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MINERALOGICAL INVESTIGATION OF ORE SPECIMENS FROM THE ASTROLABE MINERAL FIELD, PAPUA.

by

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Mineralogical investigation of ore specimens from the Astrolabe Mineral Field, Papua.

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Summary

A study of ore specimens from eight mines and prospects in the Astrolabe Mineral Field shows that the mineral assemblage is essentially the same in each, and that it consists predominantly of ironsulphides with subordinate, chalcopyrite and sphalerite, and minor galena, gold, hematite, magnetite, arsenopyrite and hydrated iron-oxides. The gangue minerals are mainly chalcedony and calcite and less commonly barytes, chlorite and talc.

The specimens from the Laloki ore show the most comprehensive mineral assemblage and variety of structural and textural relationships of the ore minerals which can be correlated with features in each of the other ores to the extent that it is confidently assumed that they all have the same history of formation.

The interpretation of the relationships of the minerals indicates that all the sulphides and chalcedony, and also probably gold, hematite and calcite, were primarily deposited simultaneously, as colloidal precipitates. This is called mineralisation phase I.

Following this, some of the minerals underwent insipient crystallisation, induced by the normal pressures and temperatures which act in a rock sequence during the passing of geological time. Other minerals retained their primary colloidal form.

Textural evidence indicates that following these events the ore minerals were reconstituted to varying degrees by wide-spread recrystallization and brecciation, also, a limited number of observations suggests that at this time, magnetite and talc were introduced into the Laloki ore. This is called mineralisation phase II.

The reconstitution of the ores is attributed to pressures resulting from tectonic activity and to a lesser extent to slight increases in temperature. The magnetite and talc are believed to have derived from the gabbro.

These events in mineralisation phase II are correlated with a major period of tectonic activity and the simultaneous introduction of the Sadowa Gabbro which, on the basis of field evidence, occurred during the Oligocene. This time relationship, and the intimate association of the ores with the Port Moresby Beds indicates that the primary deposition of the sulphides of mineralisation phase I, occurred during the Eocene.

It is concluded the the mechanism of the original deposition and subsequent reconstitution of the sulphides is well understood but this does not, in itself, define the origin of the metals or the colloidal solutions as necessarily being epigenetic or syngenetic in relation to the enclosing sediments. However evidence arising from this investigation, when considered in conjunction with field evidence, does suggest that the ores have a syngenetic rather than an epigenetic origin.

Their distribution and abundance however, cannot be explained to the extent, that an interpretation can be made of areas in the field which are likely to contain concealed ore-bodies.

INTRODUCTION

This report deals with the mineralogical examination of ore specimens from eight mines and prospects in the Astrolabe Mineral Field, Papua. The specimens were collected during the 1964 field season when the area was mapped on the scale of 400 feet to 1 inch by Yates and de Ferranti,and others, of the Bureau of Mineral Resources. This record supplements the report and maps by Yates and de Ferranti (records 1965/) which describes the field geology and the record by Joyce (1965/109) which describes the petrography of rock specimens from the area. The author visited most of the mines with J.F. Ivanac in the field during October 1964. The mines and prospects from which specimens were examined are Dubuna, Elvina, Sapphire, Mt. Diamond, Laloki, Moresby King, Paree, Ventura and D.D.H. SC4, Laloki.

Previous field geological studies have been made of most mines and prospects and an examination of the mineralogy of several specimens from the two major deposits has been made by A.B. Edwards and W.M.B. Roberts but there is no record of a detailed mineralogical study of all the ores or of any attempt to correlate the mineral assemblages and mineral associations of the various deposits.

It is the aim of this investigation to provide this and to provide information which, when considered in conjunction with field relationships may be used to establish the sequence of geological events involved in the development of the ores.

MINERALOGY

A detailed description of the minerals and their associations in each specimen is given in Appendix A and the minerals identified and their relative abundance are listed in table 1.

1. Ore minerals.

Iron Sulphides.

Iron sulphides are by far the most abundant minerals in these ores; they occur in many forms and show a variety of relationships to the other ore minerals.

Individual grains are commonly made up of marcasite and pyrite which grade imperceptibly into one another; pyrite is generally dominant. Marcasite typically forms the outer margins of the grains; in some specimens where the ironsulphides are banded, marcasite is restricted to the bands in contact with the gangue minerals (notably calcite) but in other sections it is randomly interbanded with pyrite.

These minerals most commonly form small euhedral and sub-hedral grains which can be grouped into two principal grain sizes, one having an average size of about 0.01 mm. the other about 0.2 mm; these sizes are fairly uniform in a given section or in certain areas within a specimen. Rarely the grains are larger than this, but in several specimens, brecciated, coarse grained, subhedral pyrite occurs in veins which cut through all of the other minerals.

TABLE 1.

The ore minerals(showing their approximate proportions) and the gangue minerals identified in sections from the shown mines and prospects.

PROPORTION OF ORE MINERALS

Mine or Prospect	Major approx. 50%	Subordinate approx. 10% 50%	Minor and accessory approx. 10%	Gangue Minerals
Dubuna	Pyrite Marcasite	Sphalerite	Chalcopyrite Galena Specularite	Calcite
Elvina	Pyrite Marcasite	Chalcopyrite Sphalerite Hematite	Galena ? Cubanite Hydrated iron oxides	Chalcedony Calcite
Sapphire	Pyrite	Chalcopyrite	Sphalerite Hydrated iron oxides	Clinochorite
Mt. Diamond	Pyrite		Chalcopyrite Sphalerite ? Enargite	Chalcedony
Laloki	Pyrite Marcasite Chalcopyrite	Sphalerite	Galena Gold	Calcite Barytes Chalcedony
DDH SC4 Laloki. Between 274 feet and 285 feet.	Magnetite Pyrite Chalcopyrite			Talc
Moresby King	Pyrite Marcasite Arsenopyrite	Chalcopyrite	Sphalerite Specularite Hydrated iron oxides Rutile	Quartz Chlorite
Paree	Pyrite Marcasite		Chalcopyrite Specularite	Calcite
Ventura	Pyrite		Chalcopyrite Covellite	Chalcedony

In most of the ores, grains of iron-sulphides are arranged; (a) in sequences of conformable, fine scalloped and roughly concentric bands, (b) in chain-like bands, some of these are straight, others undulate at random, (c) as fine euhedral and subhedral grains scattered randomly through the gangue and in voids between other minerals. In some places the grains have a spheroidal form.

(a) The scalloped bands are best developed in a section from Elvina (fine detail fig. 13) where they are made up of grains of intimately intergrown and alternating zones of marcasite and pyrite. The bands are typically conformable with the contact between sulphides and calcite filled cavities which they enclose and they are intergrown, near this contact, with bands of granular sphalerite and galena.

In the Dubuna ore a series of extremely fine, conformable bands of pyrite are concentrically arranged in roughly spheroidal aggregates (fig. 11).

In the Laloki ore pyrite bands are intergrown with sphalerite and chalcopyrite and in the Moresby King samples colloform bands of pyrite are intercalated with bands and curved lenses of arsenopyrite and marcasite.

(b) In sections from Mount Diamond, Ventura and Dubuna euhedral and subhedral iron-sulphide grains form short, disjointed and irregularly undulating chain-like bands in the gangue, (fig. 14). Some of these have formed along inter-crystal boundaries of the gangue minerals others occur between, and partly surround various minerals in the ore.

(c) In most of the ores fine euhedral, subhedral and spheroidal iron-sulphide grains are disseminated through the ore, these are commonly localised in patches and bands.

Individual grains of spheroidal pyrite are most abundant in the Laloki ore but subhedral pyrite forms spheroidal aggregates in specimens from Dubuna, Elvina, Moresby King and Ventura.

Spheroidal pyrite grains in the Laloki ore, (figs. 3-5), occur in bands together with loose aggregates of fine euhedral and subhedral pyrite; they range in size from 0.003 mm. to 0.08 mm. in diameter. In section they are circular and they typically contain one, and in some places two or three, concentric inner shells of what appears to be siliceous material. Some spheroids shows fine radial structures of intergrown pyrite and silica; some contain inclusions of sphalerite blebs which are arranged radially and concentrically.

Several subhedral grains of pyrite contain relic spheroidal forms. In some grains, two and as many as five spheroids have been fused together and form relatively large subhedral composite grains.

Some spheroidal pyrite grains in the gangue have been brecciated and the fragments slightly displaced.

Rarely amorphous grains of admixed sphalerite and chalcopyrite enclose pyrite spheroids, (fig. 5).

In most of the sections pyrite forms composite grains with the other minerals in the ore, but its relationship to these varies within single samples and from one sample to another. In many places its associations indicate that the iron-sulphides formed simultaneously with the other sulphides in others however there is evidence of the formation of generations of pyrite at a later stage than the pyrite described above and also later than the other sulphides.

A subordinate amount of pyrite in most sections forms composite grains with, is enclosed by, and contains inclusions of chalcopyrite, sphalerite and less commonly galena. Generally the intergrowth of these minerals is more or less allotriomorphic and inclusions are distributed at random in the host. In some places however (notably in the Laloki and Mt. Diamond ore) sphalerite and some chalcopyrite inclusions in pyrite are concentrated on zones which are conformable to the margins of the host grain.

In specimens from Dubuna, Elvina, Sapphire and Moresby King, fine granular pyrite forms rims around and extensively veins chalcopyrite and less commonly sphalerite and galena. Typically the periphery of chalcopyrite consists of a reticulated zone of intergrown chalcopyrite and pyrite and it seems certain that in these areas pyrite is invading and replacing it.

In the Moresby King samples, bands of arsenopyrite are intergrown with scalloped bands of fine grained pyrite and marcasite; all are considered to have formed simultaneously. In other parts of the section discrete grains of subhedral and anhedral arsenopyrite are brecciated and large spongy looking laths and aggregates of pyrite are veined and rimmed by granular chains of fine euhedral pyrite. This combination of pyrite also occurs in the Elvina ore.

The pyrite in most sections is brecciated, in some places only moderately so but in areas where pyrite is relatively coarse grained and occurs in dense aggregates with little or no gangue the pyrite is severely fractured and in parts, pulverised.

Chalcopyrite.

As with the iron-sulphides chalcopyrite has a number of different forms and combinations, the distribution and abundance of which varies in single specimens and from one to the other.

Chalcopyrite typically occurs in masses and grains in gangue, filling or partly filling interstices in pyrite aggregates. In some places it forms combinations with other sulphides, elsewhere it occurs alone. The grain size varies from that of extremely fine disseminated grains (notably in the Mt. Diamond specimens) which measure 0.001 mm. to massive chalcopyrite which constitutes almost the entire specimen, (notably the Laloki ore).

In the ores where chalcopyrite is associated with other sulphides it generally carries fine bleb-like inclusions of pyrite, sphalerite and less commonly galena, and in the Sapphire ore, quartz carrying pyrite. As mentioned above masses and blebs of chalcopyrite are enclosed respectively by granular rims and euhedral grains of pyrite. In addition, the sphalerite contains fine blebs of chalcopyrite in most sections, as does galena, but to a lesser extent.

In the ore specimens from Laloki, Dubuna, Moresby King and Sapphire chalcopyrite forms complex colloform and graphic intergrowths with sphalerite and galena. These relationships are important since they have a significant bearing on the interpretation of the ore genesis. They are best exhibited in the Laloki specimens (figs. 2, 6 - 9) and the following descriptions refer to this material but the various associations can be correlated with similar features in sections from Dubuna, Sapphire and Moresby King.

Chalcopyrite in the Laloki ore occurs in botryoidal, colloform, subhedral and brecciated masses all of which are intimately associated with sphalerite and minor amounts of galena, (fig. 6).

The botryoidal masses have an average size of 0.15 mm. across which are made up of an amorphous, admixture of copper and zinc sulphides which in some places contain accessory lead sulphide. These masses have scalloped margins, sphalerite is the dominant component and this is riddled by extremely fine anastomising veinlets and blebs of chalcopyrite; these have a random distribution and they give the sphalerite a brassy veneer.

In some masses these minerals form concentric colloform layers and chalcopyrite also forms radial structures in sphalerite. Galena occurs as blebs in the centre of some masses and as narrow concentric bands near the outer margins of others.

These masses occur in areas which grade imperceptibly into zones made up of chalcopyrite which contains various types of sphalerite intergrowths. Here, chalcopyrite shows an incipient crystalline form and sphalerite has segregated into colloform bands and graphic and emulsion type intergrowths in chalcopyrite, (figs. 7 & 8). In some grains sphalerite and minor galena form a narrow marginal rim which indicates that they have diffused from the main body of the grain to the outer margins.

Between this zone and adjacent to the barytes gangue subhedral chalcopyrite which is virtually free of inclusions is surrounded by relatively wide margins of sphalerite, (fig. 9). This appears to be an advanced stage of segregation of the two minerals from the intergrowth stage mentioned above. The interface between sphalerite and barytes typically has a reniform shape and minor, narrow bands of galena are intergrown around the outer margins of some sphalerite.

The limbs of small folds in the Laloki ore are made up of a roughly consistent sequence of bands of these various chalcopyrite - sphalerite combinations, (figs. 1 & 2). The core of the fold consists of barytes and a section away from this, progressively intersects zones of decreasing degrees of segregation of the copper and zinc sulphides. The band farthest away from the core consists of fine euhedral, subhedral and spheroidal pyrite.

In the Sapphire sample the variety of combinations described above were not recognised. However small (0.08mm.) spherical bodies consisting of anastomising sphalerite blebs (which resemble an asterisk) are enclosed by chalcopyrite (fig. 10). It seems that the arrangements of sphalerite within each of these bodies is controlled by the crystal structure of the host.

Chalcopyrite masses in the Elvina, Sapphire and Moresby King have leached and (or) corroded margins, (fig. 12). In the Moresby King ore these form reticulated intergrowths with pyrite and quartz which replace the chalcopyrite.

