Provenance fingerprinting of gold from the Kurnalpi Goldfield

by

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Introduction

Many alluvial gold nuggets are believed to be liberated fragments of primary hypogene mineralization (e.g. Liversidge, 1893; Petrovskaya, 1973; Hough et al., 2007; Butt and Timms, 2011). Their morphology, internal crystal structure, chemistry, and accessory inclusions provide important information on mineralizing fluid composition, physical and chemical depositional conditions, proximity to primary source, primary mineral deposit type, and post-mineralization modification, and therefore prospectivity for undiscovered bedrock gold deposits (e.g. Chapman et al., 2002; Nikolaeva et al., 2004; Hancock et al., 2009; Nikiforova et al., 2013; Hancock and Thorne, 2016).

The Geological Survey of Western Australia (GSWA) has undertaken a pilot study of provenance, metallogenesis and prospectivity for placer gold in the Kurnalpi Goldfield, approximately 85 km east-northeast of Kalgoorlie (Fig. 1). The study uses a suite of alluvial gold nuggets generously provided by mineral exploration company KalNorth Gold Mines Limited, and sourced from 36 widely distributed sites over an area of ~80 km^2 (Fig. 1). These nuggets were originally collected by local prospectors from thin gravels at the base of Quaternary channels buried 1–2 m beneath surficial loams; however, gold nuggets have also been discovered in Cenozoic laterite and calcrete deposits, and pre- or early Cenozoic deep leads in buried paleochannels (Schupp, 1985).

Known bedrock-hosted gold mineralization occurs at the Scottish Lass and Brilliant sub-economic prospects (Fig. 1). Gold occurs mainly as microscopic grains in moderately dipping quartz veins with associated silica–pyrite ± carbonate ± hematite alteration in metabasalt and north-northwesterly striking, magnetite-bearing, granophyric quartz dolerite dykes that cut ultramafic rocks (Gunther, 2004). The mineralization style at Scottish Lass and Brilliant appears to be similar to other quartz-vein stockwork deposits in the Eastern Goldfields (e.g. Darlot–Centenary; Beardsmore and Gardner, 2003), but does not seem a likely source for the coarse, nuggetty placer gold at Kurnalpi.

GSWA therefore sought to determine the nature and origin of the bedrock source for the gold nugget samples from the Kurnalpi Goldfield, using techniques that included visual morphometry, acid etching, reflectance microscopy, scanning electron microscopy with energy dispersive X-ray analysis (SEM-EDX), and laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS).

Gold nugget characteristics

Seventy-five representative gold nuggets, from a total of 274 specimens provided, were selected for detailed analysis. Degree of roundness was used as the main criterion to distinguish proximity of gold nuggets to a potential primary bedrock source. About 30% of nuggets have irregular, angular shapes and are intergrown with vein quartz (Fig. 2a), hence they appear to have been collected from very close to their primary sources. These gold nuggets were used as a baseline reference for the mineralogical characteristics of primary bedrock gold, from which these nuggets were shed. They show:

- irregularly angular, spongy, or crystalline morphologies
- intergrowth with milky and brown quartz
- monocrystalline and polycrystalline internal microstructure, with local recrystallization and twin planes; indistinct zoning
- rounded, 10–100 µm micro-inclusions comprising assemblages of galena and gold/silver or lead tellurides, and an arsenopyrite–pyrite assemblage in one grain from the Six Mile site
- silver contents ranging from 5 to 11 wt%, and 3 wt% Ag in a grain with arsenopyrite–pyrite inclusions
- Cu contents from 30 to 300 ppm, and Hg contents from 10 to 100 ppm; traces of Sb and Pb.

The localities from which these ‘proximal’ nuggets were obtained are mostly clustered in the central eastern part of the goldfield (Camp Gully, Minters Gully, Discovery Hill, Hakes Patch, and Sparkle), but some come from the vicinity of Six Mile, in the northwest (Fig. 1).

