Disseminated gold in turbidite-hosted gold deposits of Reefton (South Island, New Zealand), Victoria (Australia) and Nova Scotia (Canada)

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Abstract

The Reefton Goldfield has produced 67 t of gold from mesothermal vein gold deposits in metasedimentary rocks of the Greenland Group (Cambrian-Ordovician). The Globe-Progress deposit contributed 13.2 t (418,000 oz) of this total, predominantly from quartz lodes. Recently a resource of 14 Mt at 1.96 g /t Au (27.5 t or 882,300 oz of contained gold) has been delineated at Globe-Progress in quartz vein remnants and disseminated within adjacent sedimentary rock, much of which has been locally brecciated.

The breccias consist of quartz vein and sedimentary wall rock fragments set in a matrix of clay "rock flour" and sulphide (arsenopyrite plus minor pyrite and stibnite). Gold, closely associated with sulphide, is disseminated within the breccia.

Disseminated gold also occurs in massive siltstone and sandstone adjacent to the quartz lodes and breccias. Exploration drilling at Globe-Progress, and several other Reefton prospects (e.g. Capleston, Merrijigs and Alexander River), has intersected zones of disseminated arsenopyrite carrying up to 20 g/t or more gold. These mineralised sedimentary rocks commonly have little or no megascopic quartz and/or carbonate veining. There is little visible indication of former primary or secondary permeability for the passage of hydrothermal fluid and deposition of gold. However, porosity and permeability were formerly present in intergranular pore spaces and microveinlets, now filled with quartz, carbonate and K-mica.

The Fosterville gold deposit in Victoria bears many similarities to the Globe-Progress deposit at Reefton, in terms of age, host rocks, hydrothermal alteration and mineralisation style. Many of the disseminated-style deposits in Nova Scotia, including occurrences at North Brookfield and Moose River (Touquoy Zone), have similar characteristics to the Reefton disseminated mineralisation, but commonly have abundant pyrrhotite. Some deposits also have disseminated metal alloy grains of complex metallurgy.

Keywords: Turbidites, mesothermal gold deposits, Paleozoic, disseminated gold, quartz veins, Buller Terrane, Reefton, L30, L31, Victoria, Nova Scotia

Introduction

World-class mesothermal vein gold deposits occur in Cambrian-Ordovician turbidite sequences of the Buller Terrane in the South Island of New Zealand, central Victoria in Australia, and Nova Scotia in Canada (Christie et al., 1999). These deposits have traditionally been regarded as narrow vein targets, generally suitable for only relatively small-scale underground mining. However, exploration in the 1980s and 1990s has revealed a hitherto largely neglected new style of turbidite-hosted deposits that are potentially amenable to bulk mining operations, because of the presence of disseminated gold mineralisation. Disseminated mineralisation is currently mined at Fosterville in Victoria and resources have been identified in several other deposits, including Globe-Progress in Reefton, and North Brookfield and Moose River (Touquoy Zone) in Nova Scotia.

Reefton Goldfield

Most of the mining of mesothermal gold deposits in Paleozoic sedimentary rocks of the South Island occurred in the Reefton Goldfield (Figures 1 and 2). The mining targeted quartz veins or lodes in shear zones and produced 67 t of gold at an average grade of 16 g/t Au. Some 80 mines were established in the goldfield, with major production at Blackwater and Globe-Progress. The last gold mining operation, at Blackwater, closed in 1951.

The Reefton quartz lodes are hosted in weakly metamorphosed sandstone and mudstone of the Greenland Group (Cambrian to Ordovician). They commonly occur along shear zones that dip steeply and strike in a NNE direction, parallel to the axes of folding in the host sediments. One notable exception is the Globe-Progress shear, which is an arcuate listric structure with a predominantly west to northwest strike and south to southwest dip (Figures 3 and 4).

The Reefton gold prospects are strongly controlled by the pattern of folding at all scales (Gage, 1948). For example, the gold deposits are found in zones of close spaced and tighter folding, typically with wavelengths of 100 m to 500 m, compared with the kilometre-scale folding elsewhere (Rattenbury and Stewart, 2000). The pattern of folding also has a strong influence on the localisation of the individual ore shoots (Lew and Corner, 1988). However, most of the lodes are discordant to bedding and there are few examples of truly bedding-parallel veins.

In addition to the major lodes, stockwork quartz veins have been recorded from a few deposits in the Murray Creek area (Lawrence, 1989; Magner 1996) and at the Golden Lead workings in the Merrijigs area (Magner and Winward, 1996).

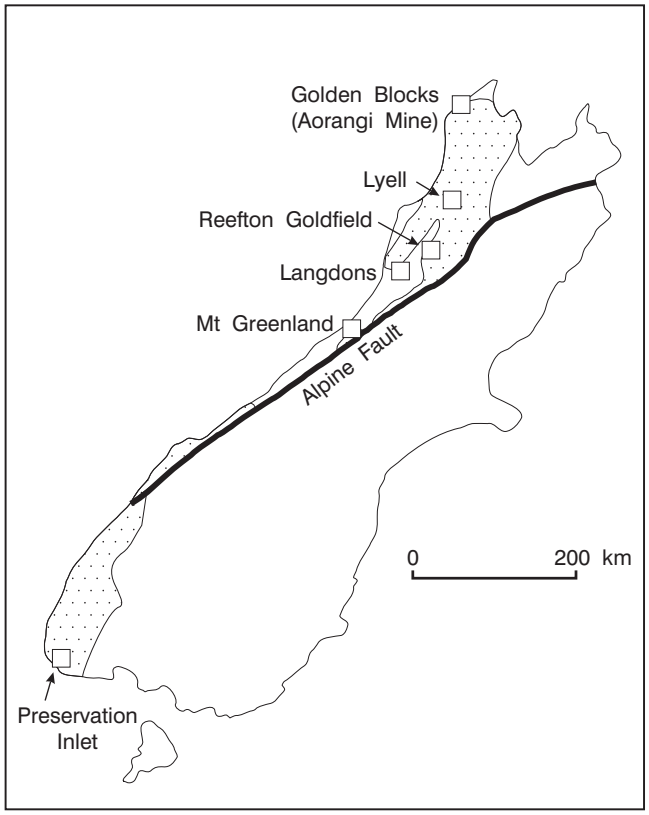

Figure 1. Locations of mesothermal lode gold deposits in the Buller terrane (stippled) of western South Island.