In the sample from Ventura, some chalcopyrite masses are partly altered to covellite and in places single grains of covellite indicate complete replacement. This is the only evidence of supergene alteration of chalcopyrite in all of the section examined.

Much of the chalcopyrite in these ores is moderately brecciated.

Sphalerite.

Sphalerite rarely makes up more than 10% of the sections examined and in several it is absent. It most commonly occurs in grains and masses, free in the gangue and also in voids within pyrite aggregates. They have an average size of about 0.3mm. and a maximum size of about 3mm. and most of them carry fine, randomly distributed inclusions of chalcopyrite, pyrite and less commonly galena.

In some sections sphalerite forms an intergral part of the scalloped bands and colloform structures of the iron-sulphides, (fig. 13). In the Elvina and Dubuna sections bands of granular sphalerite occur between iron-sulphide bands, one or two removed from the calcite filled cavities which they surround. In other specimens sphalerite grains form part of chains and bands of predominantly pyrite which enclose other sulphides.

All of the other sulphide minerals in these ores enclose sphalerite bodies which have an irregular shape and a maximum size of about 0.05 mm.

Sphalerite, as are the other sulphides, is cut by veins of gangue (notably by calcite at Elvina) which generally carry pyrite, specularite, and chalcopyrite.

The associations of sphalerite with chalcopyrite in ores from Laloki, Moresby King, Dubuna, and Sapphire are described in detail above.

Galena.

Galena was found only in specimens from Dubuna, Elvina, and Laloki and in these it forms less than 5% of the sections examined.

In the Dubuna ore galena occurs in subhedral grains, (fig. 14), and allotriomorphic masses the average size of which is 0.15 mm. Typically these occur in spaces between granular pyrite; they also form composite grains with sphalerite and chalcopyrite and they carry fine inclusions of all other sulphide minerals in the section. Some galena is partly replaced and veined by granular pyrite.

The section from Elvina contains fine bands of subhedral galena crystals and discrete euhedral grains which are intercalated with bands of iron sulphide. Their average grain size is about 0.5 mm.

The galena in the Laloki ore occurs as discrete subhedral grains in the gangue within pyrite aggregates. Irregularly shaped grains of galena also form an intergral part of some botryoidal and colloform grains of mixed sphalerite and chalcopyrite, (fig. 6).

During the segregation of the copper and zinc sulphides, galena appears to have migrated to the outer margins of the grains where it forms curved narrow lenses and rims in sphalerite, (fig. 9).

Accessory amounts of galena occur as extremely fine inclusions in the other sulphides.

Hematite.

Hematite, (almost invariably the variety specularite) occurs in five of the ores; its mode of occurrence is the same in each except in the Elvina ore where it is more abundant and shows greater diversity of forms than in the other sections.

In the Elvina specimen hematite has the following forms:

a. In irregular masses and less commonly spheroidal bodies in the calcite gangue invariably filling intersticies in pyrite aggregates.

b. As inclusions in some pyrite forming narrow zones which are conformable with the external shape of the host grain, also surrounding euhedral pyrite grains in calcite.

c. Forming small concentric structures in calcite.

d. As rods and stringers localised along inter-crystal contacts of calcite.

In the other ores hematite occurs almost exclusively as small flakes which are carried by calcite and siliceous gangue (and less commonly chlorite) which fill intersticies in the iron-sulphide aggregates. In the Moresby King narrow veins of specularite (1mm. wide) cut through all the other minerals in the section.

Also in the Moresby King lath shaped crystals of quartz in pyrite aggregates carry abundant equisized flakes of specularite, most of these have a random distribution but in some of the laths the long axis of the flakes is oriented parallel to the length of the lath.

Magnetite.

Magnetite was observed only in core from DDH SC4, Laloki, between 274 and 285 feet; these specimens were selected for examination because they are strongly magnetic.

The magnetite occurs in irregular shaped masses and veins and as randomly distributed foliae; both forms are associated with talc.

Chalcopyrite and pyrite are the only sulphides that magnetite was found directly associated with. In a section from 281 ft., chalcopyrite masses are moderately brecciated and they contain abundant, irregular and slightly corroded voids. Masses and grains of magnetite are almost exclusively localised in these voids although some veins of magnetite cut through chalcopyrite, (fig. 16). Much of the magnetite, particularly euhedral grains, have grown into the chalcopyrite. Isolated grains of magnetite in talc commonly have a euhedral form.

At 284 ft. discrete, scattered grains of pyrite are brecciated and commonly magnetite "cements" the slightly displaced fragments and fills fractures in them. Euhedral magnetite has also grown into grains of pyrite. Most of the magnetite carries fine inclusions of pyrite, (fig. 17).

At 285 ft. magnetite occurs in loosely packed shredded blades and foliae; these have a random distribution, (fig. 15). Individual blades measure up to 0.3mm. long and some are grouped in sheath like aggregates. Some blades partly enclose, grow between and seem to have forced apart fragments of brecciated euhedral pyrite. Blades of magnetite also grow into pyrite. Several grains of spheroidal pyrite occur in this section.

The magnetite in most of the sections is moderately brecciated.

Hydrated iron oxides.

These occur in several sections and in some hand specimens (notably from the Moresby King) it replaces the sulphides on the weathered surface and forms insipient gossanous boxworks.

In the Elvina specimen, hydrated iron oxides partly replace the various forms of hematite in the gangue. In the Sapphire oré it forms skeletal masses and fibrous aggregates in voids between pyrite and chalcopyrite. It does not appear to be derived from these sulphides since its contact with them is sharply defined and most of the pyrite have sharp euhedral margins.

Spongy laths of pyrite in the Moresby King specimen are partly altered to hydrated iron oxides.

Gold.

Gold, as extremely fine inclusions in sulphides and gangue was identified in the sections from Laloki. Their occurrence and size are as follows:

Host	Size
chalcopyrite	0.02 mm.
chalcopyrite	0.003mm.
sphalerite	0.003mm.
barytes, (adjacent to pyrite spheroids).	0.006mm.

Other ore-minerals.

In the Elvina ore minor-accessory amounts of a pink-brown mineral occur as bleb-like inclusions (0.005 mm.) in coarse grained pyrite, together with inclusions of chalcopyrite. Their restricted occurrence prevented a positive identification but they are considered most likely to be cubanite.

Inclusions of a similar size and abundance occur in the Mt. Diamond ore. These are strongly anisotropic and they have a brown-grey color. They are most likely enargite.

Mineral beneficiation.

The complex, heterogeneous, fine-grained intergrowths of the ore minerals described above indicates that extreme difficulty would be met when concentrating the economic minerals during beneficiation. This is not restricted to any particular ore-body, but can be expected in all of them.

2. Gangue Minerals.

Since most of the specimens consist of massive sulphides the gangue material generally forms less than 10% of each, however in all sections interstices within the ore do contain non-metallic minerals which formed during the development of the ores.

The most common of these is chalcedony. Cavities within the ore-mineral aggregate from Elvina, Mount Diamond, Laloki and Ventura are lined and filled with a micro mosaic of cryptocrystalline quartz. Individual grains commonly have a fibrous, fan-shaped structure and also spherulitic extinction under crossed nicols. Typically they are arranged in spherulitic aggregates.

In many places the siliceous material is zoned by variegated colloform bands which are roughly conformable to the walls of the enclosing cavity.

The chalcedony generally carries fine inclusions of sulphide minerals, (particularly pyrite) and also accessory amounts of clay minerals.

In some places patches and veins of relatively coarse allotriomorphic granular aggregates of quartz occur in the chalcedony matrix, these appear to have derived by the recrystallisation of this matrix.

In the Laloki ore fine veins of barytes cut through chalcedony.

Calcite is the next most abundant gangue mineral in these ores. It fills interstices between the ore minerals; fills fractures and "cements" brecciated fragments of them, particularly pyrite and arsenopyrite, and it also occurs in veins which cut all of the other minerals in the ore, including chalcedony. Clearly, this calcite post-dates these minerals.

In the Elvina and Dubuna material fine, scalloped bands of iron, zinc and lead sulphides surround calcite filled cavities.

From all localities calcite carries disseminated inclusions of all the sulphide minerals and as previously mentioned specularite is commonly associated with it.

Barytes was identified (by x-ray diffraction) only in the Laloki ore and here it has a similar mode of occurrence as described for calcite.

Interstices in the Sapphire and Moresby King ores are filled by chlorite which was identified by x-ray diffraction as leuchenbergite (clino-chlorite). Minor amounts of brucite and hydrated iron oxides also fill some small voids in a section from Sapphire.

In a section from the Moresby King, randomly distributed laths of quartz fill cavities enclosed by pyrite; also veins of quartz cut through pyrite. The quartz carries abundant inclusions of specularite and fibrous aggregates and single needles of extremely fine crystals of rutile.

The Paragenesis of Sulphide Mineralisation.

The sequence of geological events involved in the development of the sulphide ores, together with the probable order of formation of minerals during the ore forming processes are diagramatically represented in table 2.

This table is mainly based on microscopic observations of ore specimens from the Laloki Mine since these show the most comprehensive mineral assemblage and variety of structural and textural relationships of the ore minerals. These relationships however can be correlated with features in each of the other ores that were examined to the extent that it is confidently assumed that they all have the same history of formation.

The correlation of the formation of minerals with geological time, periods of tectonic activity and with the intrusion of the gabbro are based on field data recorded by Yates and de Ferranti. (1965).

1. Mineralisation Phase I.

As shown in table 2 all the sulphide minerals and the major gangue minerals were initially deposited, contemporaneously, as precipitates from colloidal solutions.

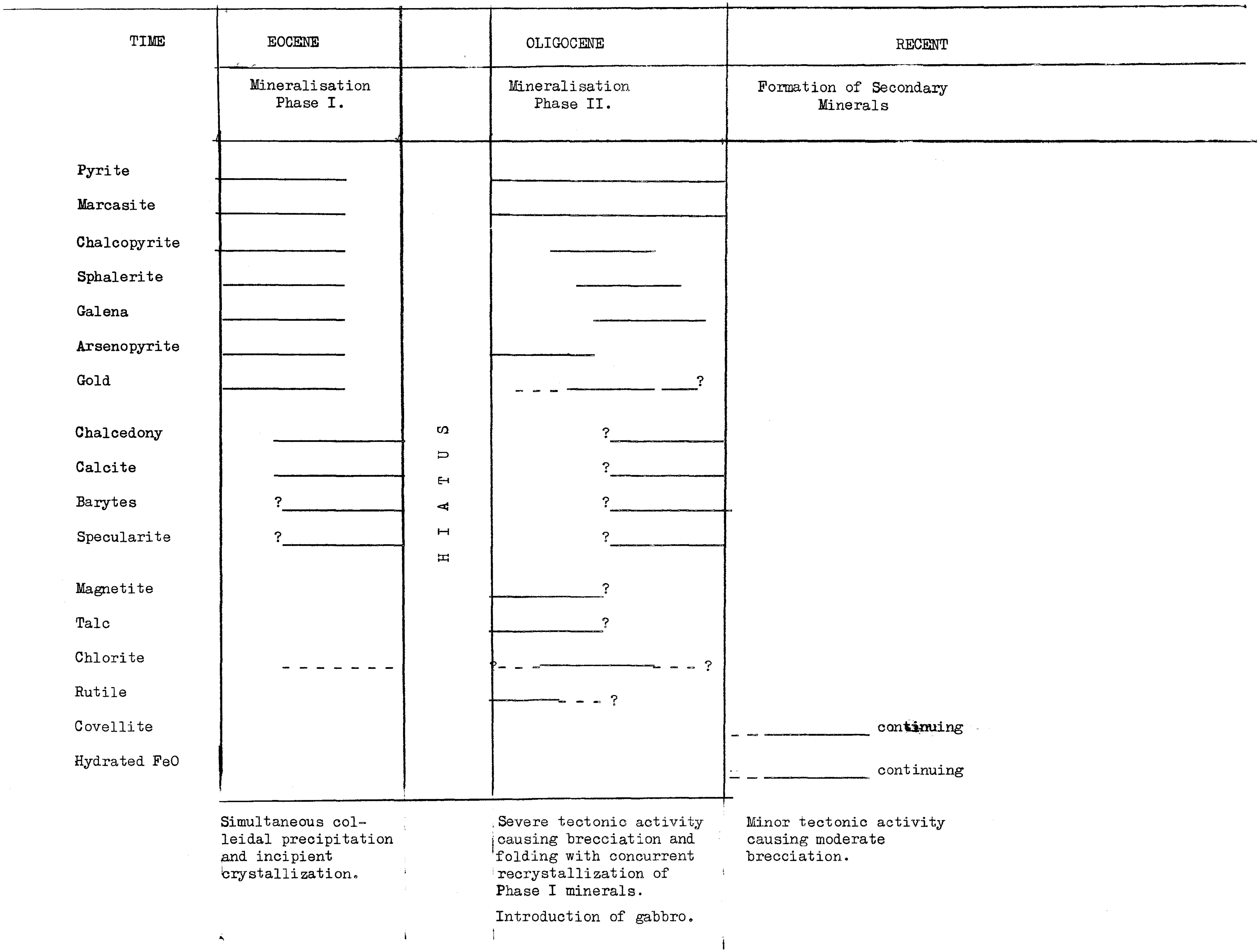
The features on which this interpretation is based are listed and then discussed below.

1. Amorphous masses of admixed sphalerite and chalcopyrite which contain internal colloform structures and scalloped margins.

2. Spheroidal pyrite grains.

TABLE 2.

DIAGRAMMATIC REPRESENTATION OF THE PARAGENESIS OF SULPHIDE ORES IN THE ASTROLABE MINERAL FIELD



3. Cryptocrystalline silica, commonly showing colloform banding and intimately associated with the ore minerals.

4. Series of scalloped bands, roughly spheroidal aggregates and concentric structures of pyrite and marcasite which in some places are intercalated with bands of sphalerite and less commonly galena and arsenopyrite.

