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The gold conveyor belt: Large-scale gold mobility in an active orogen

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ABSTRACT

The Southern Alps of New Zealand are part of an active collisional orogen where metamorphism, hydrothermal fluid flow and the formation of orogenic gold deposits are ongoing. The Southern Alps are forming due to transpressional collision between continental crust fragments on the Pacific and Australian tectonic plates. The plate tectonic rates and geometries, the sources of fluid and broad-scale fluid pathways in the hydrogeological system, and the geochemical compositions of the Torlesse Terrane rock that is being advected through the orogen are well defined so that a mass balance of metal mobility during active orogenic processing in the Southern Alps of New Zealand can be calculated. Advection of a 10 km wide × 5 km deep section of Torlesse rock through the orogen at tectonic rates (0.01 m/yr) that is then metamorphosed up to amphibolite facies causes mobilisation of over 11,27 t Au, 10.1 Mt As, 47,000 t Hg, 560,000 t Sb and 14,000 Mt H_2O in 1 Myrs. The masses of elements mobilised at the same rate along the length of the Southern Alps (>200 km) for 5 Myrs would be more than 100 times greater. The metals were mobilised by the metamorphic fluid produced during the orogenic processing of the Torlesse Terrane rocks and the concentrations of Au, As, Hg and Sb in this fluid are calculated to be 0.08, 711, 3, and 40 mg/kg, respectively. The mobilised metals form the orogenic gold deposits that occur in the Southern Alps. Different styles of gold deposits form contemporaneously during the active orogenesis of the Southern Alps, including those with a fluid temperature > rock temperature that may appear to have formed after the peak of metamorphism but are instead just the product hydrothermal fluid mineralising rocks on their retrograde metamorphic path. The mass balance shows that there has been orders of magnitude more metal mobilised in the orogen than resides in the currently known deposits. There is a clear potential for large gold deposits occurring in the yet to be uplifted parts of the Southern Alps if there have been efficient enough fluid focusing and metal precipitation mechanisms occurring under the Southern Alps.

1. Introduction

Orogenic gold deposits have produced more gold than any other style of gold deposit, but despite this economic significance there is uncertainty regarding many aspects of their formation, including the sources of metals and fluids. Some authors invoke mobility processes driven by igneous intrusions (Burrows and Spooner, 1989; Colvine 1989) or meteoric water incursion (Hagemann et al., 1994; Nesbitt et al., 1986, 1989), whilst others derive the metals from metamorphic processes on the local scale (Large et al., 2007, 2011; Thomas et al., 2011) or the regional scale (Henley et al., 1976; Kerrich and Fryer, 1979; Phillips and Powell, 2010; Pitcairn et al., 2006a, 2010). Transfer of metals from outside the metamorphic belt entirely, from the subcrustal lithosphere (Hronsky et al., 2012) or even from the mantle (Cameron, 1988; Colvine et al., 1984; Fyon et al., 1989) has been suggested. Distinguishing amongst these processes in ancient orogenic belts is commonly hindered by incomplete preservation of key parts of the orogen, and/or subsequent superimposition of geological processes (Kerrich et al., 2000). Much of our understanding of the formation of orogenic gold deposits comes from investigations of Archean to Mesozoic aged deposits, in orogens that are no longer currently active (Goldfarb et al., 2005; Groves et al., 1998; Kerrich and Wyman, 1990). Due to the conditions and depth in the Earth's crust at which these deposits form (e.g. 300 °C and 300–500 MPa equating to 5–10 km depth), active orogenic gold formation cannot be observed in the same way as with, for example, seafloor massive sulphide deposits (Herzig and Hannington, 1995) or magmatic hydrothermal deposits (Simmons and Brown, 2006, 2007). Consequently the active interrelationship between the tectonic setting and metamorphism, deformation, uplift and hydrothermal fluid production has not been clearly observed.

The Southern Alps of New Zealand are part of an active collisional orogen where metamorphism, hydrothermal fluid flow and the formation of orogenic gold deposits are ongoing (Figs. 1 and 2). The plate tectonic geometry and rates are well defined (DeMets et al., 1994; Norris et al., 1990), so that the rock flux through the orogen can be calculated. The sources of fluid and fluid pathways in the hydrogeological system are well defined (Koons, 1994; Koons et al., 1998; Templeton et al., 1998; Upton et al., 2003; Wannamaker et al., 2002), so that quantitative constraints can be put on fluid volumes and flow paths. The rocks within

