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MINERALOGICAL INVESTIGATIONS OF SPECIMENS FROM DIAMOND DRILL HOLES AT THE IRON BLOW MINE, NEAR PINE CREEK, NORTHERN TERRITORY

by

I.R. Pontifex

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SUMMARY

The ore bodies intersected by DDH 1 and 2 have a common hydrothermal origin: the mineral assemblage and the relationships of the component minerals are essentially identical in each.

Iron sulphides are the dominant ore minerals throughout, particularly in the ore-body along the western shear where pyrrhotite constitutes up to 80% of some sections. The minerals of economic interest are sphalerite, chalcopyrite, and galena. Sphalerite makes up an average of 5 to 10% of the ore minerals in the northern lens, but generally less than 5% in the other two ore intersections. Chalcopyrite occurs almost exclusively as exsolution inclusions within sphalerite or associated with it. This mineral occurs in accessory quantity only throughout the suite of specimens. Galena is present in most of the sections, but usually forms less than 5% of the ore minerals in each. No gold or silver minerals were identified in spite of significantly high assay values for these metals in some specimens, and it is suggested that gold and silver may be associated with the sphalerite-galena-lollingite complex observed in several sections.

The interpretation of the associations, textures and structures of the ore indicates that the order of formation of the component minerals corresponds with the generalised succession of minerals in hydrothermal ores, with the exception of the apparent late stage formation of lollingite. Exsolution intergrowths suggest that the temperature of formation of the ore ranged between 450°C and 350°C. There is generally no evidence of post-mineralisation tectonic disturbance of the ore minerals.

INTRODUCTION

This report deals with the mineralogical examination of 15 samples of mineralised diamond drill core from the Iron Blow Mine, Pine Creek, Northern Territory. Four specimens are from DDH 1 between 346 feet and 357 feet, and eleven from DDH 2 between 315 feet and 479 feet. DDH 1 intersects the northern ore-body. DDH 2 intersects the southern lens of the known ore-body and a pyrrhotite body along a western shear.

The samples were submitted by P. Rix on 19.6.63, and this record supplements that by Rix which describes the field geology and drilling of the Iron Blow Mine.

Fifteen polished sections and three thin sections of these specimens were examined; one was analysed by S. Goadby on the X-ray spectrograph. In addition, the semi-quantitative chemical determinations of metals present in three specimens from DDH 2 between 447 feet and 480 feet were carried out (lab. ref.

1153), and were used for the final identification of the minerals in this core.

Spectrographic Analyses

A detailed study of all the polished sections revealed that the section from DDH 2 and 317'4" (regst. no. 15154) contains the greatest variety of minerals, including all of those observed in the other sections. To assist in the identification of these minerals, particularly some which are present only in accessory quantity, minerals from selected areas of this section were isolated and analysed by the X-ray spectrograph. Following are the semi-quantitative values for metals present in specimen 15154.

major abundance	Fe, Pb, Zn, As
moderate abundance	Cu
minor abundance	Ni, Mn, Cd, Sn

The qualitative values given by A.M.D.L. for the spectrographic analysis of three specimens from DDH 2 are :

specimen 145556,	447' to 458'
metals present,	Mn, Fe, Co, Cu, Zn, As, Sb, Cd, Sn, Pb, W.
specimen 145557,	458' to 467'
metals present,	Mn, Fe, Co, Cu, Zn, As, Cd, Sn, Pb, W.
specimen 145558,	467' to 480'
metals present,	Mn, Fe, Cu, Zn, As, Sb, Cd, Pb, W.

Mineralogy

1. Sulphide Bearing Ore. The ore mineral assemblage and the relationships of the minerals within this assemblage are essentially the same in each of the sections. The abundance of specific minerals does vary slightly throughout the core.

Twelve ore minerals were recognised, they are listed below in approximate order of abundance. The positive identification of three of these is doubtful because of their restricted occurrence and fine-scale intergrowth with other minerals.

The ore minerals present are:

pyrite, pyrrhotite, marcasite, sphalerite, arsenopyrite galena, chalcopyrite, ?lollingite, bournonite, ?cubanite, ?stannite.

Pyrite is the most abundant ore mineral in almost every specimen from the northern and southern lens intersection; however, it is absent or occurs only in minor amounts in sections from the pyrrhotite body. Where pyrite is abundant it constitutes up to 70% of the specimen, it may be fine-grained, massive or coarsely crystalline.

Pyrite occurs mostly as crystalline aggregates, generally associated with vein quartz. Drusy cavities within the rock are commonly lined with octahedral pyrite euhedra which have a maximum dimension of 3 mm. Pyrite grains are generally not deformed and are distributed at random, but at 347'6" in DDH 1 pyrite is concentrated in poorly defined macrobands, the grains are slightly fractured, and show a slight elongation parallel to these bands.

In the northern and southern lens, pyrite is commonly partly or wholly replaced by marcasite and rarely by melnicovite; some grains include idiomorphs of arsenopyrite. All other minerals which are associated with pyrite grains surround them and fill cracks and embayments in them. These textural relationships are identical in all sections.

Marcasite occurs in almost every section, and generally makes up between 5% and 20% of the ore minerals. This mineral invariably occurs as a replacement product of pyrite and pyrrhotite and it replaces these minerals around their grain boundaries and along cracks within them. In many places this mineral has a lammelar habit; the lamellae are intimately intergrown with pyrite and pyrrhotite into which they grade imperceptibly. At 446'9" in DDH 2, a specimen from the pyrrhotite ore-body contains elongated grains of pyrrhotite, partly altered to marcasite; these grains are oriented along the crystallographic directions of calc-silicates. In many sections the spaces between marcasite lamellae are partly filled by sphalerite, chalcopyrite, galena, and lollingite.

Pyrrhotite occurs as a minor constituent in the southern lens, is moderately abundant in the northern lens, and is the dominant mineral in the pyrrhotite body. Some sections from the pyrrhotite body contain up to 80% pyrrhotite which generally forms irregular masses containing abundant voids which have facilitated the access of later ore minerals. In other sections pyrrhotite containing inclusions of pyrite and arsenopyrite fills embayments, and forms veins in these minerals. It is also present as discrete grains in the gangue and sulphide matrix.

