Orogenic deposits: new approaches to old goldfields in New Zealand

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INTRODUCTION

The South Island of New Zealand has had a long history of mining of orogenic gold deposits and the placer deposits that have accumulated from erosion of those deposits (Williams 1974). Research over the past decade has provided some new insights and understanding of the processes of formation of the orogenic deposits, and this new research provides a context for on-going exploration activity. This paper outlines some of the general findings of the research effort and provides some indicators for specific features of the orogenic deposit formation that are worthy of including in an exploration strategy.

South Island orogenic deposits formed in greenschist facies metasedimentary terranes that were deformed and metamorphosed during collisional orogenesis on the Pacific margin of Gondwana (Fig. 1). The orogenic deposits formed at a wide range of times between early Paleozoic and late Cenozoic, in orogenic belts that were progressively added to the Gondwana margin, so that there are many similarities and correlations between the geology of the South island and that of Eastern Australia from which New Zealand rifted in the Cretaceous (Fig. 1).

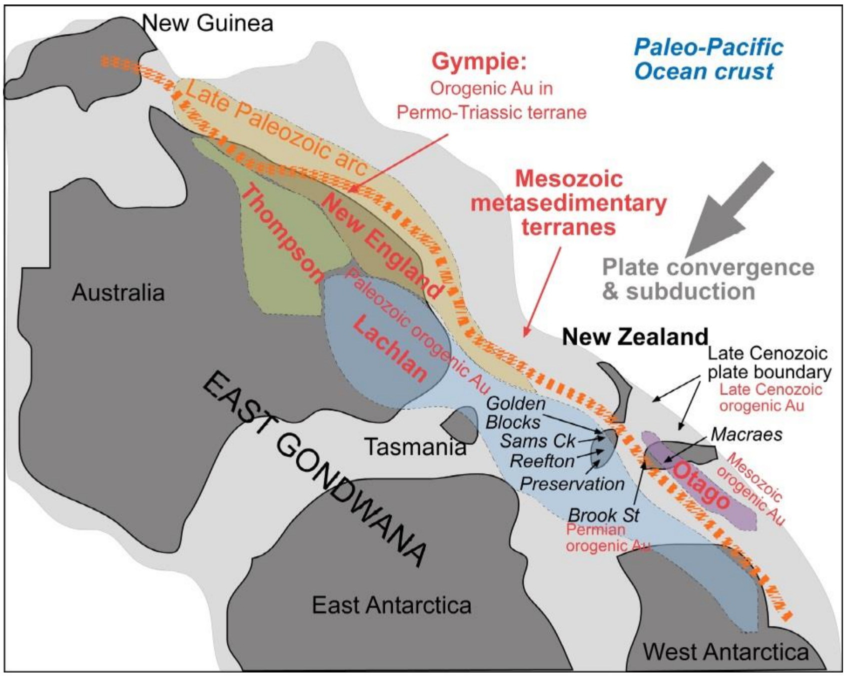

FIG 1 – Reconstruction of Paleozoic-Mesozoic orogenic belts on the Pacific margin of Gondwana (after Mortimer 2004). Principal belts with orogenic deposits are indicated, along with the general age of orogenic mineralisation and some of the New Zealand localities mentioned in the text.

Within each orogenic belt, convergent tectonics resulted in stacking and thickening of the metasediments to form a metamorphic pile 20-30 km thick. Metamorphic fluids generated in this process mobilised Au, As, W and Sb throughout the pile, but were particularly effective at metal mobility near the greenschist-amphibolite facies boundary zone within the deforming pile (Upton et al. 2011, 2014; Pitcairn et al. 2014; Goodwin et al. 2017). Structurally-controlled fluid migration followed by localised deposition of gold were widespread processes throughout the metamorphic piles, and persisted from early to late stages of the orogenic cycle as additional gold-bearing rocks were added to the orogen by principally horizontal tectonic motion (a conveyor belt mechanism; Pitcairn et al. 2014). Hence, the sources of metals and fluids in the orogens were in the metasedimentary rocks themselves, and both metal and fluids were abundant.