The features of the admixed zinc and copper sulphide masses (p. 5) (best developed in the Laloki ore) are identical to the amorphous masses with reniform margins which are commonly described in the literature and are considered to be derived by the hardening of gels and colloidal precipitates.

The nature of the masses in these ores indicates that the zinc and copper sulphides had an affinity for one another in the original colloidal solution and clumps of an admixture of these coagulated and hardened. The botryoidal margins suggests that they were produced by surface tension effects and the tendency to form a minimal surface during solidification. The fine anastomising veinlets and blebs of chalcopyrite in sphalerite may be due to segregation induced by incipient crystallisation or they may be due to diffusion and a tendency of separate minerals to coagulate in the gel state.

The fact that in some places these primary amorphous mixtures do exist shows that the ores were formed (and have partly remained) at low temperatures and pressures. This implies a surface or near surface environment of deposition.

The formation of spheroidal pyrite bodies (p 3) is commonly attributed to precipitation by bacteria and microorganisms. There is no evidence of such an origin in the material examined; conversely, in view of the relic gel strutures it is believed that the spheroidal pyrite grains in these ores are derived by the inorganic precipitation from colloidal solutions.

The relationships of cryptocrystalline silica in these ores, particularly shells of this material within spheroidal pyrite grains, indicates that it formed during the primary deposition of the sulphides.

In this silica the presence of variegated colloform bands, the fibrous nature and spherulitic extinction of individual grains in microcrystalline aggregates are characteristic features of chalcedony which is normally regarded as being derived by the crystallisation of a silica-gel like substance.

The intimate and apparent genetic association of sulphides with silica of this form indicates that they have a common solloidal origin.

The series of conformable scalloped bands of pyrite and marcasite of the type seen in specimens from Elvina and Dubuna is the most common feature of the ores which shows that they are all derived from colloidal solutions.

Although the bands are invariably made up of individual grains of iron disulphide, the distribution of these in series of scalloped bands and roughly spheroidal and concretionary structures (p. 3) strongly suggests surface tension effects. In addition, the imperfect attainment, in most cases, of minimal surface suggests the influence of surface tension in a strongly viscous medium.

There is no suggestion that this type of banding is of mechanical origin (e.g. sedimentary) although in the Laloki ore the folded bands shown in fig. 1 were probably formed mechanically. These may be deformed primary colloidal structures, deformed sedimentary structures or possibly a type of metamorphic banding. The latter is highly unlikely since the spheroidal pyrite and amorphous admixtures of zinc and copper sulphides in these bands would have been transformed to a crystalline form by such a process.

Therefore, it is postulated that the formation of the fine scalloped bands and roughly concentric structures are largely colloidal and are due to dispersed iron sulphides passing from the suspensoid to the solid state. The individual grains may have originally formed in their present subhedral and euhedral form; alternatively they may have originally had a spheroidal or structure-less form which has subsequently attained crystallinity under the influence of normal strains in the rock, or, of tectonic deformation.

The marcasite along the margins of some grains and bands, in contact with calcite, probably formed in preference to pyrite because of the effect of calcite on the pH in the immediate vicinity. In many places calcite appears to have formed contemporaneously with the colloform bands of sulphides, and the marcasite adjacent to this is assumed to be primary. The abundance of marcasite of probable primary origin indicates that the ores were formed at low temperatures.

Some calcite was mobile and was introduced into voids and fractures in the ore subsequent to the crystallisation of the sulphides; this has caused the alteration of pyrite to marcasite along some grain boundaries. This is second generation marcasite.

The zonal arrangements of interbanded marcasite and pyrite, separated from any obvious influence of associated minerals may have been produced by rhythmic precipitation from, or rhythmic diffusion in, the original gel.

The presence of bands of sphalerite and minor galena and arsenopyrite which are intergrown with the scalloped and concentric structures of iron sulphides is attributed to fluctuations in the composition of the precipitates from the original gel or to fluctuations in the diffusion of various ions through it.

Alternatively the areas in which these occur may have initially been an amorphous or cryptocrystalline mixture of sulphides and progressive crystallisation has lead to the segregation of the various mineral bands.

Regardless of the exact mechanism of segregation it is apparent that, considering the assemblage as a whole, all of these sulphides formed simultaneously from colloidal solutions.

The small size and restricted occurrence of the gold observed in these ores does not provide sufficient evidence for a positive indication of its origin. Considering the likelihood of it forming by colloidal processes there is little evidence in the literature that gold sols exist under geological conditions, it is likely however, that the dispersion of metallic gold can take place during erosion and transportation.

Since the ores probably formed at or near the surface it is therefore possible that gold of this form was incorporated in the ores by adsorption during colloidal precipitation and formed composite grains with sulphides and gangue at this time or during subsequent recrystallisation.

Much of the calcium carbonate appears to have formed contemporaneously with the ore minerals and since the ores are all enclosed by calcareous country rocks it is probable that it is derived from these. It could conceivably have formed during the deposition of the calci-lutites; during diagenesis; or during deformation, post-diagenesis.

There are no features in the carbonate gangue which suggests a colloidal origin since most of it is crystallised and typically it shows evidence of remobilisation.

The wide-spread and intimate association of calcite and sulphides (particularly the primary colloform minerals) does suggest that it played an essential part in the coagulation of the metal-rich sols which subsequently lead to the formation of these minerals.

2. Mineralisation Phase II.

Textural evidence indicates that following the primary deposition of the ore minerals they were reconstituted to varying degrees by widespread recrystallisation and brecciation, also, a limited number of observations suggests that at this time, magnetite and talc were introduced into the Laloki ore.

The extent of recrystallisation and brecciation is extremely variable on both a micro and macro scale. In some polished sections primary minerals enclosed in calcite are not altered, probably because this absorbed the majority of stresses in the rock and by responding to them was itself recrystallised but it protected the sulphides.

Field evidence thows that in some places deformation was severe. In the open-cut at Laloki and Dubuna sulphide masses are extensively folded and isolated blocks have been broken away from the main body. Also, at Laloki the ore consists in part of angular fragments of sulphides which are erratically and densely distributed through a matrix of similar sulphides.

This reconstitution is attributed mainly to increases in pressures in the ores and to a lesser extent probable slight increases in temperature and these are correlated with the period of tectonic activity and the introduction of the gabbro which according to Yates and de Ferranti (1965) took place during the Oligocene.

Evidence of recrystallisation of the ore minerals is best seen in the Laloki ore where there is a complete series of transition zones from structureless masses of admixed copper, zinc and lead sulphides to crystalline chalcopyrite surrounded by sphalerite and galena. The interpretation that these various textures represent a transition from a primary amorphous form of mineralisation phase I to the crystalline form of a subsequent phase of mineralisation is discussed below.

It is well known that solidified colloids have a tendency to aquire some degree of crystallinity and are readily transformed to a state intermediate between a colloform and a crystalline state, simply by response to the normal pressures and temperatures which develop in a rock sequence with the passing of geological time. These are commonly referred to as meta-colloids.

The amorphous masses of sphalerite containing intimately admixed chalcopyrite and minor galena and possibly the grains in which mineral segregation is slightly more advanced are believed to have formed in this way.

The grains in which mineral segregation is more advanced, and is complete, are believed to have developed from the meta-colloid state by crystallisation (or in a sense recrystallisation) which was induced by relatively increased pressures and possibly slightly increased temperatures, which were associated with the tectonic deformation of the ores.

The textural relationships in many sections (p. 4) indicates that generally one and in some places two generations of iron-sulphides formed by the recrystallisation of primary colloidal iron-sulphides.

Other evidence of recrystallisation is shown by different forms of individual pyrite grains. The grains with euhedral and subhedral outlines which enclose relic spheroidal forms and those which are zoned by pyrite of a different texture to the core of the grain are examples of the first generation pyrite which has been recrystallised at the boundaries. In some places, patches of fine grained disseminated pyrite contain equigranular relatively coarse-grained aggregates of recrystallised pyrite. Similarly cryptocrystalline silica is recrystallised in patches to allotriomorphic aggregates of quartz.

The pyrite and chalcopyrite which contain zones of fine inclusions of one another, sphalerite and hematite, which are conformable to the outline of the host grain also indicate recrystallisation.

As discussed previously some calcite in these ores appears to have been deposited contemporaneously with the sulphides, much of the calcite however was mobile at a relatively late stage of their development. Where calcite veins cut through and fill fractures in the ore minerals it is not possible to say whether this is remobilised calcite of mineralisation phase I or whether it was subsequently introduced from an external source. It is highly likely that some late generation calcite was introduced during the deformation of the ores and the adjacent calci-lutites since the country rock typically contains veins and pods of calcite localised in zones of structural weakness.

Since hematite (specularite) is almost exclusively carried by this late generation calcite it is also impossible to state its origin or its significance in the history of development of the ores. However the presence of spheroidal and concentric shells of hematite in calcite indicates the possibility of a colloidal origin. Its common occurrence and consistent association in different ores do indicate that they formed under the same conditions.

Magnetite was found only in four sections from a drill core in the Laloki ore; it is intimately associated with talc, (p. 7).

The textural relationships with pyrite and chalcopyrite all indicate that magnetite was introduced after the formation and brecciation of the sulphides. Although the sulphides in these sections show no colloform structures it is assumed that they are genetically related to the sulphides of mineralisation phase I discussed above. The crystalline form of the pyrite and the brecciated and corroded nature respectively of pyrite and chalcopyrite suggest that they have been reconstituted after their initial deposition; this appears to have taken place before or contemporaneously with the formation of the magnetite and talc. The corrosion of chalcopyrite suggests the influence of higher temperatures than is generally evident in the other ore specimens and the absence of magnetite and talc from these specimens implies that their occurrence at Laloki is anomalous.

It is concluded that the magnetite and talc were introduced from an external hydrothermal source after the primary deposition of the sulphides; hence they are probably genetically unrelated to them. The magnetite and talc are believed to have been introduced in a metasome and the most likely source for this is the gabbro which underlies the Laloki ore-body.

The possibility that the magnetite and sulphides are genetically unrelated has important implications when considering the use of magnetic geophysical methods in the prospecting for concealed sulphide ore bodies.

Chemistry of the Ores

As stated by Yates and de Ferranti (1965) the chemistry of the ores from all major mines and prospects is relatively consistent. An examination of all available assays shows that the copper content ranges from 1 to 5 per cent. Assays for gold most commonly show about 3 dwts/tons; silver content ranges up to one ounce/ton but is normally about 10 dwts/ton. In a table of analyses shown by Carne (1913), the amount of zinc in the ores ranges from 1 to 3 per cent and lead from 0.2 to 0.9 per cent. Of the remaining elements iron ranges from 30 to 50 per cent (normally about 40 percent) and silica from 1 to 13 per cent.

A notable exception to this consistency in grade, is the ore in a narrow zone of mineralisation intersected in the upper levels of diamond drill hole SC3 at the Laloki Mine. This ore assayed 10.9 per cent copper and 4 per cent zinc.

Table 3 shows the results of spectrochemical analyses of ore samples from selected mines and prospects. These analyses were done by A.D. Haldane by optical emission spectrography.

Origin of the Ores.

The conclusion that the ores were primarily deposited from colloidal solutions merely explains the mechanism of concentration of the sulphide minerals, it does not, in itself, define the origin of the metals or the colloidal solutions as necessarily being epigenetic or syngenetic in relation to the enclosing sediments, and it does not explain their distribution or abundance.

However evidence arising from this investigation, when considered in conjunction with field evidence given by Yates and de Ferranti (1965), suggests that the ores have a syngenetic rather than an epigenetic origin. These are set out below.

1. The minerals and their relationships in the ores indicate that they initially formed simultaneously in a low pressure and low temperature environment which implies that they were deposited at or near the surface.

2. A striking feature of the ores is the consistency of the major minerals and elements and the simplicity of the mineral assemblage and trace element content in comparison with the relatively complex chemistry and to a lesser extent mineralogy of ores of hydrothermal, epigenetic origin.

3. The ores are associated only with calci-lutites and black shales of the Astrolabe facies of the Port Moresby Beds. The fact that calcite played an essential part in the precipitation of the ore minerals would explain this association and the apparent lack of metasomatic introduction of elements into the ores (with the exception of magnetite and talc) suggests that the majority of the calcite was incorporated during sedimentation or diagenesis. Similarly it is likely that the clays and some components in the black shales were also responsible for the precipitation of sulphides.

To this extent the generalised distribution of the ores can be correlated with the geology but neither the mechanism of sulphide formation, nor field observations adquately explain, specifically, why each ore-body became localised where it did.

4. The presence of disseminated pyrite and pyritic nodules within the calci-lutites of the Port Moresby Beds indicates that sulphides were deposited simultaneously with these sediments. Considering the above information, a process that may be invoked for the concentration of the ores is that disseminated sulphides, minor silica and barytes formed sols during diagenesis and migrated and accummulated in areas of low pressure where they eventually formed ore.

