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Morphological evolution of gold nuggets in proximal sedimentary environments, southern New Zealand

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ABSTRACT

A rare collection of centimetre-scale proximal gold nuggets has been examined in the context of the Late Pleistocene to Holocene eluvial and colluvial sediments in which they occur, in a range of environments from arid temperate to periglacial. Liberation of supergene nuggets from their basement source in fault zones occurred progressively by physical erosion as the host basement rocks were uplifted between middle Miocene and Holocene. The host sediments are made up of poorly sorted angular greenschist facies schist debris. Some nuggets were recycled through several generations of these colluvial deposits, and additional nuggets were liberated to younger sediments during this time. The nuggets did not migrate laterally more than a few tens of metres during this repeated recycling, and were passively elevated vertically with the rising basement on to the crest and slopes of a 1600 m high mountain range. The most recently liberated nuggets retain almost all the morphological features of their supergene origin, including coarse (cm scale) crystal shapes, delicate crystalline internal structure, and imprints of oxidised pyrite crystals. Minor transport in colluvium has caused some abrasion and rounding of gold crystals. Repeated recycling progressively obscured the crystal shapes, although relict crystals are still recognisable on parts of most nuggets. Differential timing of liberation from basement has resulted in a wide range of rounding effects in groups of closely-coexisting nuggets. Variably crystalline gold overgrowths (micron scale) coat abraded surfaces of all or part of most nuggets, commonly intergrown with authigenic smectite clay minerals. These overgrowths developed from alkaline groundwater (pH 7–9) that had undergone extensive chemical interaction with labile minerals in the host colluvium. Abrasion during recycling removed some of the overgrowths, but this was replaced in the new sedimentary hosts. Physical and chemical processes affecting nuggets in these sediments have similarly affected eluvial and colluvial nuggets in a wide range of settings around the world, including Yukon (Canada), California (USA) and arid parts of Australia.

1. Introduction

Gold nuggets are significant, if volumetrically minor, components of the production of many gold mining areas worldwide, and have been the subject of legends, speculations, artisanal mining, and prospectors' aspirations since ancient times (Liversidge, 1893; Boyle, 1979; Hilson, 2002). Some of the most spectacular nugget specimens have been obtained from hydrothermal vein systems, and these can retain their original formational shapes that commonly include intricate crystalline structures (Boyle, 1979; Birch, 1987; Leicht, 1987; Joyce and McGibbon, 2004). However, most nuggets are detrital and have been extracted from placer goldfields, typically as part of regionally extensive mining and prospecting activity (Liversidge, 1893; Boyle, 1979; Wilson, 1984; Mauthner, 2004; Lowey, 2006; Hough et al., 2007; Rakovan et al., 2009; Rakovan, 2014). These detrital nuggets have been collected from fluvial sediments or soil horizons in a wide range of climatic settings from high latitude periglacial deposits, temperate landscapes, and tropical environments (Liversidge, 1893; Boyle, 1979; Wilson, 1984; Mann, 1984; Bowell, 1992; Mauthner, 2004; Hough et al., 2007; Rakovan et al., 2009).

Despite the cultural and local economic significance of detrital gold nuggets, there is little published scientific work on the geological and sedimentological settings of nugget accumulations in placer systems, at either regional or local scales. Most studies of nuggets have involved examination of the nuggets themselves after they have been removed from their placer context, and commonly these nuggets have passed through several owners before becoming available for such study (Liversidge, 1893; Wilson, 1984; Mauthner, 2004; Hough et al., 2007; Rakovan et al., 2009; Rakovan, 2014). In contrast, geological and mineralogical studies of placer deposits have focused on the more distal portions of placer systems where gold has accumulated in predictably economic concentrations that are amenable to mining (Fig. 1a,b; Boyle, 1979; Youngson and Craw, 1999; Garnett and Bassett, 2005; Lowey, 2006; Chapman et al., 2011; Chapman and Mortensen, 2016).

Economic placer deposits are dominated by small (millimetre scale) gold flakes that have been extensively physically modified by fluvial