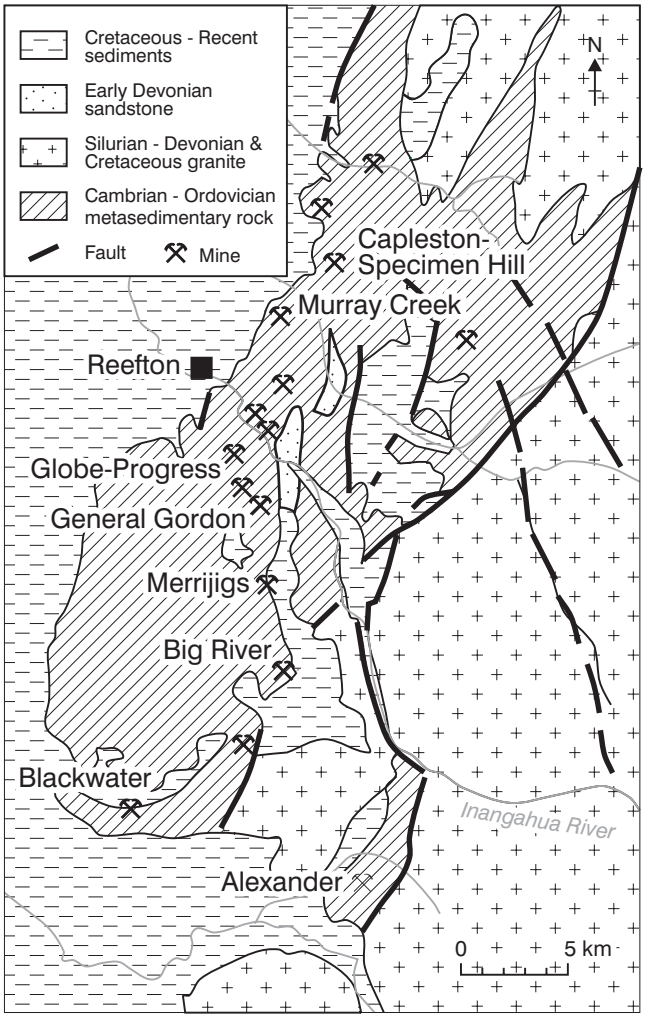

Figure 2. Geology of the Reefton Goldfield and location of major gold mines.

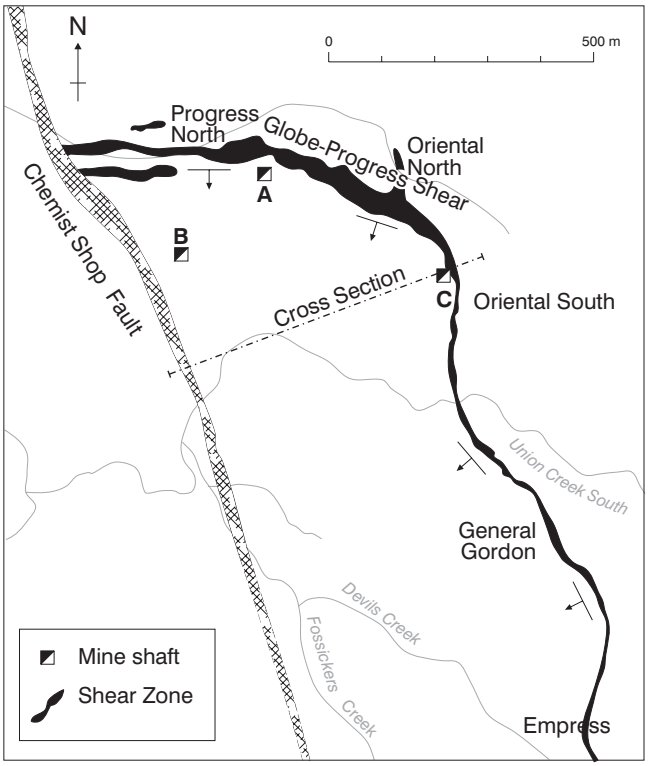

Figure 3. Geological map of the Globe-Progress prospect (GRD Macraes Ltd data).

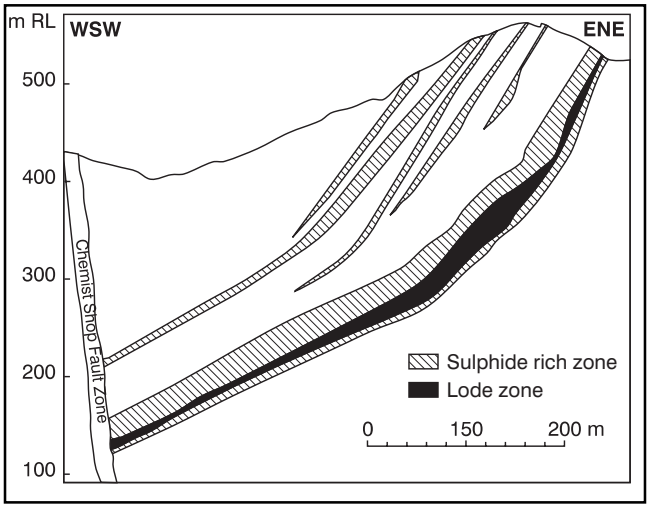

Figure 4. Cross section of the Globe-Progress prospect, as shown on Figure 3 (GRD Macraes Ltd data).

Stockwork quartz veins have also been discovered away from the areas of past mining, at the junction of Sunderland Creek and Big River, 5 km NNE along strike from Blackwater. Sampling by CRA Exploration Pty Ltd returned an assay of 0.51 g/t Au over 11 m (Patterson, 1987).

Zones of disseminated gold mineralisation are found adjacent to the quartz lodes in many deposits, where syn- and post-mineralisation deformation has produced illitic clay-rich fault breccias of quartz vein and wall rock fragments (Rosengren, 1984; Lew and Corner, 1988). These clay-rich breccias make up the bulk of the recently identified ore reserves at Globe-Progress, totalling 14.07 Mt at 1.96 g/t, and representing 27.5 t (or 882,000 oz) of contained gold (Macraes Mining, 1998). Mineralised fault breccias are developed to a lesser degree in some of the deposits to the north and south of Globe-Progress (e.g. Capleston, Oriental, General Gordon, Souvenir, Empress and Merrijigs), but have not been reported from the largest deposit in the goldfield, Blackwater. The breccias, together with remnant quartz vein material collectively comprise a mineralised envelope that averages about 4% total sulphides, mostly arsenopyrite, with lesser pyrite and local stibnite.

