Coyote gold deposit, Granites–Tanami Orogen, Western Australia

by L. Bagas[1,2], D. L. Huston[3], J. A. C. Anderson[4], and F. P. Bierlein[2]

Abstract

The Coyote gold deposit, hosted by graded turbidite units of the Paleoproterozoic (c. 1835 Ma) Killi Killi Formation of the Tanami Group, comprises a number of ore lenses localized along the limbs of the Coyote Anticline, a structure formed during the Paleoproterozoic Tanami Orogeny. The main ore lenses are along the steeply dipping south limb of this fold, just to the north of the Gonzales Fault. The Coyote Anticline was refolded about north-trending fold axes and the Gonzales Fault reactivated as a dextral transpressive structure during late (c. 1800 Ma) easterly directed compression. Dilational zones that formed in and adjacent to an approximately 10 m-thick siltstone unit controlled the movement of mineralizing fluids at moderate temperatures (~350°C) by a pressure gradient. These dilational zones formed in response to the compression.

An implication of this preliminary study is that gold mineralization in the Coyote deposit was multistage and can be temporally linked to a combination of tectonism, metamorphism, and granite emplacement, similar to the genesis of many orogenic gold deposits worldwide.

KEYWORDS: Paleoproterozoic, Tanami Group, Killi Killi Formation, Tanami Orogeny, Coyote, gold.

The Coyote gold deposit is concealed by both in situ and transported regolith to a depth of 15 m, and the base of weathering extends to a depth of up to 200 m. As a consequence of the regolith cover, AngloGold Ashanti and Tanami Gold NL have delineated the geological structure of the area with detailed lithological and structural logging of drillholes.

Coyote, Kookaburra, and Sandpiper are the only gold deposits in the western part of the Paleoproterozoic Granites–Tanami Orogen for which resources have been established, but there are other significant prospects in the area (Fig. 1).

The auriferous veins are interpreted to have been emplaced during and after the Tanami Orogeny between 1835 and 1800 Ma. The orogeny is a major tectonic event that is characterized by southeast- to east-trending folds and faults.

Between c. 1835 and 1795 Ma the region was characterized by extensive magmatism accompanied by folding. The magmatism may be associated with post-collisional extension after docking of the Halls Creek Orogen to the northwest and is broadly coeval with most of the gold deposits in the Tanami region (Huston et al., 2006).

Structural setting

The Coyote deposit is hosted by the c. 1835 Ma Killi Killi Formation of the approximately 5 km-thick Tanami Group (Huston et al., 2006). The formation is interpreted to be up to 4 km thick and comprises fine- to medium-grained, immature sandstone interbedded with lesser (10–30%) siltstone, and rare carbonaceous shale, and mafic intrusive rocks. A distinctive finer, approximately 10 m-thick siltstone-dominated sequence, locally called the 'Marker siltstone', has been used as a stratigraphic marker within the mine sequence to delineate the structure of the deposit (Fig. 2).

The Coyote deposit consists of a number of ore lenses that are within the F_{C1}* Coyote Anticline associated with the Tanami Orogeny. The deposit comprises one main (Buggsy–Gonzales) and several satellite lenses (e.g. Speedy) that form ruler-shaped lodes plunging 10–15° to the southwest (parallel to the fold axis). The Buggsy–Gonzales lode is about 1 m thick and extends 150 m down-dip and up to 300 m along strike, and the Speedy lode is about 2 m thick, and extends 40 m down-dip and 80 m along strike.

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[2] Centre for Exploration Targeting, University of Western Australia, Crawley, W.A. 6009.
[3] Geoscience Australia, GPO Box 378, Canberra, A.C.T. 2601.
[4] Tanami Gold NL, PO Box 1892, West Perth, W.A. 6872.

* 'C' refers to deformation events in the Coyote area.

