

SUPERGENE GOLD AT THE GOLDEN VIRGIN PIT, PARKER RANGE, WESTERN AUSTRALIA

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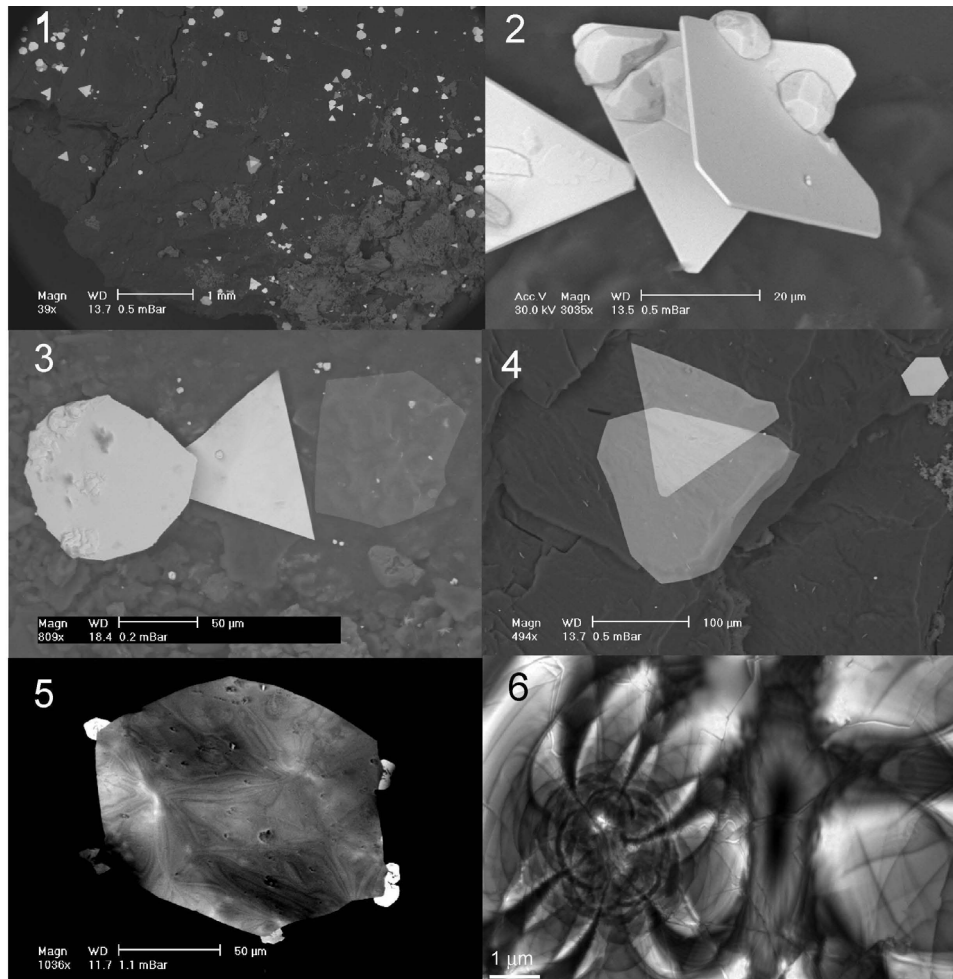
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The Parker Range is part of the Southern Cross gold province in Western Australia and is located about 350 km East of Perth. The Golden Virgin pit is a small high grade Au deposit south of Marvel Loch in the Parker Ranges where the primary mineralisation occurs as small high grade quartz veins; the mineralisation is blanketed by up to 30 m of weathered cover. A block of quartz vein approximately 1m by 40 cm from the saprock at 35 m depth near the base of the pit contained visible Au in the quartz. Upon fracturing, the block broke along a weathered fracture surface lined with different generations of iron oxides, clays and sulphates together with an exceptionally rich population of apparently supergene Au crystals (Figure 1). This provides an interesting example of co-existing primary and secondary Au in an exceptionally rich occurrence in saprock.



