ORE AND GANGUE MINERALS OF THE HERA AU-PB-ZN-AG DEPOSIT, COBAR BASIN, NSW

Angela Lay[1*] **Ian Graham[1]** **Lachlan Burrows[1]** **Adam McKinnon[2]** **Karen Privat[3]**
[1]School of Biological Earth and Environmental Sciences (BEES), University of New South Wales (UNSW) Sydney, Australia
[2]Aurelia Metals Ltd, Nymagee, Australia
[3]Electron Microscopy Unit (EMU), University of New South Wales (UNSW) Sydney, Australia
Emails: angela.lay@unsw.edu.au; i.graham@unsw.edu.au; lachlan.burrows@student.unsw.edu.au; adam.mckinnon@aureliametals.com.au; k.privat@unsw.edu.au

SUMMARY

The Hera Au-Pb-Zn-Ag deposit is located within the Cobar Basin of the Lachlan Orogen. The deposit was classified as a Cobar-type deposit, however the presence of skarn gangue mineral assemblages associated with the main mineralisation and host-rocks suggest a much higher temperature of ore formation. These gangue assemblages also are the first occurrence of these for deposits within the Cobar Basin. The gold at Hera shows poor correlation with the other metals and minerals suggesting multiple generations of crystallisation. The primary silver minerals in the deposits are Ag-sulfosalts (tetrahedrite), acanthite and dyscrasite?. The presence of Ag-sulfosalts often closely associated with gudmundite within the main mineral assemblages. Scheelite is quite common and associated with the main sulphides and also within the host siltstone.

Key words: Hera Au-Pb-Zn-Ag deposit, Cobar Basin, gold, tetrahedrite, gudmundite, scheelite

INTRODUCTION

The Hera Au-Pb-Zn-Ag deposit is located 5 km southeast of Nymagee (a historic copper mining town) (Figure 1), central western New South Wales. Early exploration history of the Hera deposit dates to 1974 when the mineralised system containing the deposit was identified. In 2000, a high-grade drill hole containing gold, copper, lead and zinc was discovered by Pasminco Exploration intersected at 300 meters below the surface (Skirka & David, 2003; Collins *et al*. 2006). Development and construction of the mine began in early 2013 and production began in late 2014 (McKinnon, 2017). The deposit currently has a total estimated mineral resource of 2.93 Mt grading at 2.8g/t Au, 2.6% Pb, 3.8% Zn, and 24g/t Ag (Aurelia Metals, 2017). There are seven known ore lenses within the deposit and each of the lenses host variable amounts of the mineral resources (Figure 2) (Aurelia Metals, 2017).

Understanding the nature of the ore and gangue minerals within the Hera deposit is important, just like any other deposits, particularly for optimisation of metallurgical parameters and providing further insights into the geological interpretations, resource and reserve estimation as well as waste storage and disposal. Previous research on the Hera deposit has largely been limited to a regional scale, which led to the deposit being classified as a 'Cobar-type' orogenic gold deposit (Collins *et al*., 2006; Fitzherbert *et al*. 2017). However, the recent discovery of skarn-like gangue assemblages, such as garnets, tremolite, zoisite, epidote, wollastonite and scheelite as well as pegmatitic albite-K-feldspar-quartz rocks indicates a higher temperature gradient than for traditional sediment-hosted 'Cobar-type' deposits. The primary focus for this study is to examine the various recently discovered gangue minerals as well as to examine the gold mineralogy that does not appear to correlate with any other metals in the deposit which suggests multiple mineralising events. This multiple events concept is also consistent with the discovery of the Ag-rich North Pod, a mineral lens which differs significantly from the other ore lenses in terms of metal associations and mineralogy.