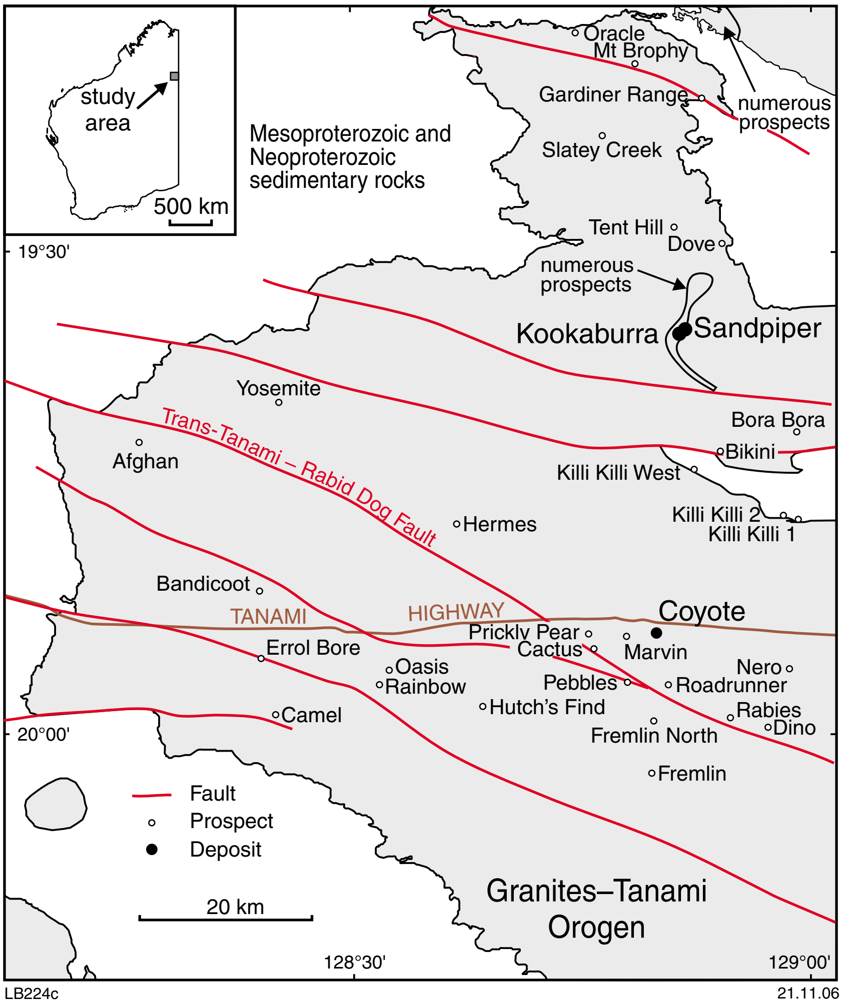

Figure 1. Mineral deposits and prospects in the western part of the Granites–Tanami Orogen, Western Australia

A major, near-vertical to steeply north-dipping fault, the Gonzales Fault (Bagas et al., 2006), is subparallel to the southern limb of the anticline (Fig. 2). The orientation of the Gonzales Fault, in combination with the angular, asymmetrical, and overturned shape of the Coyote Anticline, suggests that both the fold and fault formed during the same tectonic event. The Gonzales Fault cannot pre-date the Coyote Anticline because similar structures have not been observed at the same stratigraphic level on the northern limb of the fold. However, some of the bedding-parallel foliation in the area may be associated with earlier (pre-D_{C1}) structures, and is the subject of further investigations. In addition, local changes in the sense of movement along the Gonzales Fault, including extensional (south-side-down) and transpressional dextral movements observed along the fault, indicate that the fault has been reactivated several times.

The southeast-striking sinistral faults in the eastern part of the Coyote Anticline and the curved trace of the Coyote Anticline suggest refolding around northerly trending axes that indicate compression (D_{C2}) in an easterly direction (Fig. 2). During this easterly directed compression the Gonzales Fault was reactivated as a transpressional fault with dextral movement. Dilational zones would have formed at local perturbations along the fault during this movement, such as at the Gonzales ore lens (or lode). The structural controls on the Gonzales lode are not fully understood, but appear to have involved a complex interrelationship between faulting and parasitic folding in the limbs of the Gonzales Anticline.