Disseminated gold also occurs in massive siltstone and sandstone peripheral to, and between the quartz lodes and breccias (Lew and Corner, 1988). Zones of disseminated sulphide, carrying up to 20 g/t or more gold, have been discovered in old workings and prospecting trenches, and intersected in exploration drilling at Globe-Progress (Patterson, 1987; Lew, 1987a, 1990; Lew and Corner, 1988; Hartshorn, 1990), and several other Reefton prospects including Capleston (Corner, 1987, 1989), Murray Creek (Lawrence, 1989; Magner, 1996), Merrijigs (Lew, 1987b; Magner and Winwood, 1996), Big River (Corner, 1990) and Alexander River (Hazeldene, 1993; Dunphy and Barry, 1997).

The quartz lodes and disseminated mineralisation occur in zones of hydrothermal alteration characterised by bleaching and the development of secondary K-mica, carbonate, chlorite and sulphides (Christie and Brathwaite, 1998). Carbonate spots are prominent in finer grained lithologies. Geochemically, the alteration is characterised by enrichment in As, Sb, S and CO_2, but depletion in Na. These alteration and sulphide mineralised zones generally have a good response in induced polarisation-resistivity surveys. However, exploration by these techniques has been hindered by the effects of the rugged terrain and glacial sediment cover (Modriniak and Marsden, 1938; Harvey, 1986a, 1986b).

Globe-Progress

More than 100 holes have been drilled at Globe-Progess during the exploration and resource definition phases. Four types of auriferous lithologies have been recognised (Lew, 1987a):

- quartz veins;
- dark blue, sulphidic pug, fault breccia with clasts of quartz;
- sandstone (and to a lesser extent siltstone) with significant disseminated sulphides and minor quartz veining ± sulphides; and
- brecciated/sheared sediments (usually pale grey), generally peripheral to the clay-rich breccia, with quartz veining and minor disseminated sulphides.

The non-brecciated sediments with disseminated mineralisation typically contain up to several percent of fine grained arsenopyrite and lesser pyrite. The arsenopyrite in the highest grade disseminated mineralisation occurs as fine acicular crystals. Lower gold assays associated with more equant, coarse grained arsenopyrite crystals suggest that there

may have been two separate episodes of arsenopyrite metallisation.

Some of the best drill intersections of disseminated mineralisation associated with the Globe-Progress lode were in drill holes GB15, GB16, GB17, GB30, GB34, GB37, GB39 and GB77 (Table 1). Broad sections of disseminated mineralisation were also intersected in GB10 and in nearby trenches associated with the North Progress Lode, a splay off the Globe-Progress shear.

The geochemical assays of these sections are characterised by high concentrations of Au and As, and generally low concentrations of Sb, in contrast to the mineralised quartz veins, which have elevated Au, As and Sb. For example, the 1000Au/As ratios of both vein and disseminated intersections are typically in the range of 0.1 to 1. In contrast, As/Sb and 1000Au/Sb are around 1-10 and 0.5-5 respectively for veins, but >30 and >15 respectively for disseminated zones (Table 1).

Capleston

Disseminated mineralisation is associated with many of the quartz lodes in the Capleston area and in particular, with shallow dipping shears which dislocate the quartz shoots (Corner, 1987, 1989). The mineralisation peripheral to the quartz lodes forms envelopes up to 10 m wide around the quartz shoots and shear zones.

At the Just-in-Time workings, dump samples of sandstone and siltstone with fine grained disseminated arsenopyrite and pyrite assayed between 2.9 and 32 g/t Au (Corner, 1987). Similar style mineralisation in a small adit at 110S 100W returned an assay of 4.4 g/t Au in a 2 m channel sample (Corner, 1987). Hole DD87 CP-1 was drilled to test for disseminated mineralisation between the West and Main Just-in-Time lodes. It intersected 5.7 m of disseminated sulphides grading 2.1 g/t Au immediately below a 3.6 m wide, open stope (Corner, 1987).

At Specimen Hill, a shallow dipping shear zone exposed by trenching contained oxidised disseminated mineralisation with minimal quartz veining and returned assays of 6.3 g/t Au over a 6.0 m section, or 2.65 g/t Au over the complete 14 m trench (Trench T8; Corner, 1989).

Murray Creek

In addition to the quartz lode mineralisation in the deposits at Murray Creek, three other styles of mineralisation are present:

1. disseminated sulphide mineralisation in sediments;
2. thin stockwork quartz veining in sediments; and
3. quartz vein and disseminated mineralisation within a dolerite dike, which is locally in contact with the mined shoots (Henderson, 1917; Lawrence, 1989; Magner, 1996).

Sampling by CRA Exploration Pty Ltd has shown that significant gold mineralisation (2-3 g/t) is present in arsenopyrite and pyrite bearing sediments surrounding the veins.

Merrijigs

At Merrijigs, the Happy Valley Shear has similarities to the Globe-Progress shear in containing lenticular quartz lodes, strongly sulphidic pug zones and disseminated sulphide bearing sediments. For example, 6-7 m of disseminated mineralisation is present in the footwall of the quartz lodes intersected in MJ-1 and MJ-2 (Lew, 1987b), although assays are low (0.3-0.4 g/t Au). In the Sir Francis Drake mine area, disseminated low grade gold mineralisation up to 12 m wide has formed within the shoot (Magner and Winward, 1996).

Big River

The Big River mine was one of the most profitable in the goldfield, with an average production grade of 34 g/t Au. The 1 m wide vein is strongly diced by ENE-trending faults. Disseminated mineralisation in samples obtained by trenching gave a few values of >1 g/t Au (Corner, 1990).

Alexander River

At Alexander River, disseminated mineralisation occurs in zones peripheral to the quartz lodes (Hazeldene, 1993). High grade gold assays have been reported from trench and rock chip sampling in the Bruno Block (up to 51 g/t Au; Lew, 1988; Dunphy and Barry, 1997) and in wall rocks of the McVicar lode (e.g. 30 and 20 g/t Au; Lew, 1988). A drillhole intersection of the McVicar lode (A6/3) assayed 5.3 g/t Au, 0.27% As and 12.78 ppm Sb over the 5.4 m thick quartz vein. This was included within a 9 m wide zone grading 3.85 g/t Au, 0.27% As and 15.67 ppm Sb (Hazeldene, 1993).