KEY FEATURES OF LARGER OROGENIC AU SYSTEMS

Within the context of the above background orogenic scenarios, some key features can be identified that are important for formation of large Au deposits rather than small Au occurrences, the latter being numerous and the former being rare. The following features are described mainly in the context of the Mesozoic Otago Schist and adjacent late Cenozoic Southern Alps, and then linked to the less well-constrained Paleozoic rocks of the western South Island (Fig. 1, 2a,b).

Episodic mineralisation. The major Au mineralisation processes in the Otago Schist and related rocks were distinctly episodic reflecting specific tectonic events (Mortensen et al. 2010). The first event occurred in the early Cretaceous while low grade flanks of the schist belt were being uplifted from metamorphic depths and at the same time as the higher grade core was being pervasively deformed and metamorphosed beneath the lower grade rocks (Fig. 2b). The second event occurred in the middle to late Cretaceous and was dominated by normal faulting and shearing, with localised quartz vein emplacement (Fig. 2b). A Miocene event occurred during the inception of the Alpine Fault (Fig. 2b). This latter event was the first stage of mineralisation that continued through Plio-Peistocene in the Southern Alps (Fig. 2a).

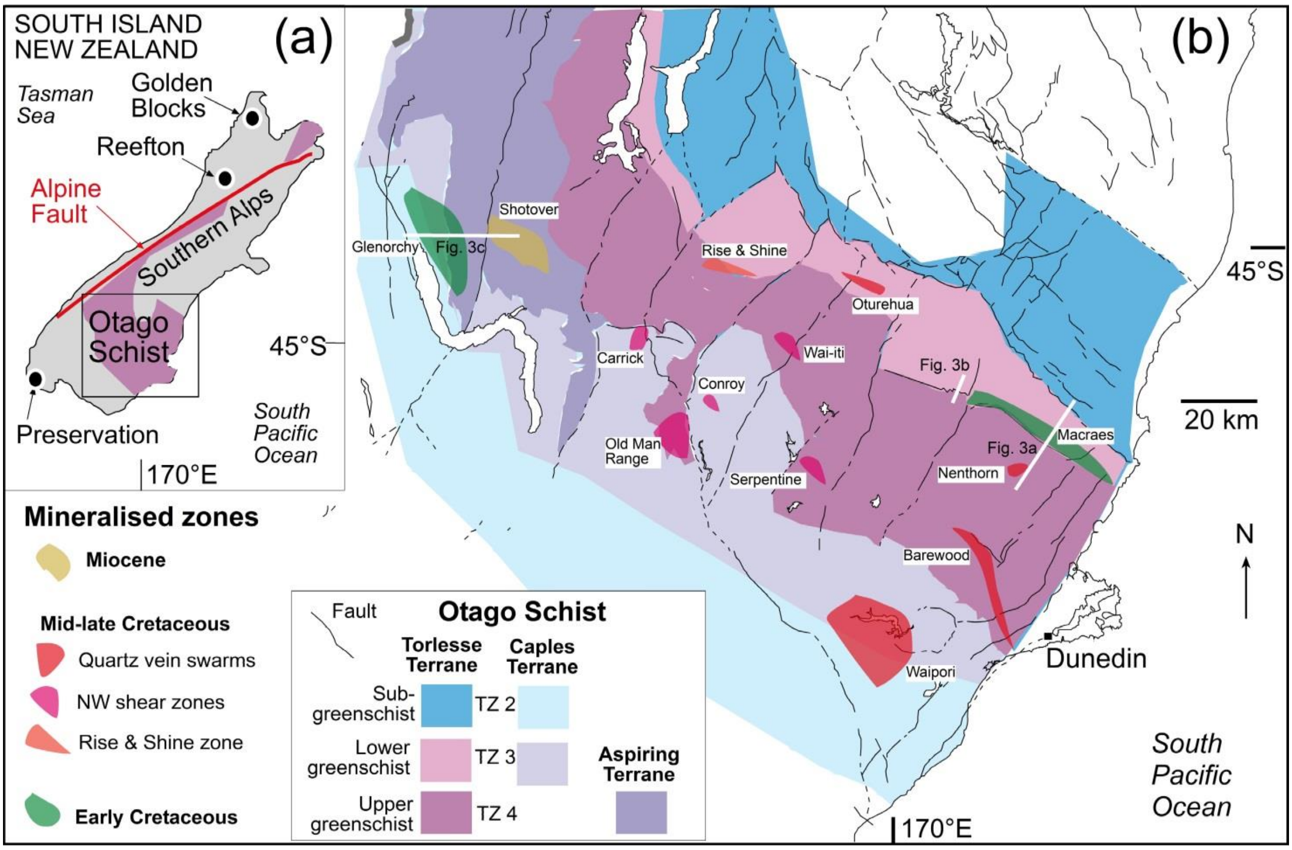

FIG 2 – Otago Schist orogenic gold belt (a) in the South Island; and (b) with principal metasedimentary terranes and their metamorphic grades. Structural zones with Au deposits of varying ages are indicated with coloured overlays. Textural Zones (TZ) give indications of degree of structural and metamorphic recrystallisation of the metasediments.

Structural control. Most fluid flow was dispersed widely through the deforming orogenic belt and did not yield significant deposits, as typified by the youngest (Plio-Pleistocene) system in the Southern Alps. Fluid flow was primarily fracture-controlled and widespread with little focussing. In contrast, the most significant deposits, which formed in the early Cretaceous (including the world-class Macraes mine; Allibone et al. 2018), were strongly structurally controlled and fluid flow was focussed into well-defined zones (Fig. 3a,b,c). These zones included shears and open fractures, but were regionally well-focussed at the map scale (Fig. 2b). Likewise, swarms of normal faults and shears, with or without quartz veins, formed in restricted zones in the mid-late Cretaceous, mostly with a northwest strike (Fig. 2b; 3a,c). It is notable that a prominent set of northeast-trending normal faults and shears, which hosted extensive hydrothermal alteration and silicification (Fig. 4), were apparently approximately coeval with the NW-striking mid-late Cretaceous structures yet have not yet yielded significant evidence for Au mineralisation. More normal-faulted vein-hosted swarms formed in localised zones during regional compressional deformation in the Miocene (Fig. 2b; 3c).