TABLE 3

SPECTROCHEMICAL ANALYSES OF COPPER ORES (by A.D. HALDANE)

Origin of Samples (Mine or Prospect)	Zn	Ni	Co	Cu	V	Mo	Sn	Pb	Ag	Bi	As	Mg	Ca	Al	Fe	Mn	In	Ge	Cd	Sb
Dubuna	* 1%	-5	7	½%	-5	20	100	700	P	–	–	L	M	L	H	M	P	P	–	–
Elvina	1000	7	300	½%	-5	20	20	20	–	–	–	L	–	L	H	L	P	–	–	–
Elvina	1500	5	500	* ½%	-5	60	5	50	P	–	–	L	M	L	H	M	P	–	–	–
Sapphire	4000	5	400	* ½%	-5	10	100	-10	P	P	P	M	L	L	H	M	P	–	–	–
Mt. Diamond	50	–	15	700	-5	2	–	-10	P	–	–	L	–	L	L	L	–	–	–	–
Mt. Diamond	* 1½	–	30	5000	-5	15	200	50	P	–	–	M	–	L	H	M	P	–	–	–
Laloki	* 1%	–	70	* ½%	30	150	70	2000	P	P	P	L	–	L	H	L	P	P	P	P
Laloki	* 1%	–	15	* ½%	7	300	100	1500	P	P	–	L	–	L	H	L	P	–	–	–
Moresby King	3000	5	100	* ½%	-5	10	20	-10	P	P	P	M	L	M	H	M	P	–	–	–
Moresby King	4000	-5	100	* ½%	-5	10	20	-10	P	P	P	L	L	L	H	M	P	–	–	–
Paree	700	–	50	* ½%	-5	10	–	50	P	–	–	L	M	L	H	M	P	–	–	–

P = present
L = low amount present
M = medium amount present
H = high amount present
-5 = less than 5 p.p.m.
– = sought but not detected
All values in p.p.m. except where shown as %

Ti is low in all specimens: Na, B and P are absent.

* = greater than.

5. If the ores are considered to be epigenetic (as many previous workers have assumed), field evidence indicates that the only source that could have given rise to the mineralisers is the Sadowa Gabbro, or differentiates of it. The mineralogical and chemical analyses of these ores, when compared with the composition of ores derived from a basic igneous source suggest that this is highly unlikely. In the Astrolabe ores there is a notable lack of pyrrhotite, ilmenite, cobalt and nickel minerals and of magnetite. The abundance of chalcedony is anomalous for ores of suggested basic igneous origin. The chemical analyses show that the content of Ni, Co, Ti, Na and Mg is lower; and the content of Sn and Pb, is higher than expected in ores of basic origin.

It is concluded that the mechanism of the formation of the sulphides and their subsequent reconstitution is well understood. The origin of the ores however is conjectural; they most likely had a syngenetic origin but their distribution and abundance cannot be explained to the extent that an interpretation can be made of areas in the Field which are likely to contain concealed ore-bodies.

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Fig. 1 Banding and folding in sulphide ore. Chalcopyrite (ch), sphalerite (sp), fine grained sub-hedral and spheroidal pyrite bands (py), barytes gangue (ba). Figs. 2-9 are from areas in the main fold.

Laloki Mine X4. Negative No. G/4596.

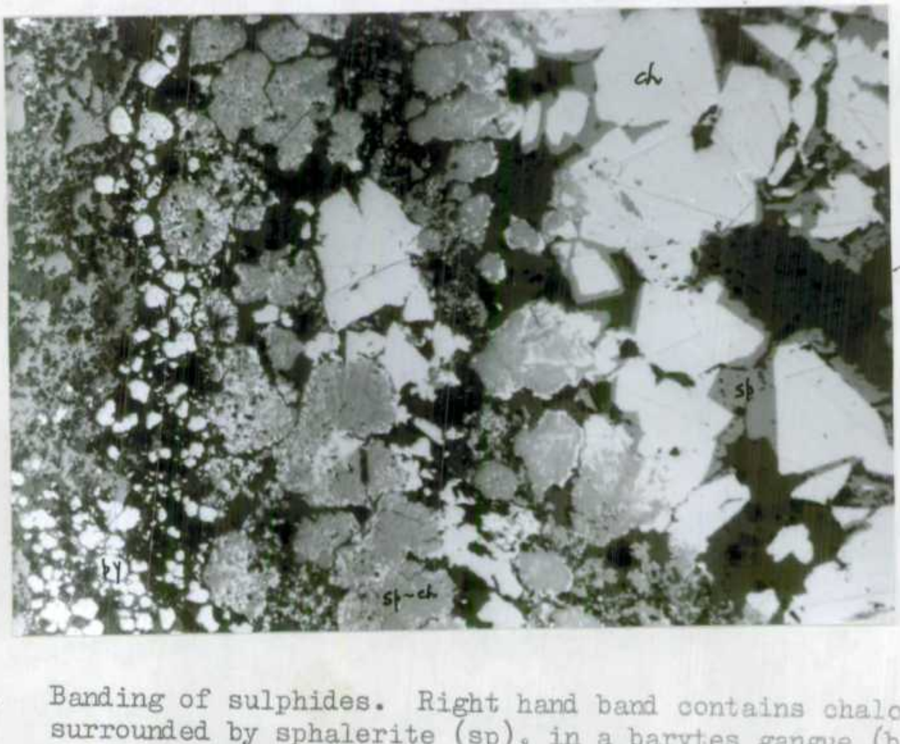


Fig. 2. Banding of sulphides. Right hand band contains chalcopyrite (ch), surrounded by sphalerite (sp), in a barytes gangue (ba). In the centre band sphalerite is partly segregated from chalcopyrite (sp-ch). The white grains in a band on the left hand margin are subhedral and spheroidal pyrite (py).

Laloki Mine. X106. Negative No. M/387/17.

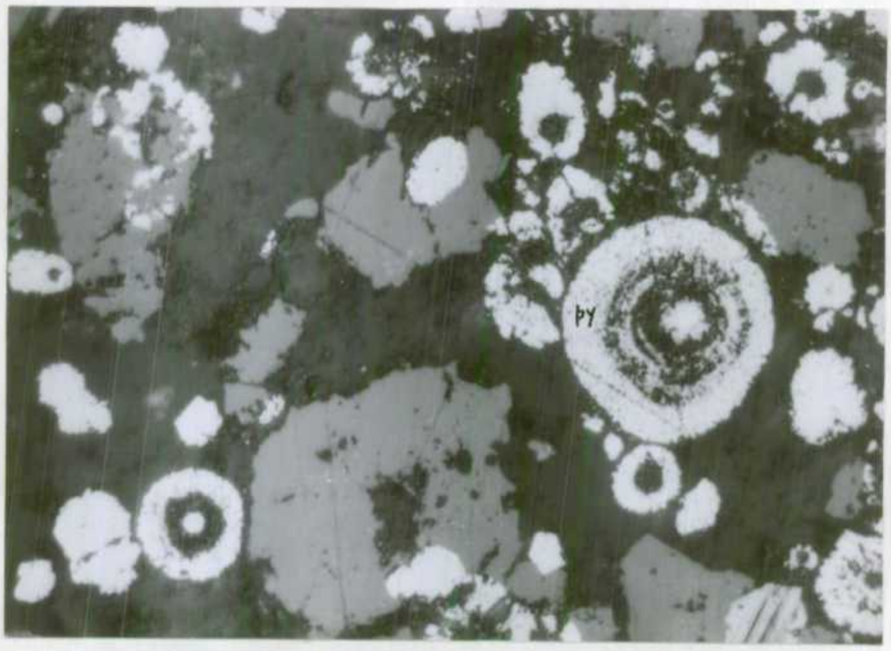


Fig. 3. Spheroidal pyrite (py) and amorphous grains of admixed sphalerite and chalcopyrite (sp - ch) in barytes gangue.

Laloki Mine. X675. Nagative No. M/387/29.

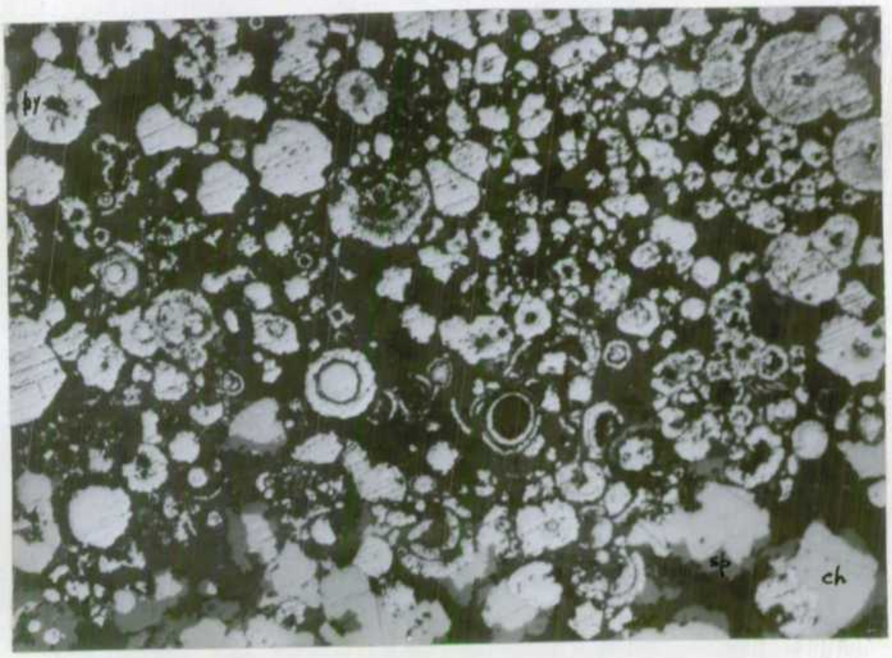


Fig. 4. Spheroidal pyrite (py) and grains of chalcopyrite (ch), surrounded by rims of sphalerite (sp).

Laloki Mine X270 Negative No. M/387/25.

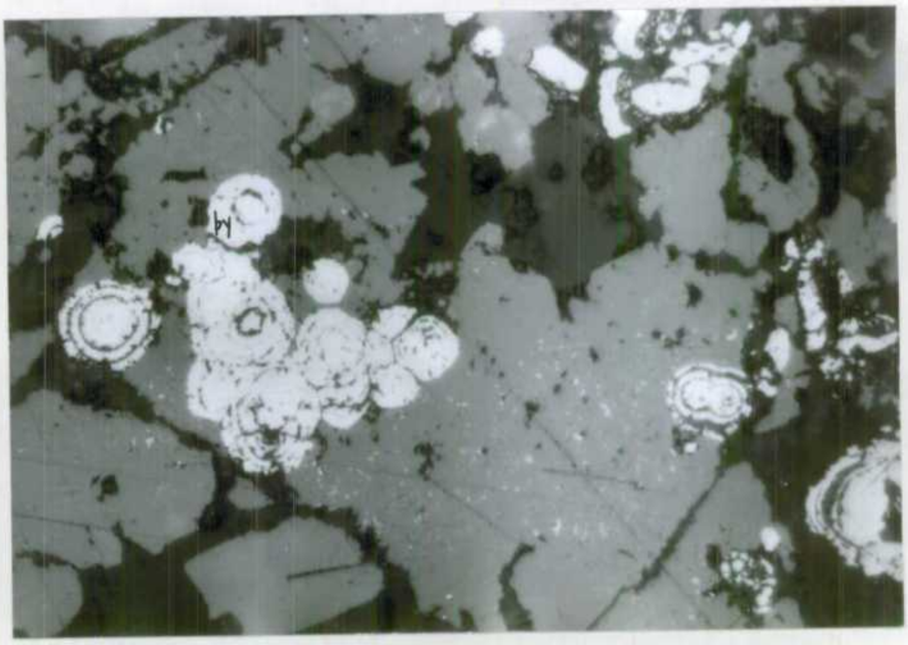


Fig. 5. Spheroidal pyrite (py) in amorphous grains of admixed sphalerite and chalcopyrite (sp - ch).

Laloki Mine X675. Negative No. M/387/28.

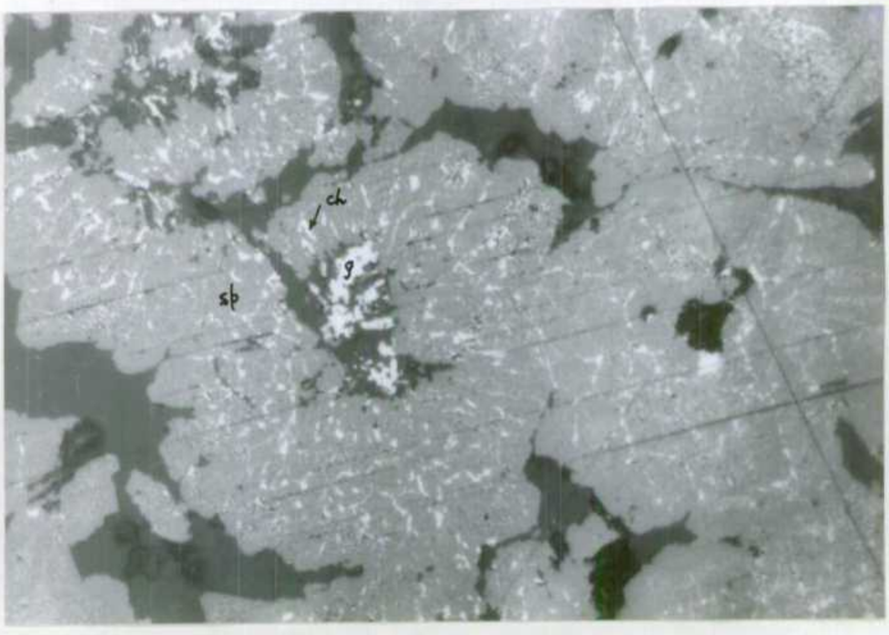


Fig. 6. Amorphous grains of admixed sphalerite (sp), chalcopyrite (ch), and galena (g), in barytes gangue.

Laloki Mine X675. Negative No. M/387/20A.