The remaining gold specimens in the sample suite were sourced from across the goldfield (including domains of ‘proximal’ nuggets), although they preserve mineralogical characteristics similar to those of the ‘proximal’ reference specimens, such as:

- relict primary compositional microstructure
- rounded 10–200 µm inclusions of galena, chalcopyrite, and Au/Ag, Pb, and Bi tellurides
- 5–9 wt% Ag; consistent 20–600 ppm Cu and more variable 1–4000 ppm Hg

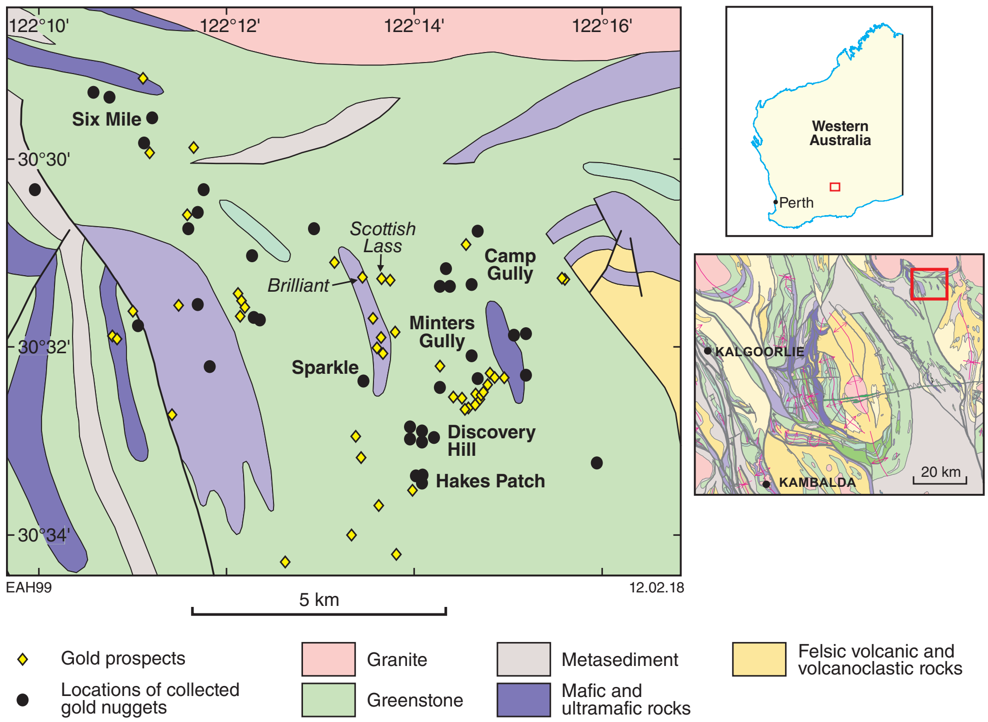

Figure 1. Geological setting of the Kurnalpi Goldfield (red frame in overview map) and locations of collected gold nuggets. Site names in italics are localities of known bedrock-hosted gold mineralization; bedrock geology from GSWA (2016)

- sporadic and universally low Sb, Te, Bi, Pb, Al, Fe, and Mg.

They also show secondary mechanical and chemical transformations indicating greater transportation from their primary source, and/or burial and in situ alteration in paleochannels for some time subsequent to erosion from the primary source. Features indicating these processes include:

- subrounded to well-rounded shapes with smooth surfaces (Fig. 2b)
- continuous to discontinuous, 5–100 µm thick marginal rims characterized by variable silver depletion and/or incipient to complete recrystallization (due to chemical leaching and mechanical deformation; Fig. 3a)
- absence of quartz; partial leaching of primary inclusions
- local recrystallization around incorporated regolith inclusions
- Fe- and Ca-rich clay inclusions and coatings; rounded maghemite, ilmenite, and hematite inclusions
- commonly well-developed veinlets along intergranular crystal boundaries, now partly filled with mixtures of clay, silica, and fine secondary gold (Fig. 3b).

The intergranular veinlets are of particular significance as they appear to have formed by a selective dissolution–(re)precipitation process similar to that for the supergene corrosive rims, although formation of the veinlets may have begun in the hypogene environment in response to deformation and hydrothermal fluid interaction. Acidic groundwater in the regolith environment further leached Ag from grain rims and intergranular crystal boundaries; because the latter were more protected from abrasion during placer transport, their full thicknesses were preserved, although eventual 'cracking' along them created channel ways that then filled with regolith minerals.

The combination of secondary features suggests placer gold grains from the Kurnalpi region are locally derived, and experienced only short periods of deformation and supergene weathering during transport from the basement to final residence in the regolith, but a more prolonged period of in situ supergene alteration.

