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Diagenetic alteration of a Mesozoic fluvial gold placer deposit, southern New Zealand

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ABSTRACT

Gold paleoplacers become progressively more affected by diagenetic processes with age and burial. Mesozoic paleoplacer deposits in southern New Zealand display intermediate stages of diagenetic transformation compared to little-affected Late Cenozoic paleoplacers and strongly-affected Paleozoic and Precambrian paleoplacers. The Mesozoic (Cretaceous) diagenesis resulted in near-pervasive alteration, cementation and lithification of the paleoplacer. Lithic clasts and matrix have been extensively altered to illite, ferrous iron-bearing smectite-vermiculite, and kaolinite, and the cement consists mainly of clays and calcite. Diagenetic pyrite, marcasite, vivianite, and Mn oxide also contributed to cementation. Alteration occurred under near-surface (<500 m depth) conditions with groundwater that had circum-neutral pH, high alkalinity, and elevated dissolved K, Mg and Ca. Detrital albite remained unaffected by alteration. Detrital gold has been variably dissolved and redeposited, with widespread formation of gold overgrowths on the 1–10 μm scales, with 1–3 wt% Ag. Gold mobility was driven by reduced sulphur complexes in the low redox, high pH diagenetic environment. The overgrowth gold locally contributed to cementation of fine clastic grains, and has intergrown with diagenetic clays and Mn oxide. Post-diagenetic oxidation of the paleoplacer deposit has transformed much of the pyrite to ferric oxyhydroxide and deposited some ferric oxyhydroxide coatings on gold. These oxidation processes have had only minor effects on gold mobility and textures. Hence, the low redox conditions of diagenetic gold mobility were distinctly different from those typically associated with oxidation-related supergene gold mobility. Diagenesis can affect economics of paleoplacer mining by hindering rock disaggregation during processing, coating gold particles with secondary minerals, and increasing the clay content of the deposit, all of which can lower the efficiency of gold recovery.

1. Introduction

Most economic placer gold deposits occur in young fluvial sediments that were deposited in the late Cenozoic or in active river systems (Boyle, 1979; Garnett and Bassett, 2005). However, the detrital gold within these placer deposits has commonly been recycled from older sedimentary rocks, some of which contained placer gold accumulations as well (Henley and Adams, 1979; Boyle, 1979; Patyk-Kara, 1999; Garnett and Bassett, 2005; Craw, 2010, 2013; Chapman and Mortensen, 2016). Gold in some of these older deposits, commonly called paleoplacers, have in turn been recycled from even older sedimentary rocks (Boyle, 1979; Henley and Adams, 1979; Patyk-Kara, 1999; Garnett and Bassett, 2005; Lowey, 2006; Craw, 2010; Frimmel, 2014; Frimmel and Hennigh, 2015). Hence, paleoplacer deposits have significance as sources of gold and can be locally economic in their own right (Garnett and Bassett, 2005).

Most paleoplacer deposits occur in uplifted, deformed, and partially eroded older sedimentary rocks, and their hosting sedimentary sequence has typically been extensively disrupted and removed by younger geological events (Lindgren, 1911; Henley and Adams, 1979; Patyk-Kara, 1999; Lowey, 2006; Craw, 2013). Consequently, economic Phanerozoic paleoplacers older than Cenozoic are relatively rare although some minor occurrences are known in Mesozoic sequences (e.g., Trumbull et al., 1992, Jurassic; Leckie and Craw, 1995, Cretaceous) and Paleozoic sequences (e.g., Jennex et al., 2000, Carboniferous; Dewitt et al., Cambrian). The most famous ancient paleoplacers are those of the Archean and Paleoproterozoic (Mossman and Harron, 1983; Minter et al., 1993; Frimmel et al., 2005; Frimmel, 2014; Frimmel and Hennigh, 2015). Of these, the Witwatersrand deposits have been the most productive of gold and therefore have received abundant mineralogical study (Reimer and Mossman, 1990; Minter, 1999;

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Frimmel et al., 2005; Heinrich, 2015). However, post-depositional transformations have largely overprinted the original detrital mineralogy of the Archean and Paleoproterozoic placers and at least some of the gold may have been introduced during later fluid flow events, either diagenetic, metamorphic or hydrothermal (Mossman and Harron, 1983; Phillips, 1988; Law and Phillips, 2005).

All paleoplacers have undergone some degree of post-depositional alteration, and these diagenetic effects are most pronounced in older (pre-Cenozoic) paleoplacers (Garnett and Bassett, 2005). Mesozoic and Paleozoic paleoplacers are typically well lithified, which has facilitated their preservation (Boyle, 1979; Dewitt et al., 1986; Jennex et al., 2000; Garnett and Bassett, 2005). However, there is a gap in knowledge of the diagenetic processes that have affected these relatively rare older paleoplacers, because of the rarity of such deposits and the past focus on the economic and sedimentological aspects, rather than post-depositional mineralogy and textures (Dewitt et al., 1986; Leckie and Craw, 1995; Jennex et al., 2000; Garnett and Bassett, 2005). In this paper, we present mineralogical and geochemical information on diagenetic processes that have occurred in a Mesozoic gold placer in New Zealand. The hosting sedimentary rocks have preserved a record of diagenesis that has cemented and lithified the original fluvial gravels and turned them into hard scarp-forming conglomerates. The diagenetic processes were driven by water-rock interaction in the sedimentary rocks, and detrital gold was one of the minerals modified by these processes. Hence, this deposit provides a window into the post-depositional processes that progressively transform young placers into ancient paleoplacers.

