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Auriferous Limonitic Stalactites from the Bimbimbie Gold Mine, New South Wales

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ABSTRACT. The Bimbimbie gold mine is situated within a syntectonic granite mass that intrudes Ordovician metasediments 11 km south-west of Batemans Bay, NSW. Three gold-pyrite quartz veins occur within the mine area, the largest – the Bimbimbie vein – being the main producer.

On the backs of a large stope into the Bimbimbie vein numerous limonitic (goethitic) stalactites occur. Two of these were assayed for gold giving 26.1ppm and 16.2ppm respectively.

The chemistry of the process leading to the incorporation of gold in these stalactites is considered in terms of the solubility of gold in the thiosulphate ion.

LAWRENCE, L.J., 1992. Auriferous limonitic stalactites from the Bimbimbie gold mine, New South Wales. Records of the Australian Museum Supplement 15: 39–43.

The Bimbimbie gold mine is located near the settlement of Bimbimbie in the eastern foothills of the Great Divide some 11 km south-west of Batemans Bay and some 7 km west-north-west of Broulee on the south coast of New South Wales (Fig.1).

The mine is of medium size and was worked mainly just prior to and after World War I. Gold grades of up to 25oz/ton (775g/t) had been reported but there was no evidence of these grades during recent re-appraisal of the workings. It has been re-opened with additional development work and sampling preparatory to further mining.

The vein material was not amenable to free milling and the concentrate (mainly fine gold with much pyrite) had to be transported to Port Kembla for roasting to release the gold.

Mine Geology

The Bimbimbie area consists of Ordovician slates and phyllites with occasional arenaceous units strongly folded and cleaved along a dominant North-South axis. These metasediments can be seen at, and to the immediate south of, the portal of the adit (Fig.2).

The metasediments have been intruded by an apparently syntectonic granite pluton with a North-South elongation. The granite is not gneissic as are the more distinctly syntectonic intrusions further south; its syntectonic nature (or more appropriately late-tectonic) being inferred from its distinctive North-South elongation. The former biotite of the granite, in the vicinity of the mine, has been altered into somewhat diffuse patches of low-iron chlorite.

Within the mine area the granite is cut by a dolerite dyke 0.75 m wide and of steep northerly dip. Adjacent to the dolerite dyke the granite is strongly sheared and heavily jointed with slickensides in several directions. To the west of the main Bimbimbie drive a 0.25 m wide chlorite dyke (chloritised dolerite) is exposed in a cross cut.

Three parallel quartz veins are contained within the granite, the Contact Vein to the east followed by the Bimbimbie Vein and then the Ocean View Vein. Neither the Contact Vein nor the Ocean View Vein were significantly productive, the main producer being the Bimbimbie Vein. This vein crops out along a ridge immediately east of the mine workings and has a North-South strike and a westerly dip of 35° to 40°; it has a length of at least 700 m. A horizontal adit was driven (South to North) along the Bimbimbie Vein for several hundred metres with winzes and raises at different points along the vein. Figure 2 shows the relevant details of the mine geology and the location of the stope which is pertinent to this study.

Mineralogy

The mineralogy of the Bimbimbie Vein is relatively simple consisting essentially of quartz with very occasional patches of orthoclase and of chlorite. In the more dilated parts (up to 25 cm wide) pyrite becomes abundant with no other opaque minerals visible macroscopically.

In polished section (Fig.3) pyrite is the dominant opaque mineral occurring mainly as sizeable aggregates of irregular shaped interlocking grains but occasionally as patches of euhedral to subhedral crystals. Much of the pyrite exhibits anomalous polarisation colours (pink, light blue, purple) as a result of lattice strain which was further indicated by small trains of crushed sulphide. The pyrite is of a paler colour than normal and does not polish readily.

Other minerals observed under the microscope include occasional patches of chalcopyrite up to 0.25 mm across showing polysynthetic deformation twinning, very sparse sphalerite and galena and traces of tetrahedrite, marcasite and graphite. These all range from 0.01 to 0.005 mm in size. A few silvery particles in micron dimension are probably a bismuth mineral but their minute size prevents their optical identification. Bulk assays showed a minor arsenic content though no arsenopyrite was observed in polished sections, but it may still occur; alternatively the tetrahedrite or even the pyrite may carry some arsenic.