Geological Setting

The Hera deposit is located on the eastern margin of the Palaeozoic Cobar Basin, an intracratonic basin within the Lachlan Orogen. The Cobar Basin developed as a half-graben system containing four deep-water troughs (e.g Mount Hope Trough, Rast Trough, Melrose Trough and Cobar Trough) surrounded by three shallow-water flanking shelfs (Winduck Shelf, Walter Range Shelf, and Kopyje Shelf) (McRae, 1987). The Cobar Basin rests on a basement of Early to Late Ordovician arenitic and pelitic metasediments (the Girilambone and Tallebung Groups) intruded by numerous Silurian granites (Rayner, 1969; Felton 1981).

The Cobar Basin is the richest polymetallic basin within the Lachlan Orogen, hosting a significant number of precious and base metal deposits related to different tectonostratigraphic units from Late Silurian to the Early Devonian. The Hera deposit is located near the contact between shelf facies sediments of the Mouramba Group and turbiditic sediments of the Amphitheatre Group within the Cobar Basin (Figure 1). The mineralisation at Hera is hosted by steeply-dipping siltstones and fine-grained sandstones of the Mouramba and Lower Amphitheatre Groups with a strong, near vertical cleavage, metamorphosed to the low-middle greenschist facies (Skirka and David, 2003; McKinnon, 2017). The deposit is structurally controlled with mineralisation occurring as steep sulfide vein/breccia zones and arranged into a number of *en echelon*, NNE-striking lodes over a total strike length exceeding 800 metres (Figure 2) (McKinnon, 2017). The orebody does not show physical surface expression, with the economic mineralisation commencing nearly 200 metres below the surface (McKinnon, 2017).