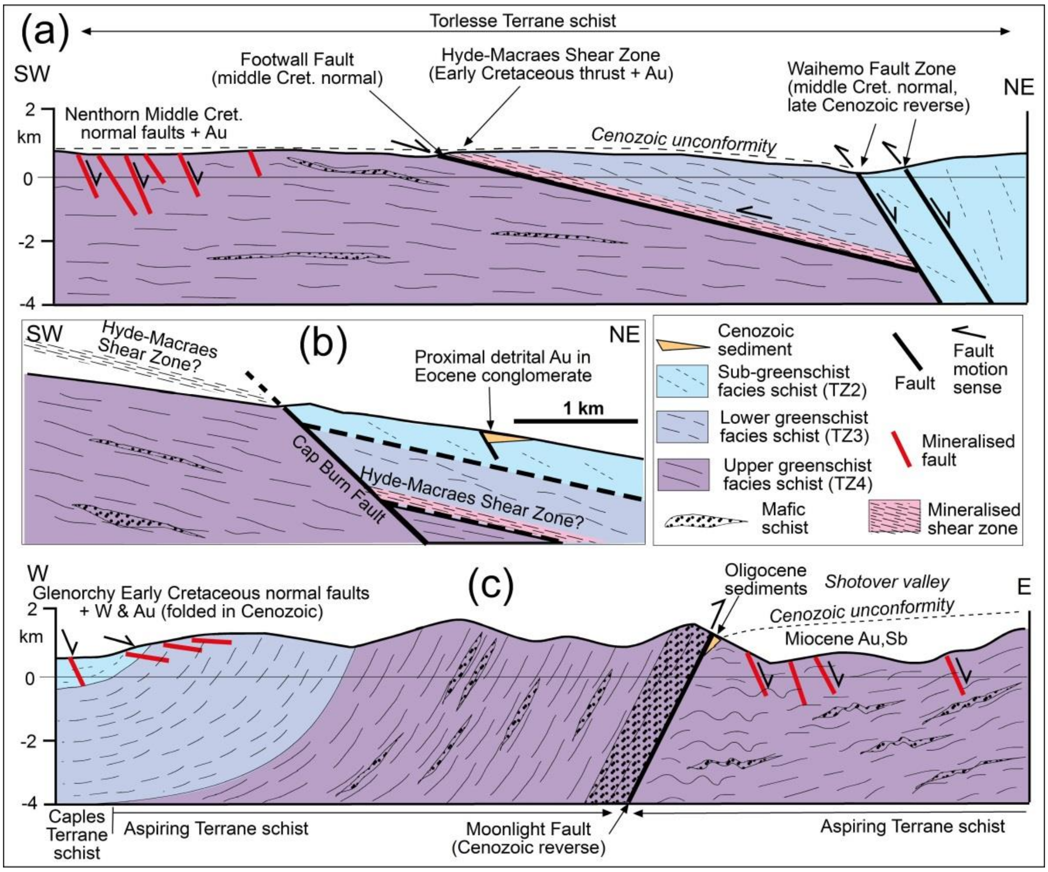

FIG 3 – Cross sections through parts of the Otago Schist belt (indicated in Fig. 2b; partly after Craw et al. 2015a), showing the structural control for gold mineralising events. (a) Early Cretaceous Hyde-Macraes Shear Zone hosts the Macraes mine, while nearby mid-Cretaceous normal faults host Au-bearing quartz vein swarms. (b) Projected structure along strike of the Hyde-Macraes Shear Zone. (c) Early Cretaceous W-rich Au poor vein swarms at Glenorchy, and Miocene Au-Sb bearing normal faults.

Disseminated mineralisation of host rock. This aspect has been important for enhancing the economic value of the Macraes deposit in particular, but is potentially important for any new mine discovery. Historic mining in Otago orogenic deposits focussed on supergene gold in quartz veins and involved small tonnages (Craw et al. 2015b; Craw and MacKenzie 2016). Modern mining is likely to occur on much larger scale, as in the Macraes deposit (>10M ounce resource at <1.5 g/tonne) where quartz veins are relatively rare. Large tonnage low grade resources typically require substantial inclusion of mineralised host rocks (Fig. 5). One possible younger analogue for the Macraes deposit is the mid-Cretaceous Rise & Shine Shear Zone (Fig. 2b, 4, 5), which is dominated by mineralised schist host rock and only minor quartz veining (MacKenzie et al. 2007).