The late (D_{C3}) Trans-Tanami – Rabid Dog Fault is between 1 and 4 km southeast of the Coyote deposit. The structure is a late approximately 125° trending, brittle, dextral strike-slip fault that hosts massive (2–3 m-thick) quartz veins.

Veining and mineralization

At least three sets of quartz veins are recognized at the Coyote deposit. These are described here as the early, quartz–chlorite, and late vein sets.

The early veins are bedding parallel, and are commonly in siltstone beds adjacent to the contacts with more competent sandstone beds. The location of these veins suggests that a competency contrast developed between the siltstone and sandstone during deformation, consistent with a flexural-slip folding mechanism.

The veins consist of quartz, and minor chlorite and carbonate, and are associated with narrow (<5 mm) chloritic wallrock alteration haloes. This veining appears to be more prevalent near parasitic anticline hinges and perturbations developed within the Coyote Anticline. In places these early veins are folded or modified within narrow bedding-parallel shear zones. The folding and shearing is consistent with continuing flexural slip during the progressive deformation that formed the Coyote Anticline. As a result of continuing deformation the early bedding-parallel veins are strongly recrystallized with fibrous textures, with laminated and boudinaged morphologies.

The early vein set is crosscut by quartz–chlorite veins that are orientated at high angles to bedding

