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GRUM JOINT VENTURE

GEOLOGY REPORT

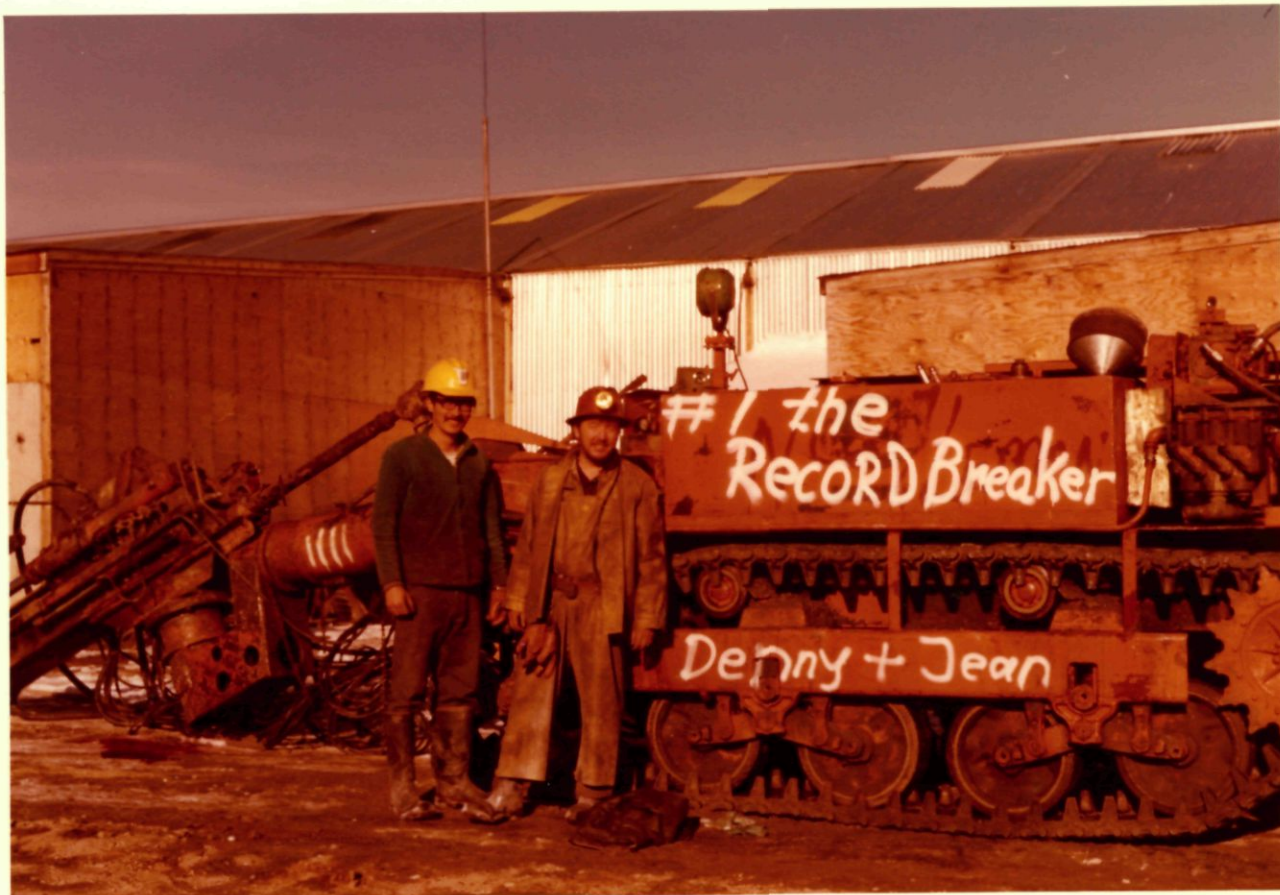
GRUM DEPOSIT - VANGORDA CREEK AREA, Y.T.

N.T.S. 105-6

by

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FEBRUARY 1978



The authors, J. Paxton and A.Y. Po in front of the "Superdrill" manufactured by the drilling contractor on the Grum project, Canadian Mine Services Ltd. This drill held the world record for underground footage drilled in a two week period in 1976.

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SUMMARY

The Grum deposit is located in the southwest flank of the Anvil Range in the south central part of the Yukon Territory. Drill indicated mineral reserve is 26 million tonnes of 10.5% combined lead-zinc and 62 gms/t silver.

The sulphide bodies are closely associated with an interstratified sequence of carbonaceous, tuffaceous and calcareous pelitic sediments. Sedimentation took place in a tectonic basin with local depressions that acted as depositional traps. Regional metamorphism deformed the whole basin structure causing complex folding and alteration of the sedimentary pile into low and medium rank metamorphic rocks. Intrusion of the Cretaceous Anvil batholith further compounded the structural complexity of the area. Deposition of the sulphide was mainly by biochemical precipitation and mechanical sedimentation.

Pyrite, sphalerite and galena constitute the dominant base metal sulphides. Minor minerals are chalcopyrite, arsenopyrite, tennantite, pyrrhotite, marcasite and magnetite. The paragenetic sequence for the sulphides is not clearly defined. It is believed that pyrite formed first and was followed by the rest of the sulphides with crystal growths from numerous nuclei. Source of the metallic cations was from volcanic activity distant from the depositional trap. These cations were transported by density current in the form of solutions, colloidal suspensions and crystal aggregates.

Drilling has established the continuity of two folded sulphide layers and indicated the presence of other peripheral sulphide occurrences. The question of whether these are separate layers deformed once, or a single layer deformed several times, is not resolved.

The sulphide layers are generally composed of massive sulphide and disseminated quartz sulphide units. The massive sulphide tends to form a band on one side and quartz sulphide on the other side of the layers. Sedimentary bedding structures are found in both units.

Over the whole deposit the average metal ratios for lead, zinc and silver are 1.6%Pb/%Zn and 16 gm/t Ag/%Pb. There is no appreciable change in metal ratio

along the plunge of the principal layers. However, differences were found between the massive and quartz sulphide units and between noses and limbs of the fold structure. The H layer is higher in Pb but lower in Ag.

A set of normal faults cut the deposit and although they have small offsets, they often have strongly fractured and friable walls which can result in serious caving problems.

Areas of close spaced open joints act as reservoirs for ground water which, when tapped, can be a serious problem until the reservoir is drained.

INTRODUCTION

The Grum lead-zinc-silver deposit is located in the south central Yukon Territory, 11 km northeast of the town of Faro. The property is being developed as a joint venture by Kerr Addison Mines Limited (60%) and Canadian Natural Resources (40%). From its discovery in late 1973 to the present, 41,000 m of surface drilling, 15,000 m of underground drilling and 2,900 m of underground drifting and cross-cutting have been completed.

This report deals with the geological aspects of the project. Although it draws on several previous reports for background data, it is primarily a record of the observations and data gathered by the authors, plus their interpretations and conclusions, during two years spent on the site. As much as possible, the major observations have been documented by photographs. Due to lack of facilities, and the remoteness of the site, only a minor amount of laboratory research has been done. Several important aspects of the deposit have been discussed only briefly since the necessary research has yet to be done. It is hoped that this report will be a guide to future geologists who will work on the Grum project.

A geological plan of the underground workings, plus six cross-sections showing the geological interpretation, are included in the back pocket.

1. Exploration History

Minor gold prospecting occurred in the area along the Pelly River during the Klondike gold rush of 1898. Intensive base metal prospecting began after 1953, the year the Vangorda showing was discovered by Mr. Al Kulan, a prospector from Whitehorse. The Vangorda was drilled in 1955 and 1956 by Kerr Addison Mines Limited and about 9 million tons of 8% combined lead-zinc was indicated. In 1963 - 66 the Swim orebody was discovered by Kerr Addison Mines Limited. It is estimated to contain 5 million tons of 9.5% lead-zinc material. In 1966 Dynasty Exploration Ltd. drilled a swampy gossan area that had previously been staked for Prospectors Airways in 1955. This drilling located the Anvil deposit containing 65 million tons of 9.1% combined lead-zinc. In 1973 A.E.X. Ltd.,

under Dr. A. Aho, discovered the Grum deposit based on drilling coincident gravity and magnetic anomalies lying along the Anvil-Vangorda-Swim trend. In 1976 Anvil Mining Corporation discovered the Dy deposit between the Swim and Vangorda. The discovery was based on the interpretation of geologic structure determined by regional geologic mapping.

2. Acknowledgements

The authors would like to acknowledge the contribution of the geologists who previously worked on the Grum, specifically, the late Dr. A. Aho, Mr. F. Chow, Dr. S. Reamsbottom, Dr. M. DeQuadros and Mr. G. Tetu. We would also like to acknowledge the work of Mrs. M. Ball and Mr. P. Haillet who assisted in the typing and drafting of the report. Finally, we wish to acknowledge the support of Mr. W.M. Sirola, Western Exploration Manager, who also made a critical reading of the manuscript, and Mr. J. Carrington, Grum Project Manager, of Kerr Addison Mines Limited.

THE REGIONAL SETTING

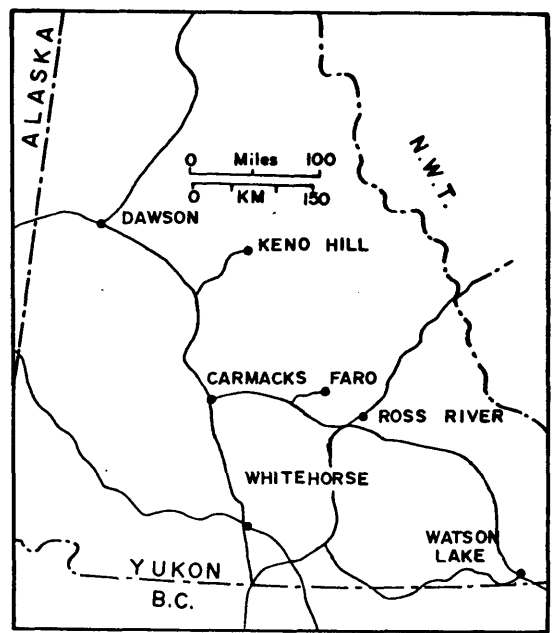
The Grum is one of a group of five similar sulphide deposits that lie like a string of beads along the southwest flank of the Anvil Range between Mount Mye and the Pelly River. The relative location of these deposits is shown on the map in figure 1. The deposits are mineralogically similar and consist of mixed sulphides associated with quartzitic, graphitic and tuffaceous material enclosed in a thick pile of highly deformed sericite phyllites (figure 2). The phyllites are thought to be early Paleozoic in age but direct evidence for this is lacking. Tempelman-Kluit (1972, p.9) dated these phyllite units as Ordovician or older based on indirect stratigraphic evidence. The phyllites form the flanks of an anticline, the Anvil Arch, the core of which is occupied by the Anvil batholith (figure 3). This is a quartz monzonite pluton of Cretaceous age. As will be documented later in this report, and as was hinted at by Tempelman-Kluit (1972, p.65), the sulphide deposits are essentially sedimentary in origin and are genetically unrelated to the batholith. The intrusion however, apparently caused a certain amount of thermal metamorphism in the sulphides. The deposit farthest from the contact, the Swim, has the finest grained sulphides and the enclosing phyllites lack high temperature minerals. The metamorphism is then seen to increase progressively toward the Anvil deposit which lies directly on the intrusive contact. The Anvil has the coarsest grained sulphides and the surrounding phyllites contain numerous secondary high temperature minerals such as garnet, staurolite and andalusite.

Paralleling the Anvil Arch is the other major structure in the area, the Tintina fault system. This group of faults is revealed by the Tintina trench which forms the valley of the Pelly River. These faults repeatedly slice the southwest limb of the Arch parallel to its axis. Related to the Tintina faults are a group of steep faults striking N60°E parallel to Blind Creek. These cut and slightly offset the Grum and Anvil deposits in several places. In the Grum five members of this group cut the sulphide zone and further complicate an already complex structure.

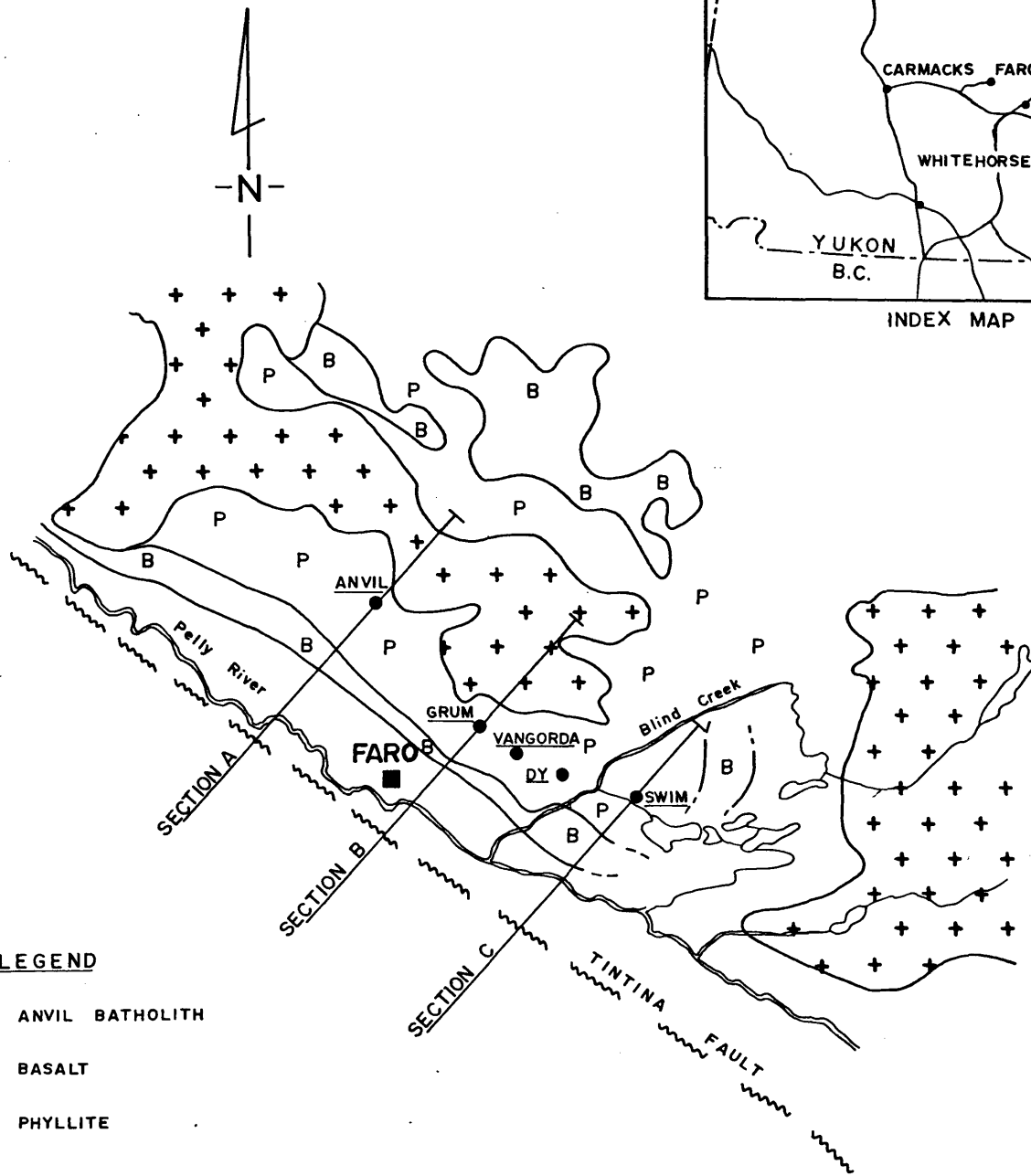
The phyllitic rocks, and to a lesser extent the sulphide lenses within them, are marked by bedding and by composition banding which is probably an indication of bedding. This banding is in turn cut and offset by a strong secondary foliation. Following Tempelman-Kluit's (1972) notation, the banding is denoted F_1 and the secondary foliation F_2 . Their relationship is shown in plates 1 and 2.

In the area of the sulphide deposits, the F_2 has a general northwest strike with a gentle dip to the southwest. Locally, flexures occur in which the dips are steeper. In the Grum the maximum F_2 dip is about 50° while the average is about 20° . The F_1 is complexly folded and transposed along the F_2 . The sulphides were originally deposited as sediments and precipitates parallel to the F_1 . Subsequently they have been in part re-mobilized and locally injected into the F_2 as shown in plate 2.

In many areas folding, brecciation, transposition, re-crystallization, and plastic flow have obscured the primary structures.



INDEX MAP

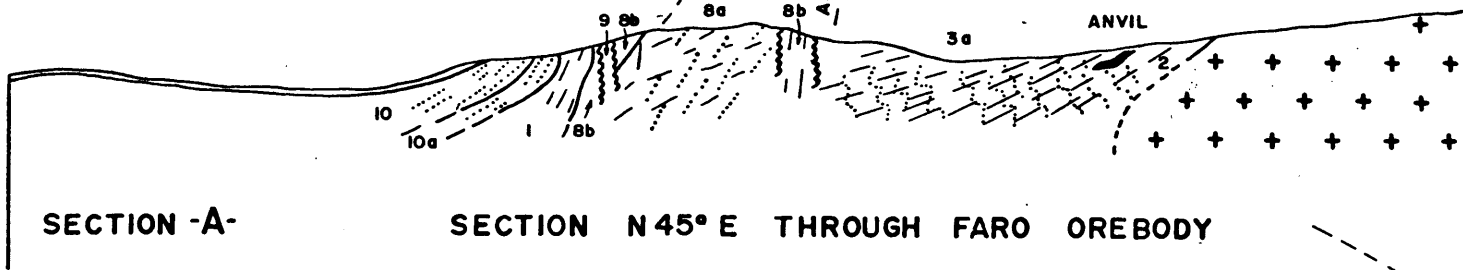


SCALE - 1 inch = 8 miles



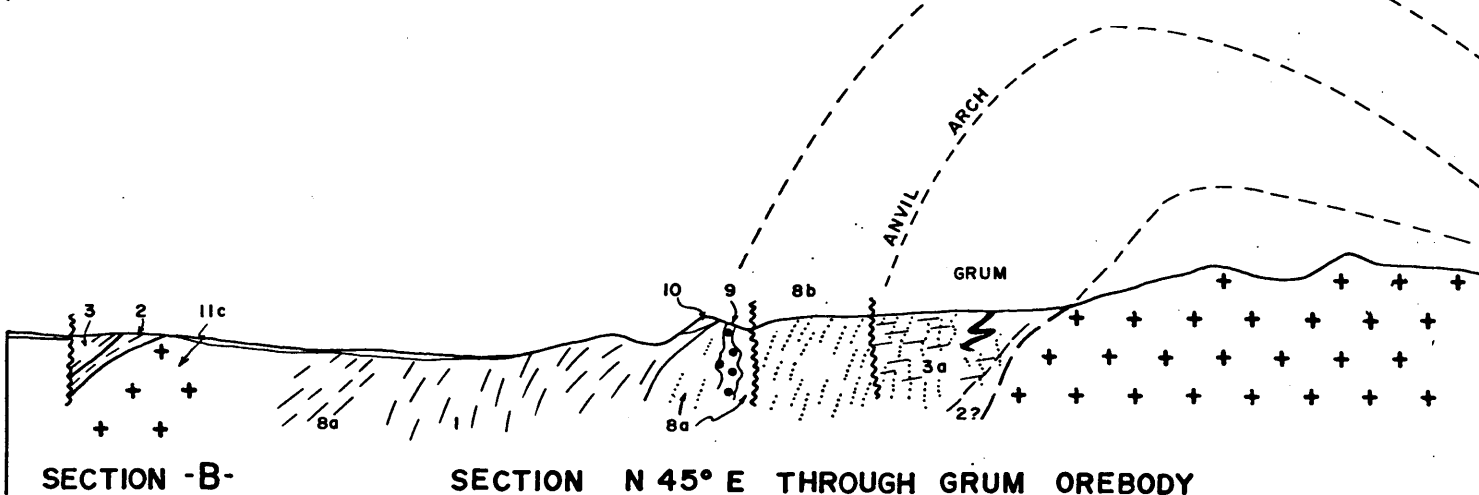
FIG. 1

GEOLOGICAL MAP
OF THE
GRUM AREA



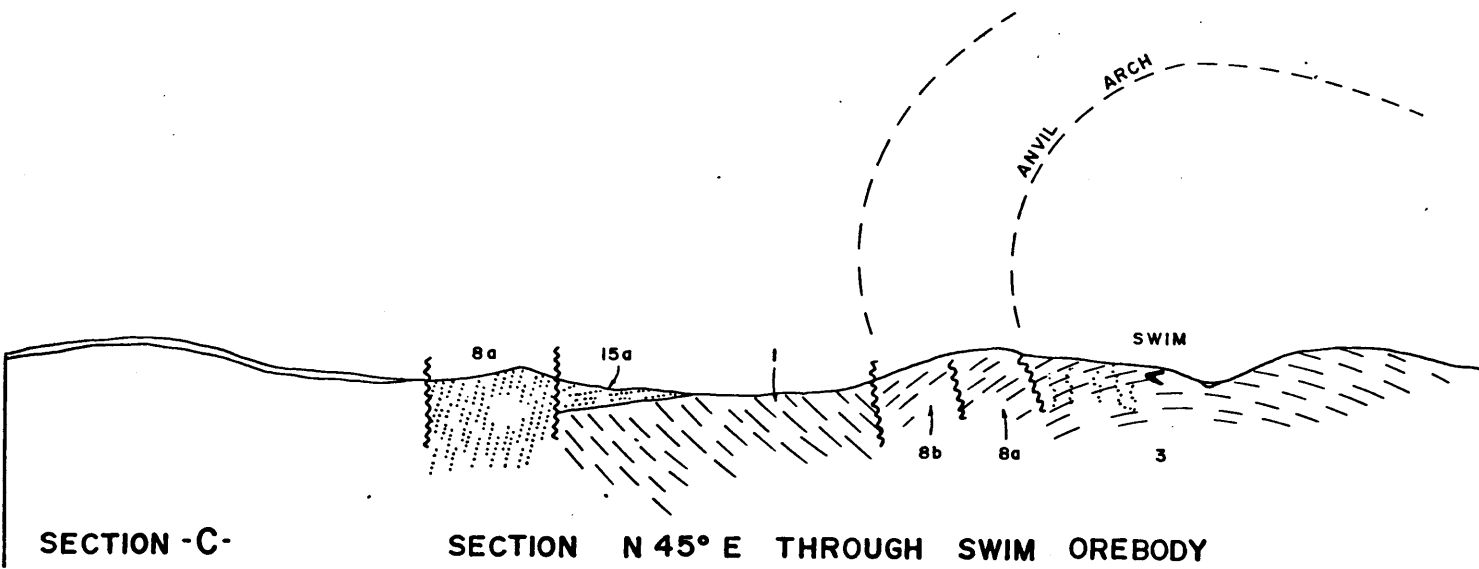
SECTION -A-

SECTION N 45° E THROUGH FARO OREBODY



SECTION -B-

SECTION N 45° E THROUGH GRUM OREBODY



SECTION -C-

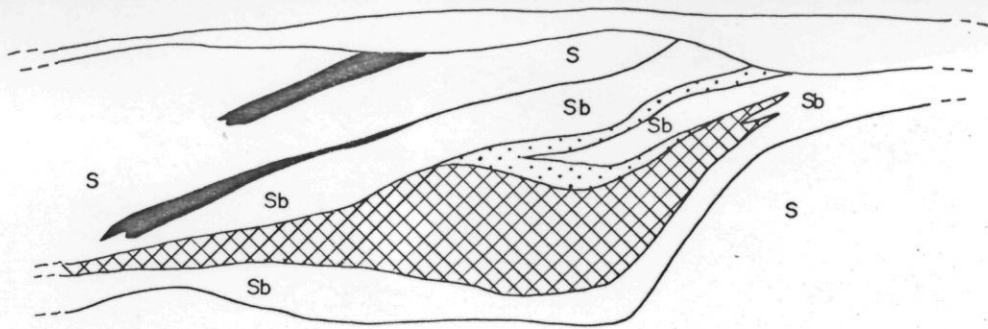
SECTION N 45° E THROUGH SWIM OREBODY

LEGEND

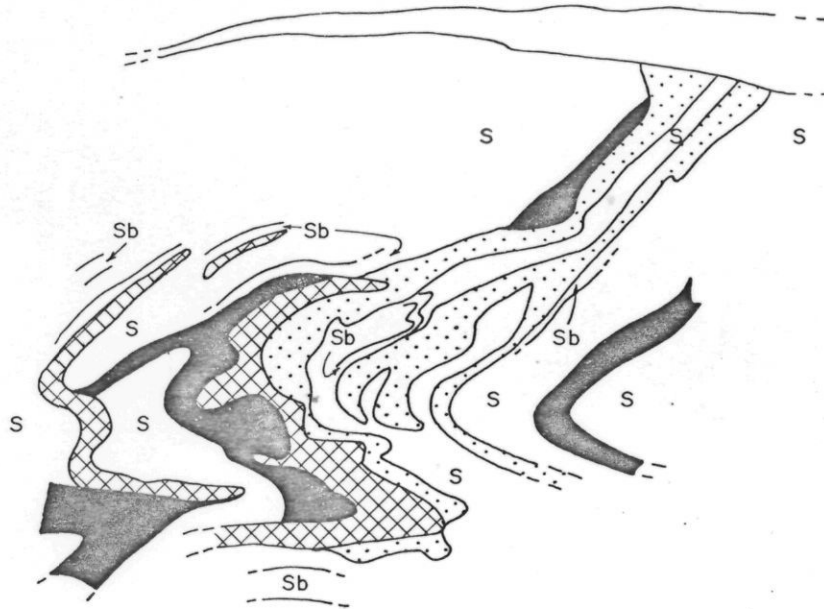
<p>15a SANDSTONE</p> <p>11 MONZONITE</p> <p>10 CONGLOMERATE</p> <p>9 SERPENTINITE</p> <p>8a RED, GREEN CHERT</p> <p>8b BASALT</p>	<p>3 SERICITE PHYLITE</p> <p>2 GARNET SCHIST</p> <p>1 MICA SCHIST</p> <p>STRUCTURE SYMBOLS</p> <p>COMPOSITION BANDING, BEDDING etc. (F)</p> <p>MICACEOUS FOLIATION (F₂)</p>
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GEOLOGICAL SECTIONS
IN THE
REGION OF THE GRUM
OREBODY
 AFTER MAPPING BY
 D.J. TEMPELMAN - KLUIT
 SCALE - 1 inch = 2 miles
 J. PAXTON

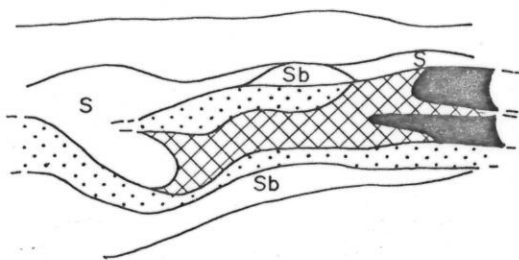
FIG. 2



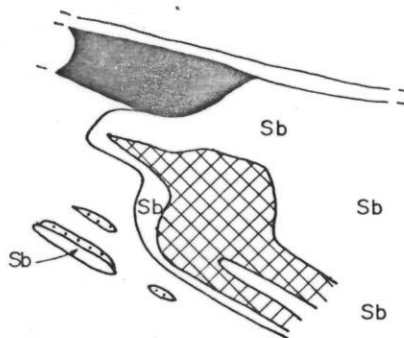
FARO



GRUM






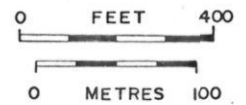
VANGORDA



SWIM

LEGEND

-  MASSIVE SULPHIDES
-  QUARTZ "
-  GRAPHITIC PHYLLITE
- Sb KAOLINIZED or BLEACHED
- S SERICITE PHYLLITE



GEOLOGICAL SECTIONS
OF
SULPHIDE DEPOSIT
IN THE
GRUM AREA

FIG. 3

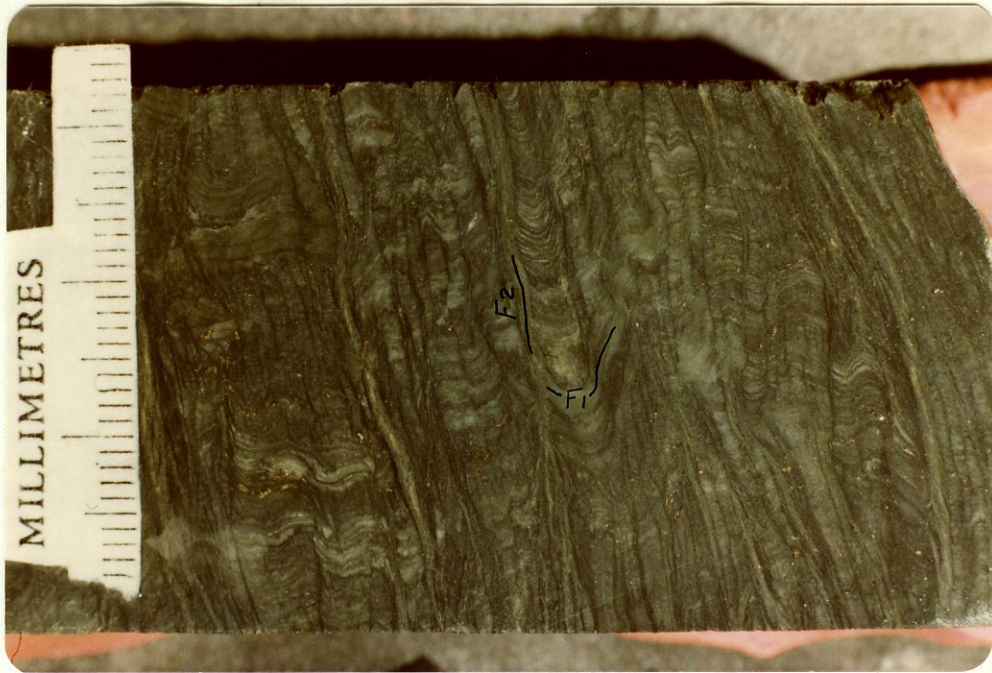


Plate 1: Quartz sericite phyllite showing F_1 and F_2
Cut specimen.

