Orogenic gold deposits in New Zealand: a new wall poster

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Abstract

The orogenic gold deposits wall poster is one in a series of posters on different mineral deposit types being produced by GNS Science to raise awareness of the characteristics of New Zealand mineral deposits and their prospectivity. Orogenic gold deposits are typically quartz vein deposits formed in fault and shear systems at crustal levels within and above the brittle ductile transition zone, at depths of 3 12 km and temperatures from 200° to 400°C. In New Zealand, orogenic gold deposits are found in regionally metamorphosed sedimentary rocks of Paleozoic and Mesozoic age. The deposits in Paleozoic rocks include those at Golden Blocks in Northwest Nelson, Lyell and Reefton on the West Coast, and Preservation Inlet in Fiordland. Quartz veins are developed along shear zones that dip steeply and generally strike parallel to the axes of folding in the greywacke and argillite/slate host rocks, although most are discordant to bedding. The lodes are typically less than 1 m wide and extend an average 200 m horizontally and vertically, but the Birthday Reef at Blackwater, Reefton, the largest quartz vein deposit in Paleozoic rocks, averages 60 cm in width and was mined over a strike length of 1070 m, and to a depth of 830 m. Disseminated gold occurs adjacent to the quartz lodes at Globe-Progress and some other Reefton deposits. The deposits in Mesozoic rocks are hosted in schist of Otago and Marlborough, and schist and greywacke of the Southern Alps. The lodes are typically lensoidal, less than 1 m wide and localised along single or multiple parallel shear zones that generally dip steeply, and are discordant to the schist foliation and bedding. A notable exception is Macraes, where the lodes are developed in the semi-concordant, low angle Hyde Macraes Shear Zone that has a strike length greater than 25 km.

Keywords: *Orogenic gold deposits, mesothermal, turbidite-hosted, Paleozoic, greywacke, Mesozoic, schist, Otago, Reefton, Marlborough, Southern Alps*

Introduction

The orogenic gold deposits wall poster is one in a series of posters on different mineral deposit types being produced by GNS Science to raise awareness of the characteristics of New Zealand mineral deposits and their prospectivity. The main target audience is the minerals industry (mainly exploration geologists) and tertiary-level geology students. Each poster in the series contains summary information on the characteristics of the specific mineral deposit type and descriptions of occurrences in New Zealand. The information for the orogenic gold deposits poster and this paper draws mainly from Christie and Brathwaite (1997) and Anon (2002), with information on individual New Zealand occurrences drawn mainly from Williams (1974) and Brathwaite and Pirajno (1993).

Characteristics

Orogenic gold deposits are typically gold bearing quartz veins formed in fault and shear systems at crustal levels within and above the brittle ductile transition zone, at depths of 3 12 km and temperatures from 200° to 400°C. Deposits may have a vertical extent of up to 2 km, and lack pronounced zoning. The quartz veins are generally referred to as lodes (or historically as reefs), because they are composite structures, consisting of quartz veins with lenses of wallrock and brecciated quartz veins and wallrock. The quartz veins split and join around the wallrock lenses. The individual quartz veins are typically banded (ribbon banded) and were formed by a "crack seal" processes involving episodic re opening of the veins, fluid flow and mineral deposition (Ramsay, 1980). The genesis of the deposits is controversial, but most current workers favour an origin related to regional metamorphism (e.g. Paterson, 1986; McKeag et al., 1989; Craw & Norris, 1991; Brathwaite & Pirajno, 1993; Becker et al., 2000), although some deposits may have had a magmatic influence in their genesis (e.g. de Ronde et al., 2000). The term orogenic derives from their occurrence in regionally metamorphosed terranes and their formation during compressional to transpressional defomation processes at convergent plate margins in accretionary and collisional orogens (Groves et al., 1998). Two major classes are recognised: turbidite-hosted lode gold deposits and greenstone lode gold deposits.