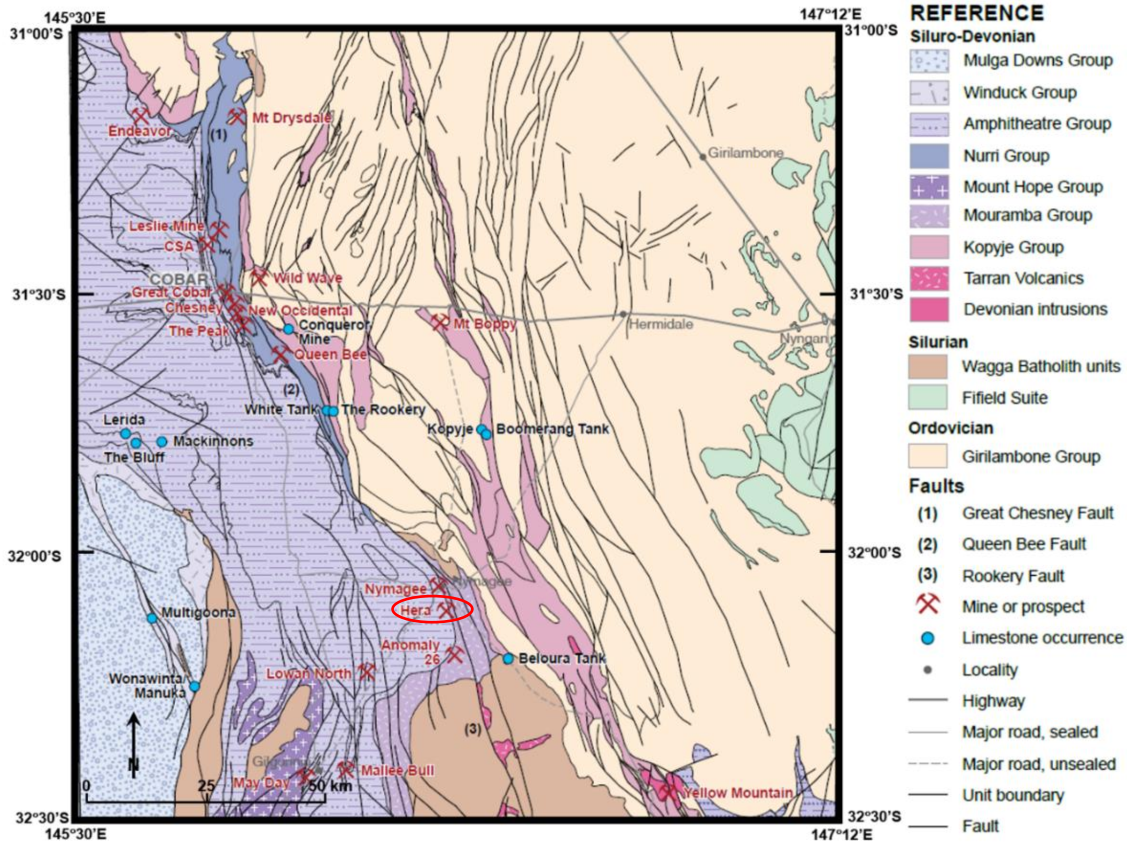

Figure 1. Geological map of the Cobar Basin modified from Fitzherbert *et al*. 2017

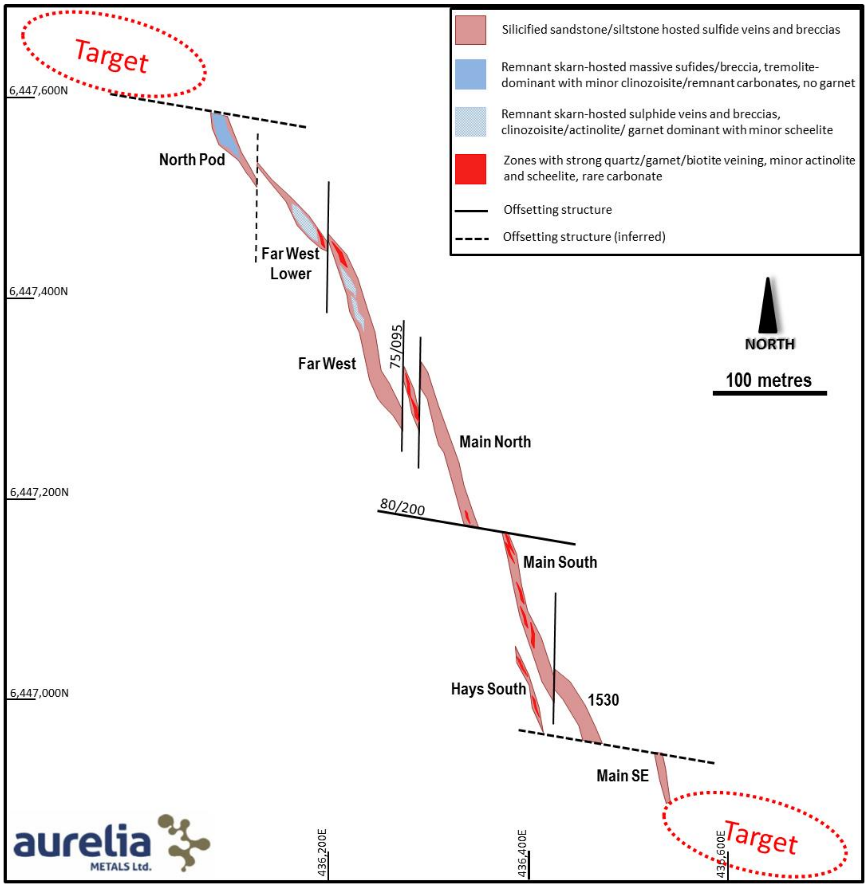

Figure 2. Local Geology of the seven mineralising lenses within the Hera Au-Pb-Zn-Ag deposit (Aurelia Metals, 2017).

METHOD

Various analytical methods are employed to achieve the primary aims in characterising and examining the ore and gangue mineralogy of the Hera deposit. Samples from the various mineralised lenses were chosen for study to best represent the variation within the deposit as a whole. These samples were then analysed using the petrographic microscope prior to any scanning electron microscope (SEM), electron microprobe analyser (EMPA), or elemental mapping analyses. Assay data for some of the lenses were also examined for any elemental correlations within the deposit.

