

# **PETROLOGY OF Zn-GOSSAN AND SULPHIDE SAMPLES FROM THE BM2 PROSPECT, YENEENA PROJECT, WESTERN AUSTRALIA**

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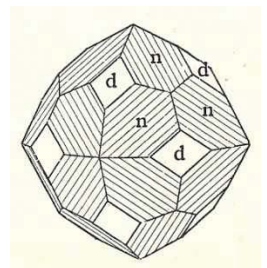
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## **INTRODUCTION**

At the request of Encounter Resources a series of five gossan and two sulphide-bearing samples were examined. Samples were in the form of diamond drill core from the BM2 prospect, Yeneena Project, in the Paterson Province of Western Australia. The main scope of the work was to determine whether a 140m long intersection of gossanous material with anomalous Zn in drill hole EPT1831 was derived from a Zn sulphide-rich precursor.

## **SAMPLES**

Following examination of diamond drill hole EPT1831, a series of five chip samples were taken for petrography. One chip of massive sphalerite was taken from drill hole EPT1854 and a slice taken of a mineralised slab of core from drill hole EPT1174. A Niton hand-held XRF unit was utilised in sample selection. Details of the samples are given below:

<b>Hole</b>	<b>Depth</b>	<b>Comment</b>
EPT1831	200.7m	Mn-rich zone approximately 20cm wide, 7-8 wt.% Zn.
EPT1831	203.5m	Fe-gossanous material, 2.07 wt.% Zn.
EPT1831	221.2m	Fe-gossanous material, 1.23 wt.% Zn.
EPT1831	279.6m	Fe-gossanous material, 0.82 wt.% Zn.
EPT1831	289.15m	Fe-gossanous material, 1.46 wt.% Zn.
EPT1854	430.05m	Massive sphalerite down-dip of EPT1831.
EPT1174	402m	Sulphide layer in carbonaceous pelite (Broadhurst Fm ).

Examples of macroscopic textures are given in Figures 1 to 5, below.

## **SAMPLE PREPARATION AND ANALYSIS**

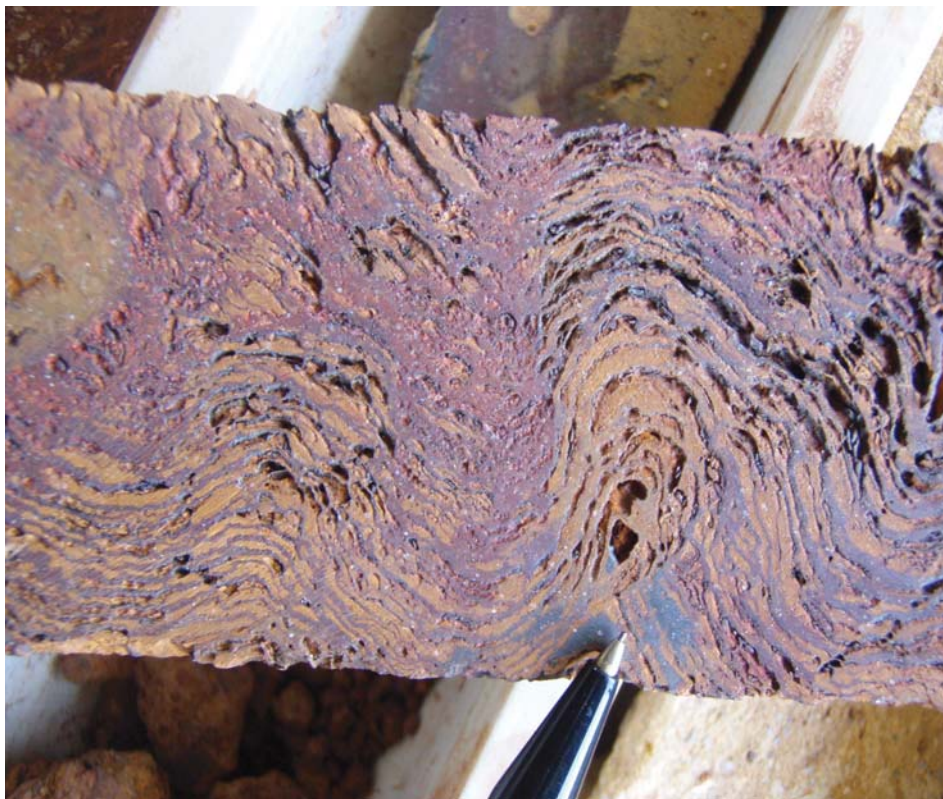
For petrographic analysis a portion of each sample was cut on a 6 inch diamond trim saw and set into a 25 mm round mould using Epofix cold-set epoxy resin. Once set, the blocks were hand ground on 1200 grit carborundum, and finally wet polished on cloth using mono-crystalline diamond pastes.

Optical examination was performed in reflected light only (owing to the samples being polished sections) using an Olympus BH2 microscope equipped with a digital camera. SEM-EDAX imaging and microanalysis was conducted using a Philips SEM equipped with an EDAX-EDS detector, operating at 30 kV and 45 nA. Samples were not required to be carbon coated as the SEM operates in so-called 'environmental mode', however, chamber pressures were reduced to 0.1 mbar in order to provide higher quality EDS analyses. All samples showed negligible radioactivity and magnetism.

Sub-samples of the sulphide-rich samples (EPT1854 and EPT1174) were crushed and hand separated into as pure a sphalerite fraction as possible. The two sphalerite separates were submitted to CODES, Hobart, Tasmania for sulphur isotope analysis. Results are pending at the time of reporting.



**Figure 1:** Void-rich colloform-textured Mn-rich material, EPT1831 200.7m. 7-8 wt.% Zn.



**Figure 2:** Contorted bedding in ferruginous gossan, EPT1831 223.5m. 1 wt.% Zn.



**Figure 3:** Brecciated gossan with boxworks, EPT1831 289.2m. Dark brown areas 1.5 wt.% Zn, light brown areas 0.6 wt.% Zn.



**Figure 4:** Massive and brecciated sphalerite from EPT1854 430.05m. 63 wt.% Zn.



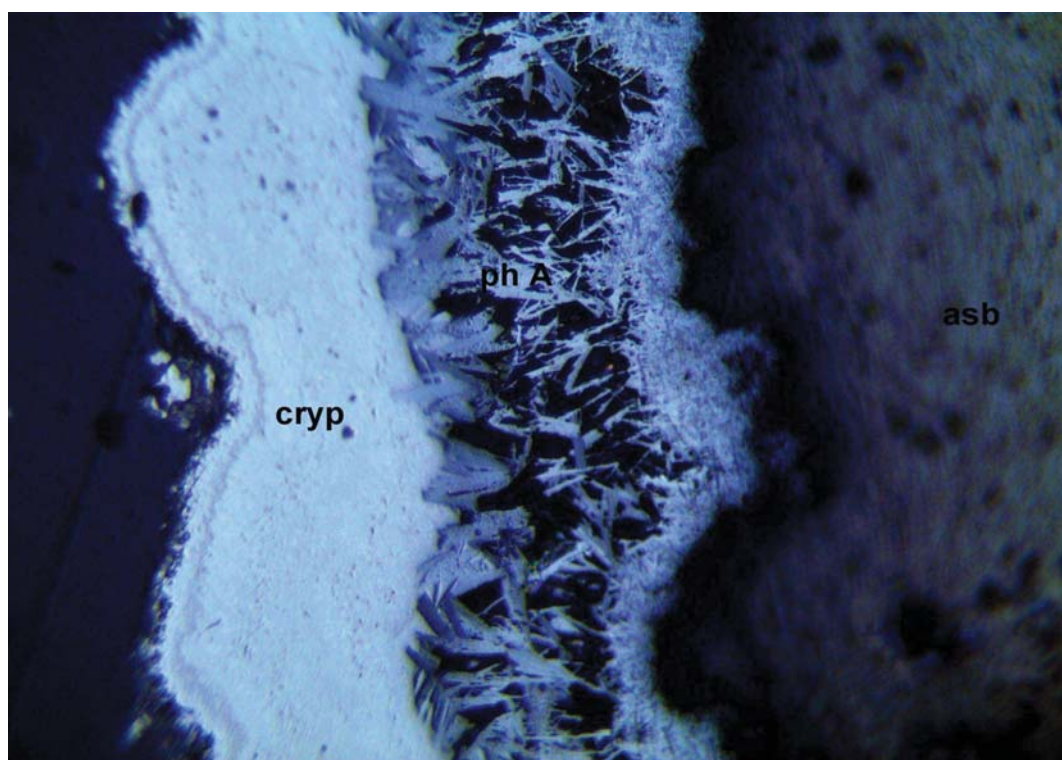
**Figure 5:** Sulphide-rich layer in carbonaceous pelite from EPT1174 402m.