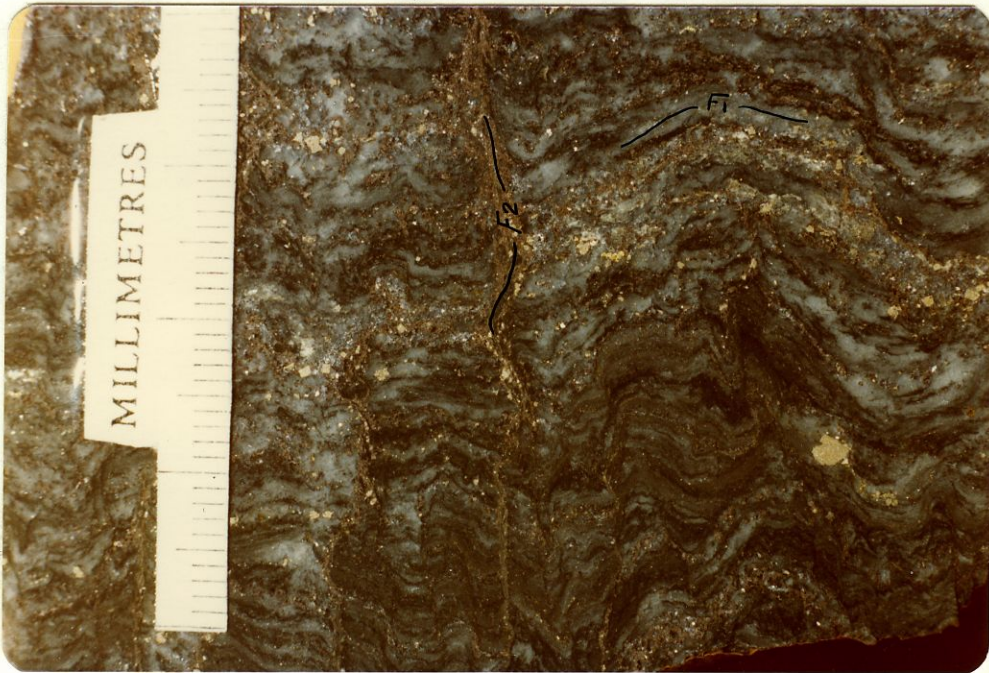


Plate 2: Quartz-sulphide type. Note sulphide following
both F_1 and F_2 . Cut specimen.

GEOLOGY OF THE GRUM DEPOSIT

The Grum deposit consists of several sulphide layers. These have been deformed into an S-shaped recumbent fold (see fig. 6, page 43). The horizontal projection of the axial line of the fold strikes N40°W and plunges 10°NW. The upper limb of the fold reaches the bedrock surface but is covered by up to 50 m of glacial till. The mineralization does not outcrop anywhere. Significant sulphide mineralization has been traced for 1680 m along strike and 366 m laterally. The layers range in thickness from a few meters up to 40 m with the average being 10 m. The thickest mineralization occurs in the fold noses. Although there is not much difference in grade between noses and limbs, it is possible that some sulphides high in lead and zinc have migrated into the noses (see Plastic Flow, page 50). In some sections (74W to 80W) the fold noses were apparently squeezed into thin wedges parallel to their axial planes. The main fold is tight, thick limbed and high grade in the southeast end and opens up down plunge to the northwest. With this opening out there is a decrease in grade until the whole structure is sub-economic from a mining point of view past section 86W. Below the main sulphide bands on the southeast end of the deposit, a zone of higher rank metamorphic rocks occur which contains biotite, garnet and staurolite. This area is also underlain by a low angle fault of unknown displacement but below which minor sulphide bands have been intersected. A number of steep normal faults cut the main sulphide zone but have relatively small displacements.

In 1977 a detailed mineral inventory was completed and a manual calculation, based on cross-sections, indicated 26 million tonnes grading 10.5% combined lead-zinc plus 62 gm/t of silver at a combined lead-zinc cut-off of 4%.

1. Lithology

(a) Rock Units

The Grum Project is generally underlain by interstratified normal pelitic and tuffaceous sediments. These were altered and deformed by regional metamorphism

into phyllites and were later intruded by the Anvil Batholith.

During the underground mapping and core logging, the phyllites were subdivided into six general types based on mineralogical composition. These types are as follows:- (1) Quartz-sericite phyllite; (2) Calcareous phyllite; (3) Graphitic phyllite; (4) Bleached phyllite; (5) Chloritic phyllite and (6) The higher rank metamorphic facies of the phyllites.

Described below are the six rock types with their corresponding rock symbols used during core logging.

Quartz-Sericite phyllite (S): By far the most abundant unit encountered in the project. It is pale to dark grey in colour with silvery sheen along cleavage planes due to parallel orientations of sericite flakes. This unit is usually interstratified with thin bands of cryptocrystalline quartz and sometimes also with calcite. The quartz bands define the F_1 and exhibit small crenulations when perpendicular to the main foliation (F_2) trend (see Plate 1).

Under the microscope, this unit is composed of: 60% sericite; 25% quartz; 5% calcite; 5% graphite and 5% opaques (mostly pyrite). The F_2 foliation is defined by alignments of plicated sericite flakes and discontinuous bands and lenses of microcrystalline quartz with minor associated grains of calcite, graphite and opaques (see Plate 3). The quartz is allotriomorphic granular and has undulose extinction. Bigger quartz crystals show cracking and incipient mechanical movement (see Plate 4). Calcite, which is easily recrystallized, shows some distinct crystal faces and characteristic sliding plane lamellae. Finer calcite grains also occur interstitially between some bigger quartz crystals. The F_1 banding is defined mostly by bands of quartz with some calcite and sericite flakes (Plate 5).

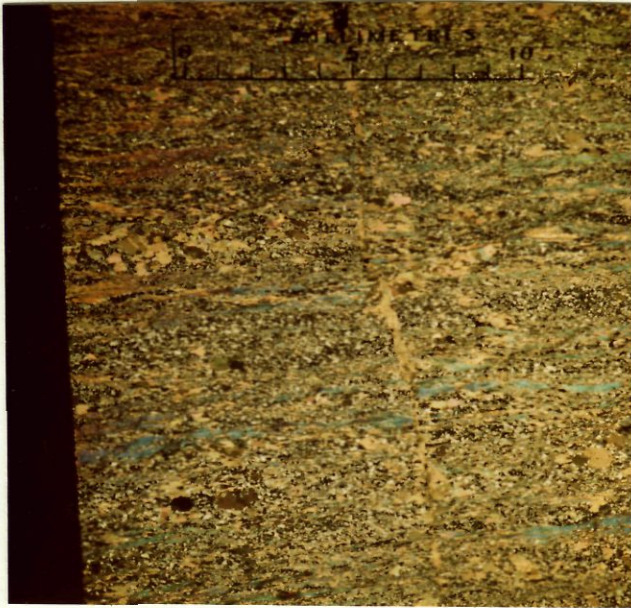


Plate 3

Quartz sericite phyllite showing the F_2 defined by flakes of sericite and bands of quartz and calcite.

Thin section x-nicol.

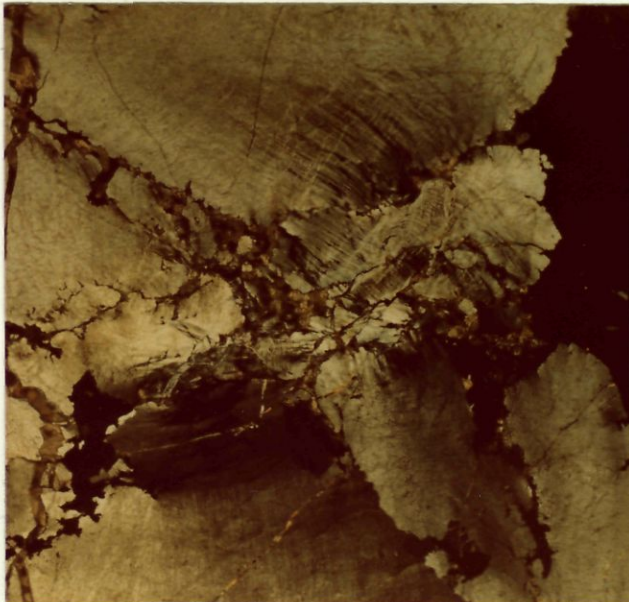


Plate 4

Large crystals of quartz. Note stress fracturing.

Thin section x-nicol.

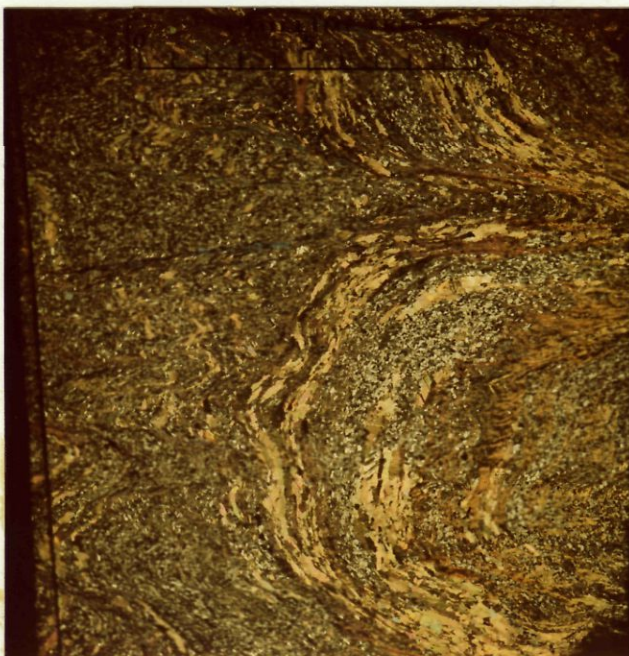


Plate 5

Quartz sericite phyllite with F_1 defined by quartz-calcite-sericite, and the F_2 defined mainly by sericite.

Thin section x-nicol.

Calcareous phyllite (SK): Similar in physical appearance to the quartz-sericite phyllite except for an increase in the carbonate constituents. Calcite occurs as bands (5 mm in average thickness) following the F_2 foliation plane together with sericite and lesser amounts of quartz (see Plate 6). The same mineral assemblage defines the F_1 foliation (Plate 7). Calcite also occurs as thin and short stringers cutting across both F_1 and F_2 foliations.

Under the microscope, this unit is composed of 50% sericite; 30% calcite; 10% quartz; 5% opaques and 5% graphite plus very minor accessory minerals (chlorite, sphene?). The micaceous minerals form the greater part of the groundmass and show parallel orientation and are at times highly contorted around lenticular aggregates of quartz or quartz-calcite. Interstratified in the groundmass are many (sometimes discontinuous) bands of microcrystalline quartz and trains of opaques. Calcite occurs as bands of anhedral to subhedral crystals and invariably shows sliding lamellae.

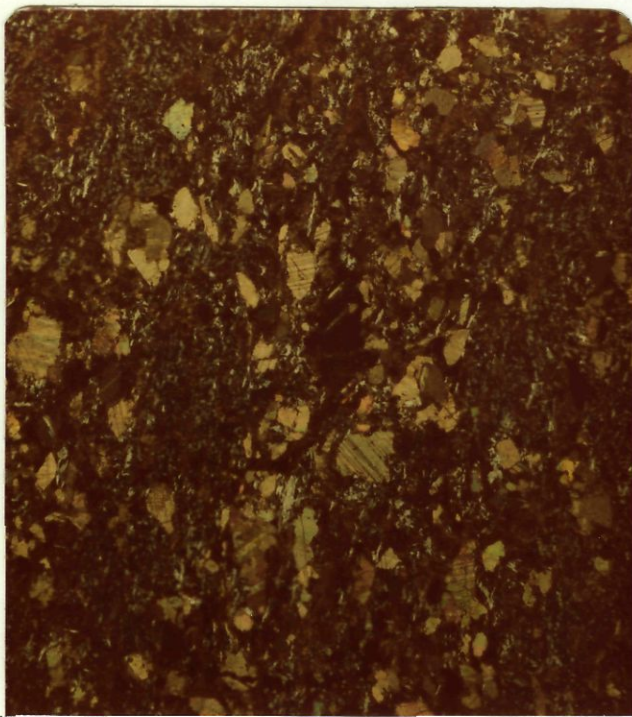


Plate 6: Thin section of calcareous phyllite showing alignments of minerals parallel to F_2 . X-nicol.

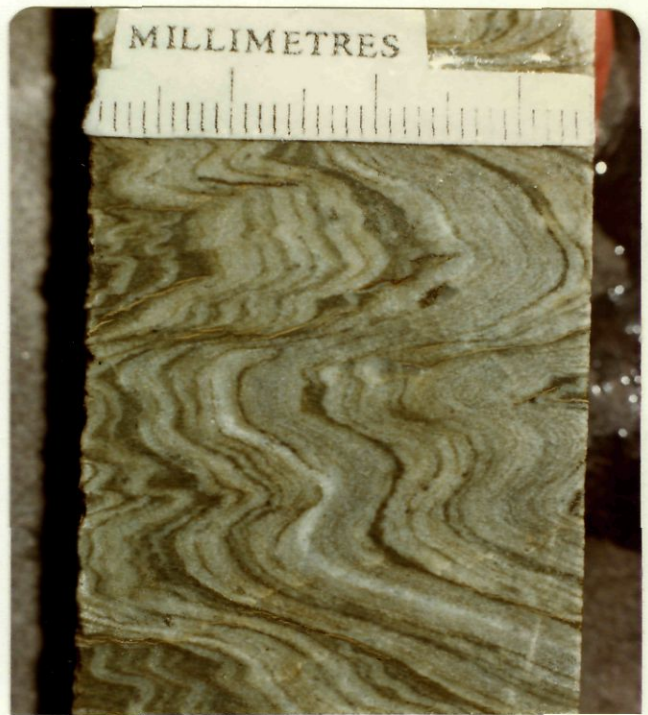


Plate 7: Cut specimen showing calcitic F_1 bands.

Graphitic phyllite (G): Dark grey to black colour and usually more fissile than the other phyllites. Included in this unit is sericite phyllite with enough carbonaceous material to mark the fingers or give a black streak when scratched. This latter variation is coded as S_G .

Under the microscope, a typical specimen is composed of fine laminae of graphite intercalated with equally fine laminae of mixed sericite, quartz, calcite and occasional sulphides. Sometimes, bands and lenses of quartz-calcite are included within the graphitic unit (see Plate 8 and Plate 9).

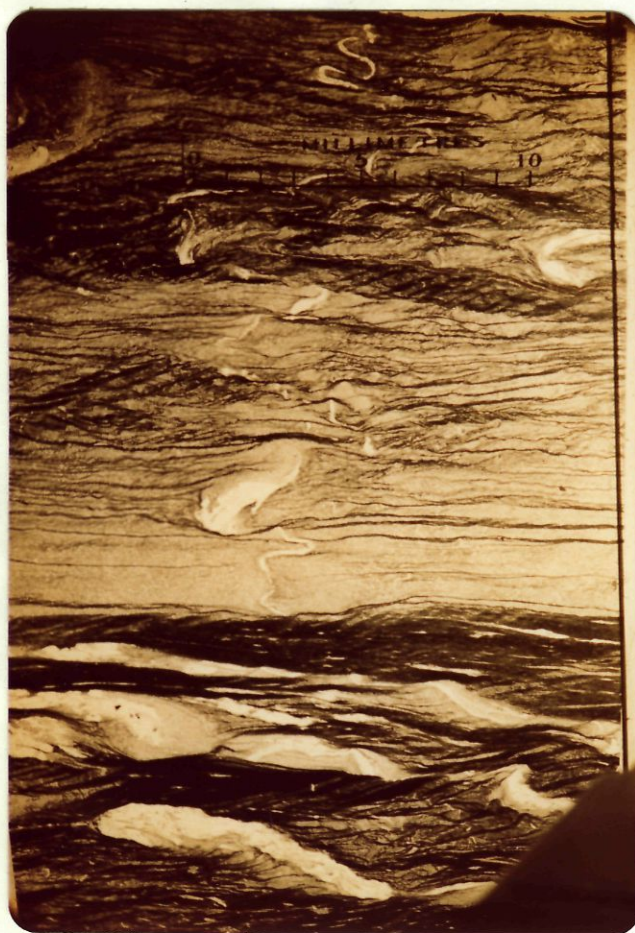


Plate 8: Thin section of graphitic phyllite showing bands and lenses of quartz-calcite and other phyllitic materials. Note sharp contacts.

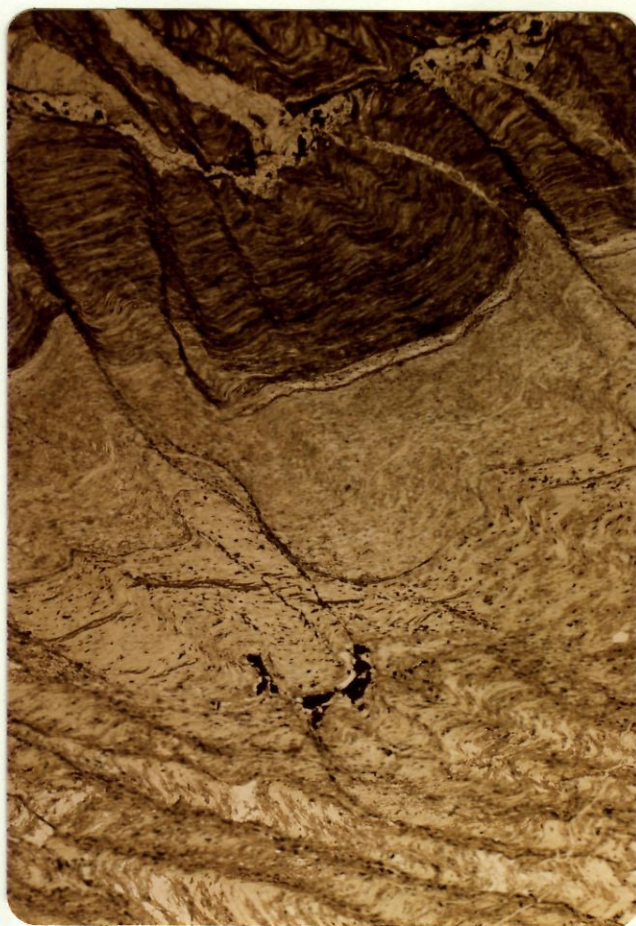


Plate 9: Thin section of contact between bleached sericite and graphitic phyllites. Note the fine inter-lamination of the two.

Bleached sericite phyllite (Sb): The term bleached sericite phyllite was applied, during core logging and underground mapping, to all rock units having colours ranging from silvery white to earth white to buff. In the earlier Grum Joint Venture Report (1975), this unit was believed to be probably caused by hydrothermal (?) alteration of the surrounding country rock. No further refinement of classifying this unit was made during the duration of the drilling and underground activities.

In re-evaluating the data, it was recognized that this unit could actually be further subdivided into two types based on mode of occurrence and probable genesis.

The first type occurs as an alteration product of the country rock, not by hydrothermal action (as this connotes active vulcanism after deposition), but by combined agencies of diagenesis, tectonism and ground water. This type has gradational contacts with the surrounding rocks, and is commonly associated with fracture zones or shear planes parallel to the F_2 foliation. It is friable and contains more clayey material with the silvery white flakes than the second type.

The second type of occurrence is as an earth buff coloured layer having distinct contacts with the surrounding rocks. It is denser (compact) and contains less clay materials than the first type described (Plate 10). This type is also found not only near and contiguous to the sulphide units (Plate 11), but also interlayered with the massive sulphide (Plate 12). Detailed examination of polished specimens (Plate 13) shows the remarkably well defined contacts and absence of embayment cavities which could suggest an advancing alteration front. The authors disagree that such features resulted from selective alteration of the country rock either by hydrothermal or ground water.

Under the microscope, the second type of bleached unit is composed (on the average) as: 60% sericite; 25% quartz; 5% calcite; 5% opaques (including grains of graphite) and 5% accessory minerals (clay, chlorite). The sericite forms lamellae interbanded with microcrystalline quartz and calcite. Some quartzose bands are discontinuous with tapering ends and are aligned parallel to F_2 foliation (Plate 14). Aggregates of quartz and calcites also form lenticules (Plates 15A and 15B) surrounded by sericite bands showing fluxion



Plate 10: Bleached sericite phyllite interstratified with cherty bands. Scale in mm.

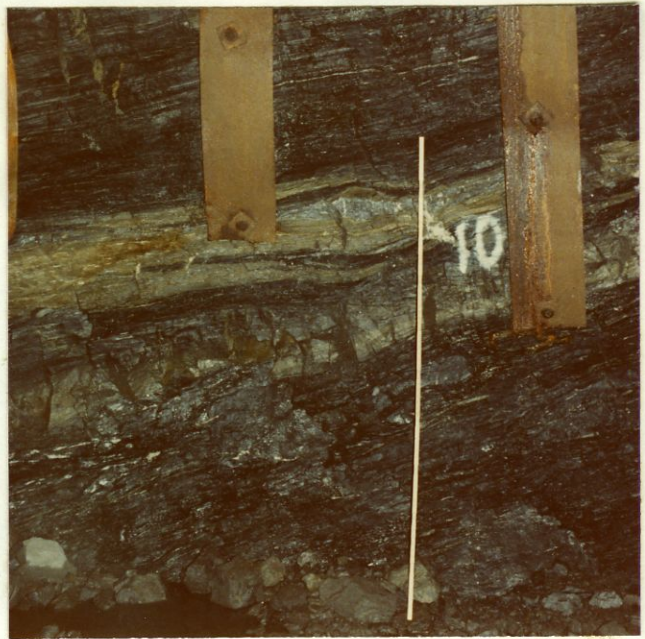


Plate 11: Bleached sericite phyllite contiguous to sulphide units. Scale rod is two meters

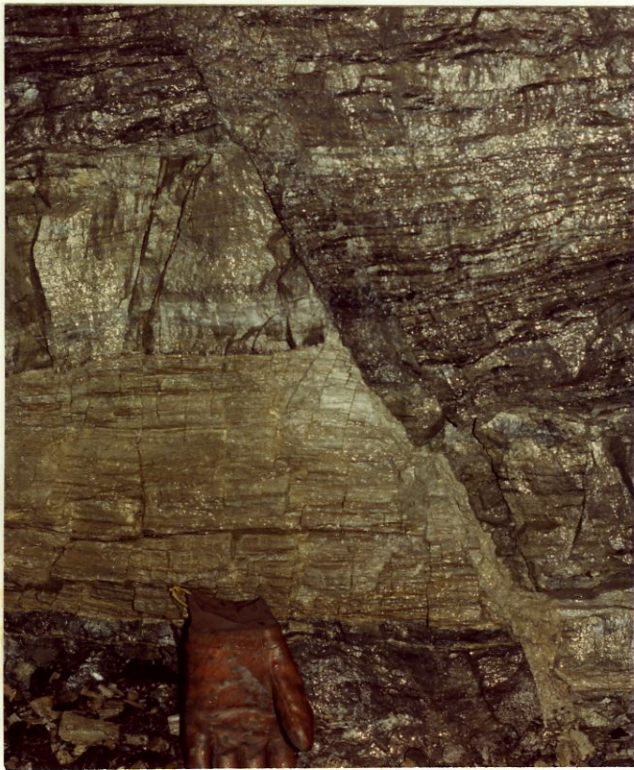


Plate 12: Bleached sericite phyllite interlayered with massive sulphide. Both units are cut and offset by fault. Note sharp contacts.

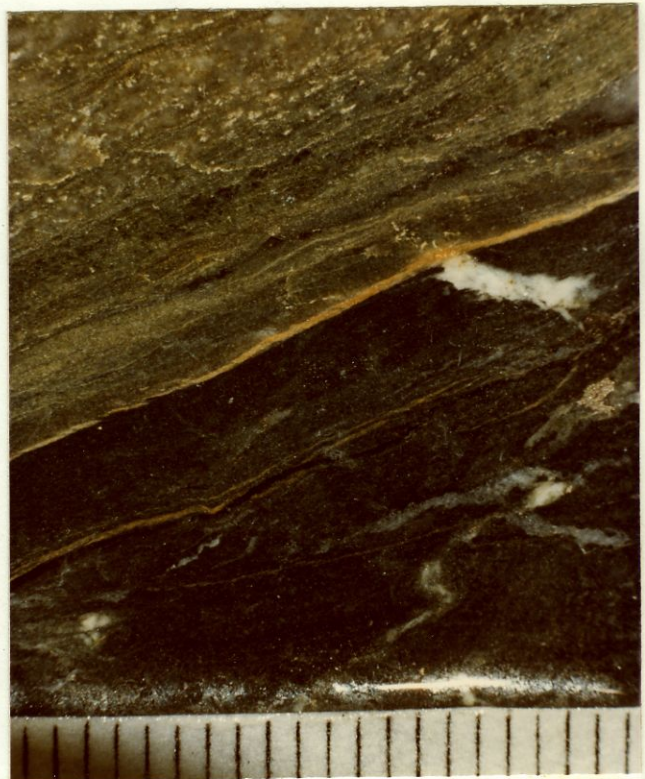


Plate 13: Cut specimen showing contact between graphitic and bleached sericite phyllite. Note sharp contact devoid of embayment caries. Scale in mm.