2. General setting

2.1. Regional geology

The Otago placer goldfield of southern New Zealand (Fig. 1) has yielded > 8 million ounces of gold, and is one of the giant placer goldfields of the circum-Pacific tectonic zone (Williams, 1974; Henley and Adams, 1979; Craw, 2010, 2013). The goldfield was the site of one of the large circum-Pacific 19th Century gold rushes. The Otago gold rush started in 1861 at a site subsequently called Gabriels Gully (Fig. 1) after the initiator of the gold rush, Gabriel Read. The gold at this site was obtained from a modern stream, but it was soon traced to a source in nearby lithic and lithified Cretaceous sedimentary rocks, the Blue Spur Conglomerate (Fig. 1) from which the gold was being recycled into the modern river. Some subsequent mining activity extracted gold from those Cretaceous sedimentary rocks and similar correlatives in the general vicinity. This paper focuses on the Blue Spur Conglomerate, which is the oldest gold-bearing sedimentary unit in the Otago goldfield and one of the few pre-Cenozoic Phanerozoic gold placers of economic interest in the world.

The basement for the goldfield is the Mesozoic metasedimentary Otago Schist belt and adjacent Paleozoic-Mesozoic terranes (Fig. 1). The Otago Schist was metamorphosed in the Jurassic and Early Cretaceous, and late metamorphic mineralisation processes emplaced some orogenic gold deposits, including the world-class Macraes deposit (Fig. 1; Mortensen et al., 2010). The varying structural and metamorphic levels of the schist basement (Fig. 1) were exhumed between Early and Late Cretaceous (Mortensen et al., 2010). Exhumation was partly driven by regional extensional tectonics, beginning in the Early Cretaceous, and involved differential motion on a network of normal faults (Bishop and Turnbull, 1996; Deckert et al., 2002; Mortensen et al., 2010). A second generation of orogenic gold mineralisation accompanied this regional extension (Mortensen et al., 2010). Cretaceous erosion along the normal fault scarps yielded localised deposits of lithic debris that were up to several kilometres thick in places (Bishop and Laird, 1976; Craw, 2010). The sedimentary rocks described in this study, the Blue Spur Conglomerate, accumulated adjacent to one of these normal faults, the Tuapeka Fault (Fig. 1).

The Blue Spur Conglomerate is a member of the regionally extensive Taratu Formation (Fig. 1), a nonmarine to marginal

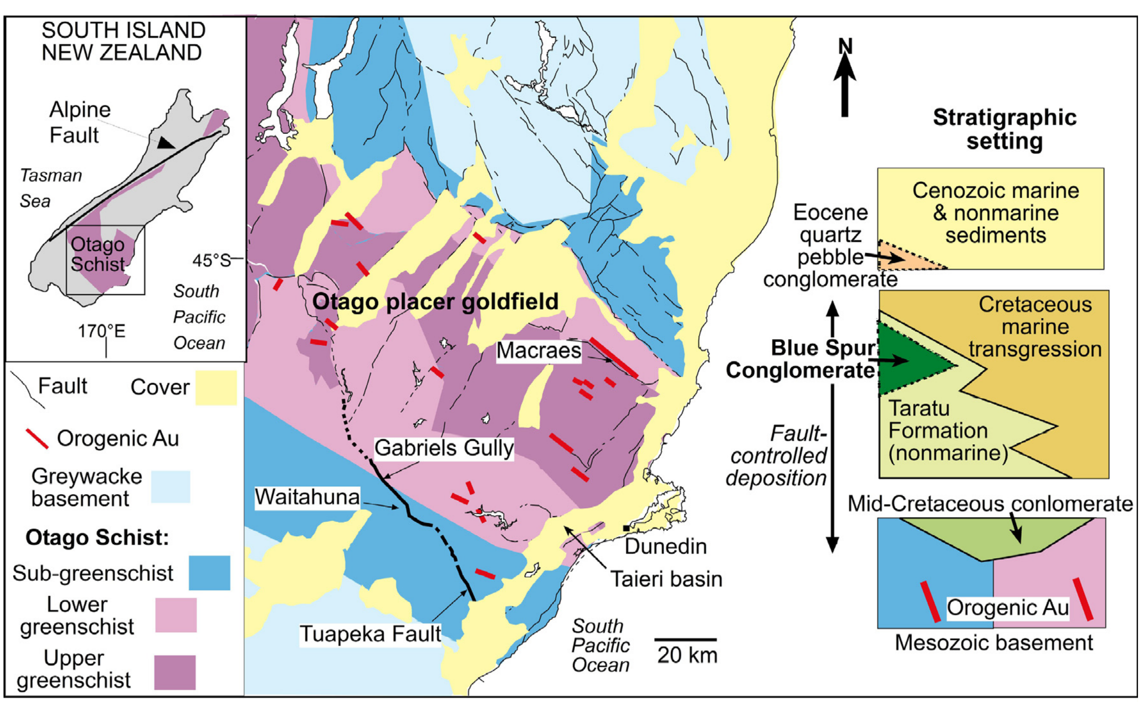

Fig. 1. Location map for the Otago placer goldfield on Otago Schist basement. Principal localities for Blue Spur Conglomerate mentioned in the text are indicated along the Tuapeka Fault system (from Bishop and Turnbull, 1996). Stratigraphic setting for the Blue Spur Conglomerate (as outlined in text) is indicated at right.