NZ Ltd. A decision on the future of this operation is expected in 2011. Other West Coast lime producers supply the market for agricultural lime and this will no doubt continue to be the main market for this material in the future. Limestone has not been widely used as aggregate apart from some use as rip rap for erosion protection.

Figure 30 Cape Foulwind Limestone quarry (foreground), cement plant (middle distance), and Westport (far distance) (GNS photo, photographer Lloyd Homer).

Figure 31 The eastern face of the Cape Foulwind limestone quarry, including the overlying Kaiata Mudstone "marl" that is quarried (photo courtesy Keith Miller, Holcim).

Figure 32 Limeworks at Ross operated by West Coast Farmers Lime Co. Ltd (photo courtesy of Terry Rea, West Coast Farmers Lime Co. Ltd).

Figure 33 Limestone quarry (West Coast Farmers Lime Co. Ltd) located above the limeworks at Ross (photo courtesy of Terry Rea, West Coast Farmers Lime Co. Ltd).

Figure 34 Bluffs of Oligocene limestone above the Pororari River and Punakaiki village (GNS photo CN32497/24, photographer Lloyd Homer).

Figure 35 Pancake Rocks of Oligocene Potikohua Limestone at Punakaiki (GNS photo CN4019 H, photographer Lloyd Homer).

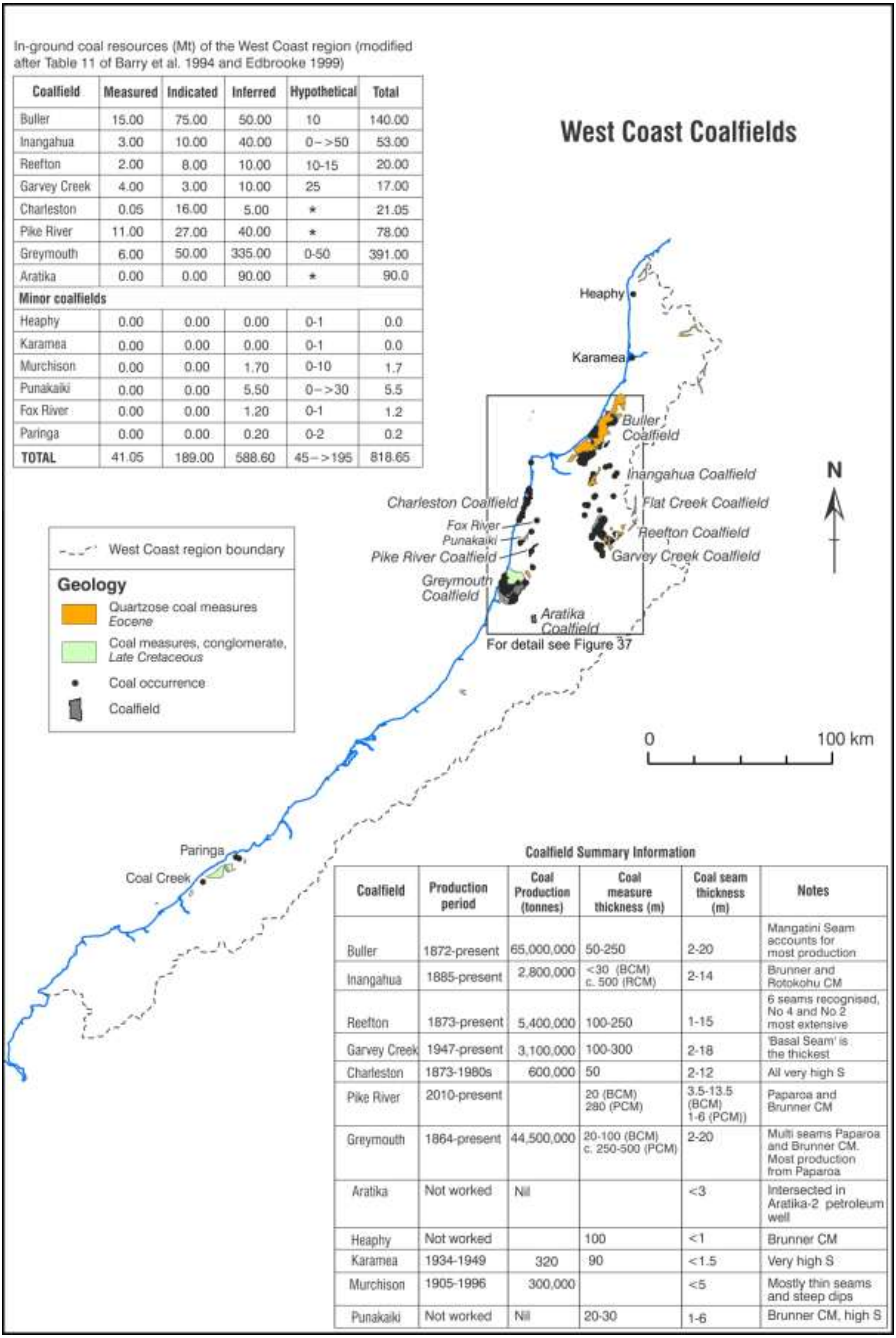
11.0 COAL

11.1 INTRODUCTION

The West Coast coal region comprises the Greymouth, Buller, Pike River, Reefton and 10 other smaller coalfields that have produced more than 120 Mt of coal to date (Figure 36 and Figure 37). Coal was discovered near Greymouth by Thomas Brunner in 1848, and the first systematic workings began at Brunner in 1864. Large scale coal mining did not start until 1878 with the opening of the Banbury Mine on the Denniston Plateau. The commissioning of the Denniston incline in 1880, and port developments at Greymouth and Westport enabled a major increase in production.

Opencast mining commenced at Stockton in 1944 and from 1975 has been on a large scale. Coal production steadily declined after World War 2, but with the start of exports in 1980, coal output has risen to record levels. At present over 1000 persons are directly involved in coal mining on the West Coast.

Annual West Coast coal production from 1994 to 2009 is shown in Figure 38. Currently producing mines are listed in Table 9.



In-ground coal resources (Mt) of the West Coast region (modified after Table 11 of Barry et al. 1994 and Edbrooke 1999)

Coalfield	Measured	Indicated	Inferred	Hypothetical	Total
Buller	15.00	75.00	50.00	10	140.00
Inangahua	3.00	10.00	40.00	0−>50	53.00
Reefton	2.00	8.00	10.00	10-15	20.00
Garvey Creek	4.00	3.00	10.00	25	17.00
Charleston	0.05	16.00	5.00	*	21.05
Pike River	11.00	27.00	40.00	*	78.00
Greymouth	6.00	50.00	335.00	0-50	391.00
Aratika	0.00	0.00	90.00	*	90.0
Minor coalfields					
Heaphy	0.00	0.00	0.00	0-1	0.0
Karamea	0.00	0.00	0.00	0-1	0.0
Murchison	0.00	0.00	1.70	0-10	1.7
Punakaiki	0.00	0.00	5.50	0−>30	5.5
Fox River	0.00	0.00	1.20	0-1	1.2
Paringa	0.00	0.00	0.20	0-2	0.2
TOTAL	41.05	189.00	588.60	45−>195	818.65

Coalfield Summary Information

Coalfield	Production period	Coal Production (tonnes)	Coal measure thickness (m)	Coal seam thickness (m)	Notes
Buller	1872-present	65,000,000	50-250	2-20	Mangatini Seam accounts for most production
Inangahua	1885-present	2,800,000	<30 (BCM) c. 500 (RCM)	2-14	Brunner and Rotokohu CM
Reefton	1873-present	5,400,000	100-250	1-15	6 seams recognised, No 4 and No 2 most extensive
Garvey Creek	1947-present	3,100,000	100-300	2-18	'Basal Seam' is the thickest
Charleston	1873-1980s	600,000	50	2-12	All very high S
Pike River	2010-present		20 (BCM) 280 (PCM)	3.5-13.5 (BCM) 1-6 (PCM))	Paparoa and Brunner CM
Greymouth	1864-present	44,500,000	20-100 (BCM) c. 250-500 (PCM)	2-20	Multi seams Paparoa and Brunner CM. Most production from Paparoa
Aratika	Not worked	Nil		<3	Intersected in Aratika-2 petroleum well
Heaphy	Not worked		100	<1	Brunner CM
Karamea	1934-1949	320	90	<1.5	Very high S
Murchison	1905-1996	300,000		<5	Mostly thin seams and steep dips
Punakaiki	Not worked	Nil	20-30	1-6	Brunner CM, high S

Figure 36 Location of West Coast coalfields and coal deposits.

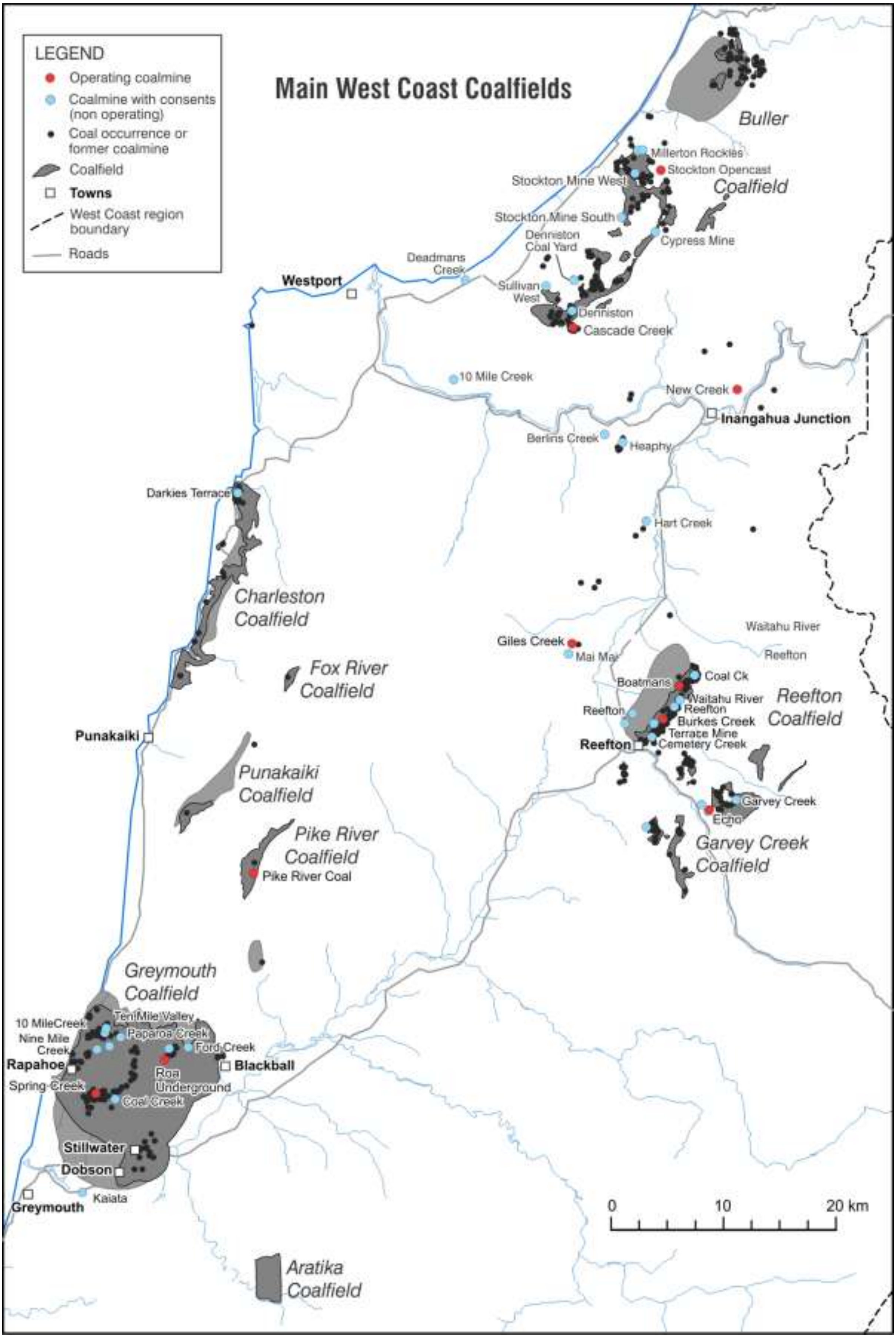


Figure 37 Location of the main West Coast coalfields.

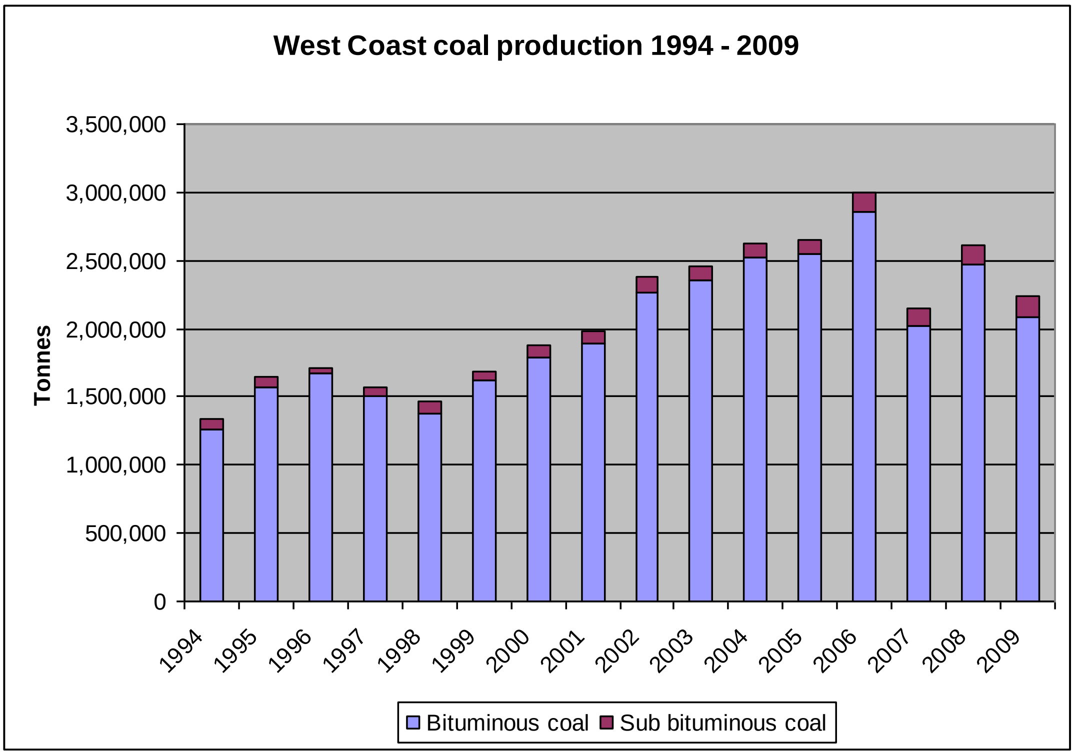


Figure 38 West Coast coal production 1994-2009.

Table 9 Operating West Coast coal mines (source: Crown Minerals)

Coalfield	Name	Owner	Type	Coal Rank	Grid ref
Buller	Stockton	Solid Energy	Opencast	Bituminous	L29:159-477
Buller	Cascade	Rochfort Coal	Opencast	Bituminous	L29:104-354
Buller	New Creek	New Creek Mining	Opencast	Bituminous	L29:258-348
Buller	Rockies	Rockies Coal	Opencast	Bituminous	L28:162-513
Pike River	Pike River*[1]	Pike River Coal Co	Underground	Bituminous	K31:820-874
Greymouth	Spring Creek	Solid Energy	Underground	Bituminous	J31:668-673
Greymouth	Roa	Roa Mining Co	Underground	Bituminous	K31:742-707
Inangahua	Heaphy	Heaphy Mining	Opencast	Sub-bituminous	L29:142-246
Inangahua	Giles Creek	Birchfield Coal Mines	Opencast	Sub-bituminous	L30:106-071
Reefton	Terrace*[2]	Solid Energy	Underground	Sub-bituminous	L30:169-911
Reefton	Burkes Creek	RJ Banks	Opencast	Bituminous	L30:184-002
Garvey Creek	Echo	Francis Mining	Opencast	Bituminous	L30:236-931
Garvey Creek	Island Block*	Solid Energy	Opencast	Bituminous	L30:225-926

*[1] Pike River ceased production following the mine accident in November 2010

*[2] Production suspended, mine on care and maintenance

The West Coast currently produces up to 3 Mt of coal annually (Figure 38), mostly of bituminous rank from opencast mining at Stockton (Solid Energy Ltd) and Garvey Creek (Francis Mining), and underground mining at Spring Creek (Solid Energy) and Roa (Francis Mining). Exports of West Coast bituminous coal reached 2.4 Mt in 2008, mostly to India and Japan, with smaller quantities going to Chile, South Africa, Brazil, China, USA and Australia. Most exports are of coking coal, with smaller amounts of thermal and specialist coals. The Pike River underground mine was developed for coking coal exports, with a projected annual production rate of 1 Mt (Whittall 2005, 2006). The mine commenced production in 2009, but production was halted by the mine accident in November 2010. The need to transport coal from the West Coast over the Southern Alps by train to the export terminal at the port of Lyttelton imposes significant costs on coal exporters.

Figure 39 Aerial view of Pike River Coal Ltd's rail load-out facility at Ikamatua. The coal was transported by rail from the West Coast to Lyttelton for loading on a ship for export. (January 2010 photo courtesy of Pike River Coal Ltd).

The production of West Coast bituminous coal has more than doubled from 1.3 Mt in 1994 to 2.8 Mt in 2006. Most of this coal has been exported. The increase in West Coast bituminous coal mine production accounts for much of the rise in New Zealand's total coal output over the last decade.

11.2 COAL MEASURES AND COAL RANK

Coal seams occur principally within two sets of coal measures: Late Cretaceous to Paleocene Paparoa Coal Measures in the Greymouth and Pike River Coalfields, and Eocene Brunner Coal Measures in the Greymouth, Pike River, Buller and other coalfields. The Rotokohu Coal Measures and Longford formation, both of Miocene age, contain seams of less economic importance.

The Greymouth, Buller, Garvey Creek and Pike River coalfields produce bituminous coal, whereas production from other areas is of sub-bituminous coal. However, coal at Fox River reaches anthracite rank. Some seams are exceptionally low in ash (0.5% or less). The low ash content, high vitrinite levels and excellent swelling properties, allows the coking coals to command premium prices on world markets.

Paparoa coals are characterised by low ash and sulphur contents. Brunner coals commonly have low to very low ash contents, but a wide range of sulphur contents, which can be very high near the roof of some seams.

11.3 COAL RESOURCES

Exploration in the 1970s and 1980s by the Ministry of Energy's New Zealand Coal Resources Survey (NZCRS) helped identify and define resources in the coalfields (Sherwood 1999). Subsequent exploration by several companies has refined the resource estimates (Figure 36, Figure 40 and Table 10).

The coal resources survey quantified the large lignite resources of Southland and Otago, and investigated coalfields throughout New Zealand. Although the West Coast accounted for only about 6% of total coal resources, the region’s coalfields include virtually all of New Zealand’s resources of bituminous coal.

Solid Energy (2009) has published the results of a comprehensive review of its coal resources which now comply with the Australasian JORC code for reporting resources and reserves. For the West Coast it assessed its Buller coalfield resources (measured, indicated and inferred) at 92 Mt, with a 15 Mt reserve, while at Greymouth resources are 79 Mt, with reserves of 1 Mt. Resources of 2 Mt were reported for Reefton.

Total West Coast coal resource estimates differ widely. The criteria for assessing resources and reserves under the JORC ore reserve code (www.jorc.org) are much more restrictive than those that were used by the NZCRS for assessing coal-in-ground resources. This, together with the Solid Energy coal resource data not covering entire coalfields accounts for the differences between the JORC compliant resources and resources assessed by Solid Energy, and the much larger coal resource estimates listed in the table in Figure 36.

Table 10 Coal resources of the West Coast region based on coal rank

Rank	**Resource category**			
	Measured (MT)	**Indicated (MT)**	**Inferred (Mt)**	**Total (Mt)**
Semi-Anthracite			1.2	1.2
Bituminous	36	155	437	628
Sub-Bituminous	5	34	150	189
Total	41	189	588	818

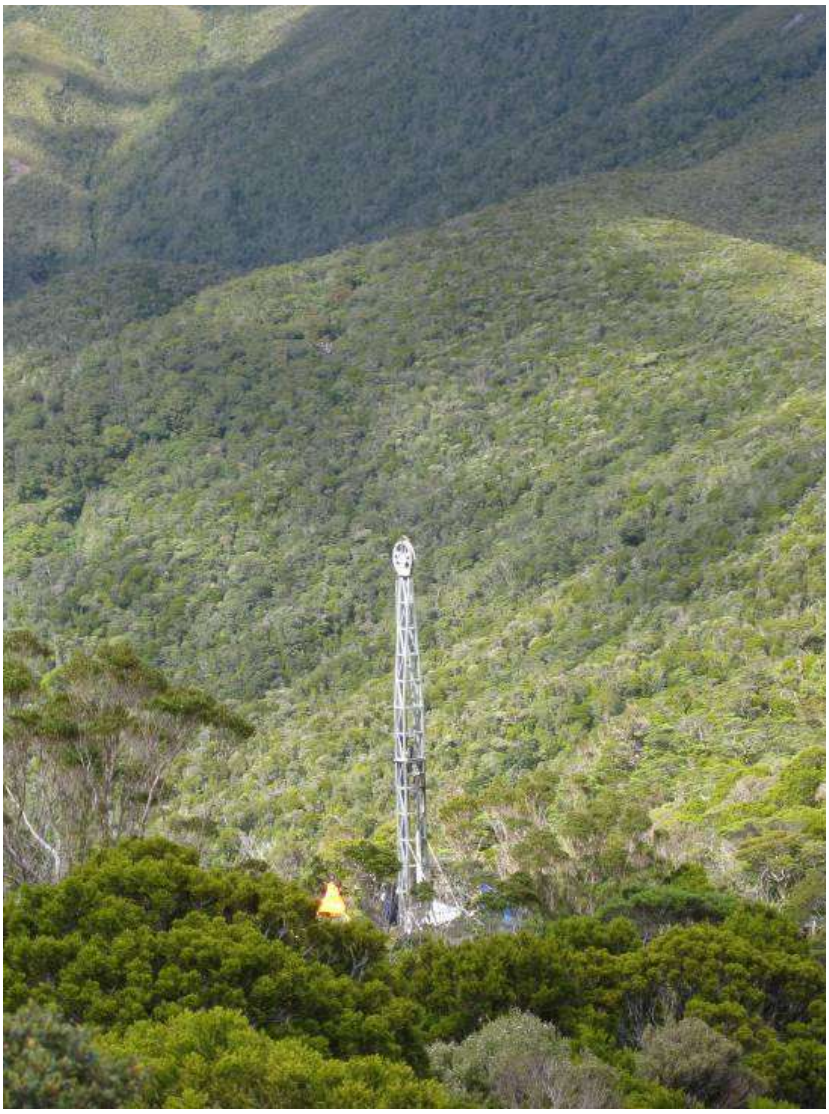


Figure 40 Small drill site with rig installed by helicopter, Pike River coalfield (January 2009 photo courtesy of Pike River Coal Ltd).

11.4 COALFIELDS

The locations of the West Coast coalfields and coal deposits are shown in Figure 36 and Figure 37. Figure 36 also has tables of coal resources and summary information.

11.4.1 Buller Coalfield

The Buller Coalfield extends from Westport to Seddonville, about 40 km to the northeast and is the main source of bituminous coal in New Zealand. The first recorded coal production was from the Albion Mine (L28/e618) in 1872. Since then, mining has been virtually continuous using mostly underground methods, but since 1994 all production has been from opencast mining. The coalfield mostly produces for international markets. Some of the coal is exceptionally low ash (< 0.5%). The unweathered coal is high swelling (up to 9) coking coal. Operating mines are the opencast Stockton, Cascade and Rockies mines.

Coal production is entirely from the Brunner Coal Measures (Mid-Late Eocene), which range in thickness from 0-250 m. Coal seams are generally best developed on the western side of the coalfield, with most coal having been won from the Mangatini coal seam, which varies from 2 m to 20 m in thickness. Structurally, the Buller Coalfield mainly comprises an uplifted anticline which is steeply down-folded adjacent to the east-dipping Kongahu Fault Zone, a reverse fault forming the western boundary to the Buller Coalfield. The eastern boundary of the coalfield occurs where the coal measures pinch out or have been removed by erosion. Minor normal faults generally strike either northeast or northwest. The coal measures thicken towards a NNE-trending axis of deposition in the centre of the coalfield.

Coal rank increases across the coalfield from high-volatile bituminous B in the east to medium-volatile bituminous in the west. Sulphur content is variable, from low to high. Ash contents towards the margins of the low ash coal pods are complexly variable.

The Stockton mine (Figure 41 and Figure 42) is the most productive bituminous coal mine in New Zealand, producing about 2 Mt per year. It is located on an exposed plateau about 25 km northeast of Westport. Much of the coal here is low in ash (<2%) and phosphorus. Several pits are worked across the plateau and coal is blended to maintain specifications. Resources are sufficient to maintain output for about 20 years at current rates of production.

Figure 41 Stockton opencast (GNS photo, photographer Lloyd Homer).

Figure 42 Stockton opencast (photo courtesy of Stuart Henley, Solid Energy).

Figure 43 Spring Creek Monitor (photo courtesy of Stuart Henley, Solid Energy).

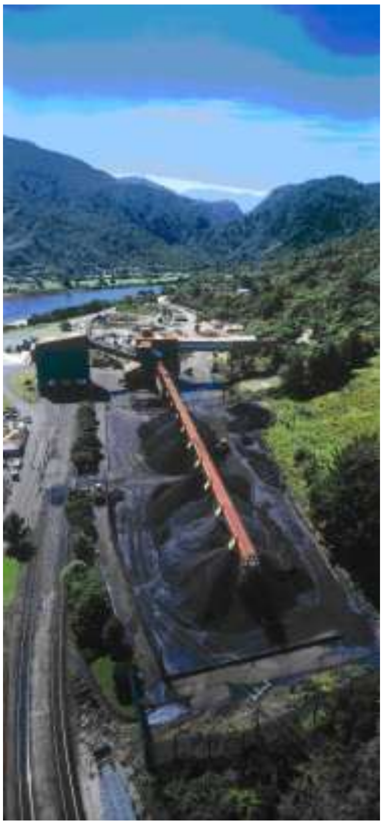


Figure 44 Solid Energy's Ngakawau coal handling facility (photo courtesy of Stuart Henley, Solid Energy).

11.4.2 Inangahua Coalfield

Coal-bearing areas (all sub-bituminous) on the eastern side of the Paparoa and Mt William ranges are included within the Inangahua Coalfield, which is centred near the village of Inangahua Junction. Coal seams persist in the Brunner Coal Measures and Rotokohu Coal Measures, although most productive seams occur in the former. Brunner Coal Measures crop out along a discontinuous narrow strip on the northwestern side of the Inangahua Valley and in scattered areas farther east. Coal is mined by opencast methods, the most productive mines are Heaphy's Opencast (L29/e114), New Creek Opencast (L29/e119) and Giles Creek Opencast. The NZCRS drilled only one hole in this coalfield and there is significant potential for additional resources.

11.4.3 Murchison Coalfield

The Murchison Coalfield includes all coal-bearing areas east of the Brunner Range and west of Mt Murchison, extending northeast and southwest from the town of Murchison. Thin, lenticular coal seams are present in the Maruia and Longford formations although none is currently worked.

11.4.4 Reefton Coalfield

Brunner Coal Measures outcrop in a narrow strip to the northeast of Reefton, bounded by Ordovician basement rocks to the southeast and Kaiata Formation (Eocene) or Plio-Pleistocene sediments to the northwest. The coal measures generally dip at 15-25^{o} NW, but are locally steeply dipping to overturned.

Six coal seams are recognised: No. 4, No. 3, No. 2 Lower, No. 2 Upper, No. 1 Lower, and No. 1 Upper (Suggate 1957). No. 4 and No. 2 Upper seams are the most extensive and generally the thickest, averaging about 5 m and 4 m thick respectively. The small Burkes Creek opencast and Boatmans underground mines are currently operating here.

11.4.5 Garvey Creek Coalfield

Three separate areas of Brunner Coal Measures are preserved within a down-faulted wedge of basement in the Victoria Range foothills, southeast of Reefton. There are a number of coal seams but the lowest, referred to as the "Basal Seam" (Suggate 1957), is by far the thickest (up to 18 m) and most extensive. Over much of the coalfield this seam has a low ash content, generally less than 3%, and when unweathered, has a sulphur content ranging from 0.5% to about 2.5% (Suggate 1957). The upper seams are impersistent, rarely of a workable thickness, and commonly have sulphur contents up to 8%. The coal is of high volatile A to B bituminous rank. The Echo opencast mine is operating here, while the Solid Energy Island Block mine is currently not producing.

11.4.6 Charleston Coalfield

A series of coal lenses of small lateral extent, but up to 13 m thick are found along approximately 10% of the 25 km long outcrop of Brunner Coal Measures that extends southwards from Charleston. The low strength of the overlying sediments (Barry 1989) limits mining to a narrow belt west of a limestone escarpment. The coal is of sub-bituminous rank with high to very high sulphur, and low ash.

11.4.7 Punakaiki Coalfield

The Brunner Coal Measures of the Punakaiki Coalfield contain a single coal seam which dips moderately steeply. The coal is sub-bituminous in rank, with high sulphur content. Ash content is mostly at moderate levels. Most of this coalfield lies within the Paparoa National Park.

11.4.8 Pike River Coalfield

Paparoa and Brunner Coal Measures crop out in a steep west-facing escarpment (Figure 8) descending from the crest of the Paparoa Range about 35 km northeast of Greymouth. Both Paparoa and Brunner coals are of high volatile A bituminous rank, Paparoa coals having higher reflectance and lower volatile contents and calorific values than Brunner coals. Sulphur content is low in Paparoa coals and low to very high in Brunner coals.

Pike River Coal Ltd developed an underground mine working the Brunner Coal Measures with access being obtained via a road from the east (Figure 45). A 2.4 km long incline from the end of the road extends into the coal measures from below, passing through basement metamorphic rocks (Figure 45 and Figure 46). Measured coal resources of 11.5 Mt and indicated resources of 27.5 Mt have been determined. Total resources (measured, indicated and inferred) are estimated at 58.5 Mt (Golder Associates 2006). Proven resources of 2.3 Mt and probable reserves of 8.7 Mt have been established (Minarco 2006). Production of coal commenced in 2009 (Figure 48 and Figure 49). Coal was transported by pipeline from the mine to a coal preparation plant, and by rail from nearby Ikamatua (Figure 39) to the port at Lyttelton, near Christchurch. An explosion in the mine on 29 November 2010 resulted in the deaths of 29 mine staff and contractors, and the mine was put into receivership in December 2010. The future of the mine was uncertain at the time of production of this report.

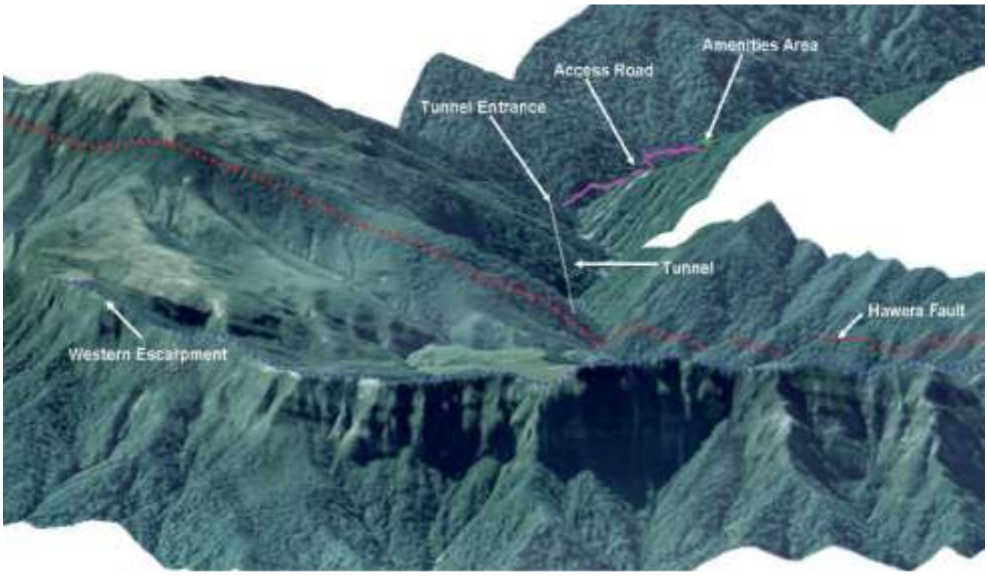


Figure 45 Perspective view looking northeast (after Figure 8 of Pike River Coal 2007).

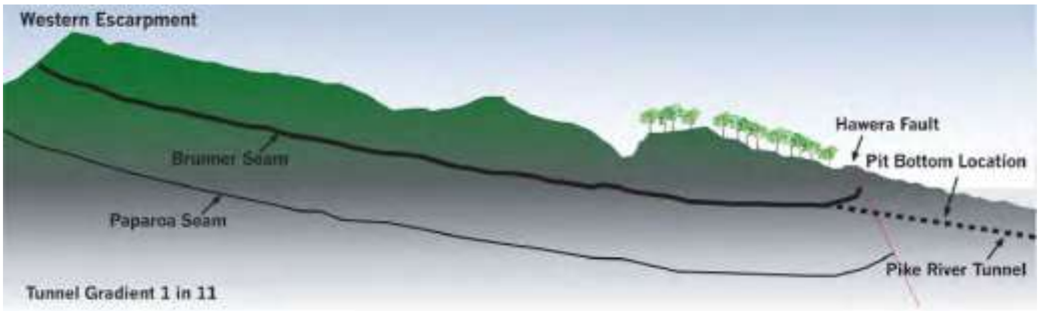


Figure 46 Pike River cross section (after Figure 9 of Pike River Coal 2007).

Figure 47 Pike River mine building blended into native bush (May 2009 photo courtesy of Pike River Coal Ltd).

Figure 48 Mining with a continuous miner at Pike River (September 2009 photo courtesy of Pike River Coal Ltd).

Figure 49 Hydro-monitor used to cut coal using high pressure water, Pike River coal mine (photo courtesy of Pike River Coal Ltd).

11.4.9 Greymouth Coalfield

The Greymouth coalfield is located to the north of the town of Greymouth. Most of the coal resource is contained within the Paparoa Coal Measures although coal has also been mined from the Brunner Coal Measures (e.g. Dobson-Brunner mining area, and the James and Castlepoint mines) and the Dunollie Coal Measures (Point Elizabeth mine). Most of the mining in the coalfield has been by underground methods, the main exceptions being Roa and Birchfield's Opencast.

Total production from Greymouth Coalfield is over 44 Mt. Most has come from four areas: Strongman, c. 5 Mt; Liverpool, c. 7 Mt; Blackball, c.5.5 Mt; and Brunner/Dobson, c.8 Mt

Following renewed exploration drilling by the NZCRS, Bowman et al. (1984) assessed the resources of the coalfield. Two sectors, Rapahoe in the west (SW of Strongman Mine) and Mt Davy–Upper Seven Mile have subsequently been further explored. These blocks of low-sulphur coal both have had seam correlation difficulties, but further exploration has helped resolve this. Some areas have complex folding and faulting. Coal rank increases eastwards from high volatile B-C bituminous rank at Rapahoe to low volatile bituminous at Roa. Ash contents, except at the margins of seams, are generally low to medium. Coal at Roa is very high swelling (9+++).

An underground mine was developed by Solid Energy at Mt Davy in 1997, but the mine was subsequently closed in 1998 after three miners were killed in two separate accidents, as it proved too hazardous to mine because of the high gas content and coal outbursts. In 2000, Grey Coal, a joint venture between Solid Energy and Todd Energy opened an underground mine at Spring Creek, planned as a replacement for Strongman 2, which closed in 2003. Development at Spring Creek was temporarily halted in 2001 while technical difficulties were resolved, but recommenced in 2002 with Solid Energy acquiring the interest held by Todd Energy. Production has steadily increased, reaching 400,000 t in 2009. Most of the coal is exported for use in steel making. Some is used for cement and lime and other manufacturing in New Zealand.

11.4.10 Minor Coalfields

The Heaphy Coal Deposit is an unworked coal deposit located on the Heaphy Track (Kahurangi National Park) near the northern boundary of the West Coast region. The coal seams occur within the Eocene Brunner Coal Measures (Leask 1977). Known coal seams are less than one metre thick and discontinuous across the coalfield.

The Karamea Coalfield comprises various outcrops of Brunner Coal Measures (Eocene) described by Wellman (1949) from around Karamea township and in the Garibaldi Range (23 km east of Karamea). The total recorded production of the coalfield is 320 t, produced from two mines near Karamea between 1934 and 1949. Its potential is limited by small resources, very high sulphur content and isolation.

In the Aratika Coalfield, coal seams, probably up to at least 3 m thick, were penetrated in the Aratika-2 oil-prospecting well located about 25 km southeast of Greymouth (K32/e75) at depths between 700 and 800 m. The low-sulphur coal is on the border of high volatile bituminous and sub-bituminous rank. The well was drilled on the flank of an anticline and coal seams may be present at depths of less than 300 m nearer to the anticlinal axis (Bates 1984).

At Garden Gully, small quantities of high-sulphur sub-bituminous C coal have been opencast mined from a steeply-dipping Brunner coal seam about 6 m thick. No estimate of resources has been made.

At Fox River, steeply-dipping, deformed and crushed Paparoa coal seams, at one place up to 10.5 m thick, are of semi-anthracite rank. An estimate of 1.2 Mt of inferred low-sulphur anthracite/semi-anthracite above river level was made by Batt (1975); Anckorn et al. (1988) listed 0.32 Mt as recoverable. All the resource is within the Paparoa National Park.

A narrow strip of late Cretaceous and Tertiary rocks is exposed discontinuously along the coast south from Bruce Bay. Coal has been reported from three areas: Paringa, Cole (Bullock) Creek, and south of Jackson Bay, but there is no record of any mining in the area. The coal seams are thin (3 m or less thick) and the coal is high ash.

11.5 FUTURE POTENTIAL

West Coast coal is used by industry within the region, is transported outside the region for use elsewhere in New Zealand, but most production is exported. Exports have accounted for much of the growth in coal production over the last 10 years increasing from 1.1 Mt in 1998 to 2.5 Mt in 2008. Coal exports are set to increase further in 2011 if the Spring Creek mine continues to increase its production, as planned by Solid Energy.

Bathurst Resources has announced a proposal to develop a new opencast coal mine for the Stockton Escarpment area under a plan to acquire the assets of L&M Coal (Bohannan 2010). The company intends to mine coking coal for export with output increasing from 600,000 t to 2 Mt over a period of several years.

While there is high demand for the West Coast’s bituminous coals, the markets for the region’s sub-bituminous coals are small. There are substantial sub-bituminous resources in the Inangahua, Reefton and Charleston coalfields, but without significant new markets, production of sub-bituminous coal will remain relatively low.

12.0 MINERAL RESOURCE ASSESSMENT OF METALLIC AND INDUSTRIAL MINERALS

12.1 ASSESSMENT METHOD

For metallic and industrial minerals, mineral resource assessments have been carried out using a three step process (Figure 50) established by the US Geological Survey (USGS) that is based on the principle of conceptual models of selected mineral deposit types (Singer & Mosier 1981; Sangster 1983; Cox 1993; Singer 1993; Grunsky et al. 1994). In this method, descriptive and genetic models are assembled for each mineral deposit type (see below). In the second step, the models are then compared with the geology of the area being assessed and estimates of resources are made. In the third step, the amount of metal and some characteristics of ore are estimated by means of grade-tonnage models.

Two methods have been used for the estimates in Step 2. The first method is an estimate on the probability of economic resources in individual known prospects, the "counting method" of Cox (1993) and Singer (1993). This is accomplished by making a percentage estimate of the probability that a specific deposit contains the average tonnage and grade for the relevant mineral deposit model. The second method is an estimate of the percentage probability of the occurrence of an as yet undiscovered economic deposit of a specific type, given knowledge of the local geology, local past production from this type of deposit, mineral exploration data and mineral deposit models. The percentages from the two parts are summed and used as a multiplying factor for the tonnage of an average deposit of this type, using both local (where available) and world mineral deposit grade and tonnage models. The resulting figures are then translated to the weight of contained metal or processed mineral and assigned a dollar value based on published commodity prices.

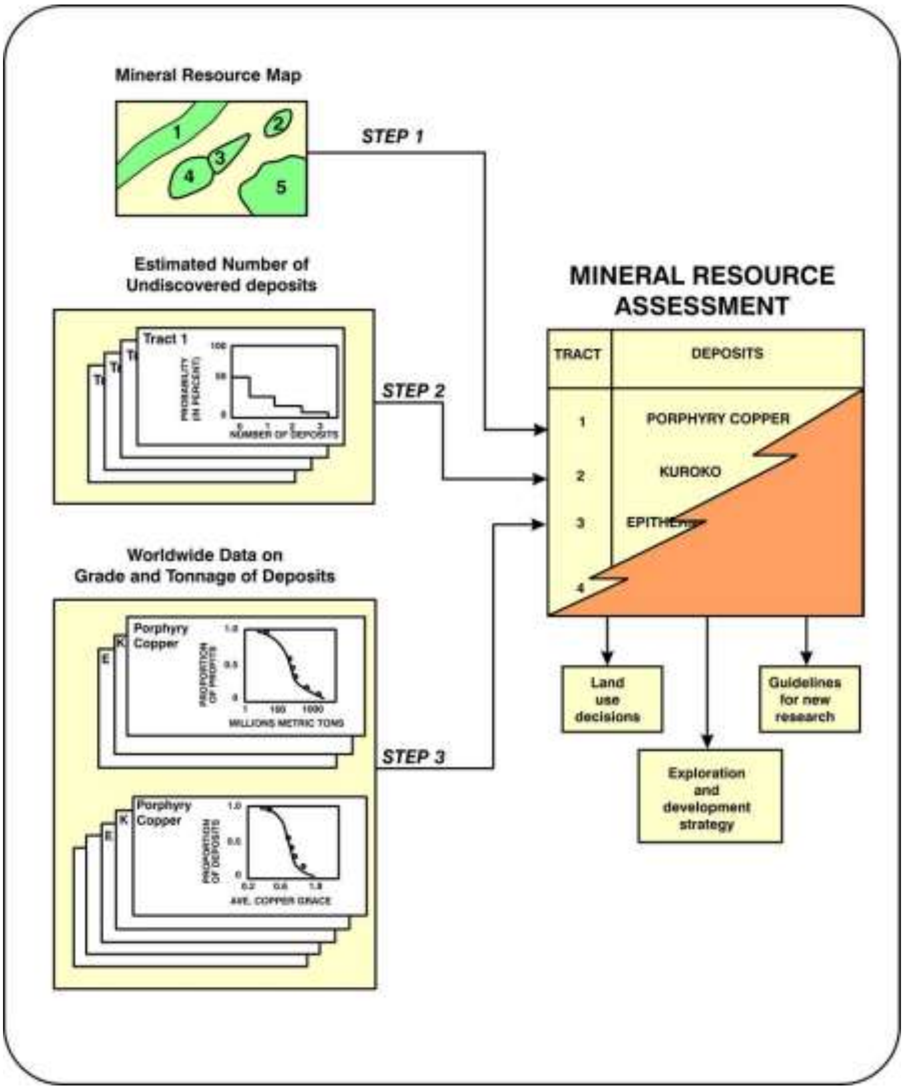


Figure 50 USGS 3-step process of mineral resource assessment.

12.2 MINERAL DEPOSIT MODELS

Mineral deposit models (e.g. Cox & Singer 1986; Kirkham et al. 1993; Eckstrand et al. 1995; Lefebure & Ray 1995; Lefebure & Höy 1996) describe the essential geological and geochemical attributes that are common to a number of similar mineral deposits that are presumed to have been formed by the same genetic process. The main attributes used in classifying a mineral deposit type are: tectonic setting, structural controls, host rock lithology, form of the deposit, main economic elements or minerals, mineralogy of ore and host rocks, and geochemical and geophysical characteristics. Mineral deposit models for the West Coast region are listed in Table 11. We have used mainly the USGS and British Columbia Geological Survey (BCGS) mineral deposit models as sources of information for our international models.

Deposit models are linked to grade-tonnage models, which show the range of grade and tonnage of different deposits of a specific type, and derive statistical parameters such as the average grade and tonnage (Cox & Singer 1986). Grade-tonnage models are compiled from pre-mining resource estimates or from production figures for mined-out deposits. These figures vary according to mining conditions (e.g. mining method used) and economic factors (e.g. metal prices), but the conditions and factors are reasonably consistent for production figures from the same district or region over specific periods of mining activity.

Table 11 Mineral deposit models for the West Coast mineral resource assessment (cf. Cox & Singer 1986)

Element or Mineral	Mineral deposit model	Submodel
Metallic minerals		
Antimony (Sb)	Vein Sb	
Beryllium (Be)	Be pegmatite	
Chromium (Cr)	Podiform Cr	
Copper (Cu)	Stratiform Cu	
	Vein Cu	
Gold (Au)	Orogenic Au	Paleozoic Orogenic Au
		Mesozoic Orogenic Au
		Orogenic Alpine Au
	Alkali intrusion-related Au	
	Moderately reduced granite Au	
	Detachment-fault-related polymetallic deposits	
	Placer Au	Alluvial placer Au
		Beach placer Au
		Marine place Au
Molybdenum (Mo)	Porphyry Mo	
Nickel (Ni)	Dunitic Ni-Cu	
Platinum Group Elements (PGE)	Alaskan PGE	
Rare Earth Elements (REE)	Carbonatite-hosted REE	
	REE-bearing monazite in granitic and metamorphic rocks	
	Placer REE	
Tin (Sn)	Greisen Sn	
Titanium (Ti)	Shoreline placer Ti	
Tungsten (W)	Vein W	
	Greisen W-Sn	
	Stratabound W	
Uranium (U)	Sandstone U	
Zinc-lead (Zn-Pb)	Zn-Pb polymetallic veins	
Zirconium (Zr)	Placer Zr	
Non metallic minerals		
Asbestos	Ultramafic-hosted asbestos	
Barite	Vein barite	
Clay	Coal measure clay	
	Clay from weathering and sedimentary clay	
Feldspar	Feldspar in pegmatites	
	Feldspar – weathered granite	
Fluorine (F)	Vein F	
Garnet	Placer garnet	
Mica	Mica in pegmatites	
Pounamu		
Serpentine		
Silica sands		
Talc-magnesite	Ultramafic hosted talc-magnesite	

13.0 METALLIC MINERAL DEPOSITS

13.1 ANTIMONY

13.1.1 Vein Sb (Figure 51)

International model

References

USGS model 27d Simple Sb deposits (Cox & Singer 1986); BCGS model I09 Stibnite veins and disseminations (Lefebure & Höy 1996).

Description

Stibnite veins, pods and disseminations in or adjacent to brecciated or sheared fault zones.

International examples

Amphoe Phra Saeng, Thailand; Caracota, Bolivia; Coimadai, Victoria, Australia; Last Chance, Nevada, USA; Lake George, New Brunswick, Canada.

Grade-tonnage data - international

USGS model 27d 50th percentile = 180 t at 35% Sb, but Christie & Brathwaite (1999a) suggested a model of 4000 t of contained Sb was more representative for New Zealand deposits, and this is adopted here.

West Coast deposits

Antimony has been reported from gold-bearing quartz veins within Greenland Group metasedimentary rocks.

Langdon's Reef, Westland

Langdon's Reef (K31/e64), also known as Langdon's Antimony Lode, in the Langdons Creek area at the southern end of the Paparoa Range, was discovered in 1879, and 17 claims were taken up by 1882. Ten tonnes of ore were shipped to England, but results were "disappointing". The lode was described by Hector (1879), McKay (1883a), and Morgan (1911) as a bedded quartz lode 0.6-2.7 m thick including 0.6 m "compact stibnite", enclosed in Greenland Group greywacke and argillite. Pyrite, arsenical pyrite, calcite, and free gold are also present in the quartz lode. Picked samples assayed up to 14.7% Sb_2S_3 (10.05% Sb), 7.8 grams/tonne (g/t) Au, and 1.5 g/t Ag. Initial values reported by Hector were 2610 g/t Au and 1120 g/t Ag, and 45.28 kg of gold were produced between 1884 and 1888. The area was investigated in the 1980s by Mineral Resources Ltd (Aliprantis 1988; Cotton & Stewart 1989).

Croesus Knob Reefs, Westland

Stibnite is present in quartz lodes at several localities in the Croesus Knob Reefs (K31/e66), 14 km north of Langdon's Reef, in the southern part of the Paparoa Range. The Croesus Knob reef system was worked primarily for gold in the period 1891-1905, principally on the Minerva, Croesus, Taffy and Garden Gully claims. Quartz vein stockworks, with veins ranging from 1 mm to 3 m width, occur along bedding planes or faults within Greenland

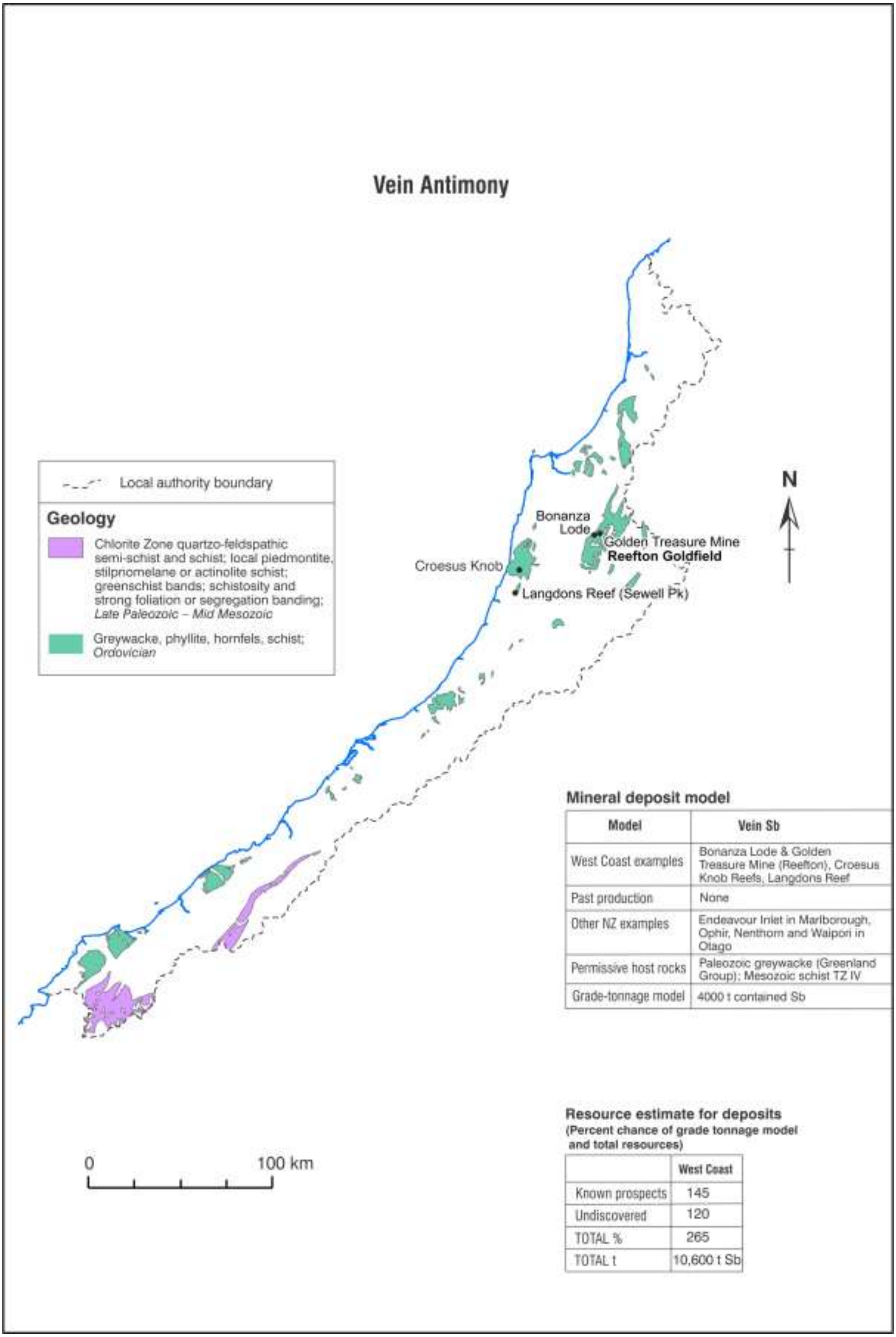
Group metasedimentary rocks. Visible gold mineralisation and associated sulphides are confined to small pockets within or on the margins of the typically lenticular quartz veins. Sulphides include pyrite, sphalerite, chalcopyrite, galena, arsenopyrite, stibnite, and bournonite ($CuPbSbS_3$). AMOCO explored the area in the early 1980s (Erceg & Barnes 1982) and reported maximum base metal values from picked material as: 7400 ppm Sb, 5700 ppm Cu, 1.72% Pb, 2400 ppm Zn, and 8490 ppm As. A peak gold value of 12 ppm was supported by weakly anomalous gold in soil samples over 500 m.