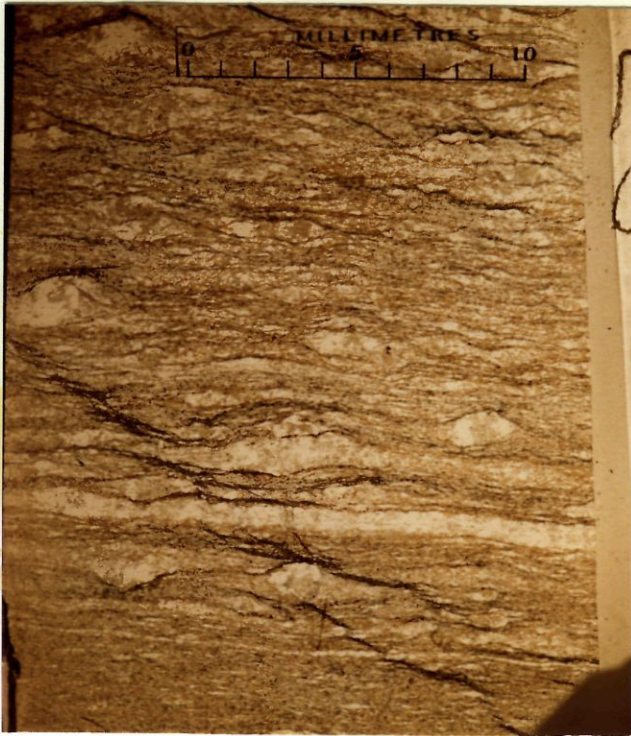


Plate 14: Bleached sericite phyllite showing augen texture aligned to the F_2 .

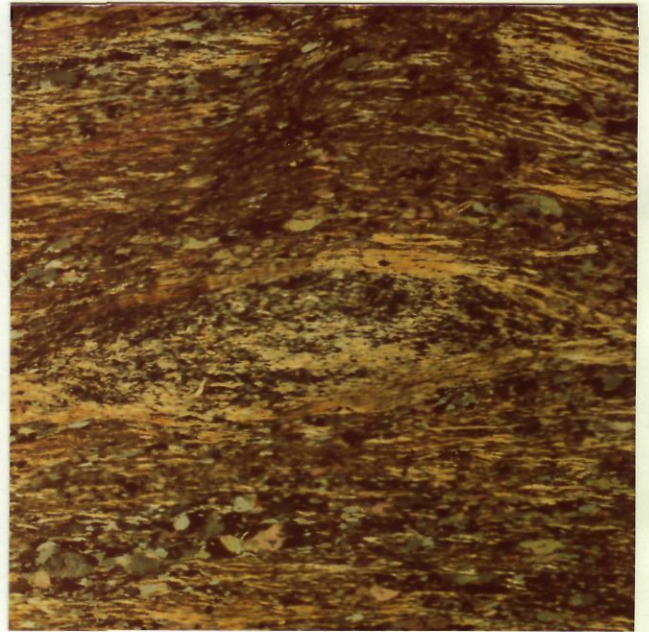
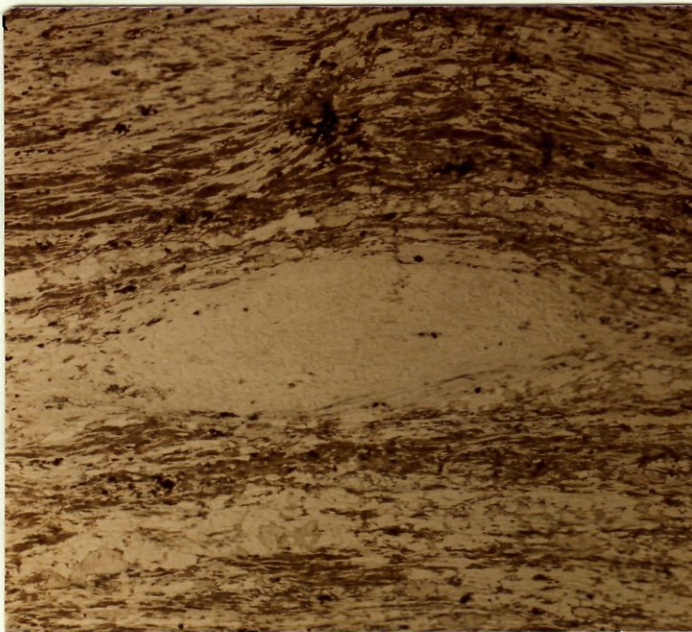


Plate 15A and 15B: Augen at high magnification. Possibly lapilli that were re-crystallized and indicate that the bleached sericite phyllite unit is an altered tuff. 15A - open nicol; 15B - cross nicol.

texture around the lenticules. Opaque grains (sulphides and leucoxene) are found commonly forming near edges of such lenticules.

These authors are of the opinion that the second type of bleached phyllite is the altered product of a definite layer and not an altered counterpart of the country rock. It is unfortunate that the degree of alteration made it difficult to ascertain the original nature of this rock type. However, it is suggested here that these layers were originally tuffaceous materials that were lithified, recrystallized and subsequently deformed contemporaneously with the sulphide units. Because of their porous and chemically unstable nature, alteration within the layers proceeded at a far more rapid rate than in the surrounding rocks. The lenticules that were observed could be lapilli fragments that were either recrystallized or dissolved with the voids being filled by secondary quartz and calcite.

Chloritic phyllite (Sc): Quartz sericite phyllite with fine grained chlorite in the groundmass or as lamellae giving the rock a distinct greenish colour in contrast to the rest of the country rock. A variation in this unit was observed where chlorite occurs as 2 - 10 mm clumps or knots giving the rock a mottled appearance.

Under the microscope this unit is composed of 50% sericite, 20 to 30% chlorite, 20% quartz, 5% calcite and 5% opaques. Many chlorite flakes tend to gather in clumps which are aligned to the foliation direction (F_2). It also forms lenticules where the flakes are randomly oriented, even transverse to the plane of foliation, but the lenticules itself are oriented parallel to the F_2 foliation. It is believed that the chlorite is authigenic and formed from the alteration of tuffaceous sediments.

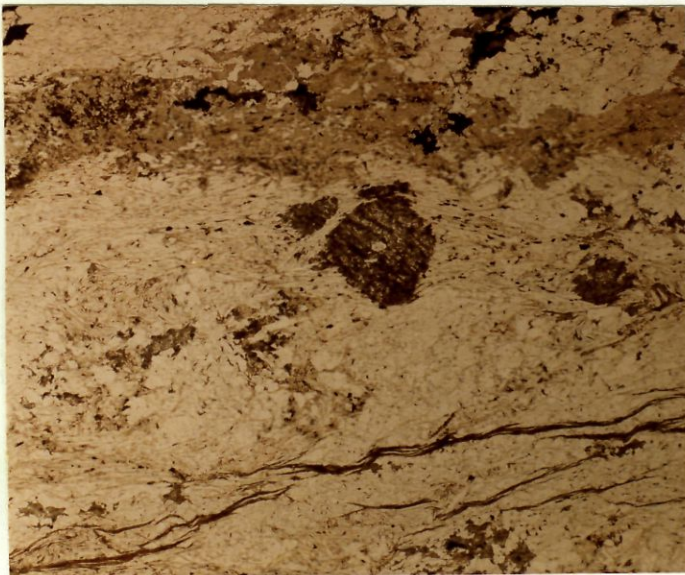
Higher Rank Metamorphic Group (H)

This sixth category comprises what are believed to be higher rank metamorphic equivalents of the phyllites. It is divided into two sub-facies, the first being biotite-chlorite and the second being biotite-garnet-stauroilite-chlorite. These two sub-facies occur in different spatial positions relative to the

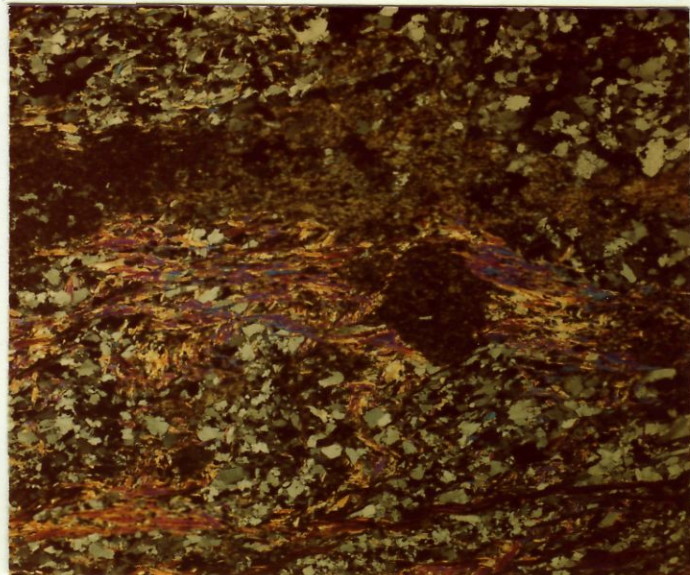
sulphide units and to the Anvil Batholith. The implication of this difference in position is discussed in the section on Stratigraphy, page 36 .

In the biotite-chlorite sub-facies, biotite and chlorite occur as thin laminae mainly parallel to the F_1 direction. Under the microscope it appears that the biotite is forming at the expense of the chlorite. Associated minerals are quartz, calcite, graphite and opaques in varying proportions.

In the biotite-garnet-staurolite-chlorite sub-facies, the biotite and chlorite are patchy in distribution but the flakes appear to be larger than in the biotite-chlorite sub-facies. The garnet is a red variety, probably almandine and/or pyrope. It is sporadically distributed usually as single crystals, although occasional clusters of twins do occur. Under the microscope, the crystals are often seen to be cracked and the spaces filled with quartz, chlorite and biotite. No definite sign of rotation of the garnets was noted which would support a pre-folding age for their formation. The staurolite is not as well formed as the garnet. The crystals are smaller and contain more inclusions and the crystal faces are not as clear as with the garnet (Plate 16A and 16B). Associated minerals are quartz, calcite and abundant minute opaque grains.



16A Open Nicol



16B Crossed Nicols

Plate 16: Thin section of the higher rank metamorphic group showing a biotite band and crystals of staurolite surrounded by sericite and quartz.

(b) Sulphide Units

The sulphide layers are basically made up of two main sulphide units, namely: massive sulphides and quartz sulphides. Both units form distinct but contiguous bands. Generally more Pb and Zn are concentrated in the massive sulphide, although in some cases the opposite may be true.

Massive Sulphide: This unit is a fine grained, dense mass with sulphide contents over 50%. Almost no foliation can be identified. Compositional banding is common. This compositional banding (sphalerite-galena-pyrite) is believed to be an F_1 structure similar to that found in the phyllites (Plate 17).

Variations in the massive sulphide units were noted, based on mineralogy and texture. These are listed below, together with the codes used during core logging:-

- M - General term for massive sulphide, particularly dense, hard and compact mass having 75% or more sulphides. (Plate 18).
- MV - Porous, vuggy and friable sulphide (Plate 19), with some associated barite in the groundmass.
- MB - Hard, dense and brittle mass showing compositional banding (Plate 17).
- MX - Brecciated massive sulphides (Plate 20).
- MI - Fine grained and massive with rounded fragments of quartz/calcite. This is believed to have undergone plastic deformation (Plate 21).
- Mb - With 25% to 75% fine grained barite crystals in the groundmass. This massive sulphide type generally grades above 10% combined lead-zinc (Plate 22).
- MQ - Hard and brittle with 25% to 50% quartz in the groundmass.

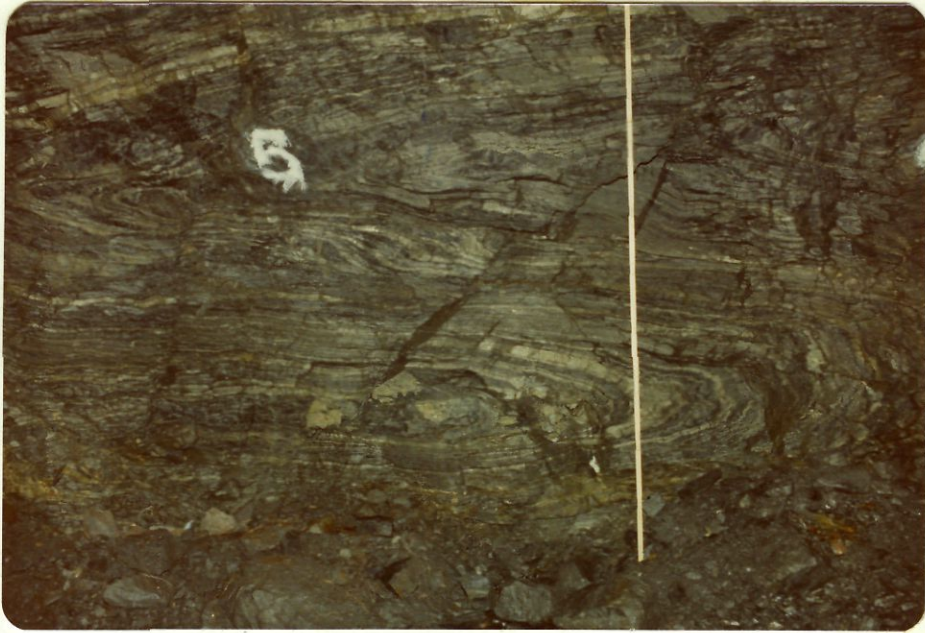


Plate 17: Folded banded massive sulphide (MB).
Compositional banding of pyrite-sphalerite-galena is
believed to be the equivalent of F_1 in the phyllites.
Scale rod is 2 m.



Plate 18: Massive
sulphide (M) enclosed
by graphitic phyllite
unit. Note sharp
contacts.

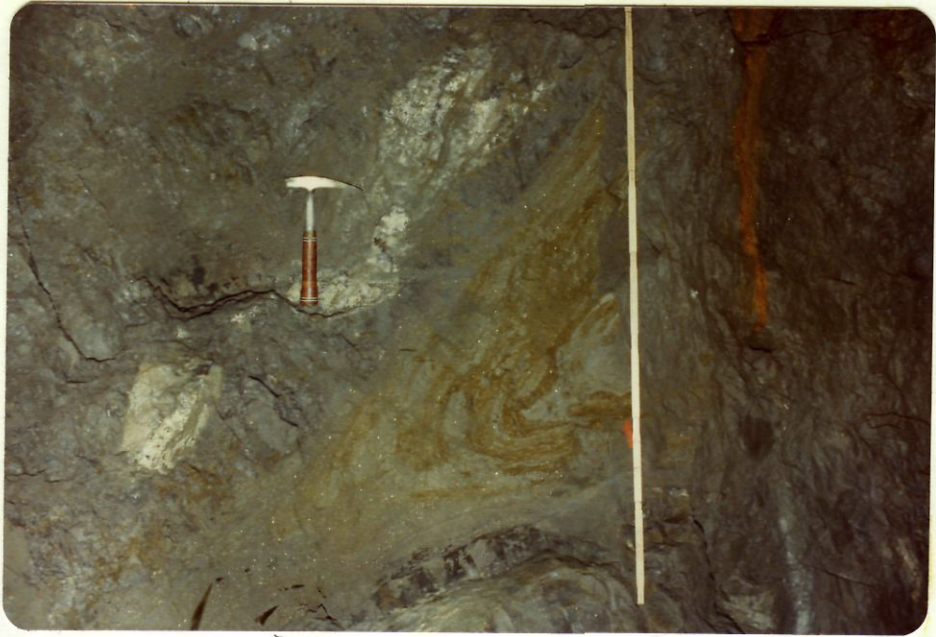


Plate 19: Porous, vuggy and friable sulphide (MV) usually with barite groundmass. Scale rod is 2 m.



Plate 20: Brecciated massive sulphide (MX). Sulphide fragments are cemented by finer grain sulphides.

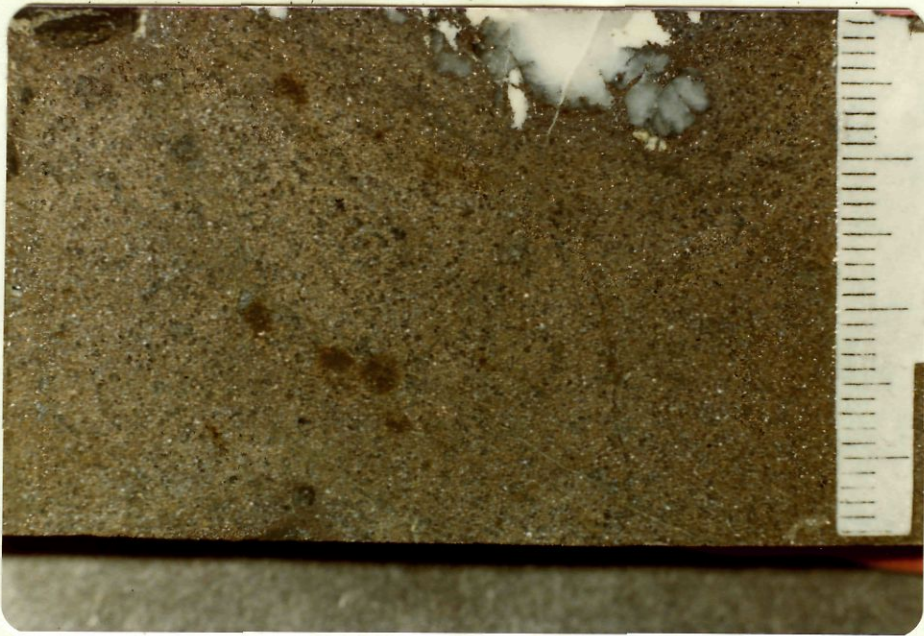


Plate 21: Massive sulphide with a rounded mass of quartz/calcite. The sulphide is believed to have undergone plastic flow. This possibly resulted in concentration of sphalerite-galena.

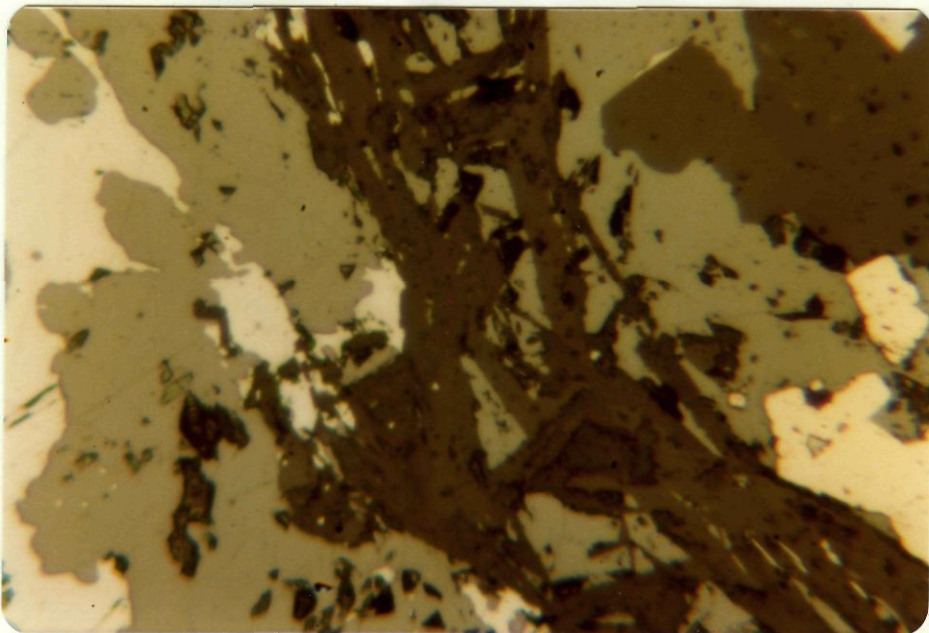


Plate 22: Barite prisms surrounded by sphalerite and partly by galena and pyrite. Barite-dark brown, sphalerite-grey, galena-off white.

Quartz-Sulphide: This unit consists of narrow 2 - 5 mm bands and lenses of quartz, sulphides, and associated phyllitic material, as well as disseminations of sulphides in a siliceous groundmass. Both F_1 and F_2 foliations are noticeable in this unit. The sulphides are usually disposed along the F_1 but it is not rare to find sulphide grains along the F_2 planes (Plate 2).

Sulphide content ranges from 5% to as high as 50%.

Sedimentary features are preserved within this unit, i.e. grain size sorting which also indicate reworking of earlier deposits (Plate 23), flame structures and load cast features (Plate 24).

Variations in this unit are listed below, together with core logging symbols:-

- P - General term for quartz-sulphide
- PB - Mineralogically massive sulphide interlaminated with quartz, sericite or graphite. The sulphide generally follow the F_1 foliation (Plate 25)
- PG - Quartz sulphide with interstratified graphitic material
- PP - Granulose quartz and sulphides. The rock has a beaded texture due to "boudins" of quartz (Plate 26)

David Carson of Noranda Exploration, in his report on the Metallurgy of the Grum Orebody (1977), estimated the percentages of each type of sulphide present as follows:-

M + MB	-	15%
Mb	-	10%
MQ	-	20%
MV	-	7%
MI	-	2%
MX	-	< 1%
P (low grade)	-	25%
(medium grade)	-	20%

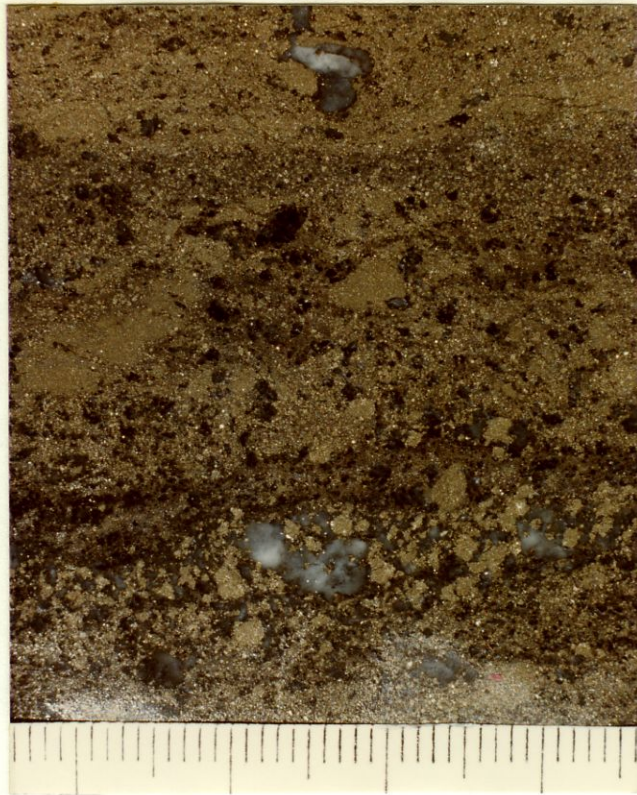


Plate 23: Grain size sorting in clastic pyrite.
Fine grained, subrounded pyritic fragments



Plate 24: Possible flame structures and load casts
indicating the sedimentary nature of the
deposit.



Plate 25: Banded quartz sulphide showing interlaminated sulphides and phyllite

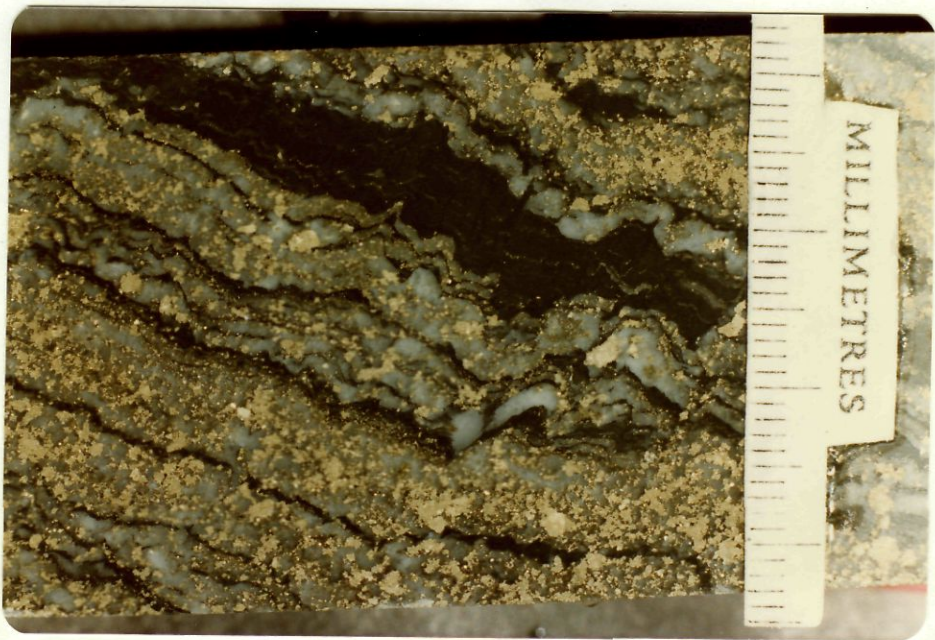


Plate 26: Beaded quartz sulphide.

2. Mineralogy: Pyrite, sphalerite and galena, in that order of abundance, are the common base metal sulphides present. Minor minerals are chalcopyrite, arsenopyrite, tennantite, pyrrhotite, magnetite and marcasite. Native gold was also reported, by David Carson, in 2 out of 88 sample sites he studied.

Pyrite is ubiquitous in both massive and quartz sulphide units. It often shows a high degree of crystallinity with clear and clean crystal faces, but it also occurs as rounded grains and with inclusions of sphalerite. In a polished section of massive sulphide, plates 27A to 27F, several of these textural variations are shown. Bands of anhedral grains change abruptly to bands of closely packed euhedral pyrite with interstitial sphalerite and galena. Abrupt changes in grain size also occur. These variations are attributed to changing conditions prevailing during sedimentary deposition and subsequent differing rates of crystal growth of the original pyrite nuclei. This process is further illustrated by plates 28A to 28D where small pyrite crystals are grouped into semicircular aggregates sometimes with nuclei of sphalerite. Although most of the pyrite grains show crystalline form, these authors believe that these are preserved atoll textures indicative of colloidal deposition. From this original colloidal state, the pyrite grew by accretion and began assuming the cubic crystal form trapping some sphalerite in the process. Where such grains occurred close together, the atolls began fusing to form circular aggregates of cubic pyrite.

Sphalerite and galena commonly occur together as contiguous grains, or as an inclusion of one in the other. These two minerals do not show the same degree of crystallinity as pyrite, perhaps due to their relative mobility. All specimens studied under the microscope show anhedral grains sometimes with simple locking (clean rectilinear or curving interface) and sometimes with mottled relationships (emulsion texture). Many large grains of sphalerite have inclusions of galena and occasionally chalcopyrite. Barite prisms were also observed completely surrounded by sphalerite and partly by galena (Plate 22).