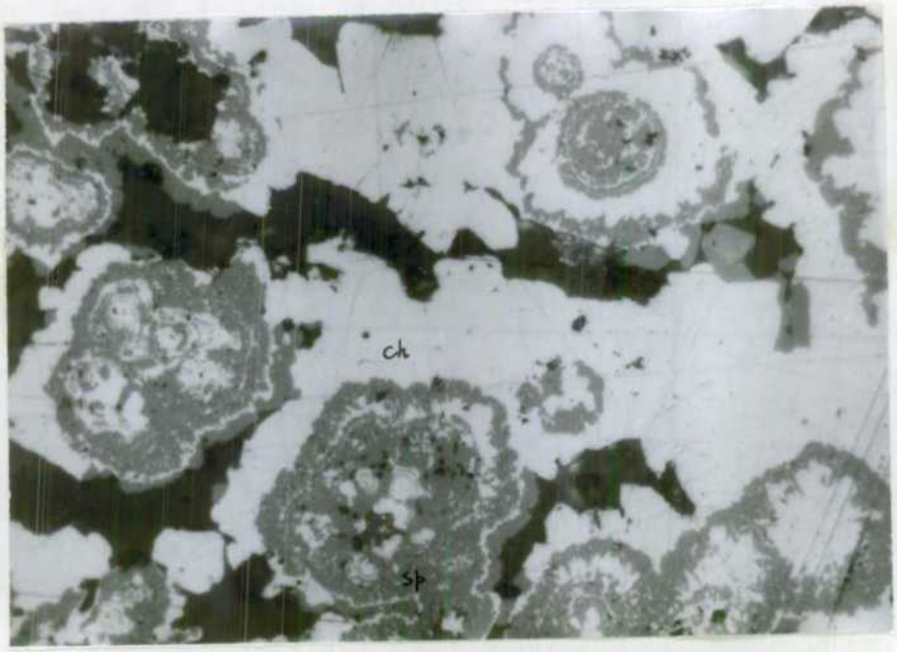


Fig. 7. Textures indicating diffusion of sphalerite (sp) from chalcopyrite (ch) which occurred during the crystallisation of chalcopyrite subsequent to its colloidal precipitation with sphalerite.

Laloki Mine. X675. Negative No. M/387/26.

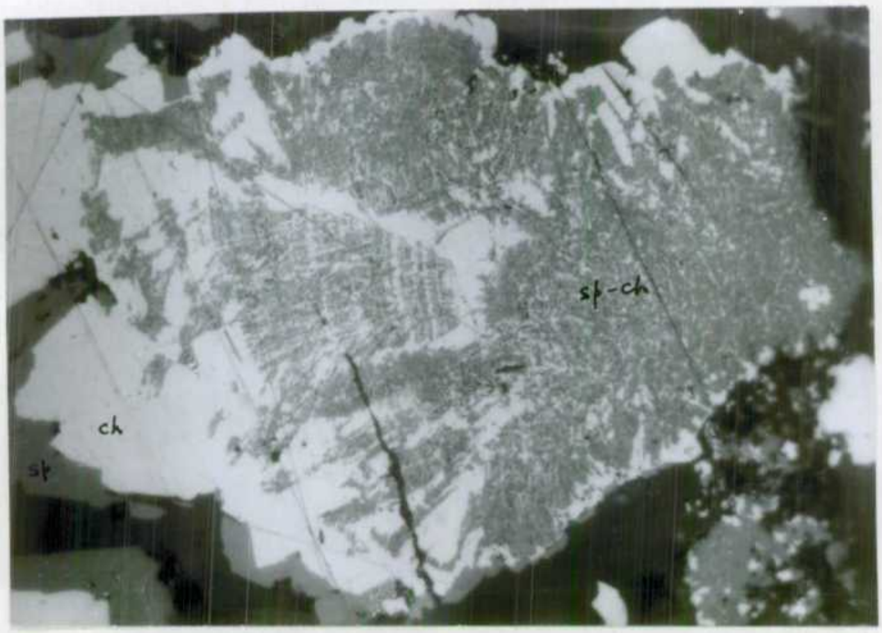


Fig. 8. Textures indicating segregation of sphalerite (sp) from chalcopyrite (ch) and forming rims around chalcopyrite.

Laloki Mine X675. Negative No. M/387/22A.

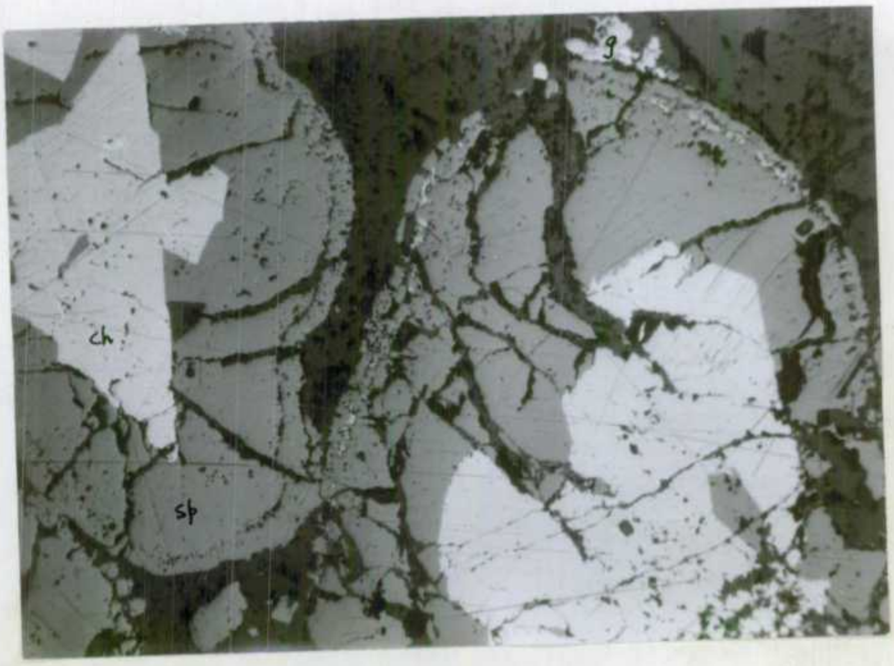


Fig. 9. Sphalerite (sp) and galena (g) which have segregated from, and now surround crystalline chalcopyrite (ch). Note the botryoidal margins of sphalerite in contact with the barytes gangue. (ba).

Laloki Mine X106. Negative No. M/387/16.

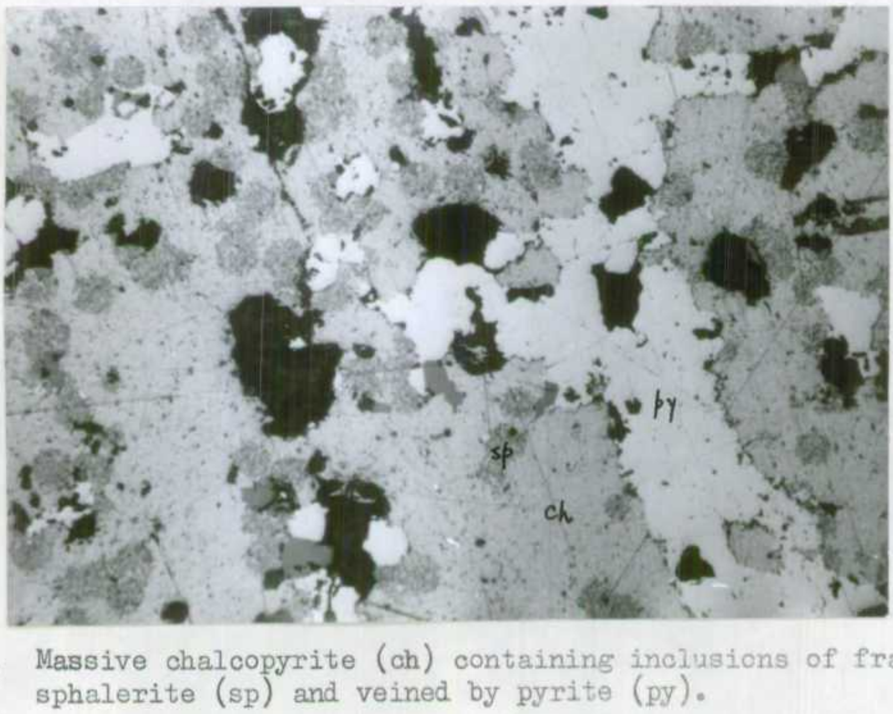


Fig. 10. Massive chalcopyrite (ch) containing inclusions of framboidal-like sphalerite (sp) and veined by pyrite (py).

Sapphire Mine. X270. Negative No. M/387/12.

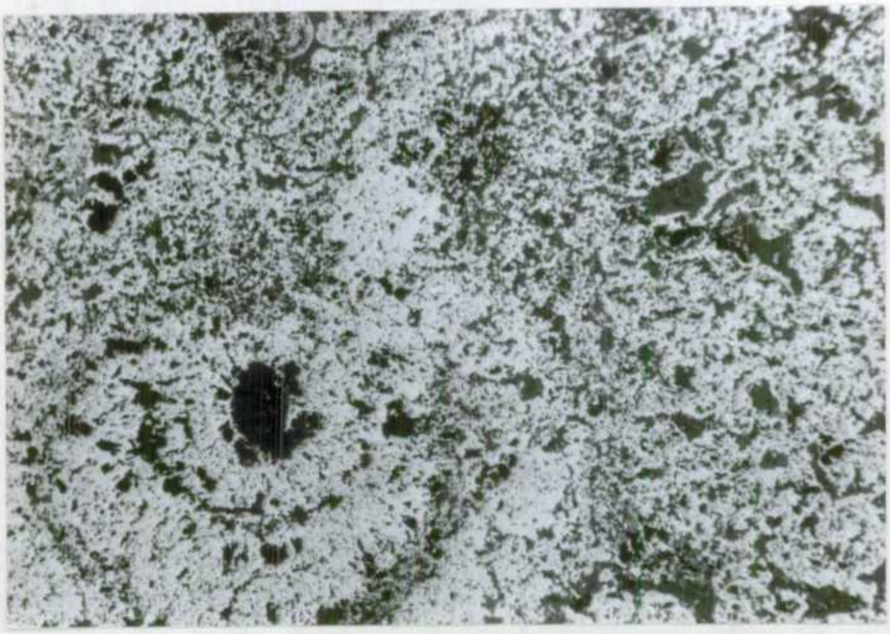


Fig. 11 Roughly concentric aggregate structures of granular pyrite.

Dubuna Mine X42. Nagative No. M/387/4.

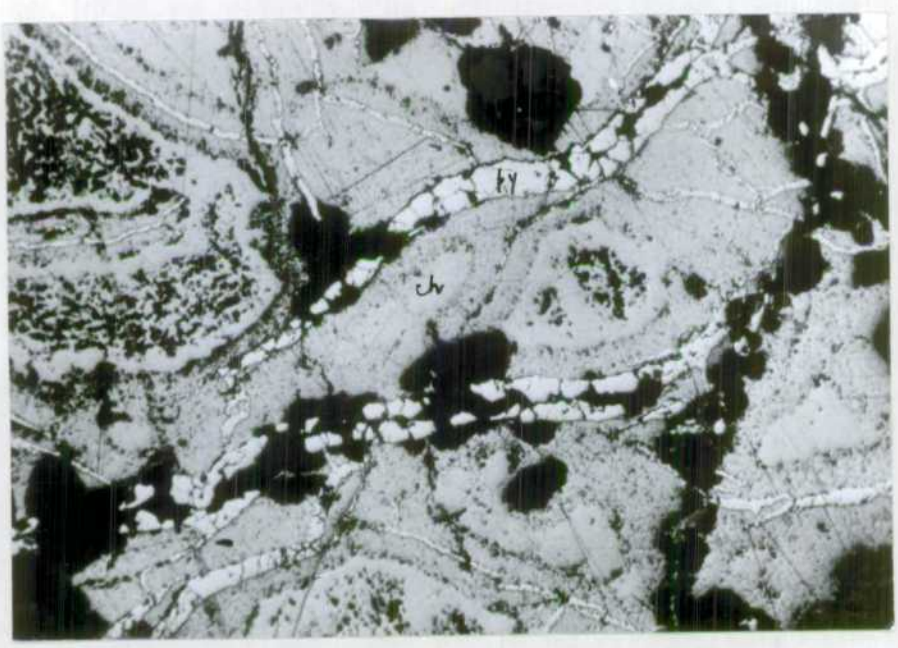


Fig. 12 Zoned chalcopyrite masses (ch) veined by a later generation of granular pyrite (py).
Sapphire Mine. X106. Negative No. M/387/9A.

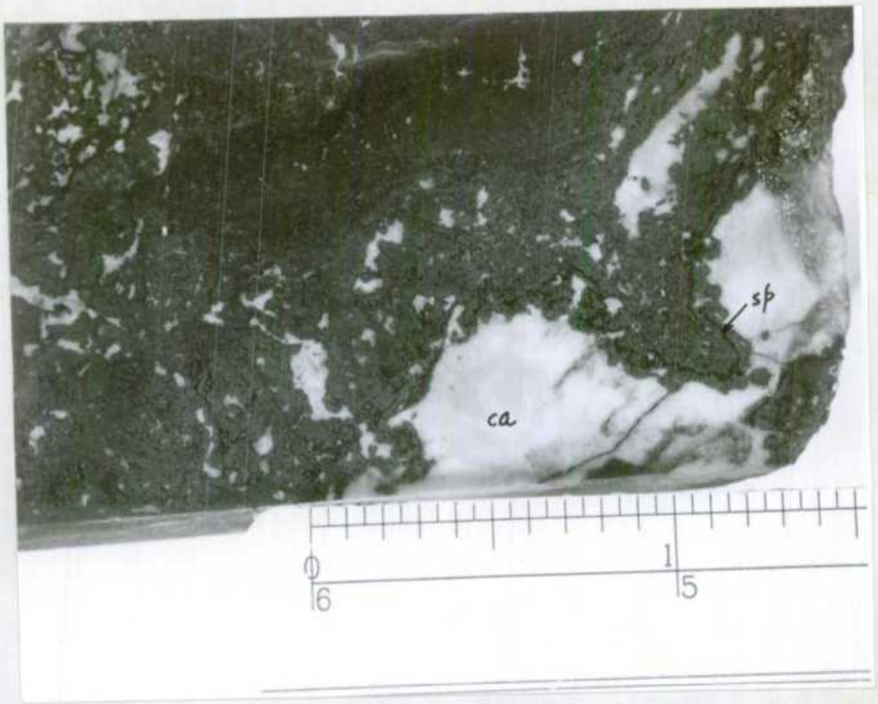


Fig. 13. See in fine detail scalloped bands of iron-sulphides conformable to contact with calcite (ca). Note intercalated fine bands of sphalerite (sp). Bands of galena also occur in this section but these are not obvious.