Sphalerite is sporadically distributed through each ore-body intersection. In the northern lens it makes up an average of about 10% of the ore minerals in each section. In the southern lens and the pyrrhotite body sphalerite is present only in accessory amounts with the exception of the section from 317'4" (southern lens) and 466' (pyrrhotite body) where sphalerite makes up respectively 20% and 30% of the ore minerals.

The mode of occurrence of sphalerite is the same in each specimen; irregular masses have a maximum dimension of 10 mm. across, and these may occur independently or form an integral part of the mineral complex.

Invariably sphalerite contains exsolution blebs and rod shaped bodies of chalcopyrite which are rarely larger than 0.05 mm. They are either randomly disseminated which gives an uneven mottled texture, or are oriented along the morphological directions in the host. Commonly chalcopyrite has migrated to, and concentrated around the periphery of the sphalerite grains.

At 353'6" in DDH 1 the segregation of chalcopyrite and sphalerite is more extreme; this has produced an allotriomorphic aggregate of these two minerals in which masses of chalcopyrite up to 10 mm. long and 3 mm. wide are interfingered with sphalerite and "intrude" the mineral along morphological directions. In some sections chalcopyrite has developed independent grains up to 0.15 mm. across, and these are usually associated with sphalerite.

Sphalerite contains rare inclusions of cubanite, enargite, and ?stannite. These have apparently been formed by exsolution, and they were observed in each of the ore-bodies intersected by the drill holes.

Arsenopyrite was observed in most sections; it generally makes up 5 to 10% of the ore minerals, but at 462'6" in DDH 2 it constitutes 80%. This mineral occurs as idiomorphic crystals ranging from 0.5 mm. to 4 mm. in maximum dimension. These crystals show well defined outlines against adjacent allotriomorphic Fe, Zn, Cu and Pb sulphides which often partly or completely enclose the arsenopyrite. Some arsenopyrite grains are slightly fractured and the above mentioned sulphides cement the resultant fragments.

Galena is present in most of the sections generally forming less then 3% of the ore minerals in each although in sections from the pyrrhotite body it may represent up to 5%. This mineral occurs in extremely irregular masses and veins usually filling intersticies, cracks and embayments of most of the other ore minerals, it often encrusts discrete pyrrhotite and sphalerite grains.

In many sections, particularly in those from the pyrrhotite body, galena shows a close spatial relationship to sphalerite. In several sections, notably at 317'4" in DDH 2, lollingite is intimately, almost exclusively associated with galena.

Lollingite In most of the specimens from the northern and southern ore bodies and less commonly in the pyrrhotite body, accessory amounts of a white highly reflective and strongly anisotropic mineral occur in fine-grained massive aggregates of interlocking grains. The individual crystals measure about 0.03 mms. in maximum dimension, they are idiomorphic, often tabular, lath and rhomb-shaped and associated with pitted gangue. The anisotropic colours are clear slate-blue, grey, blue-green and orange-brown.

These aggregates are localised in interstices of other minerals. At 357'11" DDH1, the aggregates are spatially related to sphalerite and at 317'4" DDH 2, they are almost exclusively associated with galena.

The restricted occurrence of this mineral makes its positive identification difficult.

An analysis of parts of the section from 317'4" DDH 2, in which this mineral is concentrated showed a relatively high content of As, Pb, Fe and Zn. Accessory amounts of Ni, Mn, Cd and Sn. Co and Sb were also detected by spectrographic analysis in specimens from the pyrrhotite body. The Pb and Zn are probably derived respectively from galena and sphalerite. The remaining metals, and the optical properties of this mineral suggests that it is a member of the arsenopyrite solid solution series which contains Ni, Co and Sb, these are:

arsenopyrite, lollingite, gudmundite, rammelsbergite.

This mineral was formed at a late stage in the paragenesis and considering its mineral associations, particularly galena, it could be gudmundite. However the lack of Sb in the section from 317'4" rules out this possibility.

The mode of occurrence of this mineral and its association with a calcareous gangue and with iron and copper sulphides suggests that it is lollingite.

?Cubanite occurs in minor accessory abundance in the sections from 357'11", DDH 1 and 317'4", DDH 2. Inclusions of this mineral are oriented along crystallographic directions of sphalerite in the vicinity of chalcopyrite exsolution bodies. The positive identification of this mineral was not made, its optical properties and associations, however, suggest that it is cubanite, exsolved from the sphalerite-chalcopyrite solid solution.

Bournonite. In sections from 357'11", DDH 1 and 317'4", DDH 2, accessory irregular grains of a blue-grey mineral measuring up to 0.03 mm. form veins in sphalerite, adjacent to galena and lollingite. These grains have a distinctive anisotropism and some contain needle like inclusions of chalcopyrite. This mineral is considered to be bournonite.

?Stannite. In the section from 317'4", DDH 2 several small inclusions of a brownish olive-green mineral with strong anisotropism occur in sphalerite within a chalcopyrite, galena, lollingite complex. Although a positive identification was not made, the optical properties, mineral association and the presence of Sn suggests that it is stannite.

Gold and silver assays of the order of 3.5 dwts/ton Au and 25 ozs/ton Ag were recorded by Rix in samples from 316'10", 317'4", 317'9" and 319'4" in DDH 2. No gold or silver minerals were identified in these sections and the spectrographic analysis of the section from 317'4" failed to detect the presence of Au or Ag above back ground. It is possible, however, that these elements are contained in the galena, lollingite, sphalerite complex. This is suggested on the basis that various authorities record a common association of minor amounts of Au and Ag with galena and lollingite and that sphalerite may be replaced by electrum and Ag sulpho-salts. In these specimens the maximum concentration of rare inclusions occur in sphalerite and galena.

2. Gangue In the northern lens (DDH 1) the gangue is essentially a grey crystalline carbonate rock which contains mainly dolomite and calcite. At 353'6" siderite is associated with the sulphides. Several dark-grey slate fragments in the carbonate matrix at 347'6", DDH 1 may be remnants of country rock.

In the southern lens (DDH 2) the gangue is also mainly calcareous but at 319'4" the ore minerals intrude a grey-green phyllitic rock.