Reefton Goldfield

Stibnite was found in many of the quartz lodes in the Reefton Goldfield, locally making up 10-30% of some veins (Finlayson 1909a) and causing some metallurgical difficulties during the gold recovery process (e.g. Murray Creek mines). The Reefton lodes are developed in shear zones within Greenland Group metasedimentary rocks, and most are located in a northerly trending belt of intense folding and shearing, 5 km in width. In addition to quartz, stibnite and gold, other minerals found in the goldfield included: carbonate, pyrite, arsenopyrite, chalcopyrite, galena, and molybdenite. Stibnite was reported from mines at Blackwater, Globe Hill, Crushington, Capleston-Specimen Hill, Big River, Ajax, Murray Creek, Blacks Point-Painkiller, Merrijigs, and Alexander River. The mineralisation in the Murray Creek area (L30/e255) was particularly antimony rich with up 7% reported in ore concentrates by Henderson (1917) and abundant stibnite reported from the Golden Treasure lodes by Downey (1928) and Suggate (1957). A discrete antimony-bearing lode, the Bonanza lode, was described from Aulds Creek by McKay (1883b) and Williams (1974, p. 31) noted that at the Blackwater mine, a discrete stibnite lode was believed to have been found in the country rock not far from the main lode. Recent reconnaissance geochemical exploration for antimony in the Reefton Goldfield (Riley & Ball 1971, 1972a, 1972b; Viljoen 1972) highlighted a few potential targets where small resources might be found.

Assessment

We suggest a 265% probability of resources equivalent to the model size, equating to an estimated resource of 10,600 t Sb.



Mineral deposit model

Model	Vein Sb
West Coast examples	Bonanza Lode & Golden Treasure Mine (Reefton), Croesus Knob Reefs, Langdons Reef
Past production	None
Other NZ examples	Endeavour Inlet in Marlborough, Ophir, Nenthorn and Waipori in Otago
Permissive host rocks	Paleozoic greywacke (Greenland Group); Mesozoic schist TZ IV
Grade-tonnage model	4000 t contained Sb

Resource estimate for deposits
(Percent chance of grade tonnage model and total resources)

	West Coast
Known prospects	145
Undiscovered	120
TOTAL %	265
TOTAL t	10,600 t Sb

Figure 51 Location of antimony occurrences from the GERM database, and areas of rocks prospective for Vein Sb deposits.

13.2 BERYLLIUM

13.2.1 Be pegmatite (Figure 52)

International model

References

No published international model.

Description

Beryl occurs in coarsely crystalline pegmatite dikes located peripheral to granitic intrusions. The pegmatites are composed of quartz, sodic plagioclase and microcline with or without spodumene, muscovite or lepidolite.

Grade-tonnage data

No published data. We have assigned a value of 250,000 t at 1% Be for 2,500 t of Be.

West Coast deposits

Beryl occurs in pegmatites near Charleston hosted in banded granitic Constant Gneiss. The pegmatites contain coarse grained quartz, feldspar, muscovite and biotite. Beryl occurs as columnar, pale green to colourless crystals up to 125 mm across and containing 12.82% BeO (Hutton & Seelye 1945; Officers of New Zealand Geological Survey 1970a).

Analyses from the ilmenite-bearing beach sand on the West Coast, during prospecting in the 1970s, showed traces of beryl. In the Birchfield licence, it comprised 0.01% of the heavy mineral fraction, and 0.02% at Hokitika (Zuckerman 1972a; Painter 1973a). Hutton (1950) noted that some West Coast dredge concentrates contained rare grains of gadolinite that were probably eroded from pegmatites in the Karamea granite.

Cohen et al. (1967) noted high background concentrations of beryllium in the Hawks Crag Breccia of the lower Buller Gorge area.

Assessment

We suggest a 75% probability of resources equivalent to the model size, equating to an estimated resource of 1755 t Be.

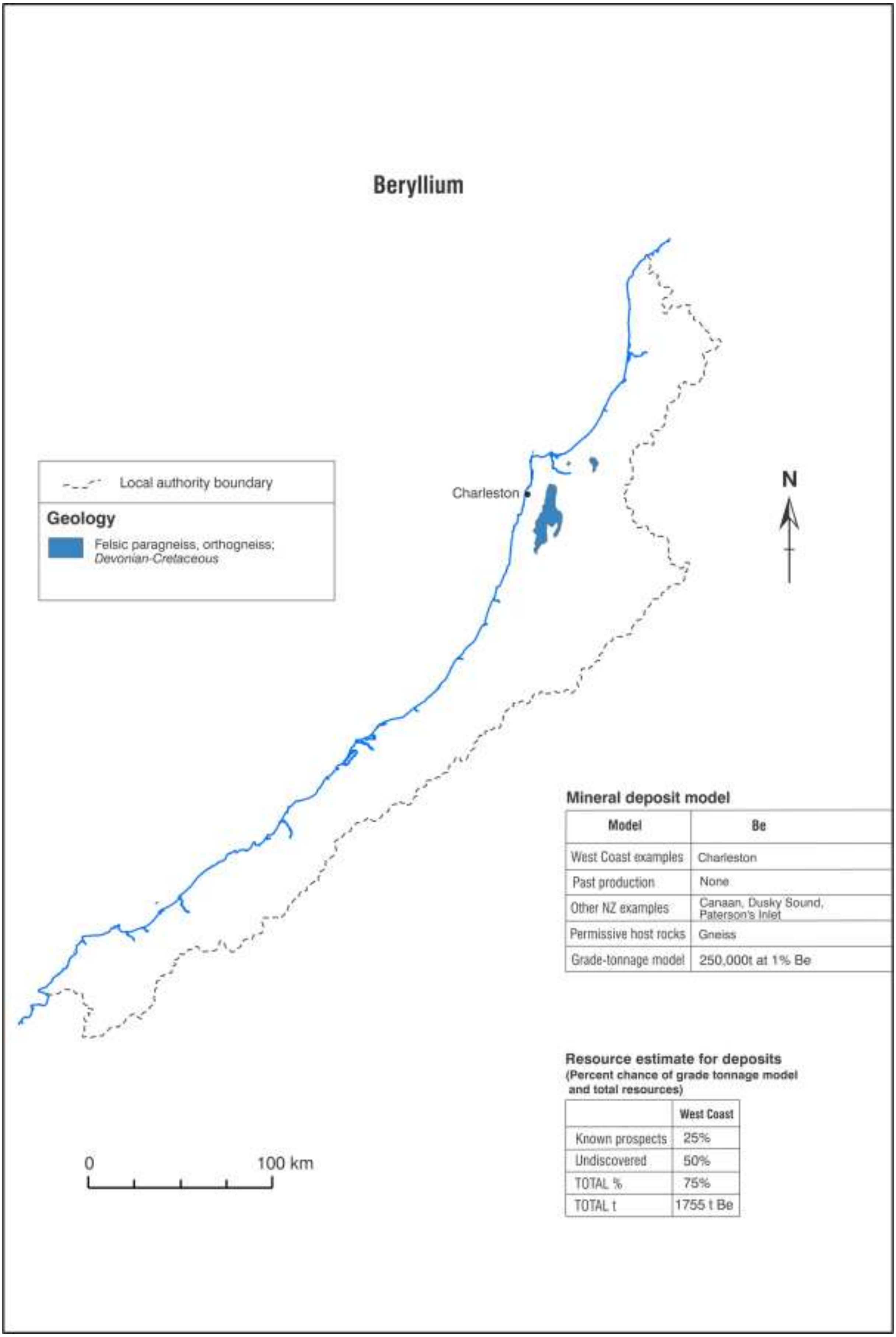


Figure 52 Location of the Charleston beryllium occurrence from the GERM database, and areas of rocks prospective for Be deposits.

13.3 CHROMIUM

13.3.1 Podiform Cr (Figure 53)

International model

References

USGS models 8a (minor) and 8b (major) Podiform chromite (Cox & Singer 1986) and BCGS model M03 Podiform chromite (Lefebure & Höy 1996)

Description

Deposits of massive chromitite occur as pods, tabular lenses or layers within ophiolitic ultramafic rocks. The deposits are formed as a primary magmatic differentiate during early olivine and chrome-spinel crystal fractionation of basaltic liquid at an oceanic spreading centre. The host rocks represent obducted fragments of oceanic, lower crustal and upper mantle ultramafic rocks within accreted oceanic terranes.

International examples

Guleman ore field, Turkey; Kalimash - Kukes-Tropoje district, Bulquize and Todo Manco - Bater-Martanesh district (Mirdita ophiolite), Albania; Tiébaghi ophiolite and Massif du Sud, New Caledonia; Acoje and Masinloc-Coto (Zambales range/ophiolite), Luzon, Phillipines; Batamshinsk, Stepninsk, Tagashaisai and Main SE ore fields (Kempirsai massif), Southern Urals, Russia; Xeraivado and Skoumtsa mines (Vourinos ophiolite), Greece; Semail ophiolite, Oman; Luobusa, Donqiao, Sartohay, Yushi, Solun, Wudu and Hegenshan deposits, China.

Grade and tonnage

Grades range from 20 to 60% Cr_2O_3 and tonnages range from several thousand tonnes to several million tonnes. USGS model 8b major podiform chromite deposits 50th percentile = 20,000 t at 46% Cr_2O_3 (9200 t Cr_2O_3) and trace Rh, Ir, Ru, Pd and Pt (Cox & Singer 1986).

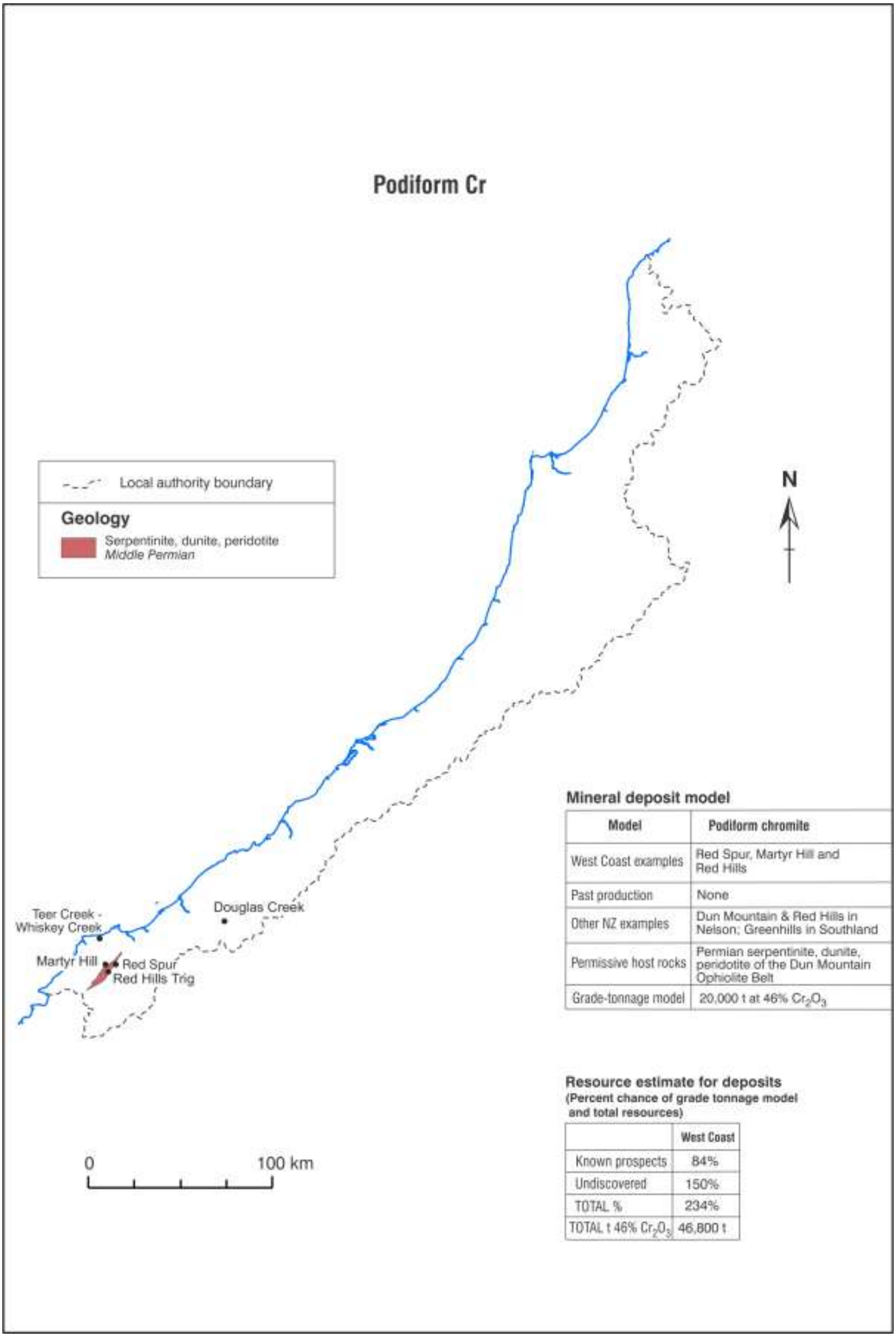
West Coast deposits

Chromite is widespread throughout the ultramafic belt (Figure 53 and Figure 54), occurring as disseminated crystals, sporadic schlierein bands (podiform chromite layers) parallel to crystal lamination, and fissure-form chromite-serpentine bands (Mutch 1965). Turner (1935) reported chromite layers 1-3 mm thick in dunite at the head of a stream that drains into Woodhen creek near Martyr Hill (E38/e5), which locally contains over 80% chromite. During 1982-84, CRA undertook a survey of the ultramafic belt to assess the potential for chromite as well as precious and other metals. Although chromite-rich laminae, similar to those noted by Turner, were seen, Mackenzie (1984) noted that “Rock chip sampling revealed Cr_2O_3 contents of less than 20%, well below refractory ore grade of 30% Cr_2O_3.” Ore grade was achieved in only one sample of hand-picked chromite.

Small amounts of alluvial chromite are found in all streams draining the ultramafic belt and on the beaches north of Jackson Bay, but no anomalously high concentrations have been encountered.

Assessment

We suggest a 234% probability of resources equivalent to the model size, equating to an estimated resource of 46,800 t of 46% Cr_2O_3.



Model	Podiform chromite
West Coast examples	Red Spur, Martyr Hill and Red Hills
Past production	None
Other NZ examples	Dun Mountain & Red Hills in Nelson; Greenhills in Southland
Permissive host rocks	Permian serpentinite, dunite, peridotite of the Dun Mountain Ophiolite Belt
Grade-tonnage model	20,000 t at 46% Cr_2O_3

	West Coast
Known prospects	84%
Undiscovered	150%
TOTAL %	234%
TOTAL t 46% Cr_2O_3	46,800 t

Figure 53 Location of chromium occurrences from the GERM database, and areas of rocks prospective for Podiform Cr deposits.

Figure 54 Red Mountains and the Red Hills Range are ultramafic rocks of the Dun Mountain Ophiolite Belt that are prospective for chromite, nickel and asbestos. The Alpine Fault trace is visible in the middle of the photo (GNS photo CN14548/34H, photographer Lloyd Homer).

13.4 COPPER

13.4.1 Stratiform Cu (Figure 55)

International model

References

USGS model 24a Cyprus massive sulphide (Cox & Singer 1986) and BCGS model G05 Cyprus massive sulphide Cu (Zn) (Lefebure & Ray 1995).

Description

Sea-floor deposition of sulphide mounds contemporaneous with mafic volcanism. Deposits typically comprise one or more lenses of massive pyrite and chalcopyrite hosted by mafic volcanic rocks and underlain by a well developed pipe-shaped stockwork zone.

International examples

Cyprus; York Harbour and Betts Cove, Newfoundland, Canada; Turner-Albright, USA; Lokken, Norway.

Grade-tonnage data

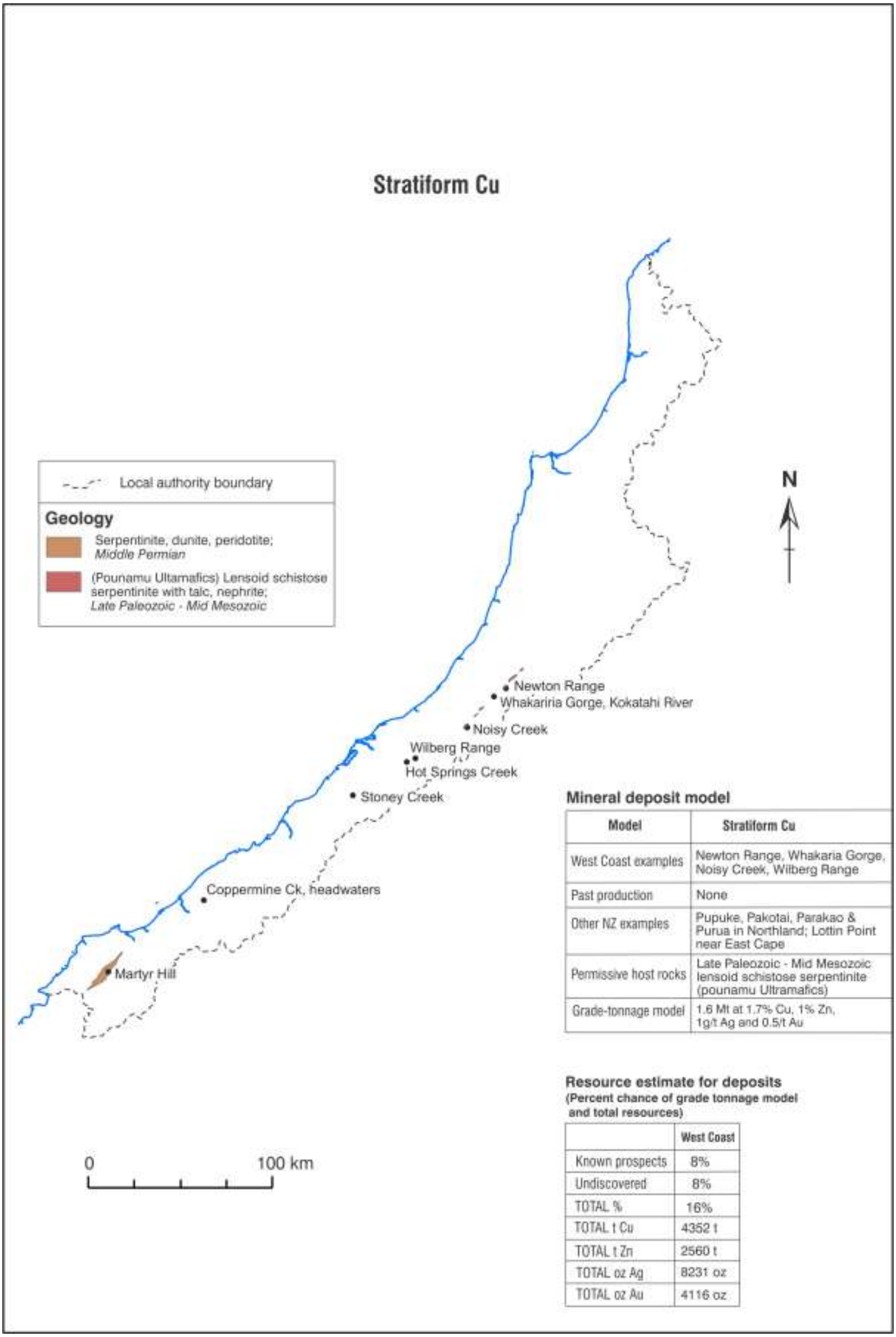
USGS model 24a 50th percentile = 1.6 Mt at 1.7% Cu, possible by-product Ag, Au, Pb and/or Zn (0-33 g/t Ag; 0-1.9 g/t Au, 0-2.1 % Zn) (Cox & Singer 1986, pp. 131-135). See also Lefebure & Höy (1996, pp. 130-131) for BCGS model G05. We have assigned a model size of 1.6 Mt at 1.7% Cu, 1% Zn, 1 g/t Ag and 0.5 g/t Au

West Coast deposits

Small massive sulphide lenses are present in greenschist metavolcanics and metaserpentinite of the Pounamu Ultramafics on the western side of the Southern Alps in Westland. The Pounamu Ultramafics are interpreted as ophiolite (ocean crust) basement to the Torlesse terrane (Cooper & Reay 1983). Copper-bearing sulphide lenses have been found in the Newton Range (Beck 1965), Diedrich, Meta and Bowen ranges (MacKenzie 1984), Whitcombe River area (Cooper & Reay 1983), and in the Wilberg Range (Gardiner 1971; Coleman 1980). Those in the Wilberg Range appear to be the largest, with a mineralised zone 3 m to 9 m wide and 1500 m long containing numerous pyrite-chalcopyrite lenses (30 cm to 90 cm wide) (McPherson et al. 1970). Later exploration in the same area (Coleman 1980) identified a much more extensive zone of mineralisation comprising many small pods of massive sulphide within greenschist, with grades between 0.5 and 2.0% Cu. An analysis from the Diedrich Range returned 5.1% Cu and 3.9 ppm Ag.

Assessment

We suggest a 16% probability of resources equivalent to the model size, equating to an estimated resource of 4352 t Cu, 2560 t Zn, 8231 oz Ag and 4116 oz Au.



Mineral deposit model

Model	Stratiform Cu
West Coast examples	Newton Range, Whakaria Gorge, Noisy Creek, Wilberg Range
Past production	None
Other NZ examples	Pupuke, Pakotai, Parakao & Purua in Northland; Lottin Point near East Cape
Permissive host rocks	Late Paleozoic - Mid Mesozoic lensoid schistose serpentinite (pounamu Ultramafics)
Grade-tonnage model	1.6 Mt at 1.7% Cu, 1% Zn, 1g/t Ag and 0.5/t Au

Resource estimate for deposits
(Percent chance of grade tonnage model and total resources)

	West Coast
Known prospects	8%
Undiscovered	8%
TOTAL %	16%
TOTAL t Cu	4352 t
TOTAL t Zn	2560 t
TOTAL oz Ag	8231 oz
TOTAL oz Au	4116 oz

Figure 55 Location of copper occurrences from the GERM database prospective for Stratiform Cu deposits.

13.4.2 Vein Cu (Figure 56)

Model

Description

Chalcopyrite-bearing quartz veins in and adjacent to granitic intrusions, possibly formed by magmatic related hydrothermal fluids. Host rocks include granitic and metasedimentary rocks. This model is used to group quartz veins that are not readily assignable to other models such as porphyry Cu, porphyry Mo, intrusion-related Au deposits and gabbroid Ni-Cu.

Grade-tonnage data – international

No comparable international model. We suggest a model size of 200,000 t at 2% Cu for 4000 t Cu.

West Coast deposits

The Waiahio Creek mineralisation (K31/e60) consists of quartz-chalcopyrite veins up to 0.4 m wide within a 200 m wide zone of hornfelsed Greenland Group metasedimentary rocks. The veins are related to a granitoid intrusion at shallow depth. Reconnaissance sampling by Lime & Marble Ltd reported concentrations of up to 3.6% Cu in float, and 400 ppm Cu in soil samples (Riley 1974). Channel sampling yielded up to 0.29% Cu over 4 m, and scheelite was noted in quartz float in the area. Low grades and rarity of veining outside the hornfelsed zone led to abandonment of the prospect. Later prospecting in the area by CRA (Price 1984) found several anomalous tungsten values in pan concentrates, but concluded that the area was only weakly mineralised, although having clear similarity to other copper-molybdenum mineralised granites in Westland and Nelson.

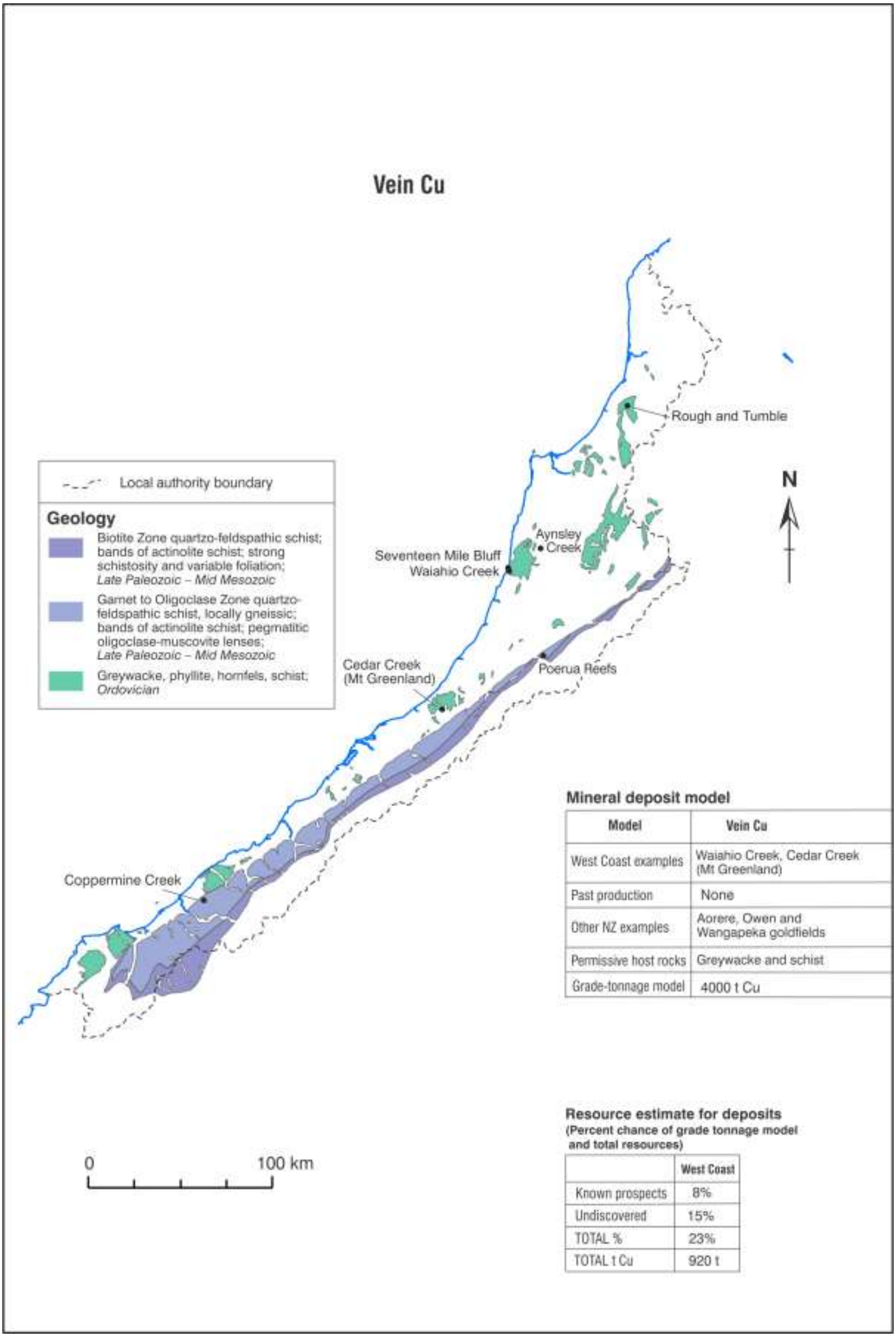
Regional prospecting programmes in the Aynsley Creek (K31/e71) stock located sparse cupriferous quartz float, but failed to locate any significant in situ mineralisation (Price 1984).

At Cedar Creek, Mt Greenland (J33/e78), minor copper mineralisation occurs within quartz veins in Greenland Group greywacke and argillite (Jury 1981). The veins range in thickness between 0.6 and 4.3 m, and were mined for gold between the late 1880s and 1940, producing some 129 kg gold at an average grade at 30 g/t (Young 1964b). No copper production is recorded. Hydrothermal-metamorphic gold-silver-copper bearing quartz veins in the South Lode of the Poerua Reefs (Morgan 1912; Downey 1928) are hosted in garnet zone schists of the Haast Schist Group.

Assessment

The West Coast examples have a similar setting to the Orogenic gold deposits, but their higher copper content suggests a closer association to magmatic hydrothermal fluids. Although not shown on Figure 56, there is also potential for Vein Cu deposits in granites.

We suggest a 23% probability of resources equivalent to the model size, equating to an estimated resource of 920 t Cu.



Model	Vein Cu
West Coast examples	Waiahio Creek, Cedar Creek (Mt Greenland)
Past production	None
Other NZ examples	Aorere, Owen and Wangapeka goldfields
Permissive host rocks	Greywacke and schist
Grade-tonnage model	4000 t Cu

	West Coast
Known prospects	8%
Undiscovered	15%
TOTAL %	23%
TOTAL t Cu	920 t

Figure 56 Location of copper occurrences from the GERM database, and areas of rocks prospective for Vein Cu deposits.

13.5 GOLD

Figure 57 shows West Coast gold production from 1988 to 2009. During this period, hard rock gold production commenced in 2007 with the opening of the Globe mine at Reefton.

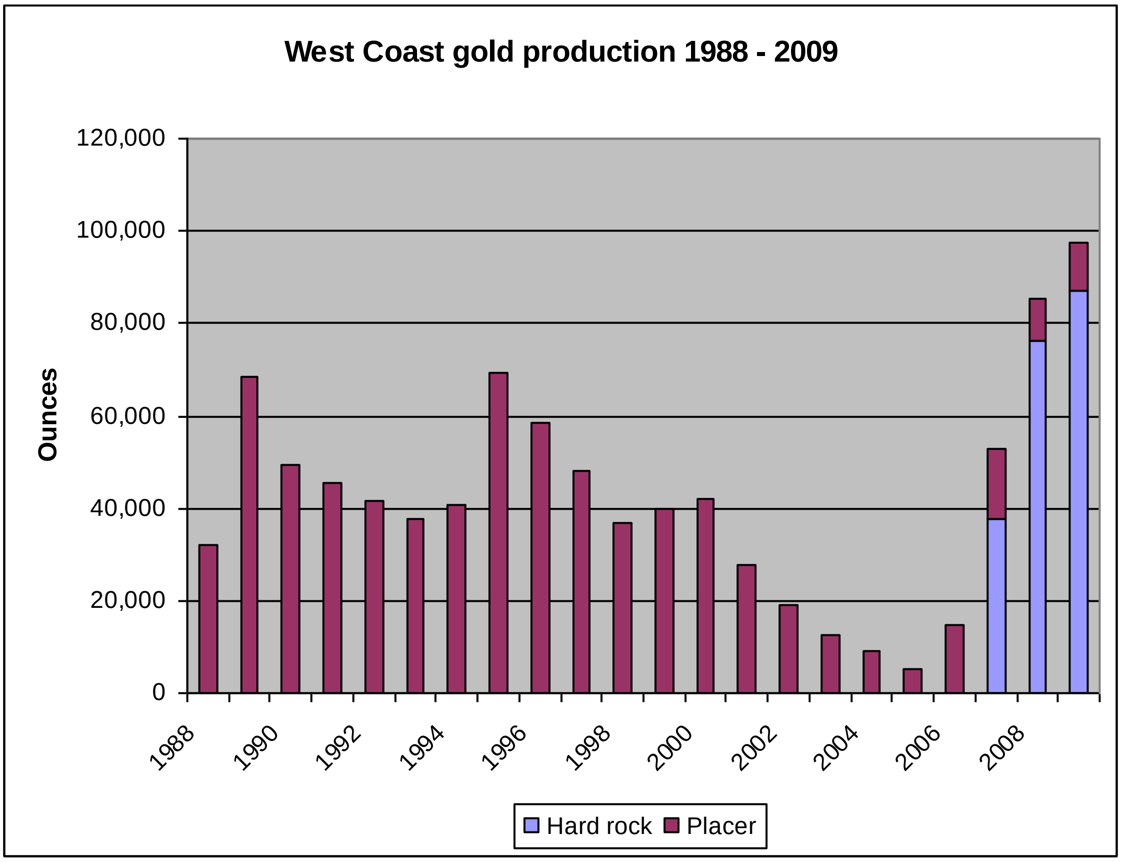


Figure 57 West Coast gold production from 1988 to 2009.

13.5.1 Orogenic shear zone Au - Paleozoic (Figure 58)

International model

References

BCGS model I03 Turbidite-hosted Au veins (Lefebure & Höy 1996); Orogenic gold deposits (Groves et al. 1998; Goldfarb et al. 2001, 2005); GNS Science Turbidite-hosted mesothermal gold deposit Model 1A Paleozoic mesothermal Au (Christie 2002).

Description

Gold-bearing quartz veins, segregations, lodes and sheeted zones hosted by fractures, faults, folds and openings in anticlines, synclines and along bedding planes in turbidites and associated poorly sorted clastic sedimentary rocks (McMillan 1996). The predominant host rock types are greywacke, siliceous wacke, shale and carbonaceous shale. Bedded cherts, iron formations, fine-grained impure carbonate rocks; minor polymictic conglomerate, tuffaceous members and minor marine volcanic flows may also be part of the stratigraphic sequence. There are younger granitic intrusions in many belts. Metamorphic grade is generally greenschist, but may reach amphibolite rank.

International examples

Bendigo, Ballarat and Castlemaine (Victoria, Australia), and Meguma Group (Nova Scotia, Canada).

Grade-tonnage data

Christie & Brathwaite (1999a) suggested a model size of 250,000 oz of contained Au. However, some much larger deposits are present in the Reefton Goldfield (e.g. Blackwater 733,000 oz Au production; Globe-Progress >1.75 Moz in pre-mining resources), and the deposits present in correlative host rocks in Victoria had a total historic production of more than 30 Moz, with 17 Moz produced from one goldfield, Bendigo. Therefore we have separated a second grade-tonnage model for the large deposits and suggest 2 Moz Au for this model.

West Coast deposits

Gold-bearing quartz lodes and disseminated gold occur in turbidite sequences of the Buller Terrane, Western Province. These rocks of the Greenland Group and equivalent sedimentary rock units are Paleozoic in age and have been faulted, folded and metamorphosed to prehnite-pumpellyite and lower greenschist facies.

The gold deposits consist of quartz veins which were formed in steeply dipping shear and fault structures. The veins contain minor native gold, pyrite and arsenopyrite, with stibnite, chalcopyrite and galena locally present. The vein quartz exhibits ribbon banded, crack-seal textures defined mainly by phyllosilicate laminae. Wallrock hydrothermal alteration consists of secondary sericite, pyrite, chlorite and carbonate in narrow zones, generally less than 1 m in width, enveloping the quartz lodes.

Christie (2002) classified the Reefton deposits into two subtypes:

“Blackwater style” characterised by relatively large, simple, undeformed quartz lodes, typically laminated (ribbon-banded), with native gold and minor sulphides. The veins have suffered little syn- to post-mineralisation deformation.

“Globe-Progress style” characterised by quartz lodes and quartz-pug breccias, with features indicative of intense syn- and post-mineralisation deformation. Recrystallisation and brecciation of massive and laminated (ribbon-banded) quartz is common. Gold is refractory, associated with abundant sulphides. Disseminated mineralisation occurs locally.

Lyell: A number of gold-bearing quartz lodes, varying from 0.3 to 6 m in width, were worked or prospected over a 5 km long zone extending NNW from Lyell Creek to New Creek. Most of the production was from the United Alpine mine (2.504 t Au, 1874-1912), from a short but thick ore shoot mined down to 500 m (Downey 1928; Barry 1996). Around Lyell Creek, a phyllitic argillite unit carrying minor pyrite and arsenopyrite, hosts the quartz lodes (M1321). In the New Creek area the country rocks are intruded and hornfelsed by granite dikes (Morgan & Bartrum 1915). Modern exploration was summarised by Pilcher et al. (2008) and consisted predominantly of stream sediment and soil geochemical surveys.

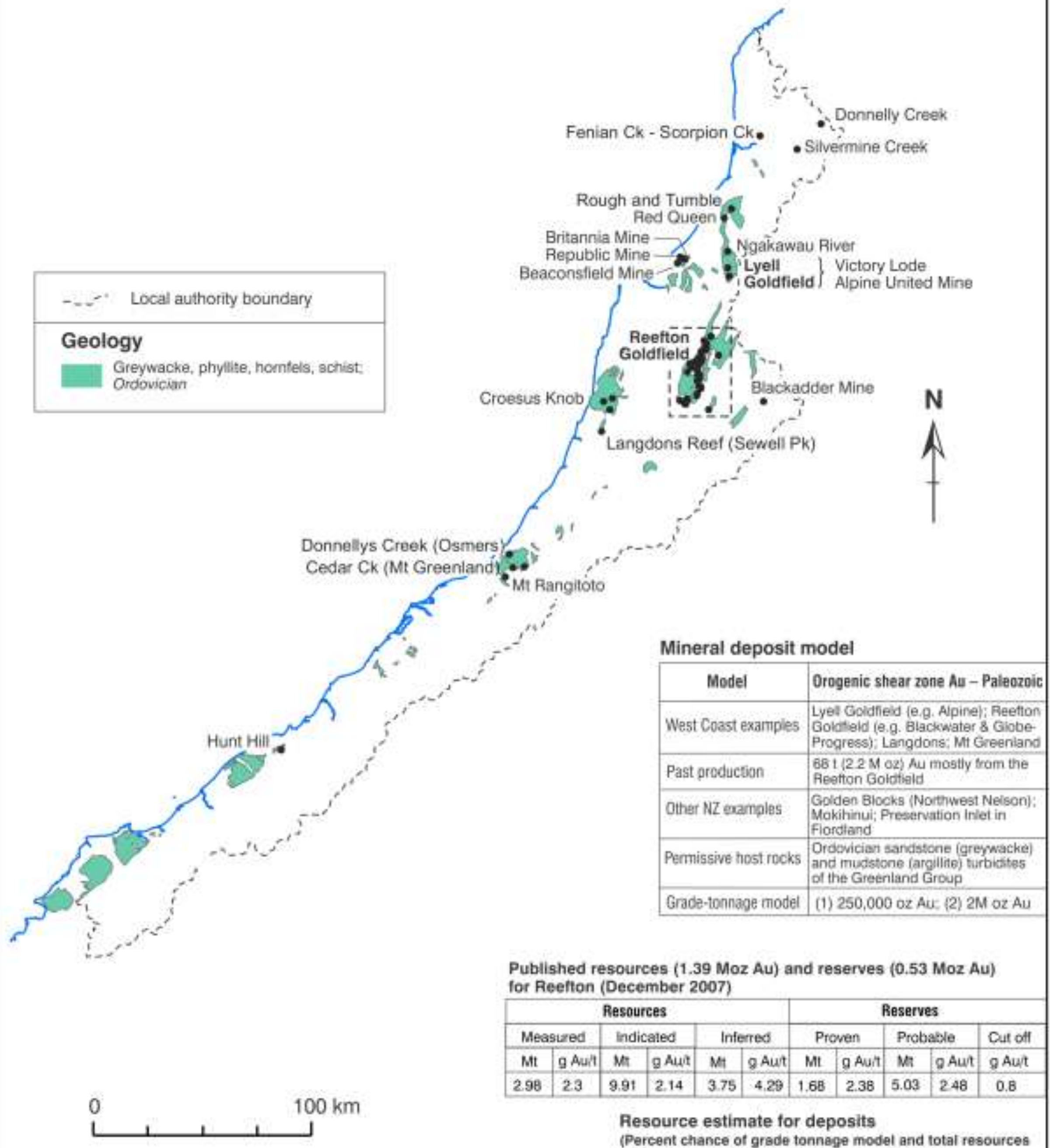
Reefton: The most important deposits are those in the Reefton area, where over 67 t of gold were produced from 84 mines between 1870 and 1951 (Table 12; Figure 58 and Figure 59). The gold quartz lodes are contained within a NNE trending belt of Greenland Group metasedimentary rocks, some 34 km in length by 10 km in width, which is in intrusive and/or fault contact along its eastern side with granites of Devonian and Cretaceous ages. To the south, the belt passes under Quaternary cover and to the north it is cut off by granite. Mafic dikes were reported from some of the old mines (Henderson 1917), and in the Inglewood Mine, a mafic dike has intruded along the hangingwall of a lode.

Table 12 Mines in the Reefton Goldfield with greater than 500 kg Au production and total Au production for the goldfield (after Christie et al. 2006)

Mine	Tonnes ore	Au oz	Au kg	Recovered grade g/t Au	Per cent of total Au
Blackwater	1 603 157	732 908	22 796	14.2	35.2
Globe-Progress	1 062 727	418 345	13 012	12.2	20.1
Wealth of Nations	458 034	208 980	6500	14.2	10.0
Keep-It-Dark	333 780	182 616	5680	17.0	8.8
Big River	124 060	135 965	4229	34.1	6.5
Ajax/Golden Fleece	136 642	89 636	2788	20.4	4.5
Welcome/Hopeful	44 867	88 607	2756	61.4	4.3
Alexander	48 492	41 089	1278	26.4	2.1
Murray Creek mines	52 943	33 887	1054	19.9	1.6
Fiery Cross	24 956	27 843	866	34.8	1.3
Just-In-Time	13 755	17 168	534	38.8	0.8
Total for 11 mines	3 903 413	1 977 044	61 493		95.2
Total for goldfield (59 mines with recorded production)	3 983 351	2 079 423	66 862		

Source: Production figures from Williams (1974) and Barry (1993)

Orogenic gold - Paleozoic



Mineral deposit model

Model	Orogenic shear zone Au – Paleozoic
West Coast examples	Lyell Goldfield (e.g. Alpine); Reefton Goldfield (e.g. Blackwater & Globe-Progress); Langdons; Mt Greenland
Past production	68 t (2.2 M oz) Au mostly from the Reefton Goldfield
Other NZ examples	Golden Blocks (Northwest Nelson); Mokihinui; Preservation Inlet in Fiordland
Permissive host rocks	Ordovician sandstone (greywacke) and mudstone (argillite) turbidites of the Greenland Group
Grade-tonnage model	(1) 250,000 oz Au; (2) 2M oz Au

Published resources (1.39 Moz Au) and reserves (0.53 Moz Au) for Reefton (December 2007)

Resources						Reserves				
Measured		Indicated		Inferred		Proven		Probable		Cut off
Mt	g Au/t	Mt	g Au/t	Mt	g Au/t	Mt	g Au/t	Mt	g Au/t	g Au/t
2.98	2.3	9.91	2.14	3.75	4.29	1.68	2.38	5.03	2.48	0.8

Resource estimate for deposits
(Percent chance of grade tonnage model and total resources in addition to published resources and reserves)

	250,000 oz Au model	2 M oz Au model	Total
Known prospects	272%		
Undiscovered	200%		
TOTAL %	472%	40%	
TOTAL oz Au	1,180,000 oz	800,000 oz	1,980,000 oz

Figure 58 Location of shear zone gold occurrences from the GERM database, and areas of rocks prospective for Orogenic/mesothermal shear zone Au deposits of Paleozoic age.

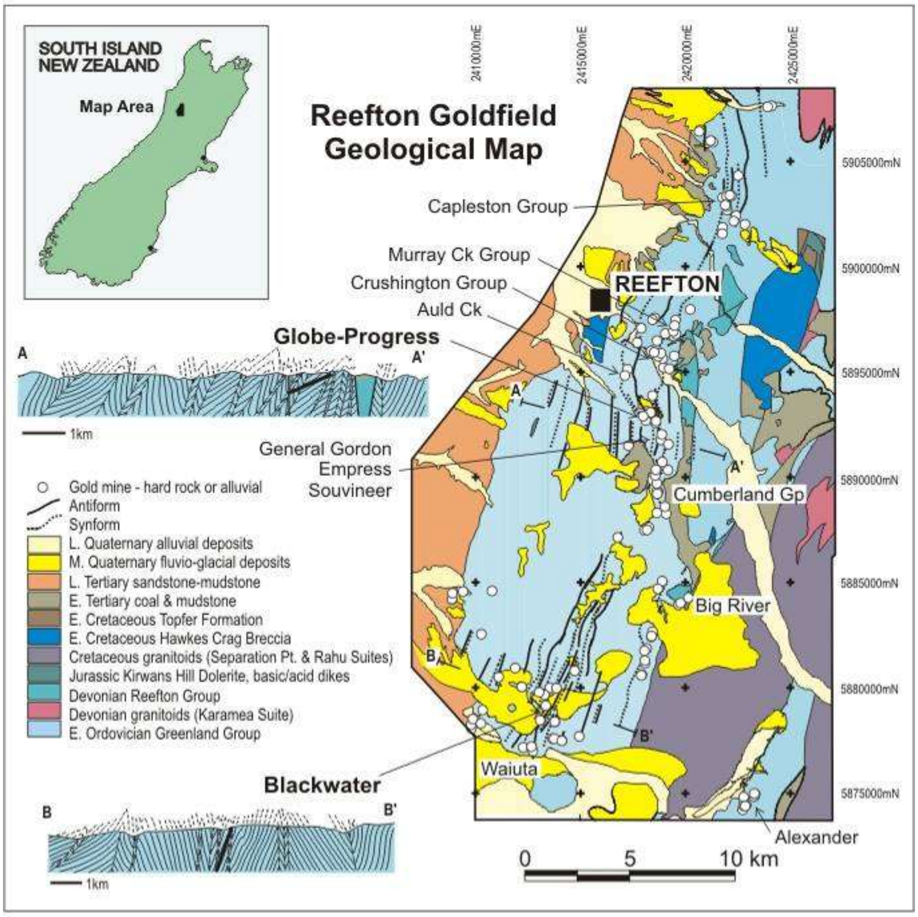


Figure 59 Geology and major mines of the Reefton goldfield (after Christie et al. 2006).

Gage (1948) considered that the pattern of folding in the Greenland Group strata was a major control on the localisation of the ore. He suggested that the quartz lodes were mostly subparallel to the regional NNE-trending fold axes, and were located on overturned limbs of the folds. Most of the lodes are confined to a corridor about 5 km in width, which may coincide with a zone of most intense folding and shearing. However, structural mapping by Rattenbury & Stewart (2000) identified a much more complex relationship between fold and shear structures at Globe Hill-Devils Creek and Waiuta than the relatively simple pattern of folding described by Gage.

The lodes (Figure 60) consist of a series of lensoid quartz shoots within one or more shear zones. The ore shoots range in width from 0.6 to 3.2 m and have a limited horizontal extent, usually less than 150 m, but they commonly persist down-plunge to considerable depth.

The largest known deposits were worked at the Blackwater and Globe-Progress mines. In the Blackwater Mine, the Birthday Reef averaged less than one metre in width but had a strike length of 1070 m, and was mined to a depth of 830 m, to produce 23 t of gold between 1909 and 1951 (Figure 61 and Figure 62). The ore is bluish-grey streaky quartz, containing gold and sulphides; predominantly pyrite and arsenopyrite, locally with stibnite and trace chalcopyrite.

Figure 60	Outcrop of the Empress Lode, a typical orogenic/mesothermal quartz lode located 1 km south of Globe-Progress, in the Reefton Goldfield. (Photo Tony Christie).

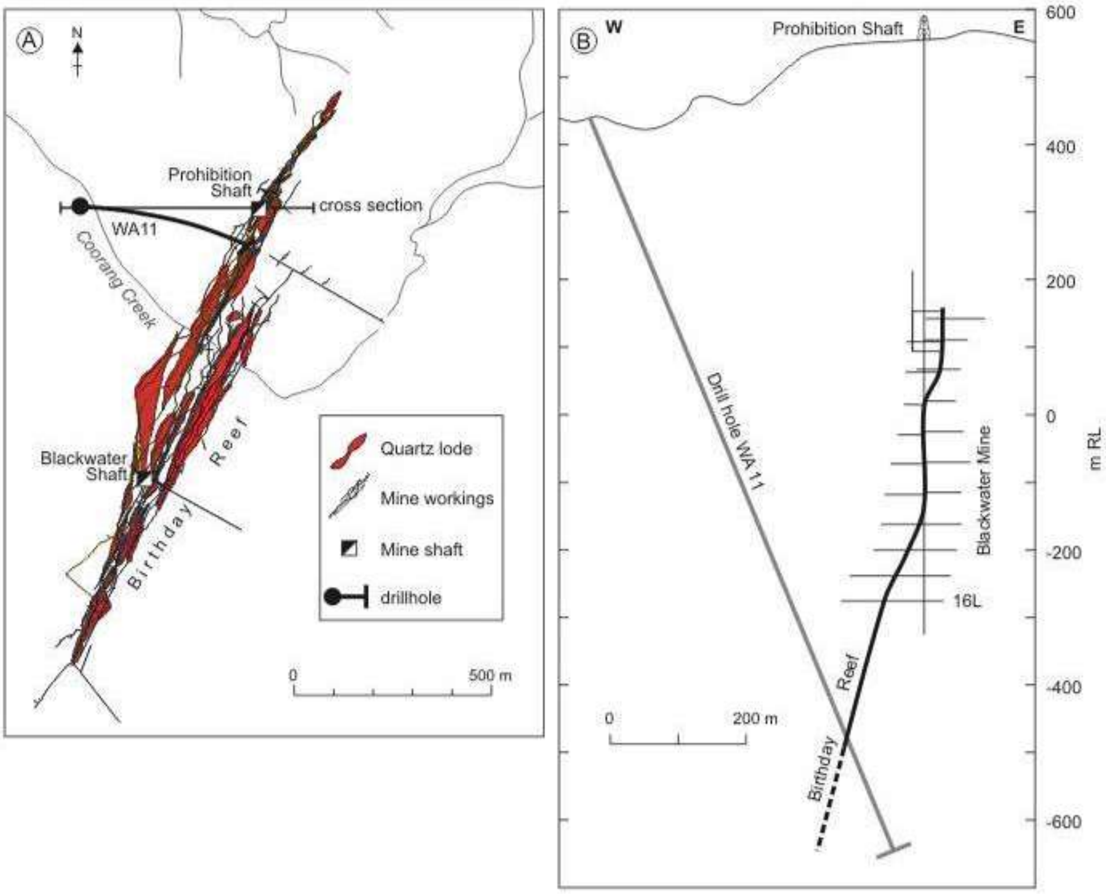


Figure 61	Map (A) and cross section (B) of the Birthday Reef and Blackwater mine workings showing the location of drill hole WA 11. (after Christie et al. 2006).

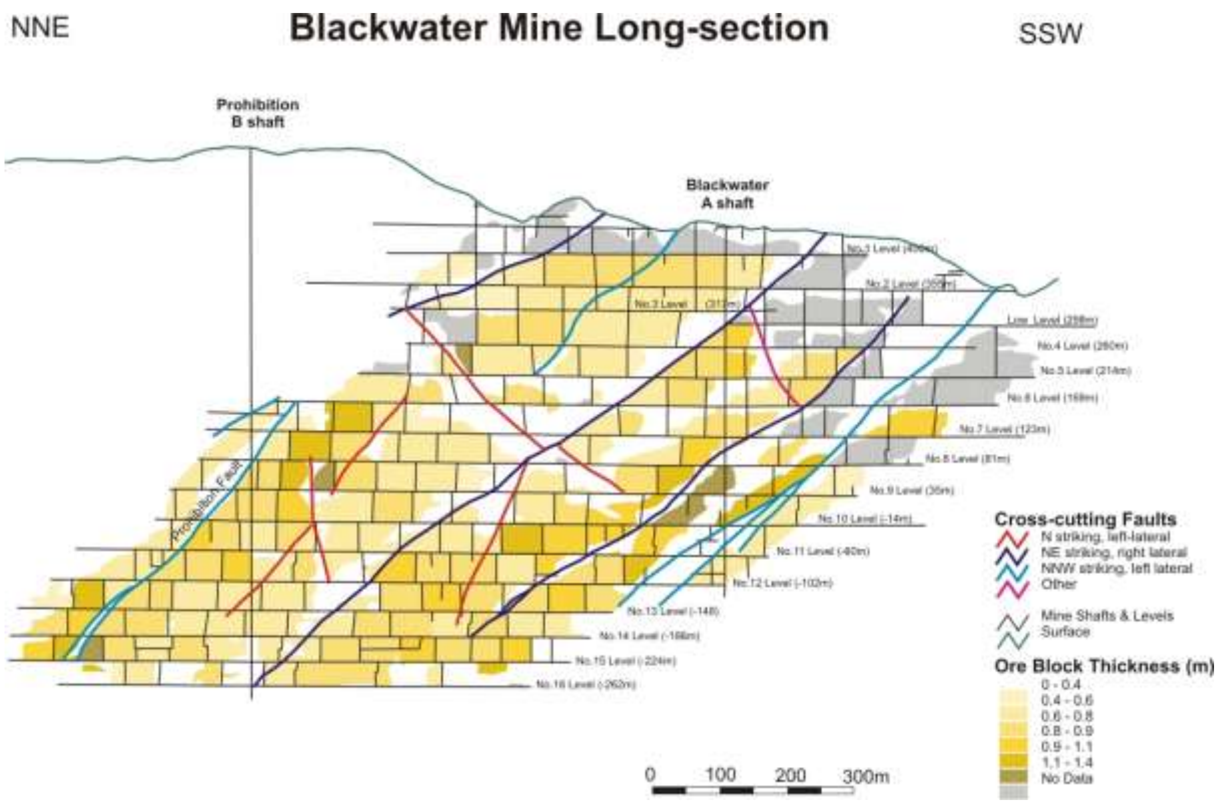


Figure 62 Blackwater mine long section (after Cox 2000).