Figures 1-6. (1). Back scattered electron image (BSE) of supergene gold crystals on the fracture surface. (2) BSE image of a cluster of triangular single crystal plates. (3) BSE image showing bright and dark contrast of pure gold crystals, change in contrast caused by variations in thickness. (4) BSE image illustrates the transparency of the thin gold plates. (5) BSE image showing internal structure to the single crystal gold lattice of a single plate. (6) Bright Field TEM image of the internal structure of a gold plate, the concentric nature is related to bend contouring and hence strain of the gold lattice.

The Au crystals were imaged using scanning electron microscopy (SEM) and transmission electron microscopy (TEM) and analysed by energy dispersive spectroscopy (EDS) to establish their shape, crystallography and composition. The primary Au contains up to 7% Ag and thus is a typical Au/Ag primary alloy and is also found within iron oxides that have a gossanous appearance presumably as pseudomorphs after sulphides that are now completely oxidised.

The supergene Au crystals, located approximately 15 cm away from the primary Au, comprise up to 200 μm but dominantly around 10 μm sized crystals, sometimes in clusters (Fig. 2). They preserve various shapes including hexagons, triangles and wires with even combinations of these co-occurring. Back scattered electron imaging, sometimes also described as atomic number contrast imaging, relates the contrast in the image to the atomic number of the material being imaged. Gold is thus normally bright and this is the case for many of the crystals we have imaged, however, the supergene Au was also found to contain a population of gold that is darker grey using this imaging technique (Figure 3). In this case the thickness of the plates is the primary control and the darker colour is an indication that there is electron beam penetration through the Au lattice. Upon closer examination it was found that many individual crystals showing this characteristic are transparent to the electron beam, to the extent that the underlying supporting materials are visible through the crystal (Figure 4). Overlapping crystals of this type are also seen to create restricted areas of bright contrast where the added thickness of the overlap stops beam penetration, the remainder of the individual crystals were transparent.

Monte Carlo modelling combined with imaging at different accelerating voltages indicates the crystals are only 20-50 nm in thickness. Attempts to directly image the edges of individual crystals were hampered by the nature of the thinnest plates lying directly on the substrate. Those that do stand on edge are clearly thicker but are still only 100 nm thick. By altering the brightness and contrast in the SEM we were also able to reveal complex internal structures to these ultra thin plates (Figure 5). Contouring of the lattice appears to produce these textures and small holes in the individual crystals appear to act as seed points. Further examination by TEM confirms these structures as likely to be bend contours related to strain of the lattice, possibly by buckling during settling onto the substrate (Figure 6). The crystals are also confirmed as single crystals by selected area electron diffraction and were found to be defect-rich.

Such nanoplates have been made experimentally by reacting organic acids with gold chloride solutions (e.g., Shankar *et al.* 2004). Interestingly, these experiments permit shape and size control of the nano-crystals formed. Supergene Au crystals on this fracture surface were found closely associated with salt crystals and were even found intergrown with barite crystals, this supports the premise that they were precipitated from groundwater. We are yet to determine the role organic acids may have played in controlling their growth parameters. Lawrence & Griffin (1995) attributed small octahedral crystals at the tips of crystal terminations as the effects of periodic flushing and several generations of supergene Au crystal precipitation. Morris *et al.* (1967) however, showed experimentally that the same feature is characteristic of final stage drying of one solution, in other words the last stage of precipitation from the gold saturated solution. The whole supergene gold deposition along the fracture surface in this sample might then represent a single event completed on the order of days to weeks rather than over prolonged timescales.

REFERENCES

- LAWRANCE L.M. & GRIFFIN B.J. 1995. Crystal features of supergene gold at Hannan South, Western Australia. *Mineralium Deposita* **29(5)**, 391-398.
- MORRIS R.H., BOTTOMS W.R. & PEACOCK R.G. 1967. Growth and defect structure of lamellar gold microcrystals. *Journal of Applied Physics* **39(7)**, 3016-3021.
- SHANKAR S., RAI A., BALAPRASAD A., SINGH A., AHMAND A. & SASTRY M. 2004. Biological synthesis of triangular gold nanoprisms. *Nature materials* **3**, 482-488.