Thin sections were examined only from the pyrrhotite body. At 446'9" a mineralised calc-silicate rock consists of a chlorite, talc, serpentine rich ground mass which contains subordinate amounts of tremolite and accessory epidote. The components generally have a random orientation suggesting that they did not form under the influence of shearing stress. The ore minerals are intimately related to the calc-silicates and some are localised along their crystallographic directions.

At 453'3", DDH 2, the rock is a medium grained crystalline limestone containing disseminated talc, and skeletal grains of pyrrhotite and chalcopyrite.

At 479'4", DDH 2, an allotriomorphic granular aggregate of calcite contains grains and aggregates of pyrite and sphalerite, both are associated with talc. Pyrite is also accompanied by minor chlorite and tremolite. Minor amounts of medium grained allotriomorphic quartz are associated with the ore minerals in each section.

Although no specific manganese minerals were identified, this element is present in all the sections analysed spectrographically. Since manganiferous carbonates are common in carbonate gangue minerals it may be postulated that this is the origin of the manganese.

Ore Genesis

The associations, textures and structures of the ore minerals indicate that each ore body has a common hydrothermal origin and that the order of formation of the component minerals corresponds with the generalised succession of minerals in hydrothermal ores. The order of formation of the ore minerals is listed below,

arsenopyrite	(earliest)
pyrrhotite	
pyrite	
marcasite	)
sphalerite	)
chalcopyrite	) formed simultaneously
?cubanite	)
?stannite	)
galena	)
bournonite	) probably formed simultaneously
lollingite	)

The textures and mineral associations also provide information related to the genesis of this ore.

The intimate association of marcasite with pyrite and pyrrhotite and the fact that it is replaced by later formed primary minerals indicates that it is hypogene marcasite which formed simultaneously or immediately after these two minerals. Following Edwards, it is suggested that a change in acidity and temperature of the residual mineralisers rendered the pyrrhotite unstable, this dissolved and repricipitated as marcasite. Edwards points out that this change generally coincides with the appearance of hypogene carbonates which are the dominant gangue minerals in these rocks.

Marcasite inverts to pyrite above 450°C and so the deposition of marcasite presumably took place at temperatures less than 450°C.

The exsolution bodies of chalcopyrite in sphalerite indicates that the original metasome contained a solid solution of Cu and Zn sulphides, during cooling this solution unmixed. According to Edwards sphalerite and chalcopyrite are capable of solid solution at temperatures above 350°C to 400°C and that solutions of chalcopyrite in sphalerite unmixed about these temperatures.

The frequent segregation of chalcopyrite to grain boundaries of sphalerite and rarely the almost complete segregation of these two minerals indicates that un-mixing occurred at about the maximum temperatures which allows unmixing, and that cooling was slow. Therefore the temperature of ore formation at the sphalerite - chalcopyrite crystallising stage approximated 400°C. Galena was one of the last minerals to form. In many sections galena and ?lollingite are closely related and both minerals were possibly deposited at approximately the same time. The deposition of lollingite at such a late stage is contradictory to the idealised sequence of deposition of hydrothermal minerals. This event may represent a reorganisation of the mineral assemblage "in situ" which took place after the emplacement of the ore bodies or it may represent a separate late phase of mineralisation.

The relationship of the calcareous and calc-silicate gangue to ore mineralisation may be interpreted in two different ways.

1. The ore minerals were introduced into a calcareous country rock. This rock was recrystallised and calc-silicates were developed by metasomatism caused by the ore fluids.

2. The carbonate gangue was introduced with the ore minerals.

The country rock in drill cores consists chiefly of phyllitic slate with interbeds of greywacke and quartz greywacke. Dunn records that carbonate rocks occur only in minor abundance in the mine area. It is apparent therefore that the carbonate gangue was introduced during the emplacement of the ore.

The general lack of evidence of shearing stress or any post-mineralisation deformation in the ore indicates that the shears recorded by Rix along which the ore is localised, were produced pre-mineralisation and that the ore minerals and carbonate gangue replaced these zones.

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APPENDIX

Descriptions of polished sections and thin sections.

Drill Hole	Depth	Field No.	Registered No.	
	346'7"	145506	15148	P.S.
D.D.H. 1	347'6"	145507	15149	P.S.
(Northern lens-	353'6"	145508	15150	P.S.
main lode)	357'11"	145509	15151	P.S.
	315'10"	145510	15152	P.S.
D.D.H. 2	316'10"	145511	15153	P.S.
(Southern lens-	317'4"	145512	15154	P.S.
main lode)	317'9"	145513	15155	P.S.
	319'4"	145514	15156	P.S.
	446'9"	145515	15157	P.S. and T.S.
D.D.H. 2	453'3"	145516	15158	P.S. and T.S.
	459'5"	145517	15159	P.S.
(Western lode)	462'6"	145518	15160	P.S.
	466'0"	145519	15161	P.S.
	479'4"	145520	15162	P.S. and T.S.

D.D.H. 1 Intersection of Northern Lens

Regst. No. 15148

Field No. 145506 Depth 346'7"

Ore minerals:

Major pyrite. Minor pyrrhotite, marcasite, arsenopyrite, sphalerite, chalcopyrite, galena, ?lollingite.

Macro:

Massive and crystalline pyrite are dispersed through a carbonate gangue and make up about 60% of the specimen. Numerous drusy cavities contain octahedral pyrite and idiomorphic rhombs of calcite and dolomite. In a section perpendicular to the core axis granular pyrite is concentrated in poorly defined bands. Generally there is no discernible structure in the rock.

Micro:

Pyrite euhedra form irregular aggregates, they are also dispersed individually through the carbonate gangue. The size of these euhedra varies up to a maximum diameter of 1 mm. Some grains are fractured, some are partly replaced by marcasite, usually around grain boundaries. Discrete marcasite grains in the gangue make up less than 5% of the ore minerals.

Idiomorphic, irregular grains of arsenopyrite range in size up to 0.08 mms. The relatively large crystals where they occasionally make contact with other ore minerals show their own well defined crystal outline against allotriomorphic grains of these minerals. Accessory amounts of a white, strongly anisotropic mineral occur in fine-grained loose, crystal aggregates, usually associated with a pitted gangue which fills interstices of the pyrite aggregate. The mineral has identical optical properties to arsenopyrite. Some of the crystals are needle shaped. The mode of occurrence of this mineral in this section and in other sections from this D.D.H. indicates that it has different genetic relationships than the coarse arsenopyrite. These observations suggest that it is either a second generation of arsenopyrite or alternatively, on the basis of spectrographic analyses it is possibly lollingite.