Globe-Progress mine produced 13 t of gold between 1879 and 1920 (Figure 63 and Figure 64). Exploration by CRA in the 1980s, and later by Macraes Mining, and its successor companies GRD Resource Developments and Ocean Gold, discovered gold-arsenopyrite-pyrite-(stibnite) mineralisation in a clay-rich breccia zone bordering the main quartz lode (Figure 65; Whetter 2006). Intensive drilling on the Globe-progress system proved reserves of 4.77 Mt at 2.78 g/t Au for a total of 427,000 oz Au (Oceana Gold Limited 2004). Gold mining commenced at Globe-Progress in 2007 and in 2009 produced 87,138 oz Au (Table 1). The mine is open cut and consists of 4 open pits; Globe Progress, General Gordon, Empress and Souvenir, developed along the Oriental mineral trend (Figure 66 and Figure 67). The plant produces a concentrate that is rail shipped 800 km south to Palmerston in Otago where it is trucked to the Macraes mine for final processing. Gold resources (1.2 Moz Au) and reserves (0.37 Moz Au), as at 31 December 2009, totalled 1.57 Moz Au (Table 13 and Table 14), whereas pre-mine resources and reserves (December 2007) are listed in Figure 58.

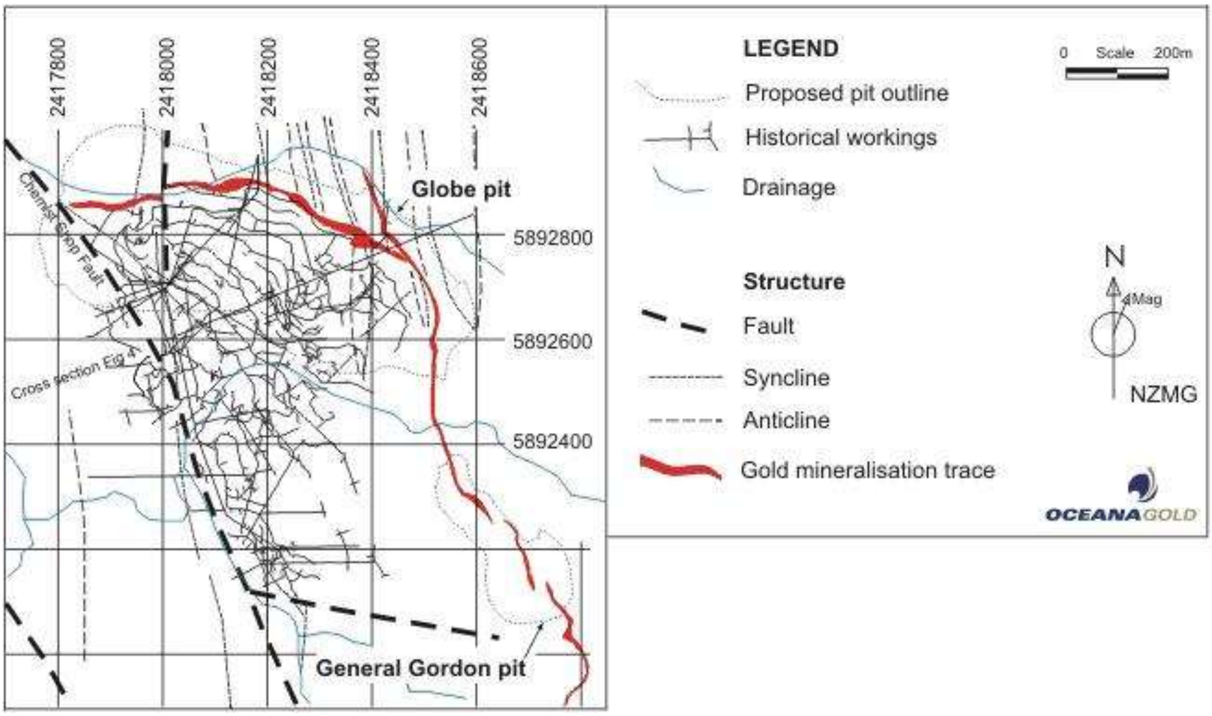


Figure 63 Historical underground workings in the Globe-Progress area, showing folding and major faults (after Whetter 2006).

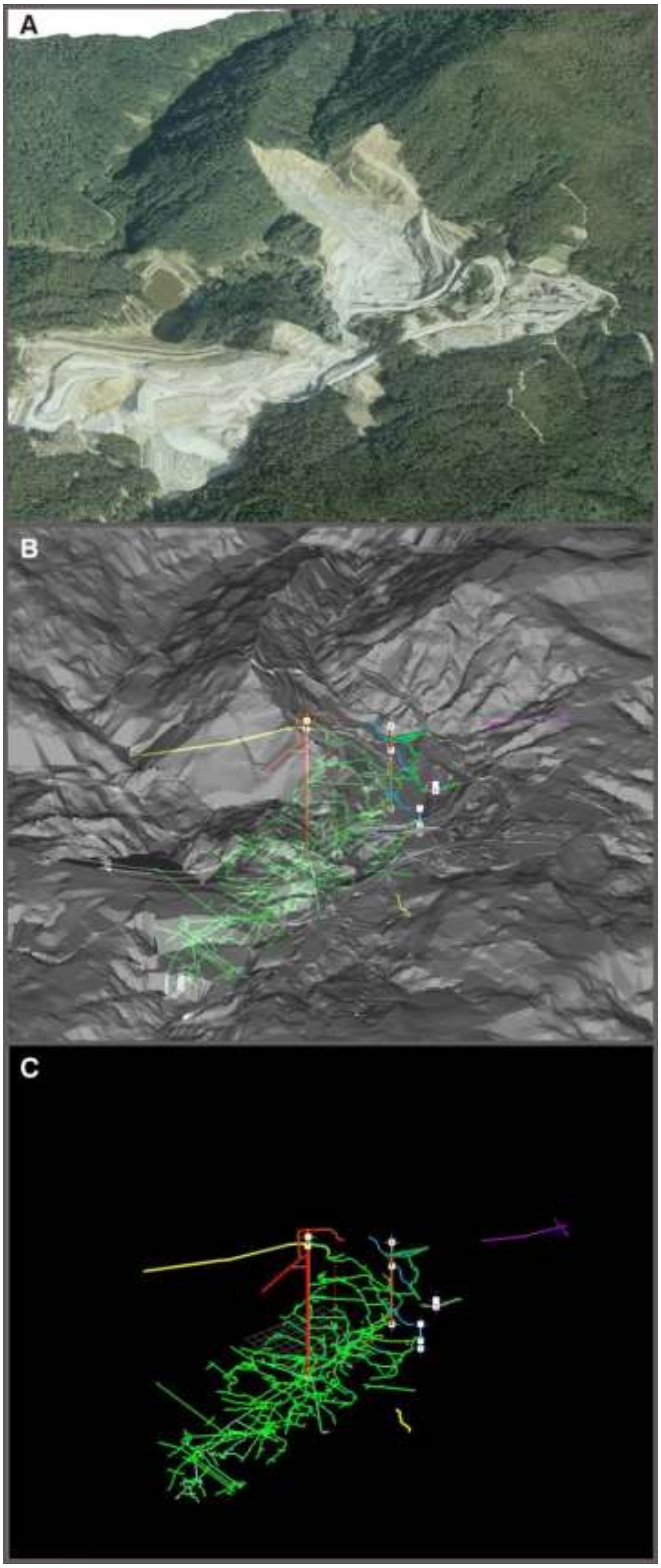


Figure 64 Perspective views of the Globe mine: A. a vertical aerial photo draped over a digital elevation model (DEM); B. DEM and underground workings of the former Globe-Progress mine; and C. underground workings (courtesy of Oceana Gold).

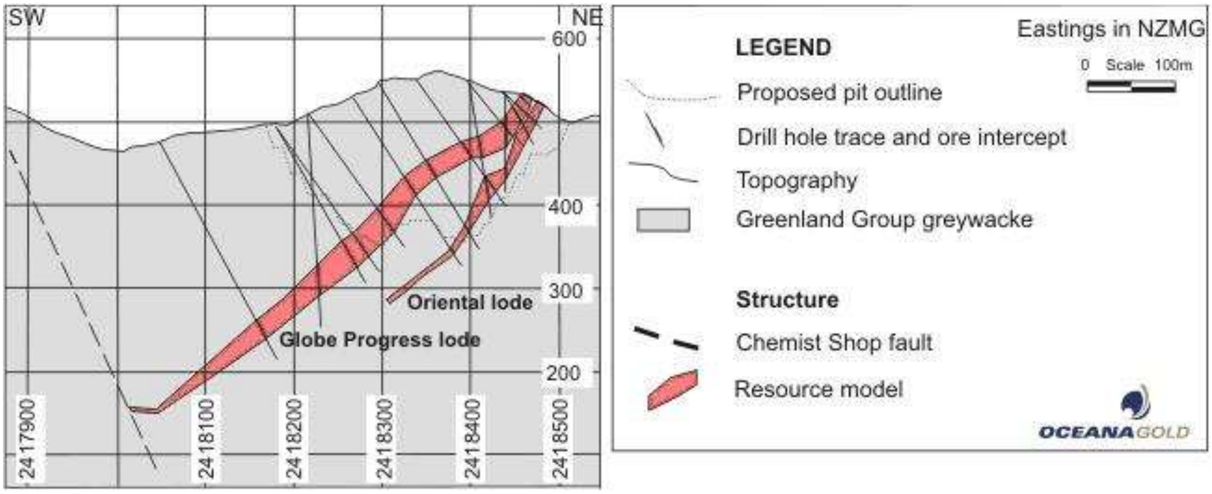


Figure 65 Cross section through the Globe-Progress deposit (after Whetter 2006).

Figure 66 View of the Globe pit looking east, October 2009 (photo courtesy Craig McIntosh, Oceana Gold).

Figure 67 View of the processing plant (right foreground), Globe pit (right distance) General Gordon and Souvenir pits (left distance), looking south southwest, February 2010 (photo courtesy of Craig McIntosh, Oceana Gold).

Table 13 Globe-Progress resources (1.2 M oz Au) as at December 31, 2009

Measured			**Indicated**			**Measured & indicated**				**Inferred resource**		
Mt	**Au g/t**		**Mt**	**Au g/t**		**Mt**	**Au g/t**	**Au Moz**		**Mt**	**Au g/t**	**Au Moz**
2.11	2.69		9.06	1.88		11.17	2.03	0.73		3.01	4.81	0.47

Source: OceanaGold Corporation Annual Report 2009

Table 14 Globe-Progress reserves (0.37 M oz Au) as at December 31, 2009

Proven			**Probable**			**Total reserve**		
Mt	**Au g/t**		**Mt**	**Au g/t**		**Mt**	**Au g/t**	**Au Moz**
1.42	2.56		3.98	1.98		5.41	2.12	0.37

Source: OceanaGold Corporation Annual Report 2009

A new programme of deep drilling was commenced at Globe–Progress in 2010 to explore for resources beneath the extent of previous mining. Results from this Globe Deeps programme were unavailable before publication of this report.

Elsewhere in the Reefton Goldfield, Oceana Gold and its predecessor companies carried out exploration at several other prospects, including Blackwater, Capleston, Crushington, Auld Creek, General Gordon, Cumberland (Merrijigs), Kirwans Hill and Alexander River (Magner et al. 1997; Blakemore et al. 2010) (Table 15). In 1995, Macraes Mining Ltd flew a combined EM (DIGHEM) and magnetic airborne survey over the Globe-Progress and General Gordon prospect areas.

At Blackwater, deep diamond drilling intersected the Birthday Reef nearly 200 m below the deepest level of the abandoned mine (16 level), to test the continuity of the vein structure with depth. The two Birthday Reef intersections yielded 0.4 m at 24.6 g/t Au in WA11 and 0.5 m at 59.7 g/t Au in WA11A. Proven ore reserves at the time of mine closure were reported as 63 000 t grading 13.75 g/t including expected dilution, all above 16 Level. The deep drilling was used to estimated resources of 0.48 Mt at 21.9 g/t Au, representing 336,000 oz or 10,450 kg of contained gold, with additional resources expected down dip. Following earlier studies by CRA Exploration and Golden Shamrock Mines in 1990 (Beetham et al. 1996), Oceana Gold commenced rehabilitation of the Prohibition Shaft in late 2004, but technical difficulties forced abandonment of this project in early 2005. A new programme of deep drilling commenced in 2010, with three -1200 m long drill holes planned (Blakemore et al. 2010). Results were expected after publication of this report.

Table 15 Recent exploration in the Reefton Goldfield (drilling to October 2010; modified after Christie et al. 2006).

Prospect areas	**Main mines**	**Mapping**	**Geochemistry**			**Trenching**	**Geophysics**	**Drilling**			
			Stream sediment	**Rock**	**Soil/wacker**			**RC holes**	**RC m**	**DDH holes***	**DDH m***
Goldfield		RM					Airborne magnetic/ radiometric survey (CRA)				
Capleston	Welcome/Hopeful Fiery Cross Just-In-Time	SM	Y	Y	CG WD & HA	Y	IP			9 (3 CRA)	972 (305 CRA)
Murray Creek	Murray Creek mines Ajax/Golden Fleece	SM	Y	Y	CG HA	Y	ground magnetics				
Crushington	Wealth of Nations Keep It Dark	SM	Y	Y	RL & limited CG HA	Y				12 (3 CRA)	1719 (352 CRA)
Auld Creek		SM	Y	Y	CG HA & WD	Y	ground magnetics			16	1822
Globe-Progress	Globe-Progress	SM	Y	Y	CG WD & HA	Y	IP, ground magnetics, and airborne EM/magnetics. Trialled down hole geophysical logging, seismics and resistivity	240	18,426	292 (35 CRA)	35,872 (6167 CRA)
General Gordon		SM	Y	Y	CG WD & HA	Y	airborne EM/magnetics. Trialled ground EM and radar	58 (1 CRA)	7700 130 CRA)	7 (2 CRA)	742 (267 CRA)
Empress		SM		Y	CG WD & HA	Y		63	5908	13	1296
Souvenir		SM		Y	CG WD & HA	Y		31	3081	9	1582
Cumberland	Alexander - Alexander mine Merrijigs – Sir Francis Drake, Cumberland, Golden Lead-OK Inkerman – Inkerman mine	SM	Y	Y	Some CG WD & HA	Y				70 (2 CRA)	8774 (310 CRA)

Prospect areas	Main mines	Mapping	Geochemistry			Trenching	Geophysics	Drilling			
			Stream sediment	Rock	Soil/wacker			RC holes	RC m	DDH holes*	DDH m*
Big River	Big River mine	SM	Y	Y	CG HA & WD	Y					
Blackwater	Blackwater	SM	Y	Y	RL WD	Y	ground magnetics, IP-resistivity			21 (6 CRA)	5021 (948 CRA)
Waiuta (area surrounding Blackwater)	South Blackwater, Homer and Millerton mines	SM	Y	Y	CG HA	Y	ground resistivity, downhole geophysical logging			4	741
Alexander River	Alexander mine	RM	Y	Y	CG HA	Y	ground magnetics			7	481

Y = Activity carried out on prospect

CG = Close grid, typically 12.5 m or 25 m spaced samples on 50 or 100 m spaced lines

RL = Reconnaissance Line, typically 25 m spaced samples on ridge or track traverses

HA = Soil geochemistry samples collected by hand auger

WD = Soil geochemistry samples collected by wacker drill

RM = Regional mapping, mostly pre-1980, measurements may be poorly located.

SM = Detailed structural mapping, post-1980, with measurements located by GPS or surveying.

T = Trenching

*CRA drill hole and metres are included in the totals

Mt Greenland: Steeply dipping quartz lodes follow WNW striking shears and fault crush zones in anticlinal axes of folded metagreywacke, and were traced for up to 3.2 km along strike (Morgan 1908; Young 1964b). The main lode plunges steeply NW, and was stoped over a width of 0.6 to 1.2 m and a length of about 60 m. Jury (1981) described a vein mineral assemblage of chalcopyrite, pyrite, arsenopyrite and sphalerite accompanied by trace amounts of galena, boulangerite, bournonite, tetrahedrite and gold, in a gangue of quartz and calcite.

Bald Hill: Ryland & Cooper (2007) described siderite-rich quartz veins in Greenland Group metasediments which are probably the source of alluvial gold in Cole Creek.

Assessment

The main exploration targets are large planar lodes of the Blackwater type, and disseminated gold associated with the lode deposits (Globe-Progress type). There is potential for additional east-west striking shear zones like Globe-Progress.

Some lode gold deposits in Victoria are very large, particularly the saddle reef systems of Bendigo and leather jacket style deposits of Ballarat. Christie et al. (1999a, 1999b) noted that saddle reef style deposits have not been found in New Zealand and the lesser occurrence of bedding parallel lodes in the Reefton Goldfield compared with Victoria is a negative feature for the potential for saddle reef systems in the Reefton Goldfield. These authors did however, speculate that the Alpine Reef in the Lyell Goldfield had some similarities to the leather jacket style of deposits, suggesting some potential for this style of vein formation.

Partington et al. (2001) reported a prospectivity assessment for the Reefton Goldfield and Blakemore et al. (2010) identified prospective targets in the Auld Creek North to Merrijigs area and ranked their prospectivity based on structural and geochemical analysis (Figure 68).

The large number of known deposits and large area of prospective rocks, suggests a 472% probability of resources equivalent to the 250,000 oz Au mineral deposit model, to give total estimated resources of 1,180,000 oz Au in addition to published resources and reserves in Globe-Progress and Blackwater. Additionally, we suggest that there is a 40% probability of resources equivalent to the 2 Moz Au model, to give total estimated resources of 800,000 oz Au for this model. These estimates total 1,980,000 oz Au and together with published resources and reserves, and minus the 200,000 oz Au from 2007-2009 production at Globe Progress, give an overall total of 3,700,000 oz Au.

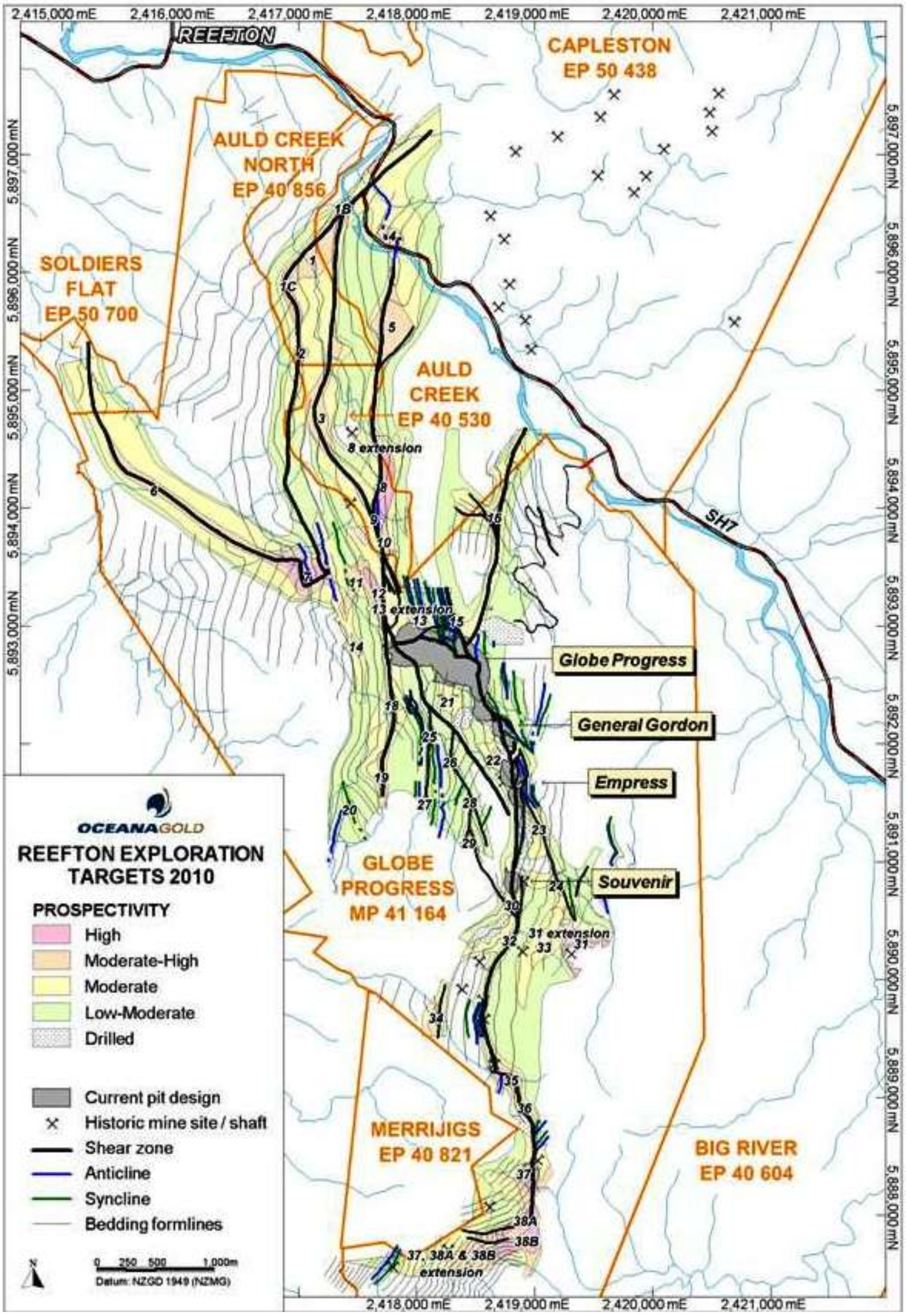


Figure 68 Prospectivity map showing target localities in part of the Reefton Goldfield. Levels of prospectivity are based on structural and geochemical analysis. (After Figure 4 of Blakemore et al. 2010).

13.5.2 Orogenic shear zone Au - Mesozoic (Figure 69)

International model

References

BCGS model I03 Turbidite-hosted Au veins (Lefebure & Höy 1996); Orogenic gold deposits (Groves et al. 1998; Goldfarb et al. 2001); GNS Science Turbidite-hosted mesothermal gold deposit Model 1B Mesozoic mesothermal Au (Christie 2002).

Description

Gold-bearing quartz veins, segregations, lodes and sheeted zones hosted by fractures, faults, folds and openings in anticlines, synclines and along bedding planes in turbidites and associated poorly sorted clastic sedimentary rocks (McMillan 1996). The predominant host rock types are greywacke, siliceous wacke, shale and carbonaceous shale. Bedded cherts, iron formations, fine-grained impure carbonate rocks; minor polymictic conglomerate, tuffaceous members and minor marine volcanic flows may also be part of the stratigraphic sequence. There are younger granitic intrusions in many belts. Metamorphic grade is generally greenschist, but may reach amphibolite rank.

New Zealand examples

Gold-bearing quartz lodes and disseminated mineralisation are associated with shear zones in the Mesozoic Haast Schist. The lodes typically dip steeply and are discordant to the foliation in the host schist. The Otago lodes typically strike northwest, parallel to the antiformal axis of the schist belt. The Marlborough lodes also strike northwest, but may have been rotated from a northeast strike when displaced from Otago by the Alpine Fault (Craw et al. 2000).

Grade and tonnage data

Individual lodes deposits are small, but there is potential for low-grade disseminated mineralisation that would have been ignored by the early miners.

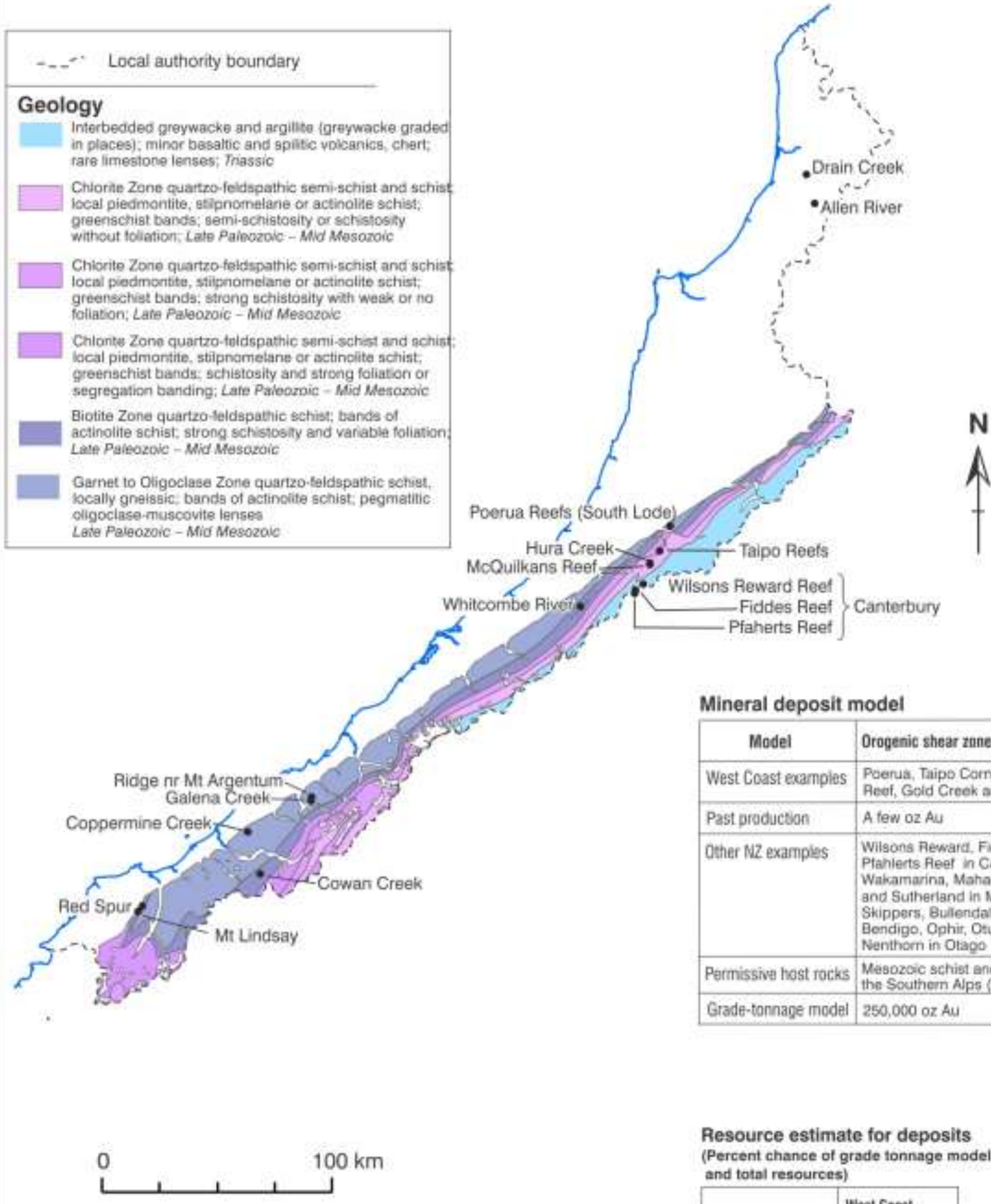
West Coast deposits

In the Southern Alps, gold-bearing quartz lodes are found in Haast Schist in the Whitcombe River and Alexander Range (Poerua Mine) and semi-schistose greywacke of the Taipo River area (Taipo Corner, Gold Creek, McQuilkans and others). East of the Main Divide, similar veins are present in low grade metagreywacke of the Wilberforce River area (Fiddes, Pfahlerts and Wilsons Reward) in the Canterbury region (Becker & Craw 2000; Becker et al. 2000). There was no significant production from these lodes. Becker et al. (2000) described the veins as occurring in a swarm c. 5-10 km wide extending over 40 km from the Wilberforce valley in Canterbury, across the Main Divide to the lower reaches of Taipo River near the Alpine Fault. The veins strike NNE, subparallel with the trend of the swarm and dip steeply (50-80^{o}), generally to the west. The veins consist of quartz lenses, commonly coarsely (cm scale) laminated, which are typically 0.5-3.0 m wide (maximum 8.0 m wide) and traceable for 5-10 m along-strike. Albite forms up to 45% of some veins, and minor chlorite, pyrite, arsenopyrite, chalcopyrite and gold occur sporadically, especially in breccias near the margins of the veins.

Assessment

We suggest a 26% probability of resources equivalent to the model size, equating to an estimated resource of 65,000 oz Au.

Orogenic gold - Mesozoic



Mineral deposit model

Model	Orogenic shear zone gold – Mesozoic
West Coast examples	Poerua, Taipo Corner, McQuilkans Reef, Gold Creek and Taipo River
Past production	A few oz Au
Other NZ examples	Wilsons Reward, Fiddes Reef and Pfahlerts Reef in Canterbury; Wakamarina, Mahakipawa, Jubilee and Sutherland in Marlborough; Skippers, Bullendale, Macetown, Bendigo, Ophir, Oturehua and Nenthorn in Otago
Permissive host rocks	Mesozoic schist and greywacke of the Southern Alps (Torlesse Terrane)
Grade-tonnage model	250,000 oz Au

Resource estimate for deposits
(Percent chance of grade tonnage model and total resources)

	West Coast
Known prospects	6%
Undiscovered	20%
TOTAL %	26%
TOTAL t	65,000 oz Au

Figure 69 Location of shear zone gold occurrences from the GERM database, and areas of rocks prospective for Orogenic/mesothermal Au deposits of Mesozoic age.

13.5.3 Orogenic Alpine Au - Cenozoic (Figure 70)

International model

References

BCGS model I03 Turbidite-hosted Au veins (Lefebure & Höy 1996); Orogenic gold deposits (Groves et al. 1998; Goldfarb et al. 2001); GNS Science Turbidite-hosted mesothermal gold deposit Model 1B Mesozoic mesothermal Au (Christie 2002).

Description

Gold-bearing quartz veins, segregations, lodes and sheeted zones hosted by fractures, faults, folds and openings in anticlines, synclines and along bedding planes in turbidites and associated poorly sorted clastic sedimentary rocks (McMillan 1996). The predominant host rock types are greywacke, siliceous wacke, shale and carbonaceous shale. Bedded cherts, iron formations, fine-grained impure carbonate rocks; minor polymictic conglomerate, tuffaceous members and minor marine volcanic flows may also be part of the stratigraphic sequence. There are younger granitic intrusions in many belts. Metamorphic grade is generally greenschist, but may reach amphibolite rank.

Grade and tonnage data

Individual lodes deposits are small, but there is potential for low-grade disseminated mineralisation.

West Coast deposits

Gold-bearing quartz-calcite veins occur in greenschist facies rocks immediately west of the Main Divide (Craw et al. 1987a, 1987b, 1994, 1999, 2002; Cox et al. 1997; Craw 1988, 1992, 1997, 2000, 2006; Craw & Campbell 2004). The veins are thin (0.1-1 m thick) and discontinuous, mainly filling extensional structures in steeply dipping fracture zones that crosscut late Cenozoic structures. The veins contain minor biotite and sulphides, and traces of scheelite and gold. The gold is fine grained (10-500 μm), although clusters of gold grains up to 1 cm occur sporadically. It is intergrown with sulphides, carbonate, or quartz. Craw et al. (1994, 1999) suggested that the veins were related to late Cenozoic deformation associated with rapid uplift along the Alpine Fault, allowing hot (250-320°C) metamorphic fluids to reach relatively shallow (4-5 km) crustal levels.

Assessment

Craw (2006) noted the small size of the veins (1-10 m^3) and suggested that their potential was limited to kilogram-scale extraction of locally rich material. We suggest a 1% probability of resources equivalent to the model size, equating to an estimated resource of 2500 oz Au.

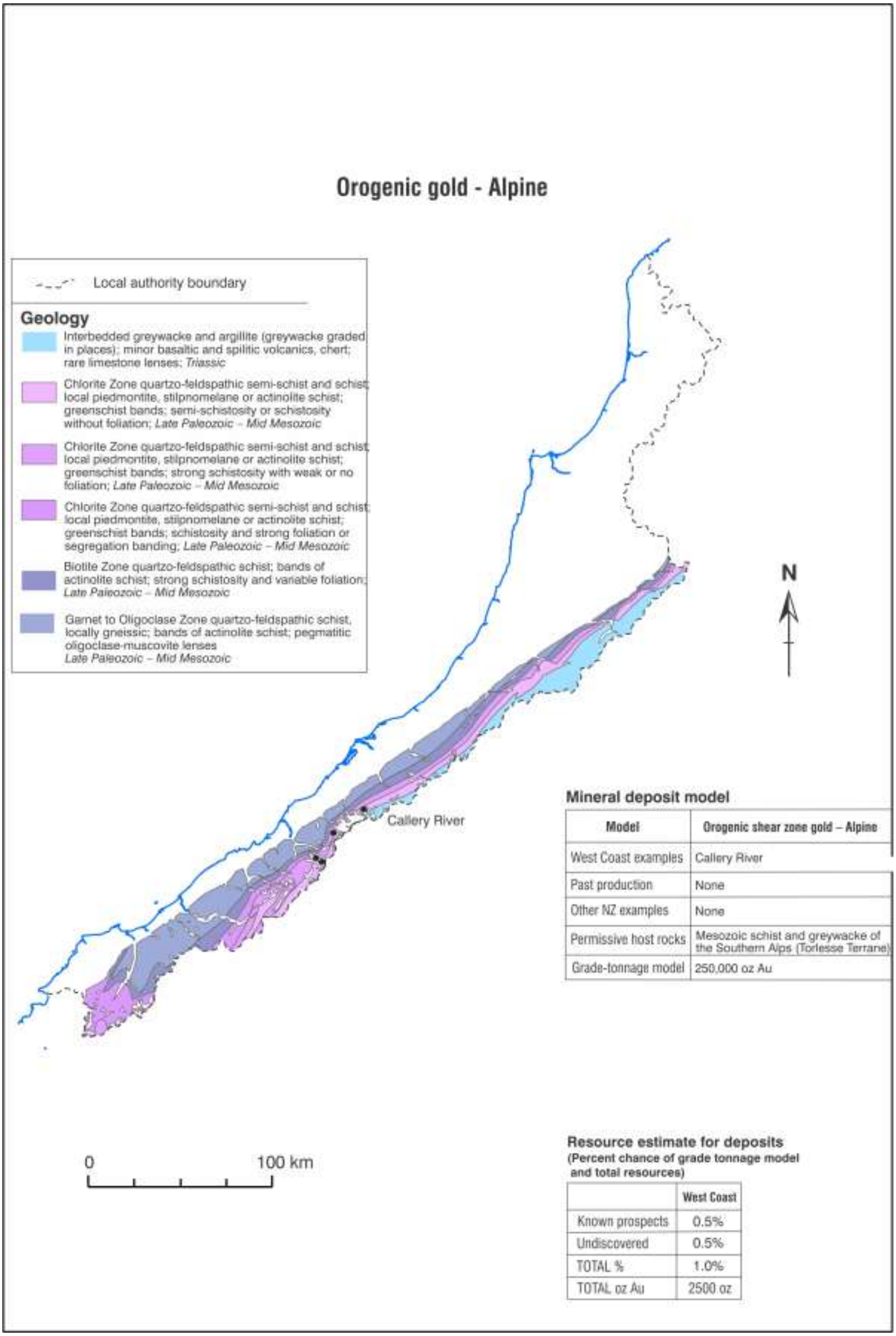


Figure 70 Occurrences of late Cenozoic gold (after Figure 3 of Craw et al. 1999), and location of rocks prospective for Alpine type Orogenic/mesothermal Au deposits.

13.5.4 Alkali intrusion-related Au (Figure 71)

International model

Reference

BCGS model H08 Alkalic Intrusion-related Au-Ag (Lefebure & Höy 1996).

Description

Quartz vein stockworks with As-Au-Ag±Zn±Pb in silicified and carbonate-altered alkalic intrusive rocks. The main metallic minerals are pyrite and arsenopyrite, with minor sphalerite, galena, gold, chalcopyrite, pyrrhotite, and graphite. The Sams Creek Au deposit, which is hosted in a peralkaline granite dike in west Nelson, is a New Zealand example (Brathwaite et al. 2006; Faure & Brathwaite 2006). The porphyritic Sams Creek granite consists of phenocrysts of perthite, arfvedsonite-riebeckite (Ar/Ar dated at 319 Ma, late Carboniferous) and quartz, with accessory ilmenite and rutile (Faure & Brathwaite 2006; Tulloch & Dunlap 2006). The main phase of mineralisation consists of veins of gold-bearing arsenopyrite-pyrite-quartz-siderite, with minor galena, sphalerite, pyrrhotite and graphite.

Grade-tonnage data

Inferred resources at Sams Creek are 13.5 Mt at 1.78 g/t Au for 770,000 oz Au. We suggest 750,000 oz Au as our mineral deposit model.

West Coast deposits

No occurrences of alkali-intrusion related Au deposits are known in the West Coast region. Prospective rocks include the alkaline Foulwind Granite and French Creek Granite (Figure 71).

Assessment

We suggest a 5% probability of resources equivalent to the model size, equating to an estimated resource of 37,500 oz Au.

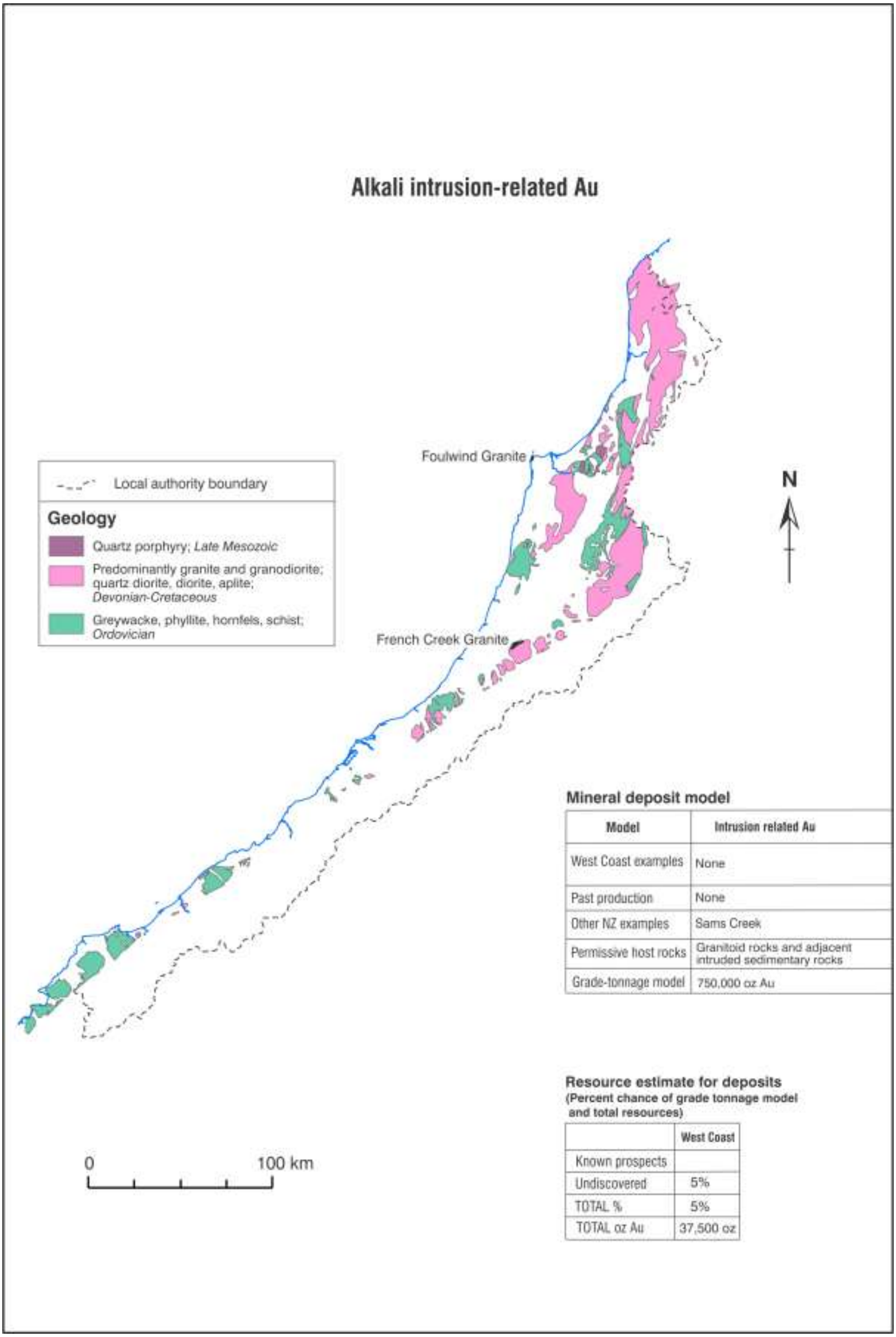


Figure 71 Areas of rocks prospective for Alkali intrusion-related Au gold deposits.

13.5.5 Moderately reduced granite Au (Figure 72)

International model

Reference

Intrusion-related Au (Lang et al. 2000; Lang & Baker 2001); Granite-related Au deposits associated with W granites (Baker et al. 2005).

BCGS model L02 Plutonic related Au quartz veins and veinlets (Lefebure & Hart 2005)

Description

Quartz vein stockworks with Au-Bi-Mo-W-Sb±Sn associated with moderately reduced (ilmenite-series) granites and granodiorites. The main metallic minerals are pyrrhotite, pyrite, arsenopyrite, molybdenite, scheelite, and bismuth and telluride minerals.

International examples

Fort Knox and Cleary Hill (Alaska); Dublin Gulch, Scheelite Dome, Clear Creek and Brewery Creek (Yukon); Timbarra (New South Wales); Kidston (Queensland); Penedona and Jales (Portugal); Salave and Solomon (Spain); Mokrsko and Petrackova hora (Czech Republic); Vasilkovskoe (Kazakstan); Niuxinshan (China); and Kori Kollo (Bolivia).

Grade-tonnage data

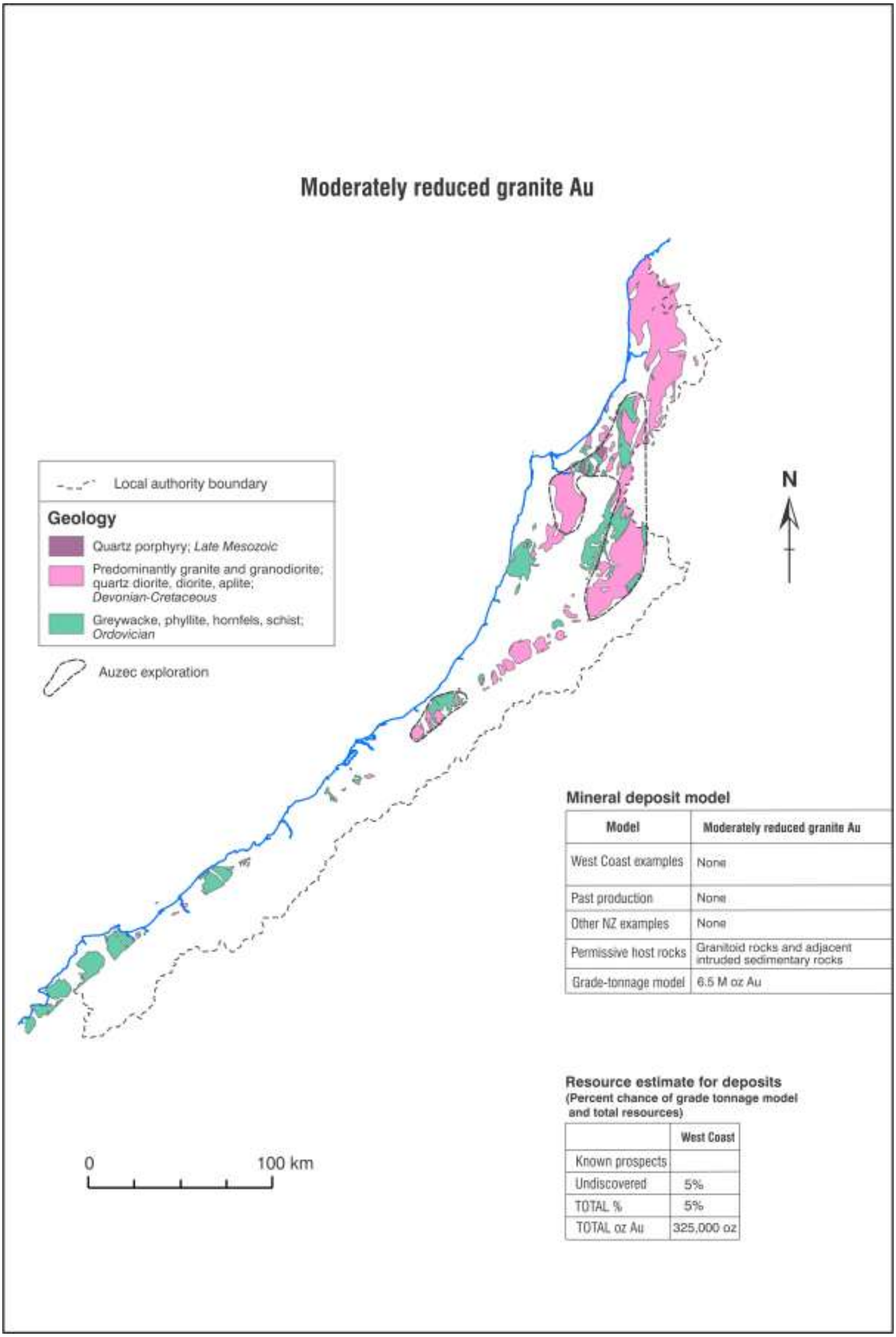
The main example is Fort Knox, Alaska which has resources of approximately 6.5 Moz Au. Other deposits include Donlin Creek (10.4 M Oz Au), Vasilkovskoe (9.5 M Oz Au), Pogo (4.9 M Oz Au) and Kidston (4.5 M Oz Au). We have assigned a model size of 6.5 Moz.

West Coast deposits

There are no known examples of these types of deposits in the West Coast region, however GIS prospectivity modelling by Kenex using regional geochemical data revealed an association of Au and Bi in several granite intrusions of the region (Mustard & Partington 2005; Partington 2009). The areas identified as most prospective for intrusion-related gold deposits are shown on Figure 72. Past stream sediment surveys (e.g. REGCHEM database) returned concentrations of up to 70 ppm Bi in the Buckland Granite and 150 ppm Bi in the Mt Rangitoto area. Follow-up sampling and analyses of granites from Mt Greenland and the Buckland granite by Auzex Resources identified bismuth and tellurium in analyses of disseminated pyrite and arsenopyrite (Mustard & Partington 2005).

Assessment

We suggest a 5% probability of resources equivalent to the model size, equating to an estimated resource of 325,000 oz Au.



Mineral deposit model

Model	Moderately reduced granite Au
West Coast examples	None
Past production	None
Other NZ examples	None
Permissive host rocks	Granitoid rocks and adjacent intruded sedimentary rocks
Grade-tonnage model	6.5 M oz Au

Resource estimate for deposits
(Percent chance of grade tonnage model and total resources)

	West Coast
Known prospects	
Undiscovered	5%
TOTAL %	5%
TOTAL oz Au	325,000 oz

Figure 72 Areas of rocks prospective for Moderately reduced granite Au deposits.

13.5.6 Detachment-fault-related polymetallic deposits (Figure 73)

International model

Reference

“Detachment-fault-related mineral deposits” Long (2004)

Description

Massive replacements, stockworks, and veins of iron and copper oxides and locally sulfides along detachment-fault structures. These deposits sometimes contain economic concentrations of gold and silver. Distal veins of quartz-barite-fluorite-Mn oxides emplaced along high-angle faults in the upper plate of detachment-faulted terranes.

International examples

Bullard, Copperstone, Osborne, Planet, Harris, Tiger Wash and Newsboy, all in Arizona, USA.

Grade-tonnage data

The Copperstone deposit has resources of 386,000 oz Au at 2.6 g/t, and the Newsboy deposit has 67,500 at 1.54 g/t (Long 2004). We assign a model size of 200,000 oz Au.

West Coast deposits

Tulloch (1988b, 1995) suggested that gold anomalies, with associated Ag, As, Sb and Cu, in exploration stream sediment geochemical surveys of the Paparoa Range may be related to a detachment fault system associated with the Paparoa Metamorphic Core Complex (Figure 73 and Figure 74). Silver, fluorite, barite, sulphide, and uranium occurrences in the lower Buller Gorge were considered to have formed by hydrothermal activity associated with the Ohika detachment fault (Tulloch 1988b, 1995; Tulloch & Kimborough 1989).

Assessment

We suggest a 15% probability of resources equivalent to the model size, equating to an estimated resource of 30,000 oz Au.

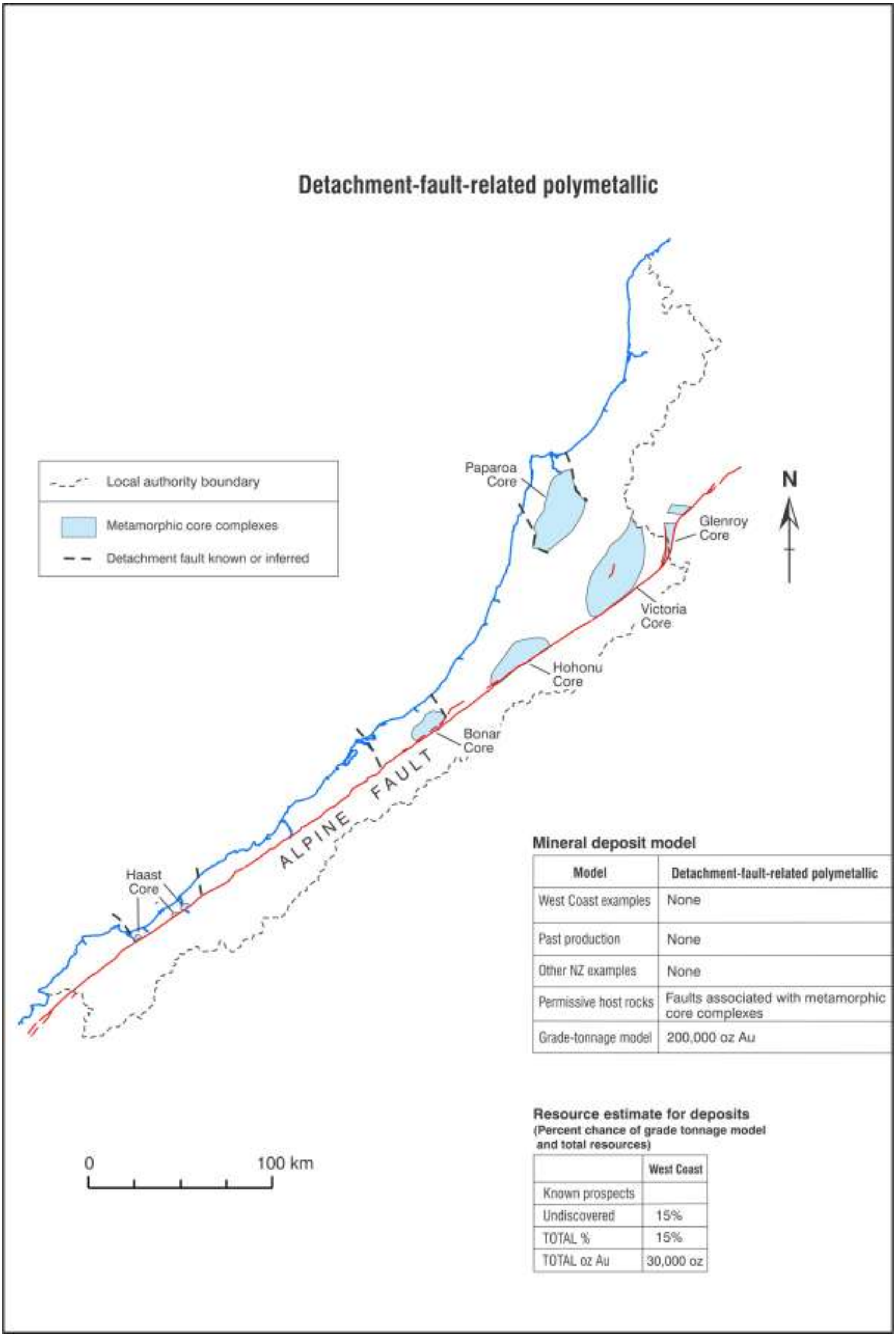


Figure 73 Location of metamorphic core complexes and detachment faults prospective for Detachment-fault-related polymetallic deposits.

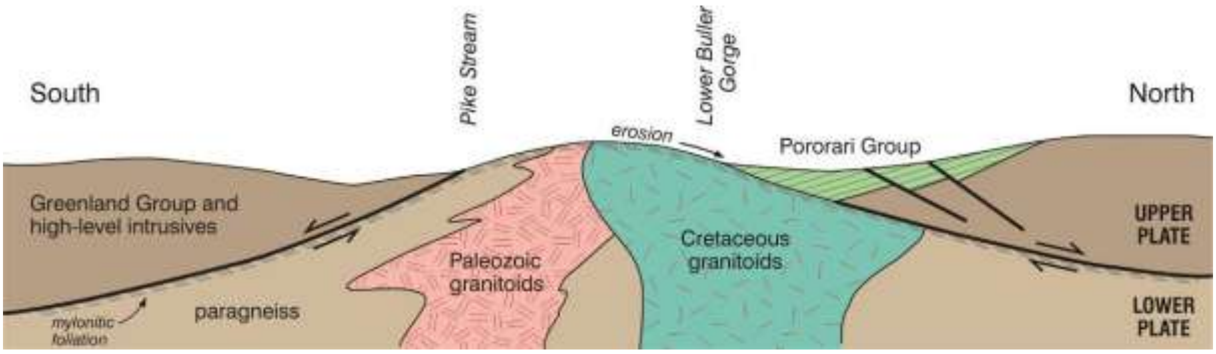


Figure 74 Diagrammatic cross section through the metamorphic core complex in the Paparoa Range. The lower plate was uplifted along shallow-dipping mylonitic detachment faults displacing the upper plate of early Paleozoic Greenland Group and some small granitoid intrusives. The extensional deformation also resulted in the formation of fault-bounded basins in the upper plate that were rapidly filled with Pororari Group terrestrial sediments derived from the eroding lower plate. (After Nathan et al. 2002, modified after Tulloch & Kimbrough 1989).