Preliminary ore microscopy work on samples of disseminated mineralisation from Globe-Progress, Merrijigs and Alexander has not located any visible gold, suggesting the possibility of the presence of "invisible gold" held in solid solution in the sulphides. GRD Macraes Ltd have been evaluating bacterial oxidation and pressure oxidation options for preliminary treatment of the relatively refractory disseminated mineralisation.

Victoria, Australia

The deposits in the Bendigo-Ballarat Zone of Central Victoria are hosted in weakly metamorphosed sandstone and mudstone of the Castlemaine Supergroup (Cambrian-Ordovician in age). Total past production was about 1000 t of gold (excluding placer gold), mostly from the deposits in the Bendigo, Ballarat and Castlemaine fields (Figure 5). Current production is from mines at Stawell and Fosterville.

The deposits are typically narrow, structurally controlled veins associated with dilatant zones in reverse faults or fold-related fractures. The main vein types are bedding parallel or concordant veins, discordant veins, saddle reefs, and stockwork veins. Bedding parallel veins are particularly

Hole	From (m)	To (m)	Interval (m)	Aspy (%)	Pyrite (%)	Au (ppm)	As (ppm)	Sb (ppm)	As/Sb	1000Au/Sb	1000Au/As
GB10	25.00	30.00	5.00	0.8	1.5	4.20	7840	38	206	111	0.5
GB10	33.00	40.00	7.00	0.4	0.9	1.70	4857	23	211	74	0.4
GB15	229.00	239.00	10.00	0.7	0.9	2.53	8040	148	54	17	0.3
GB15	266.00	275.00	9.00	0.4	0.4	1.58	5593	21	266	75	0.3
GB16	98.00	108.00	10.00	1.4	1.0	7.43	11820	307	39	24	0.6
GB17	66.70	81.00	14.30	0.9	1.1	2.43	6641	37	99	66	0.4
GB30	47.85	71.40	23.55	-	-	0.35	3726	22	169	16	0.1
GB30	80.45	83.20	2.75	-	-	0.46	980	22	45	21	0.5
GB34	120.00	131.00	11.00	-	-	2.07	6008	30	200	69	0.3
GB37	101.00	106.00	5.00	-	-	0.96	9942	42	216	21	0.1
GB39	77.00	118.90	41.90	-	-	0.48	2074	32	65	15	0.2
GB77	21.94	30.27	8.33	0.8	0.8	12.29	-	-	-	-	-
MJ13	145.00	157.00	12.00	-	-	1.30	1044	26	39	49	1.2
AX6/3	130.00	137.00	7.00	-	-	4.67	3277	15	218	311	1.4

GB = Globe-Progress; MJ = Merrijigs; AX = Alexander; Aspy = arsenopyrite; - = no data

Percent arsenopyrite and pyrite are visual estimates by core loggers

Table 1. Assay data for drill hole intersections of disseminated mineralisation from the Reefton Goldfield.

common in some of the major deposits such as Bendigo and Ballarat, in contrast to the mainly discordant vein style in the Reefton Goldfield.

Hydrothermal alteration is characterised by bleaching, the development of secondary carbonate, K-mica, chlorite and disseminated sulphides, and carbonate spots. Geochemical trends include enrichment in K, CO_2, S, and As, and depletion of Na and SiO_2 in the host metasedimentary rocks (Gao and Kwak, 1997; Bierlein et al., 1998, 2000).

Disseminated mineralisation occurs associated with hydrothermal alteration in several deposits in Victoria including Bendigo, Fosterville, Nagambie, Bailieston and Yea. Kwak and Roberts (1996) noted that many of the sulphides present in sandstone at Bendigo are in the form of spheroids and framboids which contain anomalously high Zn, Cu, Ni, Au, Sb, Pb, As and Pb, similar to some deposits in Nova Scotia (see below).

At Fosterville, 22 km east of Bendigo (Figure 6), Perseverance Corporation Ltd has open cut mined in the oxide zone since 1992 and has produced over 5.3 t (170,000 oz) of gold, with a current annual gold production of about 1.25 t (40,000 oz). Oxide ore treatment is by heap leaching. Perseverance have also defined an open-ended resource of sulphide ore beneath the area of recent mining. The mineral resource has recently been estimated as 12.16 Mt at 2.34 g/t Au for 28.5 t or 916,100 oz of contained gold (Perseverance, 2000). The operator is planning to use bacterial oxidation in the treatment of this relatively refractory ore.

The Fosterville goldfield is situated on the eastern limb of the north-south trending Strathfieldsaye Synclinorium. A series of deposits occur along two, subparallel NNW-trending fault zones: the Fosterville Line and O'Dwyers Line (Arne et al., 1998; Zurkic, 1998; Figure 6). The Fosterville Line consists of a series of mineralised zones in the footwall of the steeply west-dipping Fosterville Fault. The fault zone consists of a complex series of shear zones and fault breccias up to 35 m wide. The zone is cut by numerous northeast-trending crosscourses and offsets. The O'Dwyers Line occurs 1.5 km east of the Fosterville Line and is associated with a series of hydrothermally altered quartz porphyry dikes. Ar-Ar dating of these dikes suggests a minimum age of Middle Devonian for the mineralisation (Arne et al., 1998).

