Geology and regional setting of the Oberon gold deposit, Tanami Region

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Introduction

The Oberon orogenic gold deposit, previously called the Titania prospect, is located ~28 km north of the world-class Dead Bullock Soak mining camp within the Tanami Region of the Northern Territory (**Figure 1**). The deposit is in the advanced stages of exploration and resource development and, as of February 2024, contains a measured, indicated and inferred resource totalling 2.7 Moz of gold mineralisation with the potential for considerable future growth. The identification of mineralisation at Oberon represents a blind discovery, and continued exploration targeting and resource expansion rely upon a clear understanding of the critical camp- to deposit-scale controls on mineralisation.

Stratigraphy and tectonothermal evolution of the Oberon orogenic camp

The orogenic gold deposits of the Tanami Region are hosted by greenschist to amphibolite facies metasedimentary rocks of the 1912–1835 Ma Tanami Group (Wygralak *et al* 2005, Crispe *et al* 2007, Huston *et al* 2007, Bagas *et al* 2014). These siliciclastic and chemical sedimentary rocks were deposited within a broad intraplate basin that was part of a broader depositional system covering much of the North Australian Craton (Maidment *et al* 2020). The lower part of the Tanami Group includes the Dead Bullock Formation and its inferred lateral correlatives, the Mount Charles and Stubbins formations (Bagas *et al* 2014; Maidment *et al* 2020; Crawford *et al* in review-b). These successions include units with a prominent mafic geochemical signature (Lambeck *et al* 2008), possibly derived from basaltic volcanism within the Mount Charles Formation (Maidment *et al* 2020, Crawford *et al* in review-b). These mafic units, which are favourable host rocks for orogenic gold mineralisation, include magnetic units that have facilitated their targeting using aeromagnetic data. The upper part of the Tanami Group comprises a thick package of compositionally immature turbidites termed the Killi Killi Formation, which has a felsic geochemical signature and hosts fewer gold deposits (Lambeck *et al* 2008; 2012; Bagas *et al* 2014).

The metasedimentary units that host mineralisation at Oberon are distinct in both a geophysical and lithofacies point of view; and here are interpreted to be part of the hanging wall sequence of the Mount Charles Formation, a higher energy, lateral facies equivalent of the Middle Callie Member of the Dead Bullock Formation (Crawford *et al* in review-b). Medium-grained quartz-rich sandstones dominate the lower part of the host succession and transition upwards into fine-grained sandstones, siltstones, carbonaceous mudstones and isolated chert horizons. The succession has been informally subdivided into the Europa, Lower Leto, Upper Leto, Lower Eos, Upper Eos, and Selene beds, which conformably transition upwards into the Killi Killi Formation (**Figure 2**). The sedimentary sequence was intruded by a semi-concordant gabbroic sill, the Nemesis dolerite, prior to deformation, as well as by a series of felsic porphyry dykes, the Hera and Echo porphyries (**Figure 2**; Crawford *et al* in review-a). Mineralisation is hosted in the culmination of an east–west-trending, tight to isoclinal, doubly plunging anticline. This camp-scale structural geometry is interpreted to result from at least two discrete regional shortening events, which are temporally separated by an intervening period of felsic magmatism (**Figure 3a**; Crawford in review).

The first event to affect the Oberon camp was the D_1 Tanami Event at ca 1839 Ma (Crispe *et al* 2007, Bagas *et al* 2014, Li *et al* 2014, Crawford in review-c). The D_1 deformation is associated with approximately east–west-orientated shortening, resulting in northerly-trending, long wavelength, tight to isoclinal folds (**Figure 3a**; Bagas *et al* 2007, Joly *et al* 2010, Crawford in review). Following this, the F_1 Oberon anticline was intruded by felsic porphyry dykes between 1819 ± 2 Ma and 1812 ± 8 Ma during the Stafford Event (Crawford in review). Continued felsic magmatism during the Stafford Event led to the emplacement of large granitic intrusions, including the Frankenia and Red-Eye domes at ca 1805 Ma (Dean 2001). The emplacement of these large intrusions resulted in a warping of pre-existing D_1 structures and stratigraphy around the intrusion margins and may locally have reorientated the F_1 Oberon anticline into an east–west orientation (**Figure 3b**; Crawford in review). Following this, during the later stages of the Stafford Event, the Oberon camp was subjected to a transient period of north–south shortening that led to the development of