13.5.7 Placer Au (Figure 75-78)

International model

Reference

Onshore: USGS model 39a Placer Au-PGE (Cox & Singer 1986); BCGS model C01 Surficial placers (Lefebure & Ray 1995); BCGS model C02 Buried-channel placers (Lefebure & Ray 1995).

Offshore: BCGS model C03 Marine placers (Lefebure & Ray 1995).

Description

Onshore: Detrital gold grains and (rarely) nuggets in gravel, sand, silt, and clay, and their consolidated equivalents, in alluvial, beach ('blacksand leads'), and fluvioglacial deposits. Alluvial deposits typically formed as channel-lag and gravel-bar deposits, and beneath boulders, where gradients flatten and river velocities lessen. Winnowing action of surf caused gold concentrations in raised, present, and submerged beaches.

Offshore: Detrital gold and other heavy minerals occurring at the present or paleoseafloor surface. They usually occur in Holocene raised or submarine beach or strandline deposits along wave-dominated shorelines, but can also be found in coastal dunes, drowned fluvial channels, or as offshore relict lag concentrations.

International examples

Onshore: Sierra Nevada (California, USA), Victoria (Australia), Klondike (Yukon, Canada), Rio Tapajos (Brazil) and Yana-Kolyma belt (Russia).

Offshore: Nome, Alaska, USA; Bermagui, Australia; Country Harbour, Nova Scotia, Canada.

Grade-tonnage data

Onshore: Deposits are small to high tonnage (0.1 to 100 Mt), but low grade (0.05-5 g/t Au). Placer concentrations are highly variable both within and between individual deposits. Modern operations in the South Island typically mine deposits between 1000 and 60,000 oz Au (e.g. Manhire et al. 2006). We suggest a model size of 30,000 oz Au.

Offshore: Deposits are typically high tonnage (0.1 to 100 Mt), but low grade (0.05-0.25 g/t Au). For our assessment, we suggest a model for offshore deposits of 130,000 oz Au (e.g. 20 Mt at 0.2 g/t Au).

West Coast deposits

Tectonically induced rapid uplift in the late Cenozoic (the present rate is estimated at up to 12 mm/year) has resulted in the erosion of large volumes of gold-bearing source rocks; the quartz vein and disseminated gold deposits in the Greenland Group (Orogenic shear zone Au - Paleozoic deposits) and similar deposits in the Haast Schist east of the Alpine Fault (Orogenic Au - Mesozoic deposits and Orogenic Alpine Au - Cenozoic deposits). The gold has been concentrated into placer deposits through several glacial and interglacial cycles in the Pleistocene. Typically, the youngest deposits are the richest, because they have passed through several cycles of concentration. In addition to the gold found in the present and ancient river systems, gold has also been concentrated into beach placer deposits.

Figure 79 to Figure 88 illustrate some West Coast placer gold mining operations. From the discovery of gold in 1865 until 1980, the total production from Cenozoic placers in Westland was in excess of 200 t of gold. The exact figure is not known because of incomplete records for the many small-scale alluvial mining operations during and subsequent to the early gold rushes. A new gold mining boom occurred in the 1980s with the development of backhoe mining and portable gold recovery plants (Fricker 1984, 1989; Jury & Hancock 1989; Cotton & Rose 2006a, 2006b; Manhire et al. 2006), with about 140 operations at one time. This tapered off in the 1990s, but a new resurgence commenced in about 2009. In 2010 there were approximately 35 gold recovery plants in operation, in addition to the Grey River dredge (Figure 79 - Figure 80; Cotton & Birchfield 2006).

Alluvial placers

Alluvial placers are found in late Pleistocene fluvioglacial and Recent alluvial gravel, and to a much lesser extent in Pliocene Old Man Group gravels, overlying the Miocene-Pliocene Blue Bottom marine siltstone and mudstone, representing basement for the auriferous sediments (Jury & Hancock 1989; Suggate 1996). The gold was transported and concentrated into outwash deposits close to the terminal moraine fronts of successive glaciers. A succession of moraines and associated outwash surfaces are present and cyclic erosion and redeposition of previously deposited till and outwash gravels increased the concentration of gold. An especially favourable situation was where a sequence of ice advances terminated in the same area, with the ice or meltwater outflow from a younger advance breaking through the terminal moraine and proximal outwash of a previous advance, as at Kaniere and Rimu in the lower Hokitika valley (Suggate 1996). The largest Pleistocene placers were worked at Reefton, Dunganville, Marsden, Greenstone, Kumara, Goldsborough, Callaghans, Humphreys Gully, Kaniere, Rimu and Ross. Between Hokitika and Ross, and south of Ross, the glaciers advanced to a position west of the present day shoreline, and outwash gravels deposited during past lower sea levels are now offshore.

The present day river beds and floodplains have been extensively dredged and sluiced, especially in proximity to auriferous outwash deposits or downstream from lode-bearing Paleozoic rocks. The most extensive river bed placers are found along the Grey River and its tributaries, and in the lower valleys of the Taramakau, Arahura, and Hokitika rivers.

Beach placers

Beach placers are found in present day beaches, older postglacial beach deposits, and the raised beach deposits of successive marine interglacials which underlie the remnants of coastal terraces. Gold, along with ilmenite, magnetite, garnet, zircon, and other heavy minerals (Minehan 1989) is concentrated into lenticular beach placers known as 'blacksand leads'. Some leads contain gold-bearing sand layers with up to 10 g/m^3 in grade, although the gold is always very fine, in the size range of 0.01 to 0.1 mm (Douch 1988). The largest deposits on the West Coast were leads in Addisons Flat and adjacent terraces near Westport, in terraces near Charleston and Barrytown, the Hou Hou Lead and associated leads west of Kumara, the Lamplough Lead north of Hokitika, and leads near Okarito Lagoon and on Gillespies Beach. The older leads near Westport and Charleston were cemented and the material required crushing before processing. Dredges were used to work the Barrytown, Okarito Lagoon and Gillespies beach deposits during the 1930s-1940s. More recently, Westland Ilmenite (1991) estimated resources at Barrytown as 50 Mt of potentially mineable sand at an average grade of 100 mg/m^3 gold, 13.8% ilmenite, 0.2% zircon, and less than 0.1% each of monazite and rutile.

Placer gold mining 1865-1980

During the gold rush of 1865-1867 (gold production approximately 44,000 kg or 1.4 Moz) mining methods progressed through several stages:

Individuals panning and cradling in modern stream courses and on the beaches (black sanding).

Individuals and groups paddocking (small scale open pitting) and tunnelling the Pleistocene terrace deposits and subsequently washing the stockpiled gravels.

Groups paddocking and tunnelling cemented Pleistocene marine gravels with subsequent battery crushing before washing.

Groups “deep sinking” (shafting and tunnelling) deeply buried auriferous gravels with subsequent battery crushing before washing.

Groups hydraulic sluicing Pleistocene terrace deposits.

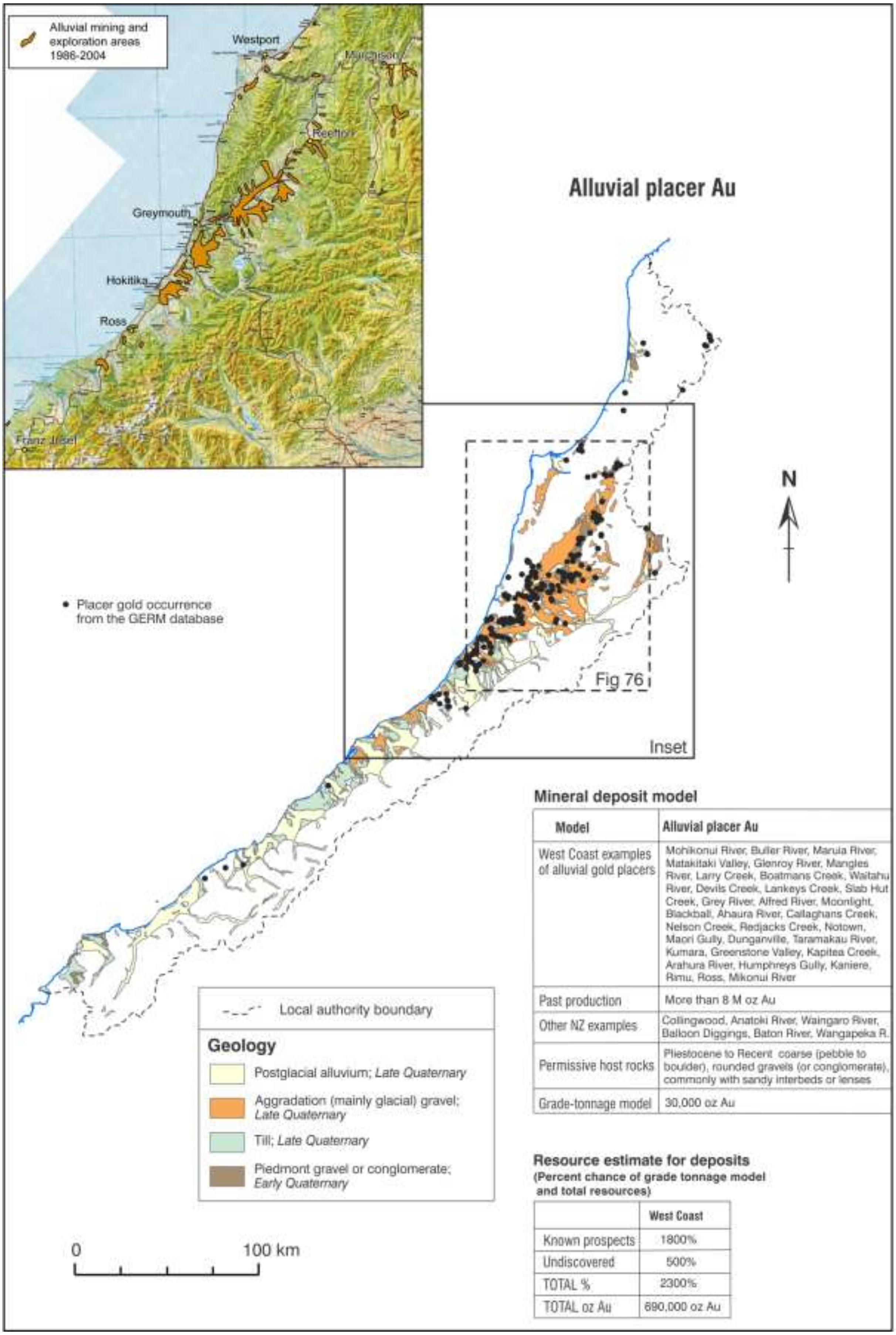
Towards the end of the gold rush, sluicing of terrace gravels became the most productive method of extraction and remained so until the introduction of large dredges in the 1930s.

Dredging operations on the West Coast occurred during two separate periods. Although the first dredge started operating around 1880, dredging did not become popular until around 1900. However, the first period, which produced approximately 700 kg (220,000 oz) of gold only lasted a few years, with most dredges ceasing operations before 1910. A second period of intense dredging activity started in the 1930’s, but waned in the 1940’s with a few stragglers carrying over into the 1950’s and one dredge, the Kaniere, continuing production until 1981 (Figure 79).

Approximately 46,000 kg (1.4 Moz) of gold were produced by dredges from the beginning of this second period until 1981. Few figures were recorded for gold recovery operations other than dredging (e.g. panning, cradling and sluicing), although they possibly amounted to some 160,000 kg (5 Moz) of gold. At least 100,000 kg (3 Moz) of gold must have been won by sluicing operations.

Placer gold mining 1980 – present

The increase in gold price in 1979-1980 fuelled the development of new mining technology consisting of hydraulic excavators feeding portable gold processing plants (Utting 1985; Fricker 1989; Cotton & Rose 2006a). About 75 percent of these plants were floated in ponds, whereas the remainder were skid mounted (Cotton & Rose 2006a). They enabled access to and efficient processing of small deposits, including many low grade and deep deposits. At its peak in 1989, there were about 140 of these plants in operation (Cotton & Rose 2006a). One of the most successful operators was L&M Mining Ltd who worked several areas in the Arahura (1987-2000; Figure 83 and Figure 86) and Mikonui (1992-1997) river valleys and the Rimu Channel at Hokitika (1987-1991; Figure 84 and Figure 85) (Manhire et al. 2006). A stacked series of nine gold-rich gravel horizons in the Jones Flat deposit at Ross was open pit mined between 1988 and 2004 (Cotton & Rose 2006b) (Figure 87 and Figure 88), and the Grey River bucket ladder dredge operated in the Grey River between 1992 and 2004 (Cotton & Birchfield 2006), and 2009-present (Figure 80 - Figure 82).



Mineral deposit model

Model	Alluvial placer Au
West Coast examples of alluvial gold placers	Mohikonui River, Buller River, Maruia River, Matakitaki Valley, Glenroy River, Mangles River, Larry Creek, Boatmans Creek, Waitahu River, Devils Creek, Lankeys Creek, Slab Hut Creek, Grey River, Alfred River, Moonlight, Blackball, Ahaura River, Callaghans Creek, Nelson Creek, Redjacks Creek, Notown, Maori Gully, Dunganville, Taramakau River, Kumara, Greenstone Valley, Kapitea Creek, Arahura River, Humphreys Gully, Kaniere, Rimu, Ross, Mikonui River
Past production	More than 8 M oz Au
Other NZ examples	Collingwood, Anatoki River, Waingaro River, Balloon Diggings, Baton River, Wangapeka R.
Permissive host rocks	Pliestocene to Recent coarse (pebble to boulder), rounded gravels (or conglomerate), commonly with sandy interbeds or lenses
Grade-tonnage model	30,000 oz Au

Resource estimate for deposits
(Percent chance of grade tonnage model and total resources)

	West Coast
Known prospects	1800%
Undiscovered	500%
TOTAL %	2300%
TOTAL oz Au	690,000 oz Au

Figure 75 Location of alluvial gold occurrences from the GERM database.

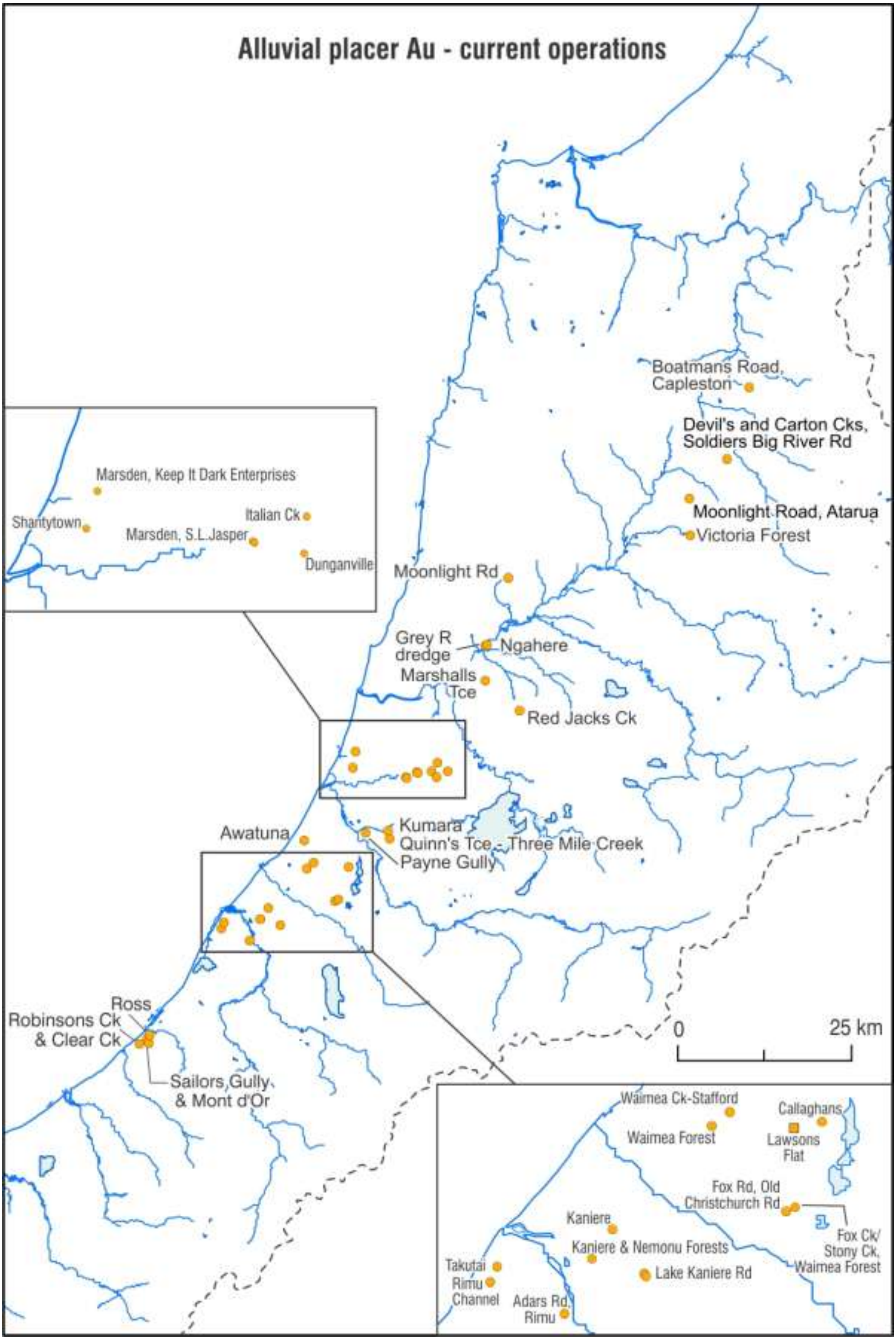
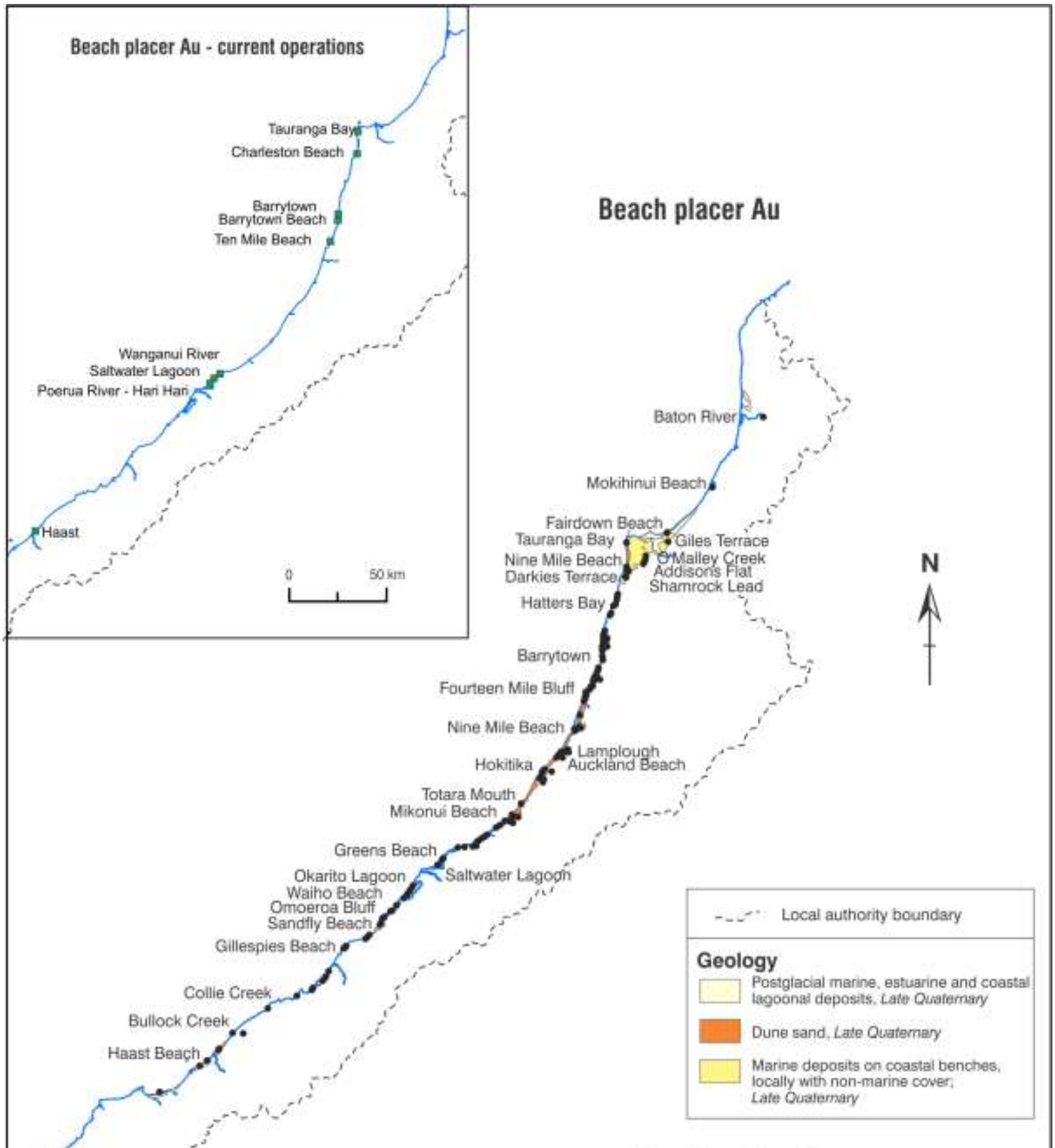


Figure 76 Locations of current alluvial gold mining.



Mineral deposit model

Model	Beach placer Au
Onshore West Coast examples	Fairdown-Northern, Addisons, Barrytown, North Beach (Greymouth), Darkies Terrace (Greymouth), South Beach (Greymouth), New River Lagoon, Lamplough Lead, Saltwater Beach, Okarito Lagoon, Five Mile Beach Okarito
Past production	Most West Coast beaches, Addisons, Darkies Terrace and Lamplough Lead
Other NZ examples	Porpoise Bay, Wallace Beach, Progress Valley Beach, Haldane Bay and Waipapa Beach in Southland
Permissive host rocks	Quaternary beach sands
Grade-tonnage model	30,000 oz Au

100 Mm^3 of sand grading 100-1000mg/m^3 for 20,000 kg (643,087 oz) Au (Jury & Hancock 1989)

Figure 77 Location of Beach placer gold occurrences from the GERM database. Inset map shows the locations of current operations.

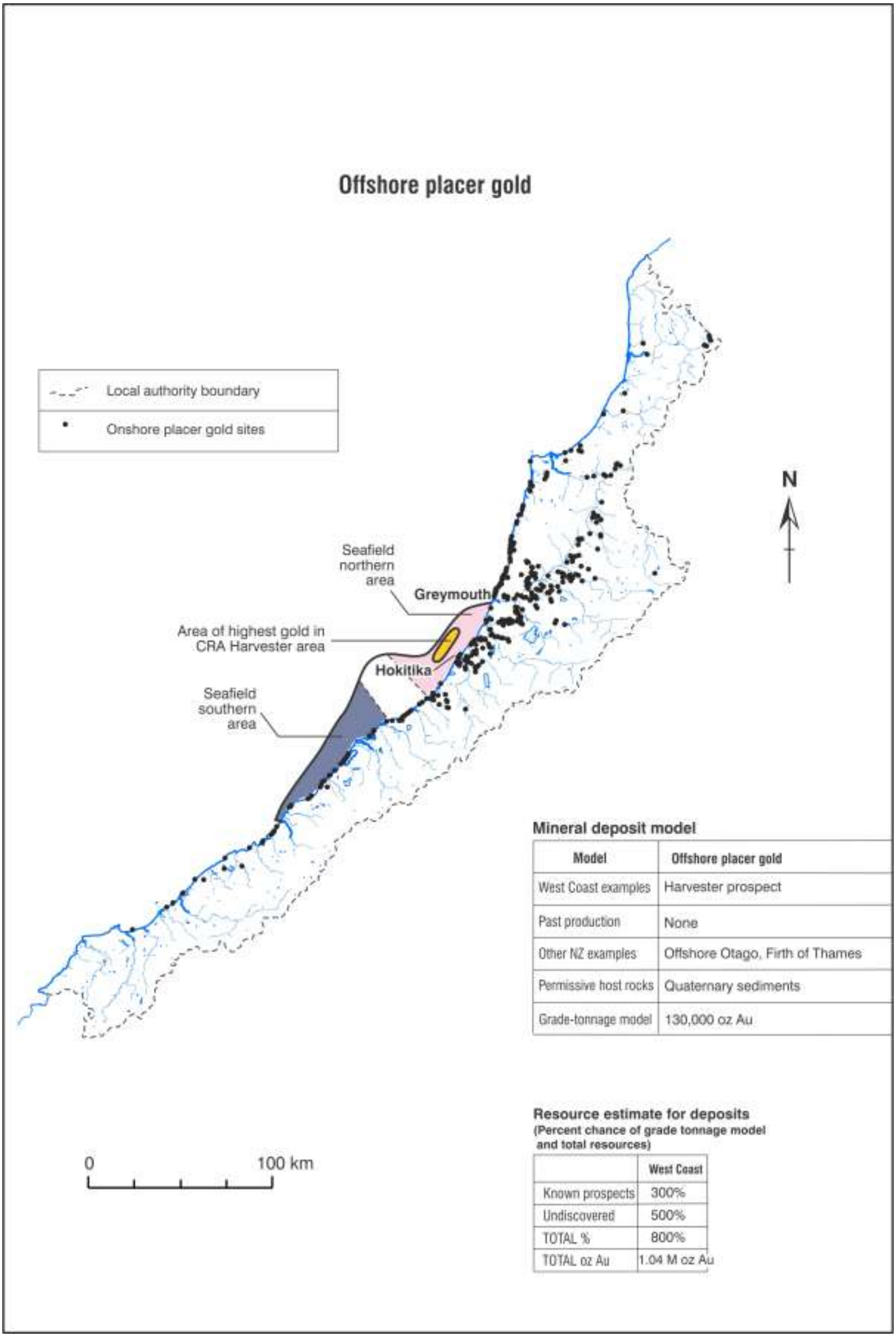


Figure 78 Location of offshore areas prospective for placer gold.

Figure 79 The Kaniere gold dredge working in the Taramakau River in 1980 (photo Tony Christie).

Figure 80 The Grey River gold dredge operated by Birchfield Minerals Ltd at Ngahere, with the Grey River beyond. The dredge is 150 m long from the front A frame to the end of the stacker and reaches 30 m above the water line. (Photo after Figure 1 of Cotton & Birchfield 2006).

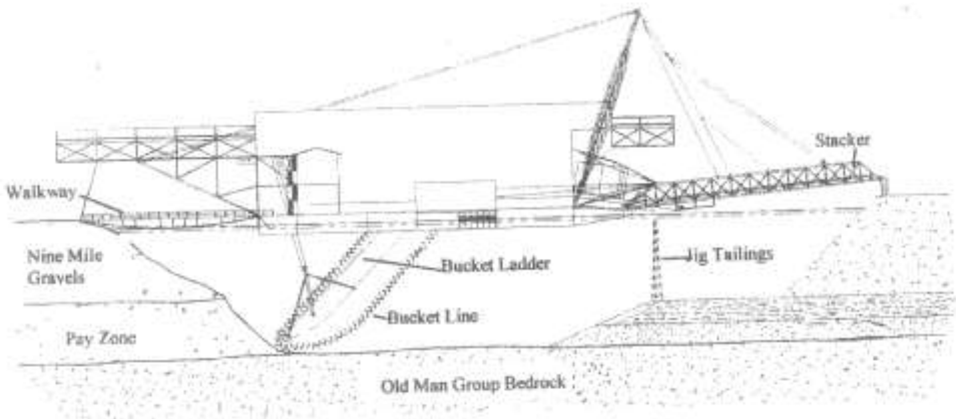


Figure 81 Schematic cross-section of the Grey River gold dredge (after Figure 5 of Cotton & Birchfield 2006).

Figure 82 The Grey River dredge at Ngahere, with the Grey River beyond (photo after Figure 3 of Cotton & Birchfield 2006).

Figure 83 DML Resources alluvial gold plant, Arahura Valley 1995 (Photo Eoin Jury).

Figure 84 L&M Mining Ltd's Rimu plant fed by a 180 tonne hydraulic excavator (photo after Figure 3 of Manhire et al. 2006).

Figure 85 L&M Mining Ltd's No. 6 Plant at Rimu. Gravels 5-22 m thick were fed to the 300 m^3/hour plant by a 180 tonne hydraulic excavator (photo c. 1995, Eoin Jury).

Figure 86 Restoration behind L&M Mining Ltd's No. 6 Plant (upper) and No. 2 Plant (lower) in the Arahura Valley. The No. 6 Plant is mining from left to right and the No. 2 Plant from right to left. Mined and restored ground is visible behind each plant. (Photo after Figure 5 of Manhire et al. 2006).

Figure 87 Jones Flat open pit gold mine (centre) in Quaternary alluvial gravels, apparently derived from Donnelly Creek (left) on the edge of Ross township. Deep leads or horizons of high gold values were worked underground beneath Ross township. The photograph was taken in 1995. Subsequently the pit was enlarged, and mining ceased in 2004. The quarry in the lower right is in limestone (GNS photos CN38487/22 and CN38488/23 composited, photographer Lloyd Homer).

Figure 88 Jones Flat open pit gold mine (see Figure 87). (Photo CN38934 Lloyd Homer).

Onshore exploration

A large number of companies carried out exploration drilling in the 1930s to identify resources to support the dredges, and from the early 1980s to find resources for the portable gold recovery plants. The latter period of exploration was reviewed by Cotton & Rose (2006a).

Offshore exploration

Four successive companies or groups have explored the West Coast offshore placer potential (Youngson 2006; Stevenson 2008):

1. In 1967, Alpine Geophysical Associates Inc (AGA 1968), under contract to Marine Mining Corporation, carried out extensive seismic (Sparker) surveys and some sampling.
2. In the early 1970s, Carpentaria Exploration Co Pty Ltd (Painter 1973c) explored two near-shore areas of South Westland, largely to assess potential offshore extensions to heavy mineral sands identified onshore.
3. In the 1980s, CRA Exploration Ltd (Price 1983a, 1983b; Price 1985, Price & Coles 1985; Wotherspoon 1989; Corner 1989) used the AGA seismic surveys as a basis for extensive grab sampling of surface sediments, and carried out vibro-coring programmes in an area offshore from the Arahura River ("Harvester Project"). They defined a c. 400,000 oz resource within this area, but considered the grade too low and abandoned the area.
4. From 2004, Seafield Resources, in joint venture with DeBeers, has carried out target development (Youngson 2006), offshore Chirp subbottom profiling (Stevenson 2006), onshore ground magnetic surveys of beaches (Kirkpatrick 2006), offshore aeromagnetic surveys (Kirkpatrick 2007), seismic surveys (Hargrave 2006) and echo sounding, swath bathymetry and marine magnetic surveys (Sedyn & Esterhuizen 2007). Exploration is ongoing including bottom coring and sampling (Fraser et al. 2010).

To date, the Seafield Resources exploration has defined two target areas referred to as the Northern target area and Southern target area (Figure 78). Stevenson (2008) noted that in the north, outwash systems are piedmont and more distal. The gold line (last glacial moraine front) is located onshore and in the northernmost area, is located furthest away from the coastline. The gold is introduced onto the shelf only during glacial periods. In the southern target area, gold is fed to the shelf by the Southern Alps hydrothermal system (Orogenic Alpine Au – Cenozoic deposits). This has supplied continuous gold to the coast during both glacial and interglacial periods. The gold line is situated offshore here (Figure 89). This area is dominated by valley glacial systems with strong lateral moraines and push moraines in shadow zones. In-between the valleys (shadow zones), gold is associated with proximal outwash facies, which have been reworked by marine shoreface erosion. Further inshore gold would be associated with marine reworking of the moraine.

The seismic data has provided information on the thicknesses, geometries, extents, inferred probable facies types and depositional environments of the different seismic stratigraphic units. Using this data, the extension of some geological features on the present day coastal plain have been mapped into the offshore environment.

Seabed sampling commenced in 2009, but results are currently confidential.

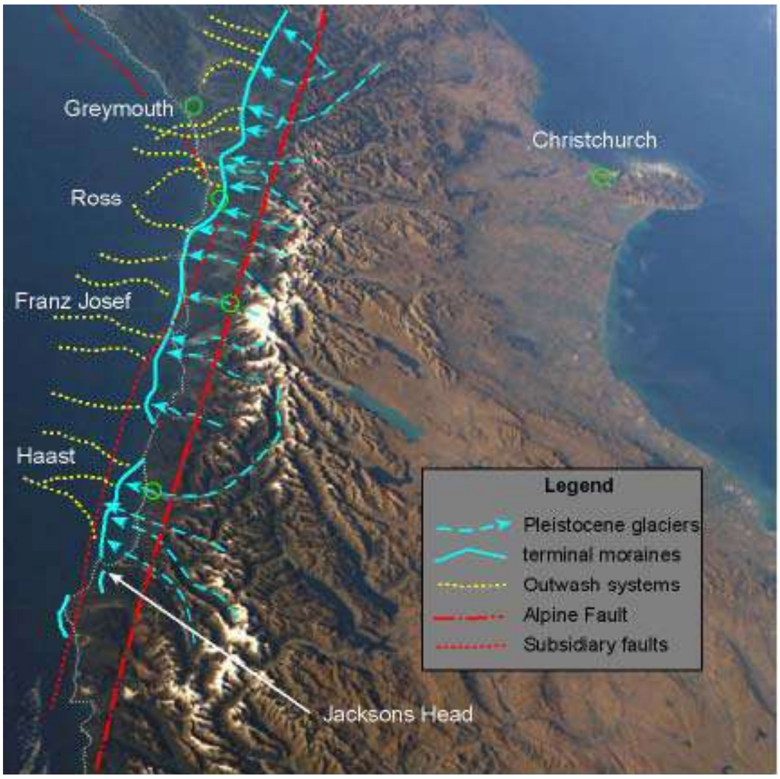


Figure 89 Schematic depiction of West Coast Late Pleistocene glaciers, terminal moraines and outwash systems after Youngson (2006). Note that the terminal moraines south of Ross lie mainly offshore.

Figure 90 The Marsol Pride, with Seafield Resources core sampling rig raised on the stern, moves to a new drilling site off the West Coast (photo courtesy of Seafield Resources).

Assessment

Onshore alluvial placers: Jury & Hancock (1989) estimated resources of 675,615 oz Au, comprising 407,765 oz Au in deep deposits and 267,850 oz Au in shallow deposits. However, combining figures from Cotton & Rose (2006a) and Crown Minerals statistics suggests that West Coast alluvial gold production between 1989 and 2009 was 701,668 oz, i.e. more than the resource estimates. Their estimates did not include undiscovered deposits. Based on our modelling method, we suggest an 2300% probability of resources equivalent to the model size of 30,000 oz Au, equating to an estimated resource of 690,000 oz Au.

Beach placers: Jury & Hancock (1989) estimated resources for the West Coast beach placers as a volume of 100 M m^3 of sand grading 100-1000 mg/m^3 and containing 20,000 kg (643,087 oz) Au.

Offshore placers: We suggest a 800% probability of resources equivalent to the model size of 130,000 oz Au, equating to an estimated resource of 1,040,000 oz Au.

13.6 MOLYBDENUM

13.6.1 Porphyry Mo (Figure 91)

International model

References

USGS model 21b Porphyry Mo, low-F (Cox & Singer 1986); BCGS model L05 Porphyry Mo (low-F-type) (Lefebure & Ray 1995).

Description

Stockwork of molybdenite-bearing quartz veinlets and fractures in granitic rocks and associated country rocks, mostly the Aorere and Greenland groups. Deposits are low grade but large and amenable to bulk mining methods.

International examples

Endako and Boss Mountain (British Columbia, Canada); Red Mountain (Yukon, Canada), Quartz Hill (Alaska, USA), Cannivan (Montana, USA), Thompson Creek (Idaho, USA), Compaccha (Peru), East Kounrad (Russia), and Jinduicheng (China).

Grade and tonnage

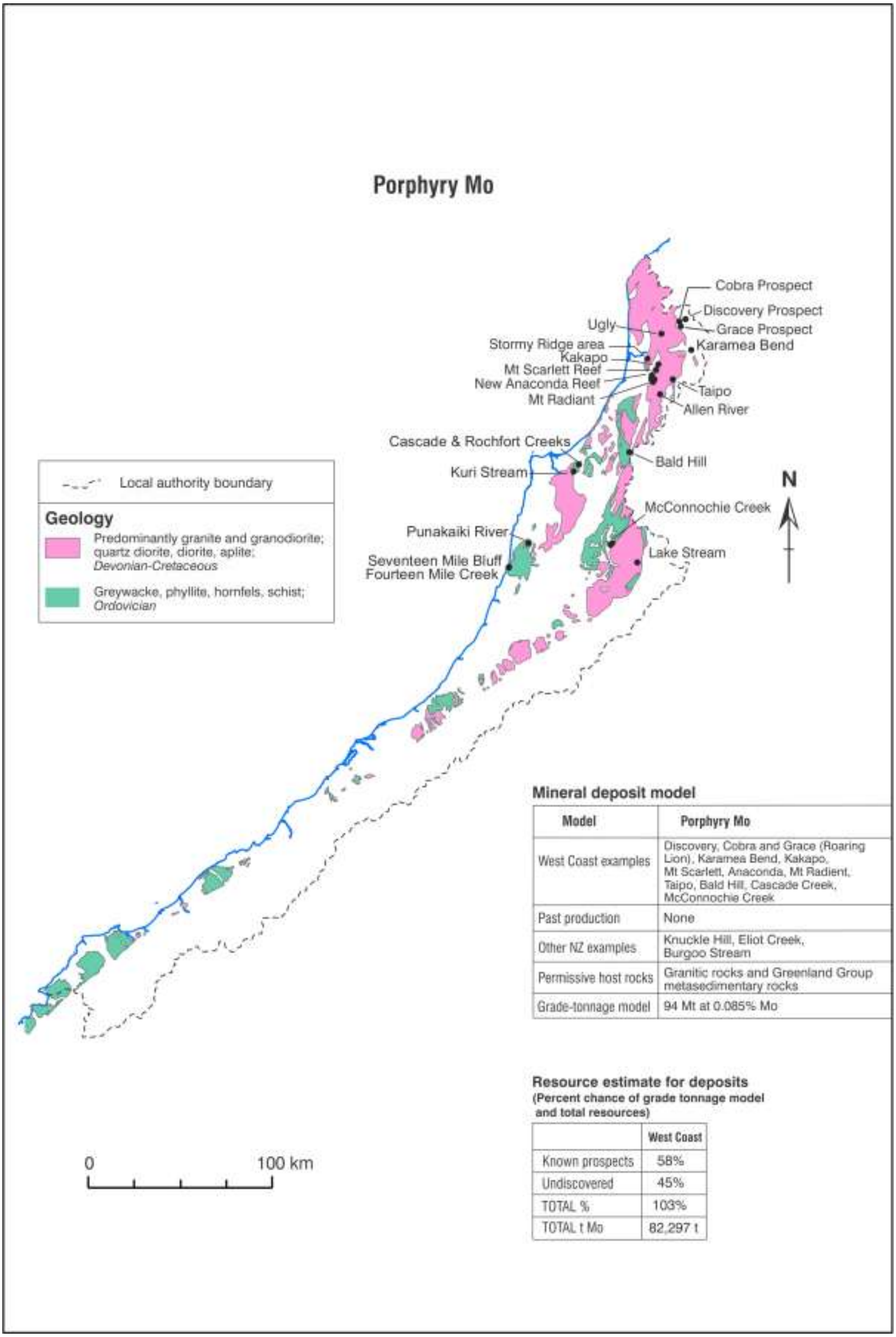
Typical size is 100 Mt at 0.1 to 0.2 % Mo. The grade tonnage model is 94 Mt at 0.085% Mo.

West Coast deposits

Several porphyry molybdenum deposits were explored from the 1960s to early 1980s (Figure 92). They are genetically related to the emplacement of Late Cretaceous I-type Separation suite granitoids into the S-type granites of the Karamea Batholith or the nearby quartzose sedimentary rocks of the Aorere Group (Eggers & Adams 1979). Most of the deposits are hosted by the sediments or intruded satellite stocks, but some (e.g. Taipo Spur; M28/e502) occur within the Karamea Batholith. Mineralisation typically occurs as molybdenite paint or disseminations in joint-controlled quartz vein stockworks. Accessory minerals include minor pyrite, chalcopyrite and pyrrhotite, and rare galena, sphalerite, and bismuth sulphosalts (Rabone 1989b).

The geochemistry of the molybdenum-bearing granitoids is characterised by low K_2O, Rb, and F, and high Sr and Ti, confirming the classification of the deposits as porphyry molybdenum rather than Climax type (Tulloch & Rabone 1993).

Many of the porphyry molybdenum deposits have associated Cu and Mo anomalies in stream sediments (Figure 13 and Figure 17).



Model	Porphyry Mo
West Coast examples	Discovery, Cobra and Grace (Roaring Lion), Karamea Bend, Kakapo, Mt Scarlett, Anaconda, Mt Radient, Taipo, Bald Hill, Cascade Creek, McConnochie Creek
Past production	None
Other NZ examples	Knuckle Hill, Eliot Creek, Burgoo Stream
Permissive host rocks	Granitic rocks and Greenland Group metasedimentary rocks
Grade-tonnage model	94 Mt at 0.085% Mo

	West Coast
Known prospects	58%
Undiscovered	45%
TOTAL %	103%
TOTAL t Mo	82,297 t

Figure 91 Location of molybdenum occurrences from the GERM database, and areas of rocks prospective for Porphyry Mo deposits.

Roaring Lion: On the Roaring Lion River, just to the east of the Karamea Batholith, stockworks of quartz-orthoclase-molybdenite veins occur in metasedimentary rocks in three separate areas - the Discovery, Cobra and Grace prospects - discovered by Kennecott geologists in 1971 and 1972 (Foster 1971b; Turbott 1972a, 1972b, 1972c; Hay 1980a, 1981). The country rocks of Ordovician sandstone, siltstone and quartzite of the Aorere Group are hornfelsed and intruded by small stocks of fine grained granodiorite. The quartz veining is controlled by pre-mineral joint sets, probably related to regional folding.

Discovery Prospect (M26/e516) covers an area of 1.5 km x 1 km (defined by the 10 ppm Mo in rock isopleth) within a larger area of low topography and few exposures (Walker 1982). Molybdenum assays range from 2 to 474 ppm Mo, but there is "no obvious centre or target" (Roberts 1989). Molybdenite and pyrite are present in quartz veins.

At Cobra (M26/e515), the 10 ppm Mo in rock isopleth defines an area of 1 km x 0.9 km. The best stockwork veining is on Cobra Face (Figure 92), a quartzite dip slope where areas of 10% veining are common. Individual veins range up to 30 cm thick, but generally they are less than 1.25 cm thick (Foster 1971b). Molybdenite is accompanied by minor pyrite and rare chalcopyrite, with local traces of galena, sphalerite, magnetite and pyrrhotite. Three diamond drillholes totalling 820 m were drilled by Amoco and BP into the metasediments at Cobra, but failed to intercept intrusive rocks (Hay 1980b; Christie 1982; Roberts 1983). They yielded a best assay result of 790 ppm Mo over 5 m.

At Grace prospect (M27/e514), the 10 ppm Mo in rock isopleth defines an area of 1 km x 1 km in the head of Grace Creek. Chalcopyrite, molybdenite and pyrite are present in 30-70 cm thick pegmatite veins, and in a weakly developed quartz vein stockwork (Foster 1971b). Stibnite was reported in one quartz vein. Rock samples returned assays up to 500 ppm Mo and 800 ppm Cu, but values were distributed erratically. "No centre of anomalous geochemistry or attendant hydrothermal alteration has been established" (Roberts 1989).

Figure 92 Cobra face (photo Franco Pirajno).

Karamea Bend (M27/e513): Also known as Big Bend, this prospect is located on the Karamea River, and was discovered by sighting a large colour anomaly formed from oxidation of sulphides in slip faces (Smale 1976; Figure 93). The mineralisation lies east of the main Karamea Batholith, and is related to the intrusion of stocks of fine-grained porphyritic granodiorites, monzonites, and diorites into Ordovician quartz-sericite schist and meta-argillite of the Roaring Lion Formation. Five separate stocks or dikes are known, and biotites from two of the stocks were dated by K-Ar at 100 ± 3 Ma, in contrast to a biotite K-Ar age of 290 ± 8 Ma in the main Karamea Batholith, 2 km west of Questa Creek (Smale 1976). Within the prospect, six anomalous zones (>100 ppm Mo) occur in a 3 km by 0.5 km strip across Questa and Sunday creeks. Molybdenite occurs in quartz-orthoclase-pyrite veins forming a stockwork in metasedimentary rocks, as disseminations adjacent to quartz veins in quartz-orthoclase altered monzonite on the margin of a porphyritic granodiorite stock in Sunday Creek, and as smears in late-stage joints (Ballantyne et al. 1971; Smale 1976; Rabone 1977; Hay 1979, 1980b, 1980c). Veins containing base metal assemblages - sphalerite, chalcopyrite, tennantite, galena, pyrrhotite and bismuth minerals - are peripheral to the centres of molybdenum mineralisation (Rabone 1977, 1989a). Alteration zones are fracture and vein controlled, with peripheral chlorite alteration succeeded by biotite, and passing into the molybdenite-bearing quartz-sericite and quartz-orthoclase veins.

Kennecott drilled two diamond drillholes (539.5 m and 344.4 m) in the head of Questa Creek, and a third hole (abandoned at 112.8 m) in Sunday Creek. Assays were up to 300 ppm Mo (Ballantyne et al. 1971). Amoco drilled two shallow Winkie holes, and a 520.4 m diamond drillhole in the headwaters of Questa Creek (Hay 1979, 1980b). The two Winkie holes assayed 162 ppm MoS_2 over 61 m and 165 ppm MoS_2 over 52 m, and the diamond hole averaged 54 ppm Mo over the 434 m of metasediments lying below 90 m of Tertiary cover.

Figure 93 Karamea Big bend molybdenum prospect exhibiting a colour anomaly caused by oxidised hydrothermal iron sulphide minerals (photo Tony Christie).

Kakapo (M27/e509): This prospect is located by the Kakapo River, a southern tributary of the Karamea River, and lies on the western margin of the Karamea Batholith. The mineralisation and alteration are generally confined to a 2.5 km by 1.2 km stock of fine- to medium-grained quartz monzonite, granodiorite and quartz diorite which intrudes the medium- to coarse-grained granite of the Karamea Suite (Stevens 1981a). The stock is intruded by pre-mineral quartz diorite and quartz latite dikes, and post-mineral lamprophyre dikes. The 10 ppm Mo in rock isopleth defines an area of 1.5 km x 1 km, whereas the strongest molybdenum mineralisation covers an area of 0.9 km by 0.4 km outlined by the 30 ppm Mo isopleth, approximately coincident with a phyllic alteration zone containing the strongest pyrite mineralisation. The phyllic alteration zone grades outward to a propylitic alteration zone extending over an area of 3 km by 1.5 km. Assays of up to 1119 ppm Mo were obtained by Amoco from quartz-veined and quartz-sericite altered granitoid rocks. Stevens (1981a) considered that the mineralising intrusive does not crop out.

Mount Radiant (L28/e505), Anaconda (L27/e506) and Mt Scarlett (L27/e503): These prospects are located on the western side of the Karamea Batholith, 20 km to the southeast of Karamea, and south of the Little Wanganui River. Molybdenum and/or copper mineralisation is present in 22 separate lenticular quartz lodes and areas of quartz vein stockworks on the eastern side of Mt Radiant and north near Mt Anaconda to Mt Scarlett. Most of the lodes strike NNE, but a few strike northwest. The mineralisation is associated with the intrusion of alkali porphyritic granites, granodiorites and pegmatite veins into older gneisses and coarse-grained granites of the Karamea Suite, and into a roof pendant of hornfels and schistose metasediments (Webb 1910; Wodzicki 1960). The main lodes are the Mt Radiant Reef, exposed in Silver Creek, and the New Anaconda Reef in Specimen Creek, each consisting of a series of parallel quartz veins with intervening country rock in lode zones 30 m and 7.6 m wide respectively. The veins contain quartz, K-feldspar, chalcopyrite, molybdenite, pyrite, tetrahedrite, bornite and bismuth minerals (Rabone 1989a). Some lodes also contain minor gold and silver (Webb 1910; Williams & Sanderson 1959). Wall rock alteration to quartz, sericite and chlorite is localised along vein margins; areas of widespread hydrothermal alteration have not been recognised (Wodzicki 1960; Maxwell 1975a; Hay 1980d). The Mt Radiant Reef was discovered in 1904, and most of the other quartz lodes in the area had been located by 1910. Underground workings were driven on the Mt Radiant Reef in 1914-15, but there is no record of ore production. Amoco drilled two shallow Winkie holes into Mt Radiant and obtained averages of 0.11% MoS_2 over the 16.5 m depth of one hole and 0.04% MoS_2 over the 19 m depth of the other hole (Hay 1980d).

Taipo Spur (M28/e502): Stockwork molybdenum mineralisation was first recognised on the steep-sided ridge between Taipo River-Karamea River and Kendal Creek by Asarco in 1967 (Fletcher 1968; Figure 94). The prospect is located on the eastern side of the Karamea Batholith, and is notable for being the only molybdenite occurrence well within the Karamea Batholith and showing no obvious relationship to the low grade metasedimentary country rocks. Also, it is one of the largest molybdenum prospects in New Zealand, with molybdenum mineralisation identified over an area of 2.7 km x 1.5 km (Maxwell 1974; Stevens 1981b). The 10 ppm Mo in rock isopleth covers an area of 2 km x 0.9 km. The mineralisation is hosted in Taipo Granite, a porphyritic granodiorite of Cretaceous age (K-Ar dated at 102-107 Ma) which intrudes the Luna Granite, a potassic granite of the Karamea Suite (Rabone 1977, 1989b). The Taipo Granite is cut by geochemically similar porphyry dikes. Hydrothermal alteration shows a poorly defined zonal pattern, with a central potassic zone consisting of a barren biotite subzone and outer epidote subzone, succeeded by an outer muscovite phyllic zone within weakly propylitised granite. The strongest molybdenum mineralisation is in shear-controlled quartz-sericite-pyrite alteration zones and quartz vein stockworks.

Molybdenite is accompanied by pyrite, magnetite and minor chalcopyrite, with rare rutile, hematite, cubanite, pyrrhotite and sphalerite. The mineralisation is associated with, and enclosed by, quartz-epidote-K feldspar or quartz-sericite-albite alteration envelopes in chlorite-sericite altered granite.

The site has been the subject of considerable exploration, with programmes by Asarco (Fletcher 1968), Kennecott (Foster 1971b), Cities Services (Maxwell 1974, 1975b, 1975c), Amoco (Ballantyne & Hay 1980), and Amoco/BP (Stevens 1981b). Four holes were drilled by Cities Services in the strongly mineralised part of this zone to a maximum downhole depth of 245 m and totalling 953.8 m. These showed average grades of 50-70 ppm Mo, with a maximum grade of 4400 ppm over 1.1 m (Maxwell 1975b, 1975c).

Figure 94 Taipo Spur molybdenum prospect exhibits a strong colour anomaly and has prominent topographic expression as a long ridge between Kendall Creek (right) and the Karamea and Taipo rivers (left foreground and left distance respectively) (GNS photo CN26329/5, photographer Lloyd Homer).

Bald Hill (L29/e142): In the headwaters of Lyell Stream, upper Buller Gorge, high level granodiorite porphyry stocks of Lyell Porphyry intrude Greenland Group greywacke and argillite, and Bald Hill granites of the western margin of the Karamea Batholith (Eggers 1978; Bates 1989; Eggers & Adams 1979). The porphyry forms a series of small high-level plutons and crosscutting dikes of quartz trondhjemite porphyry, granodiorite, quartz diorite, lamprophyre, and quartz-bearing gabbro porphyry. K-Ar ages of 112-116 Ma were obtained from Lyell Porphyry by Eggers & Adams (1979). A zone of porphyries and hornfels, approximately 2.5 km long and 0.7 km wide, contains a stockwork of quartz veins, individually up to 20 mm thick, carrying molybdenite, pyrite and chalcopyrite, with minor magnetite and bismuthinite. Significant amounts of sulphide are also related to metasomatic alteration in the sediments, and occur as disseminated mineralisation within the Lyell Porphyry. Composite rock chip samples collected over 5 m intervals yielded maximum values of 402 ppm, and selected samples gave assays of 0.01 to 0.18% Mo.