Turbidite-hosted lode gold deposits

These are gold bearing quartz lodes in turbidite sequences of metamorphosed sandstone (greywacke) and mudstone (argillite and slate) of Precambrian, Paleozoic and Mesozoic age. The host rocks are typically folded, forming anticlines and synclines, and metamorphosed up to greenschist facies. The deposits typically contain multiple quartz veins, each up to a few metres in width, and localised along shear zones that cross cut the bedding (discordant veins) or parallel bedding (concordant veins), the latter following the pattern of folding (e.g. saddle reefs of Bendigo). Recently, significant disseminated gold has been found in some deposits (Bierlein & Maher, 2001), including New Zealand examples at Globe-Progress (Christie et al., 2001) and Macraes (Craw et al., 2004). Hydrothermal alteration is generally confined to narrow zones of pervasive quartz and sericite, with disseminated carbonate, pyrite and arsenopyrite, in wallrocks adjacent to veins. Wider alteration zones are found in some deposits with disseminated gold. The veins contain quartz, carbonates, albite, chlorite, pyrite, arsenopyrite, and minor native gold and base metals. Stibnite or scheelite are significant in some deposits. The veins have a low total sulfide mineral content (<2.5%). International examples include Bendigo and Ballarat in Victoria, Australia; deposits in the Yellowknife district, Northwest Territories; and the Meguma district in Nova Scotia; Alpine Fold Belt of Europe; Tien Shan in Uzbekistan and Kyrgyzstan; Qinling Mountains, central China; and the Yana-Kolyma, Baikal, Verhoyansk and Allakh-Yun fold belts in east Asia (Bierlein & Crowe, 2000).

Greenstone lode gold deposits

These are gold-bearing quartz lodes found in Late Archean and Mesozoic greenstone belts. They are localised along or adjacent to major structural crustal breaks or suture zones, related to terrane collisional boundaries. The lodes are hosted in mafic and ultramafic volcanic rocks, banded iron formations, greywacke and conglomerate, that have been metamorphosed to greenschist and locally amphibolite facies. Wallrock alteration is characterised by quartz-pyrite-muscovite assemblages adjacent to the veins (usually within a metre) enclosed within a broader zone of carbonate alteration. The veins contain quartz, carbonate, pyrite, arsenopyrite and minor native gold and base metals. Examples of Archean age include Hollinger and Dome, in Timmins, Ontario; Mt Charlotte and Superpit on the Golden Mile in Kalgoorlie, Western Australia; Kolar in Karnataka, India; and Blanket Vubachikwe in Zimbabwe. Phanerozoic examples include deposits in the Mother Lode and Grass Valley districts of California; Alaska Juneau and Kensington in Alaska; and Sukhoi Log in Northern Siberia, Russia.

Orogenic gold deposits in New Zealand

New Zealand orogenic gold deposits are all of the turbidite-hosted type. They can be subdivided into two main types based on the age and lithologies of their host rocks: Paleozoic greywacke versus Mesozoic schist and greywacke. Erosion of the orogenic gold deposits has resulted in the formation of extensive placer gold deposits, particularly on the West Coast (Miocene-Recent alluvial and beach placers) and in Otago (Cretaceous –Recent alluvial placers).

Deposits in Paleozoic greywacke

These are found in Late Cambrian-Ordovician sedimentary rocks at Golden Blocks in Northwest Nelson, Lyell, Reefton, Langdons and Mt. Greenland on the West Coast, and at Preservation Inlet in Fiordland (Fig. 1). They exhibit many similarities to the Bendigo-Ballarat deposits in Victoria, Australia (Bierlein et al., 2004). Most deposits are hosted in greywacke and argillite (Greenland Group), except for deposits at Golden Blocks and Preservation Inlet, which are hosted in graptolitic black slate-greywacke sequences. The rocks are weakly metamorphosed up to lower greenschist facies, with metamorphic mineral assemblages of quartz, albite, muscovite and chlorite.