Zonation of mineralisation with depth of formation. There are contrasting structural and mineralogical styles of orogenic mineralisation that are related broadly to depth of formation. This zonation is well displayed in the actively rising Southern Alps hydrothermal system, where evidence of processes of young Au mobilisation and redeposition is preserved without major overprinting of deformation and erosion (Craw et al. 2009; Upton et al. 2011, 2014). The deepest-formed mineralisation processes occur under greenschist facies conditions and fluids are in near-equilibrium with host rocks (Fig. 5). The Macraes deposit is an older example of this style. At middle levels, fluids were out of equilbrium with host rocks, but could readily interact chemically with those rocks and the most prominent alteration mineral is ankerite derived from chlorite (Fig. 5). This alteration can extend for metres to tens of metres from the fluid-controlling structures (Fig. 5). At shallow levels, fluid flow is strongly fracture-controlled. These parts of the mineralising system are out of thermal and chemical equilibrium with host rocks, and there is little or no wall-rock alteration except at the centimetre scale (Fig. 5).

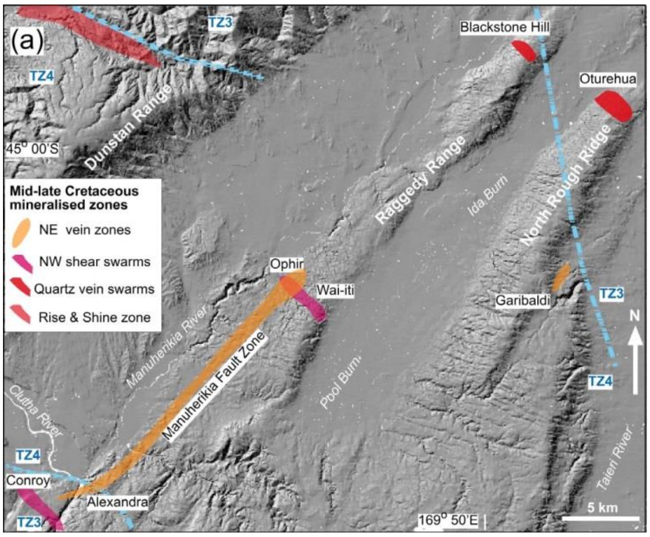

FIG 4 – Map of central Otago Schist belt showing principal mid-late Cretaceous hydrothermally altered structural zones. The orange NE striking zones are only weakly mineralised, whereas the NW striking zones have been mined historically and extensively prospected in modern times.