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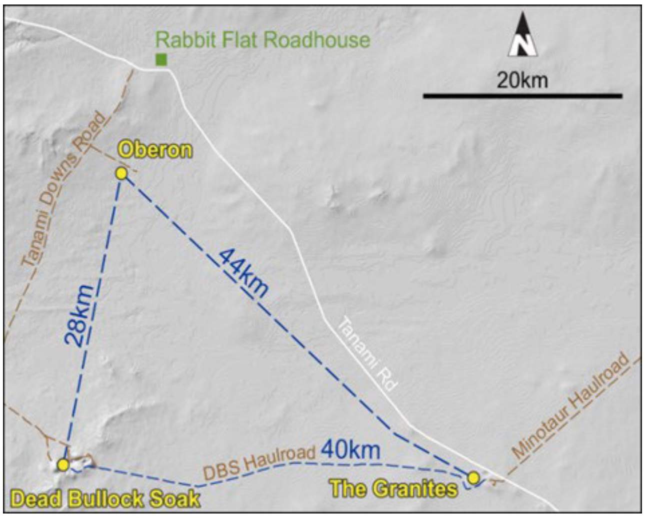

Figure 1. Location of the Oberon deposit relative to other major production centres and infrastructure.

shorter wavelength, east–west-trending, upright F_2 folds and associated S_2 axial planar foliation (**Figure 3c**). At Oberon, mineralisation is synchronous with, and forms domains sub-parallel to, the S_2 foliation, which yields an *in-situ* monazite U–Pb date of 1791 ± 11 Ma (Crawford *et al* in review-a, Crawford in review). This timing for mineralisation is consistent with the ca 1819 and ca 1812 Ma dates for felsic porphyry dykes at Oberon, which locally host mineralisation; and is comparable to ages obtained for gold mineralisation elsewhere within the region (Cross *et al* 2005, Bagas *et al* 2007, 2014; Fraser *et al* 2012, Petrella *et al* 2019).