## RESULTS

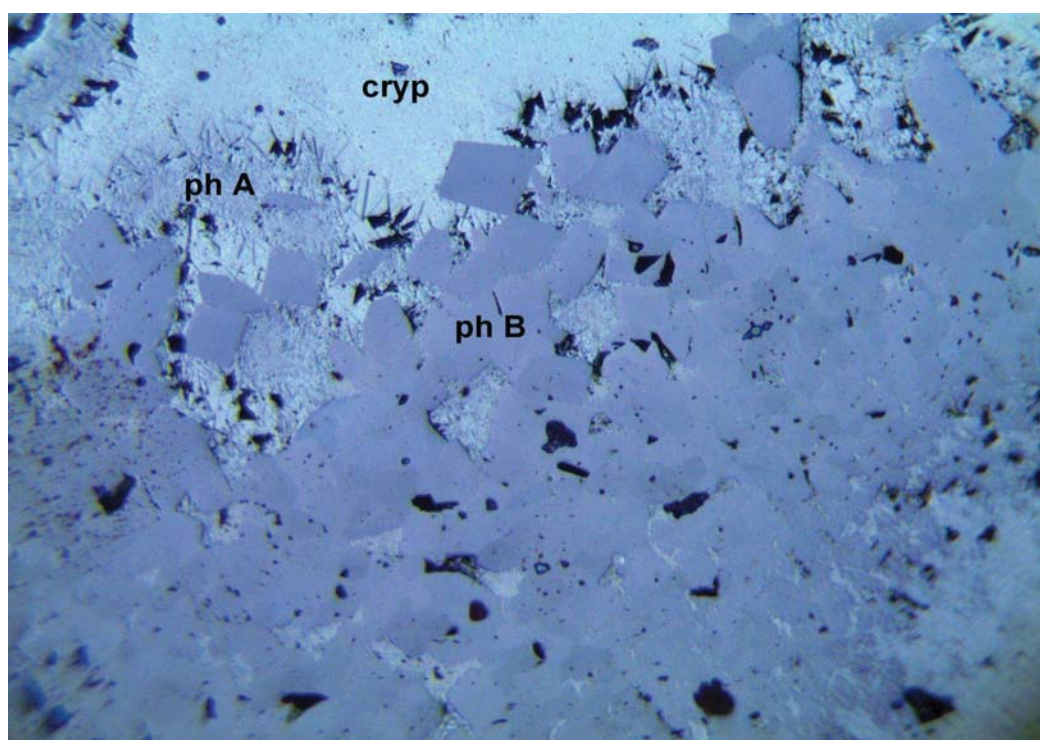
### Petrography

#### **Sample EPT1831      200.7m**

This sample represents a small (ca. 20cm) interval in the drill hole which is predominantly botryoidal/colloform Mn oxides (Figure 1) and is enriched in Zn (7-8 wt.%). Such horizons are common in the weathered zone and represent weathering redox fronts (not necessarily that of the present time). Although superficially simple, the Mn-rich zones can be mineralogically complex, which is the case here. The sample consists of colloform layers of Zn-bearing cryptomelane ( $\text{KMn}_8\text{O}_{16}$  with 2-3 wt.% ZnO), Na-bearing chalcophanite  $((\text{Zn}, \text{Na})\text{Mn}_3\text{O}_7 \cdot 3\text{H}_2\text{O})$ , Cobalt asbolane  $(\text{MnO}(\text{O}, \text{OH})_2 \cdot (\text{Co}, \text{Ni}, \text{Ca})_x(\text{OH})_{2x} \cdot n\text{H}_2\text{O})$  with up to 7.9 wt.% Co), and a euhedral, blocky Na-Zn-Mn oxide phase, possibly a Na-Zn birnessite. The bulk of the sample (by volume) is dominated by Zn-bearing cryptomelane and an intimate intergrowth of cryptomelane and chalcophanite. The Zn-rich nature of the Mn-oxides is unusual, and points to formation in the presence of Zn-rich fluids in the weathered zone. Zinc-manganese minerals such as chalcophanite usually occur in the oxide zone of weathered Zn sulphide deposits.



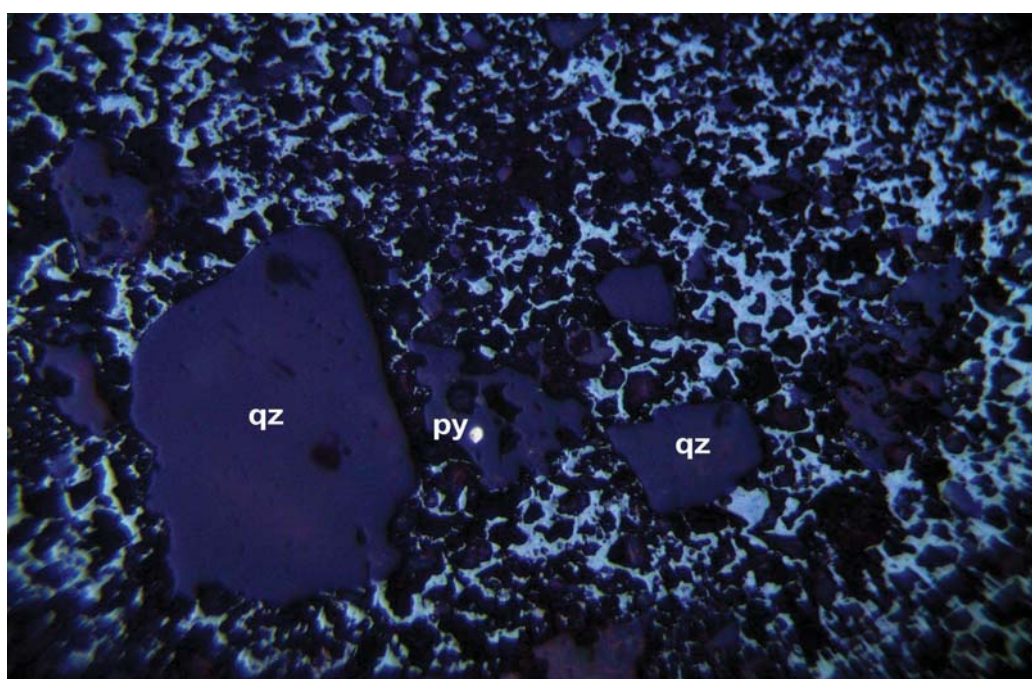
**Figure 6:** Detail of mineralogy of colloform layers in Mn-rich EPT1831 200.7m. Zn-bearing cryptomelane (cryp) overlies a layer of bladed, crystallised Na-bearing chalcophanite (ph A), which in turn overlies Co-rich asbolane (asb). Reflected light image. Field of view is 600 microns.