The ore zones are between 2 and 30 m wide, and average 5 m wide, with strike lengths up to 400 m long. They are typically developed below shears and faults and contain breccias, and veinlets and stockwork veins of quartz/carbonate, with disseminated sulphides in the surrounding and intervening host rocks, mostly sandstone. Vein textures vary from laminated (crack-seal types) to massive extensional veins often with vuggy zones towards the centre of the veins. Pyrite, arsenopyrite and stibnite are present in some veins, but most of the gold is located in the disseminated mineralisation. The disseminated arsenopyrite and pyrite grains are generally less than 1 mm in diameter. Minor free gold is present, but most gold occurs within pyrite and arsenopyrite as free grains with

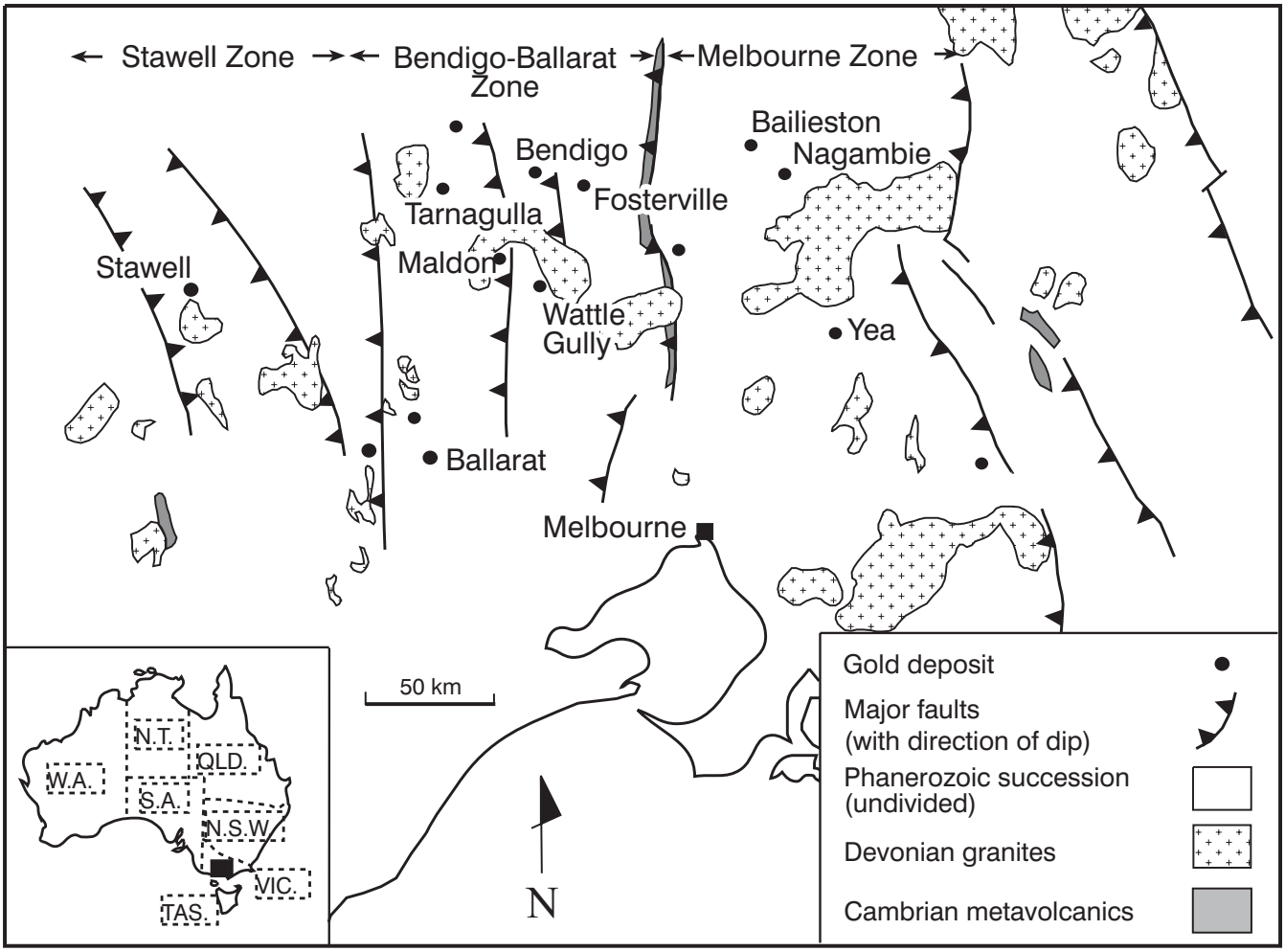

Figure 5. Location of major gold deposits in Victoria, including the disseminated gold deposits at Fosterville, Bailieston, Nagambie, and Yea.

a diameter of 1 to 10 m. Wallrock hydrothermal alteration at Fosterville is similar to that observed around other central Victorian gold deposits, with carbonatisation and sericitisation being prominent. Sulphidation and carbonatisation of the wallrock is also consistent with fluid inclusion evidence for CO_2-rich fluids that underwent phase separation (Mernagh, 1998).

At Bailieston (Sebek, 1998), disseminated gold mineralisation occurs in sandstone along the crest and southern limb of the northwest-trending Bailieston anticline. The major source of ore is a series of mineralised breccias associated with a major strike-parallel zone of shearing. The mineralised breccia zones are accompanied by irregular mineralised halos, which reflect stockwork veining and selective mineralisation and silicification of favourable beds. The gold is associated with pyrite, arsenopyrite and stibnite (Gao and Kwak, 1995).

At Nagambie (Gillies, 1990), disseminated mineralisation occurs along the southern limb of an anticlinal fold and is best developed in permeable and fractured siltstone units. The mineralised quartz stringers and stockwork veining extend up towards the crest from a zone of subvertical reverse faulting subparallel to the fold axis. This fault may have acted as the main fluid conduit, with migration along bedding towards the crest of the fold. More than 4.2 t (or 135,000 oz) of gold have been produced from the oxide zone of the Nagambie deposit by Perseverance Corporation Ltd (http://www.starnet.com.au/persever/company_profile.htm).

At Yea, two prospects, Providence and Ghin, occur on the axial zone of a northerly plunging anticlinorium, the Yea Anticline (McKnight et al., 1998). Disseminated mineralisation occurs associated with narrow veins, stockwork veins and breccia zones within the hypogene zone of the deposit. Twelve reverse circulation drill holes at the Providence prospect all returned anomalous gold throughout, with a best result of 18 m at 2.75 g/t Au in PB6. The disseminated mineralisation occurs in a 120 m wide zone, but gold grades are erratic and the high grade intersections do not correlate well between drill holes.

Kwak and Roberts (1996) cited several other deposits of disseminated mineralisation and Dickson (1998) noted several locations where gold-rich assays were obtained from metasedimentary rocks by the early prospectors, such as at Ararat, Chiltern-Rutherglen, Landsborough, Dunolly and St Arnauds, but all attempts at mining the low grade material failed.