Cascade Creek (K29/e74): Lime & Marble Ltd located copper and molybdenum mineralisation in the Cascade Creek area of the Buller Gorge in the late 1950s (Braithwaite 1959a). Subsequent exploration was carried out by McIntyre Mines (in 1969), CRA (in 1971), Otter Exploration Ltd (during 1972-3), Gold Mines (NZ) Ltd (in 1976), and BP Minerals (in 1981). Greywacke and argillite of the Greenland Group are intruded and locally hornfelsed by plutons of medium-coarse grained, pink quartz-feldspar porphyries of Buckland Granite, and by granodiorite and hyalodacite (chilled marginal phase) of the Berlins Porphyry. Basic dikes are also present in the area (Nathan 1978b). The mineralisation was explored as a porphyry molybdenum prospect, however Tulloch (1988b) suggested that it may be related to hydrothermal fluid movement along a detachment fault (Ohika Fault).

An area of propylitic alteration, 150-200 m wide and 800-1000 m long, is present mainly in Buckland Granite, but extends into Berlins Porphyry and hornfelsed Greenland Group greywacke. Bailey (1973) identified four zones, with a quartz-orthoclase core being succeeded outwards by kaolinite-sericite-quartz, kaolinite-quartz-carbonate, and kaolinite-quartz-carbonate-sericite-albite assemblages. Pyrite is disseminated in the granitoids and metasedimentary rocks, and also occurs in quartz-sericite veins up to 2 cm thick. Sulphide phases consist of pyrite, molybdenite, and minor chalcopyrite, pyrrhotite and bornite. Pyrite is typically 1-5% by volume, but locally may reach 10% (Bates 1978).

The Berlins Porphyry, and thus probably the mineralisation, has been dated at about 110 Ma (Eggers & Adams 1979).

Kuri Stream (Quartz Creek; K29/e73): Greenland Group schistose metasedimentary rocks host quartz veins containing chalcopyrite, pyrite, and molybdenite, and accessory sphalerite, covellite, chlorite, and muscovite. There are also rare fluorite veinlets. The veins are related to nearby granodiorite stocks (Braithwaite 1959b; Leach 1976; Walker 1981). In the upper Kehu Stream, veins (typically 6 to 20 cm thick) may form 10 to 25% of the rock volume. Stream sediment sampling by AHI Ltd (Leach 1976) defined localised Mo (>10 ppm), Cu (>60), and F (>1500) anomalies, but results from later rock sampling by BP Minerals were not encouraging, with values of 4-7 ppm Mo, 15-75 ppm Cu, and 100-480 ppm F (Walker 1981).

Assessment

We suggest a 103% probability of resources equivalent to the model size, equating to an estimated resource of 82,297 t Mo.

13.7 NICKEL

13.7.1 Dunitic Ni-Cu (Figure 95)

International model

References

USGS model 6b Dunitic Ni-Cu (Cox & Singer 1986); USGS model 7a Synorogenic-synvolcanic nickel-copper (Cox & Singer 1986).

Description

Disseminated sulphide mineralisation in mafic intrusive rocks.

International examples

Agnew (Perserverance) and Mt Keith in Western Australia

Grade and tonnage

USGS model 6b 50th percentile = 29 Mt at 1% Ni and 0.14% Cu

West Coast deposits

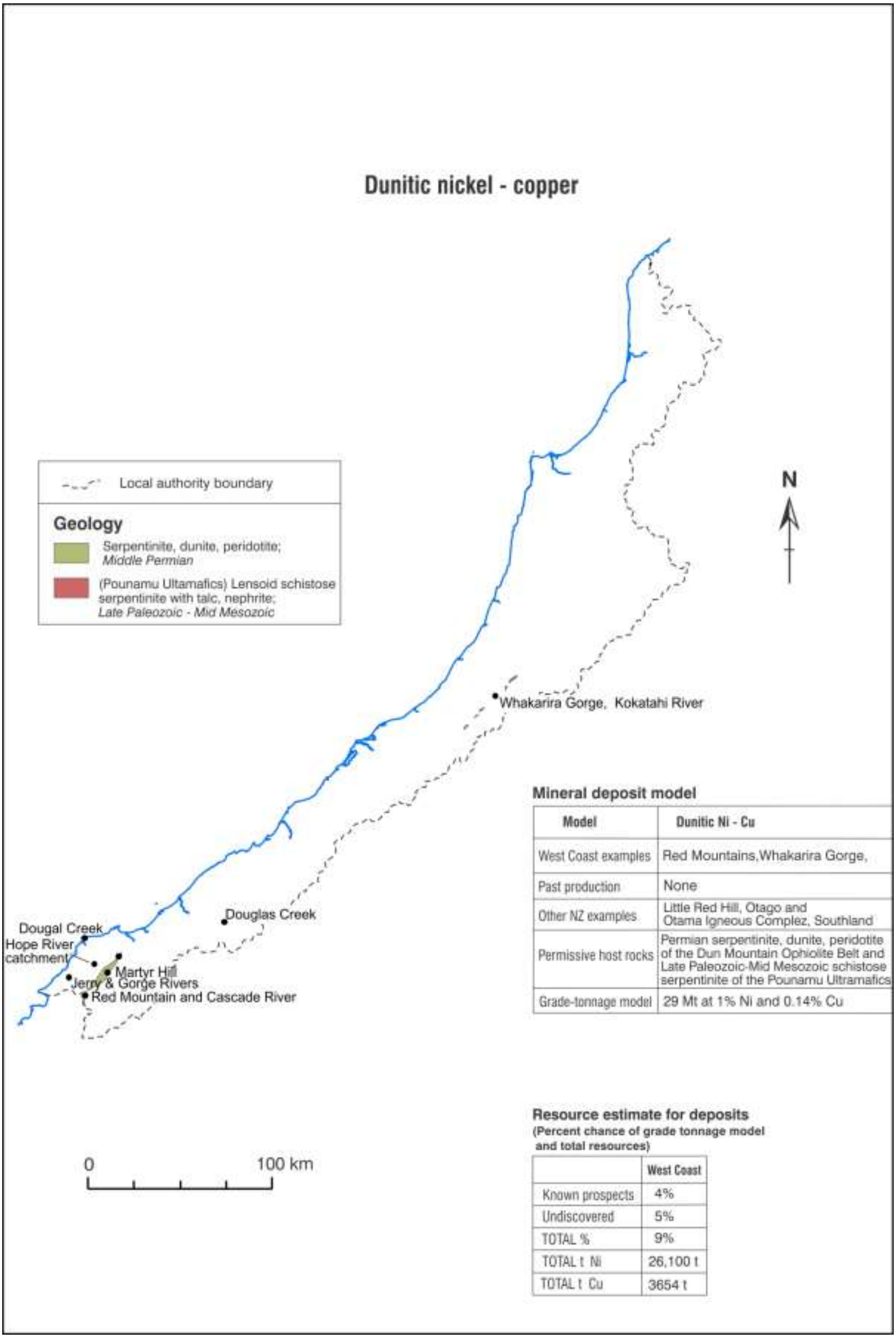
Westland: Boulders of nephritic material containing nickel mineralisation have been found in Douglas Creek (Williams 1974). In-situ mineralisation is present in the Pounamu Ultramafics as stratabound bands in Whakarira Gorge, on the Kokatahi River (J33/e85), and sporadically elsewhere as minor pyrrhotite-pentlandite-chalcopyrite, along with magnetite and chromite, disseminated in serpentinite (MacKenzie 1984). The Pounamu Ultramafics and adjacent Haast Schists were prospected by Kennecott and CRA (MacKenzie 1984), and anomalous nickel values were found associated with serpentinite margin metasomatism, where nickel has been depleted from serpentinite margins and enriched in marginal schists (MacKenzie 1984).

Red Hills Range, South Westland: On the western side of Red Mountain and Little Red Hill (north Otago), bands of pentlandite-pyrrhotite-chalcopyrite mineralisation are present in sheared serpentinites at the contact with late Paleozoic volcanic rocks. The Red Mountain occurrence consists of three bands, 0.6 m thick and up to 1 m apart, traceable for 30 m along a strike of 030^{o} (Mutch 1965). At the northern end of the Red Hills Range, awaruite is found in dunite-peridotite blocky serpentinite masses containing 0.1-0.5% Ni. Placer deposits of awaruite and native nickel are found in the Gorge and Jerry rivers (Mutch 1965; Challis 1975; E38/e5). Nickel Spoon Mining Company carried out geochemical surveys in the area and obtained values between 40 and 1900 ppm Ni for stream sediment samples, and between 65 and 3010 ppm for soil and rock samples (Happy et al. 1970; Rowlands et al. 1970; Hurst 1971).

Stream sediment samples collected from the Gorge and Jerry rivers area exhibits strong Ni anomalies in stream sediment geochemistry (Figure 16).

Assessment

We suggest a 9% probability of resources equivalent to the model size, equating to an estimated resource of 26,100 t Ni and 3654 t Cu.



Mineral deposit model

Model	Dunitic Ni - Cu
West Coast examples	Red Mountains, Whakarira Gorge,
Past production	None
Other NZ examples	Little Red Hill, Otago and Otama Igneous Complez, Southland
Permissive host rocks	Permian serpentinite, dunite, peridotite of the Dun Mountain Ophiolite Belt and Late Paleozoic-Mid Mesozoic schistose serpentinite of the Pounamu Ultramafics
Grade-tonnage model	29 Mt at 1% Ni and 0.14% Cu

Resource estimate for deposits
(Percent chance of grade tonnage model and total resources)

	West Coast
Known prospects	4%
Undiscovered	5%
TOTAL %	9%
TOTAL t Ni	26,100 t
TOTAL t Cu	3654 t

Figure 95 Location of nickel occurrences from the GERM database, and areas of rocks prospective for Dunitic Ni deposits.

13.8 PLATINUM

13.8.1 Alaskan type Pt (Figure 96)

International model

References

USGS model 9 Alaskan PGE (Cox & Singer 1986) and BCGS model M05 Alaskan-type Pt±Os±Rh±Ir (Lefebure & Höy 1996).

Description

Ultramafic intrusive complexes, commonly zoned, forming sills, stocks or intrusive bodies with poorly known external geometry. Subeconomic platinum group elements in lode occurrences are associated with: 1) thin (centimetre-scale), disrupted chromitite layers , 2) thick (metre-scale) concentrations of cumulus magnetite or 3) clinopyroxenite. Economic placer deposits appear to be derived predominantly from chromitite-hosted PGE occurrences.

Lode occurrences of PGEs are primarily controlled by magmatic cumulate stratigraphy: 1) chromitites are restricted to dunites where they form thin discontinuous layers or schlieren, pods and nodular masses seldom more than a metre in length; 2) magnetitites and concentrations of cumulus magnetite form well bedded, locally continuous layers up to six m thick intercalated with hornblende clinopyroxenite; 3) lenses and vein-like bodies of relatively coarse-grained or "pegmatoid", biotite and magnetite-poor, PGE-bearing clinopyroxenites are enclosed by finer grained, biotite and magnetite-rich, PGE-poor clinopyroxenites.

International examples

Red Mountain, Goodnews Bay, Alaska, USA; Tin Cup Peak, Oregon, USA; Ural Mountains and Aldan Shield, Russia; Fifield district, NSW, Australia.

Grade and tonnage

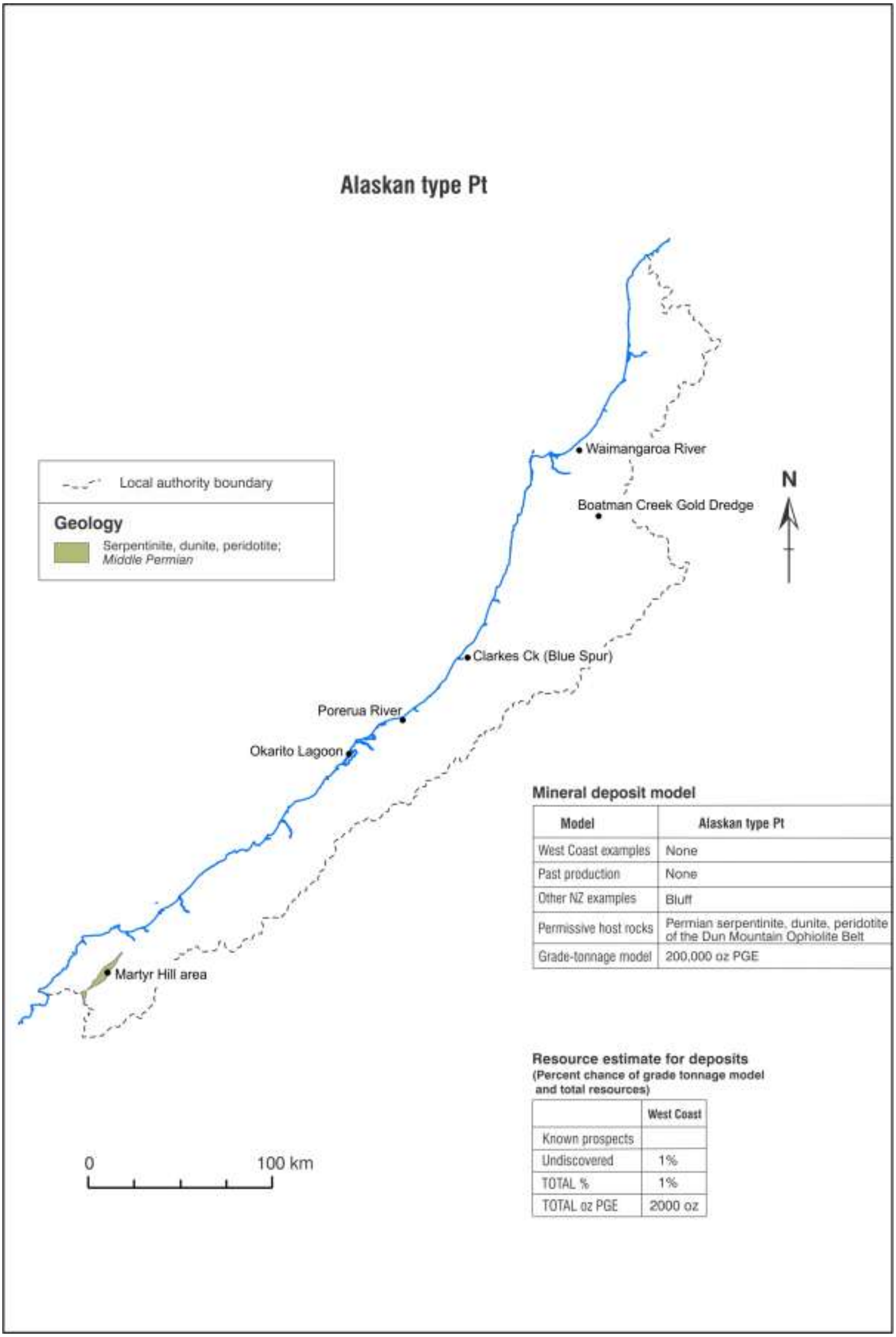
We have assigned a model size of 200,000 oz of platinum group elements (PGE).

West Coast deposits

No examples are known from the West Coast region, but their presence is suggested by the occurrence of platinum group minerals in river gravels worked for gold in Boatmans Creek (L36/e248) near Reefton (Officers of the New Zealand Geological Survey 1970a).

Assessment

We suggest a 1% probability of resources equivalent to the model size, equating to an estimated resource of 2000 oz PGE.



Mineral deposit model

Model	Alaskan type Pt
West Coast examples	None
Past production	None
Other NZ examples	Bluff
Permissive host rocks	Permian serpentinite, dunite, peridotite of the Dun Mountain Ophiolite Belt
Grade-tonnage model	200,000 oz PGE

Resource estimate for deposits
(Percent chance of grade tonnage model and total resources)

	West Coast
Known prospects	
Undiscovered	1%
TOTAL %	1%
TOTAL oz PGE	2000 oz

Figure 96 Location of rocks prospective for Alaskan type Pt deposits, along with detrital platinum occurrences from the GERM database.

13.9 RARE EARTH ELEMENTS

13.9.1 Carbonatite-hosted REE (Figure 97)

International model

References

USGS model 10 Carbonatite deposits (Cox & Singer 1986) and BCGS model N01 Carbonatite-hosted deposits (Simandi et al. 1999).

Description

Magmatic and metasomatic rare earth element mineralisations are found associated with some carbonatite and alkaline igneous intrusives.

International examples

Bayan Obo, Inner Mongolia, China; Mountain Pass, California, USA.

Grade and tonnage

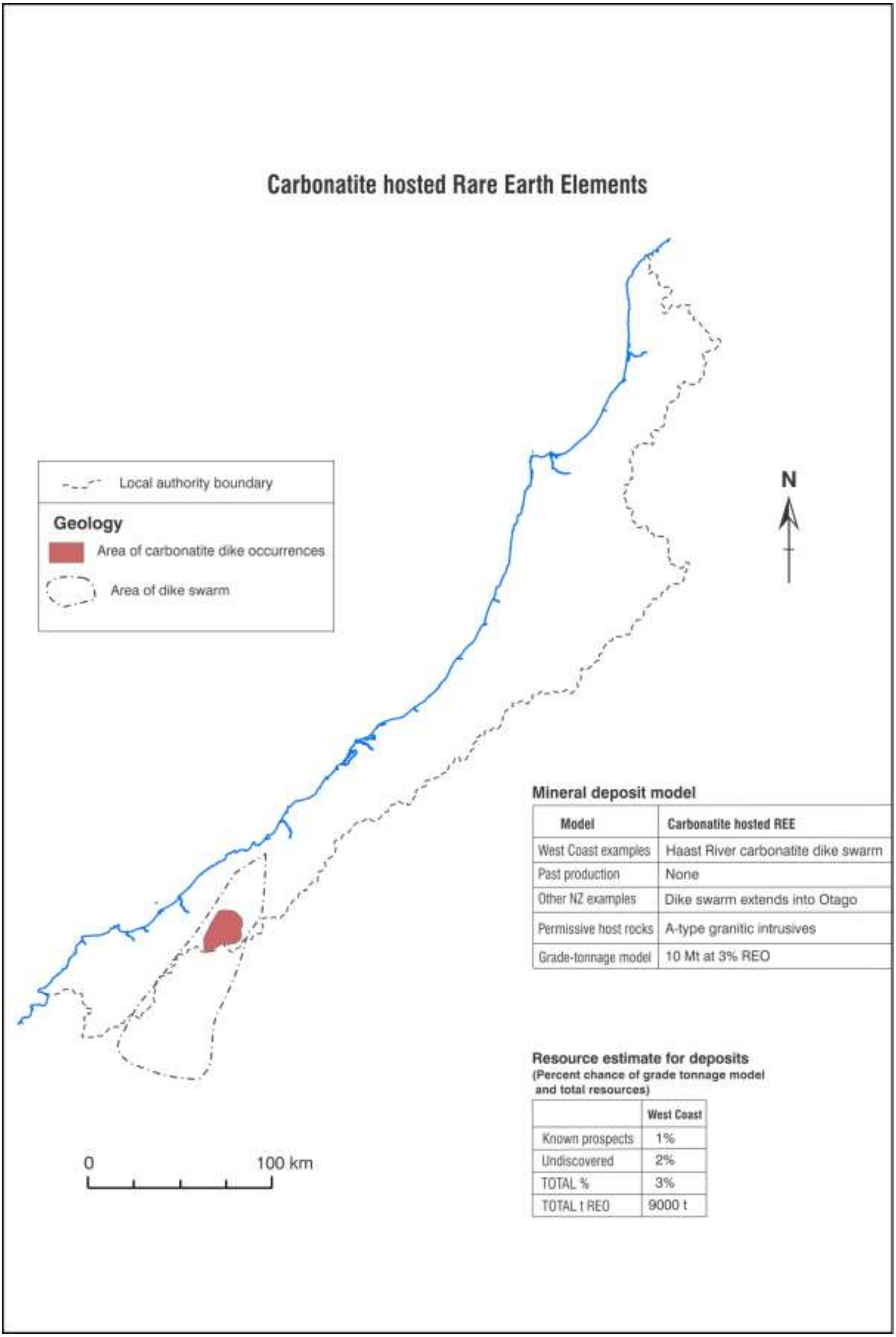
USGS model 10 50th percentile = 6.3 Mt at 0.36% Nb_2O_5 and 0.009% Re_2O_5 for 22,680 t Nb_2O_5 and 567 t Re_2O_5 (Singer 1998). Deposits range in size up to 62.5 Mt at an average grade of 4.1% rare earth oxides (Bayan Obo in Inner Mongolia, People's Republic of China). The USGS model is biased toward Nb deposits. Rare earth oxide-rich deposits are generally larger and therefore we suggest a model size of 10 Mt at 3% rare earth oxides for REO dominant deposits.

West Coast deposits

A swarm of carbonatitic lamprophyre dikes intrude Haast Schist in an area extending 110 km from the headwaters of the Paringa River on the southern side of the Alpine Fault in south Westland, south to the Shotover River in northwest Otago. Sills are also present, and a few diatreme-facies breccia pipes, similar to those exhibited by many kimberlites, have been identified (Cooper 1986). Wallace (1975) described one of these diatreme breccia pipes located adjacent to the Alpine fault at the Moeraki River as having clasts of lherzolite and harzburgite up to 1 m in size, in a mixed matrix of 1) talc-magnesite, 2) carbonatite, and 3) minor ultramafic material. The intrusives range in size from veinlets only a few centimetres wide to a sill 85 m thick. They are late Oligocene to Early Miocene in age and consist of a magmatic series ranging in composition from ultramafic peridotite, through dominant lamprophyre to subordinate tinguaite, trachyte and carbonatite (Cooper 1971, 1986, 1996). Fenitization of immediately adjacent country rock is widespread. Carbonatite varieties make up only a small proportion of the intrusives. They are found in dikes and sills up to 1.2 m thick and carry accessory albite, titanian acmite, pyrite, sphalerite, galena, rutile, apatite, monazite and thorite.

Assessment

We suggest a 3% probability of resources equivalent to the model size, equating to an estimated resource of 9000 t REO.



Model	Carbonatite hosted REE
West Coast examples	Haast River carbonatite dike swarm
Past production	None
Other NZ examples	Dike swarm extends into Otago
Permissive host rocks	A-type granitic intrusives
Grade-tonnage model	10 Mt at 3% REO

	West Coast
Known prospects	1%
Undiscovered	2%
TOTAL %	3%
TOTAL t REO	9000 t

Figure 97 Location of carbonatite dikes prospective for Carbonatite hosted Rare Earth Elements.

13.9.2 REE-bearing monazite in granitic and metamorphic rocks (Figure 98)

International model

References

REE-bearing monazite in granitic and metamorphic rocks.

Description

Granites, pegmatites and gneisses enriched in monazite $(Ce,La,Y,Th)PO_4$ and xenotime YPO_4. The REE-bearing minerals may be concentrated in hydrothermal veins or by weathering (e.g. ion adsorbtion clay type deposits).

International examples

Hydrothermal veins: Steenkamstraal, South Africa

Ion adsorbtion clay type deposits: Longnan and Xunwu, Jiangxi Province, China

Grade and tonnage

No published data. Grades (5% to 0.05% REO) and tonnage of producers and prospects are highly variable with a large proportion of REE production as a by-product. We have assigned values for a REE model of 300,000 t monazite for 250,000 t rare earth element oxides (REO).

West Coast deposits

Monazite is a common accessory mineral in many granitoid rocks of Westland. It is present in all of the main granitoid suites (Karamea, Rahu, Separation Point; Tulloch 1988a), but absent from Paleozoic Paringa (Cooper & Tulloch 1992) and Triassic to Early Cretaceous Median Suites (Mortimer et al. submitted). It is conspicuous in Foulwind and French Creek granites of the A-type Toropuhi Suite and French Creek Suites, respectively. Over the last ~15 years monazite has been used extensively for radiometric dating of igneous and metamorphic rocks, utilising both U-Pb and Th-Pb decay systems (Ireland & Gibson 1998). Xenotime accompanies monazite in Foulwind Granite and Kakapotahi granite.

Estimated monazite contents range from 0.005 wt% in Mt Murchison Granite (Separation Point Suite) to 0.015 wt% and 0.021 wt% in core and rim respectively of the Barrytown Pluton (Karamea Suite), to 0.029 wt% and 0.042 wt% in Foulwind Granite at Cape Foulwind and Tauranga Bay, respectively.

Igneous rocks with elevated REE contents

Several small areas of alkaline igneous rocks have elevated La and Ce contents. Full REE data are not available and the mineralogical hosts for these elements have not been clearly identified, except for Foulwind which contains abundant monazite and traces of xenotime. Typical values are listed in Table 16.

Table 16 Concentrations of lanthanum (La) + Cerium (Ce) + Yttrium (Y) in some granites

	(La+Ce+Y) ppm	Reference
Foulwind Granite, Westland	**286, 426**	**Tulloch et al. (submitted)**
Sams Creek, Nelson	**719**	**Tulloch (1992)**
Electric Granite, Fiordland	**299**	**Tulloch (1992)**
French Creek Granite, Westland	**264**	**Tulloch et al. (1994)**
Mandamus Intrusives, Canterbury	**400**	**Tulloch (1991)**
Average world wide low-Ca granite	**187**	**Turekian & Wedepohl (1961)**
Average world wide high-Ca granite	**161**	**Turekian & Wedepohl (1961)**

REE associated with the Paparoa metamorphic core complex

Hydrothermal systems formed when hot rocks from the deep crust were rapidly uplifted and juxtaposed under brittle, water-saturated upper crustal rocks along crustal scale detachment faults. This led to the development of extensive alteration in the vicinity of these faults in the Paparoa Range (Tulloch 1995). In addition to traces of Au, Ag, Cu, Ba, F, Fe, carbonate and U mineralisation, Tennant & Sewell (1967) reported elevated levels of REE in Paparoa Range stream sediment samples. REE abundances in Otututu and Ohikanui rivers are about four times greater than those in the Karamea area. Tulloch & Christie (2000) suggested that this mineralisation in the northern Paparoa Range, with its clear relationship to major continental rifting, has much in common with the Olympic Dam style of mineralisation, albeit this being much larger and generally of Proterozoic age.

Assessment

We suggest a 35% probability of resources equivalent to the model size, equating to an estimated resource of 87,500 t REO.

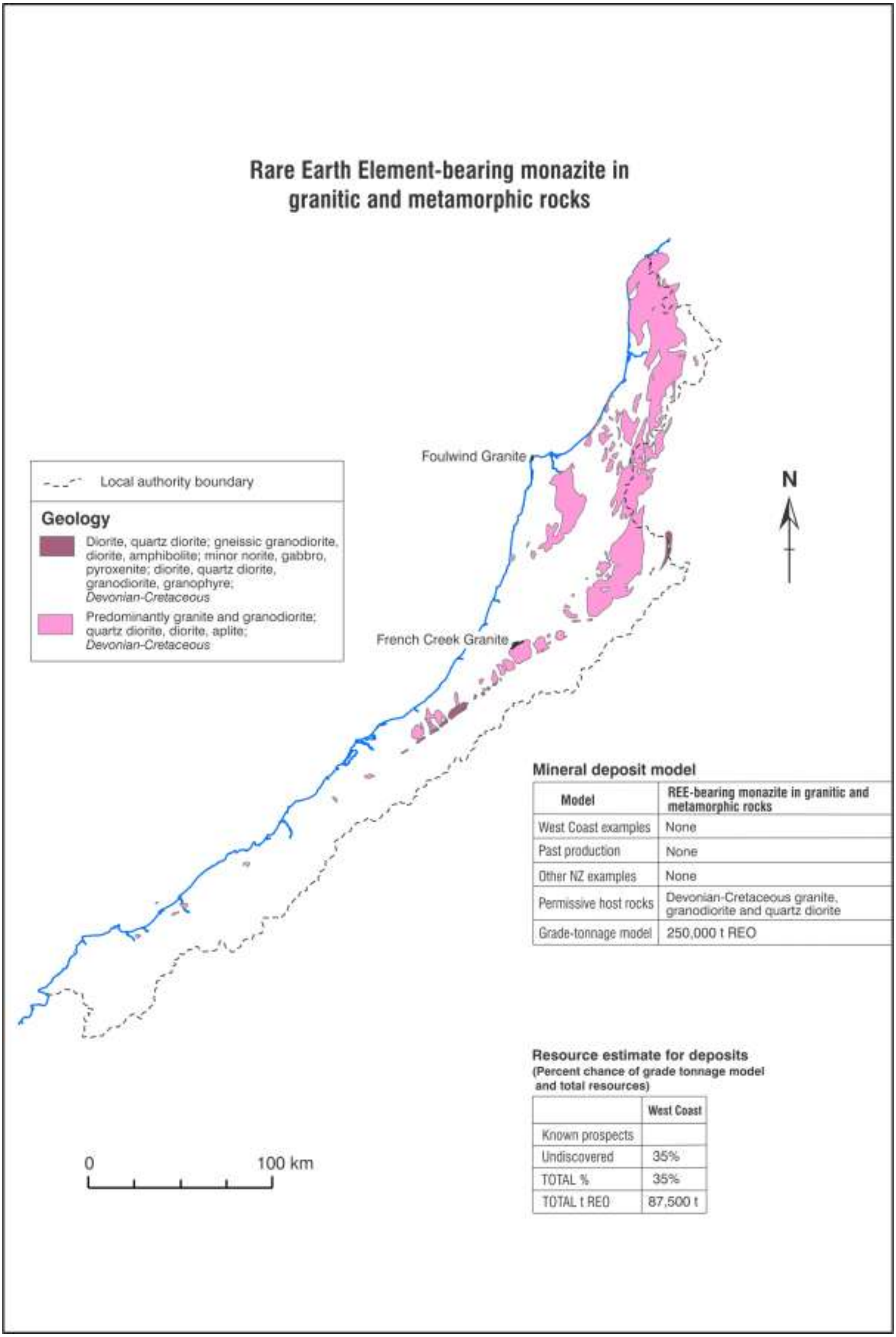


Figure 98 Areas of rocks prospective for Rare Earth Elements in granitic and metamorphic rocks.

13.9.3 Placer REE

Model

Description

Detrital REE minerals such as monazite, thorite, uranothorite, and xenotime occur in the heavy mineral fraction of beach and river sand.

West Coast deposits

Beach placers

Trace quantities of the rare earth minerals monazite, thorite, uranothorite, and xenotime are found in the ilmenite-dominated heavy mineral fraction of sand in present-day coastal beaches, in the sand and gravel deposits along a number of rivers, and in alluvial gold workings in Westport, Reefton, and Grey River areas. The largest deposits are at Westport and Barrytown. McPherson (1978 – table 7, fig. 46) summarised the known distribution of monazite obtained by Grange & Bowen (1955) in the Cape Foulwind - Charleston area (Nine Mile Beach, Constant Bay, Waitakere River). Their measurements of detrital monazite concentration ranged between 0.001 and 0.02%. The monazite content of the Barrytown sand deposit was estimated at 0.12% from emission spectrographic analyses of lanthanum on 14 drill samples (Aldridge 1970). However, estimates based on counting of monazite grains in composite drill samples, showed that the content was much lower at 0.005-0.008% (Roberts & Whitehead 1991). Concentrations in both areas are similar to those in adjacent basement rocks (see above), indicating a local source.

At Gillespies Beach, the thorite was assayed as 76.6% thorium oxide and the uranothorite as 62.6% ThO_2 and 11.5% UO_2 (Hutton 1950). Although no production figures are known, Nicholson (1955) estimated that during gold dredging operations, 0.1 ton of uranothorite was being recovered per week. Based on this estimate and assay figures of Hutton (1950), Caffyn (1971d) estimated that 147 pounds of thorium oxide must have been produced each week.

Alluvial placers

Hutton (1950) reported monazite in concentrates from gold dredges working alluvial gold deposits in several localities in Westland, including Barrytown, Blackball, Snowy River, Grey River, Ngahere, Atarau, Arahura, Rimu, Kaniere, and Slab Hutt. A partial analysis of monazite from the Ngahere dredge contained 1.23% U_3O_8 and 5.32% ThO_2 (Seelye in Nicholson 1955). Nicholson calculated that 0.75 t of monazite was being discarded per week by the Ngahere Dredge. Thorite is also present in many of the concentrates, and the presence of phosphorus in analyses of some thorite from the Red Jacks, Blackball, and Snowy River dredges led Hutton (1950) to suggest the presence of xenotime mixed with the thorite. Bradley et al. (1979) recorded monazite, thorite and uraninite in heavy mineral concentrate from the Kaniere Dredge on the Taramakau River. Analyses of the dredge concentrate by x-ray fluorescence spectroscopy yielded thorium contents of 0.027-0.22%. Minehan (1989) noted that the Kaniere Gold Dredging Company saved several tonnes of dredge concentrates with the objective of recovering thorite from the concentrates, but no follow-up work was done.

Assessment

Christie & Brathwaite (1999a) estimated resources of 17,500 t of monazite in the West Coast beach sands. Their estimate was based a total ilmenite resource of 30 Mt and a monazite:ilmenite ratio of about 1:1700.

13.10 TIN

13.10.1 Greisen Sn (Figure 99)

International model

References

USGS model 15c Sn greisen deposits (Cox & Singer 1986) and BCGS model I13 Sn veins and greisens.

Description

Disseminated cassiterite, and cassiterite-bearing veinlets, stockworks, lenses, pipes, and breccia in greisenised granite.

International examples

Lost River, Alaska, USA; Anchor Mine, Tasmania, Australia; Erzgebirge, Czech Republic

Grade and tonnage

USGS model 15c 50th percentile = 7.2 Mt at 0.28% Sn (Cox & Singer 1986).

West Coast deposits

Cassiterite is present in several hydrothermal vein and greisen type W-Sn occurrences along the western side of the Karamea Batholith in southwest Nelson and Westland (Pirajno 1985a; Tulloch & Mackenzie 1986; Kutsukake 1988; Brathwaite & Pirajno 1993). The mineralisation is localised in the apical (cupola) zones of structurally controlled granitic sheets or stocks, and in their contact zones with Greenland Group greywacke or earlier granitoid rocks. In contrast to classic Sn-W granite provinces (e.g. northeast Tasmania), the mineralisation is unusual in containing scheelite with little wolframite, cassiterite, fluorite and topaz (Tulloch & Brathwaite 1986). This mineralogy indicates a low fluorine activity in the magmatic hydrothermal fluids, and is correlated by Tulloch & Robertson (1987) with low fluorine (<1000 ppm) in the associated granites, compared to high fluorine (>3000 ppm) in classic Sn-W granites. Occurrences where cassiterite is the main mineral of economic interest are Britannia Stream and Falls Creek (J33/e68). Other occurrences where traces of cassiterite accompany scheelite are Bateman Creek, Kirwans Hill, Barrytown (K31/e63) and Doctor Hill (J33/e79). These deposits are described in the tungsten models section (Vein W and Greisen W-Sn).

Britannia Stream, Waimangaroa: Kutsukake (1988) reported minute cassiterite crystals with disseminated pyrite, chalcopyrite and hematite in a greisenised apophysis of the Britannia Granite pluton.

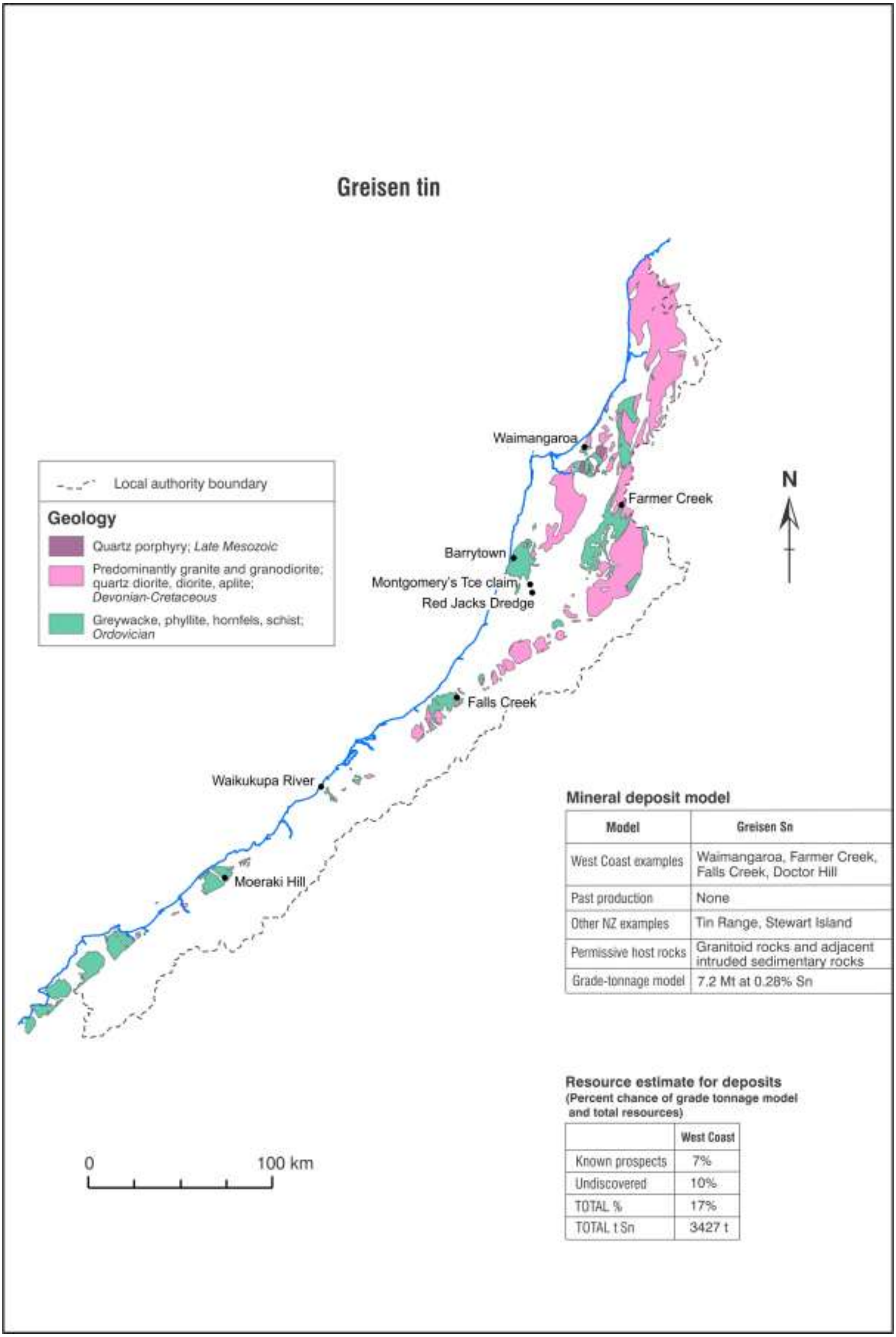
McConnochie Creek: High level granite sheets and stocks of the Karamea Batholith intrude hornfelsed Greenland Group metasedimentary rocks near Reefton, on the western slopes of the Victoria Range. At McConnochie Creek, a small granite body has an incipient greisen mineralogy consisting of albite-quartz-muscovite with accessory quantities of tourmaline, topaz and illite (Pirajno 1982a). Both endogranite and exogranite quartz vein systems are present, mineralised with pyrite, chalcopyrite, marcasite, molybdenite and native bismuth, and minor sphalerite, argentite and cassiterite. No scheelite was found at McConnochie Creek.

Falls Creek (J33/e68): Cassiterite and scheelite occur in quartz-tourmaline veins in a weakly greisenised biotite granite stock, similar to the mineralisation at nearby Doctor Hill (Mackenzie 1983; Maxwell 1989). Metasedimentary roof pendants are common as wedges subparallel to mineralised vein sets which extend at least 100 m below surface. Veins greater than 0.1 m wide have alteration zones greater than 0.2 m wide, comprising a greisen assemblage of quartz-tourmaline, with minor pyrite, arsenopyrite, scheelite, and cassiterite, and rarely pyrrhotite, molybdenite, topaz and fluorite. One 145 m diamond drill hole gave best intersections of 0.4 m of 0.3% Sn and 2% WO_3, and 0.3 m of 0.49% Sn and 0.96% WO_3. Maxwell (1989) considered that the mineralisation is exposed at a level below the apex of potentially productive greisen apophyses, although these apophyses may occur in an untested area to the south-east.

Assessment

Detrital cassiterite is widespread in the West Coast region, as “stream tin” and in trace quantities in much of the Nine Mile Formation (MacDonald 1965; Minehan 1985, 1989).

We suggest a 17% probability of resources equivalent to the model size, equating to an estimated resource of 3427 t Sn.



Mineral deposit model

Model	Greisen Sn
West Coast examples	Waimangaroa, Farmer Creek, Falls Creek, Doctor Hill
Past production	None
Other NZ examples	Tin Range, Stewart Island
Permissive host rocks	Granitoid rocks and adjacent intruded sedimentary rocks
Grade-tonnage model	7.2 Mt at 0.28% Sn

Resource estimate for deposits
(Percent chance of grade tonnage model and total resources)

	West Coast
Known prospects	7%
Undiscovered	10%
TOTAL %	17%
TOTAL t Sn	3427 t

Figure 99 Location of tin occurrences from the GERM database, and areas of rocks prospective for Greisen Sn deposits.

Figure 100 Drilling DDH MC1 at McConnochie Creek prospect by Gold Mines of NZ Ltd in 1980 (photo Franco Pirajno).

Figure 101 Cassiterite and scheelite-bearing sheeted veins, Falls Creek prospect (photo Franco Pirajno).

13.11 TITANIUM

13.11.1 Shoreline placer Ti (Figure 102)

International model

Reference

USGS model 39c Shoreline placer Ti (Cox & Singer 1986).

Description

Detrital ilmenite and other heavy minerals concentrated by beach processes. Elongate "shoestring" ore bodies parallel to coastal beaches and dunes.

International examples

Green Cove and Trail Ridge, Florida, USA; Lakehurst, New Jersey, USA; Eneabba, Western Australia.

Grade and tonnage

USGS model 39c 50th percentile = 100 Mt at 1.3% TiO_2 (Cox & Singer 1986, pp. 270-273).

West Coast deposits

Ilmenite is present in coastal sand deposits along 320 km of coastline between Karamea River in the north and Bruce Bay in the south (Brathwaite & Christie 2006). The deposits consist of narrow, elongate Holocene beach and dune deposits, generally parallel to and backing the modern storm beach (e.g. Barrytown; Suggate 1989). In some areas, ilmenite occurs in a succession of raised (interglacial) beach deposits which may be cemented to varying degrees. In the beach sands, ilmenite has been concentrated by wave action into blacksand leads with average grades of 10-25% ilmenite. In the dune sands, ilmenite occurs in concentrations generally less than 6%. Other associated heavy minerals include garnet, magnetite, zircon, and rutile, and traces of gold, monazite, cassiterite, beryl, uranothorite, scheelite, cassiterite, and xenotime (Hutton 1950; McPherson 1978; Minehan 1989). The ilmenite has abundant silicate inclusions and consequent low titanium content (45-47% TiO_2). The ilmenite was derived mainly from garnet schist of the Haast Schist along the Southern Alps (Gill in McPherson 1978).

Reconnaissance exploration has been carried out over several periods by the Department of Scientific and Industrial Research (Nicholson et al. 1958; Marshall et al. 1958; McPherson 1978), and by private companies, including Lime & Marble in joint venture with Rutile & Zircon Mines Ltd (Pullar & Henderson 1966; Pullar & Pullen 1967a, 1967b, 1968), Buller Minerals (Buller Minerals 1971a, 1971b, 1972a, 1972b), and Carpentaria Exploration (Caffyn 1971a-g, 1976; Carpentaria Exploration 1970a, 1970b, 1973; Best 1972; Zuckerman 1972a, 1972b; Painter 1972a-f, 1973a, 1973b; Beck 1976). These surveys indicate that the largest deposits are Karamea North, Birchfield, Fairdown, Carters Beach, Nine Mile Beach, Barrytown and Hokitika South, individually with reserves in the range of 1 to 10 Mt of contained ilmenite at average grades of 6 to 13.8% ilmenite (Figure 102).

Westport: McPherson (1978 – table 16 and 17, fig. 54) estimated a mineable resource in the range of 17 to 31.5 Mt of contained ilmenite at Westport. Subsequently, Austpac Gold and others have explored the ilmenite deposits near Westport and estimated a resource of 122 Mt of sand with an average grade of 4.5% ilmenite, equivalent to 5.5 Mt of contained ilmenite (Player et al. 1994; M. Turbott 1992). Austpac developed proprietary Enriched Roasting Magnetic Separation (ERMS) and Enhanced Acid Regeneration System (EARS) processes for separation of the ilmenite from garnet and other heavy minerals, and manufacture of high purity synthetic rutile with 96-97% TiO_2.

Barrytown: Exploration of the Barrytown deposit, initially by Carpentaria Exploration Co. Pty Limited, followed by Grampian Mining Co. Limited (wholly owned subsidiary company of Fletcher Challenge Limited; Mann & James 1989), and subsequently by Westland Ilmenite Limited (North Limited), has indicated the presence of 50 Mt of potentially mineable sand at an average grade of 13.8% ilmenite (6.9 Mt), 0.2% zircon, 100 mg/m^3 gold, and less than 0.1% each of monazite and rutile (Westland Ilmenite 1991). Westland Ilmenite Limited was granted a mining permit in 1998 for a proposal to mine 3 Mt of sand per year to produce 250,000 t of ilmenite concentrate annually. However, no mining was carried out partly because of environmental issues and also problems with monazite content of the sand tailings and how potential radioactivity was going to be managed.

Potential

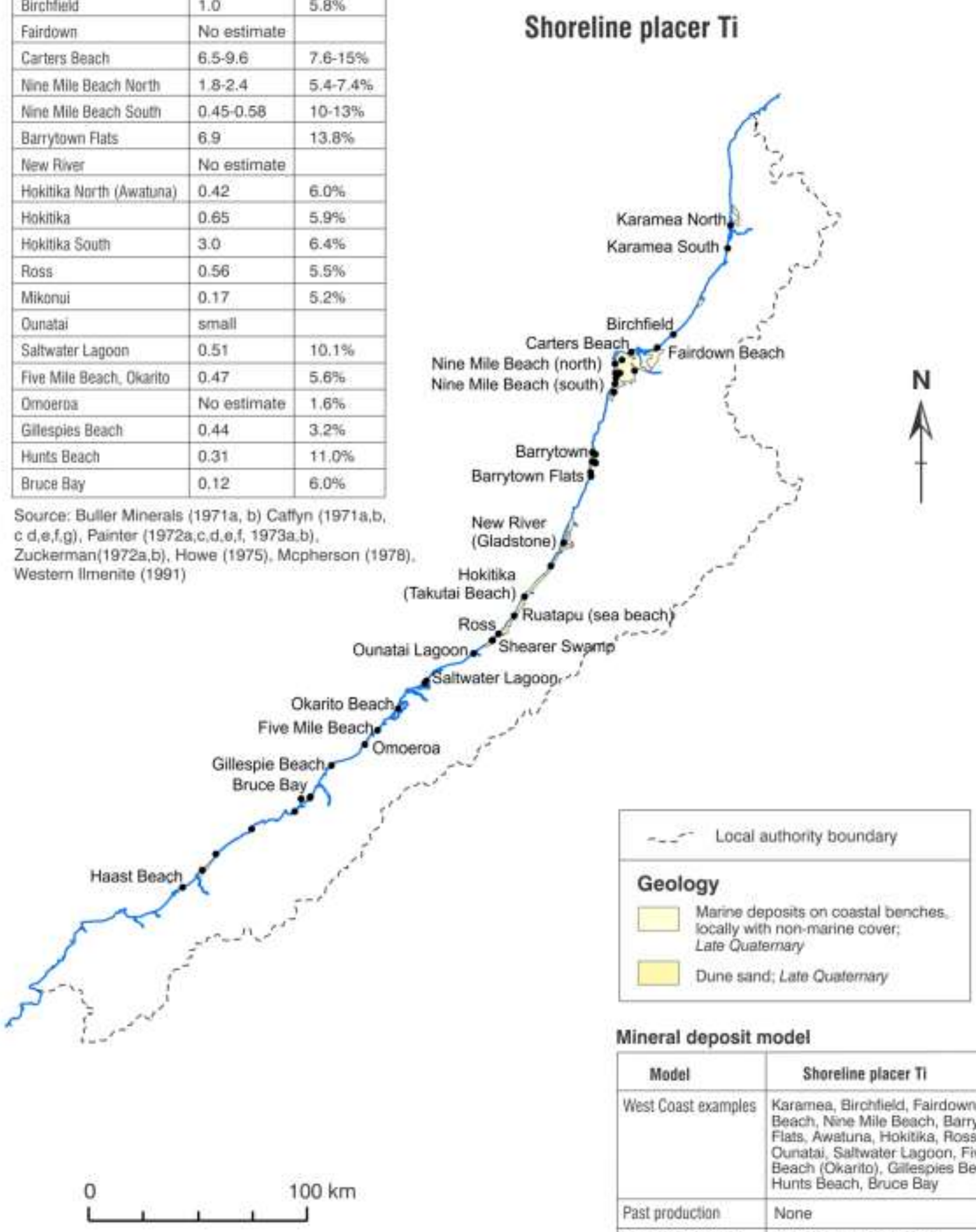
Ilmenite beach sand deposits on the West Coast are a potentially large resource. Ilmenite makes up 5-25% of the sands, but the titanium oxide content of the ilmenite is low (45-47% TiO_2) by world standards due to inclusions of garnet and other silicate minerals. The largest deposits are at Westport and Barrytown. Westport has a resource of 122 Mt of sand with an average grade of 4.5% ilmenite, equivalent to 5.5 Mt of contained ilmenite. Barrytown has 50 Mt of potentially mineable sand at an average grade of 13.8% ilmenite (6.9 Mt), 0.2% zircon, 100 mg/m^3 gold, and less than 0.1% each of monazite and rutile. These and other identified deposits make up a total resource of about 30 Mt of ilmenite (Figure 102).

Future production: The proposed operations at Westport and Barrytown could produce 10,000 t/yr of "supergrade" titanium dioxide from Westport and 250,000 t/yr of ilmenite concentrate at Barrytown.

Ilmenite resources (after Brathwaite & Christie 2006)

Location	Ilmenite (Mt)	Grade (% ilmenite)
Karamea North	2.5	6.0%
Karamea South	0.65	3.6%
Birchfield	1.0	5.8%
Fairdown	No estimate	
Carters Beach	6.5-9.6	7.6-15%
Nine Mile Beach North	1.8-2.4	5.4-7.4%
Nine Mile Beach South	0.45-0.58	10-13%
Barrytown Flats	6.9	13.8%
New River	No estimate	
Hokitika North (Awatuna)	0.42	6.0%
Hokitika	0.65	5.9%
Hokitika South	3.0	6.4%
Ross	0.56	5.5%
Mikonui	0.17	5.2%
Ounatai	small	
Saltwater Lagoon	0.51	10.1%
Five Mile Beach, Okarito	0.47	5.6%
Omoeroa	No estimate	1.6%
Gillespies Beach	0.44	3.2%
Hunts Beach	0.31	11.0%
Bruce Bay	0.12	6.0%

Source: Buller Minerals (1971a, b) Caffyn (1971a,b, c d,e,f,g), Painter (1972a,c,d,e,f, 1973a,b), Zuckerman(1972a,b), Howe (1975), Mcpherson (1978), Western Ilmenite (1991)



Mineral deposit model

Model	Shoreline placer Ti
West Coast examples	Karamea, Birchfield, Fairdown, Carters Beach, Nine Mile Beach, Barrytown Flats, Awatuna, Hokitika, Ross, Mikonui, Ounatai, Saltwater Lagoon, Five Mile Beach (Okarito), Gillespies Beach, Hunts Beach, Bruce Bay
Past production	None
Other NZ examples	Whitianga, Waihi Beach
Permissive host rocks	Well-sorted, medium- to fine-grained sand in beach, dune and inlet deposits

Figure 102 Location of ilmenite sand deposits prospective for Shoreline placer Ti type deposits.

Figure 103 Barrytown Flats viewed from the north looking south. The coastal sand deposits of the flats contain substantial resources of ilmenite (photo: Vivienne Bull).

Figure 104 Barrytown Flats ilmenite deposits viewed from the west looking east (GNS photo CN, photographer Lloyd Homer).

13.12 TUNGSTEN

13.12.1 Vein W (Figure 105)

International model

References

USGS model 15a W veins (Cox & Singer 1986) and BCGS I12 model W-veins.

Description

Wolframite, molybdenite and minor base metals in quartz veins associated with monzogranite to granite stocks intruding sandstone, shale and metamorphic equivalents.

(Note that West Coast deposits have scheelite in place of wolframite).

International examples

Pasto Bueno, Peru; Xihuashan, China; Isla de Pinos, Cuba; Hamme District, North Carolina, USA; Chicote grande, Bolivia

Grade-tonnage data - international

USGS model 15a 50th percentile = 0.56 Mt at 0.9% WO_3 for 5,040 t WO_3 (Cox & Singer 1986, pp. 65-66) (but for scheelite in place of wolframite in New Zealand deposits).

West Coast deposits

Several quartz-scheelite vein deposits are associated with granodiorite or porphyritic granite intrusions of the early Cretaceous Separation Point Suite in west Nelson. In contrast to classic Sn-W granite provinces (e.g. northeast Tasmania), the mineralisation is unusual in having scheelite dominant over wolframite and cassiterite, together with a paucity of fluorite and topaz (Tulloch & Brathwaite 1986).