Pyrrhotite occurs only in small grains either independently or associated with pyrite. Sphalerite encloses some pyrrhotite grains. Galena encrusts part of some pyrrhotite grain boundaries and transgresses them by filling cracks.

Sphalerite comprises about 5% of the ore minerals and is dispersed generally as discrete anhedra which vary in size up to 0.3 mms. across. Exsolution inclusion of chalcopyrite in the sphalerite have an irregular shape or occur as elongate blebs, needles and blades. The blebs have a maximum size of about 0.01 mm. across and some needles are 0.03 mm. long. These bodies may be oriented at random but in places they are distributed along one or more sets of crystallographic axes of the sphalerite host. Sphalerite also contains inclusions of remnant grains of earlier formed arsenopyrite, pyrrhotite and pyrite.

Regst. No. 15149.

Field No. 145507 Depth 347'6"

Ore minerals:

Major pyrite. Minor sphalerite, chalcopyrite, pyrrhotite, marcasite, ?lollingite.

Macro:

Finely crystalline and massive pyrite with minor arsenopyrite are dispersed through a crystalline carbonate gangue. Pyrite constitutes 50% of the rock. Walls of abundant small cavities are crowded with dolomite and idiomorphic pyrite commonly exhibiting an octohedral form. Fractures are marked by a concentration of finely crystalline carbonates. Several dark grey slate fragments in the matrix appear to be remnants of the original country rock which has been largely replaced by introduced sulphides.

Micro:

Pyrite is the major ore mineral. It occurs as idiomorphic grains, both as individuals and in granular aggregates. The crystal size ranges up to 0.5 mms. across. Generally there is no evidence of deformation but a few pyrite grains are slightly fractured. Where pyrite grains concentrate into indistinct macro bands, some show slight elongation parallel to these bands.

Sphalerite (5% of the section) is dispersed as discrete anhedra measuring up to 0.03 mms. but several grains in the hand specimen are 1 x 2 mms.

Chalcopyrite bleb and rod shaped exsolution inclusions in the sphalerite are usually distributed at random although some are oriented along crystallographic directions. Sphalerite enters pyrite aggregate along intergranular voids and fractures. In small sphalerite grains exsolved chalcopyrite may be the dominant mineral of the two.

Regst. No. 15150

Field No. 145508 Depth 353'6"

Ore minerals:

Major pyrrhotite. Minor pyrite, chalcopyrite, sphalerite, arsenopyrite, marcasite, galena, ?lollingite.

Macro:

Fine-grained and massive sulphides constitute about 80% of the rock. The only recognisable gangue mineral is siderite and this is intimately intergrown with sulphide minerals. Pyrrhotite makes up 70% of the ore minerals, pyrite 10%, sphalerite 10%, chalcopyrite 5%.

Micro:

Pyrrhotite occurs in irregular masses which have abundant voids. These voids facilitate the access deposition of later ore minerals. Along the pyrrhotite-siderite contact, pyrrhotite blades up to 1.5 mm. long are oriented along rhombohedral crystal axes of the carbonate.

Pyrite occurs as idiomorphic grains up to 0.8 mms. across and in gravel or aggregates. This mineral is generally distributed at random however a 'front' of pyrite grains borders part of the siderite ore contact. In several pyrite

grains massive pyrite merges into narrow peripheral zones of finely granular pyrite which have a corroded texture. Adjacent ore minerals have well defined boundaries. This type of pyrite is probably a replacement product of pre-existing massive pyrite. At some pyrite-pyrrhotite contacts the pyrrhotite permeates the granular pyrite to a limited extent. Pyrite contains abundant inclusions of idiomorphic arsenopyrite. Other ore minerals enter cracks in pyrite.

Sphalerite is localised as irregular masses in voids between pyrrhotite and pyrite. These masses have a generalised parallel orientation. Almost all the grains contain fine exsolution bodies of chalcopyrite. In addition to exsolution bodies chalcopyrite occurs in irregular, elongate, parallel masses up to 10 mms. long and 3 mms. wide. It is usually associated with minor amounts of sphalerite, both minerals have mutually interfingering boundaries and often chalcopyrite 'intrudes' sphalerite along crystallographic axes. In some grains, exsolved chalcopyrite has migrated to sphalerite grain boundaries to produce a corona.

Arsenopyrite as discrete, relatively large idiomorphic rhomb shaped crystals occur as inclusions in pyrrhotite pyrite and sphalerite. These crystals exhibit well defined crystal outlines against adjacent surrounding minerals. They are often moderately cracked and the host mineral cements the grain fragments. These relationships indicate that arsenopyrite is pre the iron and zinc sulphides.

Accessory amounts of fine grained, idiomorphic; often needle shaped crystals of analagous optical properties to arsenopyrite are contained in a fine-grained gangue. This gangue is slightly different from that of the other sulphides and it enters voids in the iron sulphides and sphalerites. The mineral is probably lollingite and is post iron sulphides and sphalerite.

Galena, in accessory amounts occurs in the intergranular voids, embayments and cracks in all the other minerals present.

Irregular lamellae of marcasite are intergrown with pyrrhotite. Often marcasite partially replaces grain boundaries of pyrrhotite, particularly where blades of this mineral penetrate the calcareous gangue.

Regst. No. 15151

Field No. 145509 Depth 357'11"

Ore Minerals:

Major pyrite, sphalerite, arsenopyrite.
Minor marcasite, galena, chalcopyrite, pyrrhotite, ?cubanite, lollingite, ?bournonite.

Macro:

Heterogeneous aggregate of fine grained ore minerals containing cellular cavities which contain octahedral pyrite. Gangue minerals make up $<10\%$ of the specimen. Narrow post ore veins contain crystalline carbonates.

Micro:

Pyrite (25%) occurs as randomly dispersed idiomorphs up to 1.5 mms. across. These often form crystal aggregates. The peripheries of several pyrite grains are surrounded by distinctive but generally irregular zones of finely granular corroded looking pyrite. In some cases distinctive straight margins bound the granular aggregates of this variety of pyrite and rarely sphalerite and galena mould the boundaries of it.