Gold occurs in the following manner: i) as irregular shaped grains adjacent to chalcopyrite. Such grains may reach 0.1 mm in size; ii) filling microscopic fractures in quartz adjacent to sulphides; iii) randomly disposed within areas of crushed and comminuted pyrite adjacent to areas of chalcopyrite with traces of sphalerite and galena; iv) in microscopic fractures in large pyrite grains; v) as tiny grains (0.01 - 0.05 mm)

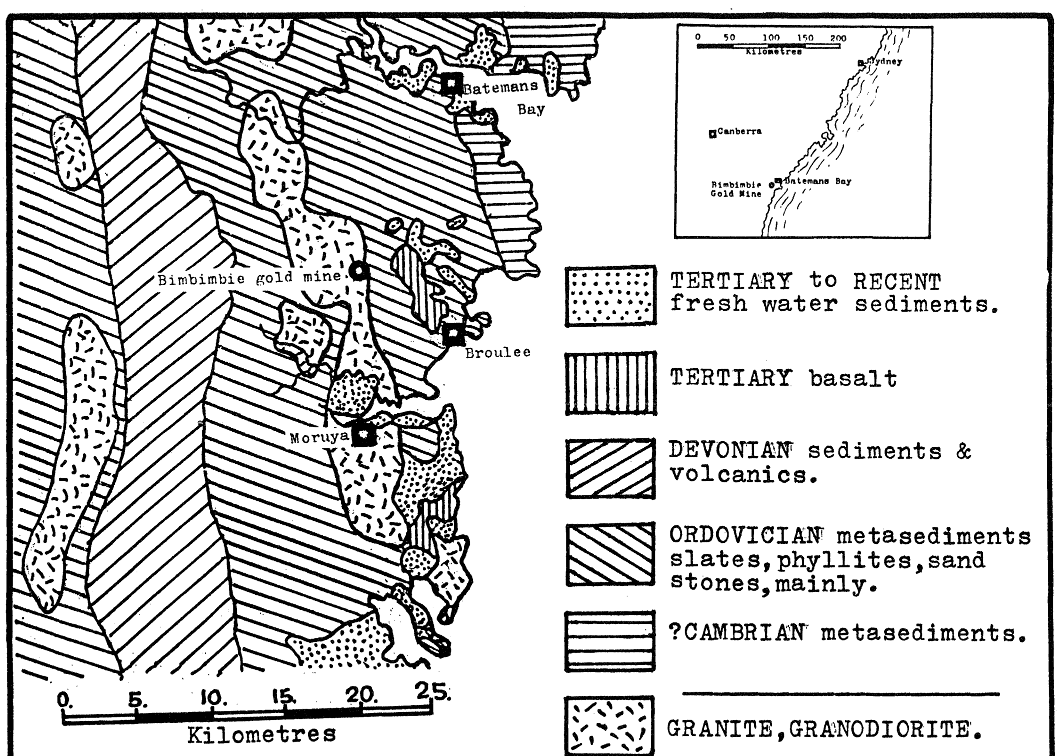


Fig.1. Locality map and regional geology. Based on NSW Geological Survey Geological Map of New South Wales, 1962.

within quartz inclusions in pyrite; and vi) as micron size particles included within pyrite crystals and grains.

Auriferous Stalactites

To the north of the air shaft along the main drive is a large stope into the Bimbimbie Vein (Fig.2) measuring 10 m by 8 m and 2.5 m high with floor and backs sloping upwards along the dip of the vein. The backs and floor of this stope are covered by a layer of silt-like sediment from seepage while the floor is also covered with bat guano.

Numerous stalactites of goethite, ranging up to 12 cm in length and 6 to 7 cm diameter at base, occur on the backs and walls of the stope. No distinct stalagmites are present but there are, in places, small dome-shaped precipitations and veneers on the floor of the stope. On some of these embryonic stalagmites 'moon-milk' (huntite $CaCO_3.3MgCO_3$) is being deposited as a white paste-like mass.