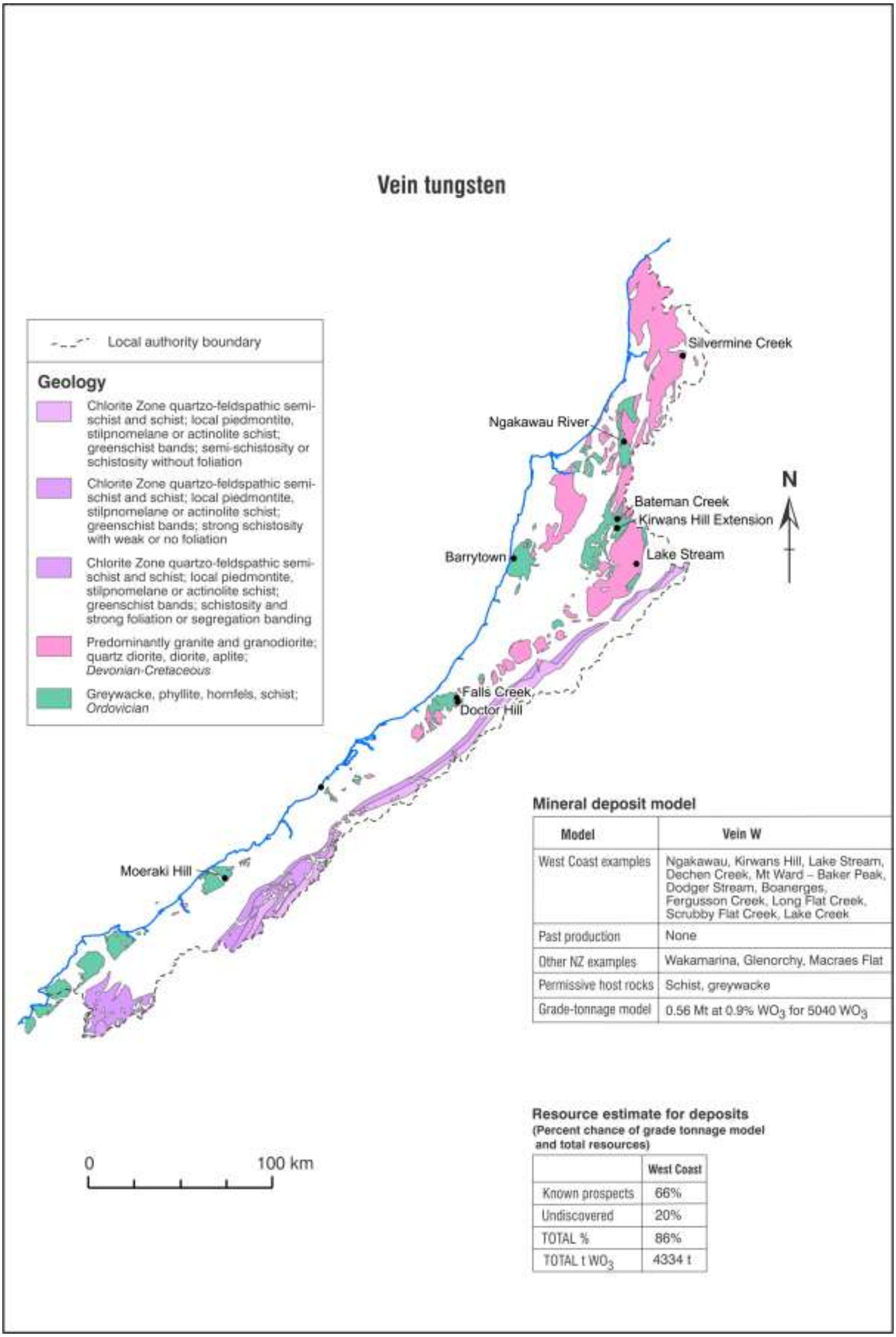
Ngakawau (L29/e9): In the headwaters of the Ngakawau River, K-feldspar porphyry stocks along the Ngakawau Fault Zone contain vein stockworks with scheelite, pyrite, arsenopyrite and trace gold (Pirajno 1982b; Riley 1982).

Kirwan's Hill Extension (L30/e253): A similar occurrence at Kirwan’s Hill has been reported by Bentley (1982) and Pirajno & Bentley (1985), who provided assay data that indicates that the tungsten is present in low concentrations (0.1 to 0.6%).

Lake Stream (L31/e43): At Lake Stream in the Victoria Range, scheelite is found in hydrothermal quartz veins accompanied by pyrite, magnetite and minor molybdenite and chalcopyrite (Pirajno 1982c). The veins are associated with metagabbro and porphyritic granite. Assay data indicate low concentrations of tungsten (0.25% WO_3).

Assessment

We suggest an 86% probability of resources equivalent to the model size, equating to an estimated resource of 4334 t WO_3.



Mineral deposit model

Model	Vein W
West Coast examples	Ngakawau, Kirwans Hill, Lake Stream, Dechen Creek, Mt Ward – Baker Peak, Dodger Stream, Boanerges, Fergusson Creek, Long Flat Creek, Scrubby Flat Creek, Lake Creek
Past production	None
Other NZ examples	Wakamarina, Glenorchy, Macraes Flat
Permissive host rocks	Schist, greywacke
Grade-tonnage model	0.56 Mt at 0.9% WO_3 for 5040 WO_3

Resource estimate for deposits
(Percent chance of grade tonnage model and total resources)

	West Coast
Known prospects	66%
Undiscovered	20%
TOTAL %	86%
TOTAL t WO_3	4334 t

Figure 105 Location of tungsten occurrences from the GERM database, and areas of rocks prospective for Vein W deposits.

13.12.2 Greisen W-Sn (Figure 106)

13.12.3 International model

References

"Sn greisen deposits" (Cox & Singer 1986, Model 15c, p. 70)

Description

Scheelite (± cassiterite) in sheeted quartz veins, stockwork quartz veins and disseminations in greisenised granitic rocks and adjacent metasedimentary rocks.

International examples

Erzgebirge on both sides of the Czech-German border (e.g. Cinovec, Czech Republic; and Sadisdorf, Germany); Panasqueira in Portugal; Lost River in Alaska; Wolfram Camp in Australia; Xihuashan in China; Mawchi in Myanmar; and Yugodzyr in Mongolia (but note that most of these are wolframite deposits).

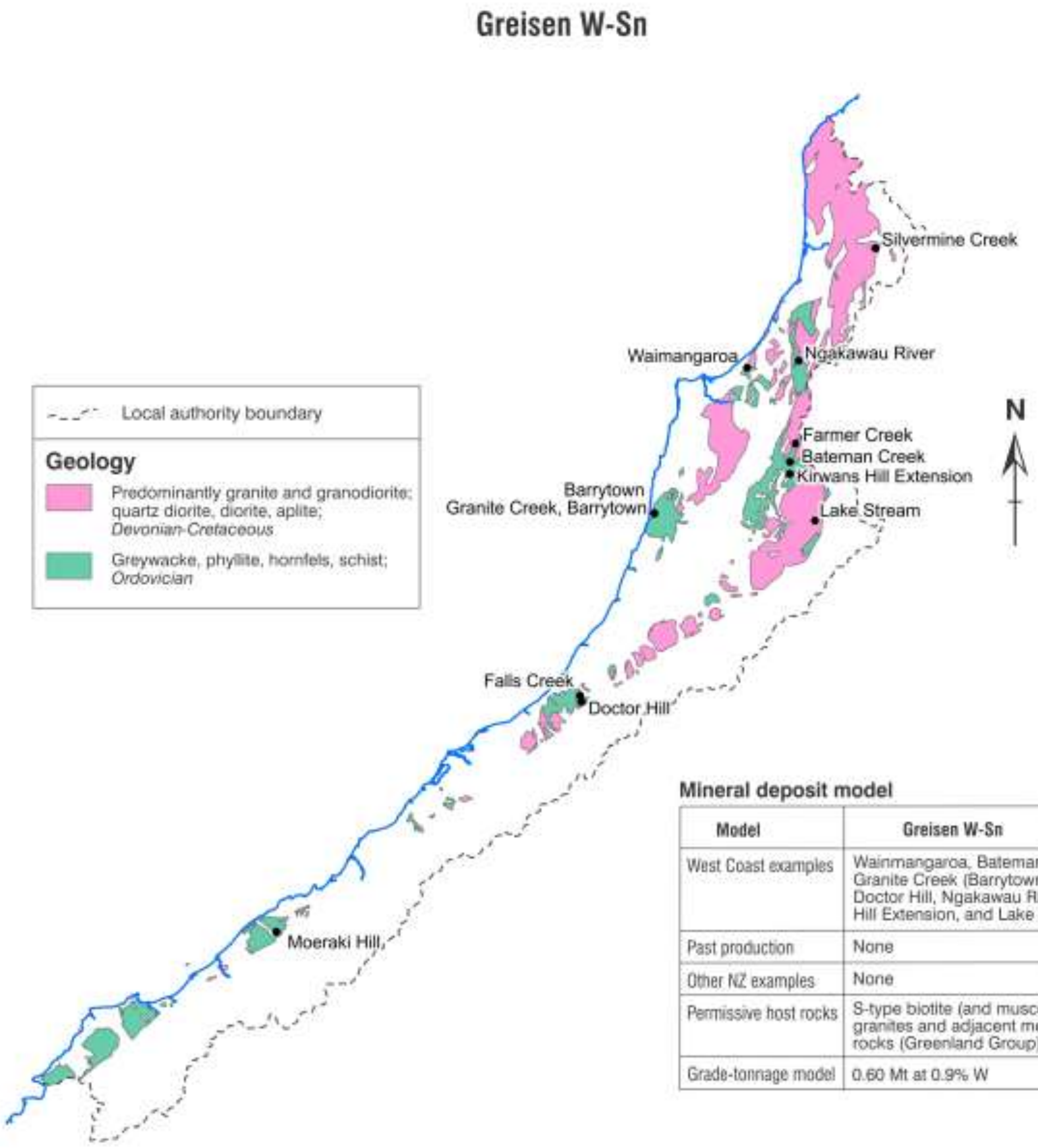
Grade-tonnage data - international

0.60 Mt at 0.9% W

West Coast deposits

A number of hydrothermal vein and greisen type W-(Sn) occurrences have been discovered along the western side of the Karamea Batholith in southwest Nelson and Westland (Pirajno 1985b; Tulloch & Mackenzie 1986; Brathwaite & Pirajno 1993). In contrast to classic Sn-W granite provinces (e.g. northeast Tasmania), the mineralisation is unusual in having scheelite dominant over wolframite and cassiterite, together with a paucity of fluorite and topaz (Tulloch & Brathwaite 1986).

Bateman Creek: Scheelite is disseminated in greisenised granite and in quartz veins hosted by greisenised granite and the adjacent Greenland Group metasediments (Pirajno & Bentley 1985). The quartz veins form sheeted systems roughly parallel to the contacts between metasediments and greisenised granite. Minerals present include: scheelite, pyrite, hematite, chalcopyrite, bornite, covellite, marcasite, molybdenite and cassiterite. The mineralised granite consists of at least three small cupolas, 350-1000 m long and 100-400 m wide, emplaced along north northwest-trending lineaments. The greisen alteration consists of muscovite, albite, tourmaline, topaz, and fluorite.



Mineral deposit model

Model	Greisen W-Sn
West Coast examples	Wainmangaroa, Bateman Creek, Granite Creek (Barrytown), Falls Creek, Doctor Hill, Ngakawau River, Kirwan's Hill Extension, and Lake Stream
Past production	None
Other NZ examples	None
Permissive host rocks	S-type biotite (and muscovite?) granites and adjacent metasedimentary rocks (Greenland Group)
Grade-tonnage model	0.60 Mt at 0.9% W

Resource estimate for deposits
(Percent chance of grade tonnage model and total resources)

	West Coast
Known prospects	40.5%
Undiscovered	110.0%
TOTAL %	150.5%
TOTAL t W	8127 t

Figure 106 Location of tungsten occurrences from the GERM database, and areas of rocks prospective for Greisen W-Sn deposits.

Kirwans Hill: Scheelite mineralisation, accompanied by minor cassiterite, pyrrhotite and chalcopyrite, is present in a sheeted quartz vein system emplaced within a major NNW striking fracture zone in tourmalinised Greenland Group rocks (Bentley 1982; Pirajno & Bentley 1985). Bentley (1982) recognised five stages of alteration: (1) biotite-tourmaline-muscovite greisen, (2) metasomatic phlogopite-clinozoisite-scheelite, (3) pyrrhotite replacement of biotite, tourmaline and muscovite, (4) deposition of quartz veins with W-Sn mineralisation, and (5) later hydrothermal activity with deposition of pyrite, calcite, and sericite in crosscutting fractures. The quartz veins range from 0.01 to 0.2 m thick and contain tourmaline, apatite, orthoclase, fluorite, scheelite, pyrrhotite, chalcopyrite, pyrite, arsenopyrite, loellingite, minor sphalerite, molybdenite, cassiterite, Ag-Pb-Bi sulphosalts, and supergene covellite, bornite and tungstite. Muscovite from a quartz vein selvage at Kirwans Hill gave a K-Ar age of 296 Ma (late Carboniferous).

Mapping and sampling by Gold Mines NZ defined two sheeted quartz-scheelite vein systems that extend for 800 m and 1 km along strike along the flanks of Kirwans Hill (Pirajno 1981). Costeaning returned strongly anomalous W, including 251.1 m at 0.15% WO_3 from the easternmost trench. Zephyr Minerals drilled two diamond drill holes on the southern flanks of the western vein system (Drummond 1994). Hole KRO-1 was drilled to a depth of a 75.4 m and returned weak assays. Hole KRO-2 was abandoned at 30 m, short of the target depth.

Auzex Resources drilled two diamond holes in 2007, KHDD07-01 to 74.9 m and KHDD07-02 to 263.2 m (Pilcher & Burns 2008; Pilcher & Cutovinos 2008). The holes were sited adjacent to the historic costean with the highest WO_3 grades to test part of the eastern vein system. Drilling intersected sheeted quartz-scheelite veins and KHDD07-02 returned 260 m at an average grade of 515 ppm WO_3. KHDD08-03 drilled in 2008 was sited 100 m along strike to the northwest. It reached 54.9 m before suspension of drilling and did not reach the targeted west dipping quartz-scheelite veins. The average grade was 436 ppm WO_3 over 54 m, but the top 7 m averaged 838 ppm WO_3. There were 3 one metre intervals >1000 ppm WO_3. From core measurements, 2 vein sets can be distinguished near orthogonal to drill direction, striking roughly N-S and correlating with mapped veins at surface: a sub vertical-steep east to steep west dipping set and a moderate west dipping set.

Figure 107 Camp at Kirwans Hill during exploration of of the Kirwans prospect by Gold Mines of NZ Ltd (photo Franco Pirajno).

Barrytown (K31/e63): Scheelite mineralisation is associated with a small pluton of potassic S-type granite intruding Greenland Group metasedimentary rocks, which are locally hornfelsed at contacts (Mackenzie & Price 1985; Tulloch 1986). Disseminated scheelite is present in a series of quartz-tourmaline veins and adjacent 1-2 m wide zones of greisenised granite or greywacke. Scheelite is accompanied by minor pyrite, rutile, hematite and pyrrhotite, and rare chalcopyrite, cassiterite and molybdenite. Wolframite is found in a single quartz-tourmaline-muscovite-topaz-pyrite vein, where it is partly replaced by scheelite. The quartz-tourmaline veins are subvertical, and are coincident with the NW-trending pluton core.

Exploration by Carpentaria Exploration Company Ltd in 1970-71, including UV lamping, and stream sediment, soil and costean rock sampling, defined a tungsten anomaly between Granite and Little Granite creeks. Apart from weak correlation of arsenic with tungsten, all other elements analysed were present at background levels. Biogeochemical prospecting (Quinn et al. 1974), utilising tree fern samples, showed good correlation of tungsten values with B-horizon soil samples.

Prospecting by CRA Ltd sought a flat-lying greisen in the roof zone (MacKenzie & Price 1985), and soil sampling defined a 150 m long anomaly (>500 ppm W), within a 500 m isopleth of greater than 100 ppm W. Tungsten values in soil samples ranged up to 2800 ppm (threshold 500 ppm), and pan concentrates up to 5376 ppm (threshold 2800 ppm). Arsenic values correlated with tungsten, with up to 390 ppm As in soils. Peak float sample values of 0.6-1.3% WO_3 for well-mineralised greisen could not be repeated by systematic rock chip sampling. Analyses by Tulloch (in MacKenzie & Price 1985) give low concentrations of tin: <5-15 ppm Sn in average Barrytown granite, 10 ppm Sn in greisen, and <5-30 ppm Sn in metasedimentary roof rocks.

Doctor Hill (J33/e79) and Falls Creek (J33/e68): Scheelite mineralisation, located by pan prospecting and UV lamping, occurs in quartz-tourmaline veins in a biotite granite stock containing roof pendants of Greenland Group metasediments (MacKenzie 1983; Maxwell 1989). At Doctor Hill, scheelite distribution is patchy, and bears no relation to width or composition of veins, except that tourmaline is a consistent associated mineral. An area of mineralisation, 200 x 150 m, is defined by geochemical anomalies and high vein frequencies. Two diamond drill holes on the anomaly established that vein densities were maintained with depth, but scheelite content was low, with a best intersection of 0.3% WO_3 over 4.35 m (Maxwell 1989).

At Falls Creek, 4 km to the north of Doctor Hill, scheelite mineralisation is exposed in a road cut, and is similar to the Doctor Hill prospect except that the biotite granite is weakly greisenised and locally pyritic, and many veins carry cassiterite. One 145 m diamond drill hole gave best intersections of 0.4 m of 2% WO_3 and 0.3% Sn, and 0.3 m of 0.96% WO_3 and 0.49% Sn.

Assessment

We suggest a 150.5% probability of resources equivalent to the model size, equating to an estimated resource of 8127 t W.

Figure 108 Drilling DDH FC1 at Falls Creek by Gold Mines of NZ Ltd in 1981 (photo Franco Pirajno).

13.12.4 Stratabound W (Figure 109)

International model

Tungsten syngenetically deposited in sediments from submarine hydrothermal solutions.

Description

Stratiform scheelite mineralisation, commonly with stibnite and cinnabar in some metavolcanic sequences, was considered to be volcanogenic exhalative in origin by Höll & Maucher (1976). A possible modern analogue is Frying Pan Lake at Waimangu Geothermal Field (Seward & Sheppard 1986).

International examples

Examples occur in Austria (Kleinarltal and Mitersill), Sardinia, Turkey, Spain, Argentina, Broken Hill district Australia, and New Mexico USA. Of these only the Mitersill Deposit has been mined at up to 400,000 t/y grading 0.5% WO_3 in 1980. Detailed isotopic and geochemical studies of the Mitersill deposit have shown that the tungsten was concentrated from mafic boninitic volcanics into a system of quartz veins during two high-grade metamorphic events (Thalhammer et al. 1989). Some tungsten skarn deposits have also been proposed as stratiform deposits, e.g. Sangdong in South Korea.

Grade-tonnage data - international

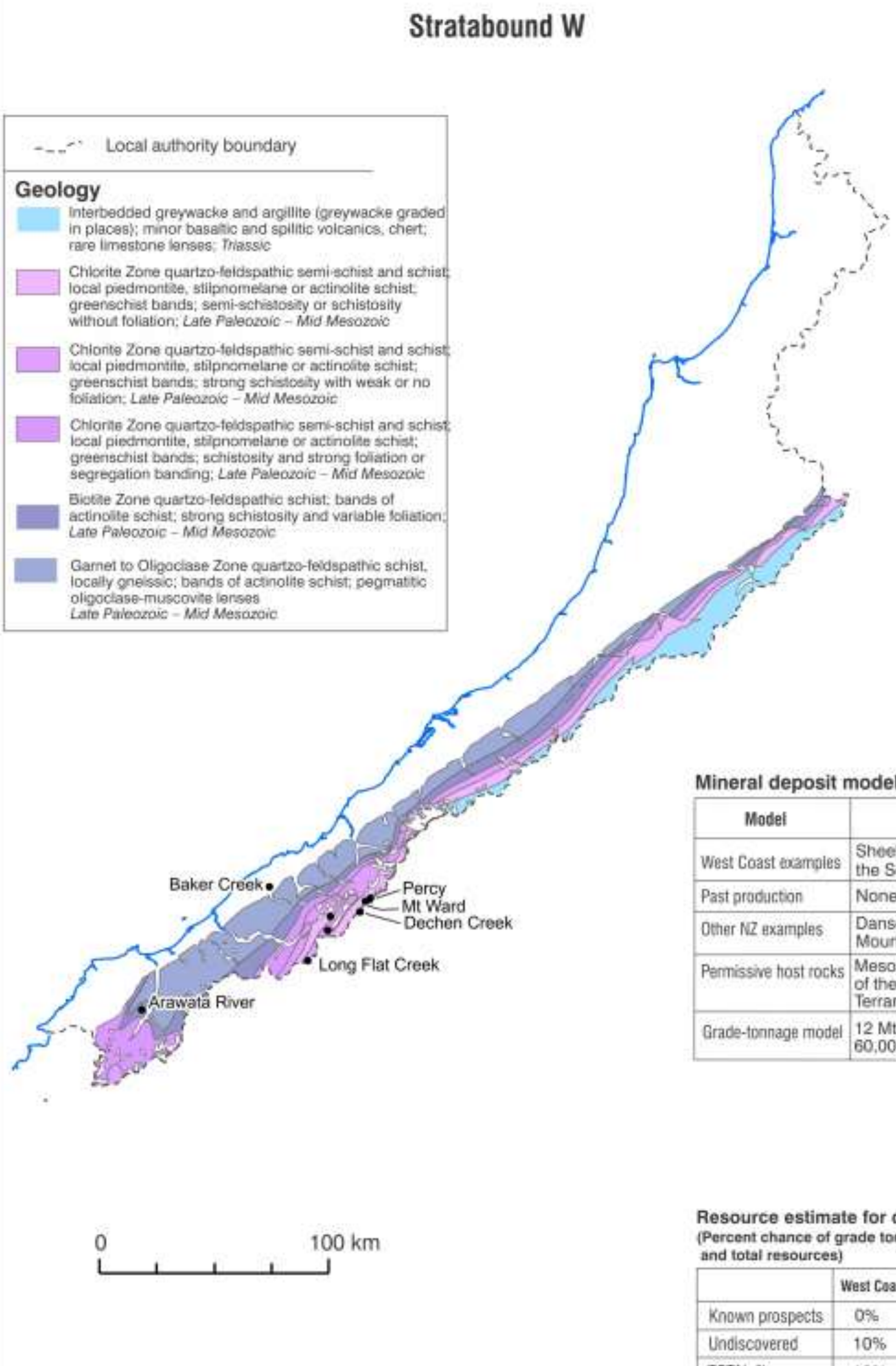
Our model is the type deposit, Mitersill in Austria, which had pre-mining resources of about 12 Mt at 0.5% WO_3 for 60,000 t WO_3.

West Coast deposits

Reconnaissance exploration in the Southern Alps by CRA Exploration Pty Ltd, outlined an extensive zone containing weak scheelite mineralisation in a belt about 8 km wide and 60 km long, from Lake Hawea north to Mount Cook National Park (Purvis et al. 1982; Hawke & Price 1983, 1989; Price et at. 1985). Scheelite is in quartz veins and segregations and is regionally localised to the vicinity of the pumpellyite-actinolite/greenschist facies boundary. It is commonly associated with calc-silicate and carbonate minerals. Occurrences of disseminated and bedding laminae-bound scheelite in chert and carbonaceous pelite were found in Long Flat and Scrubby Flat creeks, Hunter River area (Purvis et al. 1982). Wood (1983) also recognised widespread scheelite occurrences over a distance of 360 km in greenschist facies schist along the Southern Alps. He described the scheelite as occurring in disseminated spots, as well as in fine quartz veins. Craw & Norris (1991) considered that scheelite-quartz vein formation at Lake Hawea was synmetamorphic and represented tungsten mobilisation during metamorphism of the greywackes.

Assessment

We suggest a 10% probability of resources equivalent to the model size, equating to an estimated resource of 6000 t WO_3.



Mineral deposit model

Model	Stratabound W
West Coast examples	Sheelite occurrences in the Southern Alps
Past production	None
Other NZ examples	Dansey Pass and Kakanui Mountains in Otago
Permissive host rocks	Mesozoic schist and greywacke of the Southern Alps (Torlesse Terrane)
Grade-tonnage model	12 Mt at 0.5% WO_3 for 60,000 t WO_3

Resource estimate for deposits
(Percent chance of grade tonnage model and total resources)

	West Coast
Known prospects	0%
Undiscovered	10%
TOTAL %	10%
TOTAL t WO_3	6000 t

Figure 109 Areas of rocks prospective for Stratabound W deposits.

13.13 URANIUM

13.13.1 Sandstone U (Figure 110)

International model

References

USGS model 30c Sandstone U (Cox & Singer 1986) and BCGS model D05 Sandstone U.

Description

Microcrystalline uranium oxides and silicates deposited during diagenesis in localised reduced environments within fine- to medium-grained sandstone beds; some uranium oxides also deposited during redistribution by ground water at interface between oxidised and reduced ground.

International examples

Colorado Plateau, USA; Grants, New Mexico, USA; Texas Gulf Coast, USA.

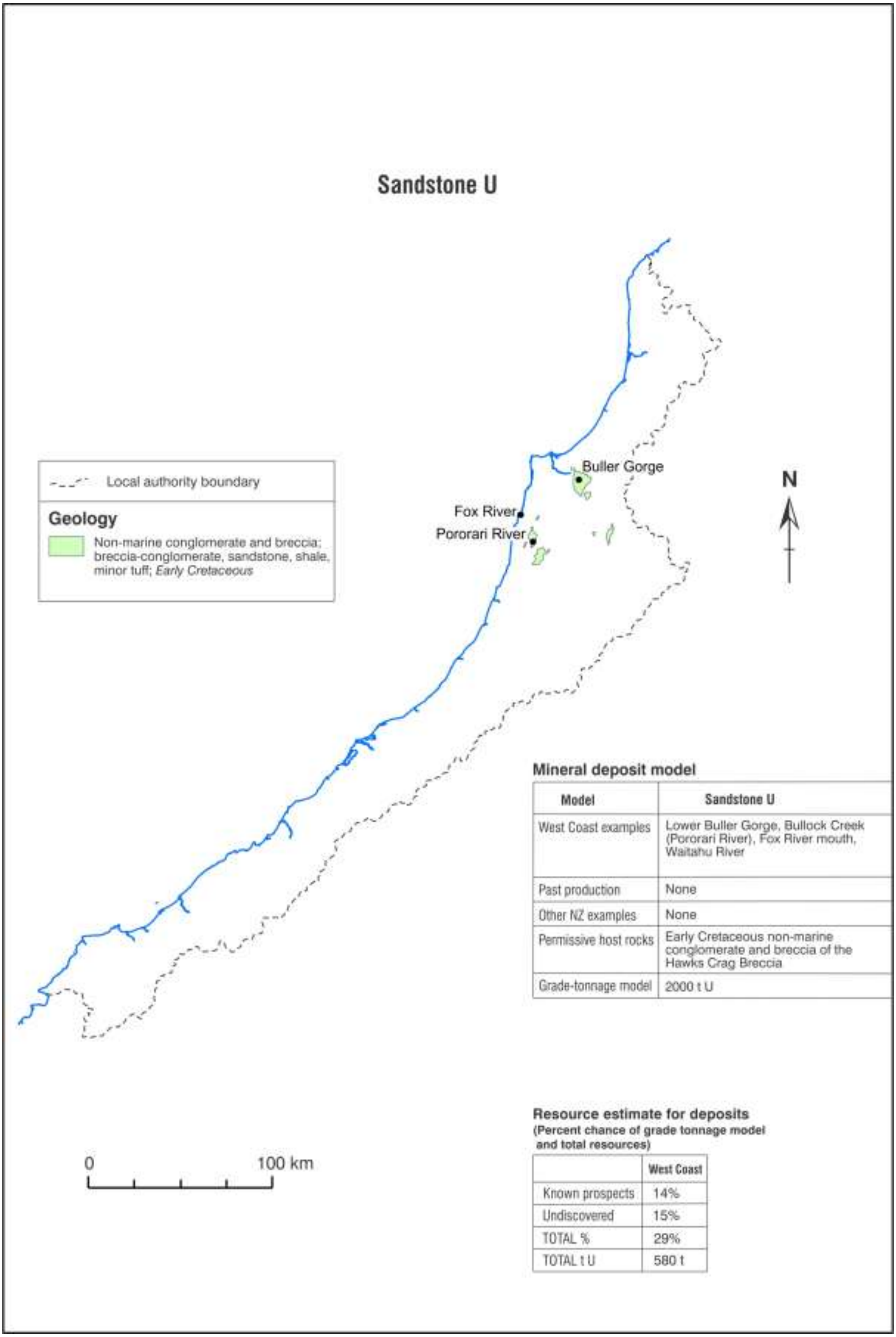
Grade-tonnage data –

Most mined deposits are in the range of 1000 t to 10,000 t of contained U, in ores with grades of 0.1 to 0.2% contained U. We use a model size of 2000 t of contained U.

West Coast deposits

The discovery of uranium in a road cutting near Hawks Crag by Frederick Cassin and Charles Jacobsen in 1955 resulted in a uranium exploration rush in the 1950s and 1960s (Figure 111 and Figure 112). Additional deposits were discovered in the lower Buller Gorge and the Pororari River areas. The uranium occurs as weak disseminations of coffinite and uraninite in non-marine conglomerate-sandstone beds of Cretaceous Hawks Crag Breccia and Watson Formation of the Pororari Group. The Hawks Crag Breccia is a coarse, angular breccia with thin carbonaceous siltstone and arkosic sandstone beds, and is mainly derived from granite of the Paparoa Range and from the Greenland group greywacke (Tulloch & Palmer 1990). It is commonly red coloured, due to hematite staining of feldspars. The Hawks Crag Breccia and Watson Formation were deposited in fault angle depressions as alluvial fan and river flood plain deposits.

Tulloch (1988b) has related the uranium mineralisation to the circulation of fluids via the Ohika Detachment Fault zone at the contact of the Pororari Group with underlying deformed granite of the Paparoa metamorphic core complex.



Mineral deposit model

Model	Sandstone U
West Coast examples	Lower Buller Gorge, Bullock Creek (Pororari River), Fox River mouth, Waitahu River
Past production	None
Other NZ examples	None
Permissive host rocks	Early Cretaceous non-marine conglomerate and breccia of the Hawks Crag Breccia
Grade-tonnage model	2000 t U

Resource estimate for deposits
(Percent chance of grade tonnage model and total resources)

	West Coast
Known prospects	14%
Undiscovered	15%
TOTAL %	29%
TOTAL t U	580 t

Figure 110 Location of uranium occurrences from the GERM database, and areas of rocks prospective for Sandstone U deposits.

Buller Gorge (29/e75): Bedded uranium deposits are found in the Tiroroa Facies of the Hawks Crag Breccia, a mainly granite-derived arkosic facies typically consisting of poorly sorted and matrix-rich, arkosic sandstone, breccia and conglomerate, containing carbonaceous streaks which appear to preferentially host the uranium mineralisation. Uranium mineralisation is found on both the north and south sides of the Buller River, but mineralisation is different in the two areas.

North of the Buller River, at least 10 lensoidal uraniferous horizons up to 60 cm in thickness were identified, however most interest was shown in three horizons (T-J, S-C and Waterfall). Riley (1969) reported grades ranging from 0.89 to 2.34 lbs U_3O_8 per short ton (2000 lb) over mining widths of 1.2 m and over limited strike lengths. Coffinite is the predominant uranium mineral, typically found with carbonate (calcite and ferroan dolomite), pyrite, and fluorite (Beck et al. 1958; Wodzicki 1959a, 1959b). Coffinite is present interstitially to clastic sand grains and pebbles. Thucolite and uraninite are also reported as primary minerals (Williams 1974). Secondary uranium minerals include autunite, ferghanite, gummite, meta-autunite, rutherfordine, schoepite, sklodowskite, uranophane, saleeite, metatorbernite, tyuyamunite, and thucholite (Beck et al. 1958; Riley 1969; Williams 1974).

Figure 111 Photographed in October 1956, a helicopter hovers at Benney's Landing on the north side of the Lower Buller Gorge – the site of Lime and Marble's uranium prospecting camp. (Photo Tas McKee).

Figure 112 Geologists and prospectors pose outside the opening to the tunnel that Lime and Marble called 'Uranium's Last Hope' on the south side of the Buller Gorge in 1960. Back (left to right): geologists Reg Sprigg and Bill Watters, and company owner Tas McKee. Front (left to right): prospectors George Sheldon and Tom Cross. (Photo courtesy of Jock Braithwaite).

South of the Buller River, and stratigraphically higher in the Hawks Crag Breccia, at least one mineralised lens up to 1.2 m thick is present, but continuity along bedding was nowhere proved for more than 90 m (Williams 1974). The main primary mineral is uraninite and there is a much wider range of associated sulphides such as pyrite and chalcopyrite (Cohen et al. 1969).

Average grades are up to 0.1% U_3O_8 over a limited section, but are generally much less. The vanadium content is very low at about 0.03%. Beryllium and molybdenum are geochemically anomalous.

Bullock Creek, Pororari River (K30/e48): Some 16 uraniferous zones have been found within the Hawks Crag Breccia and the underlying Watson Formation (Hope et al. 1959; Klaric 1967; Laird 1988). In the Hawks Crag Breccia, uranium mineralisation is highly lenticular and is associated with red granite boulders and thin carbonaceous seams. In the Watson Formation (Pororari Formation of Hope et al. 1959), more continuous uraniferous horizons occur in gritty sandstone and siltstone with carbonaceous radioactive seams and interbeds. The primary minerals thucholite and uraninite have been identified. Average grades are in the range of 0.15-0.03% U_3O_8.

CRA found that the uraniferous outcrops were lenticular, small and scattered. Assay results at five localities ranged from 0.46 to 0.82 lb U_3O_8 per short ton (2000 lbs), equivalent to 0.04%. Sample widths ranged from 0.8 to 1.8 m, with outcrop lengths possibly up to 100 m (Riley 1969).

Subsequent work by Lime & Marble Ltd (Buller Uranium Limited; Riley 1969) included additional field surveys and the driving and sampling of 35 m adits at two of the CRA localities. Average grades from the two localities were 0.5 and 0.59 lbs U_3O_8/short ton, calculated over a mining width of 1.2 m, approximately equivalent to 0.025 and 0.03 wt % radiometric. The highest grade obtained was 6.4 lbs (0.32%) over 0.3 m.

Fox River mouth (K30/e47): Carbonaceous streaks that are weakly radioactive (0.2-0.3 R/hr) are found at the southern end of a 300 m long outcrop of leached Hawks Crag Breccia south of the mouth of the Fox River (Beck et al. 1958). Whittle (in Williams 1974, p. 207) reported sporadic uraninite grains up to 3 mm in diameter, in association with "abundant" chalcopyrite.

Big River: Hope et al. (1959) noted that weak radioactivity had been detected in bedded material consisting of granite cobbles in an arkosic matrix.

Waitahu River: The Hawks Crag Breccia consists of alternating beds similar to the Blackwater facies and Tiroroa "B" facies in the Buller Gorge. Bedding is indistinct, except in places where sandstone bands occur. Low levels of radioactivity have been detected in some beds of the Tiroroa facies

The Waitahu Breccia occurrence consists mainly of granite fragments of varying size, though a certain amount of hornfelsic sandstone may be seen in some outcrops.

Other occurrences: Occurrences have also been reported from a trachyte dike within Hawks Crag Breccia in Batty Creek (Beck et al. 1958), in a quartz veinlet in granitoids at Sinclairs Castle (Beck et al. 1958), and in hornfels and granite boulders within the Hawks Crag Breccia from Big River and the Buller Gorge (Wodzicki 1959b). At Batty Creek, uranium is concentrated in veins and aggregates of zircon traceable over a distance of more than 40 m, with a maximum grade of 0.28% U_3O_8. The Big River biotite hornfels boulder described by

Wodzicki contained 0.18% U_3O_8, but the uranium-bearing phase could not be identified. Biotite granite from the same area contained 0.025% U_3O_8. Biotite hornfels boulders from Batty Creek in the Buller Gorge were strongly radioactive (0.2%), and contained uraninite, the first occurrence identified in New Zealand (Wodzicki 1959a).

Assessment

We suggest a 29% probability of resources equivalent to the model size, equating to an estimated resource of 580 t U.

13.14 ZINC AND LEAD

13.14.1 Zn-Pb polymetallic vein type zinc and lead deposits (Figure 113)

International model

References

USGS model 22c Polymetallic veins and USGS model 25b Creede epithermal veins (Cox & Singer 1986), and BCGS model I05 Polymetallic veins Ag-Pb-Zn±Au (Lefebure & Höy 1996).

Description

Sulphide-rich veins containing sphalerite, galena, silver and sulphosalt minerals in a carbonate and quartz gangue. These veins can be subdivided into those hosted by metasediments and another group hosted by volcanic or intrusive rocks. The latter type of mineralization is typically contemporaneous with emplacement of a nearby intrusion. The veins are typically steeply dipping, narrow, tabular or splayed. They commonly occur as sets of parallel and offset veins. Individual veins vary from centimetres up to more than 3 m wide and can be followed from a few hundred to more than 1000 m in length and depth. Veins may grade into broad zones of stockwork or breccia.

International examples

Metasediment host: Coeur d'Alene district, Idaho, USA; Harz Mountains and Freiberg district, Germany; Pribram district, Czech Republic.

Igneous host: Sunnyside and Idorado, Silverton district and Creede, Colorado, USA; Pachuca, Mexico.

Grade-tonnage data

Individual vein systems range from several hundred to several million tonnes grading from 5 to 1500 g/t Ag, 0.5 to 20% Pb and 0.5 to 8% Zn. The 50th percentile for polymetallic veins given by Cox in Cox & Singer (1986) is 7600 t at 820 g/t Ag, 0.13 g/t Au, 9% Pb and 2.1% Zn for 684 t Pb, 160 t Zn, 200,390 oz Ag and 32 oz Au.

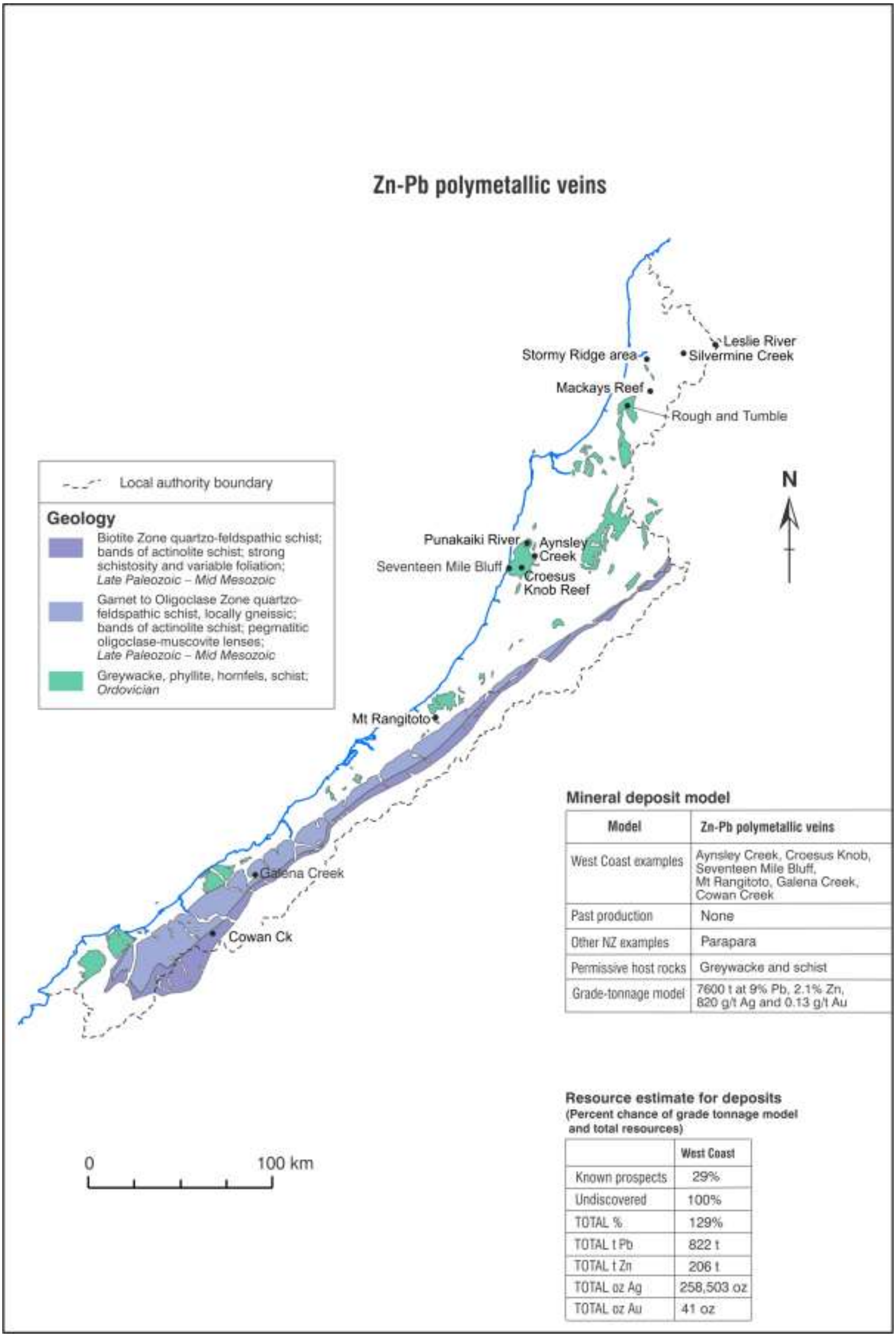
West Coast deposits

Zinc and lead mineralisation are reported principally as accessory sulphides (e.g. sphalerite and galena) in gold-bearing quartz veins in Greenland Group metasedimentary rocks (e.g. Mt Rangitoto), and in base-metal sulphide veins in granitoids, both included here as polymetallic veins. Galena has also been reported in carbonatite dikes and sills of the Haast area (e.g. Cowan Creek; Hawke 1984; Cooper 1986).

Sphalerite and rare galena and lead sulphosalts have been reported in greisen mineralisation at Barrytown (K31/e63), and assays of stream sediment samples from this locality ranged from 18 to 360 ppm Zn (threshold 180) and 12 to 240 (threshold 100) ppm Pb (MacKenzie & Price 1985).

Assessment

We suggest a 129% probability of resources equivalent to the model size, equating to an estimated resource of 882 t Pb, 206 t Zn, 258,503 oz Ag and 41oz Au.



Mineral deposit model

Model	Zn-Pb polymetallic veins
West Coast examples	Aynsley Creek, Croesus Knob, Seventeen Mile Bluff, Mt Rangitoto, Galena Creek, Cowan Creek
Past production	None
Other NZ examples	Parapara
Permissive host rocks	Greywacke and schist
Grade-tonnage model	7600 t at 9% Pb, 2.1% Zn, 820 g/t Ag and 0.13 g/t Au

Resource estimate for deposits
(Percent chance of grade tonnage model and total resources)

	West Coast
Known prospects	29%
Undiscovered	100%
TOTAL %	129%
TOTAL t Pb	822 t
TOTAL t Zn	206 t
TOTAL oz Ag	258,503 oz
TOTAL oz Au	41 oz

Figure 113 Location of zinc-lead occurrences from the GERM database, and areas of rocks prospective Zn-Pb polymetallic veins.

13.15 ZIRCONIUM

13.15.1 Placer Zr (Figure 114)

Model

Description

Detrital zircon in the heavy mineral fraction of beach sands.

Grade-tonnage data

We have assigned a model size of 0.5 Mt zircon.

West Coast deposits

Zircon ($ZrSiO_4$) is one of the principal minor constituents of ilmenite beach sands, and may comprise up to 1% of the total deposit on the northern beaches of the West Coast (Minehan 1989). Grains range from locally-derived sharply euhedral crystals to well worn anhedra. Colour ranges from colourless to pale pink or to purple (hyacinth), which may be radioactive (Hutton 1950). Localities are listed in the GERM database as I33/e2, e3; J32/e47, e74; J33/e45, e46; J33/e81, e82; K29/e4, e27, e44-e50, e70, e82, e110; K31/e62, e70, e74, e80.

Reconnaissance surveys were made by the Department of Scientific and Industrial Research in the 1950s-1970s, and were followed by prospecting and exploration by Buller Minerals and Carpentaria Exploration (see Titanium section).

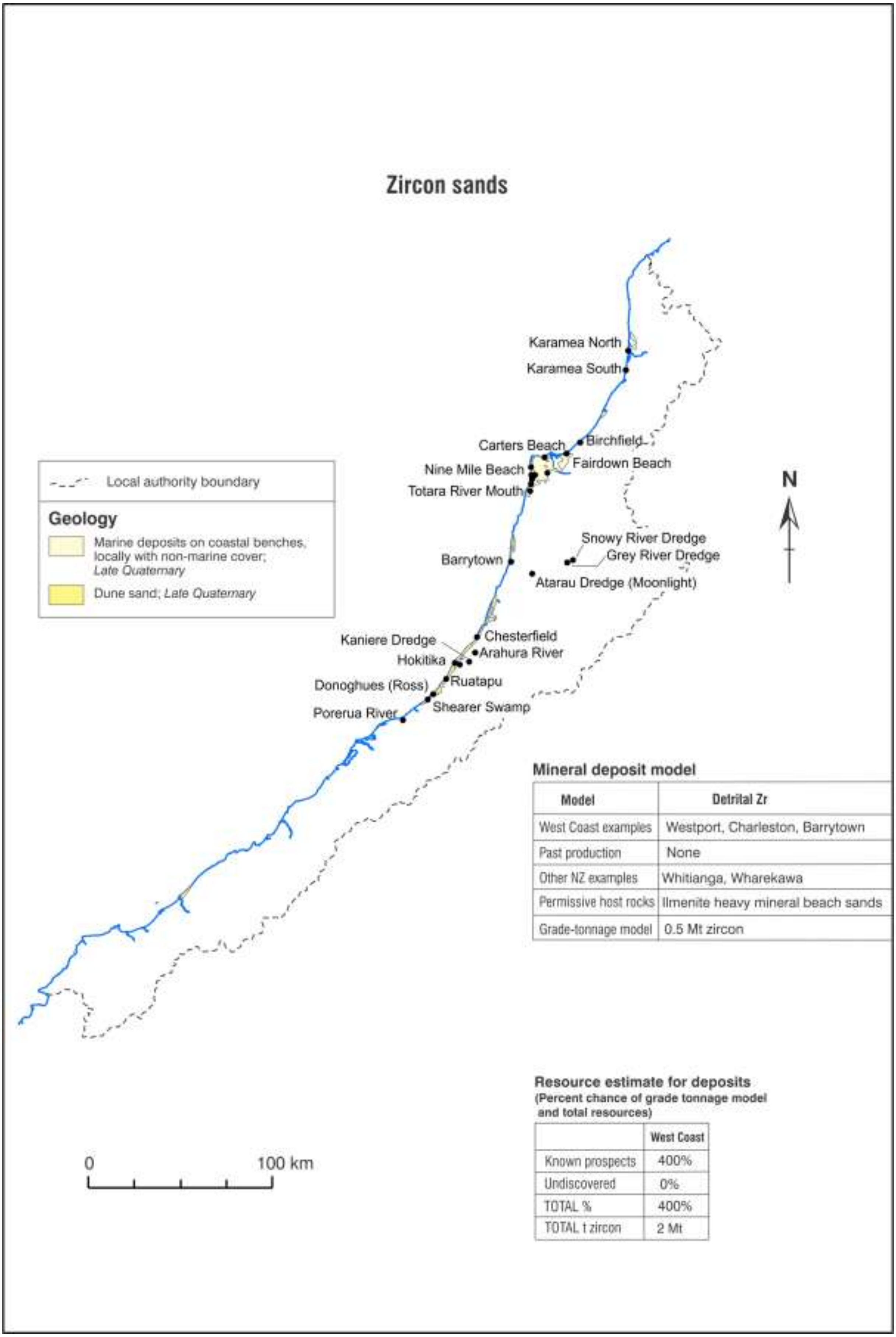
Zircon and ilmenite-bearing sand occupies beaches and dunes on the present active coast and also a succession of four or five late Pleistocene raised beaches initially mapped by Suggate (1965) and later by McPherson (1967, 1978), Nathan (1975, 1976, 1978a, 1978b), and Laird (1988) (see also Nicholson 1967). The greatest potential for extraction, along with the ilmenite, is from the present beaches and dunes of the Nine Mile Formation and younger, least weathered or cemented raised beach deposits, identified as Waites and Virgin Flat formations in the north, and as Awatuna Formation in the south.

McPherson (1967, 1978) estimated the extractable resource of zircon present in the Nine Mile, Waites, and Awatuna formations in the vicinity of Westport to be 0.93 Mt. Hancock & Associates (1980) estimated zircon resources at Westport, Charleston, and Barrytown at 0.5 Mt each.

Zircon also occurs as a minor constituent of most of the basement rock lithologies of the West Coast as well as within stream and river gravel. Beck et al. (1958) reported 6.4% ZrO_2 from a porphyry in the Buller Gorge, and Wodzicki (1959b) reported significant levels from boulders within the Hawks Crag Breccia. Average zirconium content for the Rahu Suite, which dominates the granitoid rocks of the Greymouth Sheet, is 119 ppm (73 samples) (A.J. Tulloch pers. comm. 1992).

Assessment

We suggest a 400% probability of resources equivalent to the model size, equating to an estimated resource of 2Mt of zircon.



Model	Detrital Zr
West Coast examples	Westport, Charleston, Barrytown
Past production	None
Other NZ examples	Whitianga, Wharekawa
Permissive host rocks	Ilmenite heavy mineral beach sands
Grade-tonnage model	0.5 Mt zircon

	West Coast
Known prospects	400%
Undiscovered	0%
TOTAL %	400%
TOTAL t zircon	2 Mt

Figure 114 Location of zircon occurrences from the GERM database, and areas prospective Placer Zr deposits.

14.0 NON-METALLIC MINERALS AND ROCKS

14.1 ASBESTOS

14.1.1 Ultramafic-hosted asbestos (Figure 115)

International model

USGS model 8d Serpentine-hosted asbestos (Cox & Singer 1986) and BCGS model M06 Ultramafic-hosted asbestos (Hora 1998a).

Description

Chrysotile asbestos occurs as cross fibre and/or slip fibre stockworks, or as less common agglomerates of finely matted chrysotile fibre, in serpentinized ultramafic rocks. Serpentinites may be part of ophiolite sequences in orogenic belts or synvolcanic intrusions of Archean greenstone belts.

In plan, orebodies are equidimensional to somewhat oblate zones from 100 to 1000 m in diameter within masses of serpentinized ultramafic rock. The vertical distribution of mineralized zones may be in the order of several hundreds of metres.

Asbestos veins fill tension fractures in serpentinized ultramafic rocks or form a matrix of crushed and brecciated body of serpentinite. Usually, the orebodies grade from numerous stockwork veins in the centre to a lower number of crosscutting veins on the fringes. Cross-fibre veins, where the chrysotile fibres are at a high angle to the vein walls, are more abundant than slip fibre veins which parallel the vein walls. Individual veins are up to several metres in length and for the most part less than 1 cm thick, but may be up to 10 cm thick. In some deposits, powdery agglomerates of finely matted chrysotile form the matrix for blocks and fragments of serpentinite rock.

Examples

Thetford Mines, Black Lake, Asbestos, Quebec, Canada; Belvidere mine, Vermont, USA; Coalinga, California, USA; Cana Brava, Brazil; Pano Amiandes, Cyprus, Bazhenovo, Russia; Barraba, New South Wales; Barberton, Transvaal, South Africa.

Grade-tonnage data

Total fibre content of commercial deposits is between 3 and 10%, the tonnage is between 500,000 to 150 Mt. The very large Coalinga deposit in California has reported short fibre recoveries in the order of 35 to 74%. The Stragari mine in Serbia is recovering 50-60% fibre. USGS model 8d 50th percentile = 26 Mt at 4.6% asbestos fibre. The Pyke River deposits in South Westland are large, but relatively low in fibre and therefore we have assigned a model size of 20 Mt grading 2% fibre for 400,000 t of asbestos.

West Coast deposits

In the Pyke River area of the Red Mountain segment of the Dun Mountain Ophiolite Belt, large chrysotile asbestos deposits were discovered in 1969 (Babcock 1972, 1981; Williams 1974; Thompson 1989). The asbestos deposits are localised in serpentinised peridotite around the margins of peridotite-dunite blocks. The asbestos occurs mainly as cross-fibre chrysotile in structurally controlled veins and stockwork fractures within serpentinite.

Individual fibre deposits, with greater than 0.5% visible cross fibre, range in surface area from less than 550 m^2 up to 37,000 m^2 at average grades of about 2.3% cross fibre (Babcock 1981). These fibre deposits are contained in a larger zone of weak (<0.5% cross fibre) asbestos mineralisation which is almost continuous over a length of 4 km around the flanks of Little Red Hill. The deposits of the "North Side" of this zone are estimated from drill testing and surface sampling to contain 23 to 36 Mt of asbestos-bearing rock with a yield of 1.5-2.0% of good quality fibre (Lancaster 1977). Other smaller deposits of chrysotile asbestos in serpentinite have been found in the Red Mountain segment at Martyr Hill, McKay Creek, Harrys Choice, Four Brothers Pass, and Fiery Col (Babcock et al. 1973; Lancaster 1977).