Implications for gold metallogenesis and prospectivity

Placer gold nuggets from the Kurnalpi Goldfield all have a hypogene origin, and appear to have been transported at most only a short distance within the goldfield from their primary bedrock source(s). Their original microstructure is largely preserved, with no evidence for subsequent regional hydrothermal or metamorphic alteration, and only relatively minor overprinting by physical and chemical alteration related to short periods of surface transportation followed by longer periods of residence in the regolith.

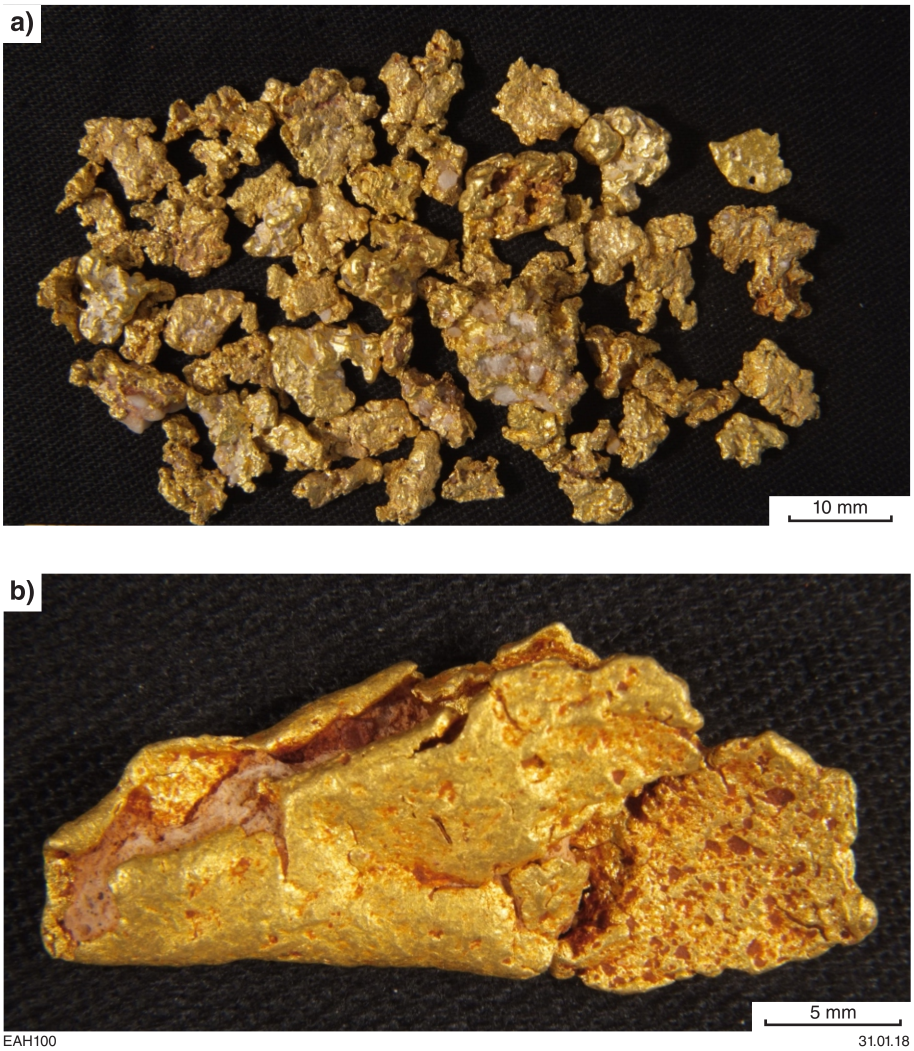

Figure 2. Morphology of gold nuggets: a) angular irregular with pitted and spongy surface, intergrowth with milky quartz; sample GSWA 201951; b) well-rounded and folded with even and smoothed pitted surface, inclusions of ferruginous clay mixture; sample GSWA 201946

The primary hypogene source for the studied alluvial gold nuggets appears to have been of the greenstone-hosted ‘orogenic’ quartz-vein style, possibly with two subtypes reflected by the gold–arsenopyrite–pyrite and gold–galena ± chalcopyrite ± Pb-Ag-Bi–telluride associations, which might indicate deeper and shallower crustal depths of formation, respectively. At the very least, these associations suggest several different, discrete sources for the nuggets. This style is distinctly different to mineralization at the Scottish Lass and Brilliant deposits, although mineralization styles at those deposits and in the placer nuggets are broadly compatible in terms of depth of formation in the crust. This suggests the Kurnalpi Goldfield remains prospective for the discovery of both these styles of orogenic gold deposits. Furthermore, placer gold nuggets are closest to their primary bedrock source in the central eastern and northwestern parts of the goldfield, indicating that these regions deserve particular scrutiny.