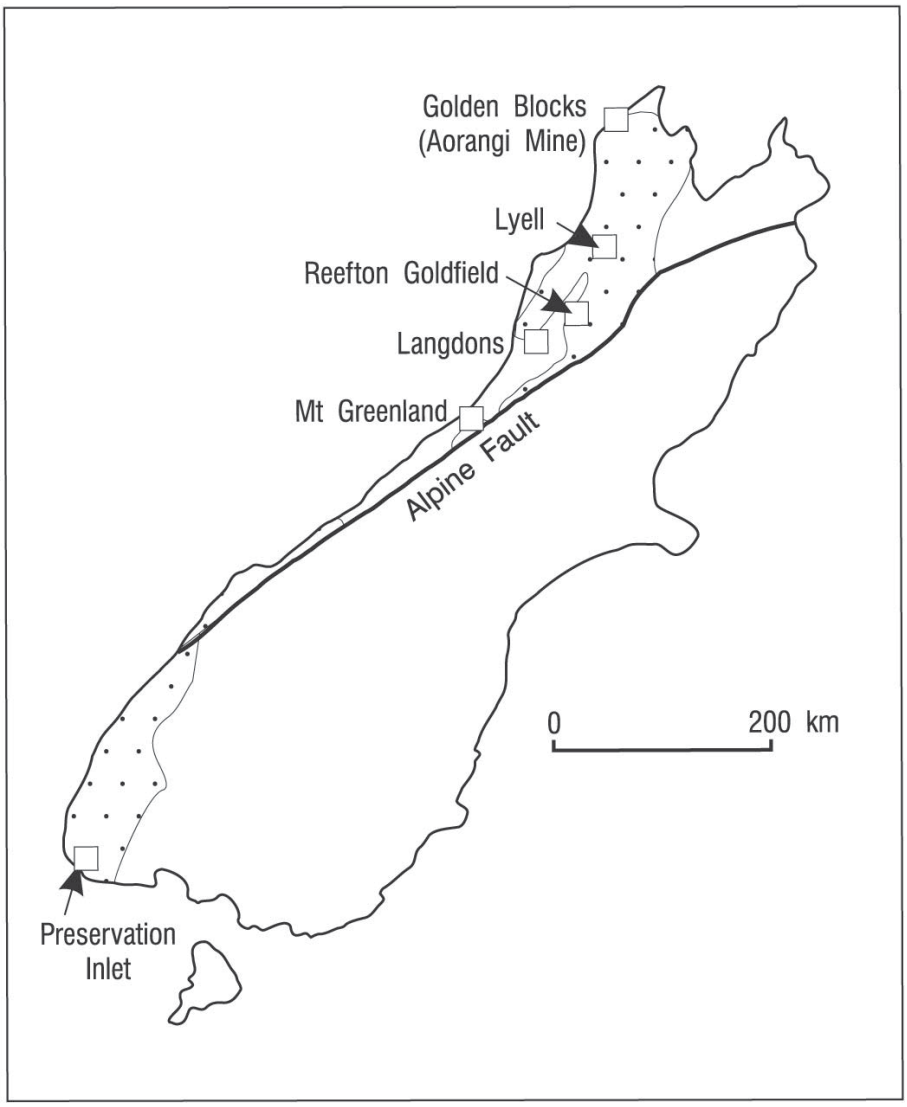

Fig. 1: Orogenic gold deposits in Early Paleozoic rocks of the Western Province (stippled) of the West Coast and Fiordland, South Island.

The most important deposits are those in the Reefton area, where over 67 t of gold were produced from 84 underground mines between 1870 and 1951 (Barry, 1993). A new open pit mine is being developed at Globe-Progress on the site of former underground mining. The gold-bearing quartz lodes are contained within a north northeast elongated belt of metasedimentary rocks (Greenland Group), some 34 km in length by 10 km in width, although they are mostly clustered in a corridor about 5 km in width, which coincides with a zone of most intense folding and shearing (Rattenbury & Stewart, 2000).

The lodes 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 may have a larger vertical extent. Wallrock hydrothermal alteration consists of sericite, carbonates (dolomite-ankerite and ferroan magnesite-magnesian siderite), arsenopyrite and pyrite in zones a few centimetres to metres in width, enveloping the quartz lodes (Christie & Brathwaite, 2003). Deposits, such as Globe-Progress, that contain significant disseminated mineralisation, exhibit much greater development of hydrothermal alteration.