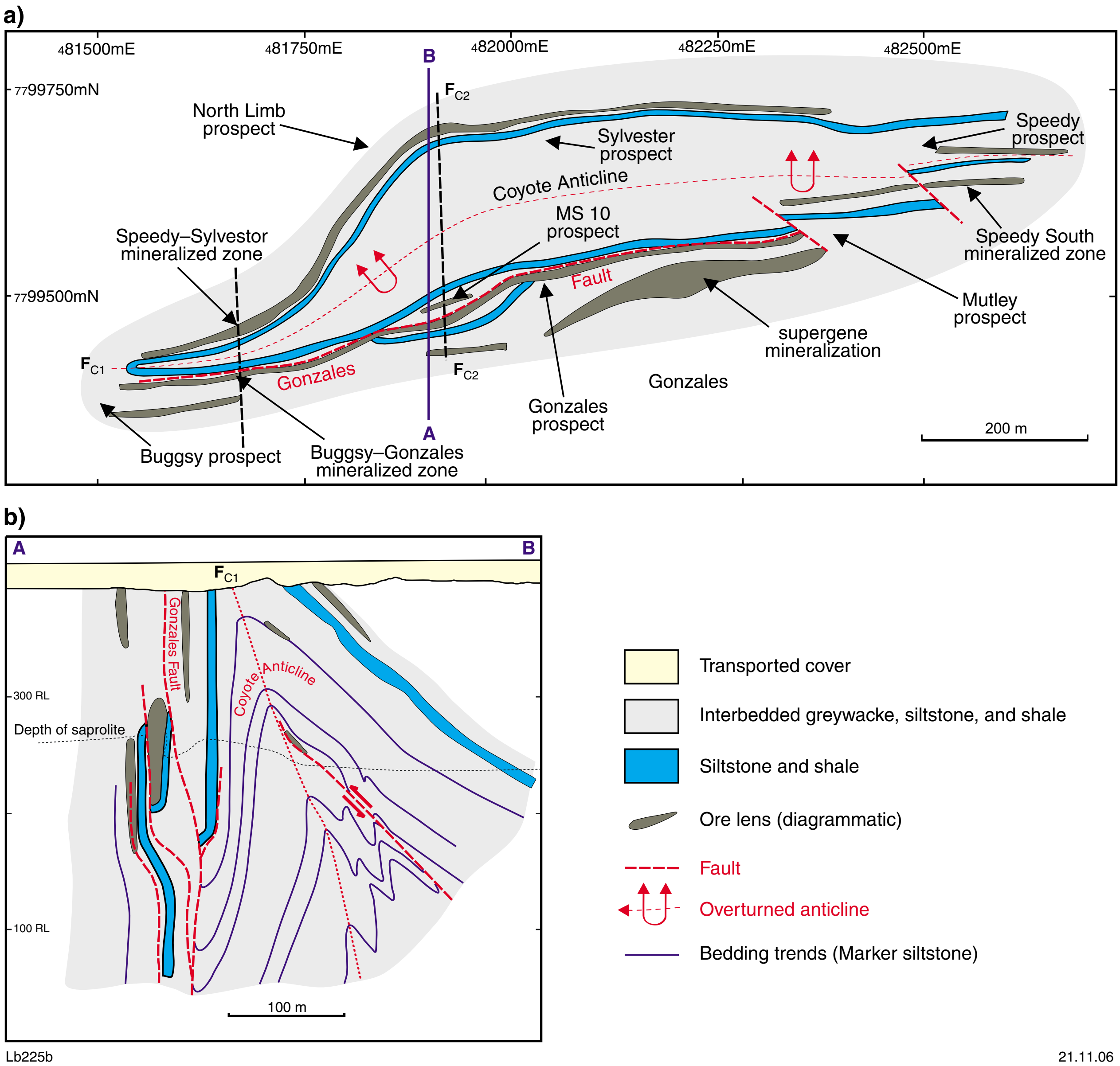

Figure 2. a) Generalized geological map of the Coyote area; b) cross section A–B of the Coyote Anticline (modified after maps provided by AngloGold Ashanti and Tanami Gold NL)

and have well-developed, 2–10 mm-thick chloritic selvages. These either represent link structures that accommodated flexural slip between bedding planes during regional folding or they constitute a later vein set. In addition, the early bedding-parallel veins are crosscut by small-scale gash or tension veins. These crosscutting veins formed across the width of the host veins and frequently propagate a short distance into the surrounding wallrock. Chloritic alteration selvages less than 10 mm wide and asymmetric in places are normally present where these veins propagate into wallrock.

Within the deposit gold is only associated with quartz veining, and the majority of the visible gold is associated with the small-scale gash or tension veins that formed within and across the early vein set. These crosscutting veins are quartz dominated, but also contain chlorite–carbonate(–sericite after biotite) with minor (<1%) pyrite–chalcopyrite–arsenopyrite–sphalerite–galena–bismuth species, and free gold.

Near the mineralization there is a second set of patchy retrogressive chlorite(–sericite–biotite) alteration that extends at most 20 mm into the wallrock. In addition, visible gold is associated with some early veins formed within sandstone units with almost no sulfides and weak silica–chlorite wallrock alteration.

The exact timing of the auriferous, bedding-parallel ‘early’ veins is unclear and has been complicated by the progressive style of deformation. However, this change in auriferous vein style suggests that there may be a continuum or multiple episodes of gold deposition between D_{C1} and D_{C2}. The late veins include massive white quartz and effervescent carbonate veins without significant alteration. These are not auriferous and are interpreted to have formed during D_{C3}.

Genetic model

Data collected in this preliminary study place some constraints on models for the genesis of gold at Coyote. Figure 2 illustrates the two major structural elements (folding and faulting) at Coyote. Even though these two types of structures may have formed during the same deformation event (D_{C1}), faults in the area were reactivated several times and folds were refolded during later deformational events.

We interpret the Coyote Anticline and the Gonzales Fault as having formed during the Tanami Orogeny, which is characterized by southeast- to east-trending angular folds (Huston et al., 2006). The earliest generation of folded quartz veins most likely formed at this time along bedding-parallel faults or shears. These veins were probably progressively folded to accommodate bedding-slip as the anticline tightened during the D_{C1} event. Because the fold is angular and generally lacks a pronounced axial-planar foliation, we interpret that it either formed at a relatively high structural level or its shape is a function of lithology.