This phenomenon suggests that the granular pyrite is a pseudomorph after the euhedral pyrite and is essentially a second generation of pyrite. The alteration was pre sphalerite and galena, probably contemporaneous with the formation of original pyrite.

Minor amounts of lamella marcasite are intergrown with pyrite. Sphalerite occassionally migrates between these lamellae. Marcasite also partially replaces pyrite along grain boundaries and occurs as small discrete grains.

Sphalerite (15%) of the minerals is dispersed at random as highly irregular pitted masses up to 4 mms. across. This mineral commonly contains small exsolution blebs of chalcopyrite and rarely of a pink-brown mineral which exhibits optical properties analagous to those of cubanite and enargite. Chalcopyrite has often migrated to the sphalerite grain boundaries and has segregated to become the major mineral of the two. Sphalerite is often concentrated along fractures in pyrite and may enclose earlier formed pyrite cubes, corroding the latter.

Arsenopyrite (15%) usually occurs as idiomorphic crystals measuring up to 0.4 mms. across, as discrete and in crystal aggregates. Often arsenopyrite is enclosed by other ore minerals particularly sphalerite.

Fine-grained, loosely packed aggregates of idiomorphic crystals, some needle shaped, have similar optical properties to arsenopyrite. These crystals are concentrated in a fine-grained gangue localised in the intergranular spaces of iron sulphides and shows a particular spatial association with sphalerite - chalcopyrite. On the basis of the mode of occurrence of this mineral and the presence of trace amounts of Co and Ni in these specimens it is considered to be lollingite.

Galena in irregular masses up to 0.5 mms. across is generally localised in intergranular spaces of iron sulphides and sphalerite, and fills voids and embayments in these minerals. It occassionally contains inclusions of idiomorphic arsenopyrite and allotriomorphic pyrite, chalcopyrite and sphalerite. The irregular habit of galena indicates that it has a greater migratory capacity than the other minerals. Accessory amounts of pyrrhotite are present as discrete grains.

Accessory amounts of a grey-white-bluish strongly anisotropic mineral is associated with sphalerite, galena, lollingite complex and it rarely contains needle like inclusions of chalcopyrite. Positive identification of this mineral could not be made however on the basis of its optical properties and mineral associations it is considered to be bournonite.

D.D.H. 2 Intersection of Southern lens of known ore body.

Regst. No. 15152

Field No. 145510 Depth 315'10"

Ore minerals identified. Major pyrite. Minor sphalerite, chalcopyrite.

Macro:

Fine-grained, massive and crystalline pyrite is associated with vein quartz. Drewsy cavities in the pyrite contain abundant octahedral crystals of pyrite. Dark grey, irregular corroded inclusions in the quartz are probably altered fragments of original hornfels - shale country rock.

Micro:

Pyrite makes up 60% of the section and occurs as idiomorphic grains and crystal aggregates. The pyrite shows no evidence of deformation.

Sphalerite. One isolated corroded grain 1.5 mm. across is present in the quartz gangue and it contains several small exsolution blebs of chalcopyrite. The non-opaque fine-grained gangue filling voids within the pyrite aggregates carry poorly defined sphalerite grains rarely larger than 0.02 mms. across.

Regst. No. 15153.

Field No. 145511 Depth 316'10".

Ore minerals identified. Minor pyrite, galena, arsenopyrite

Macro:

Massive, coarsely crystalline vein quartz carries pyrite and galena in dendritic type veins. Generally the minerals occur alone in any one vein but they may also be spatially related. Each mineral makes up 5% of the specimen.

Micro:

Pyrite is present in isolated masses up to 3 mm. across, associated with quartz.

Galena and accessory grains of arsenopyrite are localised along irregular vein like voids within the coarsely crystalline quartz.

Since the ore minerals in this section occur independently their genetic relationships could not be established.

Regst. No. 15154.

Field No. 145512 Depth 317'4"

Ore minerals:

Major sphalerite, marcasite, pyrite. Minor arsenopyrite, galena, chalcopyrite, pyrrhotite, cubanite, bournonite, ?stannite, ?lollingite.

Macro:

Dull grey, fine-grained heterogeneous ore. Obvious minerals present are pyrite, arsenopyrite and galena. A generalised banding of the ore minerals is evident on the polished surface. The gangue is a dark grey, tough fine-grained rock and this makes up 50% of the specimen.

Micro:

The entire section consists of a fine-grained heterogeneous complex of various ore minerals.

Pyrite, 10% of the section is present as independent idiomorphic grains and crystal aggregates up to 3 mms. in maximum dimension. Whole or part of the pyrite grains are commonly replaced or surrounded by other ore minerals.

Marcasite replaces pyrite. Marcasite, about 15% of the section generally has a lamellar habit and the lamellae contain inclusions of pyrite. Marcasite also occurs as irregular patches through pyrite. Individual lamellae vary from 0.005 mms. to 0.02 mms. across and up to 1.5 mms. long, they are usually parallel and grouped into aggregates of various sizes. Crystal aggregates of pyrite grade imperceptibly into lamellae of marcasite. Marcasite grains are part enclosed by sphalerite and this mineral and chalcopyrite migrate between marcasite lamellae in some places.

Sphalerite is the most abundant ore mineral and makes up about 20% of the section. It occurs in extremely irregular masses which contain abundant voids. Sphalerite commonly contains exsolution blebs of chalcopyrite which are generally oriented along the crystallographic directions of the host. The blebs are rarely longer than 0.02 mms. across, in some places chalco;yrite has developed independent grains, up to 0.15 mms. across and these are usually associated with sphalerite.

Sphalerite also contains inclusions of cubanite, bournonite and ?stannite, all present in minor accessory amounts. Cubanite occurs as small exsolution blebs oriented along the crystallographic axes of the host. Irregular grains of a grey-blue mineral, measuring up to 0.03 mms. across are associated with sphalerite, generally adjacent to galena and lollingite.masses. This mineral has a distinct anisotropism and on the basis of its optical properties and apparent association with galena it is considered to be bournonite . Several irregular inclusions of a brownish olive green mineral having a strong anisotropism occur in sphalerite in the areas showing a complex intergrowth of numerous ore minerals particularly chalcopyrite galena, marcasite and lollingite. Although the positive identification of this mineral was not made, the optical properties, the association with sphalerite and the detection of tin in several spectrographic analyses of sections of this core suggests that it is stannite.