The stalactites consist of a cellular aggregation of earthy goethite $HFeO_2$ ranging from orange-brown to red-brown in colour (Fig.4). A small portion of this

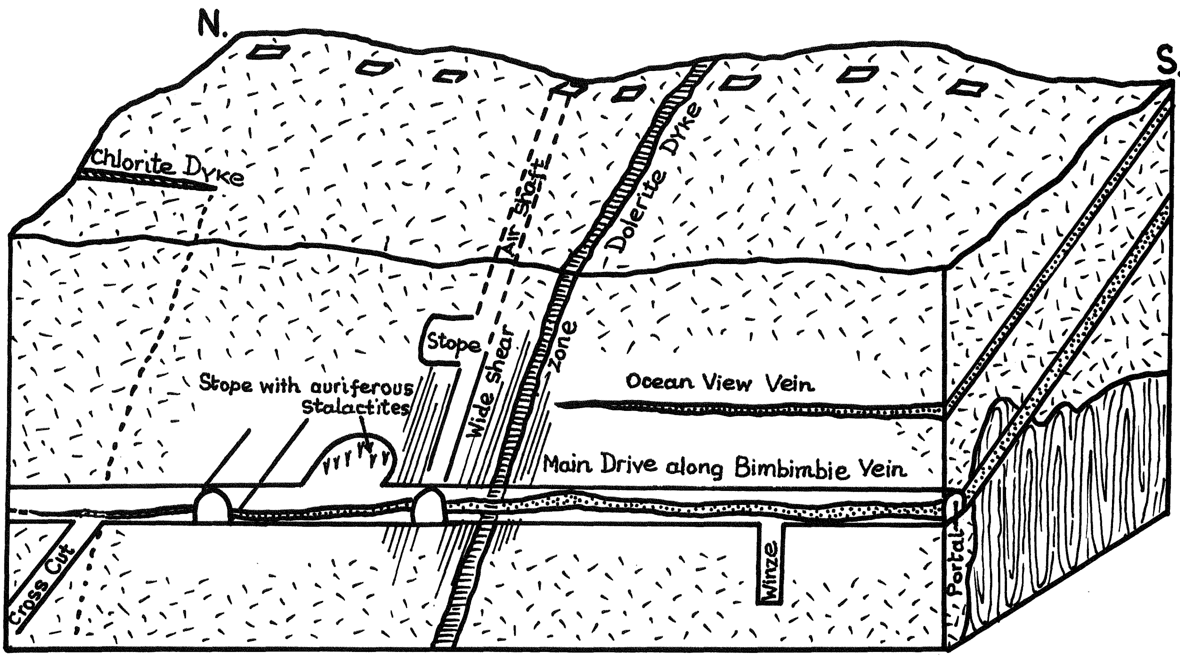


Fig.2. Bimbimbie gold mine showing relevant geology and underground workings. Centre left is stope containing limonitic stalactites. Length of section about 500 m. The section oriented North-South in order to show greater detail.