RESULTS

ORE MINERALS

The primary ore minerals within the Hera deposit from all the lenses studied comprise pyrrhotite, sphalerite, galena ± chalcopyrite ± arsenopyrite ± pyrite ± gold ± tetrahedrite ± native antimony ± gudmundite (Figures 3 & 4; Table 1). Galena and sphalerite show an intergrowth texture throughout the deposits. Tremolite is more prominent within the main sulphide assemblages within the North Pod lens. The presence of tetrahedrite and other silver-bearing minerals such as dyscrasite? and acanthite have only been identified from the North Pod lode. Observation of the sulphide minerals in thin sections indicate that when there is gudmundite present most likely silver-bearing minerals such as tetrahedrite will also be present, suggesting a strong genetic link between these two phases.

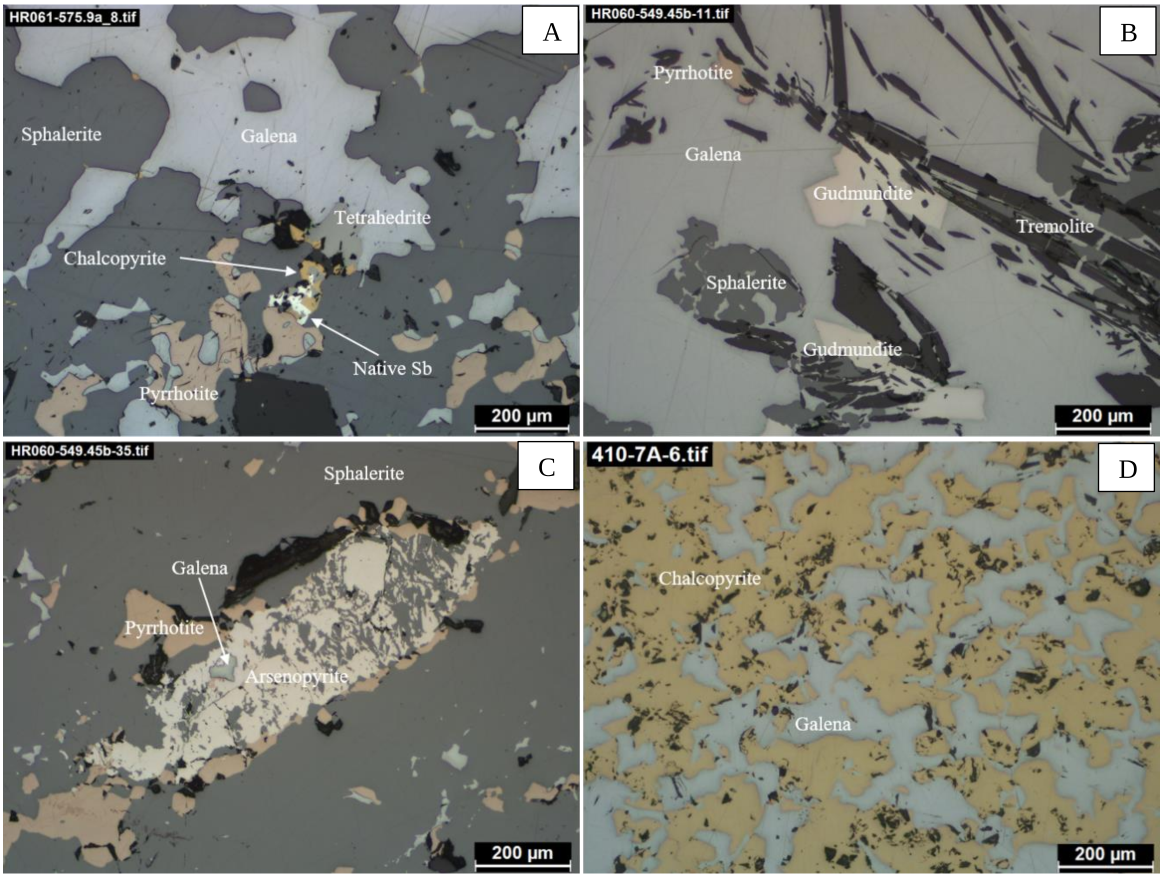

Figure 3. Reflected light photomicrographs of silver and other base metal mineral associations within the Hera Au-Pb-Zn-Ag deposit. (A) Co-crystallisation of pyrrhotite, sphalerite and galena rimmed by later tetrahedrite, chalcopyrite and native antimony (B) Pyrrhotite, sphalerite, galena and gudmundite intergrowth with decussate texture tremolite (C) Arsenopyrite rimmed by pyrrhotite, sphalerite and galena (D) Co-crystallisation of galena and chalcopyrite.

The range of chemical compositions for most of the main ore minerals at the Hera deposit (Table 2) shows that mercury (Hg) and tin (Sn) are rarely detected in any of the analysed sulphides, their maximum concentrations are detected in galena (0.14wt%) and gudmundite (0.01wt%), respectively. Most of the major sulphides contain trace of gold (Table 2).

Table 1. List of ore and gangue minerals identified in this study

Sulphide/Ore Minerals	Relative abundance	Gangue Minerals	Relative abundance
Pyrrhotite	Major	Quartz	Major