Elvina Mine. Scale 0 to 1 = 1 inch. Negative No. F/4629.

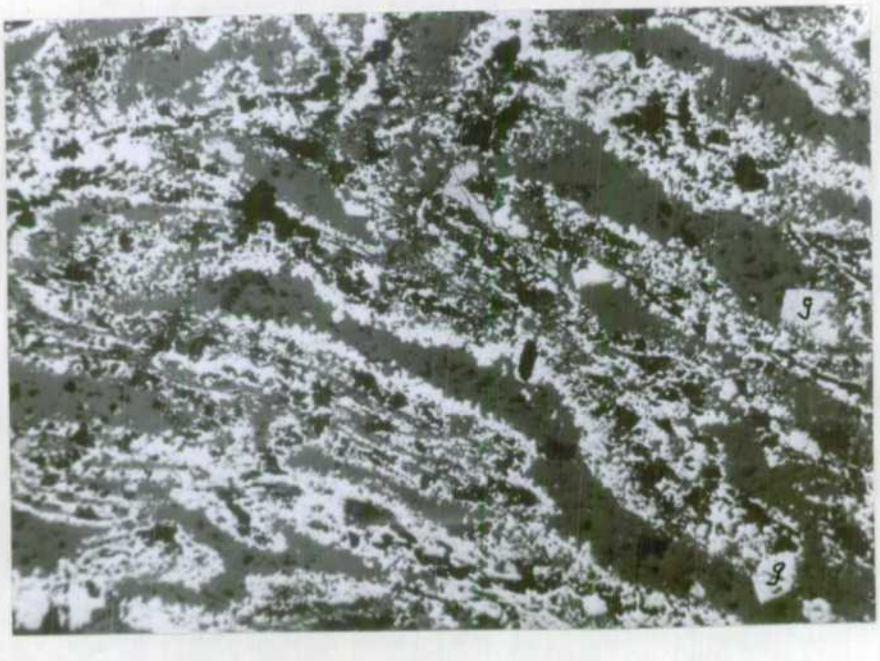


Fig. 14. Bands of granular marcasite in calcite gangue; free euhedral galena grain (g).

Dubuna Mine. X106. Negative No. M/387/5.

Fig. 15. Foliae of magnetite (mg) scattered through a talc gangue.

Laloki, DDH. SC4, 285 ft. X106
Negative No. M/393.

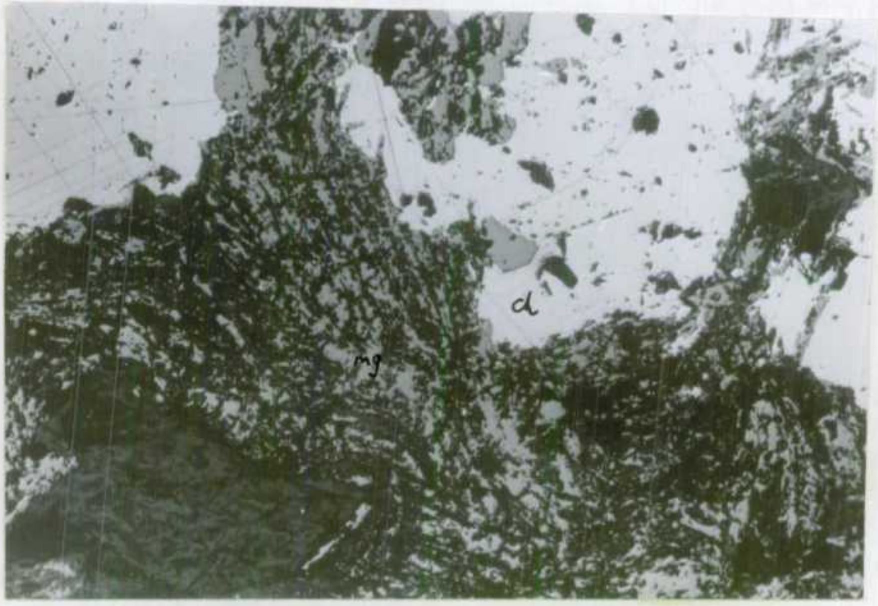


Fig. 16. Sheath like aggregates of magnetite (mg) in talc within spaces between chalcopyrite masses (ch).

Laloki DDH SC4, 281 ft. X106
Negative No. M/393.

Fig. 17 Laths of magnetite (mg) growing into and replacing brecciated, euhedral pyrite (py).

Laloki DDH. SC4, 284 ft. X270. Negative No. M/393.

Appendix A

Description of polished-sections and thin-sections.

Mine or Prospect	Regst. No.	No. of P/S.	T/S.
Dubuna	04071701	1	
Elvina	04071702	1	1
Elvina	04071703	3	
Sapphire	04071704	1	1
Mt. Diamond	04071705	1	1
Mt. Diamond	04071706	1	
Laloki	04071707	2	
Laloki	04071708	2	
Moresby King	04071709	2	
Moresby King	04071710	2	1
Paree	04071711	1	
Ventura	-	1	
D.D.H. SC4 Laloki			
274' - 275',	-	1	
281' - 282'	-	1	
284' - 285'	-	1	
285' - 286'	-	1	1

Dubuna Mine.

Regst. No. 64071701. (Refer to figs. 11 & 14).

Minerals identified. Major pyrite, marcasite. Minor chalcopyrite sphalerite, galena, hematite, calcite.

Description of hand-specimen. This is a massive ore which consists mainly of pyrite and marcasite; in some parts of the specimen these form undulating scalloped bands. Minor sphalerite and chalcopyrite occur between these masses and bands. Calcite is the only gangue and calcite crystals crowd together in voids within the ore.

Description of polished-section. The approximate proportions of the ore minerals are, pyrite-marcasite 85%, sphalerite 10%, chalcopyrite 3%, galena 2%, hematite 1%.

Most of the iron-sulphides are marcasite but in some aggregates and grains this grades imperceptibly into pyrite. These minerals generally occur in irregular aggregates as small euhedral and subhedral grains which have a fairly uniform size of an average of 0.3mm. across; they are generally not fractured.

Within the aggregates the iron-sulphides occur in a variety of forms.

a. Adjacent to the calcite gangue layers of subhedral grains form folded scalloped bands up to 2mm. wide and 7mm. long. In some bands there is a progressive vertical grading from fine grained layers to relatively coarse grained layers.

The outer layers nearest the gangue are generally marcasite.

b. Granular, chain-like bands of euhedral pyrite and marcasite grains enclose and partly enclose chalcopyrite, sphalerite and galena. Some marcasite rims around chalcopyrite are intimately intergrown with sphalerite.

c. Granular strings of pyrite and marcasite intimately follow crystal planes in some lenses of calcite gangue.

d. Colloform like bands of granular pyrite are commonly intergrown with poorly developed bands of sphalerite.

e. In some places, concentric, spongy bands of granular pyrite form spheroids which measure up to 2mm. in diameter.

Pyrite and marcasite also occur as single euhedral and subhedral grains in the calcite gangue.

The other sulphides in this section have a chaotic distribution.

Sphalerite forms irregular masses within pyrite aggregates, in the calcite gangue and intercalated with iron-sulphide bands. The masses have an average size of about 0.3mm. and a maximum size of about 2mm.

Some sphalerite encloses and intrudes pyrite, chalcopyrite and galena; it is itself enclosed by pyrite and less frequently by galena and chalcopyrite.

Much of the sphalerite contains small amounts of chalcopyrite inclusions; these have an irregular shape and they are randomly distributed through the host. Some of the inclusions appear to be an emulsion textured exsolution type, most however occur in anastomising vein-like and fine graphic intergrowths in the host.

Chalcopyrite also occurs as discrete grains in the gangue and in the pyrite matrix. In some places fine rods of chalcopyrite are oriented along the crystal planes of calcite.

Galena typically forms subhedral grains and allotriomorphic masses; these have an average size of 0.15mm. and they most commonly fill spaces within granular pyrite and enclose small pyrite grains.

Some galena crystals are partly replaced and cut by veins of granular pyrite-marcasite.

Galena forms composite grains with sphalerite and chalcopyrite and commonly it encloses grains of these minerals.

Calcite fills intergranular spaces, fractures and other voids within the ore mineral aggregate. The calcite carries single grains of the sulphide minerals and also minor amounts of specular hematite.

Elvina Mine.

Regst. No. 64071702

Minerals identified, pyrite, sphalerite, chalcopyrite, quartz.

Description of hand-specimen. This is a grey, extremely fine grained siliceous rock which contains irregular patches and veins of finely granular pyrite.

Description of thin-section. In this section the matrix surrounding the opaque minerals consists of a micro-mosaic of cryptocrystalline quartz which contains accessory amounts (2%) clay particles. Individual quartz grains have a spherulitic extinction under crossed nicols suggesting that this siliceous material is chert. The chert grades away from the opaque mineral boundary zone into a dirty cryptocrystalline matrix of quartz.

Cavities within the ore mineral aggregate are lined and filled with crypto-crystalline quartz which has a minutely fibrous fan-shaped structure and a spherulitic extinction under crossed nicols. These features are characteristic of chalcedony.

Description of polished-section. Pyrite is the predominant ore mineral in this section; it occurs in veins and breccia fragments which form irregular masses. In the veins the pyrite forms euhedral and subhedral grains, many of these are brecciated.

Minor sphalerite and chalcopyrite grains occur in voids within the pyrite aggregates and also the veins.

Marcasite was not recognised in this section.

Elvina Mine

Regst. No. 64071703. (3 sections were examined).

Minerals identified. Major pyrite, marcasite, hematite. Minor chalcopyrite, sphalerite, galena, ? cubanite, calcite, goethite.

Description of hand-specimen. This is a massive brecciated ore containing pyrite, chalcopyrite and minor sphalerite. Calcite occurs in stringers, veins and patches between the ore minerals.

Part of the specimen consists of multiple, roughly conformable, fine scalloped layers of intercalated pyrite, calcite and rarely sphalerite. These appear to be successive wave fronts conformable to the contact of sulphides and calcite gangue.

Veins of calcite cut through ore minerals and also through patches of crystalline calcite.

Descriptions of polished-sections.

64071703. A. On a macroscale this section shows fine interlayering of scalloped chains of granular pyrite; these partly enclose masses of chalcopyrite.

In the section pyrite is severely brecciated and pulverised, most of it is granular and typically it is intimately intergrown with marcasite. Interstices are filled with calcite, hematite and chalcopyrite.

Hematite occurs in a variety of forms.

a. As small spheroidal bodies in calcite, these are partly replaced by a rim of hydrated iron oxide.

b. Irregular masses, and less commonly spheroidal bodies, filling interstices in pyrite aggregates.

c. As inclusions in some pyrite forming narrow zones which are conformable with the external shape of the host grain, also surrounding subhedral pyrite grains in calcite.

d. As small curved shells in calcite. These may be remnants of spheres of hematite.

e. As rods and stringers localised along inter-crystal contacts of calcite.

Granular rims of pyrite commonly surround hematite.

Chalcopyrite occurs in irregular spongy masses in the pyrite aggregates; commonly it forms a reticulated intergrowth with pyrite which suggests that chalcopyrite is invading pyrite and replacing it. Some of these zones have differentiated into bands of different concentrations of the two minerals, this produces a poorly defined banding.

Single grains of chalcopyrite occur in the calcite gangue.

Chalcopyrite grains are moderately fractured but not as severely as pyrite. Some consist of a skeletal framework which suggests that the original crystal has been extensively leached.

Small blebs (0.005mm.) of chalcopyrite and a pink-brown mineral occur in some coarse grained pyrite. The pink-brown mineral was not positively identified but it is most likely cubanite.

No sphalerite is present in this section.

64071703.B. Most of this section consists of fine grained pyrite which occurs in rather spongy aggregates. Individual grains are commonly euhedral, most are brecciated, partly made over to marcasite and typically they form poorly defined curved zones.

Chains of euhedral pyrite crystals which occur through the matrix and cut the spongy masses appear to be recrystallised pyrite.

A straight vein of severely brecciated, anhedral, coarse grained pyrite cuts through the section. The grains appear to have been forced together which has resulted in them being pulverised.

Calcite fills most voids in the rock and cements breccia fragments of pyrite.

Chalcopyrite forms porous masses mainly in the calcite gangue; these are localised in cavities between euhedral pyrite-marcasite.

Sphalerite associated with minor chalcopyrite occurs along the edge of the coarse pyrite vein. Veins of calcite through the pyrite aggregate carry chalcopyrite and pyrite grains.

64071703.C. (Refer to Fig. 13).

The scalloped bands seen in the hand specimen are made up of granular pyrite and marcasite. There is a much greater proportion of marcasite than in sections A&B, it commonly forms margins around the iron sulphides and this grades imperceptibly into a "core" of pyrite. Some grains consist entirely of marcasite. Typically, alternate bands of marcasite and pyrite make up grains which surround pockets of calcite; the marcasite under crossed nicols is seen to form oriented crystals radiating in a fan shape from the calcite contact.

It appears that where the carbonate gangue makes contact with pyrite the pyrite has been made over to marcasite. The alternate composition banding suggests a fluctuation of conditions of crystallisation of the iron sulphides.

Fine bands of sphalerite and galena commonly occur with the pyrite banding adjacent to, or one or two bands removed from some calcite filled cavities.