**Figure 7:** Detail of Mn-rich EPT1831 200.7m. Blocky crystals of a probable Na-Zn birnessite (ph B) are overgrown by acicular crystals of Na-bearing chalcophanite (ph A) and Zn-bearing cryptomelane (cryp). Reflected light image. Field of view is 600 microns.

**Sample EPT1831 203.5m**

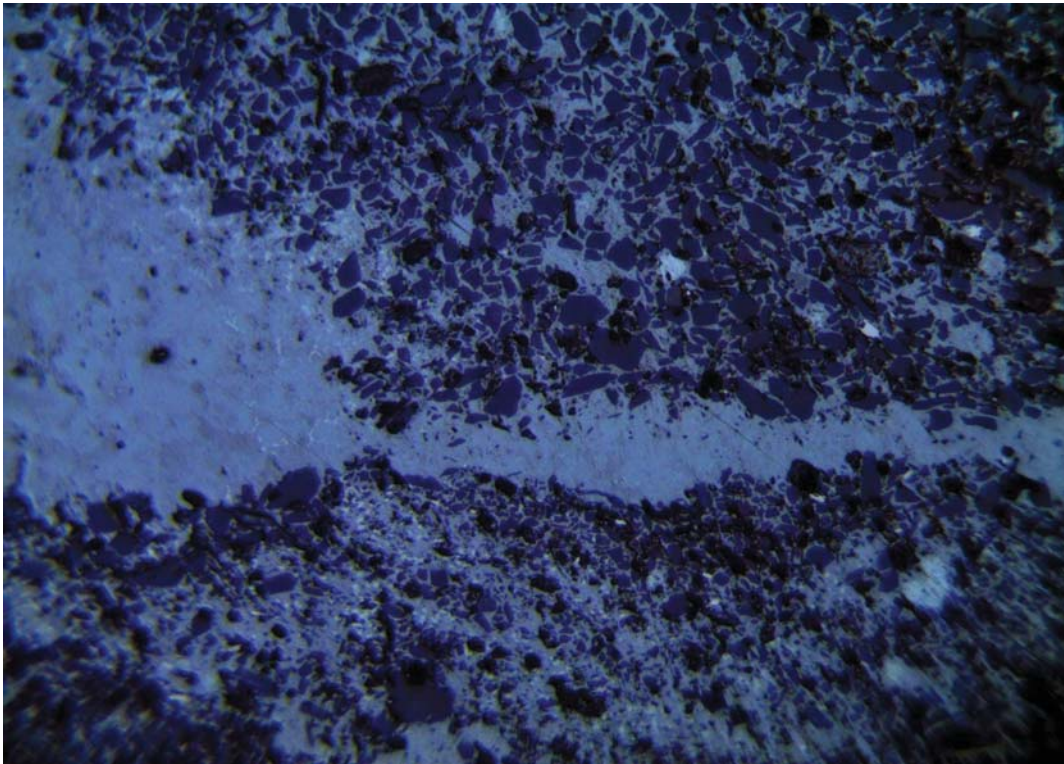
This sample of ferruginous gossanous material shows layering/banding defined mainly by hematite and goethite of varying crystallinity or cementation. It contains cellular textures locally rich in microvoids lined with botryoidal goethite. The Fe-oxides contain abundant inclusions of silt-sized and fine-sand sized angular quartz grains, and some coarser quartz crystals and fragments. Some of these quartz grains were observed with rare microinclusions of pyrite. A few detrital monazite grains to 50 microns were identified with SEM-EDAX. No relict sphalerite or high tenor secondary Zn minerals were identified. SEM-EDAX analyses of goethite locally yielded up to 4 wt.% Zn.



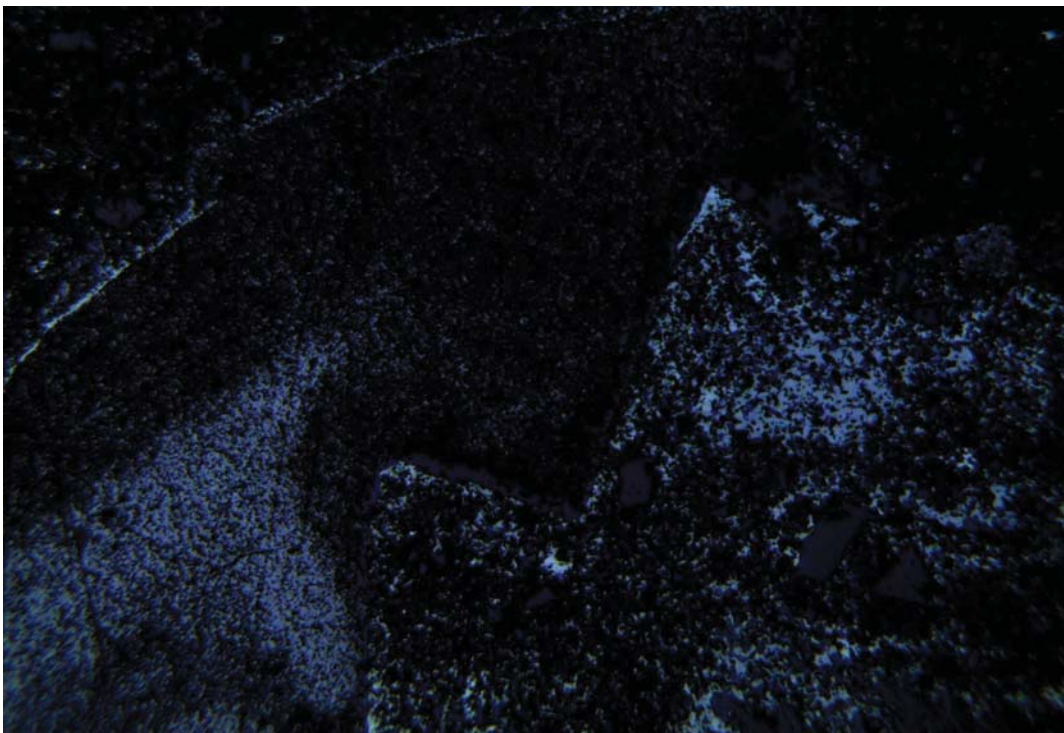
**Figure 8:** Detail of Fe-rich EPT1831 203.5m. Note cellular microtexture defined by fine-grained goethite and hematite. Silt-sized quartz inclusions are abundant as are coarser crystals (qz). A rare pyrite inclusion (py) is present in one quartz grain. Reflected light image. Field of view is 600 microns.

**Sample EPT1831 221.2m**

This sample of ferruginous gossanous material consists of fine-grained goethite and hematite with abundant inclusions of angular silt-sized (locally sand-sized i.e. >64 microns) quartz grains. Coarse, euhedral to subhedral quartz crystal aggregates to 800 microns (some with inclusions of relict pyrite) and some quartz veinlets are also present, surrounded by Fe oxides. Some crudely rhomboid shapes may be replacements of former crystalline carbonates. Some goethite-rich secondary veins cross-cut the sample. A few detrital zircon grains were identified with SEM-EDAX. No relict sphalerite or high tenor secondary Zn minerals were identified.