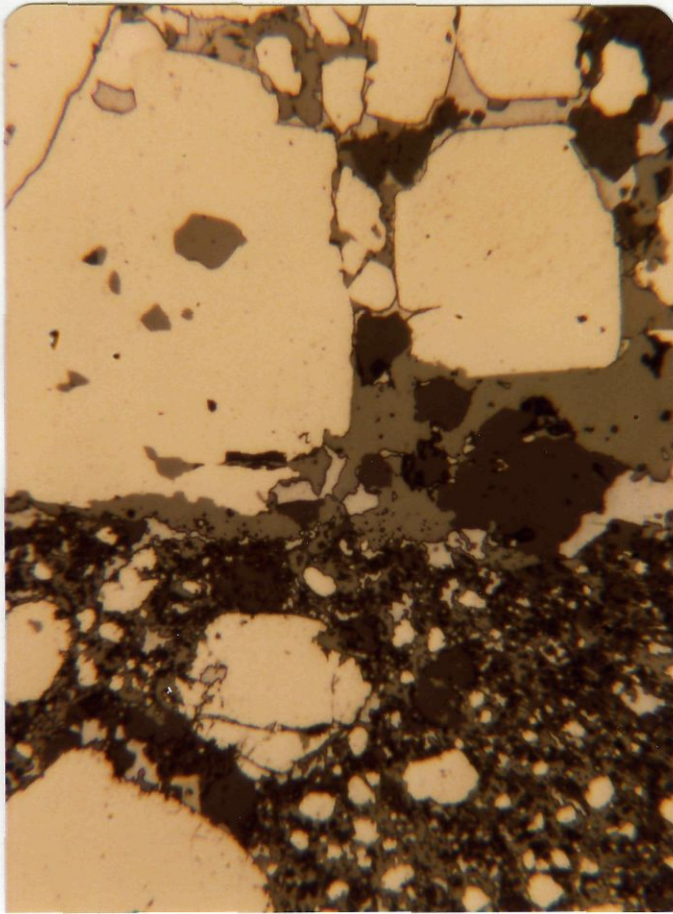


Plate 27B: Subhedral pyrite crystals formed from widely distributed nuclei and subsequent abundant supply of cations. Crystal growth proceeded unhindered forming large grains.

Surface marking change in depositional conditions.

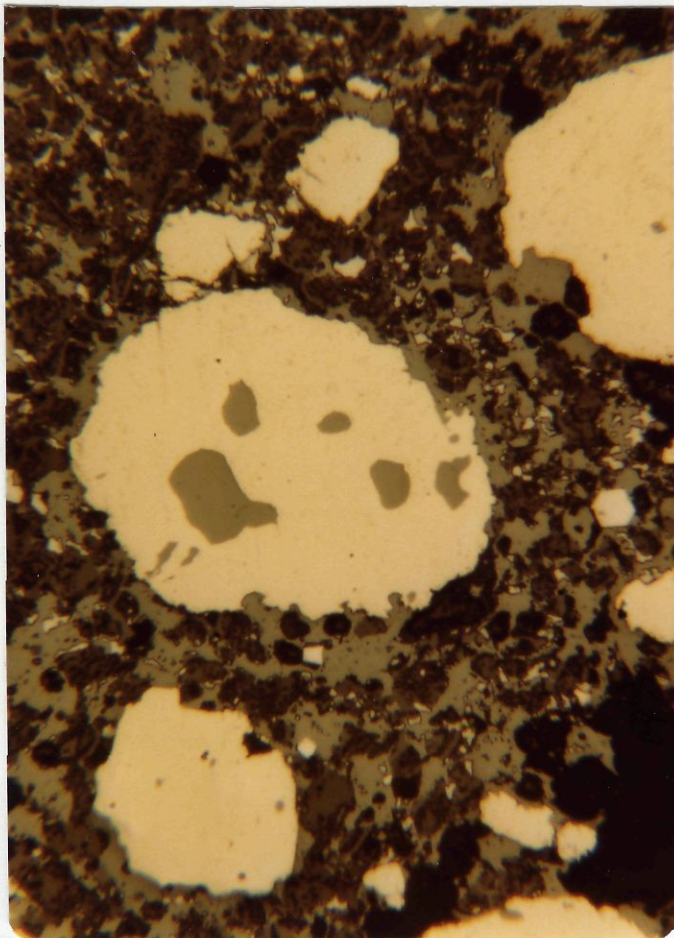
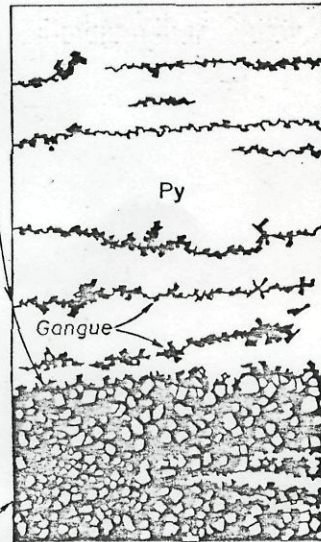


Plate 27A: Anhedral pyrite with sphalerite inclusions. Crystal growth from sparse and widely distributed nuclei. Growth probably hindered by small supply of cations and/or rapid burial.

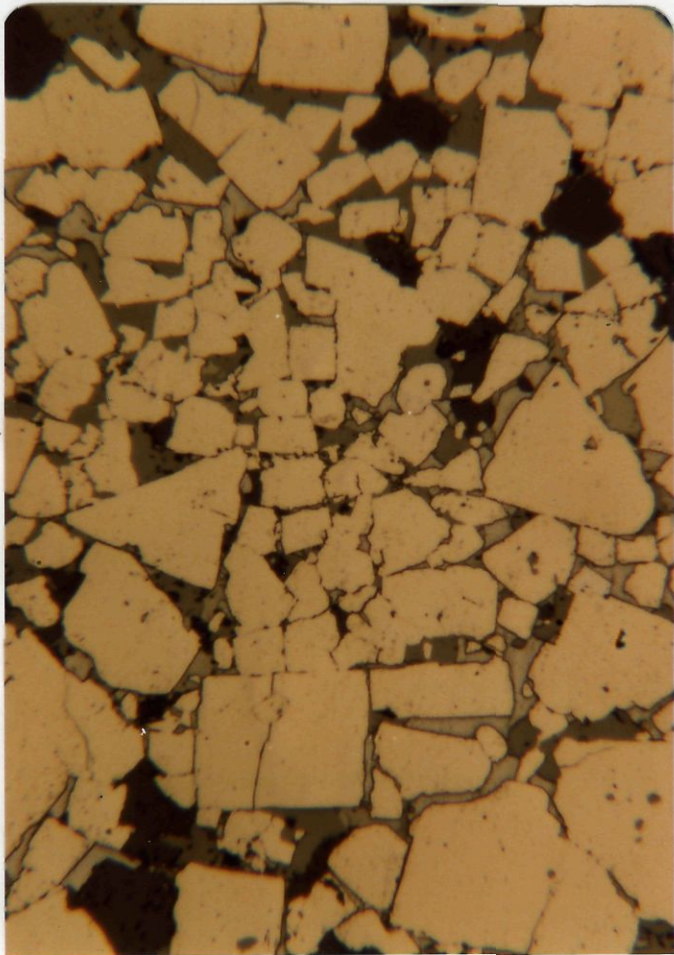


Plate 27D: Closely packed pyrite crystals. Growth is from numerous and closely spaced nuclei. Supply of cations are more or less evenly distributed preventing formation of large crystals as in 27B and C.

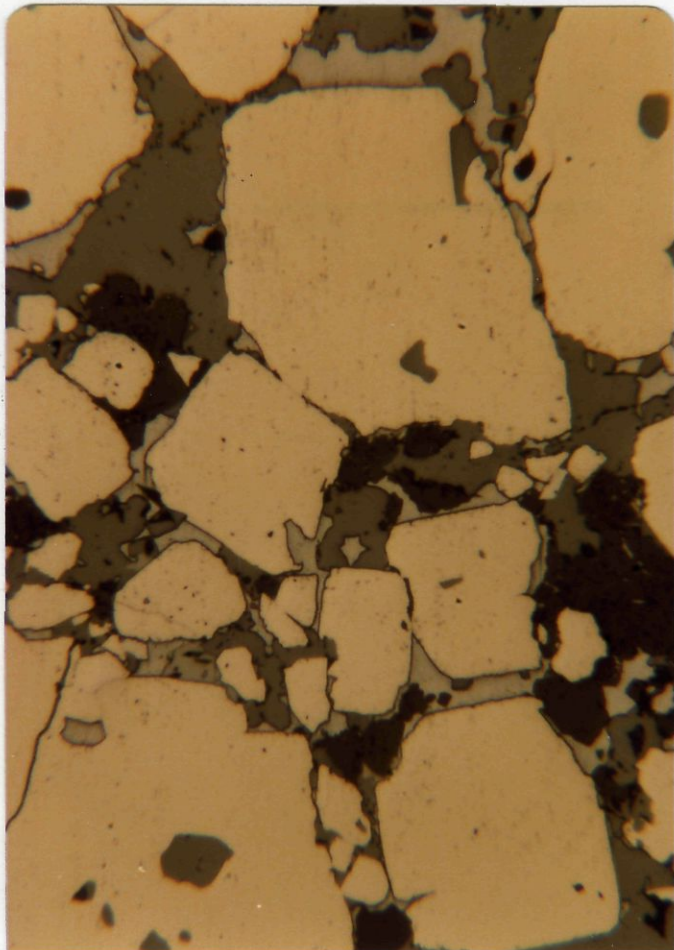
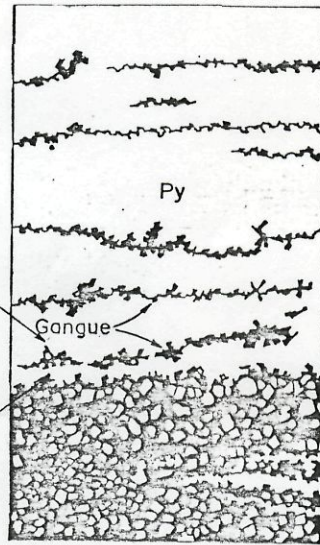


Plate 27C: Similar to 27B. Note how some of the crystal interfaces have fused where there was mutual interference.

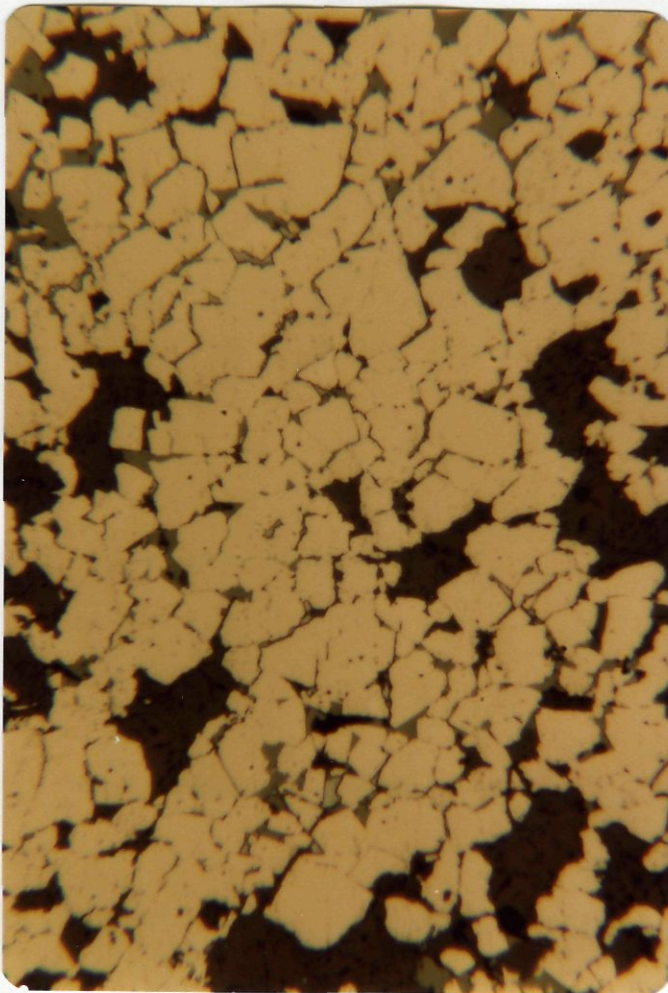


Plate F: Repetition of crystal growth from widely spaced nuclei. Note good cubic and some fused crystals.

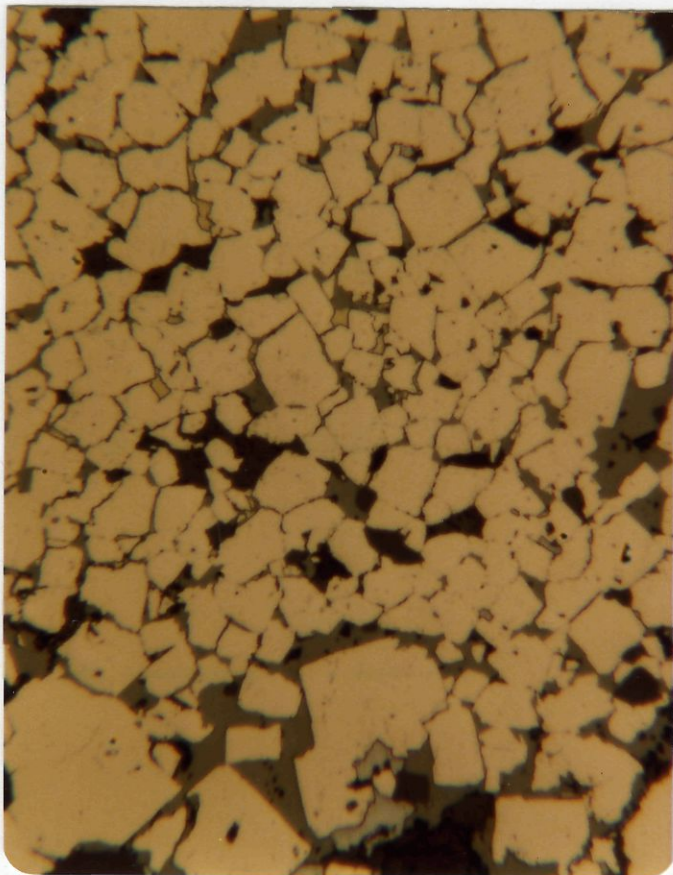
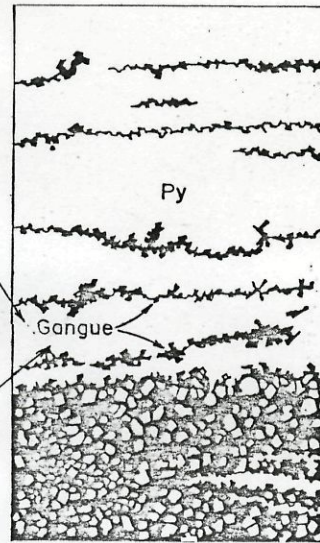


Plate 27E: Smaller pyrite crystals formed from more and closely spaced nuclei. Supply of cations are evenly distributed.

← Surface of change

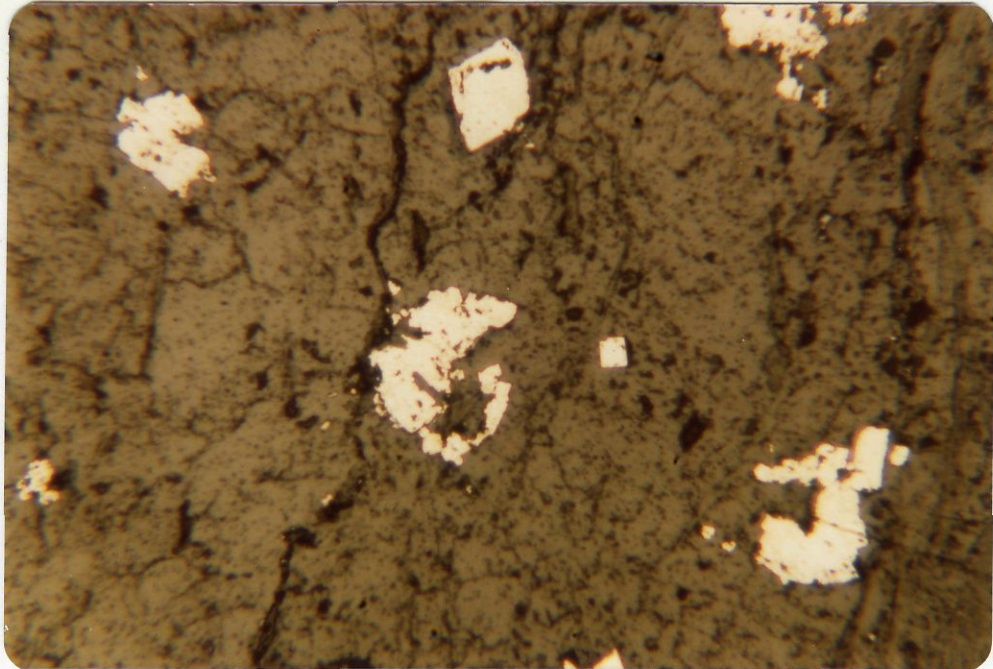


Plate 28A: Semicircular aggregates of pyrite forming atoll texture. This texture indicates original colloidal centres of crystallization.

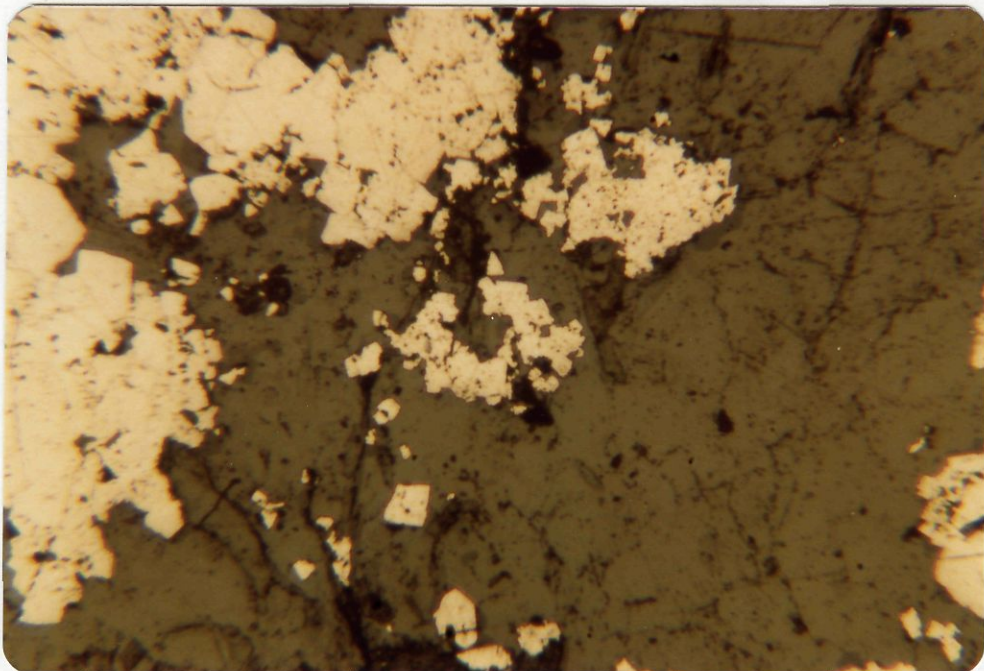


Plate 28B: Build up of pyrite crystals by accretion from original colloidal state. Note the beginning of cubic form of pyrite in the atoll and the coarser aggregates of pyrite where growth has proceeded in advance stage.

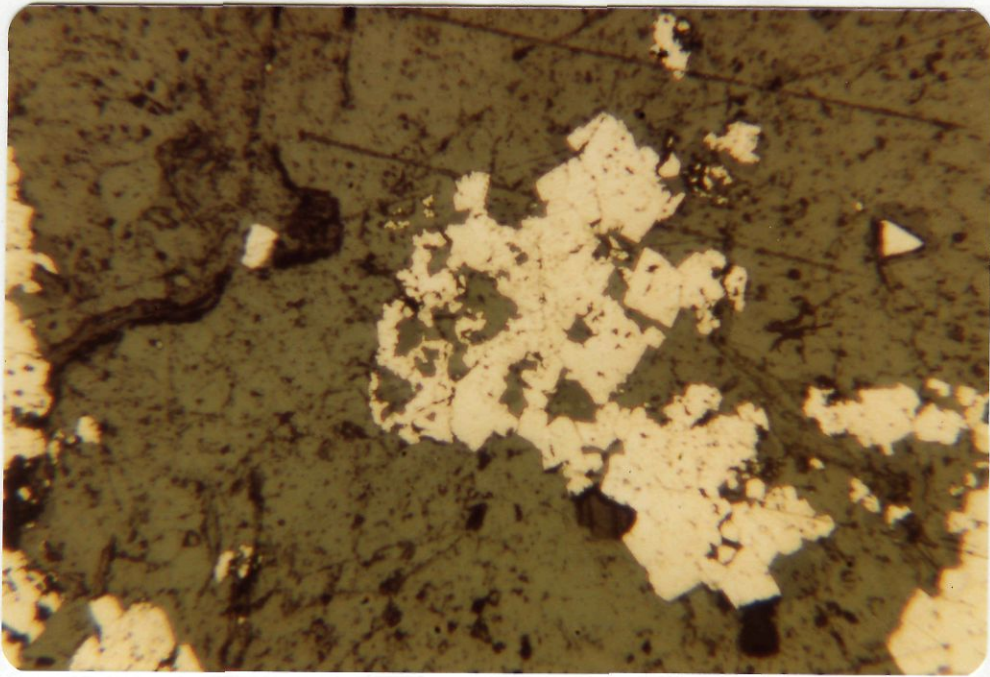


Plate 28C: Continuing growth of cubic pyrite. Atoll texture still clearly indicated. Note fusing of crystals where there is mutual interference.

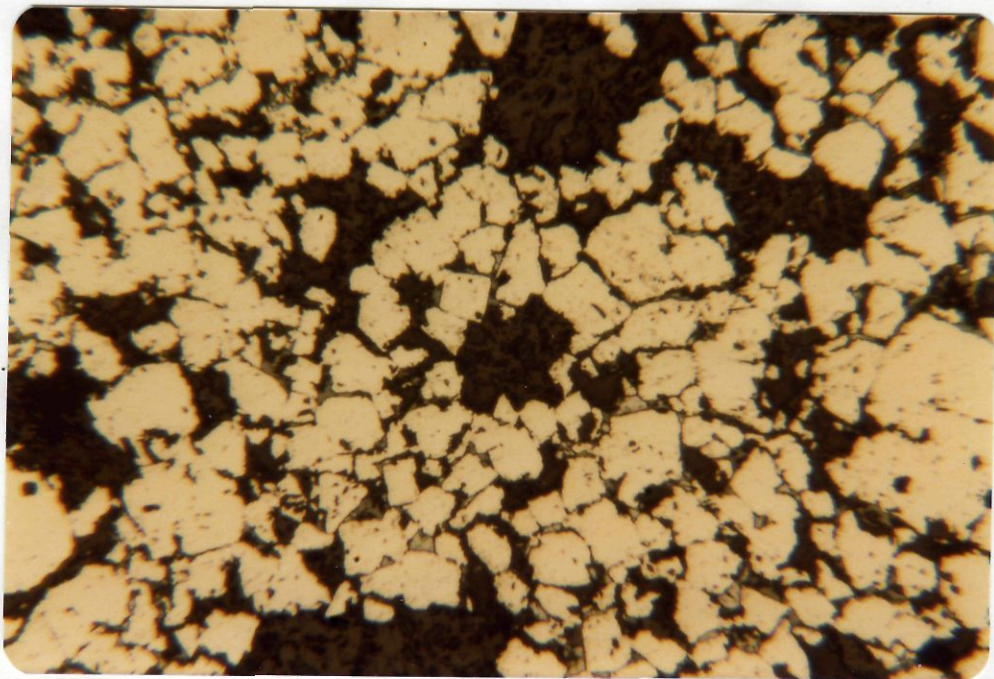


Plate 28D: Advance development of cubic pyrite still preserving atoll texture.

The minor minerals occur in varying modes either interstitially between bigger crystals (chalcopyrite, tennantite and gold), exsolved from major mineral phases (chalcopyrite from sphalerite; pyrrhotite from pyrite), replacing pre-existing minerals (pyrrhotite after pyrite or marcasite; marcasite after pyrite), microveinlets (tennantite), and as independent and isolated grains (magnetite, arsenopyrite). Cases of complex intergrowths (?) between galena and arsenopyrite were also observed (Plate 29). It is not clear whether this relationship is a case of simultaneous nucleation or replacement. But, based on crystallinity, it appears in this slide that arsenopyrite is building up slowly at the expense of galena.

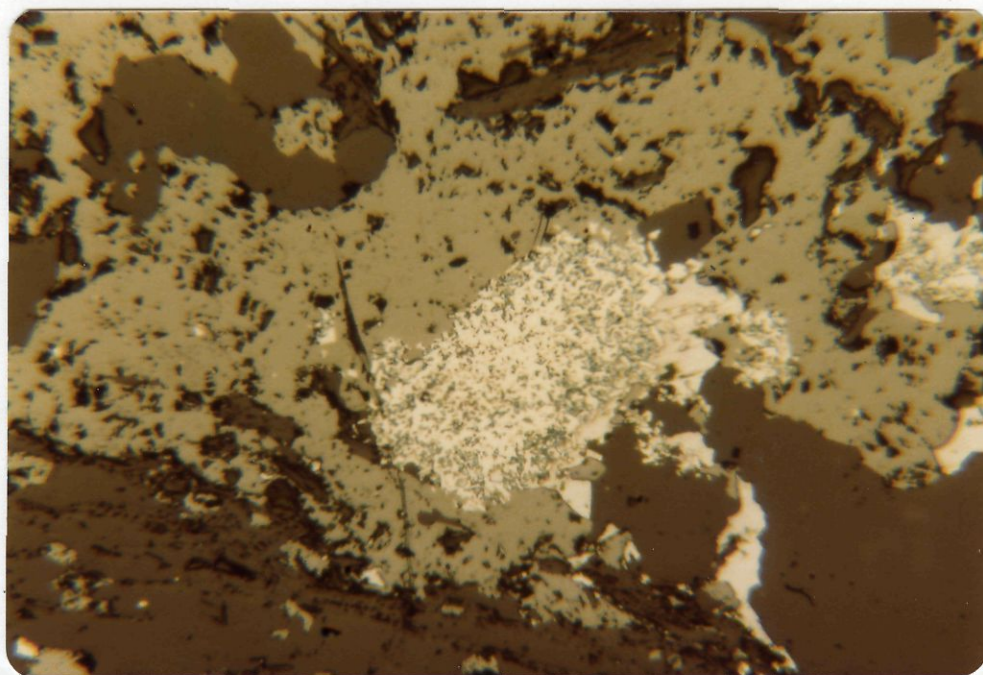


Plate 29: Intergrowth of arsenopyrite and galena.