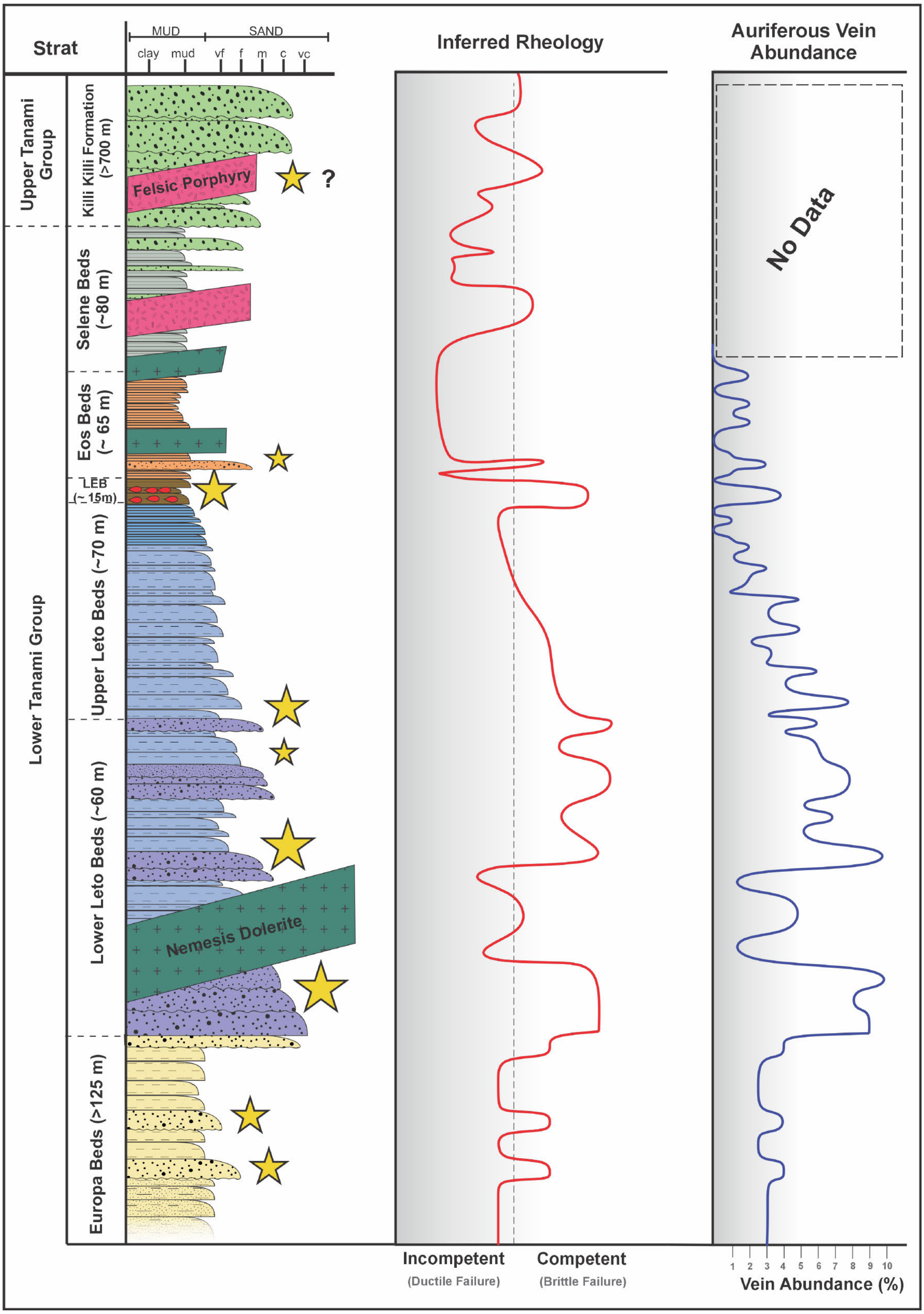

Figure 2. Schematic diagram reflecting qualitative rheological breaks associated with lithologies within the Oberon stratigraphic package and their influence on auriferous hydrothermal vein abundance. A major rheological boundary is identified between the Nemesis dolerite and the siliciclastic sediments of the Lower Leto beds; this coincides with a significant increase in auriferous vein abundance.

Rheological controls on mineralisation

At Oberon, high-grade mineralised trends (>5g/t Au) strike parallel to the sheared margins of the Nemesis dolerite, particularly on the steeply dipping southern limb (**Figure 4**). However, gold is mainly hosted in the adjacent siliciclastic sedimentary rocks that accommodated late D_2 shortening in a relatively brittle fashion, leading to the development of extensive auriferous hydrothermal fracture networks (**Figure 2, 4**; Crawford *et al* in review-a).

Sedimentary grain size and auriferous hydrothermal vein abundance measurements were collected across the strike length of the Oberon deposit and compared to the corresponding gold and arsenic assays for each studied drill core interval. Increased sedimentary grain size is associated with a significant increase in auriferous hydrothermal vein abundance and gold grade (**Figure 2**). This relationship is exemplified by the Lower Leto beds, which are dominated by interbedded sandstone and lesser siltstone horizons. Likewise, coarser-grained sandstone units and chert horizons within the more broadly mudstone-dominated Eos beds are also associated with an increased average gold grade and auriferous vein abundance (Crawford *et al* in review-a).

These observations indicate that brittle, auriferous hydrothermal fracture networks preferentially developed within rheologically more competent lithologies, particularly where such lithologies are juxtaposed against rheologically incompetent counterparts. In contrast, rheologically less competent units, such as mudstones, behaved in a more ductile manner and did not develop significant auriferous hydrothermal fracture networks. Instead, mineralisation within these units is of lower tenor and occurs as disseminated, gold-bearing arsenopyrite, which developed parallel to S_0 and S_2 (Crawford *et al* in review-a). The Nemesis dolerite, which exerts a dominant first-order control on the distribution of mineralisation, appears to have acted as a rheologically weak unit at Oberon, preferentially developing an intense S_2 foliation and a more locally developed steeply-plunging mineral lineation. This may be due to the effects of low-grade metamorphism and alteration prior to D_2 deformation.