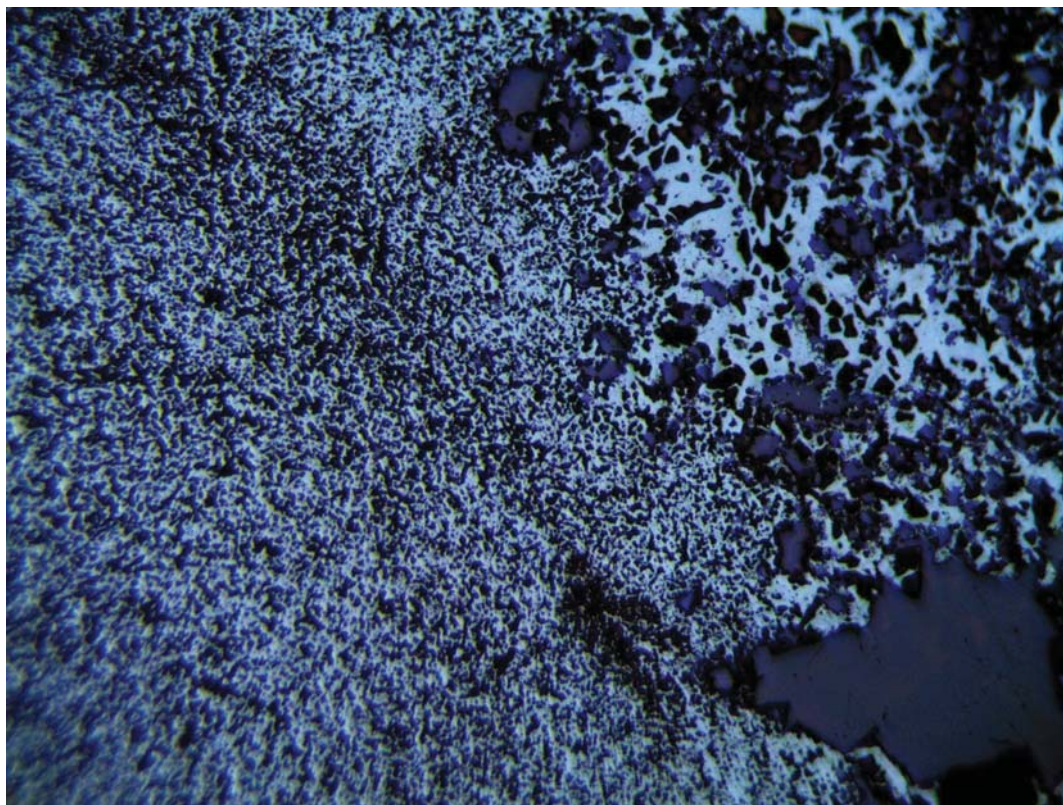
**Figure 9:** Detail of Fe-rich EPT1831 221.2m. Abundant silt-sized quartz inclusions in a matrix of fine-grained goethite and hematite (grey-blue). Reflected light image. Field of view is 600 microns.



**Figure 10:** Crude rhomboid textures suggestive of former carbonate in EPT1831 221.2m. Reflected light image. Field of view is 2400 microns.

**Sample EPT1831      279.6m**

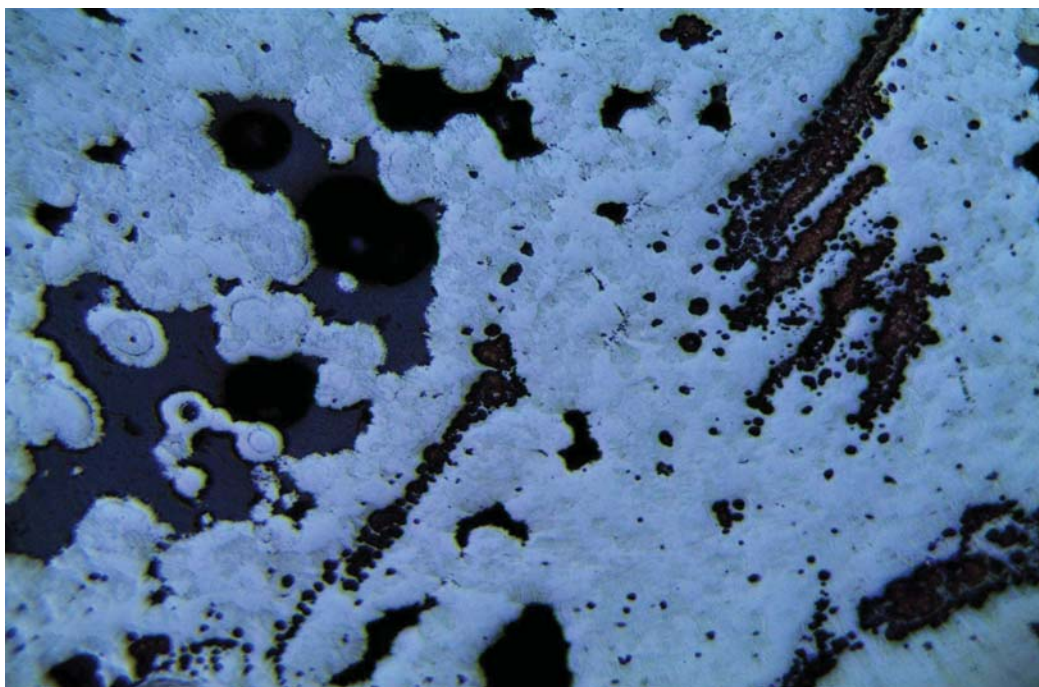
This sample of ferruginous gossanous material consists of fine-grained goethite and hematite with abundant inclusions of angular silt-sized (locally sand i.e. >64 microns) quartz grains. Coarse, euhedral to subhedral quartz crystal aggregates (some with inclusions of relict pyrite) and some quartz veinlets are also present surrounded by Fe oxides. Some crudely rhomboid shapes may be replacements of former crystalline carbonates. No relict sphalerite or high tenor secondary Zn minerals were identified.



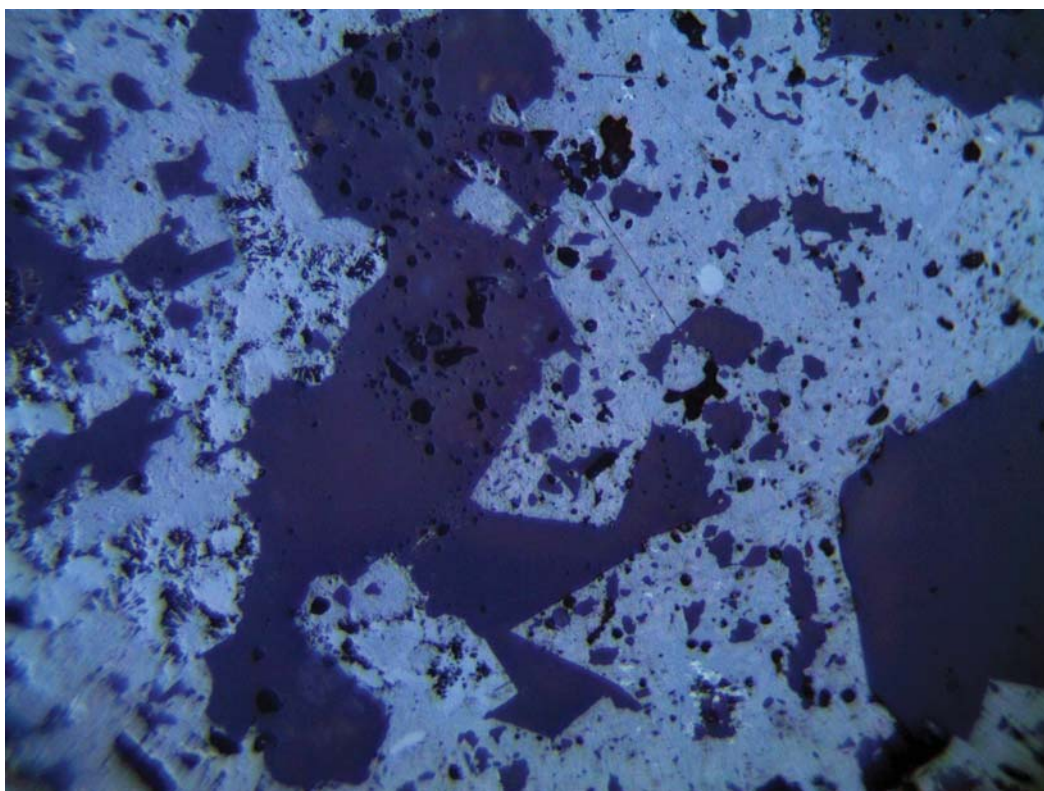
**Figure 11:** Silicate and quartz inclusions of a range of sizes in a matrix of goethite and hematite in EPT1831 279.6m. Reflected light image. Field of view is 1200 microns.