Accessory amounts of idiomorphic arsenopyrite grains occur through the mineral complex and these are generally partly enclosed by other ore minerals.

?Lollingite occurs as fine idiomorphic crystals, often needle shaped, and these are generally concentrated in micro crystalline aggregates. The aggregates are associated with a fine-grained gangue which fills intergranular spaces between the iron sulphides and sphalerite. The concentrations of this mineral are generally restricted to areas containing a high proportion of galena and sphalerite. In some places lollingite has an almost exclusive association with galena.

Galena occurs in irregular masses up to 2 mms. across which fill voids in sphalerite and the iron sulphides. Galena veins enter chalcopyrite, pyrite and sphalerite and fill between marcasite lamellae. Galena completely encrusts pyrrhotite and some lollingite grains which occur independently in the gangue.

Regst. No. 15155

Field No. 145513 Depth 317'9"

Ore minerals identified. Major pyrite, minor sphalerite, chalcopyrite, marcasite, ?lollingite.

Macro:

Ore minerals make up about 20% of the specimen and they are localised in irregular, poorly defined bands which have a generalised common orientation. The main mineral is pyrite, it is fine-grained and dispersed through a fine-grained dark-grey gangue. The gangue contains white calcareous grains.

Micro:

Pyrite, as independent idiomorphic crystals form irregular loosely packed granular aggregates. Indistinct, pale yellow-grey streaks in some grains of pyrite show a variety of strength of anisotropism. Some develop into distinct zones of marcasite which replaces pyrite. The pale streaks are probably due to intergrown marcasite and possibly to internal tensions caused by some Fe S surplus or As ad-mixture.

Sphalerite anhedra are dispersed in accessory amounts through the gangue, generally between the intergranular spaces of the pyrite. The grains measure up to 0.05 mms. across and commonly they contain small exsolution blebs of chalcopyrite. Occassionally chalcopyrite has migrated to the periphery of sphalerite grains and it may segregate to form individual grains.

Small white idiomorphic often needle shaped crystals, rarely larger than 0.03 mms. across occur in loose crystal aggregates which are dispersed in accessory amounts through the gangue, generally filling intergranular voids of pyrite. On the basis of its associations, optical properties and the spectrographic analyses of the identical mineral concentrations in section 15154 this mineral is considered to be lollingite.

The gangue is a coarsely crystalline carbonate. Ore minerals rarely form elongate blebs along the crystallographic axes of the carbonate minerals. Quartz is associated with pyrite and sphalerite.

Regst. No. 15156.

Field No. 145514 319'4"

Ore minerals identified. Major pyrite. Minor marcasite, sphalerite, chalcopyrite, galena.

Macro:

A well defined band of iron sulphide, ½" wide is associated with epigenetic coarsely crystalline quartz. These minerals intrude a grey-green fine-grained calcareous phyllitic rock which contains dispersed fine grains of lead-grey ore mineral. Drewsy cavities in the quartz are lined with crystalline pyrite of the octahedral and pyritohedron form. An isolated grain of galena is included in the quartz.

Micro:

Pyrite (60% of the section) is associated with quartz and occurs in a massive, coarsely crystalline form and in a finely granular form. Granular pyrite consists of idiomorphic grains each about 0.2 mms. across. Finely granular pyrite has the appearance of melnicovite-pyrite, a cryptocrystalline variety and this grades imperceptibly into anhedral coarsely crystalline pyrite. Both varieties show a weak anomalous anisotropism, particularly the granular type, and this suggests possible admixtures with As. Some grains are altered to marcasite.

Sphalerite occurs in accessory amounts and this is localised in interstices of the pyrite aggregate. Generally sphalerite contains exsolution blebs of chalcopyrite,

Galena is present in accessory abundance and this fills interstices in pyrite and also in sphalerite.

D.D.H. 2 Intersection of pyrrhotite body along western shear

Regst. No. 15157. Thin section No. 10934.

Field No. 145515 Depth 446'9"

Rock Type. Mineralised calc-silicate.

Ore minerals identified. Minor pyrrhotite, marcasite, sphalerite, chalcopyrite.

Macro:

Well indurated grey chloritic slate ramified in part by grey green fibrous ?amphibole. Small ore mineral grains are surrounded by a corona of black material which is also localised along fractures in the rock. This is probably a secondary iron oxide produced by the alteration of the sulphides.

Micro:

This rock has a chloritic, talcose, serpentine rich ground mass containing laths and grains of various calc silicate and Mg-rich minerals including penninite, serpentine, tremolite, talc and epidote. Generally the minerals show no common orientation. Fine flakes of talc or sericite commonly show a ghost like rhombohedral lattice texture in some patches, suggesting that they replace pre-existing calcite.

Serpentine, chlorite and talc are the most abundant minerals.

Fine-grained serpentine is common in the ground mass. Coarse serpentine is concentrated in irregular patches suggesting that it completely replaces a pre existing mineral. This serpentine is often associated with opaques.

Chlorite is common in the ground mass and the Mg-rich variety penninite occurs in moderate abundance.

Talc or possibly sericite throughout the groundmass and often in discrete aggregates occurs in colourless fibres and laths usually < 0.03 mms. long. Considering the Ca and Mg rich mineral assemblage in the rock this mineral is probably talc.

Tremolite, present in subordinate amounts as long fibrous and blade like prisms. It is commonly replaced by talc and chlorite.

Epidote euhedra are in accessory abundance, they are corroded and part replaced by chlorite.

Epigenetic quartz intrudes the rock and occassionally it follows the crystal directions of the calc silicates. Some thin barren lamellae of epigenetic quartz show a common parallel orientation suggesting that its localisation is controlled by shear or cleavage planes.

In the polished section marcasite and pyrrhotite are the most common ore minerals. These minerals often occur as elongate grains which are oriented along the crystallographic directions of some calc silicates. They also occur as discreet anhedral grains at random orientation compared to adjacent gangue minerals.