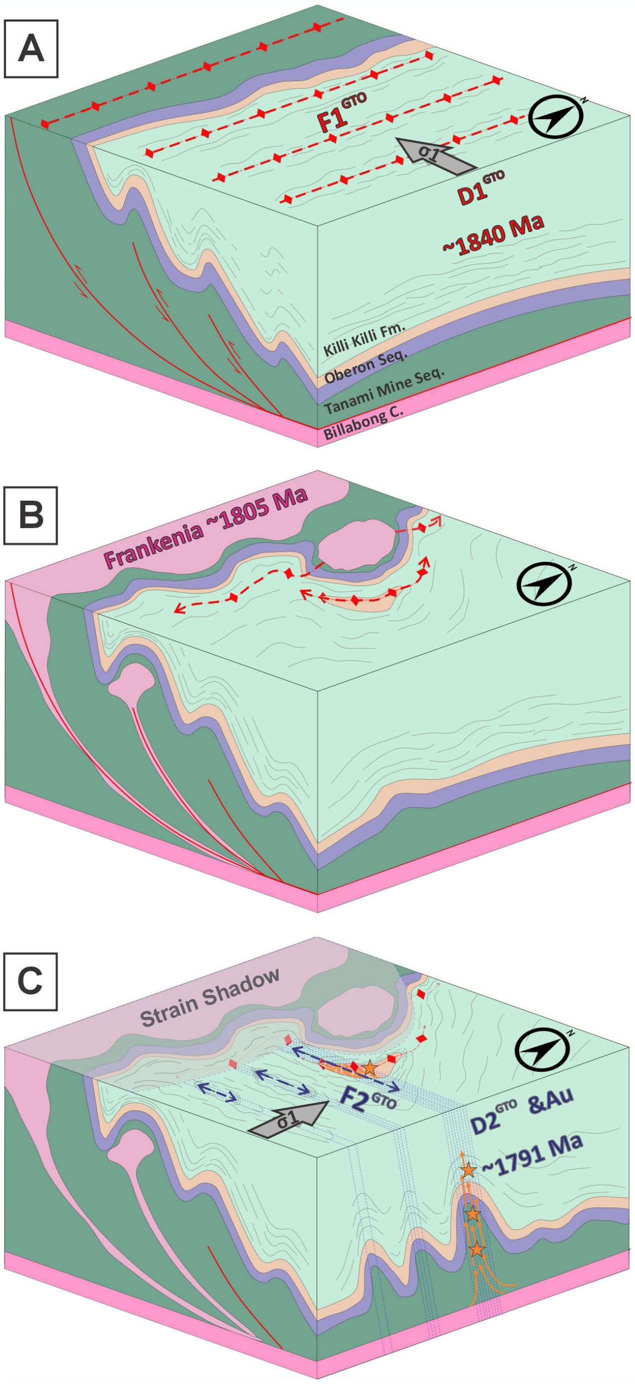

Figure 3. Tectonothermal evolution of the Oberon camp and the resultant geometry. (**a**) Approximate east–west directed shortening and the development of broad wavelength F_1 folds during the Tanami Event at ca 1840 Ma. (**b**) Magmatic phase of the Stafford Event (1820–1790 Ma) emplacement of the Frankenia Monzogranite at ca 1805 Ma. (**c**) North–south directed shortening phase of the Stafford Event. Development of shorter wavelength F_2 folds and S_2 foliation at ca 1788 Ma.

Stress field, fluid pressure and mineralisation

Detailed structural analysis indicates that mineralisation at Oberon is hosted by three discrete generations of veins (V1/V1', V2/V2', and V3/V3'). The V1/V1' veins form an array of north–south striking, sub-vertical shear veins and co-genetic, northeast–southwest striking, sub-vertical, extensional veins. The V2/V2' veins are a series of east–west-striking, sub-vertical shear veins and co-genetic sub-horizontal extension veins. The V3/V3' veins occur as a conjugate network of northwest–southeast striking and moderately dipping hybrid extensional-shear veins. Approximated stress field reconstructions based upon these vein arrays show that the Oberon deposit was subject to a low, yet variable, differential stress environment throughout its evolution. However, a regionally observable stress field perturbation between V1/V1' and V2/V2' vein development resulted in a transition from a transcurrent to a reverse shortening stress regime. Critically, within the imposed reverse shortening stress regime, hydrothermal fluids were forced to attain supra-lithostatic pressures, and the resultant V2/V2' vein network is associated with the highest and most consistent gold grade and represents the main stage of gold mineralisation (Crawford *et al* in review-a). Mineralisation occurs as coarse-grained native gold within the described vein sets and as non-lattice-bound gold micro inclusions within arsenopyrite and arsenian pyrite (Cook *et al* 2013). Both types of mineralisation occur together, and auriferous sulfides are not confined to hydrothermal veins but also appear as disseminations within the adjacent host rock (**Figure 5**).