**Sample EPT1831      289.15m**

This sample of ferruginous gossanous material consists of fine-grained goethite and hematite with a lesser silt or sand component compared to the previous samples. Voids are lined with botryoidal goethite, and this form of non-pseudomorphic, secondary goethite is common in the sample. Crystalline quartz is present in shapes that suggest former intergrowth with a euhedral rhombic carbonate (?) now replaced by secondary goethite and hematite. No relict sphalerite or high tenor secondary Zn minerals were identified.



**Figure 12:** Botryoidal, secondary and non-pseudomorphic goethite lining voids in EPT1831 289.15m. Reflected light image. Field of view is 1200 microns.



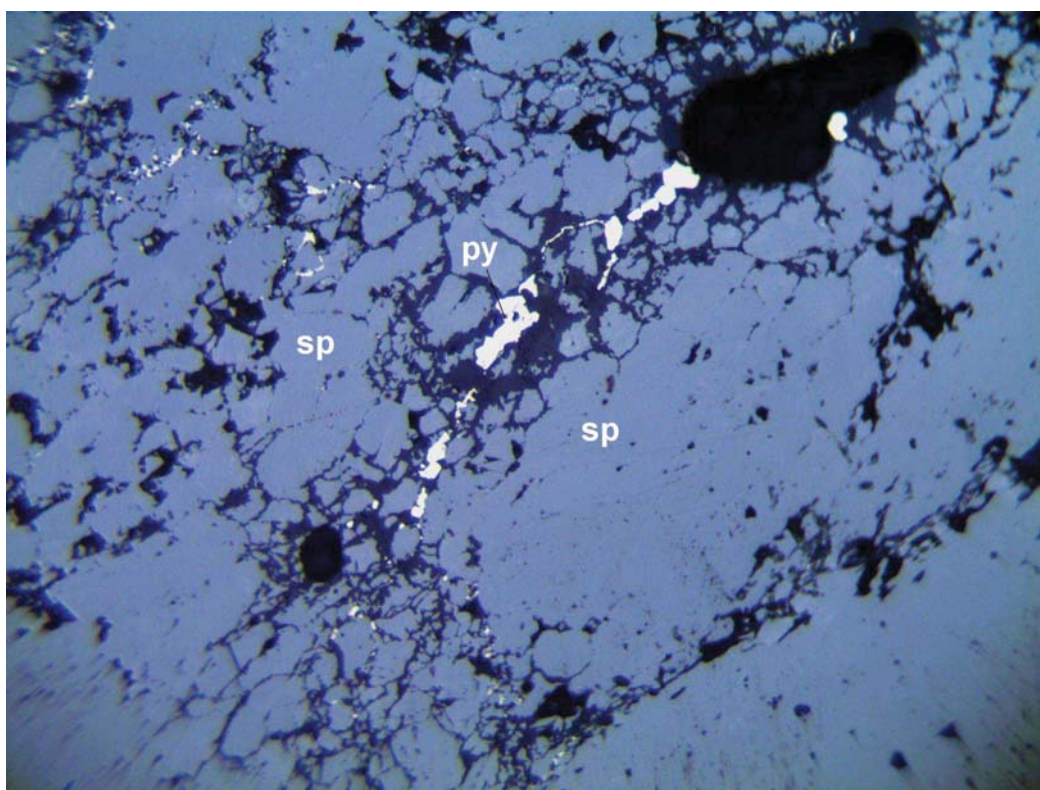
**Figure 13:** Quartz (dark grey) in rhombic shapes suggesting intergrowth with former euhedral carbonate (?) now replaced by secondary goethite and hematite in EPT1831 289.15m. Reflected light image. Field of view is 600 microns.

**Sample EPT1854 430.05m**

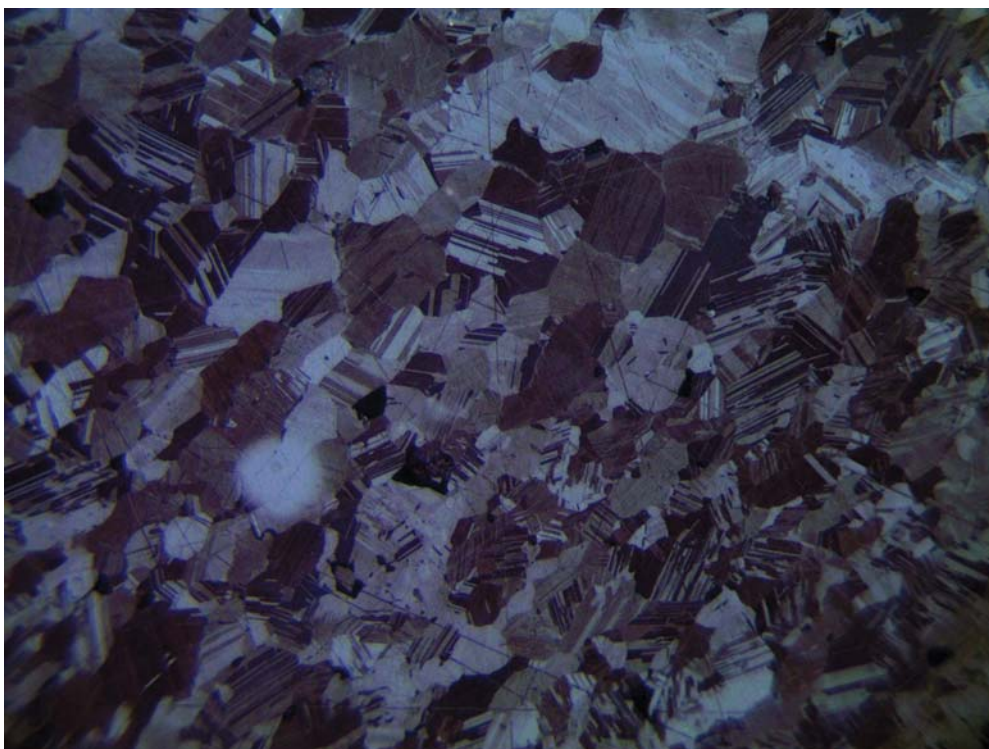
This sample consists of relatively pure, massive, crystalline sphalerite with microfractures and brecciation. The microfractures contain a sparse distribution of pyrite veinlets (generally less than 10 microns wide). Minor, coarser fractures contain euhedral quartz crystals in voids. SEM-EDAX showed the sphalerite to be very low in Fe, as anticipated from cream-white rather than amber-red internal reflections, with five analyses yielding Fe contents of 0.44 to 0.97 wt.% (mean 0.64). Surface etching using an oxidising agent revealed an annealed, equigranular texture suggestive of textural equilibrium without evidence of late-stage ductile deformation. Aside from pyrite, inclusions in the sphalerite are rare, however, high-magnification SEM scanning identified micro-inclusions of:

- a. acanthite ( $\text{Ag}_2\text{S}$ ) as 5 to 10 micron grains.
- b. galena ( $\text{PbS}$ ) as a single 10 micron grain.
- c. a poorly-characterised indium (+iron) bearing phase as a fracture fill in sphalerite.