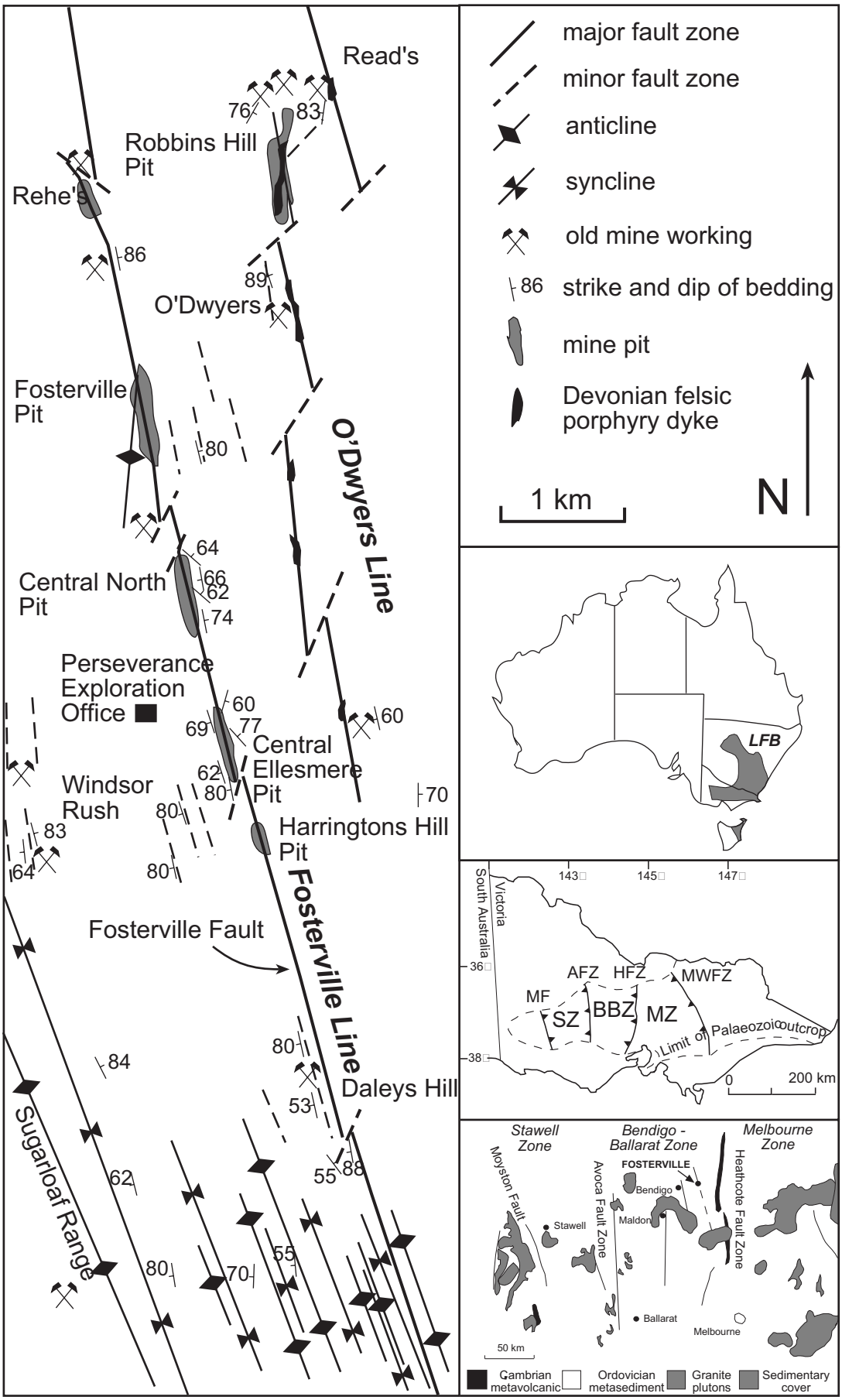

Figure 6. Location and geology of the Fosterville mine area (after Arne et al., 1998). LFB - Lachlan Fold Belt; MF - Moyston Fault; AFZ - Avoca Fault Zone; HFZ - Heathcote Fault Zone; MWFZ - Mount Wellington Fault Zone; SW - Stawell Fault Zone; BBZ - Bendigo-Ballarat Zone; MZ - Melbourne Zone.

Nova Scotia

In Nova Scotia, mesothermal vein gold deposits are present in generally weakly metamorphosed sandstone and mudstone turbidites of the Meguma Group (Lower Cambrian to Ordovician; Figure 7). About 60 deposits have been worked for a total production of 47 t Au, at an average grade of 12 g/t Au (Ryan and Smith, 1998).

The quartz vein mineralisation commonly occurs in bedding-parallel veins on the limbs of anticlines, especially where secondary structures are present (e.g. late faults, kink zones oblique to the axial planes of the folds or parasitic folds). Saddle reefs have been noted in a few deposits, namely, Harrigan Cove, Salmon River (Dufferin mine), and The Ovens. Bedding discordant veins are also important in some deposits (e.g. Caribou, Upper Seal Harbour, North Brookfield and West Gore) and include stockwork veins and fissure veins, along with less economically important angular veins, echelon veins, and 'ac' veins (Smith and Kontak, 1988).

Disseminated gold mineralisation has recently been identified in many of the vein deposits, including: North Beaverbank, Caribou, 149 East Zone at Fifteen Mile Stream, Cochrane Hill, Boston-Richardson area at Upper Seal Harbour, Beaver Dam, the Railway Showing at North Brookfield, and the argillite-hosted Touquoy Zone of the Moose River gold district (Ryan and Smith, 1998). Additionally, one showing of disseminated mineralisation has been found in vein-free sandstone lithologies at Steve's Road at North Beaverbank (between Mount Uniacke and Renfrew gold districts; Ryan and Smith, 1993; Ryan, 1997), well outside the influence of any gold district.

Hydrothermal alteration is pervasive and is highlighted by ankerite, which occurs as disseminations, enriched bedding laminations and veinlets (locally parallel to cleavage). On fresh surfaces, both sandstone and mudstone are bleached, whereas on weathered surfaces these lithologies display a characteristic brown colour. Selected whole rock geochemistry from several deposits shows this alteration to have relative major element enrichment in MnO, CaO, P_2O_5 and CO_2 and trace element enrichment in Ag, As, Au, Bi, La, Pb, Sb and W (Kontak and Smith, 1987, 1993). Associated alteration phases include sulphide minerals (arsenopyrite, pyrrhotite, pyrite and base metal sulphides), silica stringers and overgrowths on detrital quartz grains, and the common development of sericite and chlorite in the matrix of host rocks. The distribution of these features is recognised across areas up to 5 km in strike length and 1.5 km across strike (e.g. North Brookfield, Lake Catcha).