The largest known deposits are Blackwater (at Waiuta) and Globe-Progress. At Blackwater, the gold was mined from the Birthday Reef, a quartz lode that averages only 60 cm in width, but has 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. The gold occurs with pyrite and arsenopyrite, although some stibnite and trace chalcopyrite are also present in some parts of the lode.

At Globe-Progess, underground mining of quartz produced 13 t of gold between 1879 and 1920. Exploration from the 1980s discovered disseminated gold associated with arsenopyrite, pyrite, and less commonly stibnite, in tectonic breccia zones and wallrocks adjacent to the previously mined quartz lodes. This disseminated gold makes up the bulk of the resource that will be produced from the new open pit mine.

Deposits in Mesozoic schist and greywacke

Quartz lode gold deposits are found in schist in Otago and Marlborough, and in schist and greywacke in the Southern Alps (Fig. 2). They have had relatively small historic gold production mostly from underground mining of narrow steeply dipping quartz lodes. However, discovery of open-pittable gold resources in a shallow dipping shear zone at Macraes in the 1980s has increased the importance of this class. Macraes is now New Zealand's largest gold mine with the largest known resources of gold.

Pyrite and arsenopyrite are found in most lodes. Scheelite was mined from lodes at Wakamarina, Glenorchy, Macraes and Barewood, and is present in many others. Stibnite was mined at Endeavour Inlet and Carrick, and is also present at Macetown, Hindon, Nenthorn and Waipori. Accessory minerals include sphalerite, galena, chalcopyrite and cinnabar. Hydrothermal alteration consists predominantly of quartz and illite, and typically extends only a few centimetres away from the veins, although the Golden Bar lode at Wakamarina has an alteration envelope up to 10 m wide (Skinner and Brathwaite, 1999). Many of the lodes were only worked in the oxidised zone and became uneconomic when the primary zone of finer grained gold associated with arsenopyrite and pyrite was reached, typically only 20 30 m below the surface.

Macraes and other Otago lodes

At Macraes, quartz lodes are developed along the 25 km long Hyde-Macraes Shear Zone. The shear zone consists of well-defined, shallow-dipping upper and lower bounding thrusts enclosing brecciated and crushed graphitic, pelitic schist, up to 125 m thick at Round Hill (Teagle et al., 1990; de Ronde et al., 2000). Several different types of quartz veins are present in the shear zone including concordant veins and discordant stockwork and gash veins. Gold occurs with pyrite and arsenopyrite in the quartz veins and disseminated in the sheared rocks that contain carbonaceous material, mostly graphite (McKeag et al., 1989; Craw et al., 1999, 2004). Following