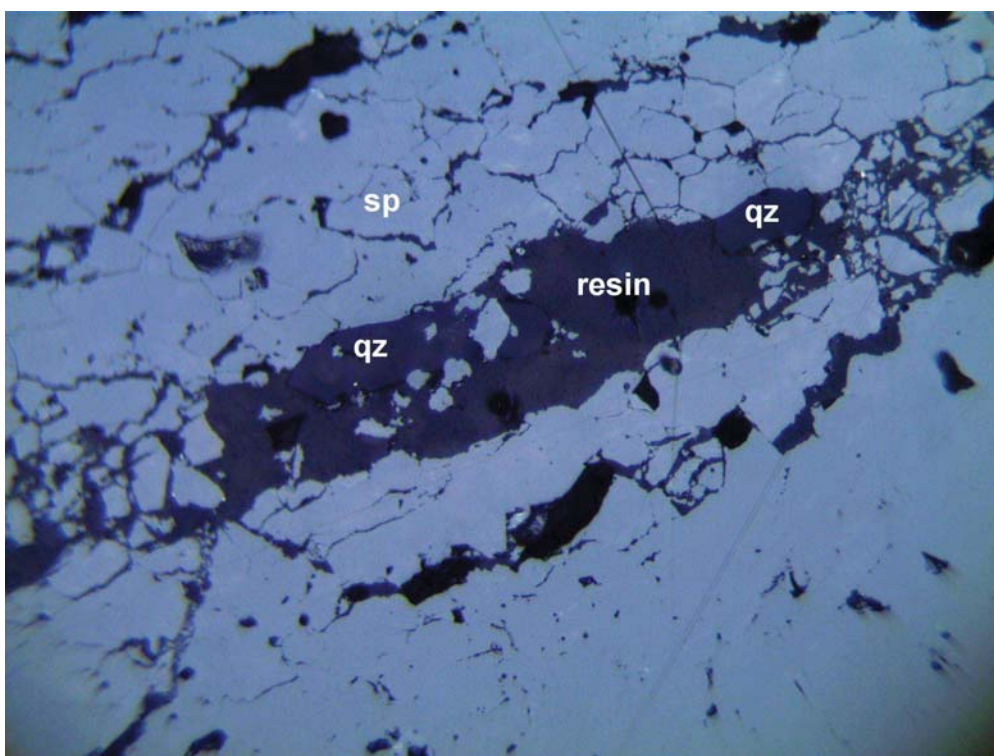
It is likely that the acanthite is the host of the anomalous Ag in the sample (60 g/t). The occurrence of a discrete indium phase in sphalerite is highly unusual and worthy of further study, indium minerals being very rare.



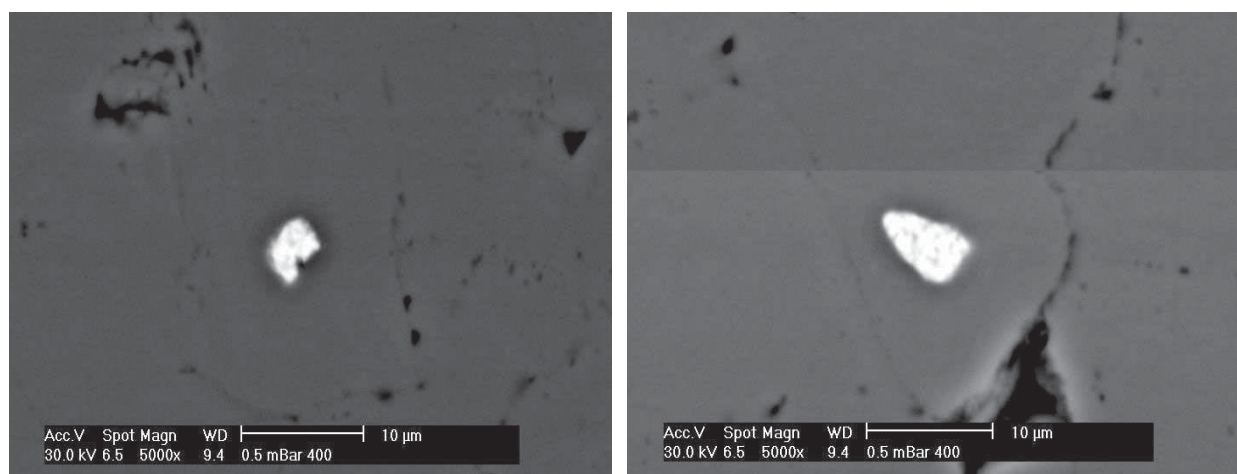
**Figure 14:** Massive and micro-brecciated sphalerite (sp) in EPT1854 430.05m, with some pyrite (py) in fractures. Reflected light image. Field of view is 600 microns.



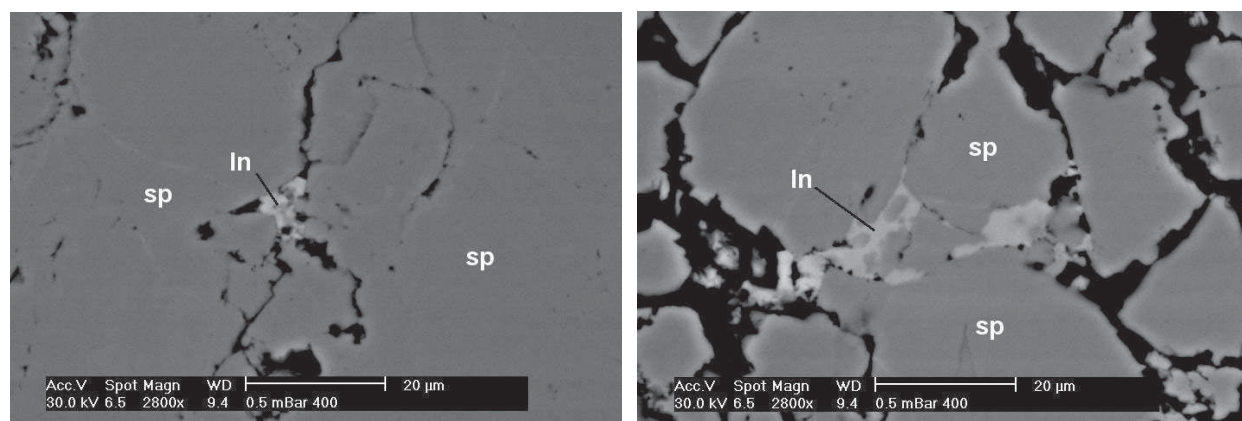
**Figure 15:** Annealed microstructure of crystalline sphalerite (sp) in EPT1854 430.05m discernible following surface etching with an oxidising agent. Reflected light image. Field of view is 600 microns.



**Figure 16:** Coarser brittle fracture in crystalline sphalerite (sp) in EPT1854 430.05m containing euhedral quartz crystals (qz). Remainder of void is filled with mounting resin. Reflected light image. Field of view is 600 microns.



**Figure 17:** Bright white inclusions of acanthite in a matrix of sphalerite in EPT1854 430.05m. Backscattered electron image.