3. Paragenesis

The paragenetic relationships of the sulphide assemblage is difficult to determine with full certainty. Based on the degree of crystallinity, cubic pyrite was the earliest to form and followed by the rest almost simultaneously with growth from independent nuclei. The colloidal pyrite may have begun precipitating together with the rest of the sulphides, but the process of crystallization of pyrite outlasted those of the other sulphides.

4. Metallurgical Response

Bulk metallurgical testing of the Grum deposit was done in various testing centres in Canada, as well as in Japan. The latest test was done at Mattagami Lake Mines Limited and completed in January 1977. In earlier tests done up until November 1976, the metallurgical response was very poor and the ore samples were subjected to fine grinding to get optimum recoveries. However, even with such treatment, the tailings still contained high lead and zinc while the lead concentrate showed unsatisfactory liberation of zinc.

In November 1976, David Carson of Noranda Exploration started a detailed mineragraphic investigation of the Grum deposit. He identified two characteristics of the ore that caused the poor ore dressing response of earlier tests. These were: (1) Strong oxidation which probably affected less than 5% of the orebody, and (2) A middling producing texture, consisting of fine inclusions of galena in sphalerite, galena-sphalerite in pyrite, and in some degree galena-sphalerite with gangue minerals.

In his report, Carson concluded that:

1. The main metallurgical problem, oxidation and galena-sphalerite intergrowth texture producing excessive amounts of middlings, probably occurs to a serious degree in less than 5% of the orebody.
2. Most Grum ores that were tested metallurgically up until November 1976 were not representative of the orebody. The test samples possessed both problems to an extreme extent.

3. It should be possible to obtain acceptable metallurgical results for more than 90% of the Grum deposit.
4. Grain size, though fine, is much coarser than other ores known to be metallurgically difficult, such as those of the Bathurst area.

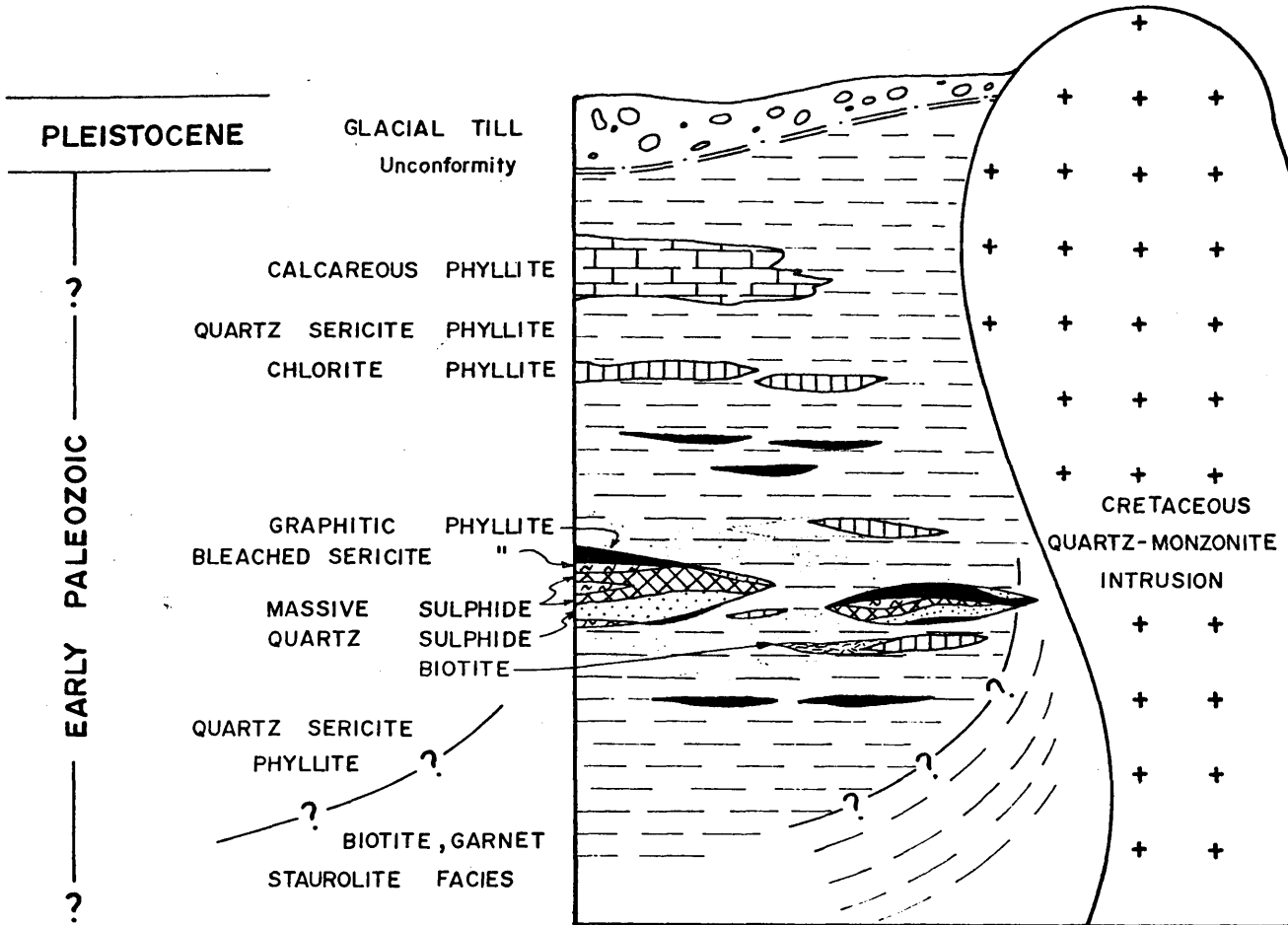
In the Mineral Inventory Report of March 1977, grain sizes were reported to be (average range): Pyrite 0.3 - 0.6 mm, galena 0.08 - 0.2 mm, sphalerite 0.05 - 0.04 mm and pyrrhotite 0.01 - 0.02 mm.

5. Stratigraphy

It is difficult to accurately ascertain the stratigraphic succession in the Grum deposit. Close inspection of the geological sections reveal numerous contradictions and ambiguities due mainly to the complex deformation of the area. Ignoring minor differences, it is nevertheless possible to make a stratigraphic model based on the more consistent patterns found (Fig. 4).

In sections of dense drilling (72W, 74W, 76W), the following general sequence occurs: quartz sericite phyllite - graphitic phyllite - bleached sericite phyllite - massive sulphide with interlayered bleached sericite phyllite - quartz sulphide - quartz sericite phyllite. The other rock units were not included because they lack the same consistent pattern found during drilling.

The sulphide zone is made up of two main layers whose continuity is drill proven and some peripheral layers not fully delineated. Whether these layers represent rhythmic sulphide depositions or repetition of one horizon due to complex folding is not clear (see Unresolved Problems, Page 43). In each of the two main layers, the massive sulphide tends to form a unit on one side (believed to be the stratigraphic top) and quartz sulphide on the other. However, there are cases where the massive sulphide grades into and is partly surrounded by quartz sulphide.



—Idealized stratigraphic section of GRUM. Illustration shows the more constant stratigraphic pattern found by drilling and depicted here without the deformation and ambiguous details.

Geologist — A.Y. Po
 Drafting — P.Haillot

JAN, 1978

FIG. 4

Thin bands of graphitic phyllite were often observed interstratified with other phyllite units, indicating sporadic deposition of organic sediments. The more significant occurrences are usually near and/or contiguous to the sulphide units or bleached sericite phyllite (Plate 13, Page 17 and Plate 18, Page 22). Contacts are sharp and distinct indicating rapid changes in the prevailing environmental conditions during sedimentation.

Separate bands of chloritic phyllite were found occurring in different spatial relationship with the sulphide layers. One group of chloritic bands are in close proximity with the sulphides while another are at some distance away. No concrete explanation for this different behaviour can be gathered from the present work. However, in the study of Kuroko type deposits, Alexander Po noted that MgO tends to decrease from near the centre of mineralization. Such decrease is caused by leaching of tuffaceous materials by acidic solutions from the connate brine.

Leaching might have commenced soon after burial preceding sericitization. The leached MgO travelled outward with the brine, the pH changing from acidic to alkaline as it continued migrating and mixing with fresher groundwater until the Mg was "locked-in" as chlorite or montmorillonite. In the same study, aluminium-rich chlorite (Al substituting for Mg) was found near and in sediments associated with sulphides. Whether this observed case can be applied to Grum is not known and to prove it would entail laboratory research work.

The calcareous phyllite unit was found in erratic distribution throughout the phyllite sequence. Continuity could not be established to satisfactorily suggest a definite band or horizon, partly because early logging work failed to describe this unit. Nevertheless, it appears that calcareous phyllite is more concentrated in the western part of the area which is believed to be stratigraphically above the sulphides. No conclusion can be reached as to whether this concentration is biogenic or caused by crystallization of calcite from the breakdown of calcium bearing pre-existing minerals.

The stratigraphic position of the higher ranking metamorphic rocks is not clear. Irregular biotite zones were recognized in sections 62W, 64W, 66W and 68W on the north side of the sulphides and paralleling the folding of the sulphides. Stratigraphically, these zones would appear to be lower than the sulphide units. Biotite, along with staurolite and garnet is also found in some deep drilling just below the lower sulphide unit. Biotite is an anti-stress mineral and its formation from sericite and chlorite is hindered by strong shearing stress. It therefore usually forms in the early stages of regional metamorphism, largely at the expense of chlorite. Garnet indicates a more advanced stage of metamorphism than biotite. Almandine, the common red garnet with high iron content, is a stress mineral. It forms mainly at the expense of the remaining chlorite in the rock and draws additional iron from magnetite. At the time of its formation there is no breakdown of biotite. This reaction requires a higher grade of metamorphism. Staurolite is another stress mineral but is also favoured by elevated temperatures and so may indicate a thermal aureole. It therefore appears that two spatially separate, successive metamorphic imprints occur in this region. From this the following conclusions may be drawn:-

- (1) Regional metamorphism had advanced to the biotite grade before the major folding took place because the biotite zones parallel the folds.
- (2) The major folding took place previous to the formation of the biotite-garnet-staurolite zone, because this zone does not parallel the folded sulphide layers.
- (3) The biotite-garnet-staurolite zone is possibly a part of the thermal aureole around the Anvil Batholith.

The biotite zones, because of their tabular shape, and because they conform to the F_1 direction probably represent original strata of slightly different original composition rather than higher grades of metamorphism, but both factors could have been involved. The biotite zone is of higher rank metamorphically than the chlorite-sericite layers but bands of sericite without chlorite can be of either rank.

6. Structural Geology

(a) The Evolution of the Structural Model

During the first two years of work on the Grum, all the structural information had to be obtained from drill core since there were no outcrops in the area and no underground openings. Except in the massive sulphide sections, the core usually showed F_1 banding and F_2 foliation as described previously. In most cases the sulphide bands were seen to follow the F_1 direction. Because the hole to hole correlation of the sulphide intersections was poor and also because numerous small folded F_1 structures could be seen in the core, it was assumed that the main sulphide bands were folded on a large scale. The prediction of the location of these large folds was thus the key to the determination of the shape and continuity of the sulphide layers.

In the summer of 1975, geologist T. Takeda began a re-study of all the core logs and began plotting a new set of cross-sections. The core had been logged by several people and although the phyllites had been subdivided into sericitic, graphitic, chloritic and bleached types, the gradational character of their contacts and the subjective nature of the logging made any overall interpretation difficult. Takeda's method of interpretation was to make the assumption that the chloritic and graphitic types were mutually exclusive. In the description of an intersection in a log, if there was any mention of chlorite, it was grouped with the chloritic phyllites and if there was any mention of graphite, it was grouped with the graphitic phyllites. If neither mineral was mentioned, the intersection was not considered. He then used the chlorite-graphite interface as a marker horizon to define the major fold noses. He was then able to fit the sulphide zones into this framework of major folds. By the end of 1975 the underground decline was completed and underground drilling was begun, using Takeda's fold model as a guide.

The first section drilled in detail from underground was 72W. Expectations of a simple fold pattern as shown on Takeda's sections had to be modified. It became apparent that although most of the major folds existed, there were

also many other apparently unrelated masses of sulphides. In the attempt to define the shape of these masses, drill intersection spacing was cut down to fifteen meters and a good deal more drilling was done than had been anticipated. Drilling was continued on the 72W section and on all the subsequent sections until it was felt that the shapes of the sulphide bodies were defined sufficiently for mining and ore inventory purposes. In most cases the correlation between intersections was made on the basis of proximity and of lead-zinc assay. Interpretation was also helped by carefully noting the angular relationships between the F_1 , F_2 and core axis. Combining these observations with underground drift geology, it was possible to determine the position of the axial plane and direction of vergence in many cases as shown in figure 5.

Concurrently with the drilling, underground drifting and cross-cutting were going on. Geologic mapping of these openings was done while mining was in progress. The active mining faces were mapped at least once each day (mining normally proceeded in each heading at the rate of three rounds per day) and every fifty meters or so at least one wall was washed down and mapped in detail. Due to the large size of the openings (4.2 meters square), the back could not be mapped accurately. The wall mapping was used in conjunction with the daily face sketches to construct a breast height plan in the plane of the underground workings (included in pocket). The mapping was often done under difficult conditions and occasionally geologic information was destroyed by mining before it could be recorded.

Late in 1976 the mining and drilling programmes on the site were completed. This was followed by a major effort to correlate all the data and produce a structural model of the deposit. This effort was frustrated until the position of the major fold noses was determined relative to the set of steep faults mainly striking $N 60^{\circ} E$ which cut the sulphide zone. By assuming certain displacements on these faults, a model was constructed which satisfied most of the data. An isometric presentation of this model is shown in figure 6.

A detailed description of the processing of the data used to create this model is contained in Appendix A of this report.

DIAGRAM SHOWING HOW MAJOR FOLDS CAN BE INFERRED FROM CORE OBSERVATIONS

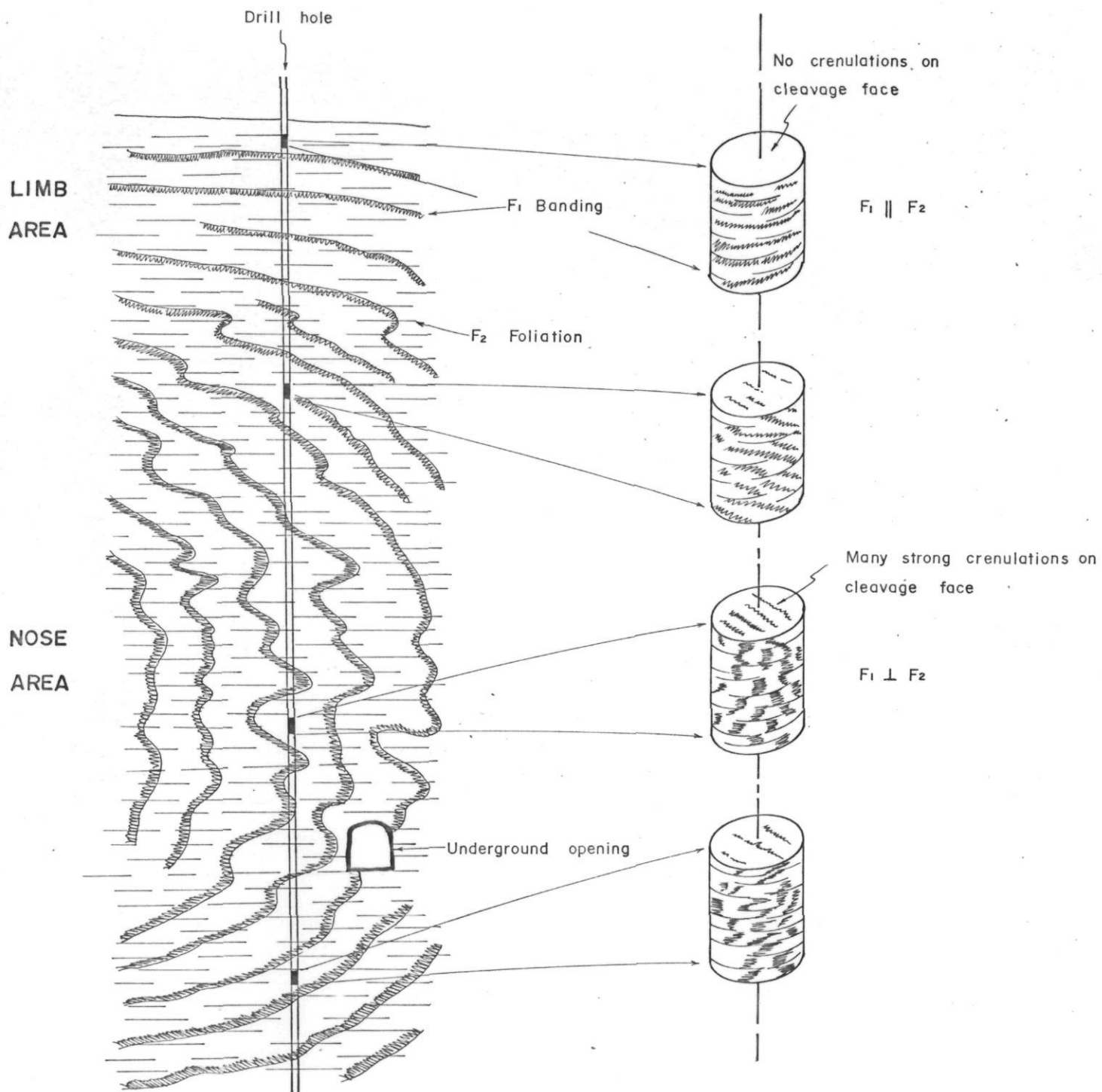
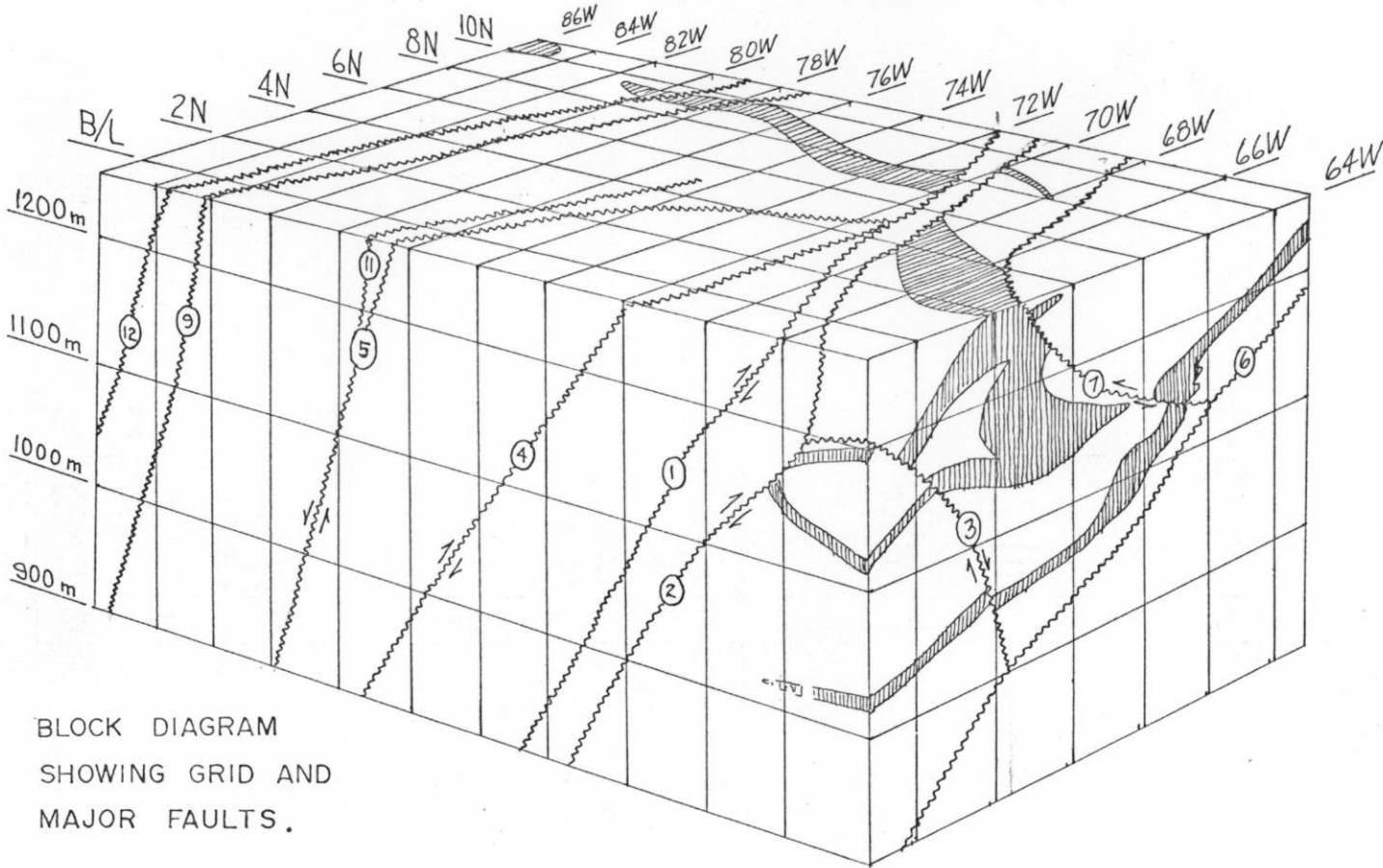
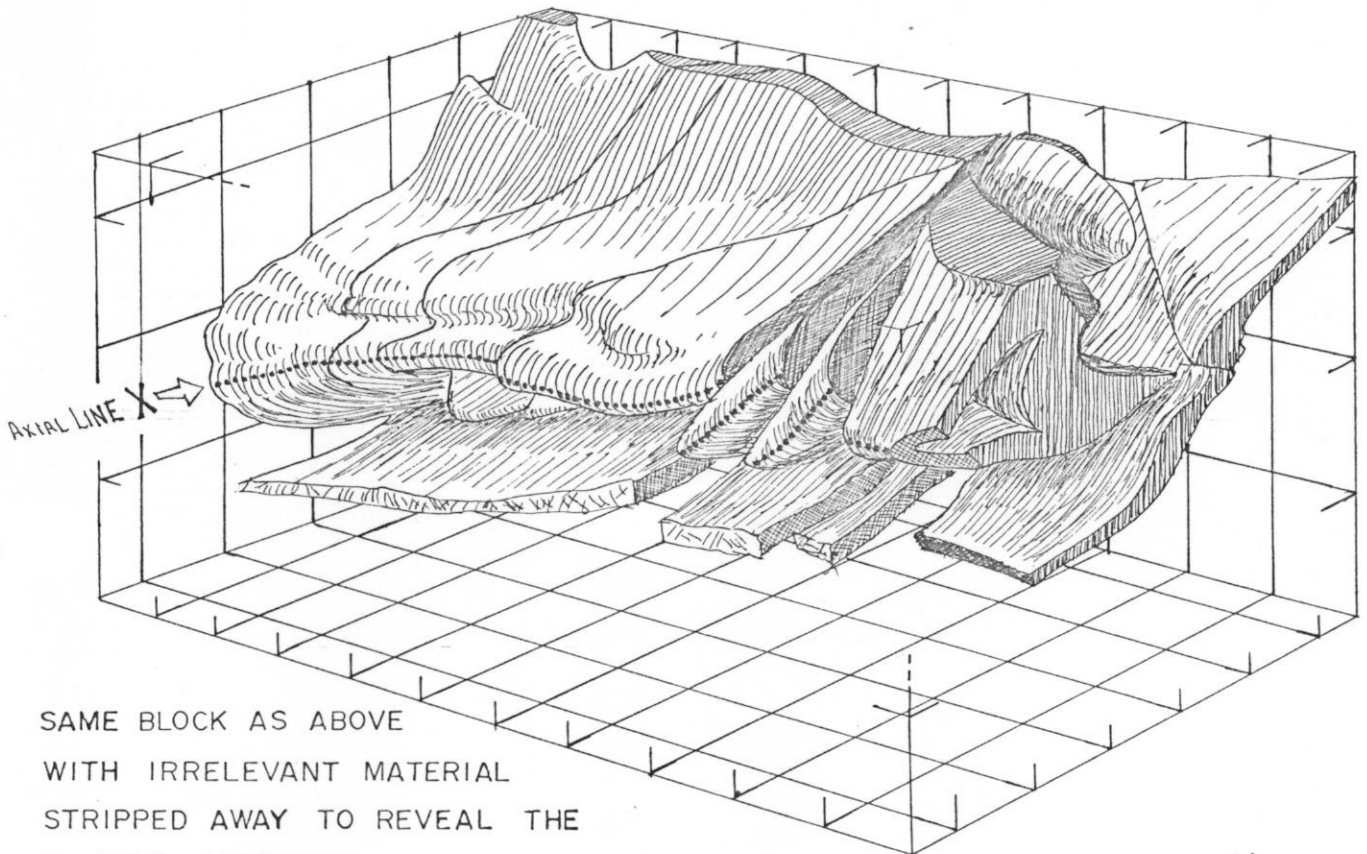


FIG. 5

STRUCTURAL DIAGRAMS - GRUM ORE ZONE



BLOCK DIAGRAM
SHOWING GRID AND
MAJOR FAULTS.



SAME BLOCK AS ABOVE
WITH IRRELEVANT MATERIAL
STRIPPED AWAY TO REVEAL THE
X FOLD AXIS.

FIG. 6

Jim Patton
March 1977

(b) Unresolved Problems in the Structural Model

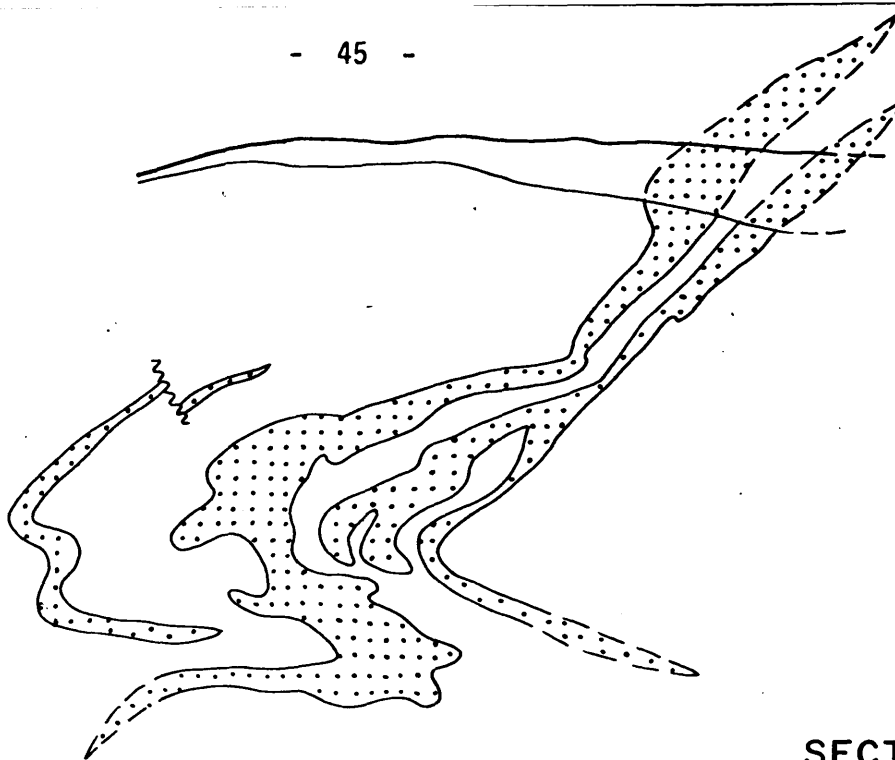
The number of episodes of deposition of sulphides and of fold deformation remains problematical. One school of thought contends that several layers of sulphide were deposited one above the other and the whole was subjected to one major deformation which produced the folding as well as the F_2 foliation. The opposing contention is that there have been several fold deformations at different orientations affecting only one main sulphide layer, the F_2 foliation being formed as a result of the last of this series of deformations. The diagrams in figure 7 are intended to show these two interpretations.