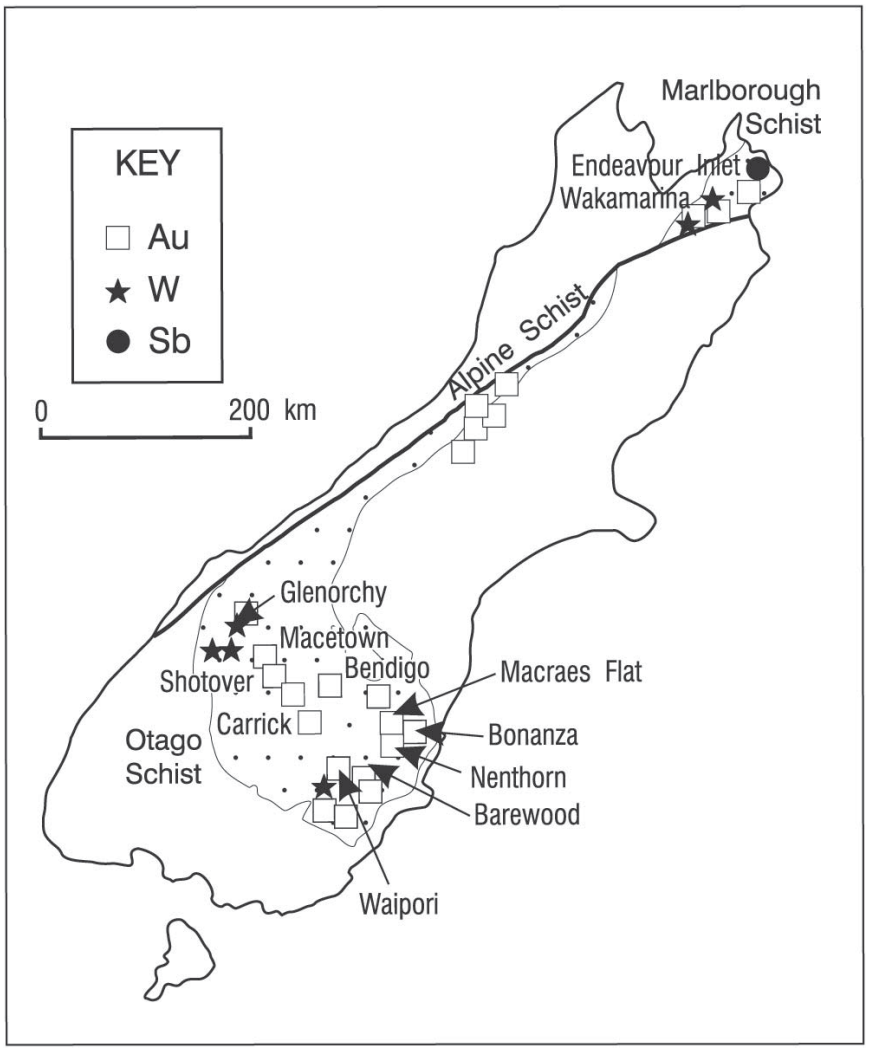

Fig. 2: Orogenic gold deposits in Mesozoic schist and greywacke (stippled) of Marlborough, Southern Alps, and Otago, South Island.

mining, the ore has to be treated by pressure oxidation to obtain good recovery from the fine grained disseminated mineralisation. Calcite, scheelite and minor stibnite and chalcopyrite are also present. Wallrock alteration is confined to minor sericite and kaolinite.

The only other known mineralised low angle thrust in Otago is the Rise and Shine, which had only very small past production (Grieve, 1991; Winsor, 1991). All other known gold-bearing lodes dip at moderate to high angles, although the extensive strike length of host structures at Barewood (20 km) and Carrick (10 km) have encouraged exploration for Macraes style large tonnage, low gold grade mineralisation.

Wakamarina, Marlborough

The Wakamarina mine was the largest gold producer in the Marlborough region (556 kg Au; 390 t W). The main lode, the Golden Bar, was traced over a strike length of 1.8 km, although it was worked only over a length of 818 m. It consists of a 2 m wide lode that cuts gently dipping mylonitic schist, quartzite and metabasite country rocks (Skinner & Brathwaite, 1999). The lode consists of ribbon banded quartz containing minor scheelite, pyrite and rare gold.

Gold quartz mineralisation in the Southern Alps

In the Main Divide of the Southern Alps, gold-bearing quartz lodes are found in Haast Schist in the Whitcombe River and Alexander Range (Poerua Mine), semi-schistose greywacke of the Taipo River area (Taipo Corner, Gold Creek, McQuilkans and others) and in low grade

metagreywacke of the Wilberforce River area (Fiddes, Pfahlerts and Wilsons Reward) (Williams, 1974). There was no significant gold production from these lodes. Until recently they have been grouped with the Mesozoic veins of Otago and Marlborough, but structural similarities with veins in the Callery River area, 25 km northeast of Mount Cook, may indicate a Cenozoic age (Becker et al., 2000). The Callery River veins are thin and contain quartz and calcite, with minor biotite and sulphides, and traces of scheelite and gold (Craw et al., 1987). They are 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 (Craw et al., 1987) and provide clues for interpreting the formation of the older lodes in Otago (Craw et al., 1987, 1997).

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Bob Brathwaite has BSc and MSc degrees from Victoria University of Wellington, and a PhD from the University of Tasmania. He spent 15 years in mine and exploration geology in Australia with several major mining companies. In 1979 he joined the New Zealand Geological Survey (now GNS Science), where he has been a Senior Minerals Geologist for the past 25 years.