Small quantities of asbestos of good quality occur in pockets and veins enclosed in talc-serpentinite rocks of the Pounamu Ultramafics. Morgan (1908, p 148) listed the main localities as near Mt Jumbletop (J33/e119), Tom and Dicks creeks, tributaries of the Whitcomb River, and Mount Bowen. Other localities include Magnetite Creek (K33/e63), McArthur Crags (K33/e64, e65, e66) and Station Creek, Matakitaki Valley (Officers of the New Zealand Geological Survey 1970b; Williams 1974).

Assessment

We suggest a 125% probability of resources equivalent to the model size, equating to an estimated resource of 500,000 t asbestos (25 Mt at 2% asbestos fibre).

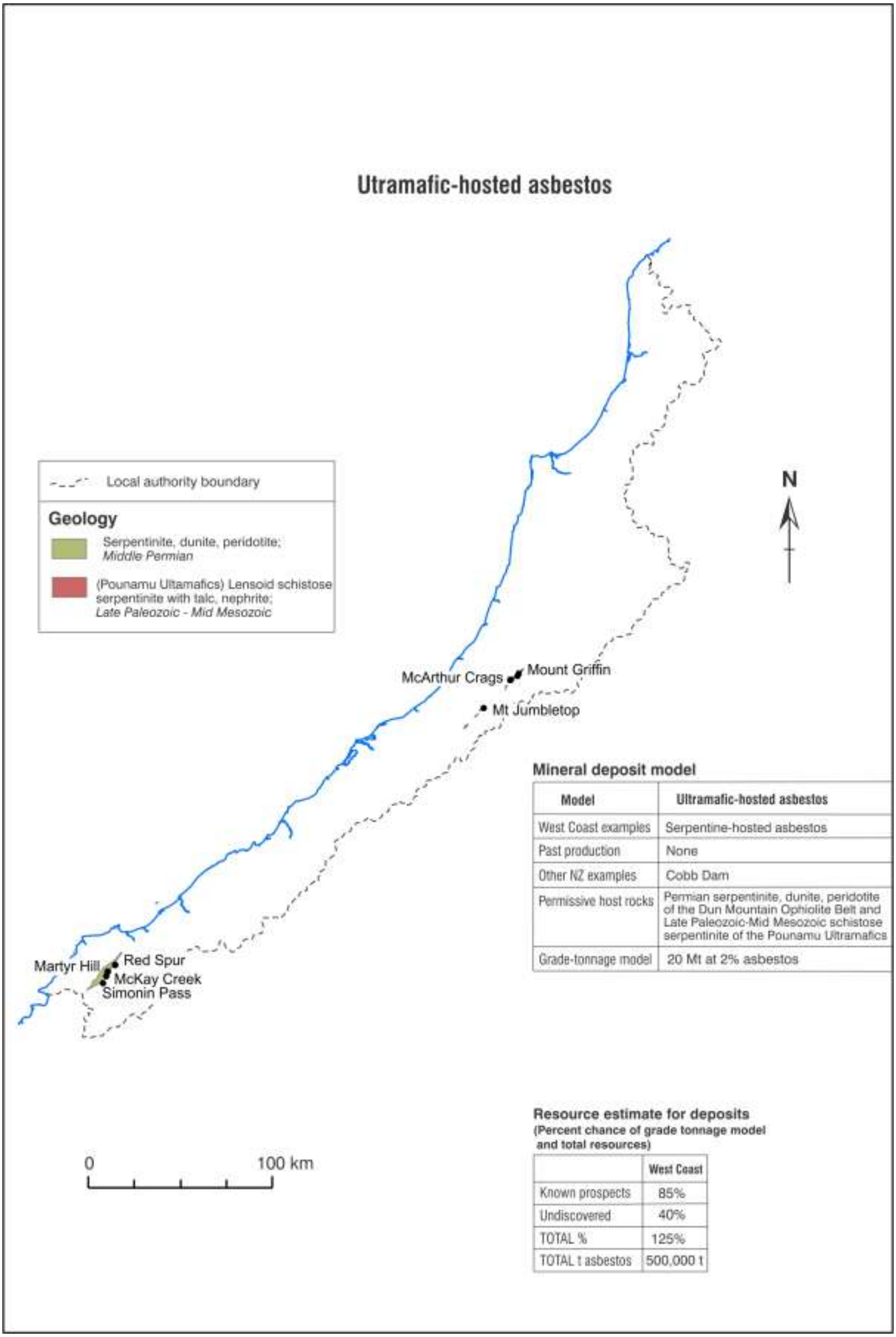


Figure 115 Location of asbestos occurrences from the GERM database, and areas of rocks prospective for Ultramafic-hosted asbestos deposits.

14.2 BARITE

14.2.1 Vein barite (Figure 116)

Model

BCGS model I10 vein barite (Lefebure & Höy 1996)

Description

Barite in fissure-filling voids resulting from mechanical deformation, including dilatant zones along faults and folds, gash fractures, joints and bedding planes; also in shear and breccia zones along faults. The deposits are tabular/lenticular bodies and breccias, collapse breccias and related cavity fills, veins with manto-type orebodies in carbonate host rocks. The veins are several hundreds to over 1000 m in length and some are up to 20 m thick. Some veins are mined to a depth of 500 m below surface.

Examples

Bonarta, Jbel Ighoud, Morocco; Wolfach, Bad Lauterberg, Germany; Roznava, Slovakia; Matchewan, Ontario, Lake Ainslie, Nova Scotia; Collier Cove, Newfoundland.

Grade-tonnage data

Most deposits in production are selectively mining high grade orebodies with over 80% barite. The deposit size varies from a few thousand up to some 3 Mt. Deposits at Thompson Hill are individually less that 3000 t grading approximately 50% $CaSO_4$. We have assigned a model size of 5000 t at 50% $BaSO_4$.

West Coast deposits

Barite veins are present in coal measure grits, 3-5 km southeast of Millerton (Morgan & Bartrum 1915), and 2.5 km southwest of the Stockton coal mine (Gage 1944). They are up to 23 cm in width, up to 140 m long, have a steep to vertical dip, and strike north to northwest. Barite also occurs in fluorite veins in the Buller Gorge area (Sinclairs Castle) and in quartz veins hosted in quartz porphyry at Coalbrookdale where the veins have a maximum thickness of about 75 mm and maximum length of 1 m.

Hutton (1950) noted traces of barite in concentrates from the Grey River gold dredge.

Assessment

We suggest a 40% probability of resources equivalent to the model size, equating to an estimated resource of 2000 t at 50% $BaSO_4$.

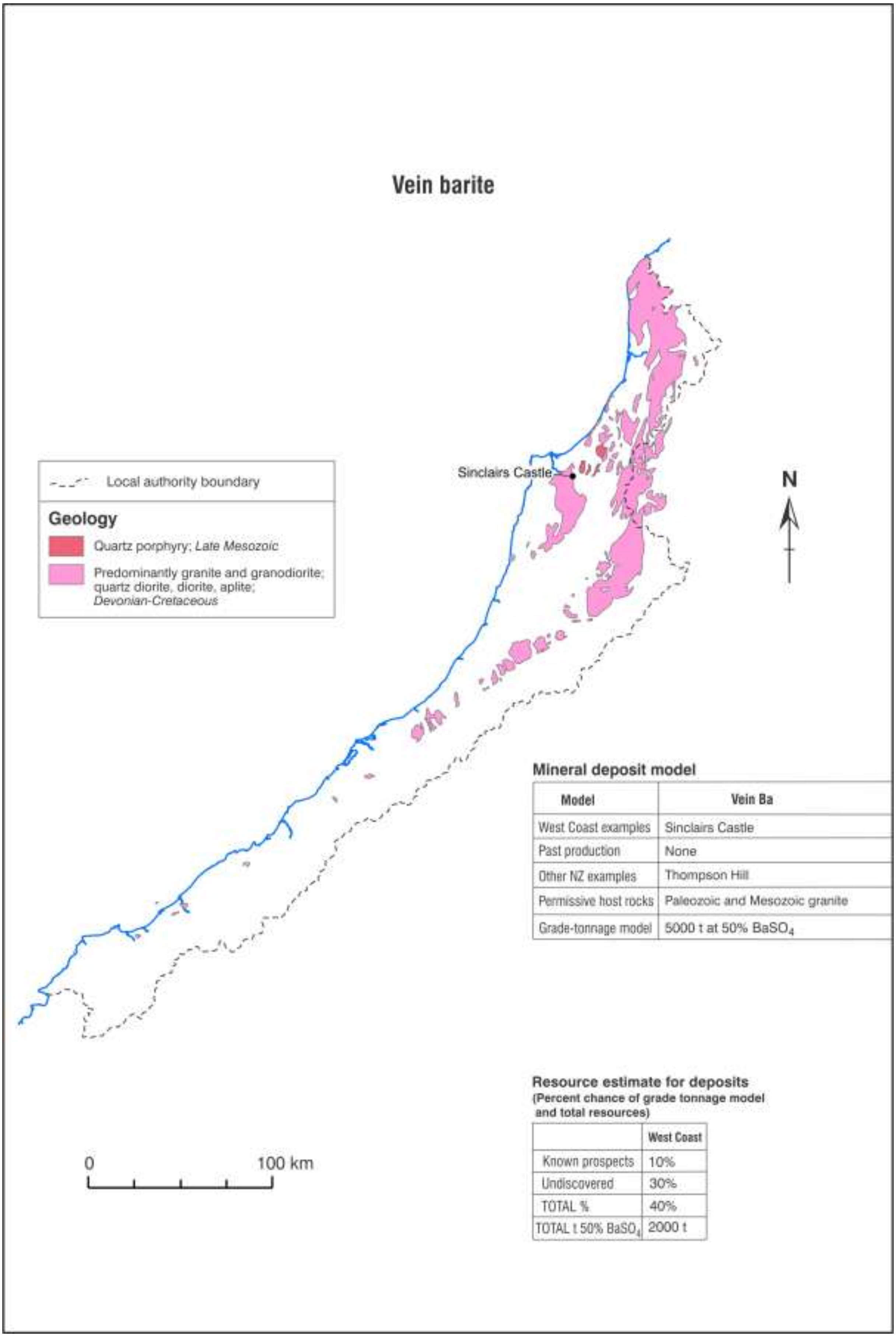


Figure 116 Location of barite occurrences from the GERM database, and areas of rocks prospective for vein barite deposits.

14.3 CLAYS

14.3.1 Coal measure clay (Figure 117)

Model

Description

Clay deposits associated with coal measures originate as primary sedimentary deposits or as deposits of mudstone that have been acid leached to produce fire clays. The fireclays are usually plastic, refractory and burn to pale colours. The kaolinite bearing beds are associated with coal (sub-bituminous and lignite), mudstone, siltstone, sandstone and conglomerate. The beds exhibit variable thickness, usually a few metres; sometimes multiple beds have an aggregate thickness of approximately 20 m. Deposits commonly extend over areas of at least several square kilometres. The kaolinite may be associated with quartz, and minor limonite, goethite, feldspar, mica, siderite, pyrite, ilmenite, leucoxene and anatase may be present.

Grade and tonnage data

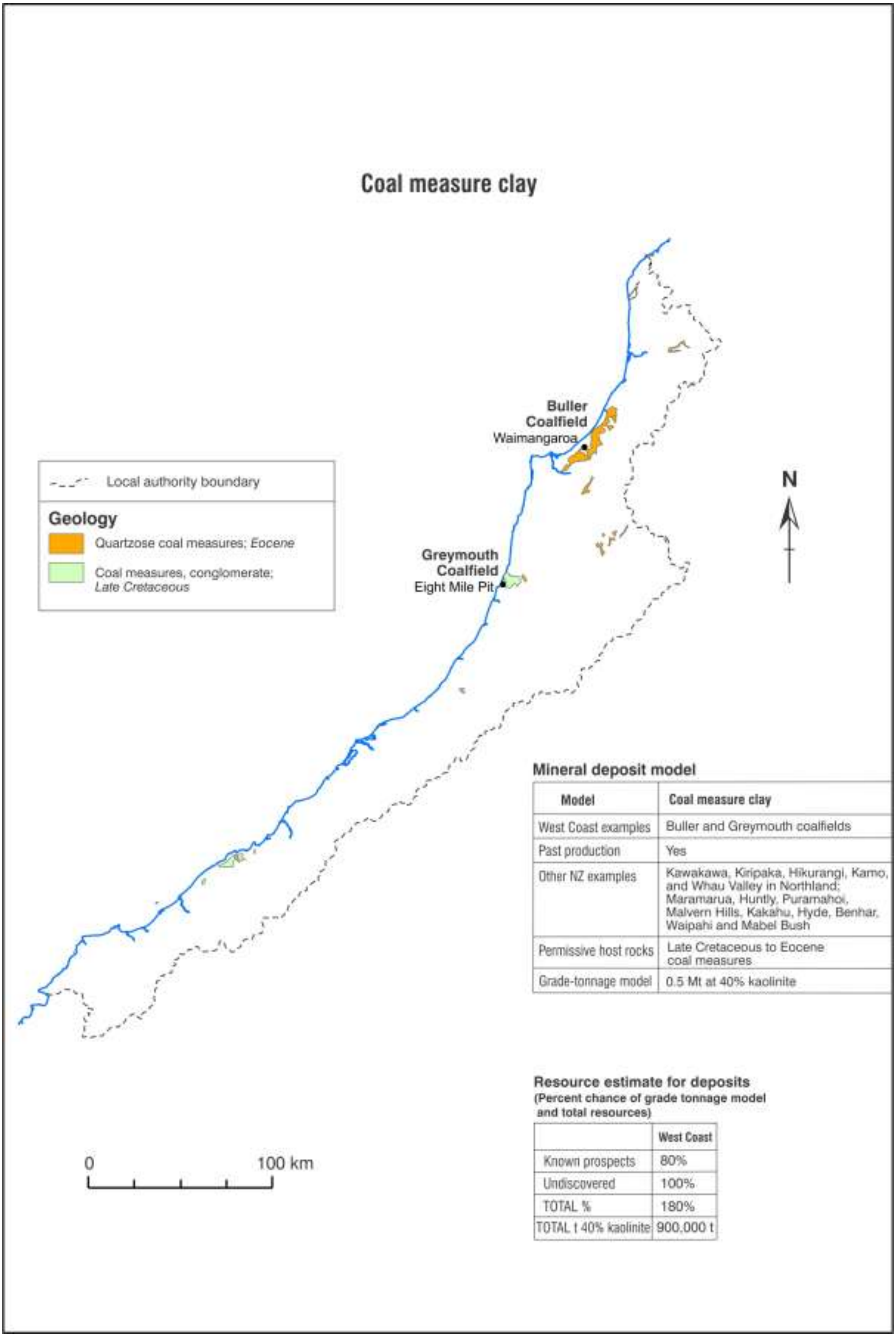
Christie & Barker (2007) suggested 0.5 Mt at 40% kaolinite for a Northland model which we use here for the West Coast.

West Coast deposits

Kaolinitic clay deposits are present in some coal measures, as products of deep weathering of basement rocks, and in some Tertiary mudstone units (e.g. Blue Bottom Group). Fireclays are present as "underclays" immediately beneath coal seams, and as thin, distinct beds which may be fossil soils, in the Brunner Coal Measures and Dunollie Coal Measure member throughout the Greymouth Coalfield. The floor clay of the main Brunner seam was worked in conjunction with the coal in several mines and was used for making firebricks and building bricks. More recently, coal seam underclay has been extracted at Eight Mile Pit (J31/e21). The clay is mostly kaolinite although some is siliceous, and mica is present in small quantities. Fireclays are less common in the Buller Coalfield, although an 0.6 m thick clay bed, occurring locally between two thick coal seams, was worked in the Ironbridge mine at Denniston (Henderson 1943). Clay has recently been produced from Brunner Coal Measures at Waimangaroa (K29/e16).

Assessment

We suggest a 180% probability of resources equivalent to the model size, equating to an estimated resource of 900,000 t of 40% kaolinite.



Mineral deposit model

Model	Coal measure clay
West Coast examples	Buller and Greymouth coalfields
Past production	Yes
Other NZ examples	Kawakawa, Kiripaka, Hikurangi, Kamo, and Whau Valley in Northland; Maramarua, Huntly, Puramahoi, Malvern Hills, Kakahu, Hyde, Benhar, Waipahi and Mabel Bush
Permissive host rocks	Late Cretaceous to Eocene coal measures
Grade-tonnage model	0.5 Mt at 40% kaolinite

Resource estimate for deposits
(Percent chance of grade tonnage model and total resources)

	West Coast
Known prospects	80%
Undiscovered	100%
TOTAL %	180%
TOTAL t 40% kaolinite	900,000 t

Figure 117 Areas of rocks prospective for Coal measure clay deposits.

14.3.2 Clay from weathering and sedimentary clay (Figure 118)

Clay from weathering: USGS models 21k.3 Sedimentary kaolin and 38h Residual kaolin (Orris 1998) and BCGS model E07 Sedimentary kaolin (Hora 1998b).

Model

Clay from weathering: Kaolinitic clays formed by weathering of feldspathic rocks may be sufficiently concentrated to form residual clay deposits (Harvey & Murray 1997).

Sedimentary clay: Kaolinitic clays formed by weathering of feldspathic rocks are eroded and transported to estuaries, lagoons, oxbow lakes and ponds forming beds, lenses and saucer-shaped bodies of clay (Harvey & Murray 1997). These are hosted by clastic sedimentary rocks, with or without coaly layers or coal seams. Diatomite deposits may also be present. Kaolinite is the main mineral, and halloysite, quartz, dickite, nacrite, diaspore, boehmite and gibbsite may be present. Post-depositional leaching, oxidation, and diagenesis can significantly modify the original clay mineralogy with improvement of kaolin quality.

The clay beds exhibit variable thickness, usually a few metres; sometimes multiple beds have an aggregate thickness of approximately 20 m. Deposits commonly extend over areas of at least several square kilometres.

International examples of weathering and sedimentary clay deposits

Cypress Hills, Alberta, Canada; Eastend, Wood Mountain, Ravenscrag, Saskatchewan, Canada; Moose River Basin, Ontario, Canada; Shubenacadie Valley, Nova Scotia, Canada; Aiken, South Carolina, USA; Wrens, Sandersville, Macon-Gordon, Andersonville, Georgia, USA; Eufaula, Alabama, USA; Weipa, Queensland, Australia; Jari, Capim, Brazil.

Grade and tonnage data

Published data on individual deposits are scarce. Deposits in Georgia, USA contain 90 to 95% kaolinite. Individual Cretaceous beds are reported to be up to 12 m thick and extend more than 2 km while those in the Tertiary sequence are 10 to 25 m thick and up to 18 km along strike. The Weipa deposit in Australia is 8 to 12 m thick and contains 40 to 70% kaolinite. In Brazil, the Jari deposit contains more than 250 Mt of commercial grade kaolin, and the Capim deposit contains greater than 200 Mt of kaolin. Ball clay deposits in Tennessee and Kentucky consist of kaolin with from 5 to 30% silica; individual deposits may be more than 9 m thick and extend over areas from 100 to 800 m long and up to 300 m wide.

We suggest a model size of 0.5 Mt at 50% kaolinite for these types of clay deposits.

West Coast deposits

Clay from weathering: Clay formed by the deep weathering of gneiss, granite, or greywacke basement rocks is present beneath the Tertiary sedimentary rocks at a few locations, and consists mainly of kaolinite with some quartz and mica. Some is suitable for use as fireclays after appropriate beneficiation. The best material occurs at Charleston, formed from the weathering of gneiss, and was mined in the White Horse quarry (K29/e24) and Bromielow Pit (K30/e4).

Sedimentary: Some of the mudstone units of the Tertiary sedimentary sequence have been worked as brick clay. Clay has been mined from mudstone of the Blue Bottom Group in the

Greymouth area and used for making firebricks (Morgan 1911; Gage 1952; Nathan 1978a). Morgan & Bartrum (1915) noted that the Kaiata mudstone and Port Elizabeth beds are other potential sources, as is clay at McLeod Terrace near Ross noted by Morgan (1908).

Assessment

We suggest a 140% probability of resources equivalent to the model size, equating to an estimated resource of 700,000 t of 40%.

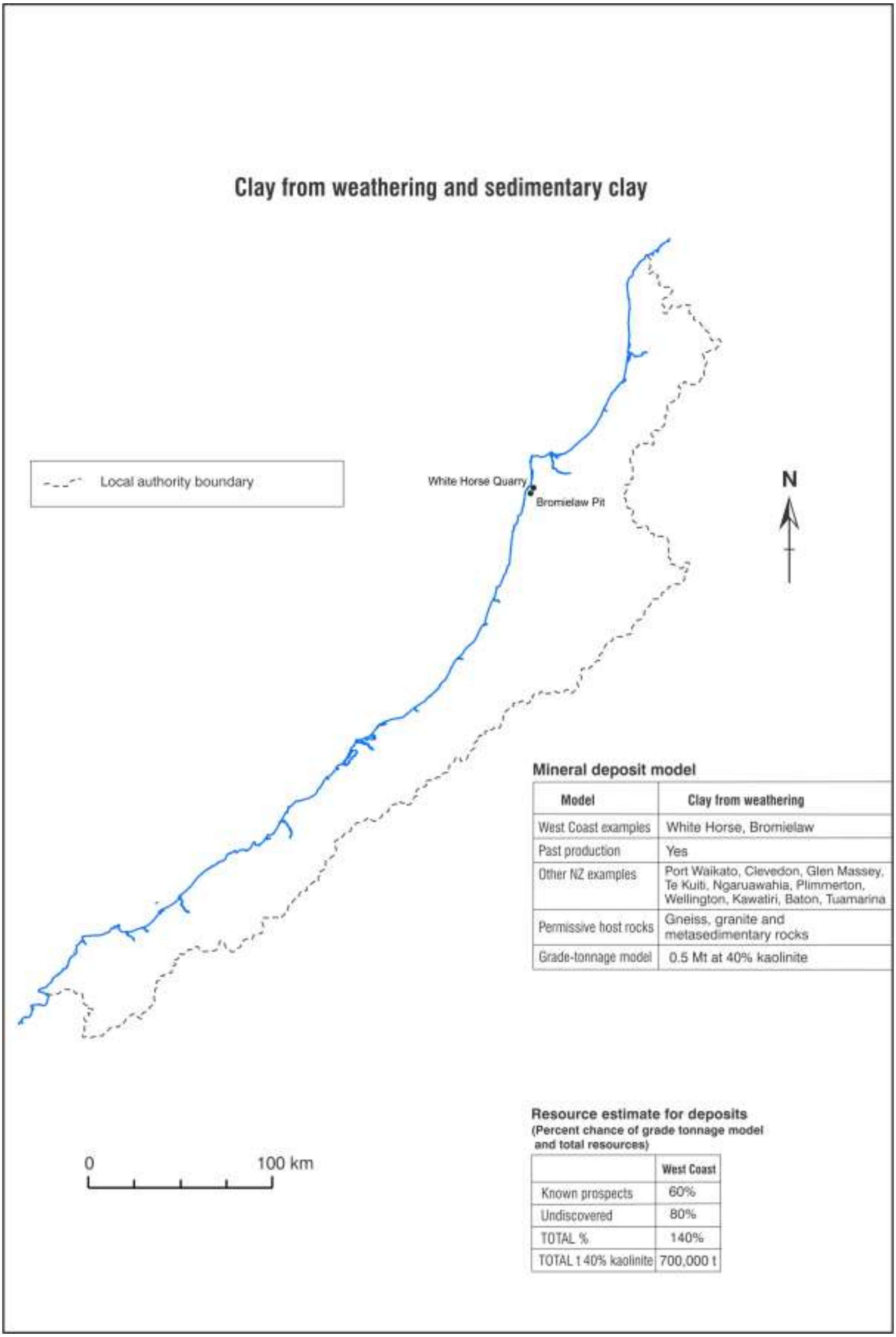


Figure 118 Location of clay occurrences from the GERM database relating to the Clay from weathering and sedimentary clay mineral deposit models.

14.4 FELDSPAR

14.4.1 Feldspar in pegmatites (Figure 119)

International model

International model

BCGS model O04 Feldspar-quartz pegmatite.

Description

Feldspar in pegmatite and aplite dikes in granites.

Grade and tonnage data

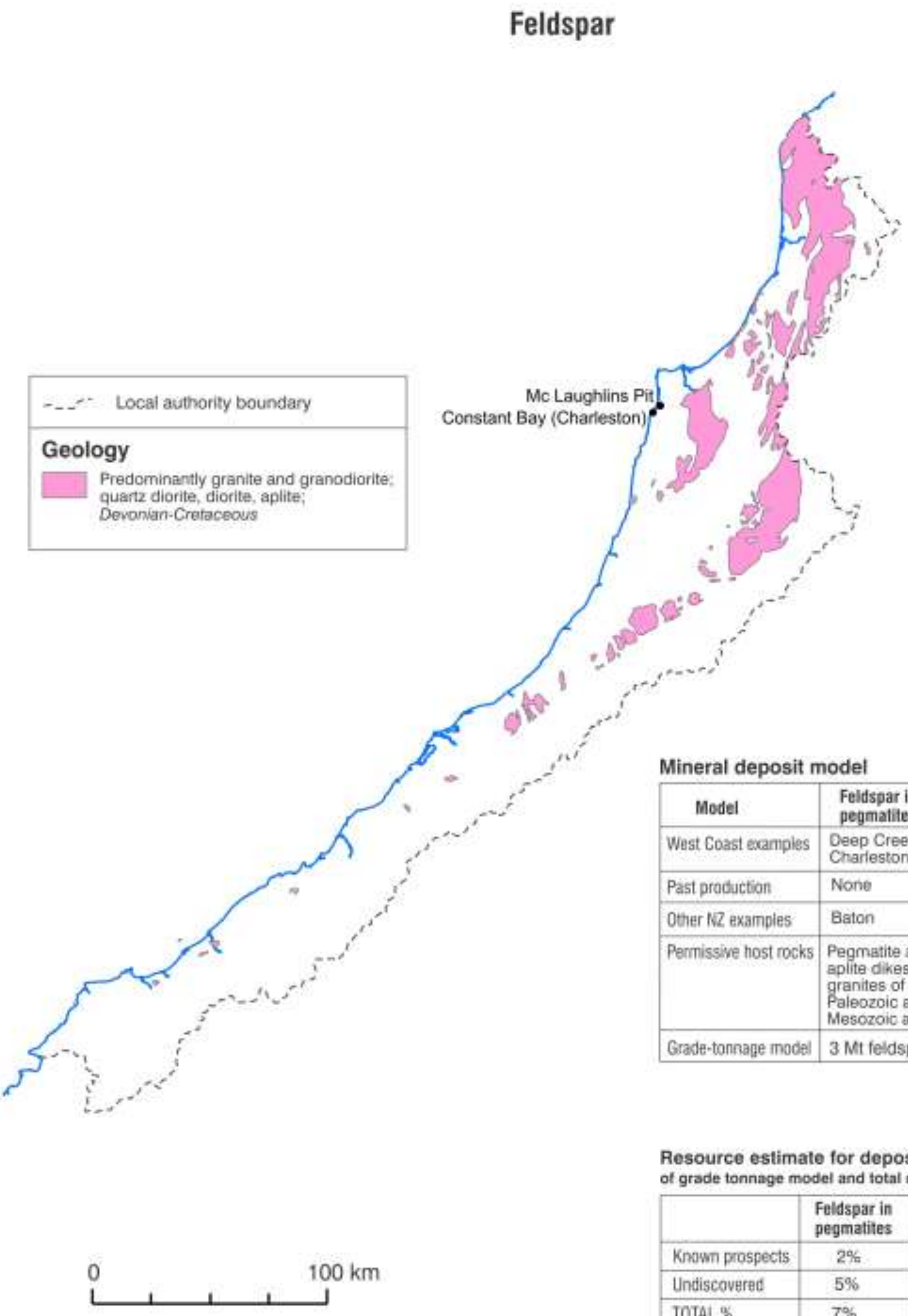
No published international model. We suggest a model size of 3 Mt of contained feldspar.

West Coast deposits

Feldspar is a major constituent of the granitoid suites of the West Coast, and pegmatites are relatively common. The region has not been extensively prospected for this commodity. Feldspar was reported at Constant Bay (K29/e95) near Charleston as a component in pegmatite dikes which were mined for mica (Henderson 1950; Anon 1962; Young 1963). Anon (1962) noted that hand picked material was of good quality. Henderson (1950) considered that the feldspar content of the dikes was at most 30% and resources were described as small. However, Young (1963) suggested that prospecting should be undertaken to find additional dikes.

Assessment

We suggest a 7% probability of resources equivalent to the model size, equating to an estimated resource of 210,000 t of feldspar.



Mineral deposit model

Model	Feldspar in pegmatites	Feldspar in weathered granite
West Coast examples	Deep Creek, Charleston	None
Past production	None	None
Other NZ examples	Baton	Baton Saddle
Permissive host rocks	Pegmatite and aplite dikes in granites of Paleozoic and Mesozoic age	Granites of Paleozoic and Mesozoic age
Grade-tonnage model	3 Mt feldspar	2 Mt feldspar

Resource estimate for deposits (Percent chance of grade tonnage model and total resources)

	Feldspar in pegmatites	Feldspar in weathered granite
Known prospects	2%	0%
Undiscovered	5%	5%
TOTAL %	7%	5%
TOTAL t	210,000 t	100,000 t

Figure 119 Location of feldspar occurrences from the GERM database, and areas of rocks prospective for Feldspar in pegmatites and Feldspar in weathered granite deposits.

14.4.2 Feldspar – weathered granite (Figure 119)

14.4.3 International model

No published international model.

Description

Residual feldspar produced from weathering of granite plutons.

Grade and tonnage data

No published international model. We suggest a model size of 2 Mt of contained feldspar.

West Coast deposits

Although no West Coast examples are known, the abundance of granites in the region suggests there is potential for deposits of weathered feldspar.

Assessment

We suggest a 5% probability of resources equivalent to the model size, equating to an estimated resource of 100,000 t of feldspar.

14.5 FLUORITE

14.5.1 Vein F (Figure 120)

International model

References

BCGS model Vein fluorite-barite I11 (Lefebure & Höy 1996).

Description

Fluorite and barite fill dilatant shear and breccia zones along faults and folds, gash fractures, joints and bedding planes as well as stockworks. They form tabular or lenticular bodies and breccias or stockworks and breccia pipes. The veins are usually 1-5 m thick and may be over a 1000 m long. Some particularly large veins in Sardinia are 3 km in length and up to 20 m thick (Torgola vein). Some vein deposits were mined up to 500 m below surface, however the usual mining depth is 200 to 300 m down the dip from the outcrop.

International examples

Eaglet and Rexspar, British Columbia, Canada; Madoc, Ontario, Canada; St. Lawrence, Newfoundland, Canada; Nabburg-Woelsendorf, Ilmenau and Schoenbrunn, Germany; Torgola, Prestavel and Gerrai, Italy; Auvergne, Morvan, France; Mongolia, China.

Grade-tonnage data - international

Past producers reported grades in general between 30% and 60% fluorite, with occasional higher grade orebodies. The deposit size varies; up to 6 Mt. In British Columbia, Eaglet reported 1.8 Mt of 15% CaF_2, Rexspar 1.4 Mt of 23% CaF_2 (Lefebure & Höy 1996). We have selected 2 Mt at 20% CaF_2 for our model.

West Coast deposits

Wekakura: At Wekakura, near the mouth of the Heaphy River, thin veins, clusters, and lenticular patches of fluorite occur within granite of the Karamea Suite (Riley & Hume 1973). Limited reconnaissance geochemical surveys were carried out in this relatively inaccessible area, but failed to locate additional significant mineralisation, although the source of a stream sediment anomaly north of Bivouac Creek was not defined. Chip sampling at the most mineralised sites gave CaF_2 content in the range 0.16-0.36%, with the best channel sample at 5.4% over 3 m (Riley & Hume 1973).

Background levels of fluorine in the Karamea Suite and Rahu Suite granitoids range up to about 1000 ppm, contrasting with up to 500 ppm in the I-type Separation Point Suite (Tulloch & Robertson 1987).

Kehu Stream (K29/e68): In the headwaters of Kehu Stream, green fluorite veins, less than 0.3 m thick, cut Berlins Porphyry (Nathan 1978b), and a breccia pipe containing up to 30% fluorite was located in the Kehu pluton by AHI Minerals (Leach 1976). Stream sediment and rock chip fluorine concentrations decrease rapidly away from the known mineralisation. Walker (1981) briefly re-examined the occurrence, and concluded that the lens was not a breccia pipe and instead, interpreted it as a pneumatolytic replacement or fissure lens of limited extent.

Sinclairs Castle (K29/e69): The Sinclairs Castle occurrence consists of small veins in Railway Quartz Diorite (Beck et al. 1958; Leach 1976). Numerous minor occurrences of fluorite veining have been reported throughout the area, including sparse small veins in pink porphyry in Fluorite Creek, and fluorite-bearing float in Cascade, V37, and Rochfort Creeks (Bates 1978). Regional geochemistry in the Cascade Creek area, carried out as part of molybdenum prospecting by Gold Mines of New Zealand, reported maximum fluorine levels of 1080 ppm in 51 stream sediment samples, and 1530 ppm in rock samples, with only 9 values exceeding 100 ppm F (Bates 1978).

Assessment

We suggest a 16% probability of resources equivalent to the model size, equating to an estimated resource of 320,000 t at 20% CaF_2.

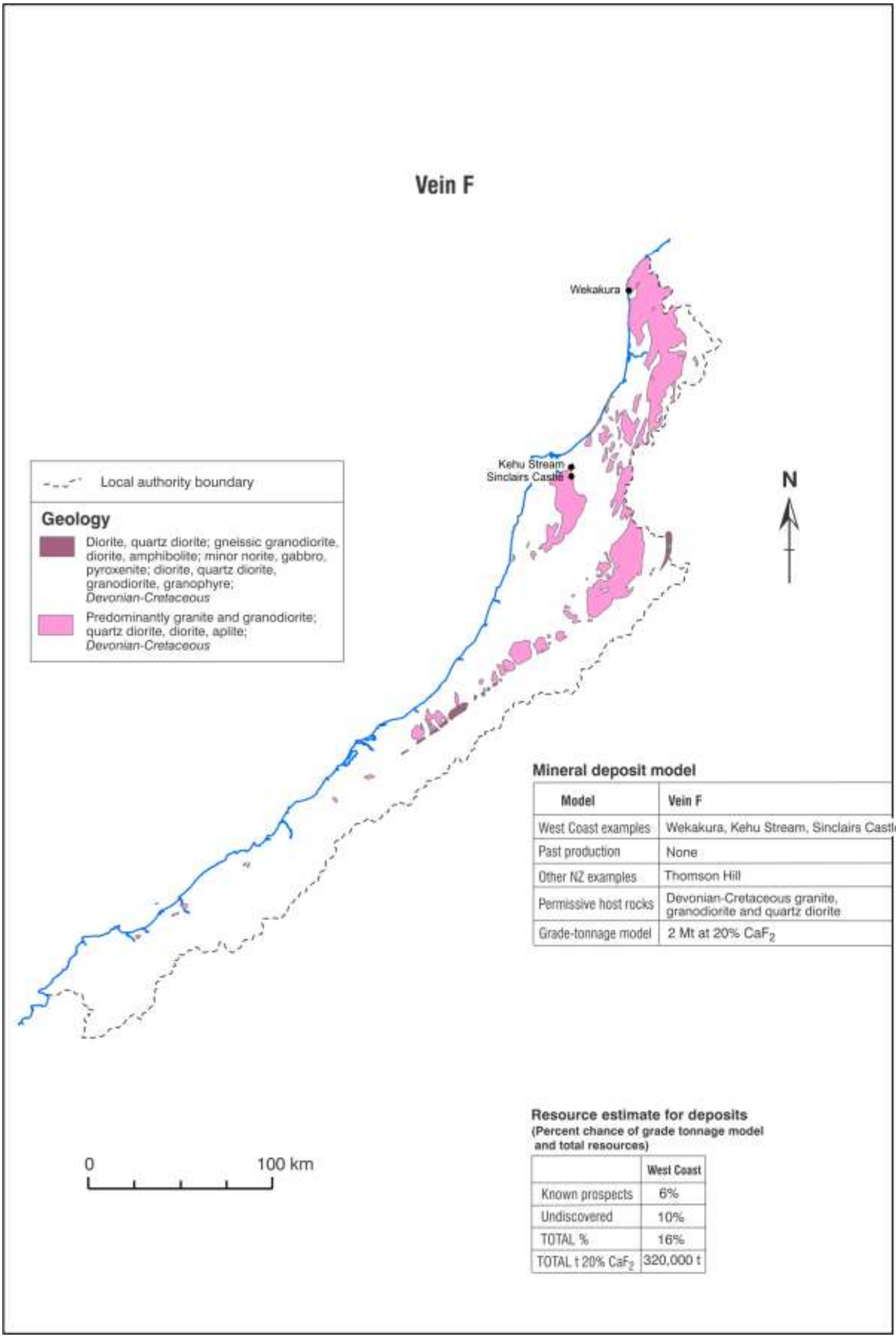


Figure 120 Location of fluorite occurrences from the GERM database, and areas of rocks prospective for Vein F deposits.

14.6 GARNET

14.6.1 Garnet (Figure 121)

Model

Description

Detrital garnet in heavy mineral beach sand.

West Coast deposits

Garnet is a minor constituent in most Quaternary fluvial and ilmenite beach sand deposits on the West Coast, but in the Westport area it is a major constituent in the ilmenite beachsand where it is typically twice as abundant as ilmenite. Composition is typically in the pyrope-almandine field, with minor andradite (Hutton 1950). Grain morphology is either angular or subrounded, suggesting two sources (McPherson 1978). The presence of angular grains in the Fox, Four Mile, and Totara rivers suggests local sources, probably from the Charleston Metamorphic Group gneiss. The well-rounded garnet is derived from the extensive garnet-zone schists in the Southern Alps, and has been transported northwards by longshore drift. Also, some garnet may have been reworked through intermediate deposits, perhaps Tertiary or Quaternary in age

Assessment

We have not estimated the resources of garnet. Minehan (1989) suggested that the West Coast beach sand garnet was of little economic value as an abrasive because of its very fine grain size, well rounded grain shape, and common shattered nature.

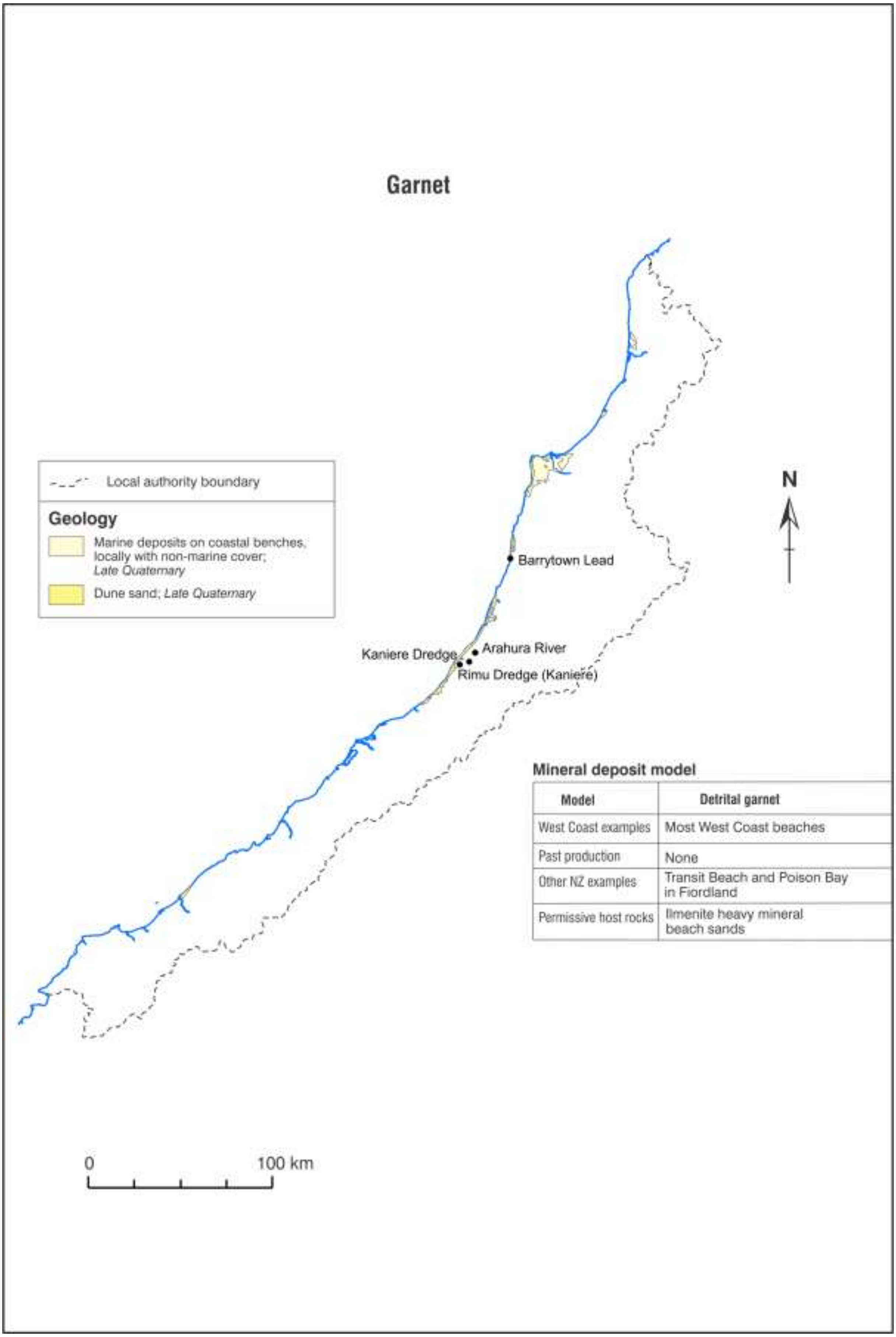


Figure 121 Location of garnet occurrences from the GERM database, and areas of sediments prospective for detrital garnet deposits.

14.7 MICA

14.7.1 Mica in pegmatites (Figure 122)

Model

USGS model 13f Mica-bearing pegmatite and BCGS model O03 Muscovite pegmatite.

Description

Mica in pegmatites.

Grade-tonnage data

No published international model. We suggest a model size of 5 Mt at 15% mica for 750,000 t mica.

West Coast deposits

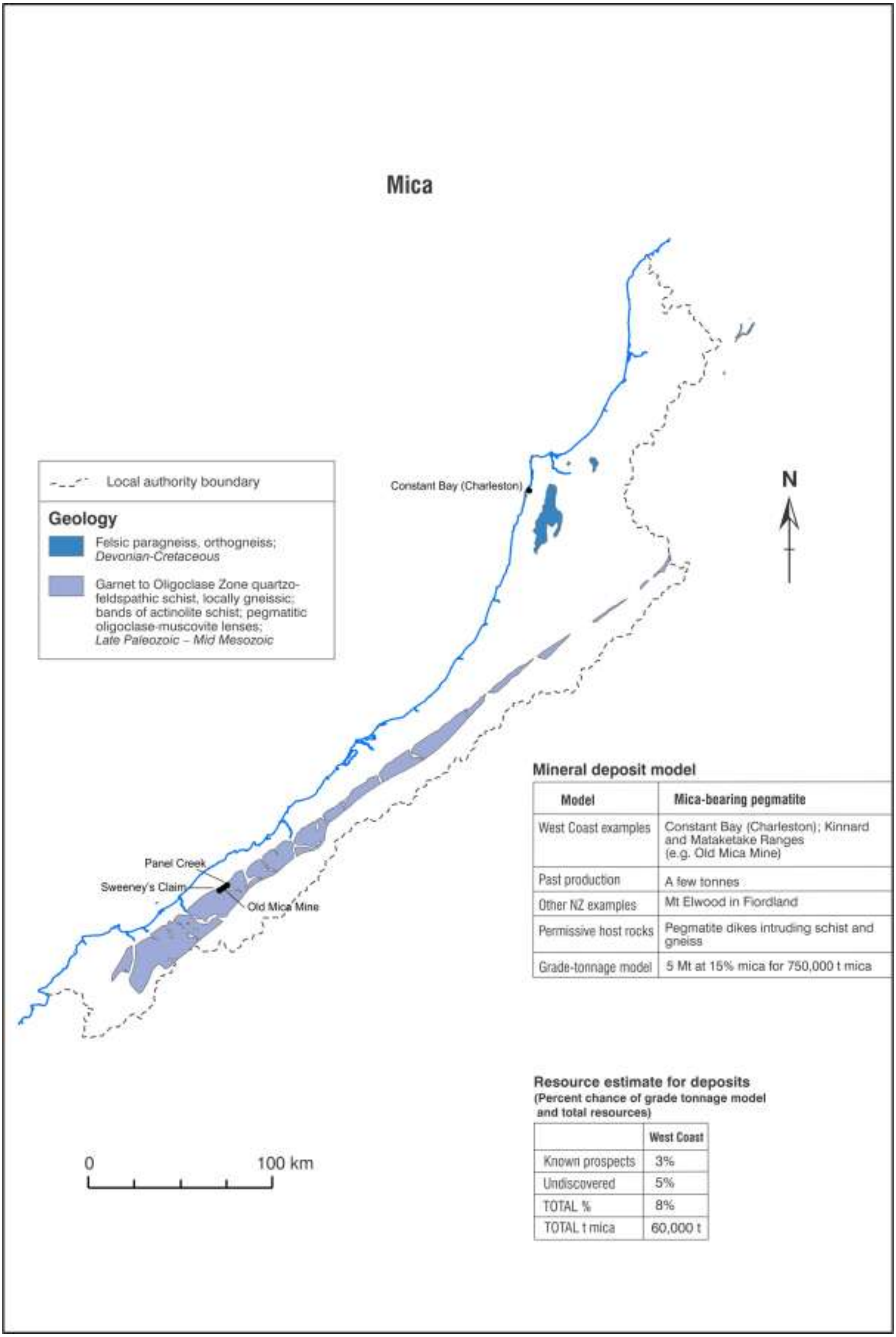
Constant Bay (K29/e95): A pegmatite vein in the Charleston Metamorphic Group at Constant Bay (K29/e95) was worked between 1911 and 1912, and 2 t of mica were exported. Muscovite occurs in sheets up to 0.25 m in diameter in granitic pegmatite associated with orthoclase crystals up to 0.45 m (Morgan & Bartrum 1915). However, the commercial grade is low. Mica also comprises 10% of a 20 m wide pegmatite dyke nearby at Deep Creek, but little of the mica is of good quality (Henderson 1950). Approximately 6000 t of pegmatite were proven, but the mica content is not well known (Officers of New Zealand Geological Survey 1970b).

Kinnard and Mataketake Ranges (G37/e2, 3, 5, 6): Mica is found in the Kinnard and Mataketake Ranges (G37/e2, 3, 5, 6) originally discovered by C. Douglas (Wellman 1947). The mica (muscovite) is found in lensoid pegmatite bodies, generally concordant to the surrounding oligoclase-zone schist, but cross-cutting in detail. Workable mica occurs as irregular shoots within the pegmatites, books of mica making up a high percentage of the shoots. Originally a small amount of mica was produced from Sweeney’s claim (G37/e5), above the bush-line at an altitude of over 1000 m. In 1944, H.W. Wellman discovered a better more accessible deposit at an elevation of 500 m (Old Mica Mine; G37/e6). Wallace (1974) subsequently mapped the northern end of Mataketake Range in detail, and his map shows the distribution of pegmatite bodies.

Wellman (1955) reported that usable mica made up a small proportion of the total mined. In Sweeneys Claim, less than 20% of the mica recovered was selected for trimming, but an average of 40% from the Old Mica Mine was selected. The largest book was 60 x 25 x 12 cm, which when trimmed produced 18 x 15 cm sheets. The average size of the sheets produced is estimated at 5 x 8 cm. The Old Mica Mine was worked for about a year until late 1945, when the urgent wartime demand for mica ceased.

Assessment

We suggest a 8% probability of resources equivalent to the model size, equating to an estimated resource of 60,000 t mica.



Mineral deposit model

Model	Mica-bearing pegmatite
West Coast examples	Constant Bay (Charleston); Kinnard and Mataketake Ranges (e.g. Old Mica Mine)
Past production	A few tonnes
Other NZ examples	Mt Elwood in Fiordland
Permissive host rocks	Pegmatite dikes intruding schist and gneiss
Grade-tonnage model	5 Mt at 15% mica for 750,000 t mica

Resource estimate for deposits
(Percent chance of grade tonnage model and total resources)

	West Coast
Known prospects	3%
Undiscovered	5%
TOTAL %	8%
TOTAL t mica	60,000 t

Figure 122 Location of mica occurrences from the GERM database, and areas of rocks prospective for Mica-bearing pegmatite deposits.

14.8 POUNAMU

14.8.1 Pounamu (Figure 123)

Model

International: BCGS model Q01 Jade.

New Zealand: Nephrite forms under moderate metamorphic conditions as narrow metasomatic reaction zones between contrasting protoliths involving silicic metasediments (quartzo-feldspathic schist) and either ultramafic rocks such as serpentinite, or magnesium-rich carbonates. True nephrite fabrics are developed only locally where marginal shearing is intense.

West Coast deposits

New Zealand greenstone and New Zealand jade are common terms for nephrite, an amphibole group mineral with a composition within the tremolite ($Ca_2Mg_5Si_8O_{22}(OH)_2$) - actinolite ($Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$) series. Pounamu, the Māori term for greenstone, includes a wider variety of rocks; both nephrite and bowenite (a serpentine mineral). Jade is generally either nephrite or jadeite (pyroxene group). For example, Chinese jade is jadeite and therefore not strictly equivalent to the New Zealand nephrite jade.

Nephrite has a felted texture, consisting of interweaving, microscopic, acicular tremolite-actinolite crystals. The mineral was used by Māori for jewellery, tools (e.g. adzes, chisels gouges and knives for carving and cutting wood, and fish hooks) and weapons (e.g. mere clubs and points for spears), and has strong cultural and spiritual significance. Modern use is mainly for jewellery and ornaments. Ownership of pounamu was vested with Ngāi Tahu in September 1997 as part of their Treaty of Waitangi claim (Figure 124). Māori recognise three main varieties of nephrite on the basis of colour and texture, namely kawakawa, kahurangi and inanga. Bowenite is known to Māori as tangiwai.

Descriptive studies of nephrite and occurrences in New Zealand were made by Finlayson (1909b), Turner (1935), Coleman (1966), Beck (1984), and Beck & Mason (2002). Most greenstone has been recovered as active river float or from alluvial placers, especially from the Arahura, Taramakau, and Hokitika rivers, although some has also been recovered from glacial boulders (e.g. Cascade Plateau). In several localities, however, nephrite has been located in outcrop within the Pounamu Ultramafics belt.

Olderog Creek, a tributary of the Arahura River, is an important locality, with 11 float boulder or nephrite gravel occurrences noted in the GERM data file (K33/e6, e7, e9, e11, e14, e36, e37, e44-46, e48). Johnston (1983) described a rare occurrence of nephrite and semi-nephrite from Jade Creek, a tributary of Olderog Creek, at the western end of the Tara Tama Range in the McArthur Crags area (K33/e67), where nephrite boulders up to 25 t have been exploited. In the head of Jade Creek, the Pounamu Ultramafics thins to less than 1.0 m thick, and contains pods of nephrite and semi-nephrite up to 0.6 m thick, grading downwards into diopsidic pyroxenite, and overlain by well foliated greenschist (Johnston 1983). Bell & Fraser (1906) mentioned nephrite segregations, up to 0.6 m across, within the Pounamu Ultramafics in the Griffin Range, immediately to the north of the Tara Tama Range (K33/e22). Other Pounamu lithologies include biotite schist, tremolitic marble, and serpentinite. Additional greenstone localities listed in the GERM data file include: Griffin Creek (K33/e58, e60), Nephrite Creek (K33/e59), Mt Griffin (K33/e61), Cold Creek (K33/e62), Arahura River

(K33/e68), Douglas Creek (G37/e1), Jackson River (E38/e10), and the Makarora River between Muddy Creek and Haast Pass (G38/e9).

Assessment

Studies have been carried out to assess pounamu resources (Cox et al. 2005) and to fingerprint their source (Adams et al. 2005, 2007; Campbell et al. 2008a 2008b). Resource estimates made to date are confidential. Because pounamu has significant spiritual value to Māori, the value of the resources may be far greater to the owners, Ngāi Tahu, than can be estimated as a mineable mineral commodity. Therefore, no estimate of resources is made here.