The evidence in support of the multiple layer, single deformation hypothesis is as follows:-

- (1) In detail each body of sulphides has slightly different characteristics such as barite content, silicification and lead-zinc content.
- (2) No marker horizon can be recognized linking all the sulphide bodies into one depositional basin.
- (3) The multiple layer, single deposition hypothesis is the simplest and does not require radical changes in the orientation of the stress field to explain the structure.
- (4) Volcanic activity usually occurs as a series of pulses within a main cycle. Therefore, if the sulphides are of volcanic origin one would expect them to occur as a series of superimposed layers.

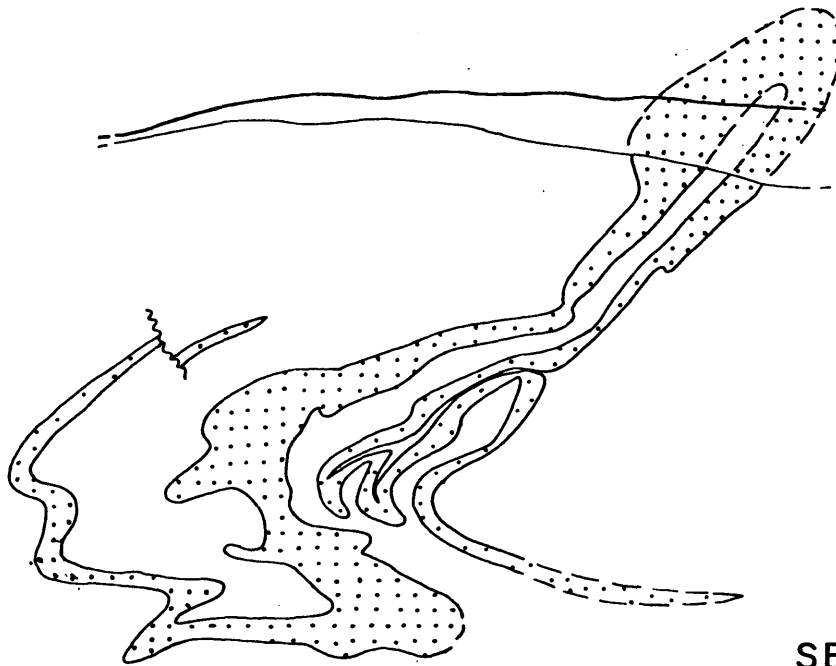
The evidence in support of the single layer, multiple deformation hypothesis is as follows:-

- (1) In several of the cross-sections of the geologic model (see maps in pocket, 80W and 84W), the stratigraphic succession of graphitic phyllite - massive sulphides - quartz sulphides, appears to be reversed in the two main sulphide layers. These could be opposing limbs of a first deformation fold.



SECTION 76 W

- A - The multiple layer , single deformation interpretation



SECTION 76 W

- B - The single layer , multiple deformation interpretation

- (2) Within both the phyllites and the sulphides, small folded folds were occasionally observed, with the shape shown in the following diagram and plate:-

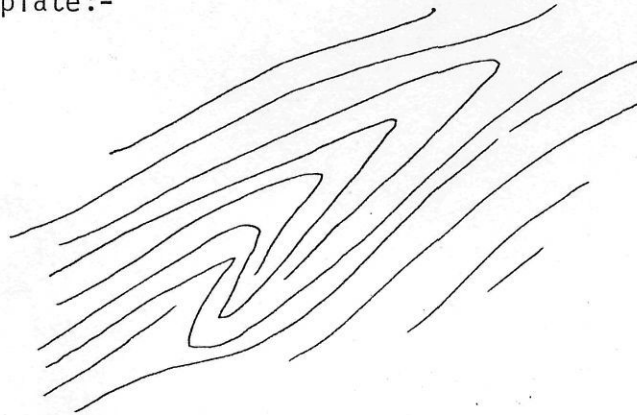


FIG. 8

Typical folded dragfold



PLATE 30

Folded dragfold in drill core

These folds can be interpreted to indicate multiple major deformations at differing orientations after the manner shown in figure 9 on the next page.

POSSIBLE MODE OF FORMATION OF FOLDED DRAG FOLDS

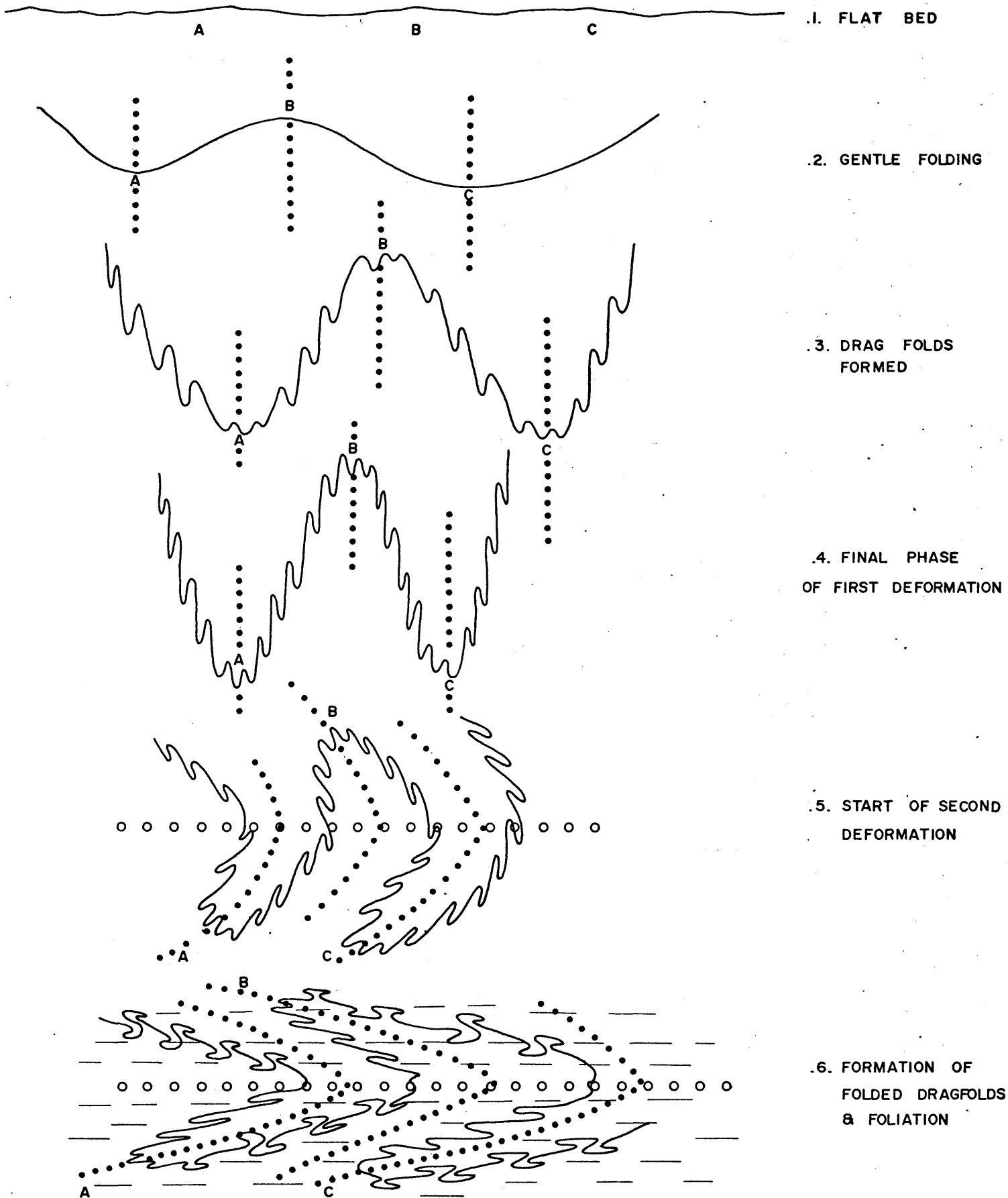


FIG. 9

(c) Folding

Small scale folding at Grum has been observed in the drill core and in the underground openings. Most of the folds mapped underground have axial lines which trend N 40°W and plunge 10° NW. The major folds have all been inferred. One of the largest and best folds seen underground was a recumbent isoclinal fold in a band of bleached tuff in the main decline at approximately 5S, 74W. Folding has also been accompanied by brecciation, plastic flow and by the formation of boudin (Plate 31). Other well developed folds were observed on the upper limb of the second sulphide layer in the 84W cross-cut (See plate 32 and section 84W in pocket).

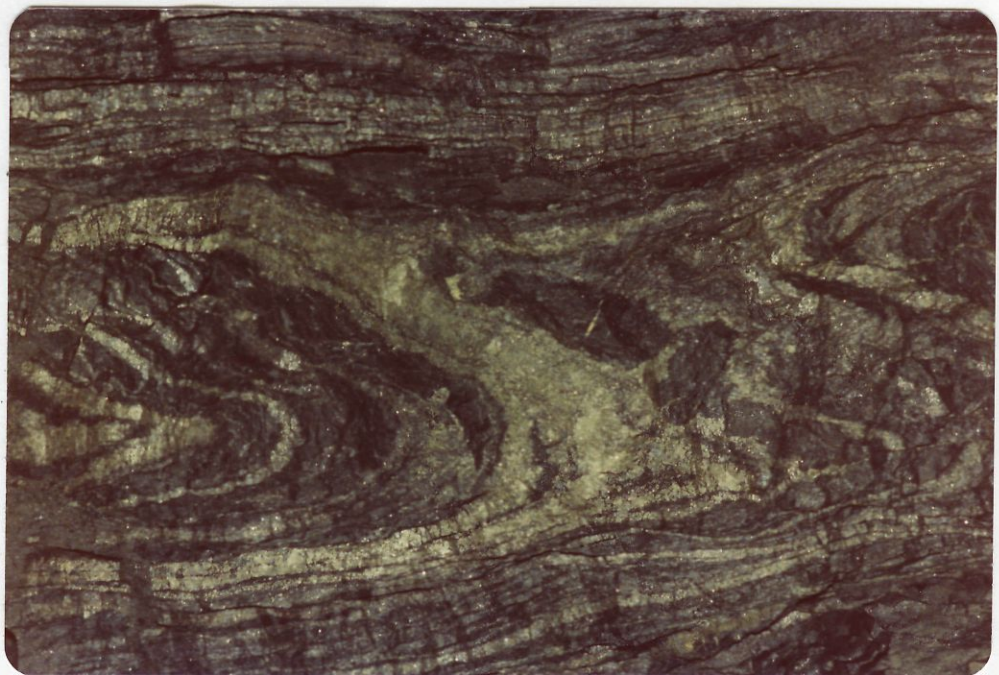
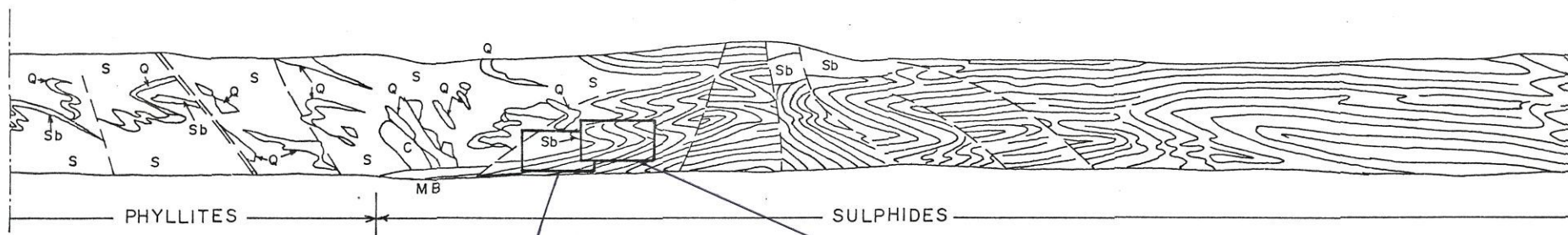


Plate 31: Folding in massive banded sulphides in the 84W cross section showing plastic flow, brecciation and the formation of boudin structure. Note the thickening of the bands in the fold nose.

GRUM 84 W X-C . West wall geological map - looking west

SCALE - 1: 250

0 2.5 5 7.5 10M



MASSIVE SULPHIDES

- 49 -

MASSIVE SULPHIDES - CONTACT

(d) Plastic Flow

In the underground mapping, massive sulphides were seen to intrude the surrounding rocks in several areas. This is believed to be due to plastic flow of the sulphide since no associated veinlets or contact alterations were observed which one would expect with a fluid intrusion. The process proposed is that in reaction to the stress, the sphalerite and galena which commonly surround pyrite grains in the massive sulphide, undergo numerous minute movements along cleavage plans to produce flow, carrying the pyrite grains along as inclusions. This flow destroys all previous bedding structures and results in the typical MI type massive sulphide. A certain amount of quartz and calcite are also involved and occasionally form rosettes of coarse crystals in the sulphides or as irregular rounded masses of milky quartz. Examples are shown in plates 33, 34 and 35.



Plate 33: Massive sulphides
intruding phyllites



Plate 34: Massive sulphide intruding bleached phyllite.



Plate 35: Massive sulphide flowing around phyllite fragments.

Note quartz-calcite rosette.

(e) Faulting

Most of the major faults at Grum belong to the previously mentioned set parallel to Blind Creek, striking approximately N 60°E and having steep dips. These faults are commonly filled with up to two meters of sticky gouge and breccia. Generally the rock near the fault plane is so strongly fractured that it is friable. This makes mining through any of the larger faults at Grum a serious undertaking and great care must be taken not to let uncontrolled caving get started. All the faults mapped at Grum are tension faults with relatively small offsets. The thick gouge zones are thought to be due as much to spalling of the walls of the faults into the zone, as to movement along the fault. This process is especially evident where faults cut sulphides near the end of the 2 N/E drift, to form dilation zones filled with a breccia of sulphide fragments in a sulphide groundmass.

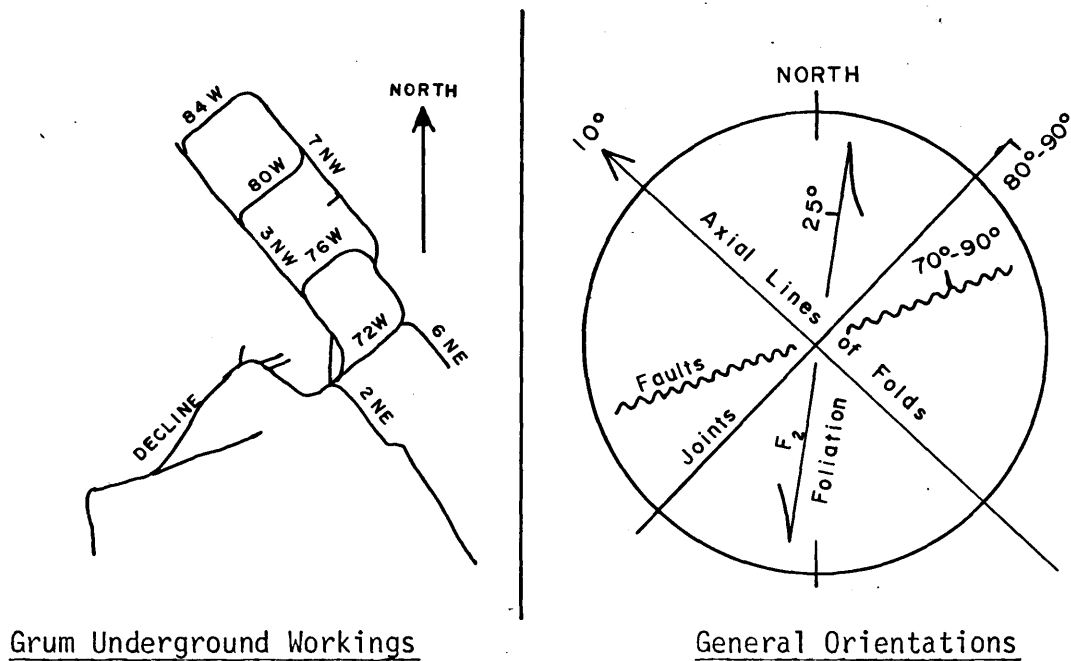


Plate 36: Fault in sulphides in 72W. Cross-section at approximately 2N.

Scale: rod equals one meter.

(f) Joints

Numerous joints occur in all the Grum rocks, with the quartz sulphide type having the most. By far the most prominent set occurs at right angles to the axial planes of the major folds. The joints occur both as open fractures or are filled with calcite and quartz. When open, they act as a reservoir for ground water which in turn can feed into a breccia zone or a porous sulphide zone to create serious temporary mining problems. Several times during the underground mining at Grum, strong flows of water were encountered which, after a couple of weeks, diminished to a trickle as the joint reservoir was depleted. The relation between folds, foliation and joints in the underground workings is shown below in figure 10.



Grum Underground Workings

General Orientations

Fig. 10: Orientation of the main structural elements at Grum

(g) Bedding

F_1 banding, which is possibly bedding, is seen in most of the Grum rock types and has been described previously in the section on lithology. Graded bedding and perhaps cross bedding occur locally in the quartz-sulphides and was only observed when sawn specimens became available. As yet bedding tops determined

by these structures have not been used to attack the problem described previously regarding the number of sulphide layers and deformations in the structural model.

7. Metal Ratios

During 1977, in connection with the study of open pit mining feasibility, a computer version of the Grum structural model was made with the help of the Norcomp division of Noranda Mines Ltd. In this model, the mineral zone was divided into 5 m x 5 m x 9 m blocks. Blocks which were intersected by drill holes were called actual value blocks if the intersection included assays. All the assays within an actual value block were computed to give a weighted average value for the block. All the actual value blocks and their locations within the block matrix were stored in the computer as the actual value file (AVF). Print-outs could then be made of any section or plan desired showing the actual value blocks in their relative positions. For the metal ratio study, Norcomp produced print-outs showing the metal ratios of the actual value blocks on each of the principal sections, 62W to 84W. The ratios chosen were zinc % over lead % and silver gm/t over lead %.

On each ratio section, the interpreted sulphide boundary was superimposed. The sulphide outline was divided as shown in figure 11 and the various groups of ratios compared. The object was to find any systematic variations in the data. First, similar parts of the structure were compared up and down the plunge. Second, different parts of the structure were compared to one another on the same section. Finally, grouping all sections together, different layers and different types of materials were compared.

The comparisons were made by plotting the block ratio values as points on a triangular or rectangular ratio diagram showing the Zn/Pb ratio versus the Ag/Pb ratio. For each group considered, the number of points per grid unit was reduced to a percentage. Since the number of points per grid unit is a measure of the variance about the mean for the group, reducing to percentages allowed the variance of the different groups to be compared, as well as their ratio values.

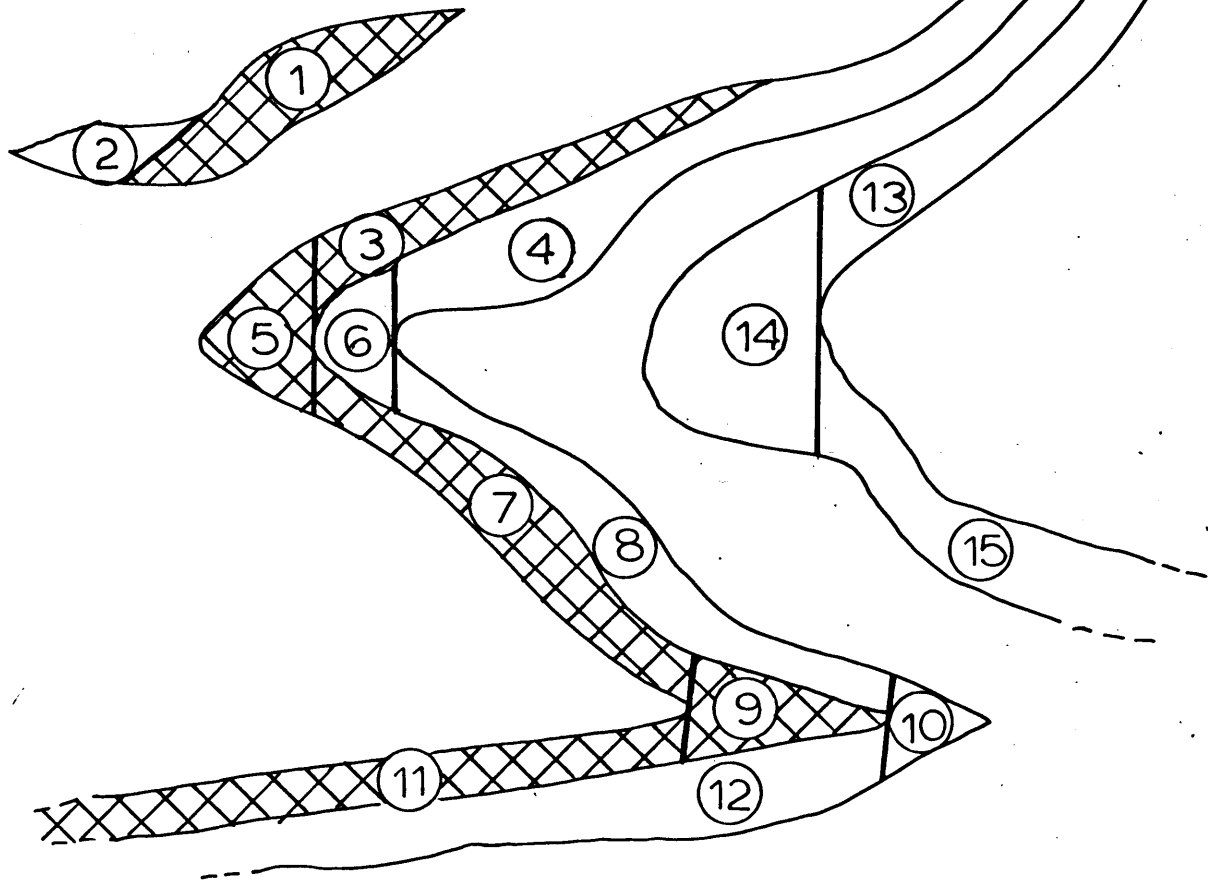
The results of this study were as follows:-

1. There is no appreciable change in the metal ratios longitudinally, that is along the plunge of the fold structure.
2. In cross-section, there is no appreciable change in metal ratios in limbs compared to noses of the major folds.
3. In cross-section, the variance is greater in the nose areas than in the limb areas.
4. There is a notable difference in metal ratios between quartz sulphide and massive sulphide material in the noses, but not in the limbs. In the noses the quartz sulphide has less zinc and silver than the massive sulphide. This is shown in figure 12.
5. In both noses and limbs the variance of the metal ratios is greater in the quartz sulphide than in the massive sulphide.
6. Comparing layers one, two and H, including both quartz sulphide and massive sulphide over the whole deposit, layers one and two are similar both in ratio value and in variance. Layer H is markedly different, having higher lead content and slightly less silver, and having much lower variance in both ratios. This is shown in figure 13.
7. Silver does not vary directly with lead. The earlier belief that the silver is "locked in" with the lead is questionable.
8. The average metal ratio of the A.V.F. blocks was found to be approximately 1.6 Zn % over Pb % and 16 Ag gm/t over Pb %. This compares to 1.63 Zn % over Pb % and 15.7 Ag gm/t over Pb % derived from the weighted average grades in the mineral inventory.

From the above results the authors draw the following conclusions.

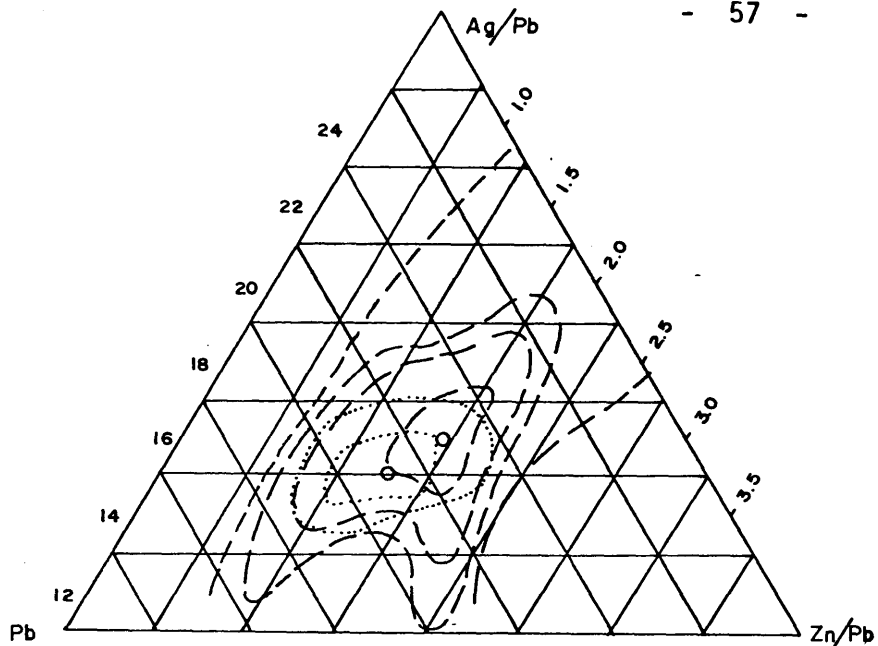
The greater variance in the ratios in the fold noses is due to remobilization and plastic flow of the sulphides at these sites. The greater variance and difference in ratios between quartz sulphide and massive sulphide is a primary feature and is due to their different rates and conditions of deposition.

Layer H, which is stratigraphically high, is a separate entity deposited under different conditions and possible at a different time than the rest of the deposit.