Sphalerite is localised in some interstices of the crystalline gangue. Some sphalerite contains exsolution blebs of chalcopyrite but this is not as common as in previously examined sections. Chalcopyrite grains are present in the epigenetic quartz and through the gangue.

No pyrite is present.

Regst. No. 15158 Thin section No. 10936.

Field No. 145516 Depth 453'3".

Rock Type. Mineralised, talcose-marble.

Ore Minerals. Minor pyrrhotite, chalcopyrite.

Macro:

Grey, medium-grained crystalline limestone (65%) containing disseminated fine-grained talc (15%) and pyrrhotite.

Micro:

About 50% of the rock consists of an allotriomorphic granular aggregate of calcite essentially a metamorphic texture. Clear laths of flaky mineral optically negative and having a high birefringence are dispersed through the marble and they often replace calcite grains. This mineral shows particular association with ore minerals with which it is intimately intergrown. Considering the macro identification, this mineral is probably talc. Talc also accumulates in fibrous aggregates which are clouded with opaque impurities and clays. Ore minerals ramify the calcite matrix. Quartz is present in accessory amounts, it is stressed and not necessarily associated with sulphides.

In the polished section, discreet irregular masses of pyrrhotite measuring up to 0.1 mms. across are often associated with lesser amounts of chalcopyrite. Chalcopyrite also occurs as independent grains. No pyrite or sphalerite is present in this section.

Regst. No. 15159.

Field No. 145517. Depth 459'5".

Ore minerals identified. Major pyrrhotite. Minor chalcopyrite, sphalerite, arsenopyrite, galena.

Macro:

Massive sulphide, 80% pyrrhotite, 10% chalcopyrite. Chalcopyrite is dispersed at random through the pyrrhotite.

Micro:

Massive pyrrhotite is moderately fractured and cracks and voids have provided access for later ore minerals.

Allotriomorphic grains of chalcopyrite up to 20 mms. in maximum dimension are dispersed at random as discreet grains, localised within pyrrhotite interstices. Commonly chalcopyrite part surrounds sphalerite grains, it intrudes sphalerite and pyrrhotite as irregular veins filling peripheral embayments and it encloses remnant grains of and fills fractures in arsenopyrite.

Sphalerite (5% of the section) occurs as allotriomorphic masses between pyrrhotite. Almost invariably sphalerite contains abundant irregularly shaped exsolution inclusions of chalcopyrite, some of which are concentrated along the crystallographic axes of the host.

Arsenopyrite grains measure up to 0.5 mms. across, some are idiomorphic and often they are fractured. Chalcopyrite, sphalerite and pyrrhotite commonly enclose the arsenopyrite and cement brecciated fragments.

Minor accessory amounts of galena are associated with the sphalerite and also occur in voids of pyrrhotite.

Regst. No. 15160.

Field No. 145518. Depth 462'6".

Ore minerals identified. Major arsenopyrite. Minor pyrrhotite, sphalerite, chalcopyrite, galena.

Macro:

Crystalline arsenopyrite makes up about 40% of the specimen and about 80% of the ore minerals. This mineral, together with minor amounts of related pyrrhotite and chalcopyrite are contained within a crystalline carbonate gangue.

Micro:

Arsenopyrite as idiomorphic crystals up to 4 mms. across occur singly and in coarsely crystalline aggregates. The grains are slightly brecciated.

The arsenopyrite often shows its own well defined crystal outline against adjacent pyrrhotite, and chalcopyrite and this suggests that arsenopyrite is the older mineral.

Pyrrhotite occurs as irregular allotriomorphic masses as discrete grains or filling arsenopyrite interstices. The grains are often brecciated and contain abundant voids.

Several allotriomorphic masses of chalcopyrite occur at random within the carbonate gangue. Some include grains of sphalerite and pyrrhotite.

Sphalerite containing exsolution blebs of chalcopyrite is often localised between arsenopyrite grains and filling cracks in this mineral. Allotriomorphic sphalerite and chalcopyrite are intimately intergrown.

One grain of galena 0.10 mms. across is associated with sphalerite and it has migrated along part of a sphalerite-arsenopyrite contact. Galena in accessory amounts partly fills voids in arsenopyrite, pyrrhotite and sphalerite.

Regst. No. 15161

Field No. 145519. Depth 466'0"

Ore minerals identified. Major sphalerite, pyrrhotite, arsenopyrite. Minor pyrite, chalcopyrite, galena, marcasite.

Macro:

Massive sulphide ore consisting of a fine-grained aggregate of crystalline arsenopyrite, pyrrhotite and minor amounts of chalcopyrite and sphalerite. This aggregate contains several pyrite idiomorphs up to 5 mm. across. Sphalerite is concentrated in a poorly defined band.

Micro:

Arsenopyrite makes up 10% of the section and is dispersed at random as idiomorphic grains up to 1.5 mms. in maximum dimension. Generally the grains exhibit well defined crystal outlines against adjacent minerals. Some idiomorphs are included in large pyrite euhedra.

Pyrrhotite constitutes 10% of the section in irregular masses which show great variation in size, up to 2mms. across. The grains contain abundant voids and occassionally fine streaky lamellae of marcasite.

Sphalerite is the dominant mineral in the section representing 30%. Almost invariably it contains exsolution blebs and rod shaped bodies of chalcopyrite. Sphalerite often forms mutual boundaries with its most common associate, pyrrhotite and it is also often concentrated in voids of this mineral. Chalcopyrite is present as individual irregular masses in pyrrhotite voids.

Pyrite in accessory amounts as large singular euhedra which are partially, some completely replaced by marcasite.

Several grains of galena less than 0.02 mm. across fill voids in all the above mentioned minerals.

Regst. No. 15162.

Field No. 45520. Slide No. 10936. Depth 479'4".

Rock Type. Mineralised talcose-sericitic marble.

Ore minerals. Arsenopyrite, pyrite, sphalerite, chalcopyrite, marcasite, enargite.

Macro:

Grey fine-grained dolomitic talc-sericite schist. Ore minerals make up about 5% of the specimen and consist mainly of pyrite and subordinate arsenopyrite and sphalerite. Pyrite cubes measure up to 3 mms. across. Fine-grained pyrite, arsenopyrite and sphalerite are disseminated generally along the schistocity of the rock.