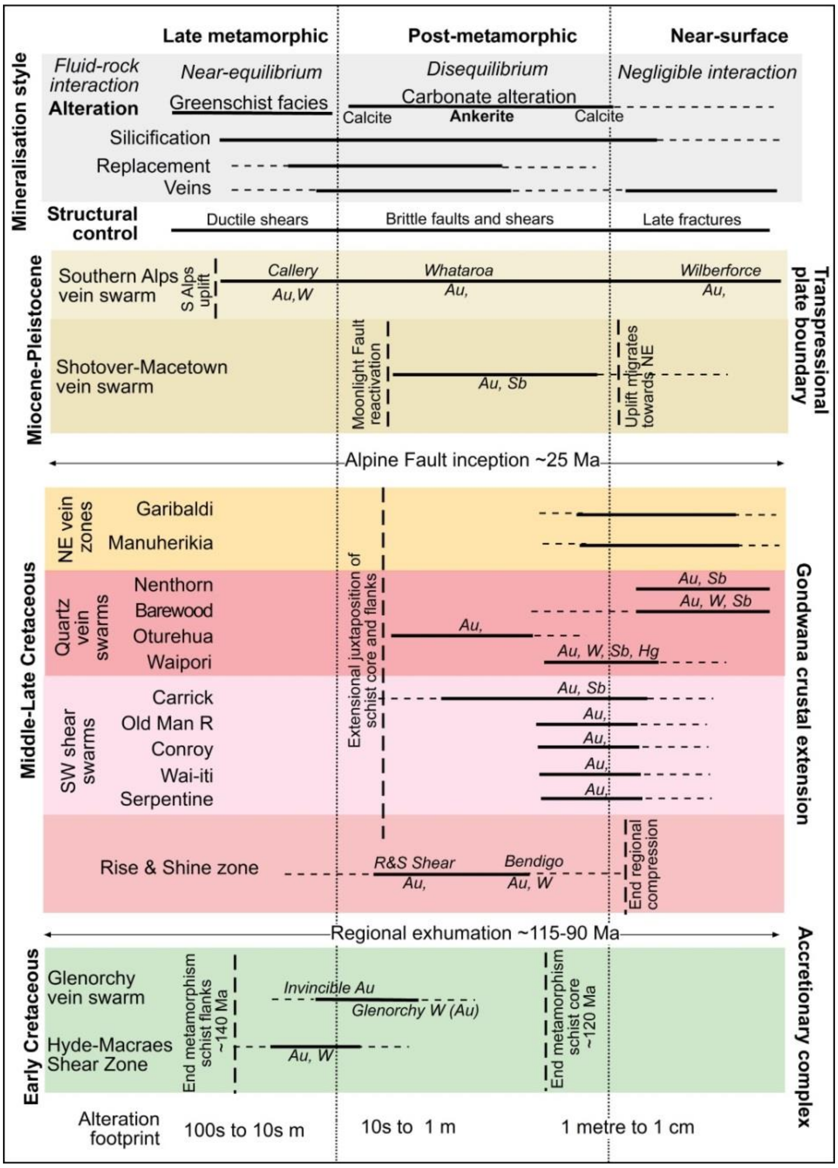

FIG 5 – Summary of temporal, structural, and hydrothermal features of principal mineralised zones in the Otago Schist belt and adjacent Southern Alps.

PALEOZOIC OROGENIC SYSTEMS

The Paleozoic orogenic deposits on the western side of the South Island (Fig. 1; 2a) have most of the features that are described above for the younger deposits, although each deposit has its own characteristics. The most productive deposit, the Blackwater mine near Reefton, was focused on a single large quartz vein (Fig. 6a,b; Hamisi et al. 2016; Allibone et al. 2019). This vein was formed in the latter stages of greenschist facies metamorphism, and the vein textures and mineralisation styles are essentially identical to those of veins at Macraes mine in Otago (MacKenzie and Craw 2016). Disseminated mineralisation in host rocks extends for up to 20 m from the vein, and involved ankeritic alteration in chemical disequilibrium with the host rocks (Fig. 6). The nearby Globe-Progress mine (reactivated 2007-2015) was initially mineralised in the same late metamorphic event as at Blackwater, and was subsequently overprinted by a second event with Au-As-Sb enrichment associated with brittle shearing (Fig. 6).