Grades in the disseminated gold deposits vary up to 5.5 g/t Au. The gold occurs as native gold and electrum in grains of 0.5 m to 2 mm in diameter, but most are <100 m. They are present as inclusions in detrital silicate minerals and sulphides (primarily arsenopyrite and pyrrhotite), and as micro-fracture infillings within sandstone and mudstone lithologies.

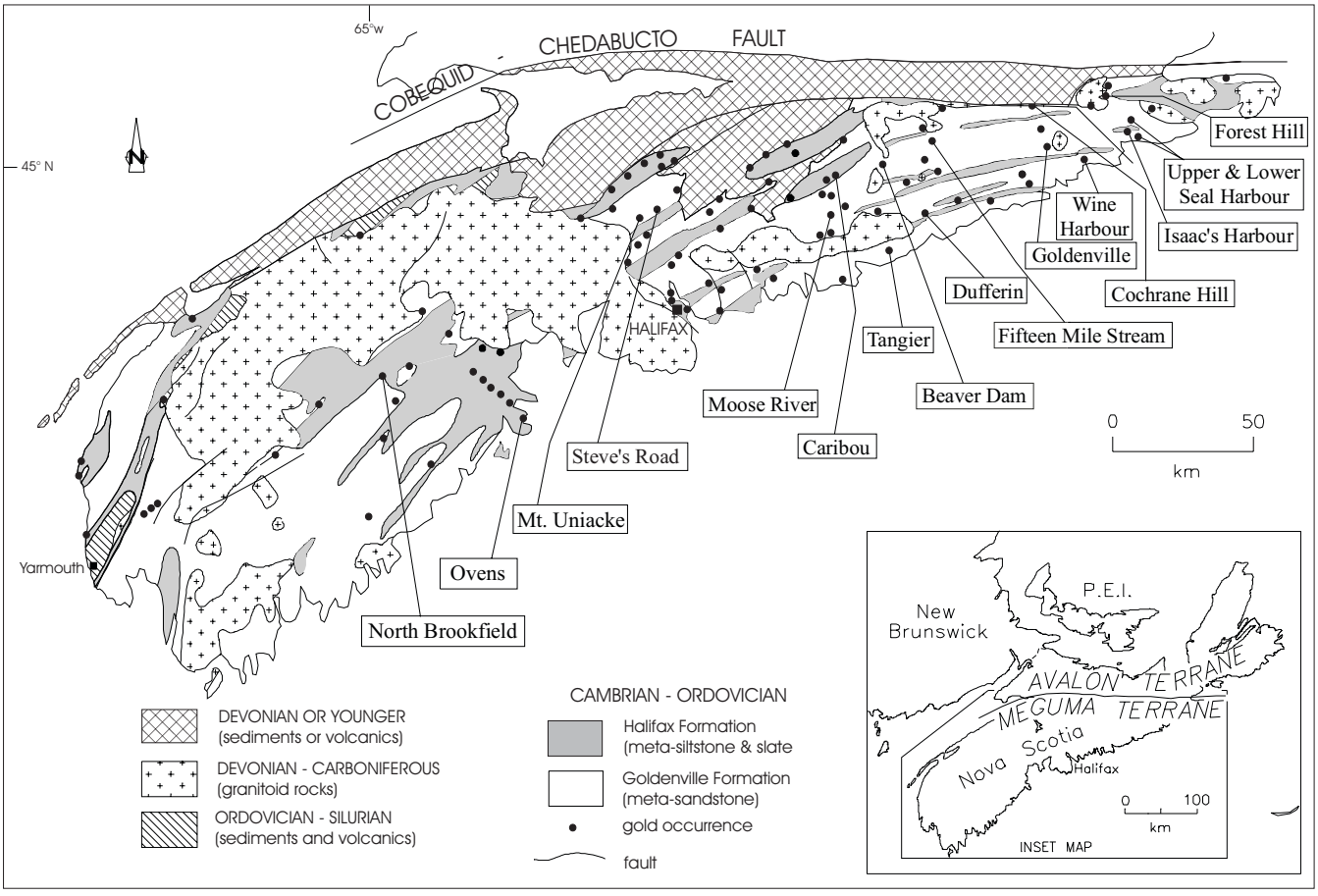

Figure 7. Location of major gold deposits in the Meguma Group of Nova Scotia, Canada.

In several deposits, the gold is associated with intermetallic compounds that consist of complex metal alloys and native metals of Au, Pb, Ag and Cu with local concentrations of W, Sn, Co-rich Pb and sulphide mineralogy. These alloys occur in two forms, irregularly-shaped metal alloy grains (0.5 to 1.0 mm) and spheroids (~10 m to ~200 m diameter). The irregularly-shaped metal alloy grains have characteristic framboidal and colloform textures and consist of metal alloys (mainly Au, Ag, Pb, Cu) and native metals (Au, Ag, Pb, W) surrounded by minor sulphides (cubanite, chalcopyrite, galena, sphalerite, arsenopyrite, loellingite, pyrrhotite, pyrite). The spheroids typically have an electrum core, within a matrix of Au-Pb alloy, surrounded sequentially by thin zones (metal alloy or sulphide) rich in Pb, As, Fe and Cu. The spheroids often form an integral part of the larger, irregular-shaped metal alloy grains. Their diagnostic feature is the presence of native metals including, Pb, Ag, Cu, Fe, Sb, W, Bi and Sn (or a combination thereof) within the mineralised samples (Smith and MacKay, 1993; Ryan and Smith, 1993).

At North Brookfield, the disseminated mineralisation occurs in a zone about 10 m thick, mostly hosted in sandstone, with minor interbedded siltstone and mudstone. The top of the disseminated zone is marked by a distinctive chipwacke unit containing clasts of mudstone, whereas the bottom of the zone is marked by massive sandstone with abundant arsenopyrite porphyroblasts. The rocks of the mineralised zone, and above and below it are cut by thin quartz and/or carbonate veinlets, 0.5 to 5 mm thick, typically at a density of about 10 per metre. The average grade of this zone is 1.2 g/t Au (Smith et al., 1994).