Sphalerite	Major	Tremolite	Major
Galena	Major	Biotite	Major
Chalcopyrite	Minor	Chlorite	Major
Gold	Minor	Calcite	Minor
Tetrahedrite	Minor	Scheelite	Minor
Gudmundite	Minor	Garnet	Minor
Acanthite	Trace	Zoisite	Trace
Arsenopyrite	Trace	Epidote	Trace
Native antimony	Trace	Wollastonite	Trace
Pyrite	Trace		
Cubanite	Trace		
Dyscrasite?	Trace		

Table 2. Range of EMPA analyses of the main sulphides at Hera (in wt%)

Sulphide	# analysis		As	Hg	Fe	Au	S	Co	Ag	Pb	Ni	In	Bi	Cu	Sn	Zn	Sb	Total
Pyrrhotite	82	Min	0.00	0.00	59.25	0.00	36.86	0.08	0.00	0.08	0.00	0.00	0.07	0.00	0.00	0.00	0.00	97.79
		Max	0.03	0.00	62.03	0.08	38.98	0.11	0.04	0.96	0.01	0.01	0.22	0.38	0.00	1.70	0.00	100.65
Sphalerite	37	Min	0.00	0.00	7.43	0.00	33.13	0.00	0.00	0.02	0.00	0.00	0.03	0.00	0.00	54.57	0.00	98.21
		Max	0.19	0.00	10.38	0.09	34.10	0.02	0.08	0.52	0.02	0.01	0.23	0.21	0.05	57.56	0.00	100.15
Galena	51	Min	0.00	0.00	0.00	0.00	12.98	0.00	0.00	84.20	0.00	0.00	0.17	0.00	0.00	0.00	0.00	98.23
		Max	0.00	0.14	0.67	0.00	13.70	0.02	0.00	87.88	0.02	0.00	0.45	0.26	0.04	3.26	0.03	102.54
Chalcopyrite	26	Min	0.00	0.00	28.15	0.00	33.51	0.03	0.00	0.06	0.00	0.00	0.04	32.42	0.00	0.03	0.00	97.91
		Max	0.03	0.00	30.64	0.05	34.89	0.05	3.85	1.19	0.01	0.00	0.19	34.88	0.00	2.16	2.18	101.21
Tetraherite	16	Min	0.01	0.00	5.49	0.00	24.75	0.00	0.91	0.12	0.00	0.00	0.02	36.95	0.00	1.38	28.72	100.88
		Max	0.11	0.00	6.00	0.06	25.40	0.02	2.87	0.88	0.02	0.00	0.12	39.02	0.00	2.60	30.05	102.44
Arsenopyrite	6	Min	41.84	0.00	35.17	0.00	20.66	0.06	0.00	0.10	0.00	0.00	0.03	0.00	0.00	0.17	0.00	100.02
		Max	44.00	0.00	35.87	0.05	21.84	0.14	0.02	0.19	0.03	0.00	0.11	0.04	0.00	0.45	0.48	101.19
Gudmundite	29	Min	0.06	0.00	24.87	0.00	14.58	0.03	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	50.41	98.91
		Max	0.58	0.00	27.56	0.10	17.36	0.65	4.99	0.93	0.88	0.00	0.14	3.80	0.01	1.89	59.22	102.28