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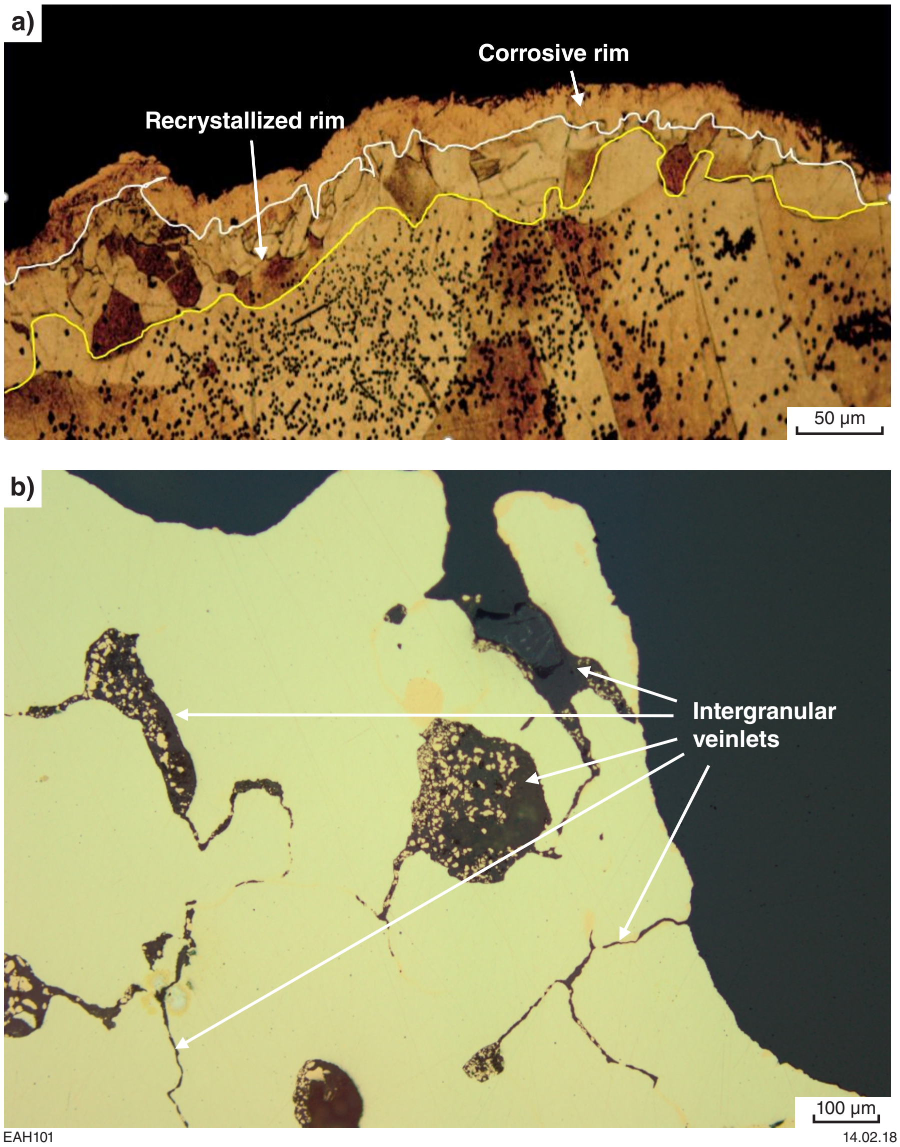

Figure 3. Reflected light photomicrographs of cut and polished gold nuggets showing their microstructure: a) compacted, thin, corrosive rim of pure gold overgrowing larger recrystallized marginal rim; several bent twin planes in grain's interior; silver chloride crystals (black dots) after aqua regia etching; sample GSWA 201933; b) well-developed, large, intergranular veinlets filled with mixture of clay, silica, and fine secondary gold; sample GSWA 201931

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