In the Touquoy Zone of the Moose River area, the disseminated mineralisation is hosted in finer grained sediments, and the hydrothermal alteration is more prominent (but not necessarily more intensive) than at North Brookfield. The alteration is marked by abundant carbonate spotting and carbonate flooding of the sediments. There are fewer veins than at North Brookfield but they tend to be thicker, typically 2-5 mm thick, but veins 2-3 cm thick are also present. Isolated grains and clots of visible gold occur in the veins and in the sediments, far removed from the veins. Indicated and inferred resources defined by drilling and bulk sampling at Moose River total 5.7 Mt at 2.2 g/t (Soever, 1998).

Discussion

The examples of disseminated mineralisation described from Reefton, and analogous occurrences in Victoria and Nova Scotia represent a variety of different types:

1. disseminated mineralisation peripheral to large veins (many examples);
2. disseminated mineralisation peripheral to stockwork quartz veins and breccias (Fosterville, Victoria);
3. disseminated mineralisation cut by minor thin veins (many examples); and
4. disseminated mineralisation with no nearby veins (Steve's Road, Nova Scotia).

In the Reefton Goldfield, the disseminated mineralisation in the clay-rich fault breccias probably represents reworked former disseminated mineralisation in the wall rocks of the quartz veins (1. above).

In many of the occurrences, the mineralised metasedimentary rocks commonly have few quartz and/or carbonate veins and are identified on the basis of the presence of abundant finely disseminated sulphides in drill core with high gold and arsenic assays. Megascopically, the sandstones and siltstones have little sign of primary or secondary permeability for the passage of hydrothermal fluid to cause hydrothermal alteration and mineralisation. However, closer examination usually reveals three potential forms of porosity and permeability:

1. primary porosity in the form of intergranular pore spaces subsequently filled by secondary carbonate, K-mica and sulphides precipitated from the hydrothermal fluid;
2. secondary porosity developed by the hydrothermal alteration of pre-existing minerals such as detrital feldspar and muscovite; and
3. secondary porosity developed in fractures now represented by millimetre to sub-millimetre scale veinlets spaced centimetres or decimetres apart, and filled with quartz and/or carbonate.

The geothermal fields of the Taupo Volcanic Zone (New Zealand) provide a modern example of hydrothermal fluid flow through apparently massive lithified rock. The Ohaaki and Kawerau fields have wells partly drilled in "basement" greywacke. This rock has a porosity between 3% and 10% (C.P. Wood, pers. comm.). The rock contains small veinlets and open cavities that are millimetres wide and separated by centimetres to decimetres. For example, Wood (1996) noted the occurrence of prismatic quartz crystals at a depth of 2340 m in drill hole BR29, suggesting the former presence of open cavities at least 2 mm wide. These spaces provide porosity but their lack of interconnection provides little permeability (Wood, 1996). Fracturing is required to develop permeability and this is obviously present in the mesothermal deposits in the vicinity of veins and shear zones as evidenced by the microscale veinlets.

Additionally, there are pressure effects that may increase permeability. The fault valve model for mineralisation in mesothermal veins (e.g. Cox et al., 1995) involves repeated cycles of fluid migration out from the fault and into the wall rocks, and then back into the fault as a response to phases of sealing and fault failure respectively. The model envisages a pressure differential between the fault and the wall rocks that would increase permeability to allow the fluids to penetrate the wall rocks for distances of several tens of metres.

Kwak and Roberts (1996) suggested that favourable factors for the deposition of disseminated sulphides by fluid over-pressure were: competent lithological units, major discordant structures, reactive feldspar or carbonate (that through dissolution could have resulted in increased porosity) and geology favourable for the production of a "choke" mechanism

(basically a lithological and/or structural trap). These factors are all empirically evident in the Reefton district.

Many of the deposits in Nova Scotia have abundant pyrrhotite that is absent from the Reefton deposits. Similarly, the grains and spheroids with unusual metallurgy recorded from deposits in Nova Scotia and Bendigo have not been recognised in the Reefton deposits. Smith (1986) considered several genetic models for the formation of the grains, including a model of fluid doming and replacement of biogenic material (e.g. algae) or of a colloidal gel with multistage remobilisation and enrichment. Overgrowth relationships (e.g. electrum overgrows Au-Pb mineralogy and in turn, both overgrow an Au-Pb-As mineral) suggest multiple stages of mineral paragenesis.

Oxidation has been an important factor in rendering some Victorian deposits amenable to mining by heap leaching. In contrast, there is very little oxidation of the Reefton and Nova Scotia deposits.

Conclusions

- Disseminated gold is found associated with turbidite-hosted mesothermal vein gold deposits in Paleozoic turbidite sequences in Reefton, Victoria and Nova Scotia.
- The disseminated mineralisation occurs in a variety of settings including: peripheral zones to quartz lodes; zones associated with stockwork quartz veins and breccias; zones spatially separate from the major lodes, but possibly related to shear zones and micro-veining; and zones unrelated to veins or shears (e.g. Steve's Road, Nova Scotia).
- At Reefton, disseminated mineralisation has been noted at most of the deposits recently explored by CRA Exploration Pty Ltd and GRD Macraes Ltd, including those in the Capleston, Globe-Progress, Merrijigs, Big River and Alexander River areas, but is apparently absent at Blackwater, the largest quartz lode deposit in the goldfield.
- The disseminated mineralisation was formed as part of an alteration process related to hydrothermal fluid flowing through the rocks. Porosity and permeability were provided by alteration of feldspar and mica, and the presence of intergranular pore spaces and fractures, now represented by microveinlets filled with secondary quartz, carbonate and K-mica. The fracturing was associated with folding, shearing and faulting (vein formation) of the host sediments.
- Some disseminated deposits in Nova Scotia have abundant pyrrhotite, suggesting different physicochemical conditions of deposition to other deposits in Nova Scotia and those in Reefton, where the iron sulphide mineralogy is arsenopyrite and pyrite, and pyrrhotite is apparently absent or present in low concentrations.
- Spheroid grains and grains with polymetallic alloys present in some Nova Scotian deposits and Bendigo have not been recognised in the Reefton Goldfield.
- The occurrence of substantial resources (>15 t or >0.5 million oz Au) in known disseminated gold deposits in the Reefton Goldfield, Victoria and Nova Scotia, demonstrates that disseminated mineralisation represents a significant exploration target in areas of turbidite-hosted mesothermal vein gold deposits.

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