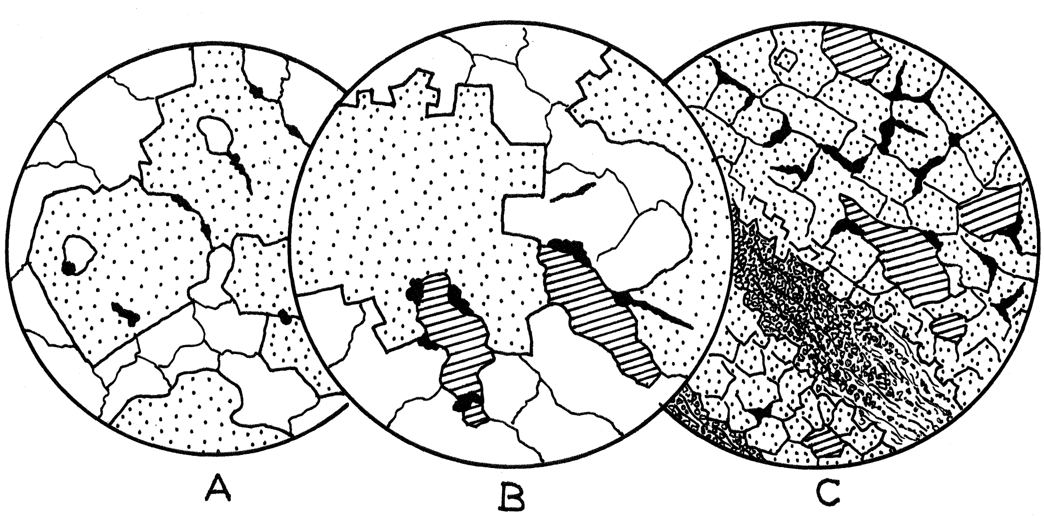


Fig.3. Drawings of polished sections of Bimbimbie ore. Gold shown in black; pyrite dotted; chalcopyrite lined and quartz unshaded. Magnified x35.

material, crushed and examined under an ore microscope, showed occasional scales whose optical properties would correspond to lepidocrosite FeO(OH). The stalacties and the precipitates on the floor and walls are encrusted in a veneer of 2 to 3 mm of calcite, the calcium no doubt derived from the breakdown of the plagioclase of the granite.

Two stalactites were removed and assayed for gold giving 26.1ppm and 16.2ppm respectively. It is not known if all stalactites contain gold though it would seem likely that most would carry at least traces of the metal.

Geochemical Aspects

The stope containing the stalactites is adjacent to a zone of strong shearing and joining in the granite and this has provided access for much seepage which continues to the present time.

The solubility and supergene enrichment of gold has been the subject of much recent research and review (e.g., Lakin *et al.*, 1974; Boyle *et al.*, 1975; Mann, 1984; Webster, 1984). The solubility of gold to form chloro-complexes has been known for some time but some emphasis is now being placed on the dissolution of gold by the thiosulphate ion $S_2O_3^{2-}$. Gold dissolves in the thiosulphate ion to produce gold thiosulphate. The reactions commencing with the oxidation of pyrite are as follows:

$$2FeS_2 + 3O_2 \rightarrow 2Fe^{2+} + 2S_2O_3^{2-}$$
$$Au + 2S_2O_3^{2-} \rightarrow Au(S_2O_3)_2^{3-} + e^-$$

Gold thiosulphate complexes may also arise by the dissolution of gold in sodium or potassium thiosulphate to yield compounds such as $Na_3Au(S_2o_3)_2$ which decompose to give $Au(S_2o_3)_2^{3-}$ ions. Such ions remain in solution for a time but would break down to gold and other compounds as the zone of reduction is approached.

The chemistry involved in the generation of thiosulphate and its action on gold has been studied by Krauskopf, 1951, Goleva *et al.*, 1970, Goldhaber, 1983, and Webster, 1984. The reactions are pH and Eh sensitive with a pH requirement of over 7. Experiments with pyrite (e.g., Goldhaber op.cit.) found that at a pH of 7.5 80% of dissolved sulphur occurs as thiosulphate ion. Natural crystals of pyrite reacted with distilled water and atmospheric oxygen for 6 weeks dissolved to give traces of thiosulphate (up to 5 times 10^{-5}M).