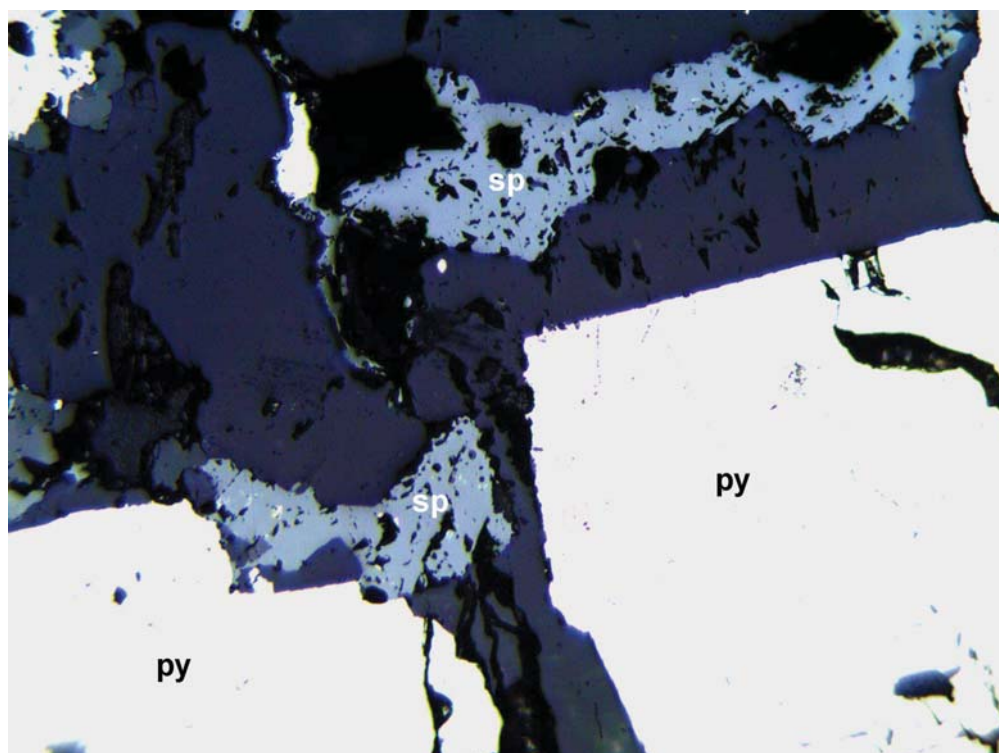
**Figure 18:** Poorly characterised indium (+Fe) phase (In) present as microfracture fill in sphalerite(sp) in EPT1854 430.05m. Backscattered electron image.

### **Sample EPT1174      402m**

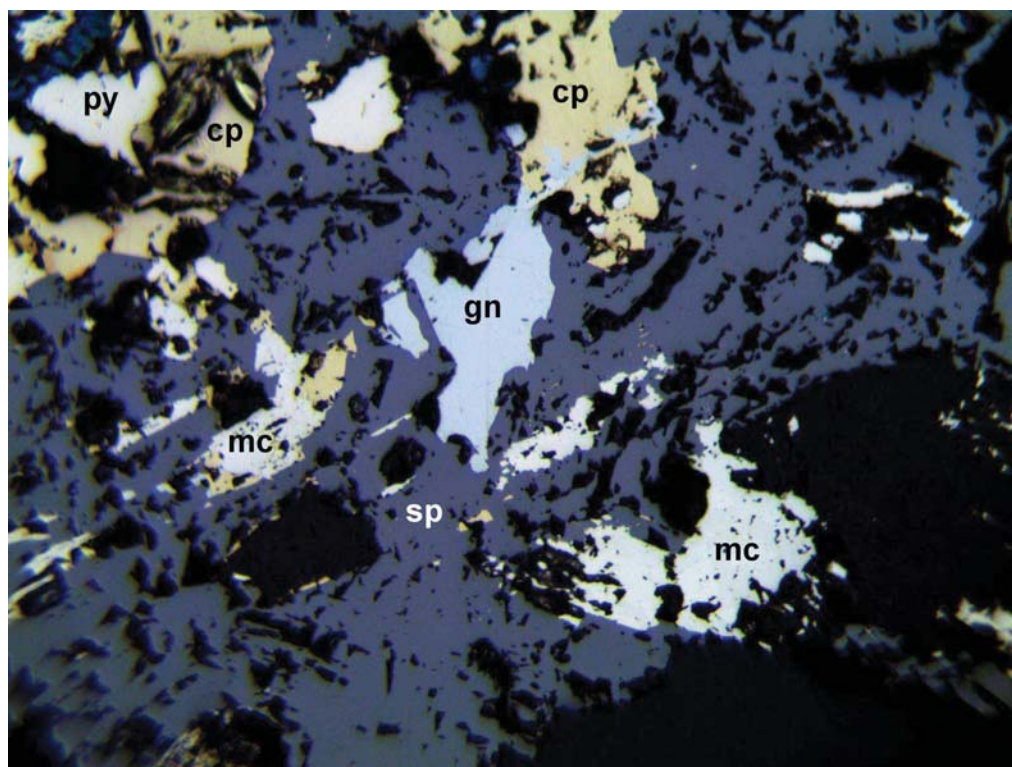
This sample comprised part of a 2cm wide, bedding-parallel sulphide horizon in a carbonaceous pelite (Figure 5). The sulphide-rich horizon is dominated by Fe sulphides in the form of:

- a. coarsely-crystalline pyrite crystals containing clean zones and zones rich in platy silicate inclusions.
- b. anhedral masses of crystalline marcasite.

The marcasite is not porous but is intergrown with crudely-formed quartz crystals to 200 micron, and is thus interpreted to be hypogene rather than supergene. Minor inclusions of pyrrhotite and chalcopyrite were noted. Anhedral sphalerite is the second-most abundant component and occurs on the margin of the Fe sulphide-rich zone. The sphalerite contains scattered grain-boundary blebs and segregations of chalcopyrite and a little covellite. Locally, the sphalerite contained anhedral bodies of galena to several hundred microns across. Sphalerite would appear to be partly replacing marcasite. Surface etching of sphalerite revealed an annealed micro-structure as seen in EPT1854.



**Figure 19:** Coarsely euhedral pyrite (py) associated with anhedral sphalerite (sp) containing minor chalcopyrite inclusions in EPT1174 402m. Reflected light image. Field of view is 1200 microns.



**Figure 20:** Anhedral sphalerite (sp) which appears to replace marcasite (mc) and contains coarse inclusions of galena (gn), chalcopyrite (cp) and pyrite (py). Sample EPT1174 402m. Reflected light image. Field of view is 1200 microns.

## DISCUSSION

### Genesis of the EPT1831 gossan zone

Two hypotheses were considered for the formation of the thick intersection of Zn-bearing gossan, located near the tectonised contact between the Broadhurst formation sulphidic pelites and the dolomite breccias. The first was that existing Fe-oxides derived from weathering of barren Fe sulphides accumulated in the shear zone had been enriched in Zn due to downward movement of Zn-bearing meteoric waters generated from the weathering of Zn anomalous Broadhurst formation to the SW.

The second was that a massive/brecciated sulphide position existed along the contact which contained primary Zn sulphide. This latter hypothesis is favoured on two pieces of evidence; the rarity of exotic Zn deposits world-wide, and the presence of massive sphalerite in a down-dip position in EPT1854. Textures in the gossans suggest a mixture of protolith associations, as expected on a tectonised contact; laminated shales in the case of Figure 2, and sulphide-rich breccias in the case of Figure 3. Carbonate-bearing protoliths are suggested by relict carbonate microtextures (Figures 10 and 13) and the abundance of angular silt- to sand-sized quartz grains (an interpreted residue of sandy carbonate dissolution). Both the gossan and down-dip sphalerite thus appear to occur in a tectonised transition zone between pelitic and carbonate lithologies. This zone is also characterised by elevated Mn (1000's of ppm) even below the base of weathering, a possible proxy for hydrothermal activity. The high Fe content of the gossans and the lack of residual Zn minerals would suggest the primary ore material consisted of a mixture of Fe and Zn sulphides rather than the pure, Fe-poor sphalerite seen in EPT1854. Most of the Zn observed now in the Fe-rich gossans is likely to be residual Zn, adsorbed or incorporated into the goethite structure.