As discussed above the gold appears to have been deposited during a protracted period between D_{C1} and D_{C2}. During this period competency contrasts between siltstone and sandstone beds promoted and localized dilation, and allowed emplacement of quartz–chlorite–pyrite–chalcopyrite(–arsenopyrite–galena–bismuth minerals–gold) veins. The association of these veins with biotite-bearing alteration selvages, and the results of fluid-inclusion studies by T. Mernagh (2006, written comm.) suggest that the veins formed at temperatures around 350°C. This protracted mineralization between D_{C1} and D_{C2} suggests that the gold mineralization was multi-phase and may have been related to both the Tanami Orogeny as well as deformation processes leading to the emplacement of the c. 1800 Ma granites in the region (Fig. 3; Bagas et al., 2006). This hypothesis is supported by preliminary sensitive high-resolution ion microprobe (SHRIMP) analyses of hydrothermal xenotime that is paragenetically associated with gold at Coyote, and gives an age of 1791 ± 8 Ma (Bagas et al., 2006). However, it must be pointed out that this date is regarded as a minimum age for gold mineralization because of possible resetting by thermal perturbations associated with the emplacement of c. 1800 Ma granites in the region.

Gold deposition and granite emplacement probably occurred as the stress field associated with deformation relaxed, with the associated pressure release allowing gold to be deposited and granite to be emplaced (Fig. 3). Moreover, the decrease in pressure allowed the auriferous fluids to effervesce, as indicated by fluid-inclusion studies, causing gold deposition as H_2S partitioned into a CO_2-rich vapour (Mernagh, T., 2006, written comm.). It is likely that the regional relaxation was accompanied by a regional decrease in temperature, which may be reflected in the replacement of biotite by chlorite in the late-stage paragenesis of the auriferous veins. If gold deposition occurred slightly after arsenopyrite deposition, the distribution of gold and arsenic would not exactly coincide, matching geochemical observations at Coyote and other gold deposits in the region (Huston et al., 2006), as well as similar observations in analogous terrains elsewhere (e.g. central Victoria; Bierlein et al., 2000).

This model implies that similar processes enhancing gold deposition may have also occurred in other areas of low pressure that developed towards the end of the D_{C2} event (Fig. 3). The Gonzales Fault as a whole appears to define a significant although narrow mineralized corridor. Gold is also present on the northern limb of the Coyote Anticline in late bedding-parallel veining adjacent to the sheared contact between the Marker siltstone and the overlying turbiditic sandstone.

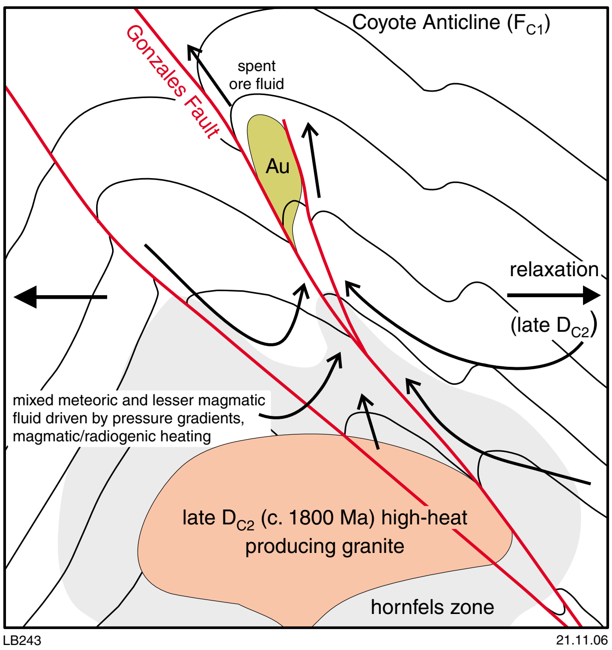

Figure 3. Genetic model for the Coyote gold deposit

Such bedding contacts represent zones with significant competency differences and are commonly brecciated or faulted, forming dilation zones where gold is deposited.

The lack of a clear lithogeochemical control at Coyote, such as that interpreted at The Granites goldfield in the Northern Territory (Huston et al., 2006), suggests that structural traps were important in localizing gold in the Coyote deposit. Such structural control may be the most important factor for gold deposition in the Killi Killi Formation in both Western Australia and the Northern Territory. These turbiditic units generally lack the chemically reactive rocks that are highly effective gold traps elsewhere in the region (Huston et al., 2006). In this respect, Coyote has many similarities with 'slate belt-hosted' orogenic gold deposits in the western Lachlan Orogen of Australia, and in Alaska in the United States of America (Goldfarb et al., 2001).

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