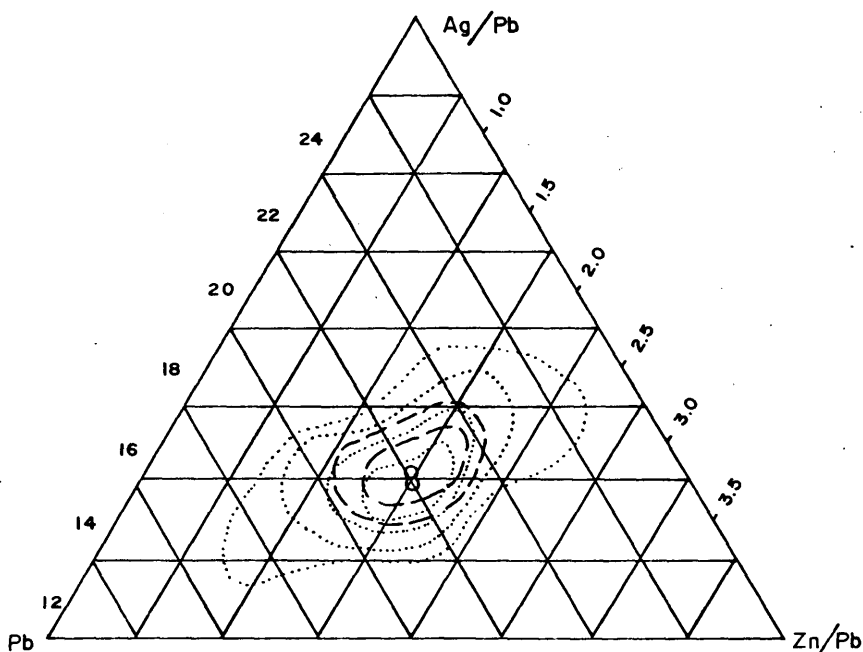
1. H zone, massive sulphide
2. H zone, quartz sulphide
3. Layer 1, upper limb, massive sulphide
4. Layer 1, upper limb, quartz sulphide
5. Layer 1, nose x, massive sulphide
6. Layer 1, nose x, quartz sulphide
7. Layer 1, lower limb, massive sulphide
8. Layer 1, lower limb, quartz sulphide
9. Layer 1, nose U, massive sulphide
10. Layer 1, nose U, quartz sulphide
11. Layer 1, bottom limb or D zone, massive sulphide
12. Layer 1, bottom limb or D zone, quartz sulphide
13. Layer 2, upper limb, quartz sulphide
14. Layer 2, nose S, quartz sulphide
15. Layer 2, lower limb, quartz sulphide

Figure 11 - Generalized section of the Grum showing the divisions used in the metal ratio study.



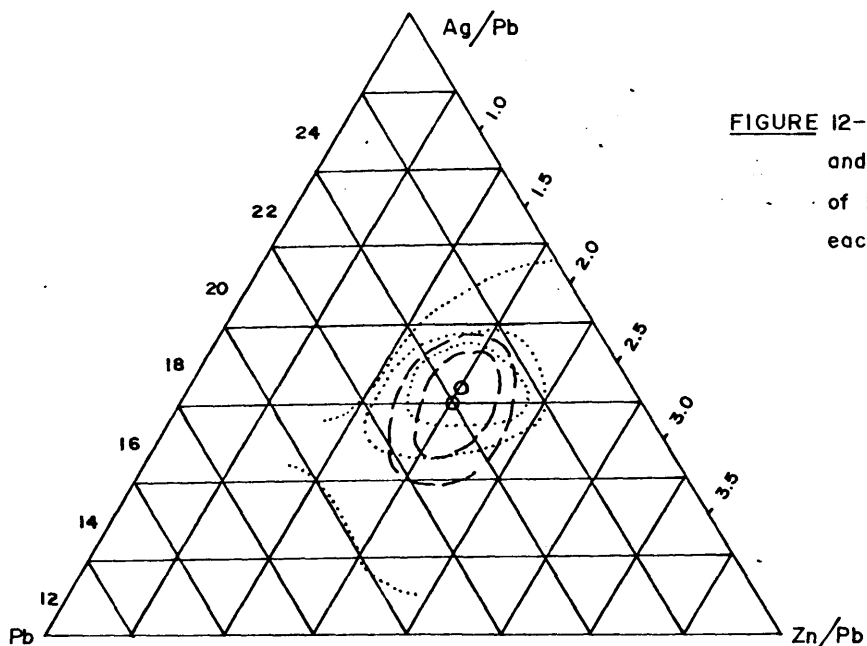
A- NOSE

A - Note difference in metal ratio average and the orientation of long axes of the enclosed fields.



B- UPPER LIMB

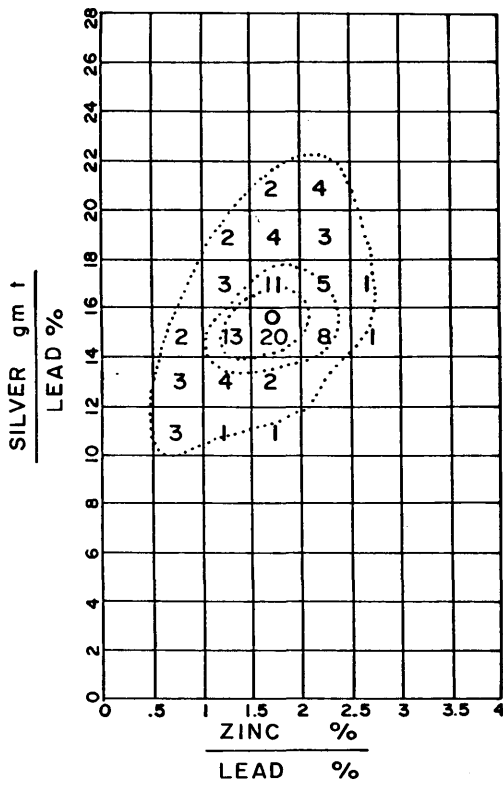
B - Note the close overlapping of fields.



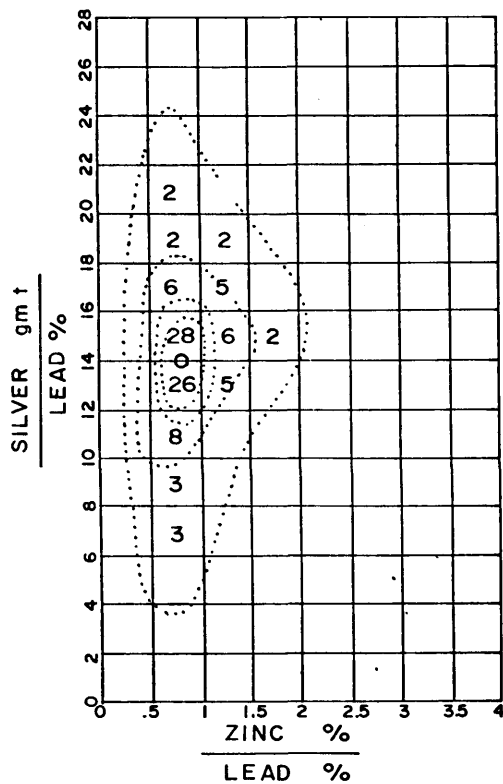
C- LOWER LIMB

FIGURE 12-Comparison of metal ratio for massive sulphides and quartz sulphides along fold noses and limbs of layer I. Dots represent average metal ratio for each respective material.

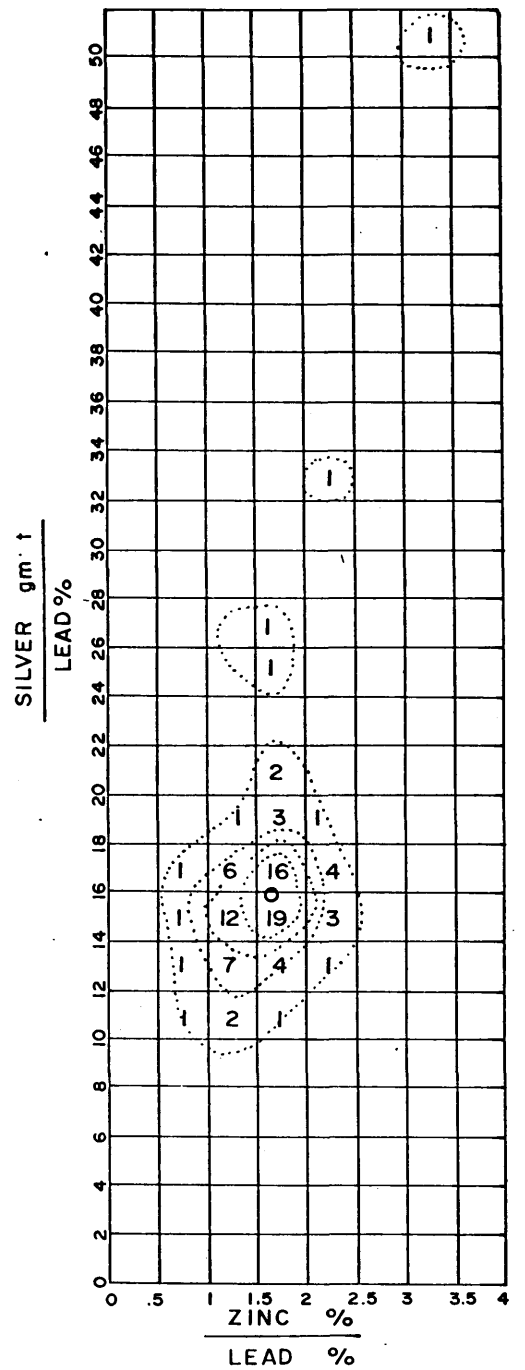
--- Massive sulphides
..... Quartz



N# 2 LAYER (220 points)



H LAYER (61 points)



No. 1 LAYER (478 points)

FIGURE — A comparison of layers 1, 2 and H, including both P & M sulphide types from section 62W to 84W. The numbers on the grid are the percentage of the total point count falling within the grid squares.

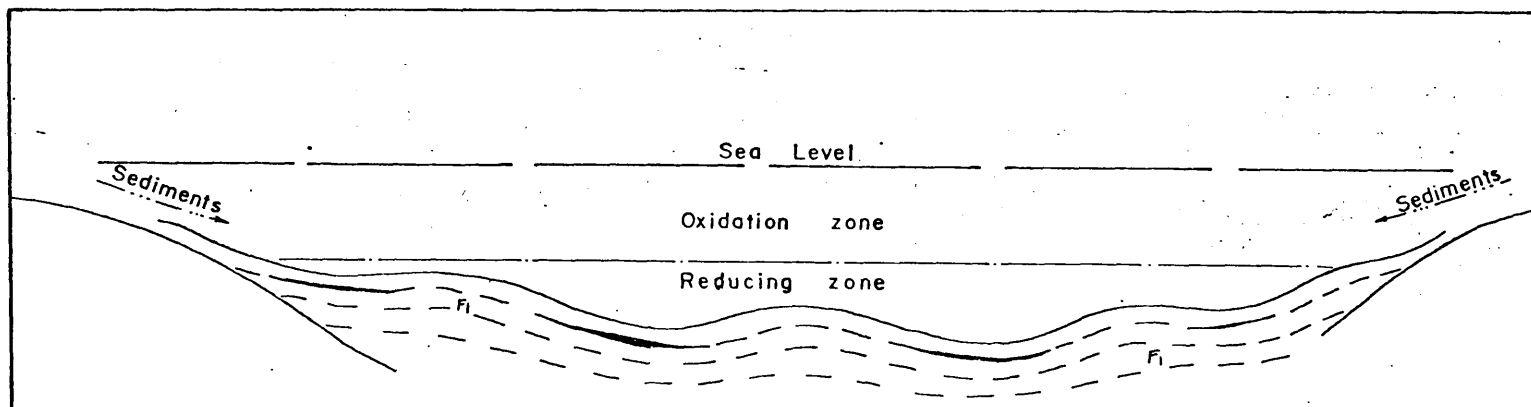
FIGURE 13

SUGGESTED MODE OF DEPOSITION

There are many interpretations forwarded regarding the formation of the Grum deposits. However, it is believed by many, including the authors, that Grum is a submarine volcanogenic-sedimentary type deposit. It was formed by volcanic activity whose emanations were transported by density currents and deposited in restricted basins as thick turbidites coeval with other normal sediments. The reasons for this belief are:-

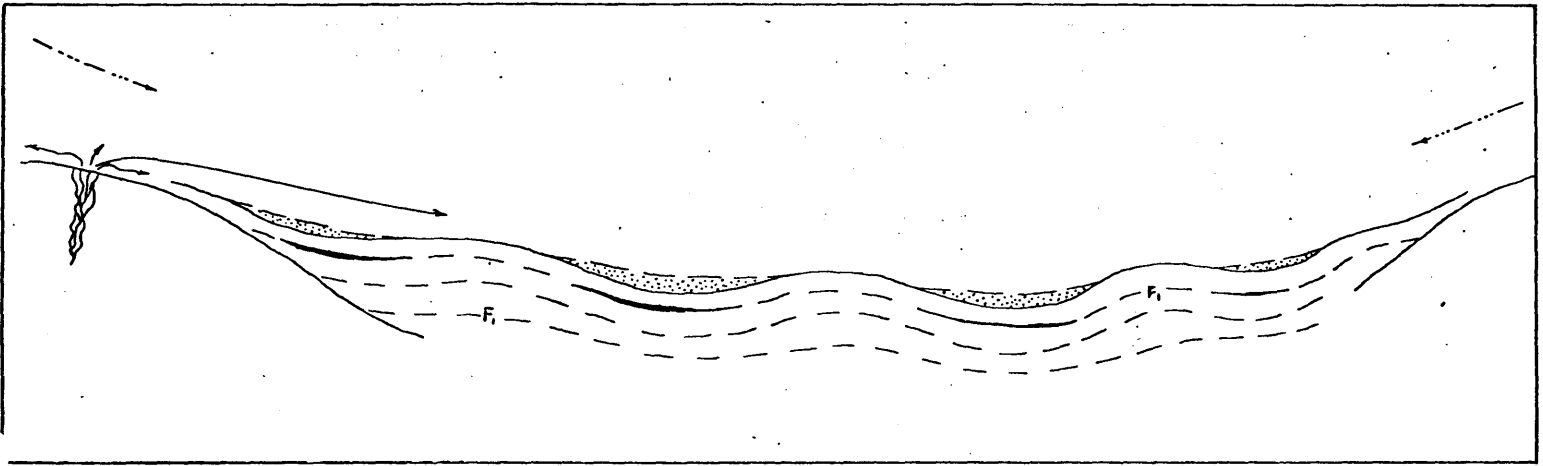
- (1) Many sedimentary features are present in the sulphides.
- (2) It has a close association with tuffaceous and normal pelitic sediments which are finely stratified.
- (3) Presence of preserved atoll texture in the pyrite indicates colloidal deposition.
- (4) Presence of thick carbonaceous horizons contiguous to the sulphide bands, indicating thriving organic life during the period of deposition and a euxinic environment in the trap basins.

With the above observations, the authors suggest the following stages and possible conditions prevailing during the formation of the Grum deposit.

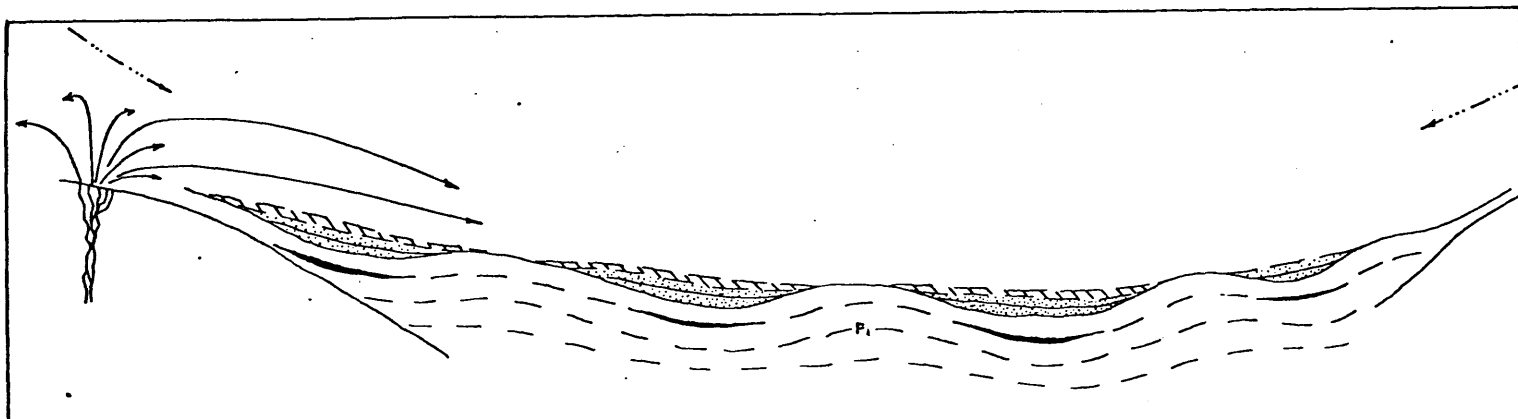


Stage 1: Quiet sedimentation of normal pelitic sediments and occasional organic remains. Locale is an open sea with irregular seabed topography. Local depressions act as restricted basins below the influence of wave action.

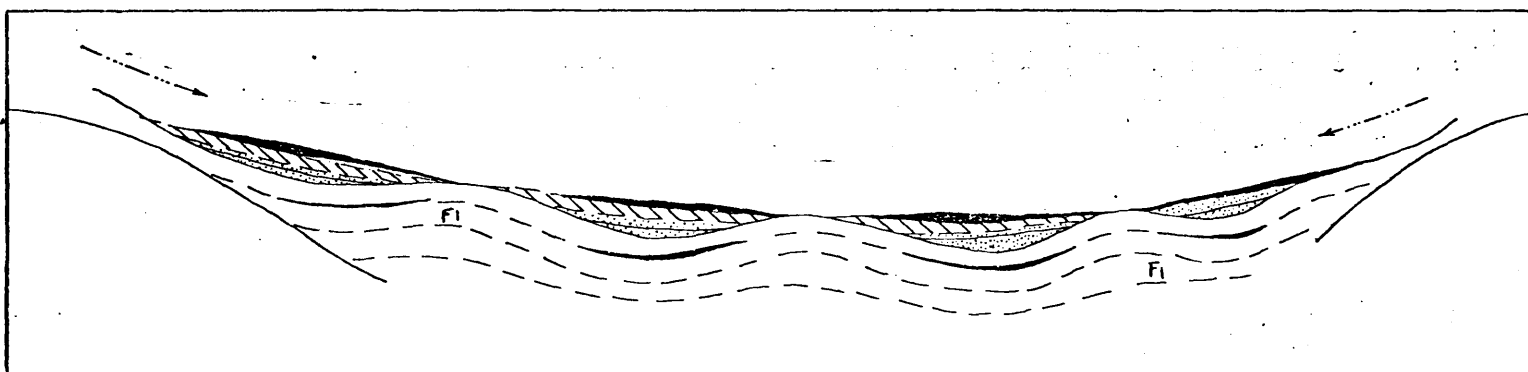
where euxinic conditions prevail. Such basins are characterized by high organic (anaerobic) activity and reducing conditions. Quiet sedimentation proceeds at a constant and low rate, forming uniform fine laminae. Carbonaceous materials are intermittently or seasonally being deposited and interstratified. Compaction of earlier sedimentary materials proceeds together with slow subsidence of the entire sedimentary (tectonic) basin.



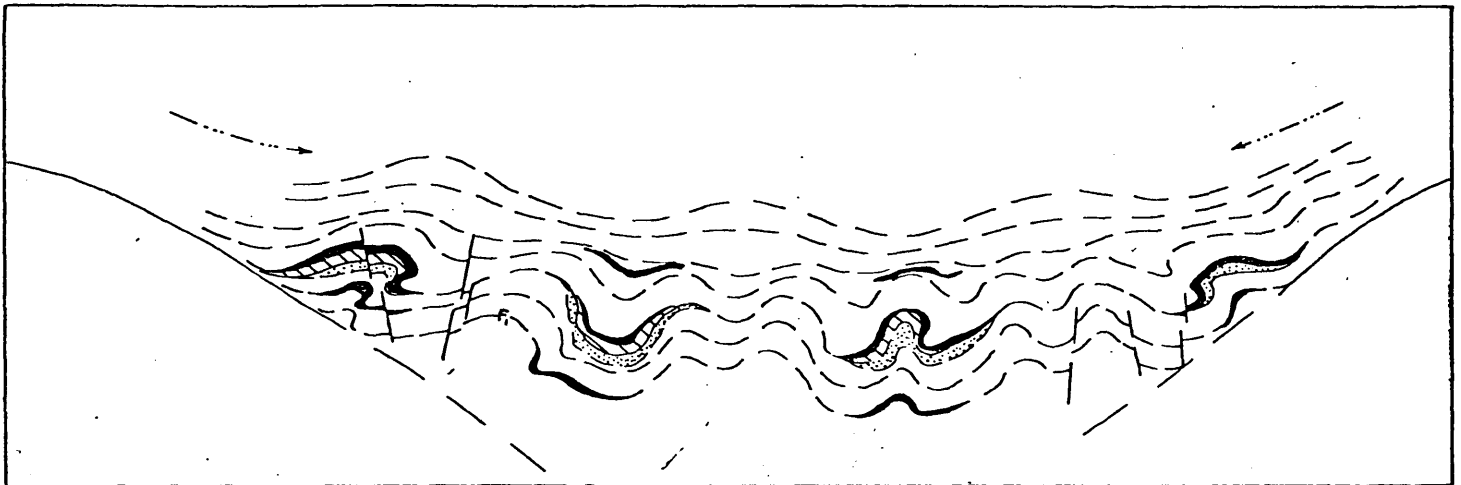
Stage 2: Distal volcanic activity introduces pyroclastic materials and silica rich solutions into the sea. These are transported together with normal sediments by turbidity current and deposited along the seabed. Increasing intensity of vulcanism introduces more volcanic materials relative to normal sediments. These result in thicker volcano-clastic deposits of tuff and cherty materials. Fumarolic activities following the violent phase of vulcanism began adding metallic cations as sulphide/chloride complexes into the sea. Mixing with seawater and reduction by sulphur bacteria triggers precipitation and formation of mineralized layers. Some cations flocculate and form colloidal gels which slowly precipitate. Those deposited in depressions are immediately covered by subsequent sediments and lie undisturbed. Those precipitated on unprotected surfaces are sometimes re-worked and mechanically transported until deposited and preserved in the local depressions.



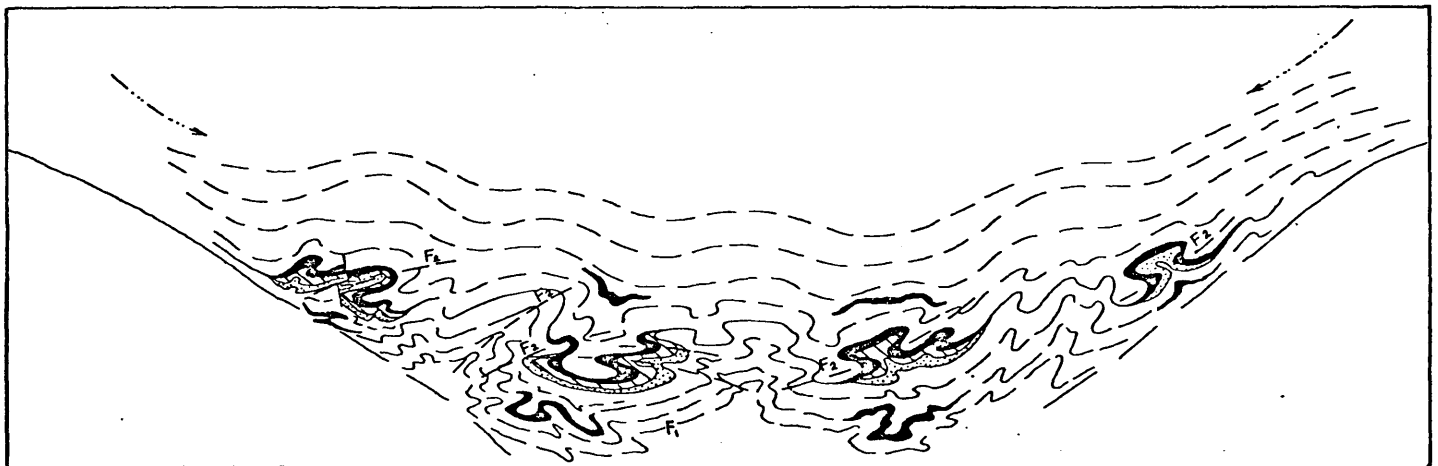
Stage 3: Increasing fumarolic activity introduced abundant sulphur and sulphide complexes and resulted in abnormal increases in population of sulphur bacteria. This caused rapid precipitation of sulphides especially in the local depressions where the brines were trapped and began to concentrate. Earlier formed layers began to recrystallize. The waning stages of fumarolic activity were accompanied by pulses of violent vulcanism. The massive sulphide layers were being precipitated together with some tuffaceous materials.



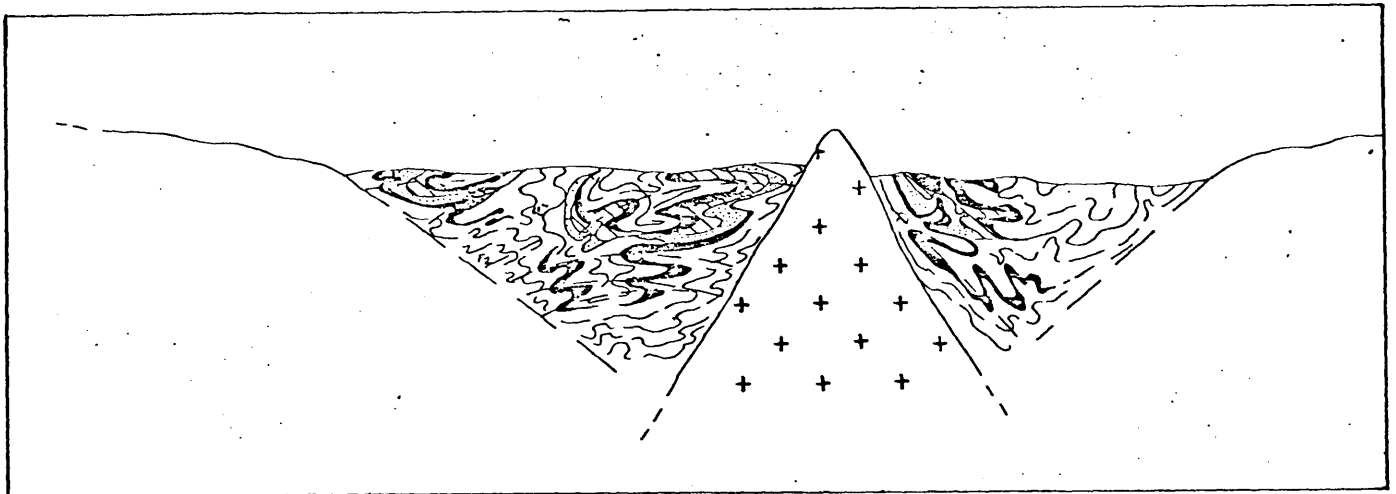
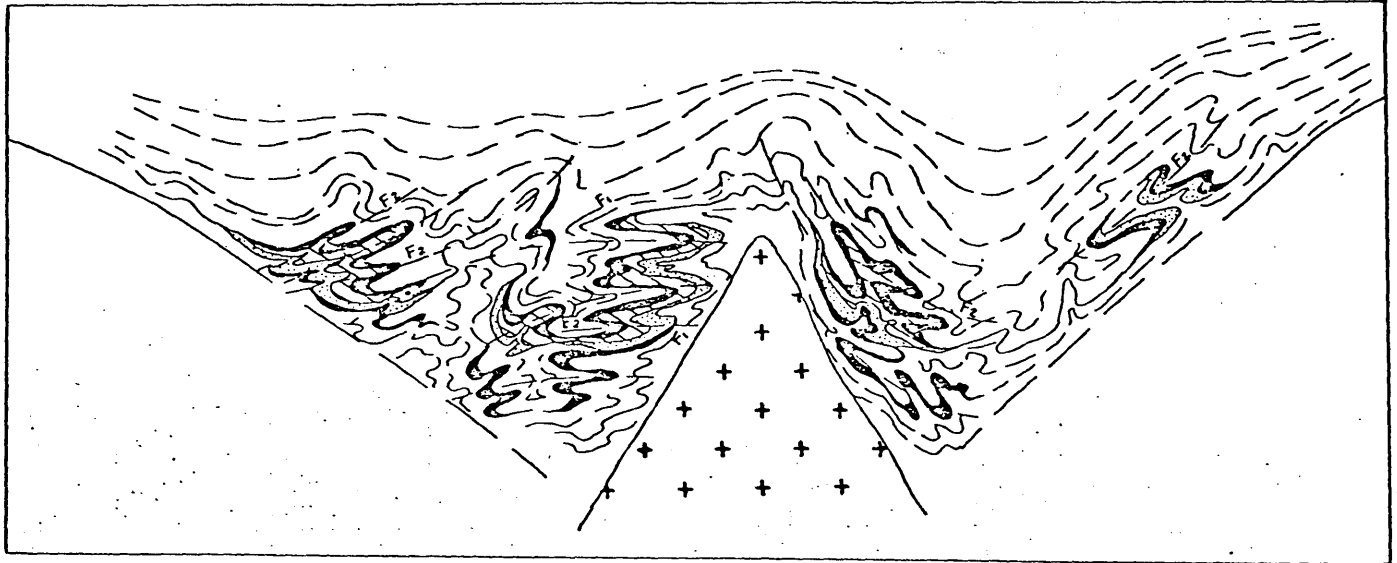
Stage 4: Cessation of vulcanism cut off the abundant supply of sulphur and sulphide complexes. The thriving sulphur bacteria began to die and formed layers of ooze on top of the sulphide layers. These were then converted to carbonaceous material by the reducing conditions near the seabed. Most of the carbonaceous material formed in the euxinic basins. In basins where no volcanic materials were deposited, only carbonaceous beds with no significant amount of sulphides were formed. The only sulphides present are those occasional grains reduced from seawater sulphates.