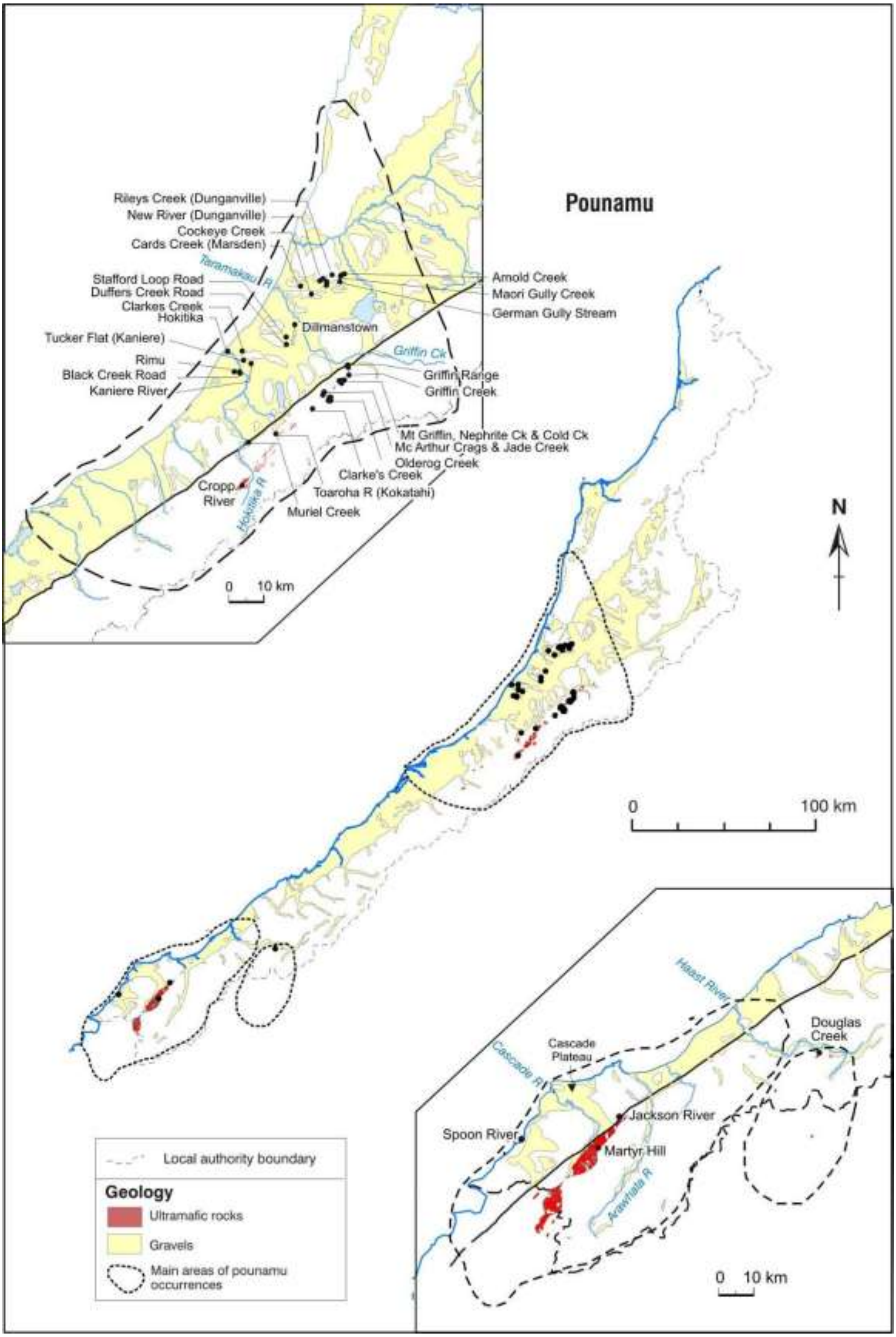


Figure 123 Location of pounamu (greenstone) occurrences from the GERM database, and areas of rocks prospective for Pounamu deposits.

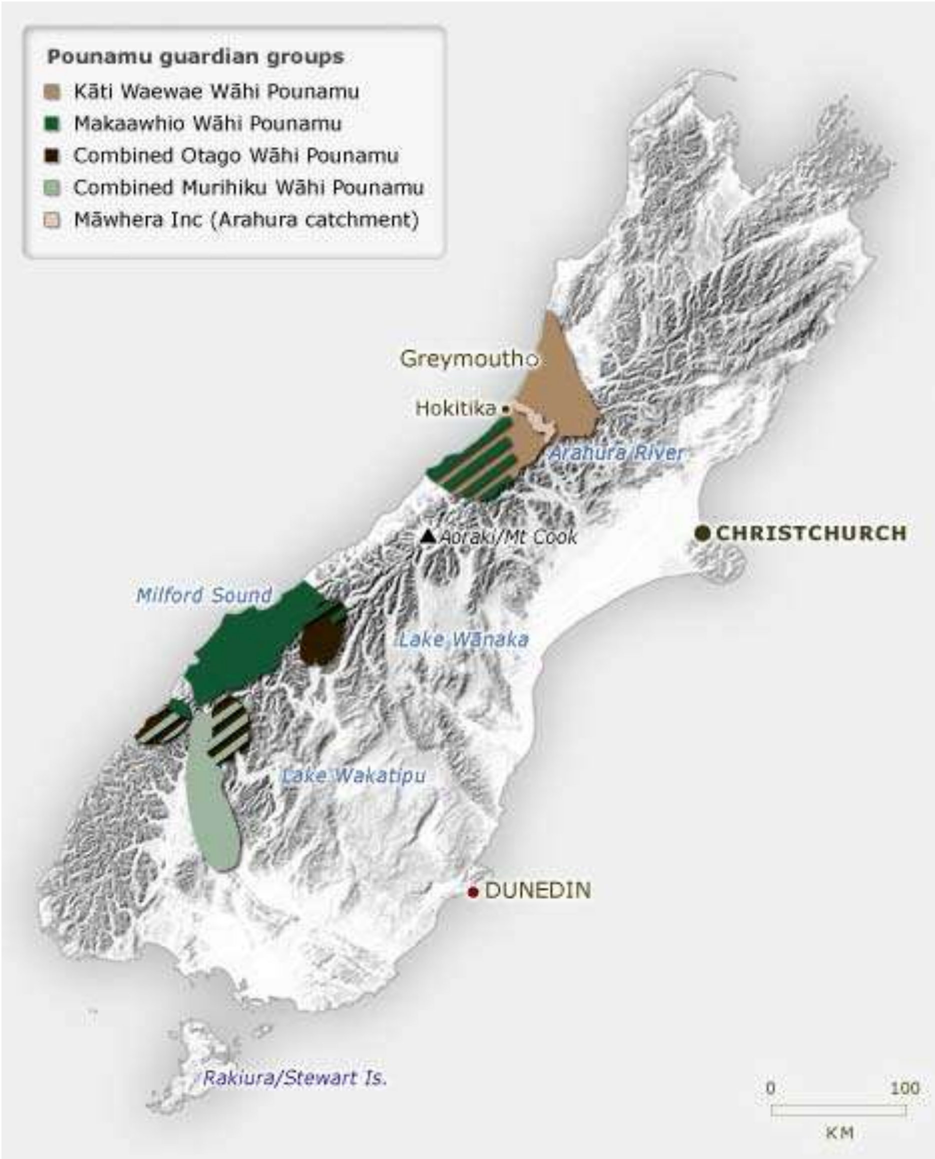


Figure 124 Most pounamu resources are owned and managed by South Island Māori –Te Rūnanga o Ngāi Tahu. The resource is managed by local rūnanga or kaitiaki (guardians) who have authority over their respective fields depending on historical interests (shown by colours on the map). Source: Te Rūnanga o Ngāi Tahu, Pounamu Management Plan.

14.9 SERPENTINE

14.9.1 Serpentine (Figure 125)

Model

Grade-tonnage data

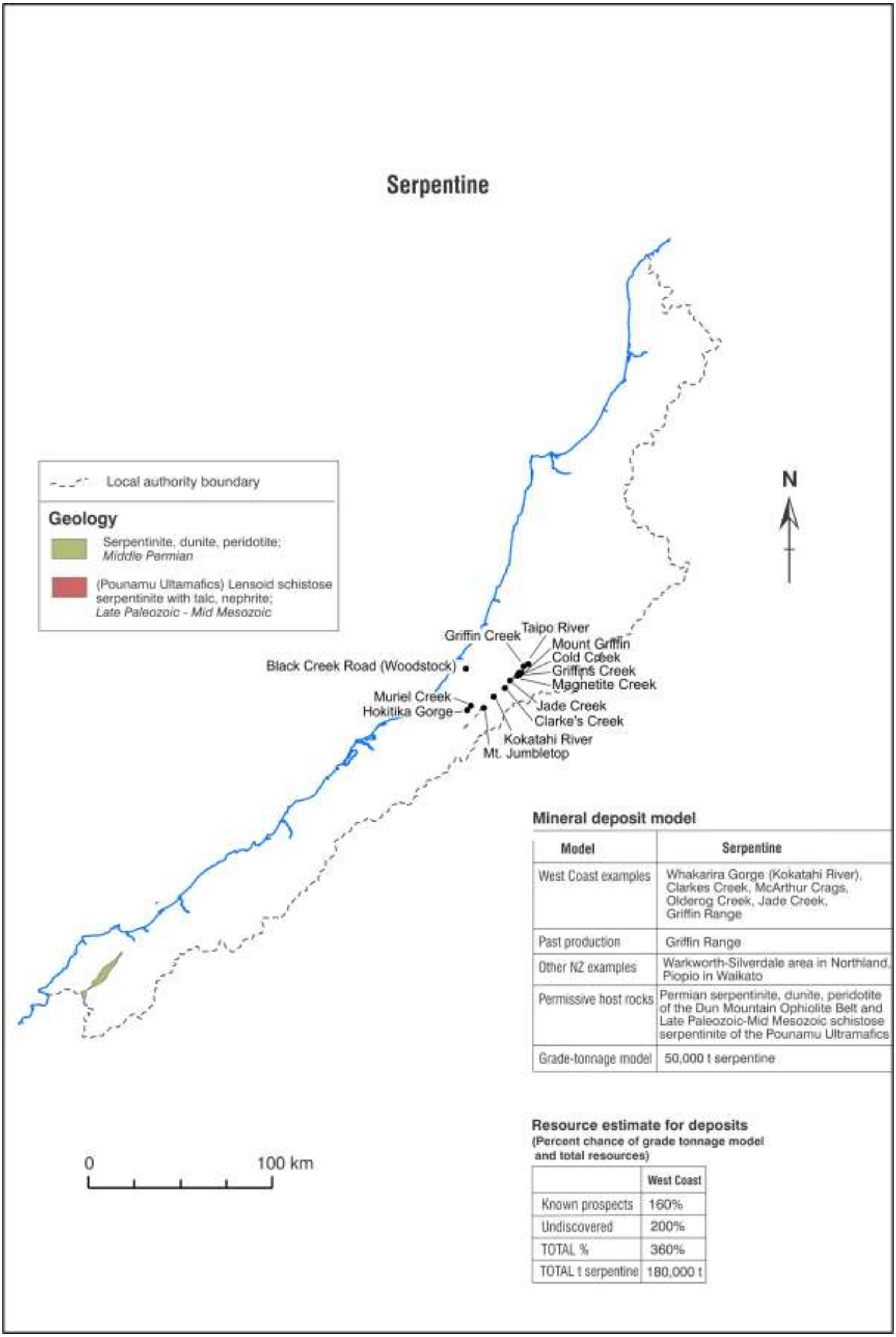
No published international model. We suggest a model size of 50,000 t serpentine for individual bodies of serpentinite.

West Coast deposits

Numerous lenses of ultramafic rocks (Pounamu Ultramafics), which are typically less than 60 m wide and 200 m long, and seldom larger than 90 m wide and 1.4 km long, are present in the biotite and garnet zones of the Haast Schist, east of the Alpine Fault (Bell & Fraser 1906; Morgan 1908, Gair 1962; Coleman 1966). These lenses were tectonically emplaced prior to metamorphism to meta-serpentinite, and are composed predominantly of antigorite with minor talc, magnesite, magnetite, actinolite, and nephrite. They usually exhibit a schistose or semi-schistose texture. The lenses are parallel to subparallel to each other and are most common in the Hokitika, Arahura, and Taramakau valleys. Specific localities include: Whakarira Gorge in the Kokatahi River (J33/e120), Clarkes Creek (J33/e118), the McArthur Crags area (K33/e64-66), Olderog and Jade creeks (K33/e67), and the Griffin Range area (K33/e20, e58-63). Massive serpentinite was quarried at the eastern base of Mt Griffin (K33/e28), mainly between 1912 and 1914, for use as facing stone. The quarry exposes a conformable serpentinite lens 15 m thick, striking 035^{o} and dipping 51^{o} east (Coleman 1966). The serpentinite is variegated in shades of light to dark green and consists essentially of antigorite, magnesite, and magnetite, with segregations and veins of talc present in minor amounts.

Assessment

We suggest a 360% probability of resources equivalent to the model size, equating to an estimated resource of 180,000 t of serpentine.



Mineral deposit model

Model	Serpentine
West Coast examples	Whakarira Gorge (Kokatahi River), Clarkes Creek, McArthur Crags, Olderog Creek, Jade Creek, Griffin Range
Past production	Griffin Range
Other NZ examples	Warkworth-Silverdale area in Northland, Piopio in Waikato
Permissive host rocks	Permian serpentinite, dunite, peridotite of the Dun Mountain Ophiolite Belt and Late Paleozoic-Mid Mesozoic schistose serpentinite of the Pounamu Ultramafics
Grade-tonnage model	50,000 t serpentine

Resource estimate for deposits
(Percent chance of grade tonnage model and total resources)

	West Coast
Known prospects	160%
Undiscovered	200%
TOTAL %	360%
TOTAL t serpentine	180,000 t

Figure 125 Location of serpentine occurrences from the GERM database, and areas of rocks prospective for serpentinite deposits.

14.10 SILICA

14.10.1 Silica sands (Figure 126)

Model

Description

Beach and dune quartz sand.

Grade-tonnage data

We have assigned a model size of 5 Mt of silica.

West Coast deposits

Quartz rich sand and sandstone occurs in the Buller, Charleston, and Greymouth coalfields, and at Cape Foulwind and Ross (Young 1964a; McPherson 1966; Nathan 1975). "Morgan & Bartrum (1915) reported favourably on the siliceous sandstones of the Buller Coalfield coal measures for the possible manufacture of firebricks. The material appears too micaceous and carbonaceous for ferro-silicon manufacture, however, and it is doubtful whether the silica content normally exceeds 80%" (Young 1964a, p 511).

Eocene quartz sand at Charleston (Little Totara Sand) is present in an extensive coastal strip up to 2.5 km wide and 6.5 km long. It immediately overlies the Brunner Coal Measures and was deposited in a nearshore marine environment "with much current activity, possibly a tidal sandbar or beach" (Nathan 1975, p 7). Silica grades are less than 95% (average around 85%) and the sand has high concentrations of feldspar (typically 10% and up to 30%) and muscovite (up to 5%). Young (1964a, p 522) noted "none of the samples is suitable, in its present form, for either glass-making (too poorly graded) or moulding sand (too few clay-sized particles)". However, Scahill & Shannon (1964) noted that the sands "when bonded with Porangahau bentonite, are particularly suitable for foundry moulding purposes where high permeability and low green strength are required." The quartz sand is extracted from McLaughlins pit (Little Totara River quarry; K29/e28) for use in cement manufacture.

In the Greymouth Coalfield, a 1-3.6 m thick unit of quartzite (ganister) overlies the main Brunner coal seam and is overlain by a thin coal seam, or by carbonaceous shale or coal measure sands. Some parts of the unit contain more than 98% silica, but marked lateral changes in thickness and silica content limit the available resources.

At Ross, quartz sand containing around 98% silica is present in Coal Creek (J33/e1). Five bands of white quartz sand, each 1.2-3.4 m thick, are present in a sequence totalling 12 m thick. Resources total only about 10,000 t (Wellman 1945). The grain size distribution is unsatisfactory for glass making and the sand would need to be blended with clay to be used as moulding sand (Dunn et al., in Wellman 1945).

Assessment

We suggest a 160% probability of resources equivalent to the model size, equating to an estimated resource of 8 Mt of silica.

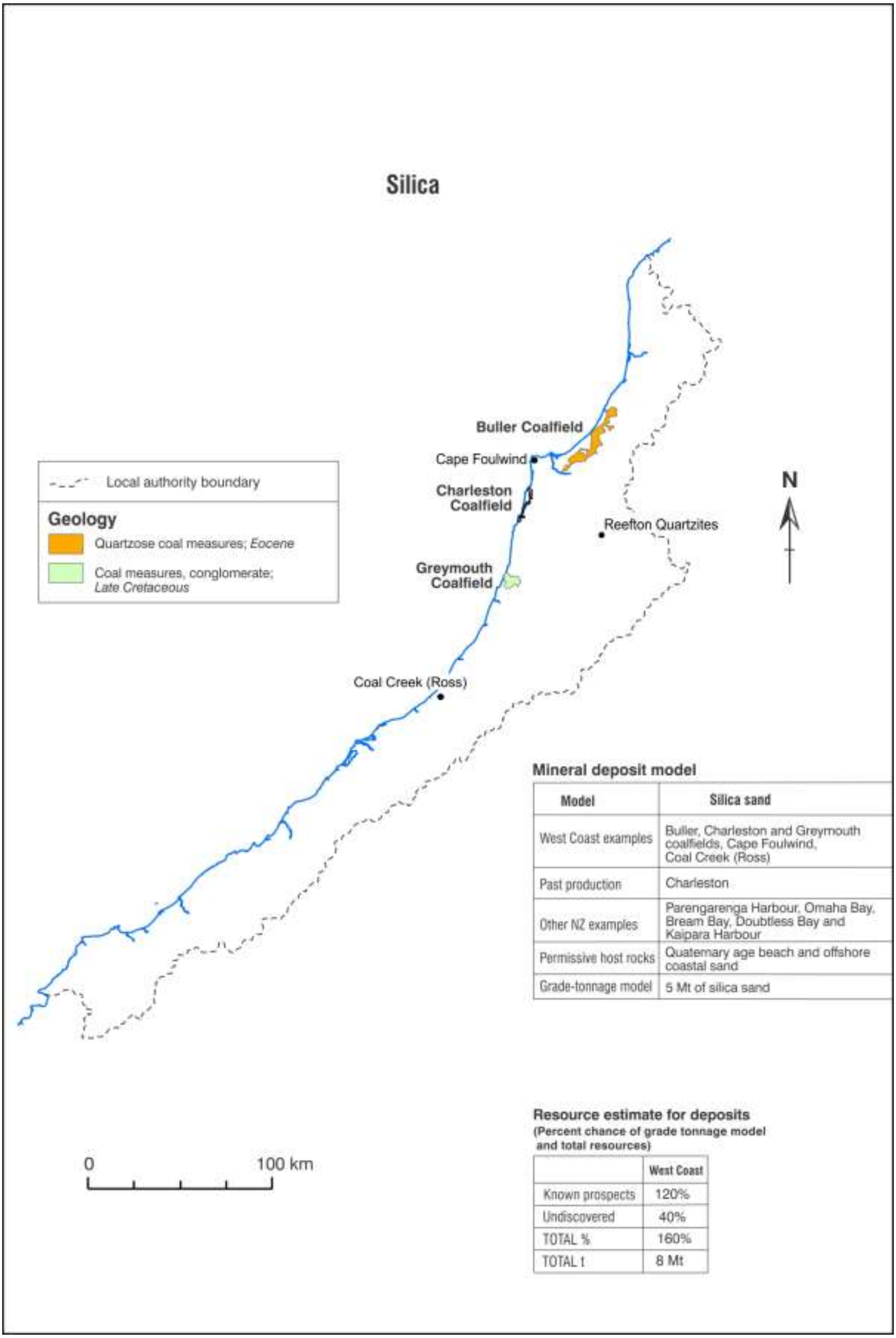


Figure 126 Location of silica occurrences from the GERM database, and areas of rocks prospective for silica sand deposits.

14.11 TALC-MAGNESITE

14.11.1 Ultramafic-hosted talc-magnesite (Figure 127)

Model

USGS models 8f Ultramafic-hosted magnesite and 8g Ultramafic-hosted talc (Orris 1998) and BCGS model M07 Ultramafic-hosted talc-magnesite (Simandi et al. 1999).

Description

Ultramafic-hosted talc-carbonate deposits are located either along regional faults cutting ultramafic rocks or at contacts between ultramafic rocks and siliceous country rock. The ultramafic host rock is typically, but not necessarily of ophiolitic affiliation. Deposits related to regional fault systems cutting ultramafic host rock are commonly magnesite-rich. Deposits located within sheets of serpentinised peridotite, found along the periphery of ultramafic intrusions or near the borders of tectonically transported peridotite slices are typically talc-rich.

The fault-related deposits are irregular bodies having their largest dimensions parallel to the faults. In some cases only the hanging wall of the faults is mineralised. Small ultramafic lenses are commonly entirely serpentinised, whereas larger lenses consist of peridotite cores surrounded by serpentinite. Steatite and talc schists are most likely to be found at the contact of the serpentinite with siliceous rocks, however they may also form tabular or irregular bodies.

International examples

Deloro magnesite-talc deposit, Ontario, Canada; Luzcan mine of Thetford township and Van Reet mine, Ponton township, Quebec, Canada; Windham, Vermont, USA; Lahnaslampi mine, Finland.

Grade-tonnage data - international

The grade and size of these deposits is highly variable. The Deloro deposit consists of 54% magnesite and 28% talc. The Lahnaslampi orebody in Finland contains over 30 Mt exceeding 50% talc and 0.1 to 0.2% Ni. Nickel concentrate is produced from the tailings at Lahnaslampi. We suggest a model size of 1 Mt of talc magnesite.

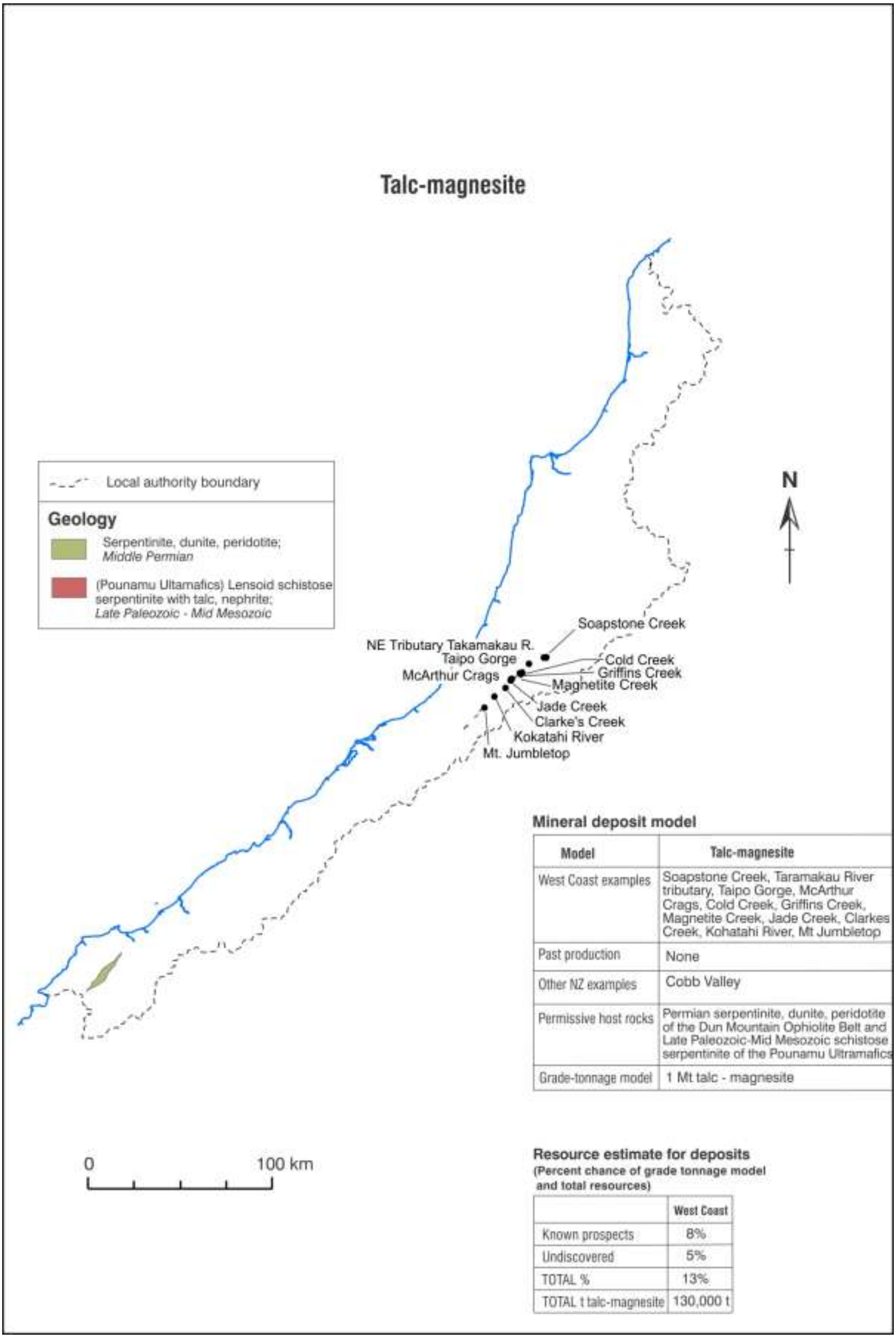
West Coast deposits

Talc is present as segregations and veins within serpentinite of the Pounamu Ultramafics. All known deposits are small and poor access is a major limiting factor to potential future development. Most are impure mixtures of talc, calcite, and dolomite, although some are of good quality, locally recrystallised, massive material. The colour is usually grey, but in some cases it has a pale green shade and thin pieces may be translucent. Occurrences include: (a) Soapstone Creek (K33/e55) on the northern side of the Taramakau River where the main band is 6 m wide and of good quality; (b) an unnamed northern tributary of the Taramakau River (K33/e56); (c) Taipo Gorge (K33/e57) where a band of impure talc is up to 15 m wide; (d) in the headwaters of Griffin Creek (K33/e60), where several lenses contain good quality, though generally impure, talc; (e) between the old serpentine quarry and the summit of Mount Griffin (K33/e61) where a talc lens of fair quality is present; (f) Whakarira Gorge (Kokatahi River; J33/e120) where rather impure talc comprises a 9 m thick band; (g) on Mt

Jumbletop (J33/e119) where there is a band of impure talc about 6 m wide; (h) Nephrite Creek (K33/e59); and (i) the McArthur Crags area (K33/e64-e67).

Assessment

We suggest a 13% probability of resources equivalent to the model size, equating to an estimated resource of 130,000 t of talc-magnesite.



Mineral deposit model

Model	Talc-magnesite
West Coast examples	Soapstone Creek, Taramakau River tributary, Taipo Gorge, McArthur Crags, Cold Creek, Griffins Creek, Magnetite Creek, Jade Creek, Clarkes Creek, Kohatahi River, Mt Jumbletop
Past production	None
Other NZ examples	Cobb Valley
Permissive host rocks	Permian serpentinite, dunite, peridotite of the Dun Mountain Ophiolite Belt and Late Paleozoic-Mid Mesozoic schistose serpentinite of the Pounamu Ultramafics
Grade-tonnage model	1 Mt talc - magnesite

Resource estimate for deposits
(Percent chance of grade tonnage model and total resources)

	West Coast
Known prospects	8%
Undiscovered	5%
TOTAL %	13%
TOTAL t talc-magnesite	130,000 t

Figure 127 Location of talc occurrences from the GERM database, and areas of rocks prospective for Talc-magnesite deposits.

15.0 VALUE OF MINERAL RESOURCES

Resource potential for 28 types of metallic mineral deposit and 10 non-metallic mineral deposit types have been outlined in the previous sections of this report and listed in Tables 17 and Table 18.

Table 17 Potential resources of metals by mineral deposit type

Metal	Deposit type	Potential resources
Antimony	Vein Sb	10,600 t Sb
Beryllium	Be pegmatite	1755 t Be
Chromium	Podiform Cr	46,800 t 40% Cr2O3
Copper	Stratiform Cu	4352 t Cu
		2560 t Zn
		8231 oz Ag
		4116 oz Au
	Vein Cu	920 t Cu
Gold	Orogenic/mesothermal shear zone Au - Paleozoic	3.7 M oz Au
	Orogenic/mesothermal Au – Mesozoic	65,000 oz Au
	Orogenic Alpine Au	2500 oz Au
	Alkali intrusion-related Au	37,500 oz Au
	Moderately reduced granite Au	325,000 oz Au
	Detachment-fault-related polymetallic deposits	30,000 oz Au
	Placer gold – onshore alluvial placers	690,000 oz Au
	Placer gold – beach placers	643,087 oz Au
	Placer gold – offshore marine placers	1,040,000 oz Au
Molybdenum	Porphyry Mo	82,297 t Mo
Nickel	Dunitic Ni-Cu	26,100 t Ni
		3654 t Cu
Platinum	Alaskan type Pt	2000 oz Pt
Rare Earth Elements	Carbonatite-hosted REE	9000 t REO
	REE-bearing monazite in granitic and metamorphic rocks	87,500 t REO
	Placer REE	17,500 t monazite
Tin	Greisen Sn	3427 t Sn
Titanium	Shoreline placer Ti	30 Mt ilmenite
Tungsten	Vein W	4334 t WO_3
	Greisen W-Sn	8127 t W
	Stratabound W	6000 t WO_3
Uranium	Sandstone U	580 t U
Zinc-lead	Zn-Pb polymetallic vein	206 t Zn 882 t Pb 258,503 oz Ag 41 oz Au
Zirconium	Placer Zr	2 Mt zircon

Table 18 Potential resources of non-metallic minerals and rocks (excluding coal, aggregate and building stone for construction)

Mineral	Deposit type	Potential resources, tonnes
Asbestos	Ultramafic-hosted asbestos	500,000 t asbestos
Barite	Vein barite	2000 t 50% $BaSO_4$
Clay	Coal measure clay	900,000 t 40% kaolinite
	Clay from weathering and sedimentary clay	700,000 t kaolinite
Feldspar	Feldspar in pegmatites	210,000 t feldspar
	Feldspar – weathered granite	100,000 t feldspar
Fluorite	Vein F	320,000 t 20% CaF_2
Garnet	Placer garnet	Not assessed
Mica	Mica in pegmatites	60,000 t mica
Pounamu		Not assessed
Serpentine	Serpentine	180,000 t serpentine
Silica	Silica sands	8 Mt silica sand
Talc	Ultramafic-hosted talc-magnesite	130,000 t talc-magnesite

15.1 PRODUCTION SCENARIOS

The West Coast region continues to be one of New Zealand's most prospective areas for coal, orogenic gold (Paleozoic) and placer gold deposits and is a major producer of these commodities. Ten coal mines, one hard rock gold mine and several placer gold mines are currently operating. A range of other metallic and non-metallic minerals are present in the West Coast region and there is potential for production for some commodities, provided sufficient resources can be discovered and markets can be secured. For example, ilmenite resources have been identified and mining proposed at Westport and Barrytown, but problems of processing and markets have so far prevented these projects from going ahead. Molybdenum and tungsten deposits are known, but the resources identified with limited exploration to date are small. Antimony, clay, mica and silica sand have been produced in the past.

This section of the report proposes three possible scenarios of future annual mineral production for economic modelling in the subsequent study by economists Berl Economics Ltd (Leung-Wai & Generosa 2010). The growth of aggregate production is constrained by the small size of the market within the region, and while major projects may boost demand during their construction, significant expansion over an extended period would depend on transporting material to other regions of New Zealand. Published coal resources are large in relation to current rates of production and the main constraints on expansion have been related to mining geotechnical issues and limitations on transport. Export coal prices are a major factor also. For gold and other high value minerals, known resources are not large but good exploration potential exists, particularly for gold. The expansion in the value of these minerals in the future would require new mineral discoveries that depend on a sustained increase in the level of exploration activity. Prices for these commodities influence the level of exploration activity. The way Crown land is managed is a major factor as most of the areas with potential are located on Crown land.

15.1.1 Commodity prices

Commodity prices for use in the scenarios have been obtained from sources dated between 2007 and 2010 (Table 19). Commodity prices vary over time and have risen strongly over the past 5 years. In spite of some spectacular metal price increases over this period (about 5-fold for copper), inflation adjusted metal prices are still well below past peak values.

As coal and gold dominate current West Coast mineral production and resource potential, the prices of these commodities heavily influence current and potential mineral resource values. The most recent production data published by Crown Minerals is available for calendar year 2009. Their statistics include a value for gold of $NZ1182 per ounce which is below Minerals West Coast estimates for 2009 (pers. comm. Peter O'Sullivan). We have used a gold price of $NZ1560 per ounce based on monthly average US dollar gold prices and NZ dollar exchange rates, which is close to the value calculated by Minerals West Coast.

Crown Minerals no longer publishes resource values for coal, and prices have varied widely over the last 5 years. Actual sales prices are unavailable due to their commercial sensitivity. Published values for Australian coking coal since 2005 have ranged from $US98 in 2007 to a peak of $US300 in 2008. Prices fell sharply from that peak to about $US140 per tonne in 2009. Using a $US 0.70 exchange rate this converts to a price of $NZ 200 for coking coal.

Coal and gold prices have been volatile over the last 5 years and this is likely to continue. We have not attempted to predict how these may change in the future and have used these 2009 prices for our estimates of future production value in the scenarios that follow.

Table 19 Mineral Prices

Mineral commodity	Source	Price Quoted Overseas	Price NZ $	Price NZ $ rounded
Aggregate: rock for reclamation and protection	CM 2009 prod stats		$12.47 / t	$13 / t
Aggregate: rock sand and gravel for building	CM 2009 prod stats		$13.53 / t	$14 / t
Aggregate: rock, sand and gravel for roading	CM 2009 prod stats		$12.43 / t	$13 / t
Aggregate: rock, sand, gravel and clay for fill	CM 2009 prod stats		$6.14 / t	$6 / t
Antimony	www	US$ 6000 / t	$8400 / t	$8400 / t
Barite (Barytes drilling grade)	IM March & June 2010	US $ 70 / t	$98 / t	$98 / t
Building and dimension stone	CM 2009 prod stats		$190.06 / t	$190 / t
Chromite (40% Cr_2O_3)	IM March & June 2010	US $ 230 / t	$ 322 / t	$ 322 / t
Clay – kaolinite	IM March & June 2010	US$ 120 / t	$ 168 / t	$ 168 / t
Clay for bricks, tiles etc	CM 2009 prod stats		$138.65 / t	$139 / t
Clay for pottery and ceramics	CM 2008 prod stats		$808.81 / t	$809 / t
Coal – bituminous (export coking)				$200 / t
Coal – sub-bituminous (domestic thermal)				$125 / t
Copper	MJ April-May 2010	US$ 6470 / t	$9058 / t	$9058 / t
Decorative pebbles including scoria	CM 2009 prod stats		$42.63 / t	$43 / t
Feldspar	IM March & June 2010	US$ 22 / t	$30.8 / t	$31 / t

Mineral commodity	Source	Price Quoted Overseas	Price NZ $	Price NZ $ rounded
Fluorite (fluorspar)	IM March & June 2010	US$ 260 / t	$364 / t	$364 / t
Gold	Average 12 month price July 2009 -June 2010 and exchange rate of 0.7	US$ 1,090 / oz	$1560 / oz	$1560 /oz
Lead	MJ April-May 2010	US$ 1671 / t	$2339 / t	$2339 / t
Limestone for agriculture	CM 2009 prod stats		$21.47 / t	$21 / t
Limestone for industry	CM 2009 prod stats		$26.95 / t	$27 / t
Limestone and marl for cement				$12.50 /t
Mica	IM March & June 2010	US $ 350 / t	$490 / t	$490 / t
Molybdenum (oxide)	www	US$ 32,000 / t	$44,800 / t	$44,800 / t
Nickel	MJ April-May 2010	US$ 19,785 / t	$27,699 / t	$27,700
Platinum	MJ April-May 2010	US$ 1,547 / oz	$2166 / oz	$2166 / oz
Rare earth minerals	IM March & June 2010	US $ 10 / lb	$14 / lb	$28,000 / t
Sand for industry	CM 2009 prod stats		$12.88 / t	$13 / t
Serpentine	CM 2007 prod stats		$ 63.75 / t	$64 / t
Silica sand	CM 2009 prod stats		$8.37 / t	$8.40 / t
Silica sand (glass sand)	IM March & June 2010	US $ 18 / t	$25.2 / t	$25 / t
Silver	MJ April-May 2010	US$ 18 / oz	$25.20 / oz	$25 / oz
Talc				$150 / t
Tin	MJ April-May 2010	US$ 17,062 / t	$23,887 / t	$23,890 / t
Titanium (54% TiO2 ilmenite concentrate)	IM March & June 2010	US$ 70 / t	$98 / t	$98 / t
Uranium	MJ April-May 2010	US$ 41.1 / lb	$57.54 / lb	$116,000 / t
Tungsten	www Oct 2009	US$ 26 / kg	$35,100 / t	$35,100 / t
Zinc	MJ April-May 2010	US$ 1758 / t	$2461 / t	$2461 / t
Zircon	MJ April-May 2010	US$ 830 / t	$1162 / t	$1162 / t

CM 2009 prod stats = Crown Minerals 2009 production statistics, averages for all New Zealand for individual commodities

CM 2008 prod stats = Crown Minerals 2008 production statistics, averages for all New Zealand for individual commodities

IM = Industrial Minerals

MJ = Mining Journal

US$ 1 = NZ$ 1.40

15.1.2 Scenarios 1 and 2

The first scenario is a business as usual case maintaining current levels of coal and mineral production, which would require development of new coal and gold resources to replace those currently mined (Table 20). The second scenario (Table 21) increases production to past highest recorded levels of annual production in the period 2000 to 2009, except placer gold where we use a 1995 figure from Table 1 of Cotton & Rose (2006a). The third scenario takes a more optimistic approach and proposes an increase in coal and gold production, an increase in aggregate production (based mainly on exports to other regions), and production of additional mineral commodities (Table 22). We suggest that this third scenario might be possible in 15 years, provided that:

There is a sufficient level of exploration to define the new resources and

The resources, if discovered, can be developed.

15.1.3 Scenario 3

The increased future mineral production scenario involves the proposal of several hypothetical new mining operations based on the prospectivity of specific commodities.

Scenario 3 aggregate

An increase of aggregate production results from the export of 500,000 t of aggregate per year to other regions such as Auckland. The export of aggregate from the West Coast to other parts of New Zealand (notably Auckland) has been investigated (Temple 2000, Brockett 2004), and is not economic with current aggregate prices. However, as demand and shortages increase, a resulting increase in price will change this situation. Export material would be high value, high quality aggregate (e.g. for concrete, and roading basecourse and sealing materials). Potential sources of such material are the active river gravels and existing or possibly new hard rock quarries that are within an economic distance of a port. Sustainable extraction rates for aggregate production from active river gravels would require additional investigation.

Scenario 3 coal

Current annual West Coast bituminous coal production is about 2.5 Mt. The Bathurst proposal may add another 2 Mt giving a total annual production of 4.5 Mt for our future scenarios. Large published resources suggest that this quantity of production can be sustained long term (i.e. at least 20 years). An increase in production above this figure is limited by the complex transport chain and geotechnical risks of underground mining. Barging may be a possibility to increase exports.

Scenario 3 gold – hard rock

Globe-Progress and its nearby extensions will be mostly exhausted, but this reduction in production could be compensated by developing deep resources and extensions in the Blackwater mine. In the longer term, there is potential for additional discoveries of orogenic gold resources and intrusion-related and detachment fault related gold deposits. We suggest an annual production of 120,000 oz Au, with a total gross value of $187 M/yr, probably from two mines or a high grade single mine.

Scenario 3 gold – onshore and offshore placer

We suggest an increase in placer mining to 120,000 oz Au that could result from onshore placer mining at recent maximum levels (e.g. 69,350 oz in 1995) and the addition of 50,000 oz from offshore placer gold mining. This would equate to a gross value of $187 M/yr.

Scenario 3 ilmenite (titanium)

We envisage one ilmenite mining operation at the production rate planned previously for the Barrytown deposit: 3 Mt of sand per year to produce 250,000 t of ilmenite concentrate annually.

Scenario 3 unspecified new metallic mining operations

There is potential for production of additional metallic mineral commodities such as chromium, copper, lead-zinc, molybdenum, nickel, platinum, rare earth elements, tin, tungsten, and by-products such as antimony (from hard rock gold production), gold (from ilmenite sand production), silver (from zinc-lead production), zirconium (from placer gold or ilmenite production). Although the probability of this outcome is not high, the returns would be large because of the high value of the commodities, and therefore an annual production value of $50 M is assigned, without specifying the individual commodities or types of mining operations.

Scenario 3 unspecified new non-metallic mining operations

There is potential for production of additional non-metallic mineral commodities such as clay, silica sands, and by-products such as garnet (from placer gold or ilmenite production), and an annual production value of $10 M is assigned, without specifying the individual commodities or types of mining operations.

Table 20 Annual production scenario 1 involving maintenance of current levels of mineral and coal production

Mineral commodity	Production (2009)	Price	Value
Bituminous coal	2,085,486 t	$200 / t	$417,097,200
Sub bituminous coal	151,045 t	$125 / t	$18,880,625
Gold, hard rock Reefton	87,000 oz	$1560 / oz	$135,720,000
Gold, placer	10,160 oz	$1560 / oz	$15,849,600
Building and Dimension stone	-	$190 / t	
Decorative pebbles including scoria	4393 t	$43 / t	$188,899
Limestone for agriculture	86,296 t	$21 / t	$1812,216
Limestone for industry & roading	597 t	$27 / t	$16,119
Limestone and marl for cement (2006)	840,000 t	$12.50 / t	$10,500,000
Rock for reclamation & protection	51,230 t	$13 / t	$665,990
Rock, sand and gravel for building	3200 t	$14 / t	$44,800
Rock, sand and gravel for roading	71,715 t	$13 / t	$932,295
Rock, sand, gravel & clay for fill	39,138 t	$6 / t	$234,828
Sand for industry	9450 t	$13 / t	$122,850
Serpentine	-	$64 / t	
Total value			$602,065,422

Table 21 Annual production scenario 2 involving increases of production to past annual maximums

Mineral commodity	Year	Production	Price	Value
Bituminous coal	2006	2,863,029 t	$200 / t	$572,605,800
Sub bituminous coal	2009	151,045 t	$125 / t	$18,880,625
Gold, hard rock Reefton	2009	87,000 oz	$1560 / oz	$135,720,000
Gold, placer	1995	69,349 oz	$1560	$115,743,481
Building and Dimension stone	2003	3340 t	$190 / t	$634,600
Decorative pebbles including scoria	2008	16,070 t	$43 / t	$691,010
Limestone for agriculture	2001	161,000 t	$21 / t	$3,381,000
Limestone for industry & roading	2008	4249 t	$27 / t	$114,723
Limestone and marl for cement (2007, 2008 and 2009 unavailable – withheld)	2006	840,000 t	$12.50 / t	$10,500,000
Rock for reclamation & protection	2006	103,295 t	$13 / t	$1,342,835
Rock, sand and gravel for building	2006	80,000 t	$14 / t	$1,120,000
Rock, sand and gravel for roading	2006	362,743 t	$13 / t	$4,715,659
Rock, sand, gravel & clay for fill	2001	40,300 t	$6 / t	$241,800
Sand for industry	2005	50,300 t	$13 / t	$653,900
Serpentine	2003 & 2005	20 t	$64 / t	$1280
Talc	2002	10 t	$150 / t	$1500
Total value				$866,348,213

Table 22 Annual production scenario 3 involving an increase in coal and gold-silver mining, export of aggregate and increases in other commodities to past annual maximums

Mineral commodity	Production	Price	Value
Bituminous coal	4,500,000 t	$200 / t	$900,000,000
Sub bituminous coal	151,045 t	$125 / t	$18,880,625
Gold, hard rock	120,000 oz	$1560 / oz	$187,200,000
Gold, placer (onshore and offshore)	120,000 oz	$1560 / oz	$187,200,000
Ilmenite	250,000 t conc	$90 / t	$24,500,000
Building and Dimension stone	3340 t	$190 / t	$634,600
Decorative pebbles including scoria	16,070 t	$43 / t	$691,010
Limestone for agriculture	161,000 t	$21 / t	$3,381,000
Limestone for industry & roading	4249 t	$27 / t	$114,723
Limestone and marl for cement	840,000 t	$10 / t	$10,500,000
Rock for reclamation & protection	103,295 t	$13 / t	$1,342,835
Rock, sand and gravel for building	80,000 t	$14 / t	$1,120,000
Rock, sand and gravel for roading	362,743 t	$13 / t	$4,715,659
Rock, sand, gravel & clay for fill	40,300 t	$6 / t	$241,800
Aggregate for export	500,000 t	$15 / t	$7,500,000
Sand for industry	50,300 t	$13 / t	$653,900
Serpentine	20 t	$64 / t	$1280
Talc	10 t	$150 / t	$1500
Other unspecified metallic mineral commodities			$50,000,000
Other unspecified non-metallic mineral commodities			$10,000,000
Total			$1,408,678,932

Current total mineral production in the West Coast region has a value of about $602 M per year (Table 20). The scenario 2 of increasing annual production to past annual maximums would increase production to $866 M (Table 21). The scenario 3 of increased aggregate production, new coal and gold production to levels higher than present, continuation of mining of other commodities to past annual maximums, and mining of new commodities could increase production to $1,409 M (Table 22).

15.1.4 Berl report production values

Some production and commodity prices used in the BERL report (Leung-Wai & Generosa 2010) differ from those used in this report. The total value of current West Coast mine production of $602 million in Table 20 is based on the 2009 mine production data reported by Crown Minerals using a gold price of $1560 per ounce and coal prices of $125 and $200 per tonne for sub bituminous and bituminous (export) coal respectively. For their analysis, Berl (Leung-Wai & Generosa 2010) have calculated the volume and value of current production for scenario 1 using information provided by Minerals West Coast for 2010. Coal production is estimated at 2.9 Mt, and gold production at 119,400 ounces. A gold price of $1850 and an export coal price of $225 per tonne give a total value of current production of $885 M for current production that is used in their report for scenario 1.

For scenario, 3 Berl (Leung-Wai & Generosa 2010) have used a higher coal production rate (4.65 Mt versus 4.5 Mt in this report) and the revised coal and gold prices quoted above to produce a value of production of $1,606 M (versus our $1,409 M).

15.2 EXPLORATION SPENDING

Since 2000, Crown Minerals has compiled statistics on exploration spending throughout New Zealand based on annual returns that are filed by permit holders. The data include spending on exploration for both minerals and coal, but not petroleum, which is reported separately. Spending data is published by region with consents and administration being reported separately from actual exploration spending. Separate data is available for prospecting (low impact regional reconnaissance surveys) and exploration which includes drilling and feasibility studies. The figures vary considerable from year to year. Offshore (subsea) spending is added to that for the adjacent region. We have used total spending data for exploration and prospecting for both minerals and coal, that includes consents and other costs. Most of this is spent within the region on field activities and consent-seeking from agencies and landowners within the region.

Exploration spending on the West Coast has ranged from $0.4m in 2002 to $7.7M for the 9 months from April to December 2008 (Figure 128). A high level of exploration activity is continuing, with Oceanagold indicating it intends to increase its expenditure on onshore, hard rock gold exploration to about $4 million per year, mainly in the Reefton district. That, together with planned coal developments should maintain the current level of exploration spending for the near future.

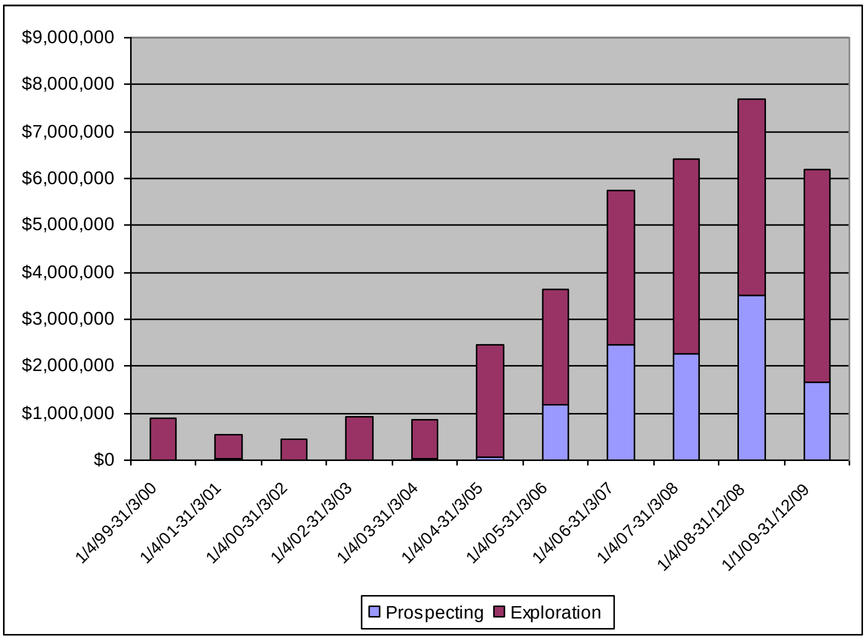


Figure 128 Total mineral exploration spending for the West Coast, 2000 – 2009 (source: Crown Minerals).

Figure 129 compares West Coast exploration spending with the total recorded for New Zealand. The total has ranged between $2.5 million in 2001 and $38.5 million in 2006, and the West Coast proportion of that between 6% and 23%. Since 2006 it has remained at about 20% of the total.

Exploration spending can be included in the three proposed scenarios for the future as an additional economic benefit of the minerals industry. For scenario 1 the 2009 spending rate of $6.2 million per year is used. Scenario 2 is based on past highest recorded levels. For the West Coast this is $7.7 million for the 9 months from April to December 2008, which is equivalent to $10.2 million for a full year.

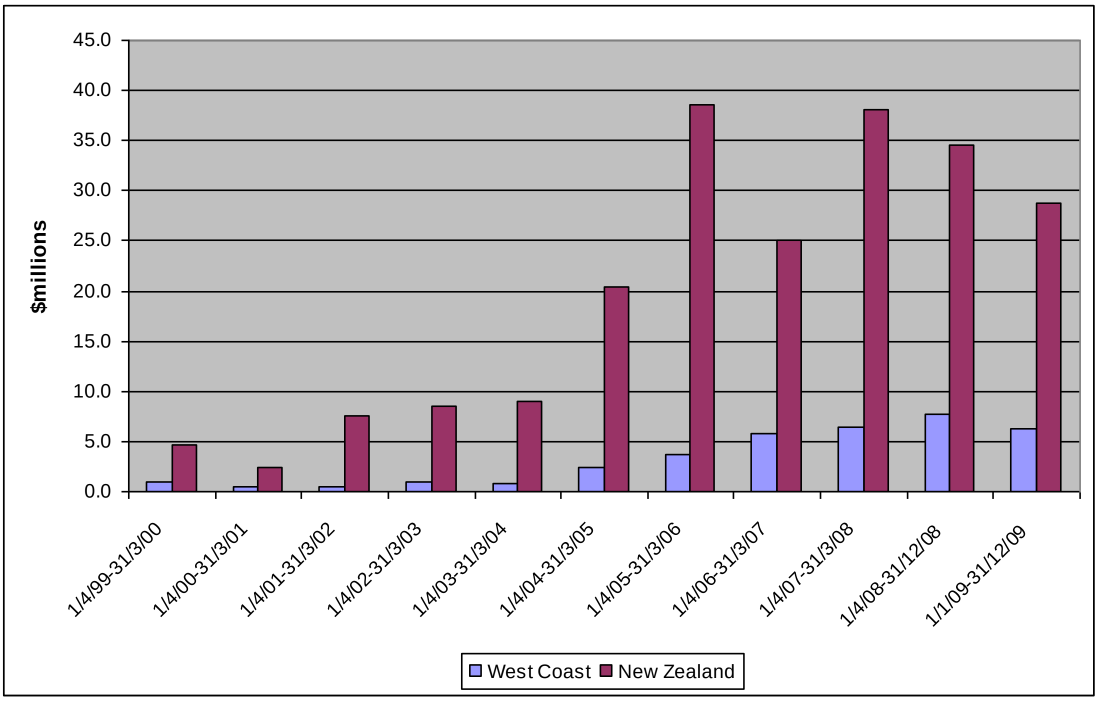


Figure 129 Total mineral exploration spending for the West Coast and New Zealand, 2000 – 2009 (source: Crown Minerals).

The third scenario involves hypothetical new mining operations. A substantial and prolonged increase in exploration spending would be needed to discover and delineate these deposits and to maintain the resource base depleted by mining. For the purposes of this scenario we propose that an annual rate of spending of double the average of the last 4 years would be required. That would amount to $14 million per year.

16.0 CONCLUSIONS

Production of aggregate is likely to be maintained, possibly with a small increase if the regional economy and population grow. There is potential to expand the market for aggregate by exporting aggregate to other regions such as Auckland. Risks include sustainability of river gravel resources.

Coal, gold and ilmenite (possibly with by-product zircon and monazite) offer the best potential for exploration and development.

Other commodities present with lesser potential include clay, copper, lead and zinc, molybdenum, rare earth elements, tin, tungsten.

Current total mineral production in the West Coast region has a value of about $602 M per year. A scenario (Scenario 2) of increasing annual production to past annual maximums would increase production to $866 M. A scenario (Scenario 3) of increased aggregate production, new coal and gold production to levels higher than present, continuation of mining of other commodities to past annual maximums, and mining of new commodities could increase production to $1,409 M.

A sustained level of mineral exploration is required to locate and define the mineral resources in order to expand the contribution of the minerals industry to the local economy. Attracting explorers to work in the region will require the creation of an environment conducive to investment by the private sector in mineral exploration and development.

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