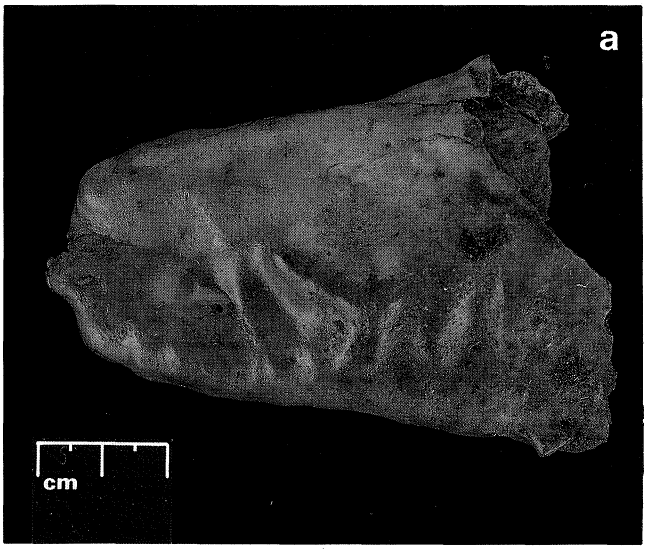
The gold thiosulphate is reduced to gold at the base of the zone of oxidation. Precipitation of the gold may be induced by the presence of iron, viz:

$$Au^{2+} + 3Fe^{2+} + 6H_2O \rightarrow Au^o + 3HFeO_2 + 9H^+$$

The above reaction would also account for the precipitation of goethite as in the stalactites at Bimbimbie. Gold detected in the stalactites is probably in the form of an absorbed colloid within the cellular goethite which makes up the bulk of the stalactites. The abundant surface areas of the cellular goethite would facilitate substantial absorption.

Conclusions

The Bimbimbie gold mine possesses the requisite constitution for the generation of supergene gold by the thiosulphate reaction. The plentiful pyrite could provide the thiosulphate but this would require the



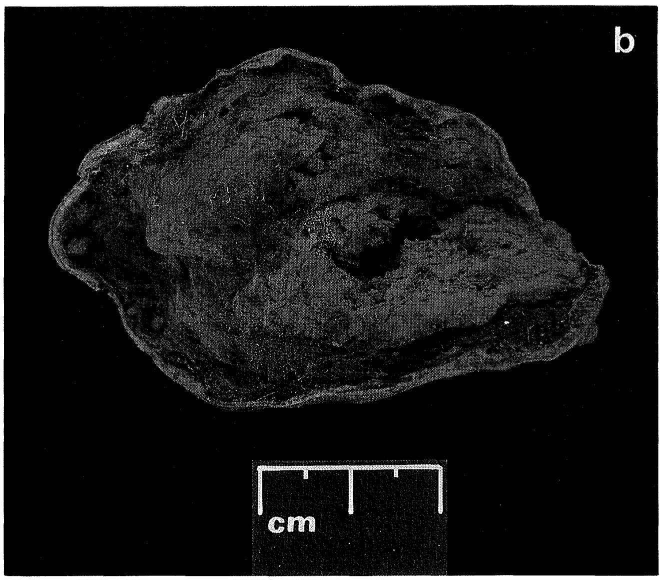


Fig.4. A limonitic stalactite 7.5 cm in length. In A the longitudinal features, including the veneer of calcite, are shown; B is a transverse section showing the cellular nature of the material of which the stalactite is composed.

buffering of the pH by calcite or other carbonate to maintain a distinctly alkaline environment. Whilst no calcite has been seen in the gangue, carbonate has formed as an external coating on the stalactites and, in the form of huntite, deposited on the floor of the stope. Whilst the presence of these carbonates is not unequivocal proof of alkali conditions at the time of the proposed thiosulphate reactions, it does indicate that carbonates are capable of forming within the mine workings. The source of the calcite (and huntite) would appear to be related to the weathering products of the relevant rock-forming minerals of the granite.

Assays of 19.3ppm were obtained from the sludge and efflorescence on the walls and backs of a small gold mine in Fiji (Lawrence, 1984). It is significant that this supergene gold, where the thiosulphate reaction was proposed, like the Bimbimbie case, was deposited in an open mine, i.e., post-mine gold. The small Fiji mine commenced working in 1940 so that over 40 years (to 1980) supergene gold had accumulated at an average rate of 0.48ppm of the surface precipitates per annum. The Bimbimbie mine started in 1912 and in the ensuing 74 years since then supergene gold has accumulated at the average rate of 0.35ppm of the post-mine precipitates.

This paper seeks to record yet another example, in the growing list, of measurable supergene gold deposition, albeit of small magnitude.

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