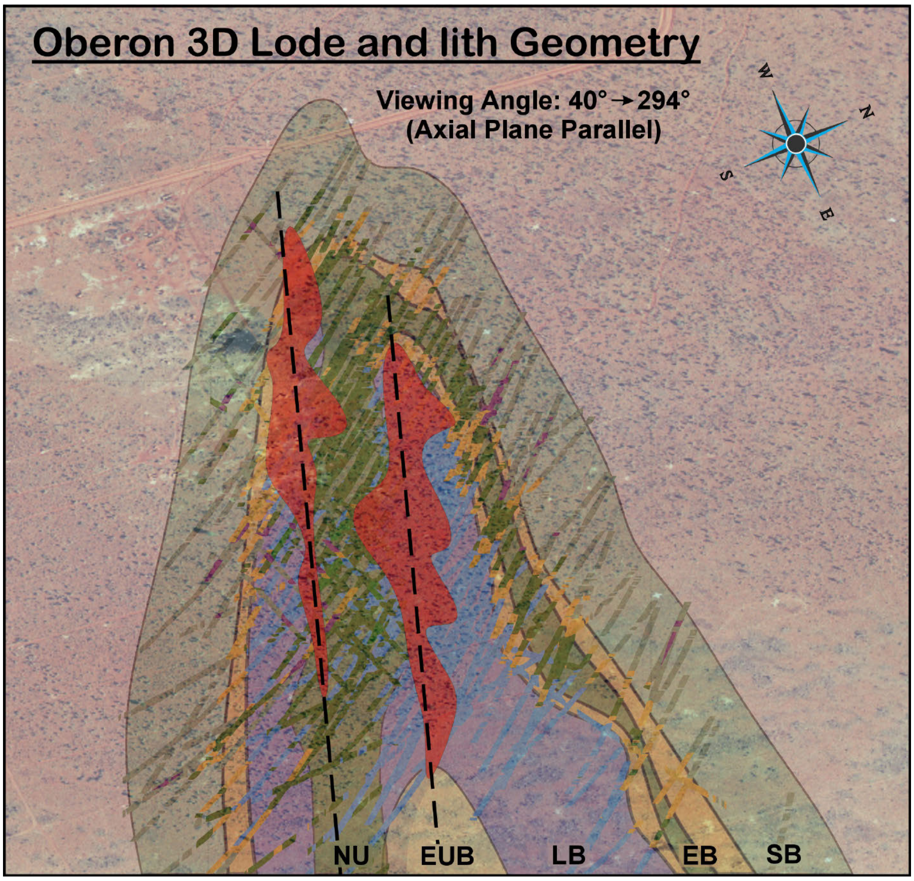

Figure 4. View looking west down-plunge of the Oberon anticline (40→294). All diamond drillholes and logged stratigraphy are shown. Red polygons highlight two prominent mineralised trends (> 5g/t), which exploit the contact between the Nemesis dolerite (microgabbro) and host sediments. SB = Selene beds, EB = Eos beds, LB = Leto beds, EUB = Europa beds, NU = Nemesis dolerite.