Micro:

Essentially an allotriomorphic granular aggregate of calcite containing grains and aggregates of pyrite and sphalerite. Calcite grains form mutually interlocking contacts of characteristic metamorphic texture. In all cases the ore minerals are associated with concentrations of talc or sericite. Both are apparent in hand specimen, both have similar optical properties. Considering the mineral associations in this rock this mineral is probably talc. The intimate association of talc and opaque minerals suggests they are genetically related.

Some flakes of chlorite and laths of tremolite commonly occur associated with pyrite. Minor amounts of medium grained allotriomorphic quartz partly enclose some ore minerals. This quartz shows undulose extinction.

Fine dust like opaques are disseminated through the marble and often they occur as inclusions concentrated along calcite crystallographic axes.

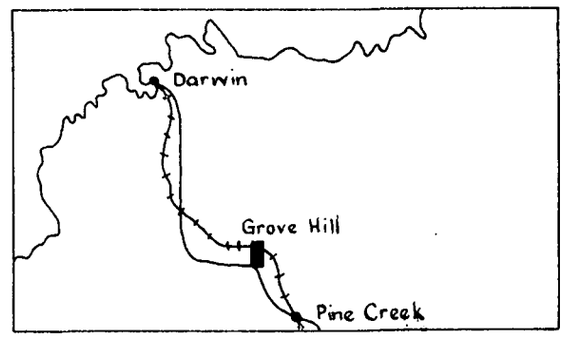
In the polished section irregular masses of pyrite are distributed at random through the section. Sphalerite also occurs in irregular grains and generally it contains exsolution inclusions of chalcopyrite. One grain contains an enargite inclusion which is surrounded by a chalcopyrite corona. Accessory amounts of chalcopyrite occur as discreet grains. The sphalerite partially surrounds and enters voids in arsenopyrite and pyrite grains.

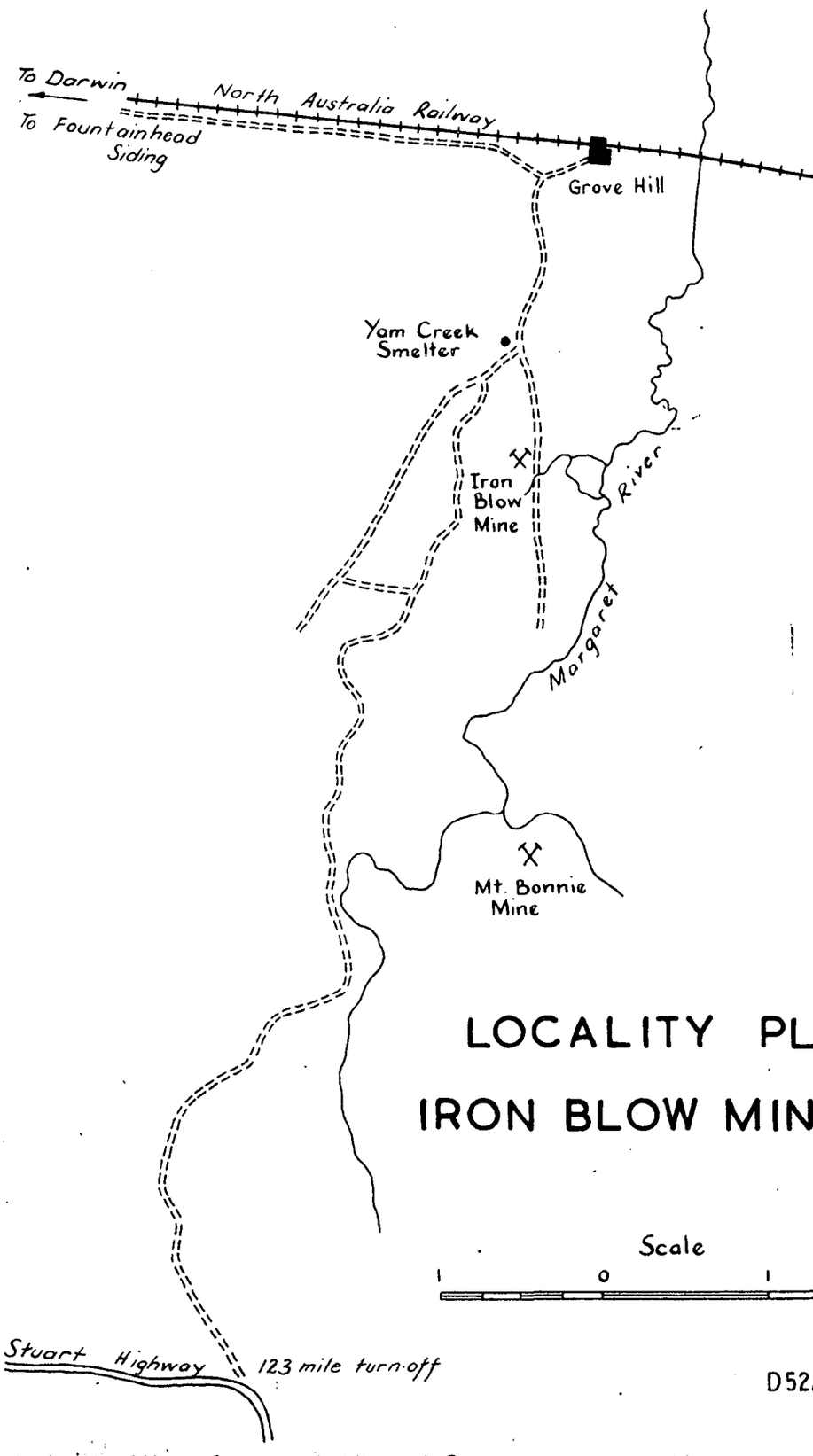
Arsenopyrite occurs in small often idiomorphic crystals throughout the carbonate and may form well defined crystal edges against allotriomorphic pyrite.

Marcasite often partly replaces pyrite and occassionally it completely replaces this mineral forming a pseudomorph.

D52/8/DM/1

PLATE 1





LOCALITY PLAN

IRON BLOW MINE, N.T.

Scale

1 0 1 2 MILES

D52/A8/97

Resident Geologists Office, Bureau of Mineral Resources, Darwin March 1961

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