The galena in these bands forms euhedral and subhedral crystals 0.5 mm. across. These have been brecciated and calcite crystals cut some.

Chalcopyrite occurs as small masses, associated with calcite and enclosed in pyrite.

Sapphire Mine.

Regstr. No. 64071704. (Refer to figs. 10&12).

Minerals identified. Major pyrite,chalcopyrite, chlorite. Minor sphalerite, hydrated oron-oxides.

Description of hand-specimen. This is a massive ore which consists mainly of iron-sulphides and chalcopyrite.

Description of polished-section. This specimen consists mainly of irregular masses of chalcopyrite which contain chaotically scattered granular pyrite aggregates, veins of granular pyrite, minor sphalerite and hydrated iron oxides.

Chalcopyrite generally has a leached, and or corroded texture and in many grains zones of various degrees of leaching have formed parallel to the grain boundaries.

Small (0.08mm.) spherical bodies consisting of anastomising sphalerite blebs are scattered through most of the chalcopyrite. This relationship indicates that the arrangement of the sphalerite blebs within these bodies is controlled by the crystal structure of the chalcopyrite host.

Chalcopyrite masses are extensively veined and their edges are commonly rimmed by reticulated intergrowth of granular pyrite. This pyrite generally grades imperceptibly into marcasite which is the major iron sulphide in many veins. Chalcopyrite also encloses grains of quartz carrying pyrite inclusions; veins of granular pyrite cut all three of these components.

Voids between the chalcopyrite are filled with skeletal masses and fibrous aggregates of hydrated iron oxides (limonite). Limonite encloses and partly encloses grains of pyrite and chalcopyrite; it does not appear to be derived from these sulphides since the contact is sharply defined and much of the pyrite has a sharp euhedral outline.

Some cavities in the specimen are filled with extremely fine grained aggregates of randomly oriented chlorite flakes. An x-ray diffraction photo of this mineral failed to enable a positive identification to be made however it is most likely leuchtenbergite (clino-chlorite). The possiblity of this mineral being glauconite or antigorite was checked but found to be negative. These patches of chlorite make up about 15% of the section; they are commonly rimmed and stained by limonite. Minor amounts of brucite also fill some small voids in this specimen.

Calcite was not observed in this specimen.

Mt. Diamond.

Regst. No. 64071705
Minerals identified. Pyrite, chalcopyrite.

Description of hand-specimen. This specimen consists of a dark grey, extremely fine grained siliceous rock which contains narrow leached cavities more or less parallel to poorly defined banding in the rock. Fine grained pyrite is disseminated through the siliceous matrix. Narrow bands of quartz give rise to small veins which cut across the ?bedding.

Description of thin-section. The thin-section consists of a micro-mosaic of cryptocrystalline quartz which contains fairly evenly distributed, fine opaque grains. Under crossed nicols most of the quartz grains in the matrix show spherulitic extinction which is characteristic of chalcedony and chert.

Several thin fracture fill veins of crystalline quartz are randomly distributed through the rock. Isolated patches of medium grained allotriomorphic quartz aggregates incorporate minor amounts of interstitial clay.

In some areas, quartz grains which show a minutely fibrous texture are arranged in spherulitic aggregates. Some chains of quartz form colloform bands.

This rock is essentially chalcedony. The patches of siltstone may have been incorporated during the initial formation of the chalcedony or they may represent the original rock which has been replaced by chalcedonic silica.

Description of polished-section. Fine grained pyrite is ubiquitous through the section, individual grains generally have a euhedral shape and their average size is 0.04mm.

The distribution of the grains appears to be unrelated to the banding in the chert or to the quartz veins.

Minor amounts of discrete chalcopyrite grains are disseminated through the rock at random. These make up about 2% of the section.

Mt. Diamond

Regst. No. 64071706

Minerals identified. Major, pyrite. Minor, sphalerite, chalcopyrite, ?enargite.

Description of hand-specimen. This is a massive sulphide ore which consists mainly of fine grained pyrite. Most of the pyrite is concentrated in poorly defined disjointed, granular bands which are intercalated with ill-defined, discontinuous bands of non-carbonate gangue.

Description of polished-section. Most of the pyrite occurs as discrete euhedral grains which have an average size of about 0.12mm., these are moderately brecciated.

The coarse grains seem to have a random distribution in aggregates, the fine grains form short, disjointed bands.

Coarse-grained euhedral pyrite is commonly enclosed by a spongy rim of pyrite, the contact between the two is in some places sharp and in other places diffuse. This zoning may have occurred during the initial crystallisation of the pyrite or it may be a recrystallisation, corrosion or leaching effect which occurred after the primary crystallisation.

Some coarse euhedral pyrite carries bleb like inclusions of sphalerite and rarely chalcopyrite; commonly these inclusions are concentrated in zones which are parallel to the edges of the host crystal.

Pyrite also contains minor amounts of anisotropic brown-grey inclusions, their small size and restricted occurrence prevented a positive identification but they are most likely enargite.

Irregular patches of chalcopyrite and sphalerite occur in voids in pyrite aggregates; commonly these partly envelope some pyrite crystals. Much of the chalcopyrite contains bleb like inclusions of sphalerite.

Sphalerite is typically peppered with pyrite and minor chalcopyrite blebs.

Laloki

Regst. No. 64071707. (Refer to figs. 1-9).

Minerals identified. Major pyrite-marcasite, chalcopyrite. Minor sphalerite, galena, gold.

Description of hand-specimen. This is a massive ore consisting of almost equal amounts of chalcopyrite and pyrite with minor sphalerite. In some parts of the specimen these minerals form contorted disjointed bands up to 1cm. wide. Other parts are massive and show no banding.

Description of polished-section. The pyrite generally occurs as discrete grains which have an average size of about 0.015 mm. and many of which are partly made over to marcasite. The grains have a subhedral and less commonly a euhedral and spheroidal form. The fine grained pyrite is generally concentrated in patches and discontinuous bands which may fill voids within chalcopyrite masses.

Relatively coarse grained euhedral pyrite is associated with the chalcopyrite and sphalerite intergrowths, this contains bleb like inclusions of sphalerite. The pyrite is typically fractured.

The spheroidal pyrite occurs most commonly in the loose fine grained aggregates and bands but they also occur in the gangue between the other sulphide minerals. In section, the outside shape of the spheroidal pyrite grains may be rounded or irregular but within the grain there is one, (and in some places 2 or 3) concentric inner shells of pyrite and what appears to be a siliceous material. In some the presence of concentric cavities suggest that the original material has been removed.

Some spheroidal pyrite has a radial structure made up of intergrowths of pyrite and siliceous material; in some, sphalerite blebs are arranged concentrically and radially.

Grains consisting of 2 and as many as 5 spheroids were apparently joined early in their development to form one grain.

Several anhedral pyrite grains contain incomplete relic spheroidal forms. Admixed chalcopyrite and sphalerite enclose spheroidal pyrite.

Chalcopyrite occurs in large botryoidal, subhedral and some brecciated masses in which it is intimately associated with sphalerite and accessory amounts of galena.

Adjacent to cavities filled with barytes sphalerite forms rims around coarse subhedral chalcopyrite which is almost free of inclusions. The outer margins of the sphalerite rim is typically botryoidal.

In other areas where the minerals are more crowded, sphalerite, in addition to forming a narrow rim around chalcopyrite forms complex graphic and dendritic intergrowths with it. The intergrowths commonly have a scalloped colloform type of banding which form a cockade texture in some grains.

These textures appear to have derived by the segregation of sphalerite and chalcopyrite from a preexisting amorphous, homogeneous mixture of copper and zinc sulphides, in some places containing minor lead sulphide.

Amorphous looking masses in which sphalerite is the most abundant component are riddled by extremely fine anastomising veinlets and blebs of chalcopyrite. These have a random distribution and they give the sphalerite a brassy veneer.

In grains where some segregation of the two minerals has taken place chalcopyrite shows the beginnings of attaining a crystalline form and

In grains where some segregation of the two minerals has taken place chalcopyrite shows the beginnings of attaining a crystalline form and sphalerite forms banded, colloform, and emulsion type inclusions within it. The density of these varies and appears to depend on the extent to which the two minerals have segregated from their original state.

The various types of intergrowths and the extent of segregation are differentiated more or less into zones which impart a poorly defined macro-scale banding to the specimen. In some parts these bands are intercalated with bands of pyrite aggregates, in other areas all the sulphide minerals form complex aggregates with no discernable differentiation.

Small masses of sphalerite which are unrelated to ad-mixed chalcopyrite commonly carry inclusions of anhedral chalcopyrite grains, spheroidal pyrite and minor amounts of galena. Botryoidal banding occurs in some free grains of sphalerite in the carbonate gangue.

One grain of gold was observed in chalcopyrite, one in sphalerite and one in the barytes gangue between spheroids of pyrite. The diameter of these bleb-like inclusions is 0.02mm., 0.003mm., and 0.006mm. respectively.

Voids between and within the ore minerals are filled by barytes and less commonly chalcedonic silica. The barytes occurs in aggregates of medium sized lath like crystals; the silica is minutely crystalline, sub-translucent and is variegated by fine scalloped bands which are roughly conformable to the shope of the cavity. Both of these minerals may occur in the same void, and rarely fine veins of varytes cut through the silica suggesting that it formed later.

Laloki

Regst. No. 64071708 (Refer to figs. 1-9).

Minerals identified. Major pyrite, chalcopyrite sphalerite, Minor, galena, gold.

Description of hand-specimen. This is a massive ore of chalcopyrite, pyrite and sphalerite. Banding is more extensively developed in this specimen than in any others examined. The banding consists of more or less conformable bands of chalcopyrite (up to 5mm. wide), fine grained pyrite (up to 2mm. wide), sphalerite (up to 3mm. wide), with a core of barytes.

Description of polished-section. In this section the minerals have similar associations textures and structures as described in 64071707. Folds within the ore are made up of a fairly consistent sequence of mineral bands which occur in the following order, outwards from the core of the fold. The approximate width of these bands is given in the description of hand specimen.

a. Core of folds commonly consist of barytes.

b. The band adjacent to barytes consists of coarse subhedral grains of chalcopyrite which are rimmed by sphalerite. The sphalerite is commonly crustiform and its contact with barytes is typically botryoidal or a reticulated intergrowth zone.

c. Band (b) grades imperceptibly outwards into a zone which consists of chalcopyrite containing colloform, banded, graphic and dendritic intergrowths of sphalerite as described in 64071707. Rims of sphalerite in chalcopyrite are roughly conformable with the edges of the chalcopyrite host. Blebs of galena were observed in the centre of many of these mixed grains.

d. This zone grades into an area where sphalerite is the dominant mineral but it does contain intergrown chalcopyrite. The chalcopyrite occurs in an extremely fine anastomising vein system through the sphalerite. These masses are frequently made up of concentric colloform layers. The average size of the sphalerite spheroids is about 0.15mm.

Chalcopyrite forms radial and concentric structures in sphalerite and commonly narrow concentric bands of galena occur towards the outer margins of the sphalerite.

e. The zone (d) merges into an irregular band of fine euhedral, subhedral and spheroidal pyrite grains. Loose pyrite aggregates also partly fill voids between copper and zinc sulphides and in several places pyrite spheroids 0.07mm. across are enclosed in chalcopyrite and sphalerite. The pyrite is moderately brecciated and some spheroids are fractured and the fragments displaced. Hence brecciation occurred after the formation of these spheroids.

One grain of gold 0.003mm. across was observed in chalcopyrite.

D.D.H. SC4. Laloki

274 - 275 ft.

The hand-specimen consists of massive, severely brecciated chalcopyrite with fine grained magnetite filling some of the fracture cavities.

In the polished-section magnetite is seen to be mostly localised in voids within chalcopyrite.

The magnetite in patches and veins generally occurs in irregular masses up to 0.5mm. across; these are enclosed in a similar gangue to that in the specimen from 284 ft. which proved to be talc.

Isolated grains of magnetite (also mostly in voids) most commonly have a subhedral form but some are euhedral.

Accessory amounts of small, (0.01mm.) subhedral grains of magnetite are enclosed by chalcopyrite. These do not appear to have been introduced into cavities between breccia fragments but they seem to have been incorporated during the formation of the chalcopyrite host.

DDH SC4 Laloki (Refer to fig. 16).

281 - 282 ft.

The specimen is strongly magnetic, it is mainly massive chalcopyrite which contains irregularly shaped veins and masses of fine grained magnetite. The masses have a maximum size of 5mm. across.

In the polished-section the chalcopyrite is seen to contain abundant voids which typically contain subhedral grains and small masses of magnetite. Much of the magnetite, particularly euhedral grains, have grown into the chalcopyrite walls of these cavities, thus replacing them.

The magnetite in the centre of some of the larger masses has a bladed form and in some places foliae of magnetite form sheath shaped aggregates some of which appear to have been forced between fragments of chalcopyrite. Most magnetite is fractured.

Chalcopyrite carries minor bleb like inclusions of pyrite.

DDH SC4 Laloki (Refer to fig. 17).

284 - 285 ft.

This specimen consists entirely of a fine grained aggregate of bladed magnetite. Small films of talc show fine slickensides. The rock is strongly magnetic.

In polished-section the magnetite blades and foliae are seen to have a chaotic, random distribution. Some are grouped in sheath like aggregates, some form small irregularly shaped masses.

Magnetite carries accessory amounts of extremely fine inclusions of pyrite and rarely chalcopyrite and hematite.

Several euhedral pyrite grains in the section are brecciated and partly replaced by magnetite.

In thin-section the gangue material was identified as talc.

D.D.H. SC4 Laloki

285 - 286 ft. (Refer to fig. 15).

The hand-specimen is strongly magnetic and consists of densely packed, fine grained magnetite which contains disseminated grains of pyrite. Cavities in the rock are filled with talc and a small shear plane is lined by talc marked with fine slickensides.