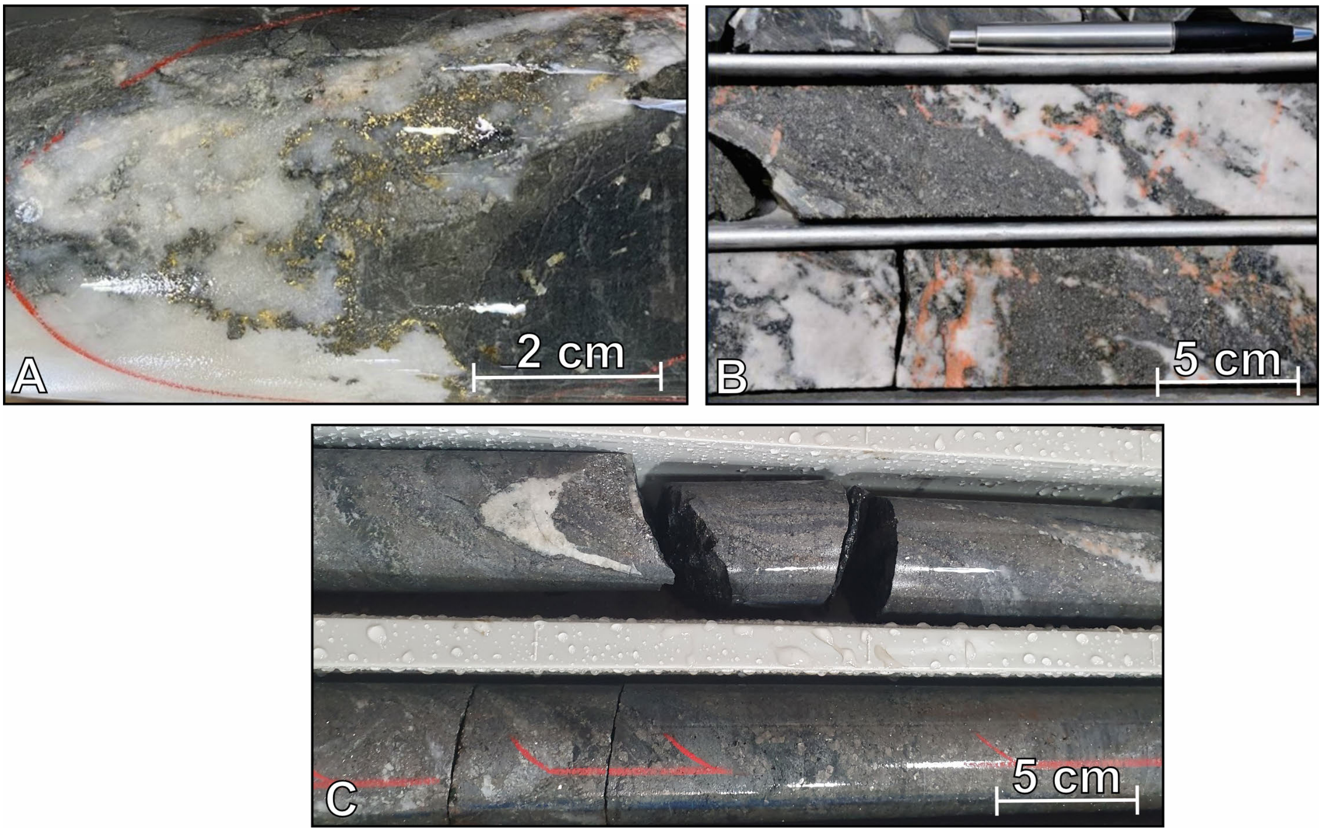

Figure 5. Typical examples of mineralisation within the Oberon deposit. (**a**) Coarse native gold within a quartz vein. (**b**) Auriferous arsenopyrite within quartz veins. (**c**) Disseminated auriferous arsenopyrite in sandstone.

Summary

Our work indicates that within the known extent of the Oberon gold deposit, several critical factors control the location and style of mineralisation. At regional-scale, the Oberon deposit is unusual in that it is hosted by a succession that differs from those hosting mineralisation at Dead Bullock Soak, The Granites, Groundrush, and the Tanami Mine Corridor. The development of mineralisation in what is interpreted to be the upper Mount Charles Formation represents previously unrecognised, new exploration space within the region. At the deposit-scale, mineralised trends are intimately associated with the sheared margins of the Nemesis dolerite. However, high-grade mineralisation is best developed within the adjacent sedimentary package, particularly within rheologically more competent units, including coarse-grained sandstones and chert horizons. Within the deposit, a stress field perturbation, which may have been driven by far-field tectonic events, was essential for the onset of the mainstage, economically significant gold mineralisation. These deposit-scale controls, combined with a clear understanding of the evolution of a complex camp-scale fold geometry, may be used to predict ore-shoot location, geometry and mineralogy in areas of low data density.

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