The gold mineralisation at Hera shows little correlation to any other metals, which may suggest having formed during a separate mineralising event to the main sulphide mineralisation. This is also supported by the finding of gold (primarily in the form of electrum) having an irregular distribution and either being associated with various sulphide minerals, such as pyrrhotite, sphalerite, or galena, or within the host siltstone (Figure 4). This random association may suggest a few generations of gold crystallisation in terms of its paragenesis.

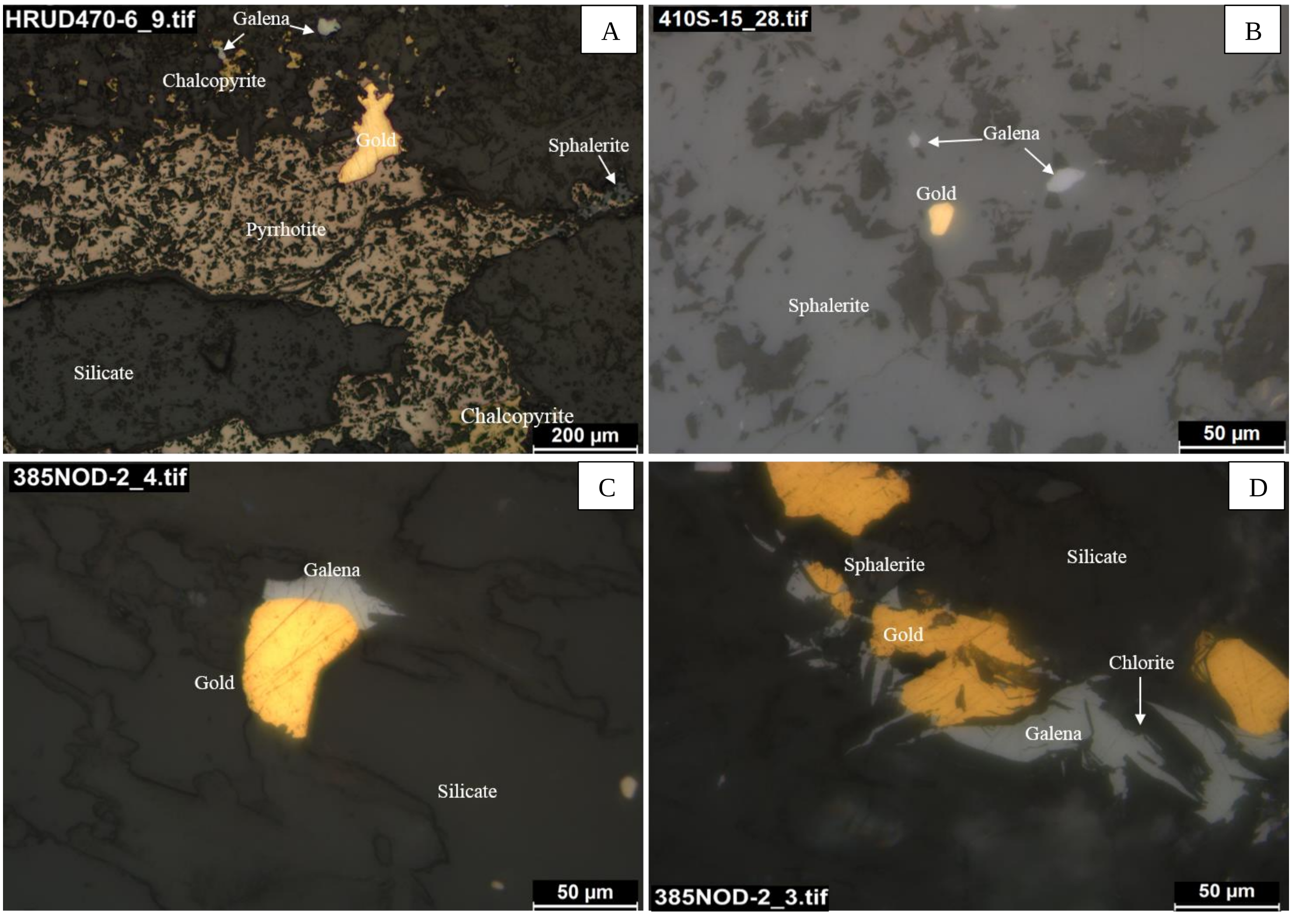

Figure 4. Gold occurrences and its minerals associations within the Hera Au-Pb-Zn-Ag deposit in reflected light photomicrographs. (A) Gold associated with Hera main sulphide assemblage (pyrrhotite, sphalerite, galena and chalcopyrite) (B) Gold as inclusion within Fe-poor sphalerite (C) Gold rimmed by galena within host siltstone (D) Gold rimmed by galena intergrowth with chlorite in host siltstone.

GANGUE MINERALS

The occurrence of skarn-like gangue mineral assemblages (e.g. garnet, tremolite, zoisite, epidote and wollastonite) and scheelite (Table 1) offers a convincing evidence that the original classification for the deposit as a Cobar-type deposit is inconsistent with the presence of these higher temperature phases. Scheelite is more abundant within the deposit than previously thought, primarily due it occurring as pale-coloured small grains. Figure 5 shows the variety of gangue minerals identified within the deposit. Garnet typically occurs away from the mineralisation and within the host siltstone. There are possibly two generations of garnet, coarser-grained massive garnet and fine-grained euhedral-shaped