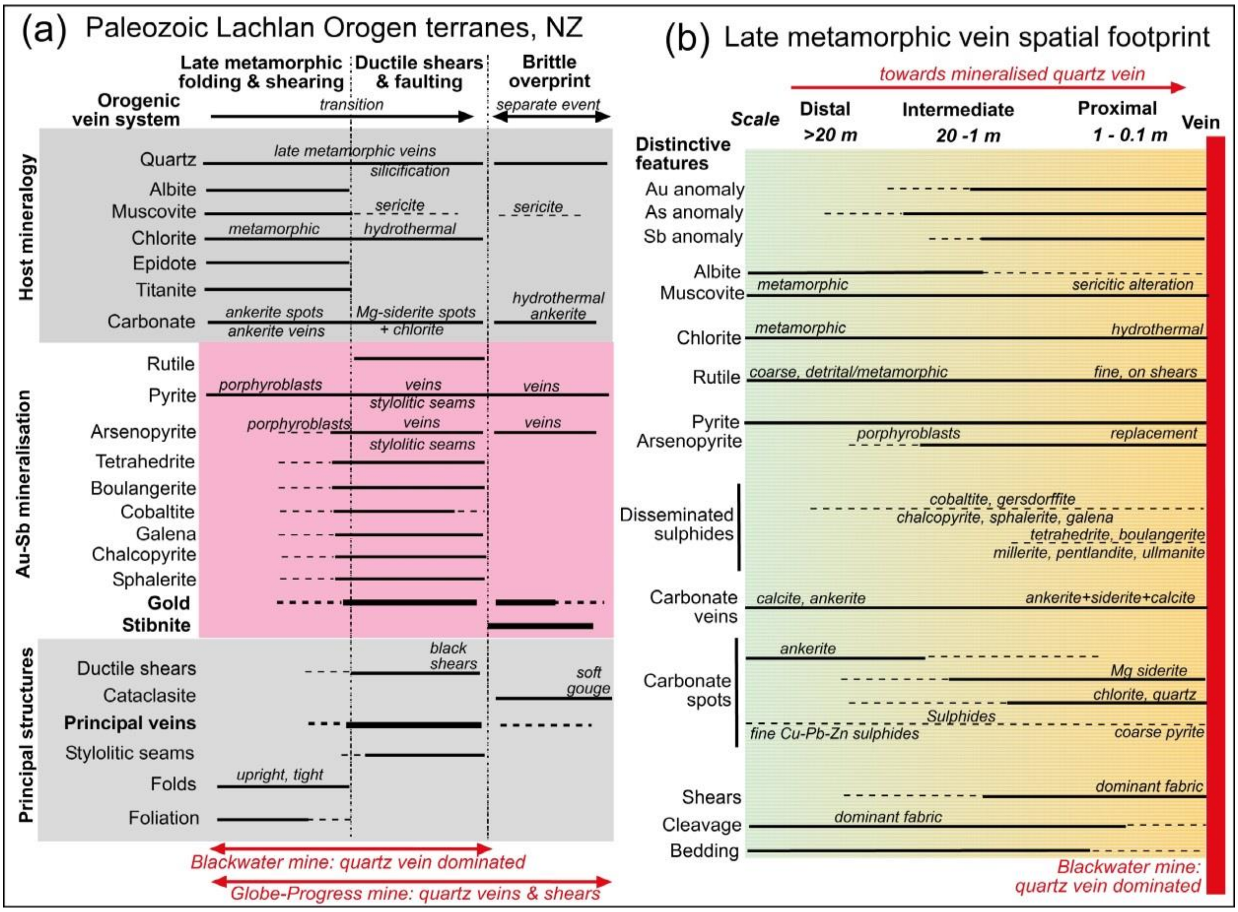

FIG 6 – Summary of the paragenesis of Paleozoic orogenic deposits on West Coast of South Island (after Hamisi et al. 2016; MacKenzie et al. 2016).

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