It is conceivable that between the fully oxidised and heavily leached gossanous zone in EPT1831 and the massive sphalerite in EPT1854, a zone of secondary Zn enrichment is present. It would be expected that this zone would be rich in secondary Zn minerals such as smithsonite ( $\text{ZnCO}_3$ ), hemimorphite ( $\text{Zn}_4\text{Si}_2\text{O}_7(\text{OH})_2 \cdot \text{H}_2\text{O}$ ) and hydrozincite ( $\text{Zn}_5(\text{CO}_3)_2(\text{OH})_6$ ).

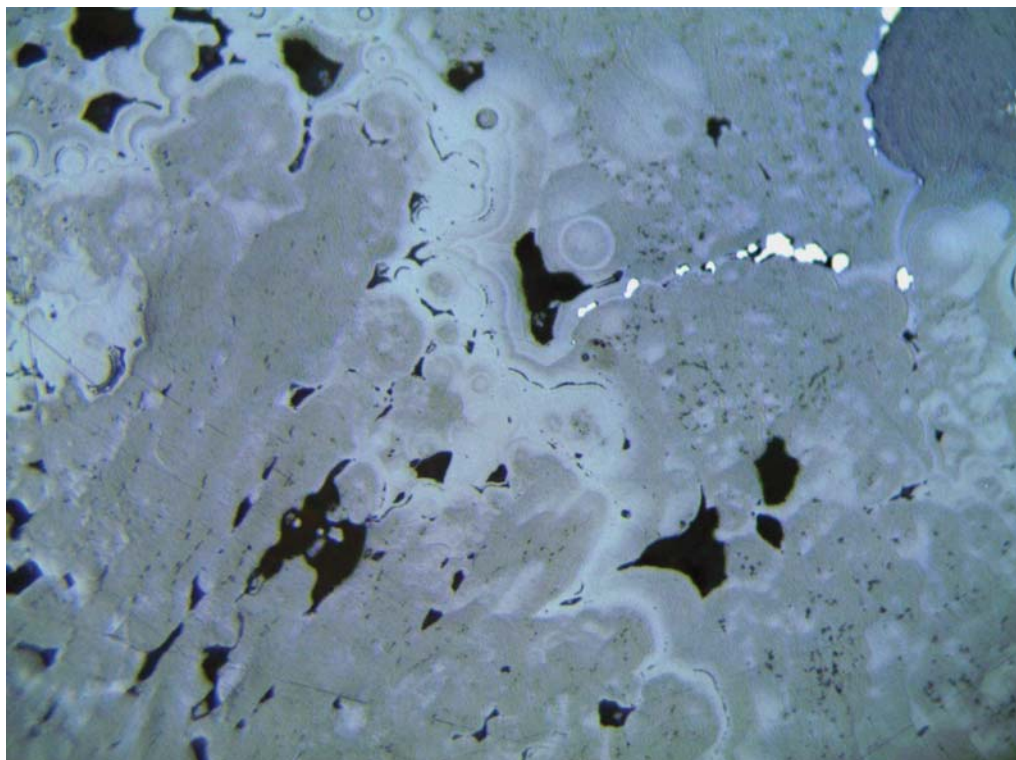
### Genesis of the EPT1854 massive sphalerite

Initial examination of the massive, very low-Fe, and very pure sphalerite in a down-dip position below a gossan zone led to hypothesis that the EPT1854 intersection may represent secondary supergene sphalerite, such as locally occurs at Broken Hill, NSW (Lawrence and Rafter, 1962). More detailed microscopic and SEM examination has resulted in this hypothesis being rejected on basis of the following pieces of evidence:

1. Equigranular annealed textures (Figure 15) rather than colloform textures (e.g. Figure 21).
2. The presence of significant Ag, probably mainly hosted in the observed acanthite inclusions.
3. Brecciated textures with euhedral quartz crystals in voids and fractures.

As a relatively inexpensive check, a sample of the EPT1854 sphalerite together with a separate from the Broadhurst Fm pelite EPT1174 were submitted for sulphur isotope analysis. Lawrence and Rafter

(1962) noted a marked difference between the sulphur isotope composition of Broken Hill hypogene sphalerite ( $\delta S^{34} = +0.4$  to  $+1.1$  per mil) and supergene sphalerite ( $\delta S^{34} = -31$  to  $-48$  per mil). The comparison will be made for BM2 assuming typical near-zero per mil sulphur isotope compositions for primary Proterozoic sulphides. The massive, brecciated sphalerite is proposed to be hydrothermal in origin, but given the low Fe content it may be a low temperature hydrothermal occurrence, and a replacement-style system, as proposed by Encounter, is plausible.



**Figure 21:** Colloform microstructure in low-Fe supergene sphalerite from South Mine, Broken Hill, NSW. Minor white, globular, secondary galena is associated. Black areas are voids. Contrast with Figure 15. Reflected light image. Field of view is 1200 microns.

As mentioned, the presence of an indium mineral associated with the sphalerite is noteworthy, particularly as whole rock assays do not suggest exceptionally high In assays. Data provided by Encounter showed In levels to a maximum of 114 ppm. While anomalous, In levels up to 6 wt.% can be accommodated into the sphalerite crystal structure, however, this is surmised to occur by a coupled substitution ( $Cu^{+}In^{3+} \leftrightarrow Zn^{2+}Fe^{2+}$ ) as discussed in Cook *et al.* (2009). In the absence of significant Cu (e.g. <200 ppm in the EPT1854 sample), it is possible that the indium could not be accommodated and was instead precipitated as discrete In minerals.

**REFERENCES**

**Cook, N.J., Ciobanu, C.L., Pring, A., Skinner, W., Shimizu, M., Danyushevsky, L., Saini-Eidukat, B., Melcher, F. (2009)** Trace and minor elements in sphalerite: a LA-ICPMS study. *Geochimica et Cosmochimica Acta*, Vol. 73, pg. 4761-4791.

**Lawrence, L.J., Rafter, T.A. (1962)** Sulfur isotope distribution in sulfides and sulfates from Broken Hill South, New South Wales. *Economic Geology*, Vol. 57, pg. 217-225.

## ADDENDUM – SULPHUR ISOTOPE ANALYSES

Results of sulphur isotope analyses of sphalerite separates from the two sulphide-rich samples (EPT1854 430.05m and EPT1174 402m) were received from CODES on 18-2-2014. Raw  $\delta S^{34}$  values determined by mass spectrometry were normalised to an internal standard (Canyon Diablo troilite) and are given below:

Sample	Style	$\delta S^{34}$ ‰
EPT1174 402m	Sulphide layer in graphitic pelite	-6.58
EPT1854 430.05m	Massive, low-Fe sphalerite	-7.78

The absolute values are typical of most Proterozoic magmatic and hydrothermal sulphide systems (i.e. within the range  $0 \pm 10$  per mil  $\delta S^{34}$ ), but perhaps more importantly, both samples were within 1.2 per mil of each other. This suggests a genetic connection between the massive zinc mineralisation and the zinc-rich sulphides hosted in the Broadhurst Formation pelites. The absence of a strong negative  $\delta S^{34}$  signature for the EPT1854 sample gives further weight to the argument that it is not supergene sphalerite.