garnet ranging in size from 5-50µm. Some of the garnet has been partially replaced with recrystallised coarse-grained quartz leaving just a remnant garnet shell (Figure 5A). The gangue minerals typically associated with the main mineralisation are tremolite, zoisite, chlorite, calcite, muscovite or biotite (Figure 5B, C & F). Scheelite is typically rimmed by Mg-rich chlorite (Figure 5D). The wollastonite was found within the main lode, is typically fractured and has calcite replacement along the fractures (Figure 5E).

CONCLUSIONS

This detailed study of the ore and gangue mineralogy is important and essential because the identification of new gangue mineral assemblages for the Hera deposit indicate a higher temperature of formation than traditional sediment-hosted Cobar deposits. The assay data for gold shows little correlation with any other metals in the deposit, this is also shown in the thin sections where gold appears to be distributed randomly within the deposit, some associated with the main sulphides and some disseminated within the host siltstone. This suggests possible multiple generations of gold crystallisation within the deposit. The main sulphide mineralisation assemblage consists of pyrrhotite ± sphalerite ± galena ± chalcopyrite ± arsenopyrite ± pyrite ± gold ± Ag-sulfosalt (tetrahedrite) ± native antimony ± gudmundite. Cubanite, dyscrasite? and acanthite are rare in the deposit. Ag-bearing minerals are typically late in the paragenesis and are often found when gudmundite is present. The skarn-like mineral assemblage associated with the mineralisation and within the host rock indicates that the deposit formed at a higher temperature than typical Cobar-type deposits.