In the polished-section magnetite is seen to occur most commonly in loosely packed shredded blades and foliae-like forms. Individual foliae measure up to 0.3mm. long and some of these are grouped in sheath like aggregates. Magnetite is also present in irregularly shaped masses and subhedral grains. Some magnetite carries fine (0.001mm.) inclusions of pyrite and rarely chalcopyrite. Some magnetite is fractured.

Pyrite, as discrete grains have an average size of 0.4mm. across; these are generally fractured and the breccia fragments are slightly displaced. Blades and sub-hedral grains of magnetite partly enclose pyrite and typically they partly fill fracture cavities and voids within the pyrite. In many places it appears that the magnetite (carried by gangue) has been forced between breccia fragments of pyrite and this has been largely responsible for their displacement. Blades of magnetite have frequently grown into pyrite and thus replaced it.

Several small spheroidal shaped grains of pyrite occur in the rock matrix.

Small irregularly shaped grains of chalcopyrite are disseminated through the section and make up about 2% of the rock. These occur near pyrite, and commonly the two minerals are intergrown.

The chalcopyrite is also fractured and magnetite partly encloses it and occurs in voids of most grains.

Moresby King

Regst. No. 64071710

Minerals identified. Major pyrite quartz. Minor marcasite chalcopyrite, specularite, sphalerite, rutile.

Description of hand-specimen. This specimen is a finely cellular mass of sulphide minerals consisting mainly of laths and masses of quartz enclosed by fine crystals of pyrite. Crypto-crystalline silica fills some cavities in the rock. Hydrated iron oxides encrust the weathered surface.

Description of polished-section. The mineral associations in these sections differ slightly from those in 64071709 which is also from Moresby King.

The sections consist mainly of a fine skeletal network of euhedral iron sulphides with quartz filling most of the cavities. Pyrite is the dominant mineral and this is intimately intergrown with minor amounts of marcasite.

Some euhedral pyrite grains form lath shaped aggregates, generally however they occur in short chain like bands, many of which form the perimeter of roughly quadrangular and rectangular structures. The out-side margin of these forms is usually straight, the inside margin is irregular indicating that free crystal growth of the pyrite only took place towards the centre.

Quartz typically fills the space enclosed by pyrite rims so that much of the quartz occurs in lath shaped crystals. Quartz also fills intercrystal voids of pyrite aggregates and veins of quartz cut through some of the ironsulphides.

Abundant, equi-sized flakes of specularite are carried by the quartz, most of these have a random distribution, but in some of the laths the long axis of the flakes is oriented parallel to the length of the lath.

Quartz also carries inclusions of euhedral pyrite, minor amounts of small chalcopyrite masses and under crossed nicols it is seen to contain abundant long fine needles of a highly refractive mineral. These needles have a random distribution; in some places they form dense fibrous aggregates. These were also examined in thin-section and the combination of their properties indicates that they are almost certainly rutile. Some of the quartz filling the cavities is zones by scalloped colloform bands which are roughly conformable to the walls of the cavity.

Chalcopyrite occurs in spongy looking masses; these are extensively replaced by quartz and fine grained pyrite in quartz. The quartz and granular pyrite has invaded chalcopyrite along crystal planes and in many places the shape of previously existing chalcopyrite is outlined by a rim of pyrite grains surrounding quartz.

This pyrite is the same as the second generation pyrite described in 64071709.

Some chalcopyrite carries small inclusions of sphalerite.

Moresby King

Regst. No. 64071709

Minerals identified. Major arsenopyrite, pyrite, marcasite, chalcopyrite. Minor sphalerite, specularite, chlorite, quartz, limonite.

Description of hand-specimen. This is a massive sulphide ore; it is oxidised on the weathered surface to gossanous box-works which have formed from sulphides.

Description of polished-section. Two sections were examined. Large (average 1 mm. across) subhedral and euhedral grains of arsenopyrite, most of which are brecciated and pulverised, are distributed at random through the section. In some places euhedral arsenopyrite grains form scalloped bands and spheroidal structures; in one area they form a roughly oval shaped rim around an irregular core of spongy looking pyrite. The outer margins of the pyrite core are intergrown with fine bands and lenses of marcasite and arsenopyrite.

Two generations of pyrite occur in this section. One consists of large lath shaped masses of spongy looking pyrite which fills cavities between and cements fragments of arsenopyrite. In places it forms a mottled intergrowth with arsenopyrite, extensively replacing it. The spongy texture of this pyrite has facilitated the alteration of it to limonite.

The second generation pyrite occurs in fine-grained aggregates which commonly form a reticulated intergrowth surrounding chalcopyrite. This generation pyrite also occurs in granular chain like veins which cut through chalcopyrite and in feathery acicular aggregates and bands.

Chalcopyrite occurs in fractured and leached masses many of which contain banded leach zones roughly conformable to the outline of the grains.

Some chalcopyrite encrusts and intrudes into the spongy laths of the first generation pyrite but it is itself extensively replaced by the second generation pyrite.

Minor amounts of small (0.02mm.) sphalerite inclusions occur in some chalcopyrite.

Many voids between the ore minerals are filled with extremely fine grained aggregates of chlorite flakes some of which carry specularite and hydrated iron-oxides. In one section a narrow vein of specularite (1 mm. wide) cuts through all the other minerals.

Some cavities are filled with quartz.

Paree

Regst. No. 64071711

Minerals identified. Major pyrite, marcasite. Minor chalcopyrite, hematite, calcite.

Description of hand-specimen. This is a massive sulphide ore which is cut by stringers and veins of calcite.

Description of polished-section. Fine, euhedral and subhedral grains of iron-sulphide are scattered in loose aggregates through a calcite gangue. The grains consist of intimately intergrown pyrite and marcasite; they have an average size of 0.04mm.

In part of the section the iron-sulphide grains form finely scalloped bands some of which surround small pockets of calcite.

Patches of chalcopyrite up to 0.5mm. across occur in the gangue, these typically intrude pyrite aggregates.

Minor-accessory grains of hematite also occur in the gangue, these have a random distribution.

Ventura

Minerals identified. Major pyrite. Minor chalcopyrite, covellite.

Description of polished-section. This section consists of fine euhedral and subhedral pyrite grains disseminated through a siliceous gangue.

There are two size groups of the pyrite.

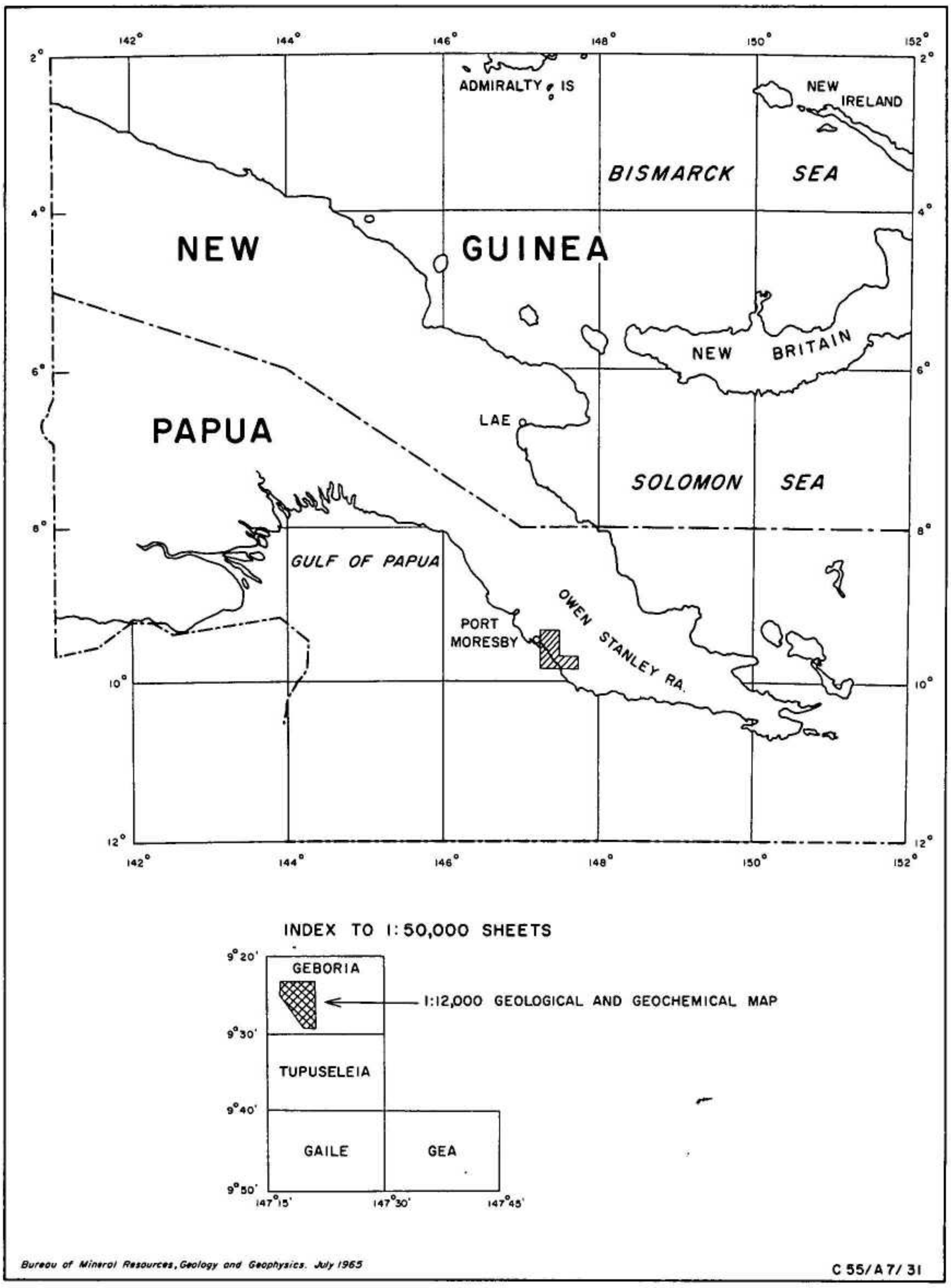
The fine-grained pyrite has an average size of 0.02 mm. and this is generally localised in patches.

The coarse-grained pyrite has an average size of 0.4 mm., this commonly forms chain like bands through the gangue, some of which surround the fine grained patches.

Many of the pyrite grains are brecciated and fine fragments have been strung out through the quartz gangue.

Small discrete masses of chalcopyrite occur in quartz within interstices of pyrite, these are commonly partly altered to covellite and in some places single grains of covellite indicate complete replacement. This is the only evidence of supergene alteration of the chalcopyrite in all of the sections examined.

Figure 1



To accompany Records 1965/132 & 1965/161


PLATE 8
GEOLOGY AND GEOCHEMISTRY
ASTROLABE MINERAL FIELD
TERRITORY OF PAPUA-NEW GUINEA
SCALE 1:12,000
0 1000 2000 3000 FEET
CAINOZOIC
QUATERNARY Recent
Qra Alluvium
Qrs Scree
TERTIARY
Pliocene Astrolabe Agglomerate Tpa Massive, coarse, dark grey basaltic agglomerate; tuff and basalt lenses
Middle-Upper Miocene Siro Conglomerate Tms Poorly consolidated conglomerate, siltstone
Oligocene Sadowa Gabbro Tos Coarse to fine olivine gabbro, gabbro, pyroxene hornblende diorite
Eocene Port Moresby Beds Tem Thin-bedded to laminated, grey or pink calcilutite and lutite; black, grey, green shale; calcilutite and lutite breccia; dark grey tuff. Red to pink massive calcilutite or limestone
g Gossan
gs Iron stained sediments
Geological boundary (broken where location approximate, queried where inferred)
Strike and dip of strata – measured
Strike and dip of strata – prevailing
Vertical strata
Strike and dip of foliation
Shaft
Shaft–inaccessible
Portal and approach of adit
Portal and approach of adit-workings inaccessible
Mine dump
Costean
Unworked deposit of Copper
Minor occurrence of Copper
Road
Vehicle track
Foot track
Power transmission line
Timber edge
"Laloki" Homestead
Buildings
Contours at 10' intervals; datum: mean sea level, Port Moresby
Trigonometrical station
●1267 Stream sediment sample
295/4 Stream sediment sample and detrital magnetic concentrate
Cu250 Anomalous stream sediment sample containing 250 p.p.m. Copper
*Cu250 Contaminated anomalous stream sediment sample containing 250 p.p.m. Copper
MCu250 Anomalous detrital magnetic concentrate containing 250 p.p.m. Copper
CxCu Cold extractable Copper
Zn Zinc
Compiled and published by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Base map compiled for the Division of National Mapping, Department of National Development by Queensland Aerial Survey Company Pty Ltd and Australian Aerial Mapping Pty Ltd from aerial photographs flown in 1964. Some additions to the base map by the Bureau of Mineral Resources field party
Geology, 1964, by: K. R. Yates, R. Z. deFerranti, J. F. Ivanac, I. R. Pontifex
Compiled, 1965, by: R. Z. deFerranti, A. Skoda
Drawn by: A. Skoda
To accompany Report 105 and Records 1965/132, 1965/161
C55/A7/28
29,367,000'N
1,747,000'E
1,756,000'
SECTION
Scale ratio: V/H = 1
Folding partially schematic. Recent scree omitted from section
A
B
Foot track
Eriama Creek
Sapphire Mine
Sapphire Creek
Track
Laloki River
Rouna Road
Tem
Tos
Tem ?
Tms
HOSPITAL HILL
Moresby King
Sapphire
Federal Flag
Merrie England
Sapphire King
BROWN HILL
SADOWA
FORTRESS HILL
WINDCOCK RIDGE
Ruby
KATHS CREST
Dubuna
Elvina
Mount Diamond
Molberi Village
Hercules