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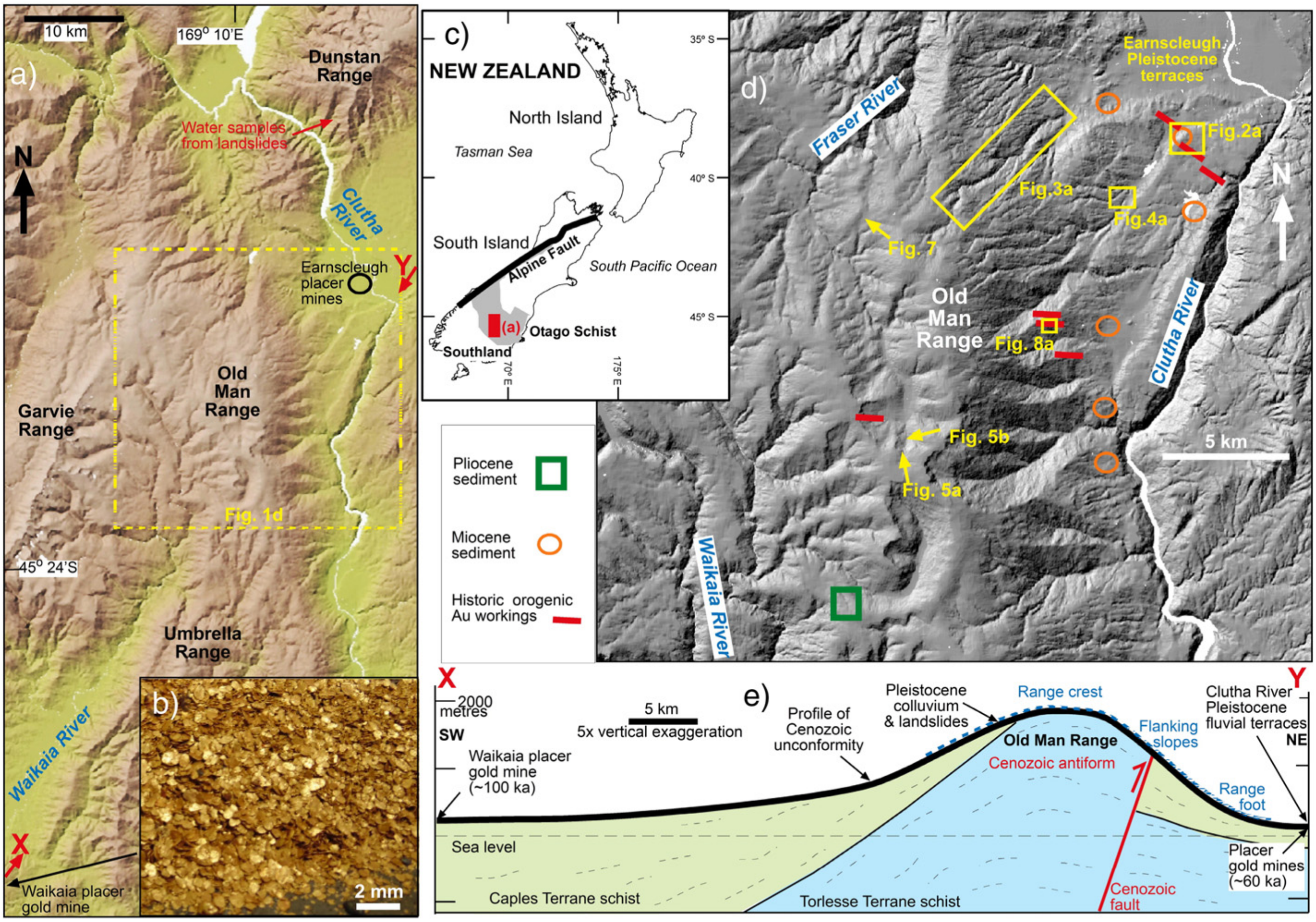

Fig. 1. General setting for placer gold deposits of the Old Man Range. (a) Location of Old Man Range and Waikaia placer gold mine in southern New Zealand. (b) Distal flaky placer gold from Waikaia mine in Late Pleistocene fluvial sediments. (c) Regional geological setting. (d) Hillshade image of Old Man Range, showing the locations of sites mentioned in the text. (e) Cross section (X-Y in a; 5× vertical exaggeration) through the Old Man Range.

transport (Fig. 1b; Knight et al., 1999; Youngson and Craw, 1999; Lowey, 2006; McClenaghan and Cabri, 2011). These smaller gold particles have been transported kilometres to hundreds of kilometres, commonly involving several stages of sedimentary recycling (Knight et al., 1999; Youngson and Craw, 1999; Garnett and Bassett, 2005; Lowey, 2006). Degree of shape modification, especially flattening, of these transported gold particles can be an indicator of distance of travel from source(s), and this shape modification has been suggested as a potentially useful prospecting tool for detection of previously unknown basement-hosted sources (Knight et al., 1999; Townley et al., 2003; McClenaghan and Cabri, 2011). Gold morphology in proximal placer deposits, the focus of the present study, has received relatively little scientific attention, because these placers are volumetrically small and are of only minor economic interest for mining (Youngson and Craw, 1995; Garnett and Bassett, 2005). These proximal placer deposits, hosted in eluvial and colluvial sediments, contain larger nuggets that do not travel far (metres to tens of metres) from sources because of their physical inertia in fluvial environments (Knight et al., 1999; Townley et al., 2003; Mauthner, 2004; Garnett and Bassett, 2005).

This paper describes nuggets and their hosting sediments in proximal placer settings, to fill a knowledge gap in the nature of processes that occur in the sedimentary pathways between basement gold sources and the better-studied distal placer gold deposits (Fig. 1a-e). We document proximal nugget occurrences in a range of climatic and sedimentological environments, from periglacial to arid temperate, on a single actively rising mountain range in southern New Zealand (Fig. 1a, d). The dynamic tectonic setting ensures that the sediments and geological context for proximal nugget placer accumulation are very young (Late Pleistocene to Holocene) and processes affecting nuggets are still active and observable. This young setting is in strong contrast to most nugget-hosting regions around the world where nugget-bearing sediments have evolved and recycled over tens or hundreds of millions of years on ancient landscapes (Liversidge, 1893; Boyle, 1979; Wilson, 1984; Hough et al., 2007).

2. General setting

The studied mountain range, the Old Man Range, lies at the western edge of the Otago Schist belt, a Mesozoic metasedimentary belt in the southern South Island of New Zealand (Fig. 1a,c). The schist belt has numerous Cretaceous orogenic gold-bearing vein systems and mineralised faults that have shed gold to form a major placer goldfield that has yielded >8 million ounces of gold (Williams, 1974; Mortensen et al., 2010). Most of that placer gold was extracted from fluvial sediments that range in age from Cretaceous to Holocene, and there has been extensive recycling of detrital gold through the evolving fluvial system over this time (Henley and Adams, 1979; Craw, 2010, 2013). The Clutha River catchment (Fig. 1a) has been the most productive part of the placer goldfield (Williams, 1974; Craw, 2013).

Placer gold began to accumulate in the late Cretaceous as the schist belt was progressively exhumed during a period of regional extensional tectonics. Extension and subsidence continued to the Oligocene, when