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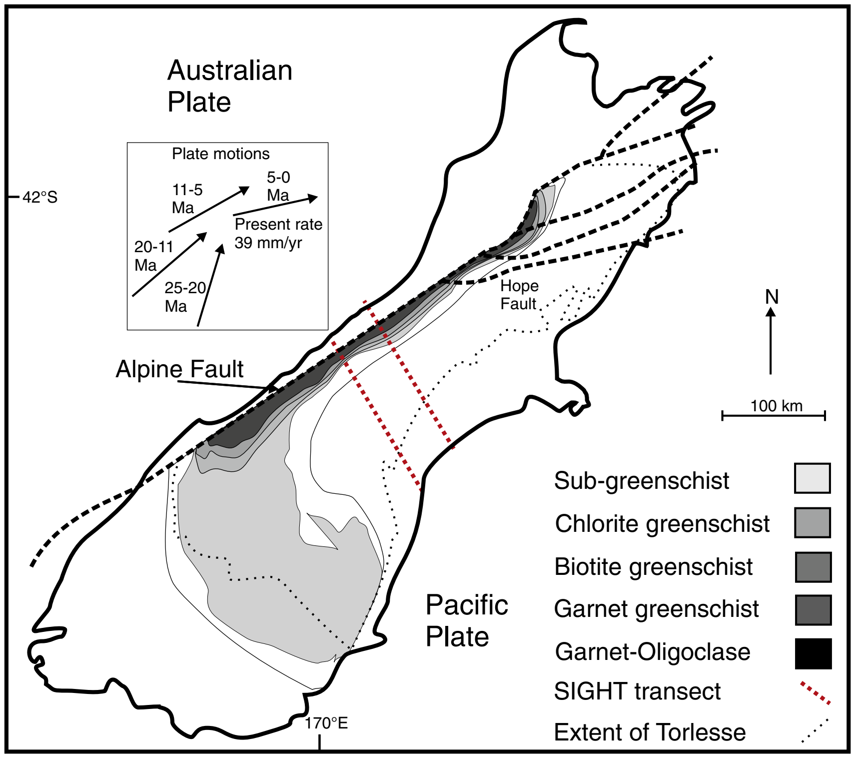

Fig. 1. Geological map of the Otago and Alpine Schist showing the relative plate motions, the extent of the Torlesse Terrane, the extent of the different metamorphic facies and the position of the SIGHT geophysical surveys.
After: Craw et al (2002) and Wannamaker et al. (2002).

the Southern Alps have broadly uniform initial compositional range so that geochemical zones of enrichment and depletion can be identified (Pitcairn et al., 2006a, 2010). A key feature of the Southern Alps metamorphic belt relevant to the controversy on metal sources is the absence of any igneous activity, which simplifies the interpretation of the various observations.

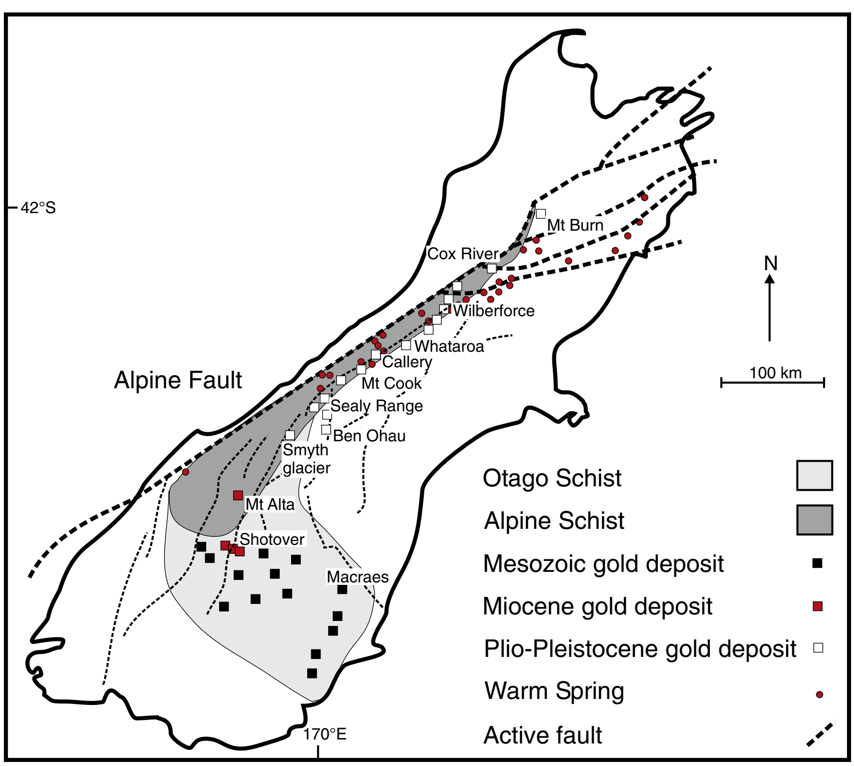

Fig. 2. Geological map of the Otago and Alpine Schist showing major active fault zones and the positions of hot springs and gold deposits in the Southern Alps.
After: Craw et al (2002) and Wannamaker et al. (2002).