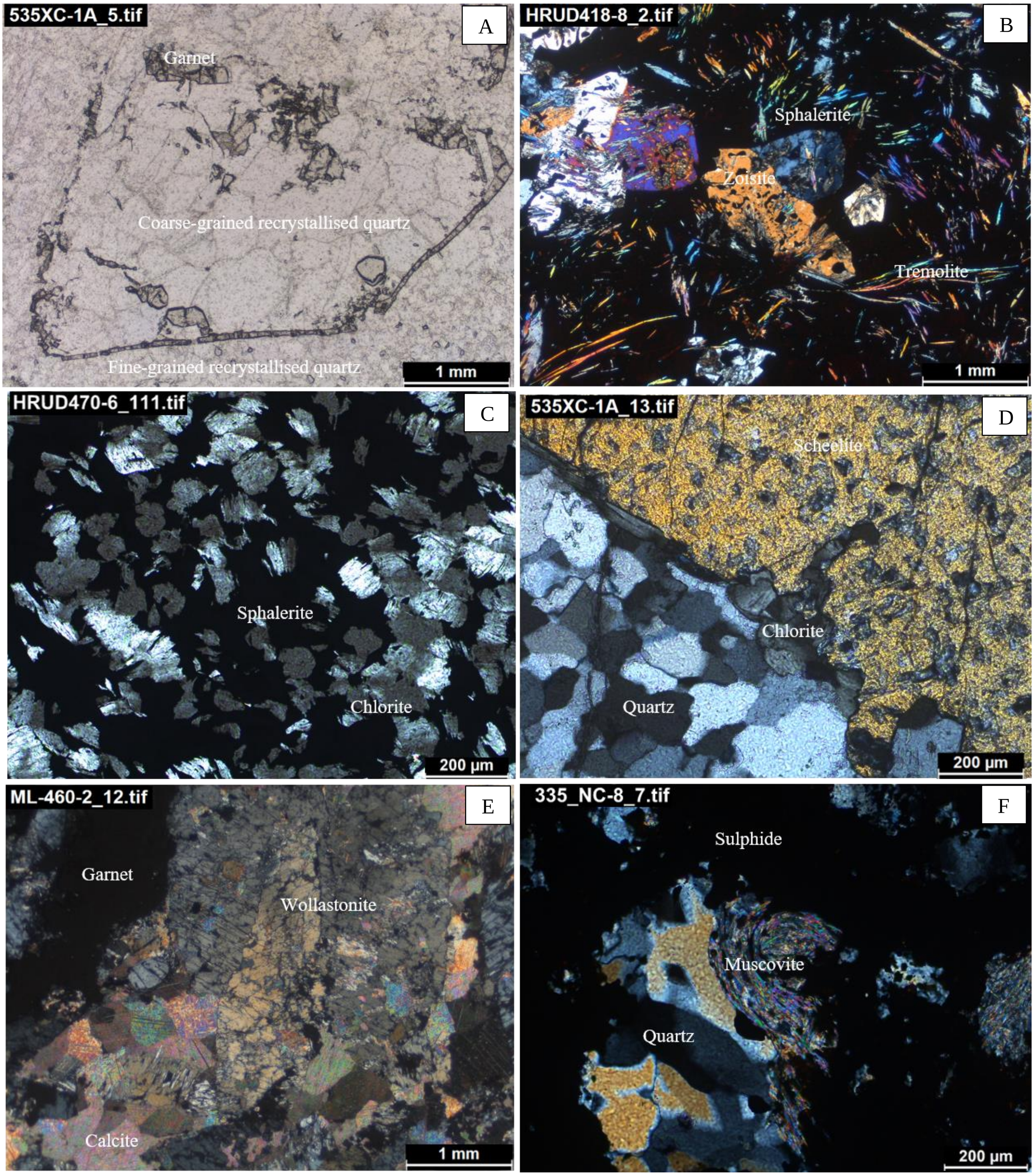

Figure 5. Transmitted light photomicrographs of gangue minerals within the Hera deposit. (A) Coarse-grained recrystallised quartz replacing garnet in the host siltstone (B) Intergrowth of zoisite and acicular tremolite within Fe-poor sphalerite (C) Fe-poor chlorite and sulfide intergrowth (D) Scheelite rimmed by Mg-rich chlorite and quartz (E) Calcite replacing wollastonite (F) Ductile deformation of muscovite associated with sulphides and quartz.

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