Stage 5: Resumption of normal sedimentation and burial of earlier sediments. Lithification and recrystallization in progress at varying rate dependent on chemical nature of materials and depth of burial. Tectonic adjustment occurring as entire basin continues to buckle down. Introduction of calcareous sediments or formation of bioherm/biostrome. Possible formation of sericite and biotite grade metamorphic facies at depth.



Stage 6: Continued sedimentation and subsidence of the entire sedimentary basin. Possible formation of the F_2 foliation transposing some original F_1 . Tectonic adjustments of sediments within the basin continue.



Stage 7: · Intrusion of the Mt. Mye quartz monzonite batholith with possible formation of a garnet-staurolite-biotite thermal aureole and subsequently followed by erosion and further tectonic adjustment.

EXPLORATION GUIDES

The mode of deposition as suggested offers some guides in identifying targets for exploration. It suggests that the Grum deposit was formed coeval with the volcanoclastic facies of sedimentation and accumulated thickly in local depressions of a tectonic sedimentary basin. It therefore follows that recognition of the proper stratigraphy and structure is very important in further exploration of the Grum area.

In proceeding with exploration work, areas where a sequence of pelitic sediments and volcanoclastics are present should be sought. This is then followed by delineation of favourable basins as indicated by thick graphitic layers.

Fold noses where thickening of the deposit may occur due to doubling of sulphide layers should also be favoured. Such thickening may or may not be accompanied by sphalerite-galena enrichment due to remobilization.

CONCLUSIONS

The geological work that has been done to date on the Grum leads the authors to the following conclusions:-

- (1) The Grum is a volcanogenic sedimentary deposit. The source of the base metal sulphides was volcanic. They were accumulated and preserved in local depressions within a large tectonic basin, at a distance from the source in deep water unaffected by wave action. Transportation to the site of deposition was probably by density current and there was probably some re-working of pre-deposited pyritic sediments. Deposition was both by biochemical precipitation and by mechanical sedimentation.
- (2) The sulphide bodies at the Grum, and similar bodies elsewhere in the area, are consistently associated with carbonaceous material and tuff bands.
- (3) Recognition of the proper stratigraphic horizon and local basinal structure is the key in doing further exploration in the area.
- (4) There is no reason for limiting exploratory drilling to the phyllites above the garnet-staurolite metamorphic facies because this is a post depositional feature.
- (5) The sulphides, which were originally horizontal layers, have been complexly folded. This folding has been accompanied by plastic flow of some of the sulphides, especially sphalerite and galena.
- (6) This deformation also produced a strong foliation in the phyllitic rock surrounding the sulphides, parallel to the axial planes of the folds.
- (7) A strong set of joints was developed at right angles to the axial lines or hinges of the above folds. This joint system locally forms reservoirs for groundwater. These reservoirs can produce strong flows of water when intersected by mining

operations but soon drain and so far have been only a temporary problem.

- (8) A steep set of normal faults cut the Grum sulphide zone but have relatively minor displacements. The intense fracturing associated with these faults weakens the ground and can constitute a serious mining problem due to uncontrolled caving.
- (9) The metal ratio of layers one and two are similar while layer H has a marked increase in lead and decrease in silver. There is no change in metal ratio along the plunge of the principal layers.
- (10) Grum, Swim, Vangorda, Faro and Dy were probably deposited in similar environmental conditions. Other deposits may well occur in the area.

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- Templeman-Kluit, D.J. - 1972: Geology and Origin of the Faro, Vangorda and Swim Concordant Zinc-Lead Deposits, Central Yukon Territory; G.S.C. Bulletin 208.

APPENDIX A

How the 1977 Grum Structural Model was built

When the drilling and underground work was completed at the Grum site late in 1976, all the geologic data were gathered in Vancouver.

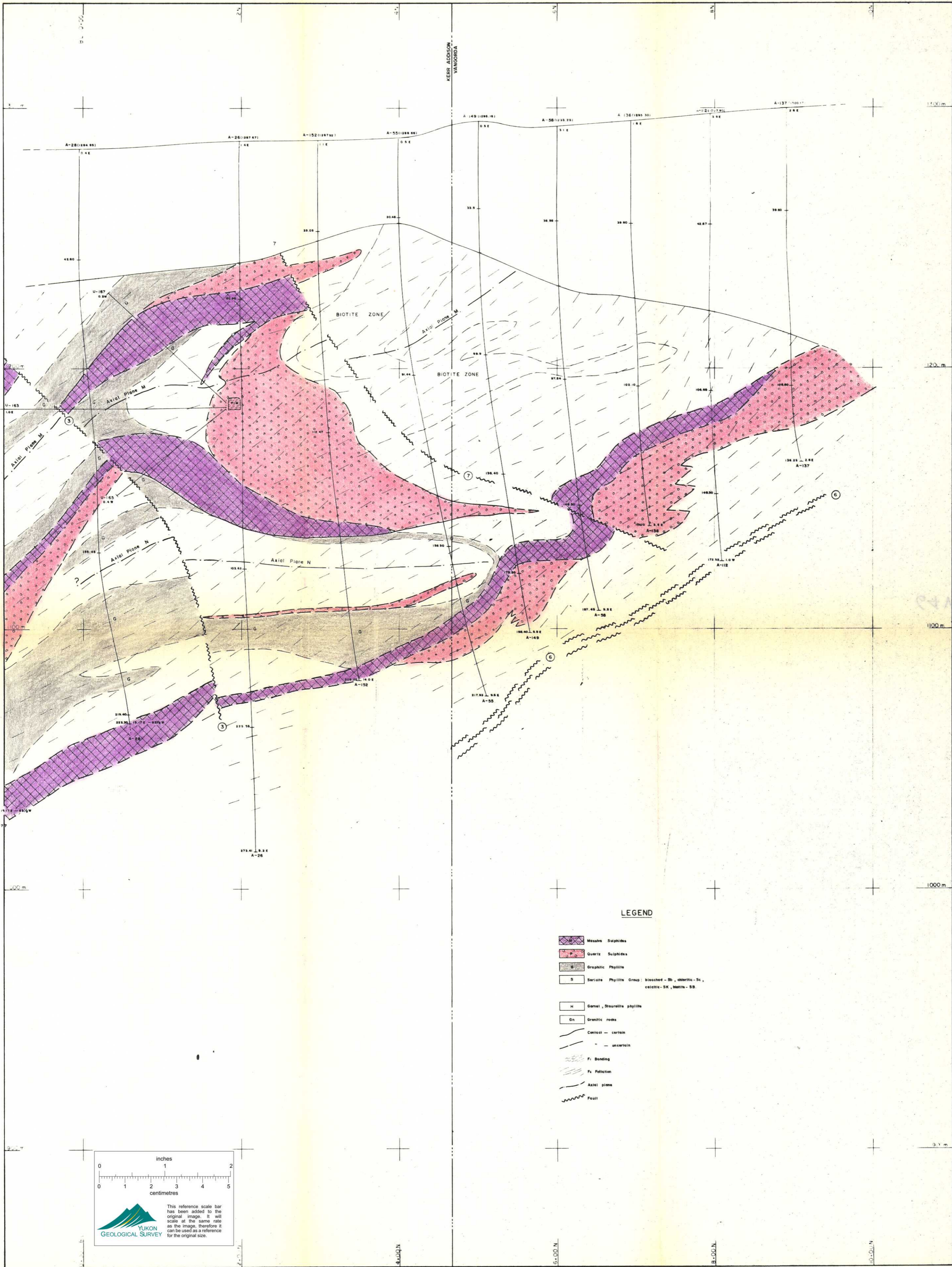
All the drill holes over 50 meters had been tested for hole deviation. This deviation survey data was reviewed and corrected where necessary. Next, all the drill hole collar surveys were reviewed and checked. An accurate plan of the drill holes in the ore area was prepared, showing the location of each hole collar, plus the position and elevation of the deflection points derived from the deviation tests. Finally, the even numbered section lines were drawn on the plans 60.69 meters apart.

A master set of sections was then prepared. On the cross sections it was decided that all drill holes or portions of drill holes lying within one quarter of the distance to the next section (15.17 meters) both in front or behind the section, would be shown on the section as a right angle projection to the section. On the longitudinal sections it was decided that all the drill holes or portions of drill holes lying within one half the distance to the next section (30.48 meters) would be shown on the section. These sections thus showed the projected trace of each hole. At the collar, at the end, and at convenient points along the hole, the distance of the hole in front or behind the section plane was shown.

A complete set of these sections was then reproduced from the master set and as much geological data as possible was plotted on them from the drilling logs, using the same system of symbols as that used in the map legends. Assay data were purposely omitted. All underground mapping data was then added. A complete set of these sections was then printed and coloured.

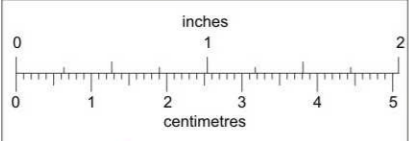
A careful interpretation of the geology on each section was then attempted taking special note of the way the F_1 and F_2 dips recorded in the core logs related to the F_1 and F_2 mapped in the underground workings. The final step

was then to relate the structure from section to section. At first this seemed an impossible task. A series of plans was produced to try to correlate the sections, but was not successful. Then a composite plan showing the contours of all the main fault planes was prepared. After many trials, it became apparent that if the sulphides and graphitic phyllites were considered as a unit, and if certain offsets were assumed along the faults, a more or less logical correlation of the sulphide bands from section to section could be made. This resulted in a fairly consistent structural model for the whole deposit. In its final form, the axial planes of the major folds and the fold noses were identified by letter. The faults were identified by number. This model was then used as a basis for drawing the ore boundaries on the assay sections in the ore inventory report. At this time, small adjustments were made in the interpreted outline on the sections, to compensate for the plunge. This model was also used as a basis for the 1977 computer programme to design an open pit mining system.

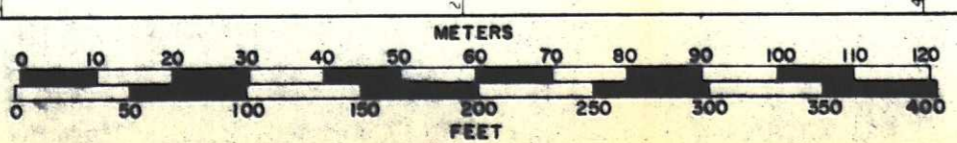


LEGEND

- Mesotho Sulphides
- Quartz Sulphides
- Graphitic Phyllite
- Sericite Phyllite Group: bleached - Sb, chloritic - Sc, calcitic - SK, Mottled - SB
- Gneiss, Stroullite phyllite
- Granitic rocks
- Contact - certain
- Contact - uncertain
- F₁ Folding
- F₂ Foliation
- Axial plane
- Fault



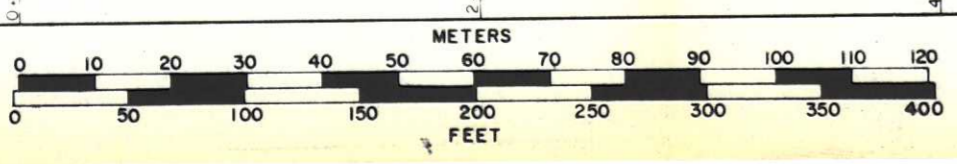
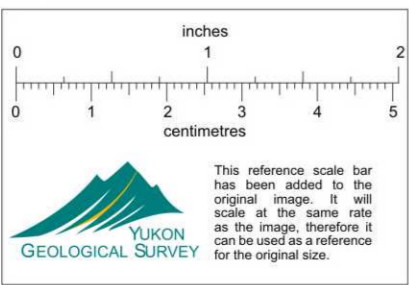
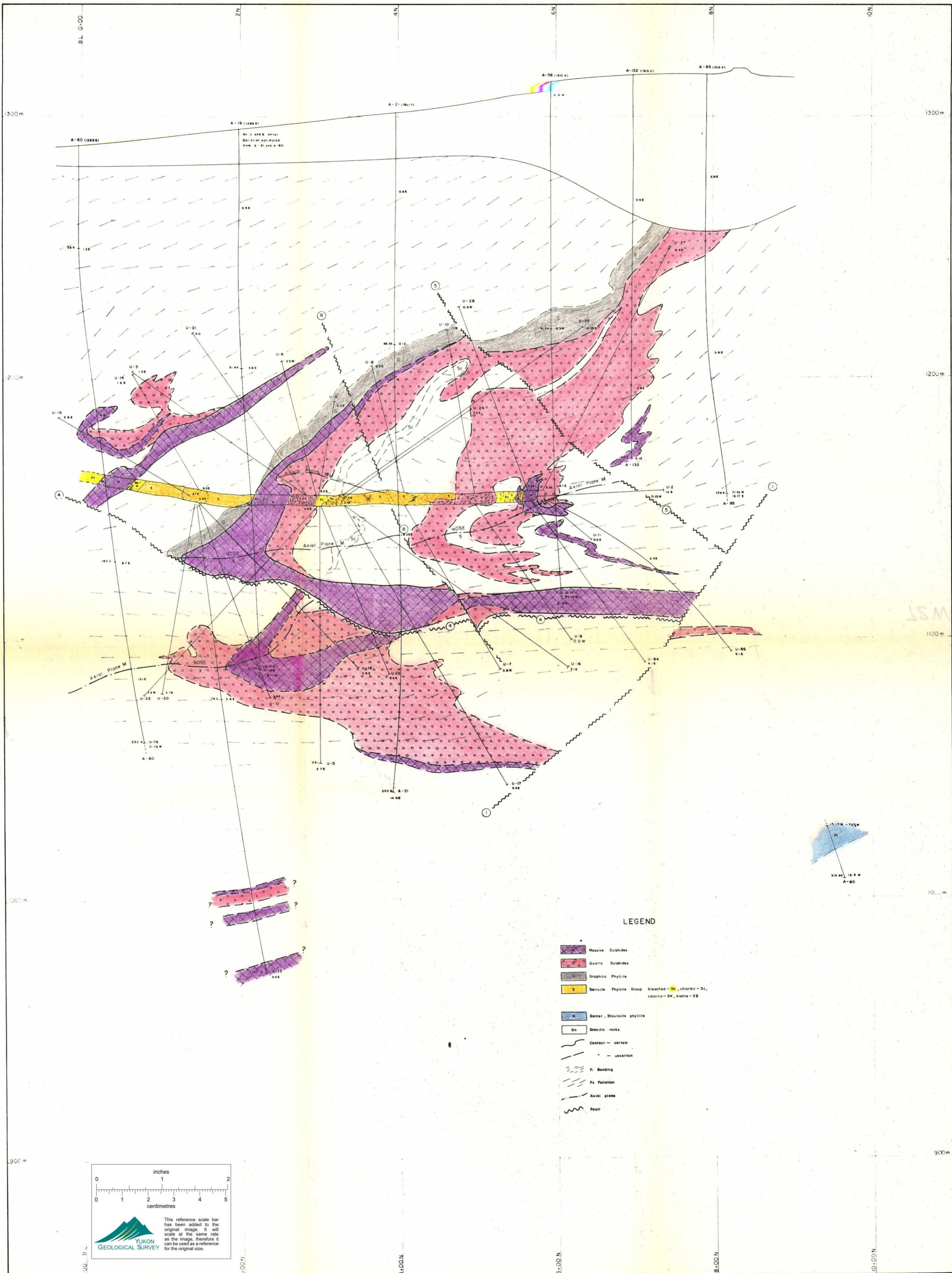
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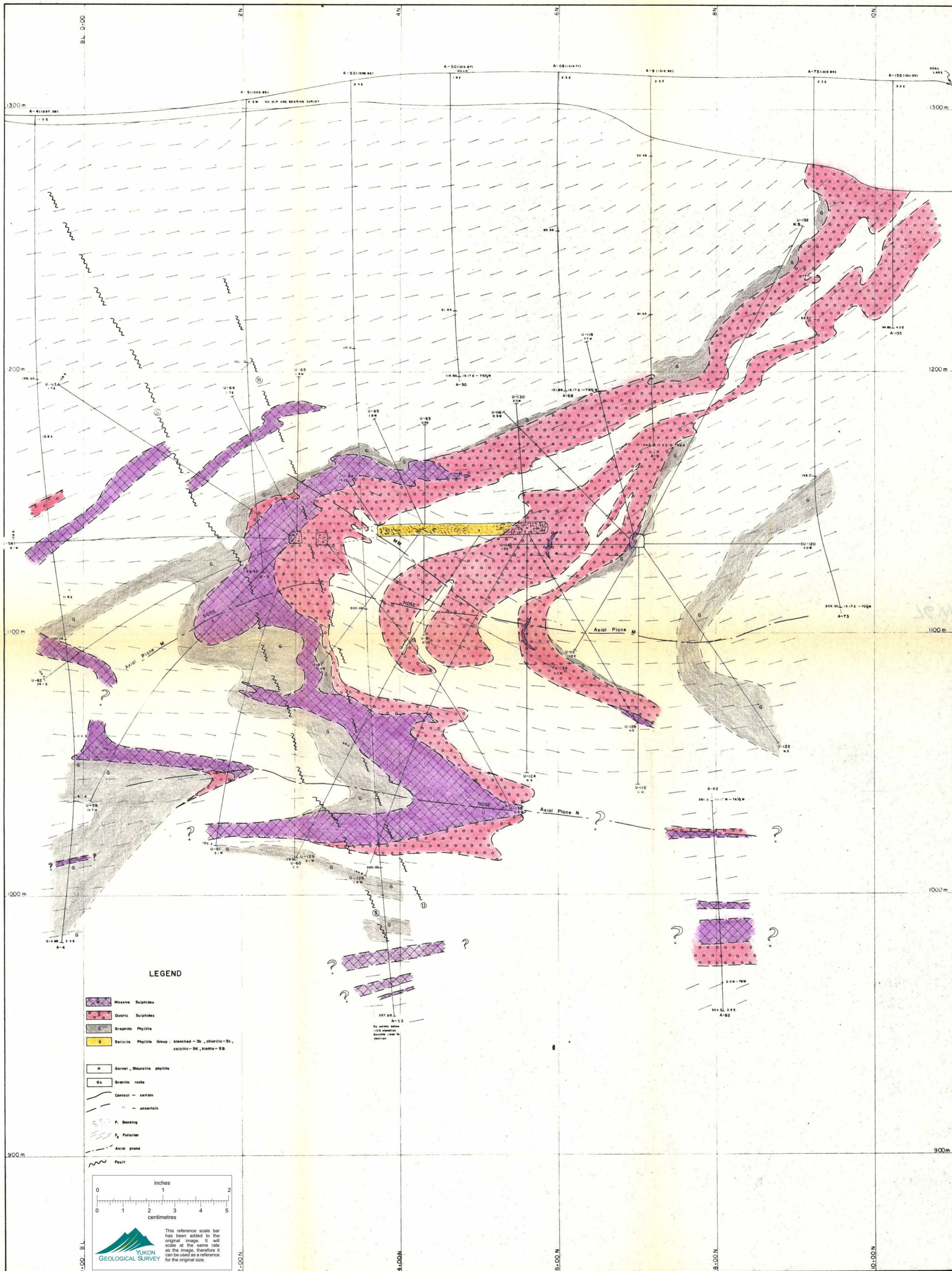
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GEOLGY SECTION 64W



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 - Quartz Sulphides
 - Graphitic Phyllites
 - Sericite Phyllite Group bleached - **SB**, chlorite - **Sc**, calcitic - **SK**, barite - **SB**
 - Garnet, Staurolite phyllite
 - Granitic rocks
 - Contact - certain
 - Contact - uncertain
 - F. Folding
 - F_x Foliation
 - Axial plane
 - Fault

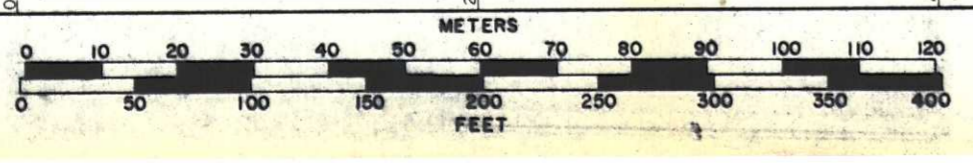
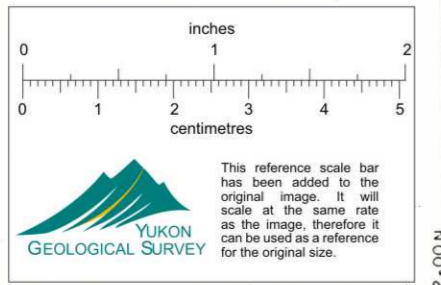
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SECTION 72W



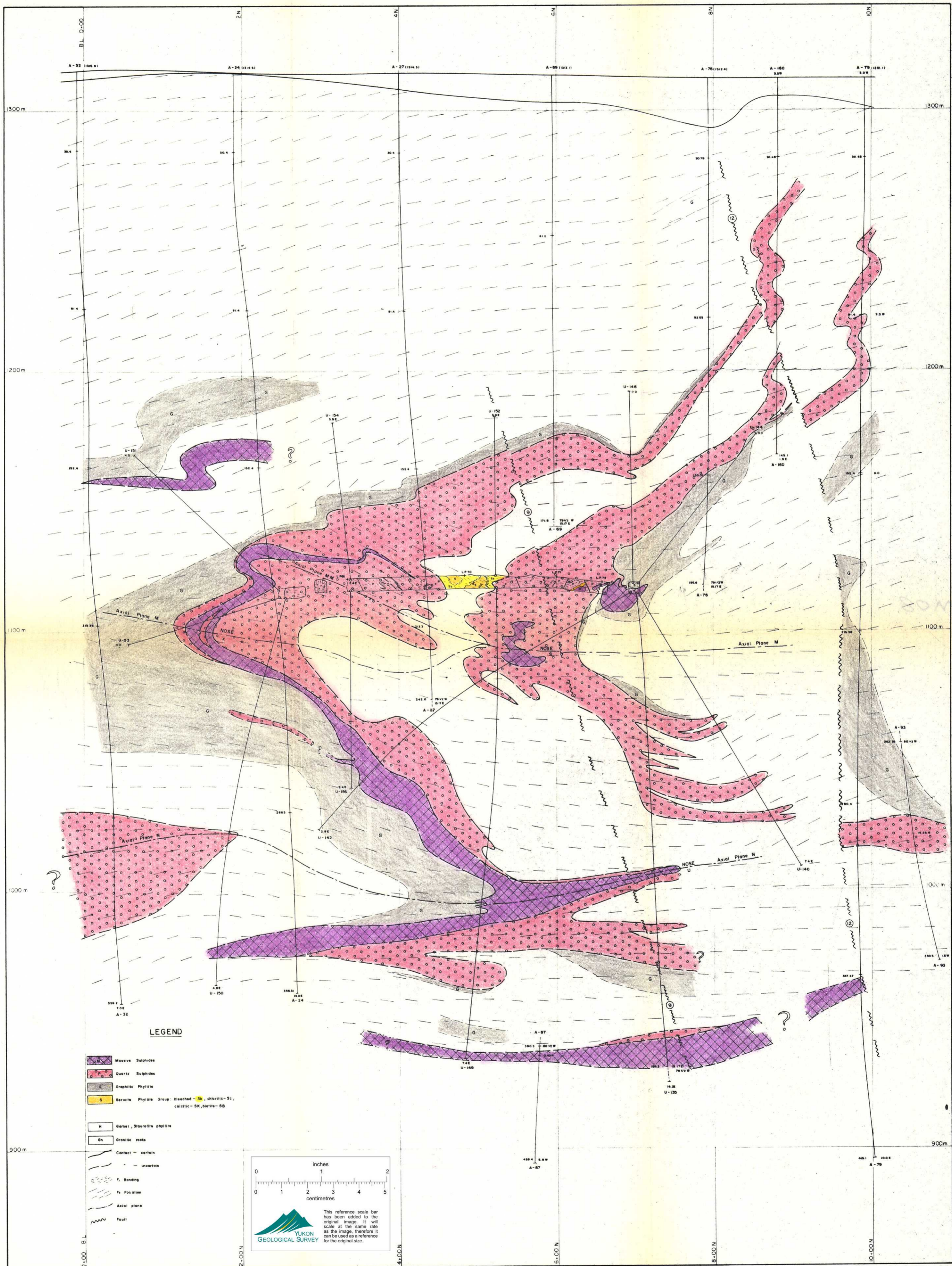
LEGEND

- Massive Sulphides
- Quartz Sulphides
- Graphitic Phyllite
- Sericite Phyllite Group: bleached - Sb, chloritic - Sc, calcitic - Sk, biotitic - Ss
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- Granitic rocks
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- uncertain
- F₁ Folding
- F₂ Foliation
- Axial planes
- Fault



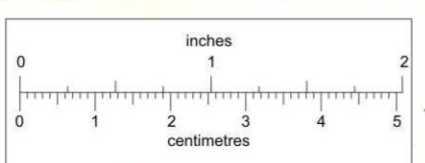
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REVISION STAGE 2	
GEOLOGY SECTION 76W	

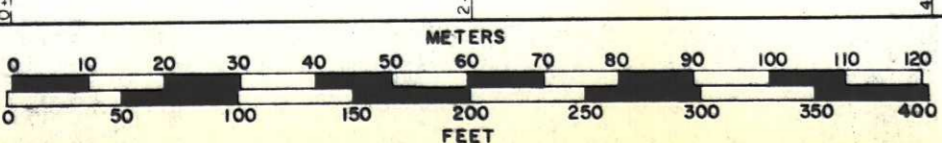


LEGEND

- Massive Sulphides
- Quartz Sulphides
- Graphitic Phyllite
- Baricite Phyllite Group: bleached - 3b, chlorite - 3c, calcitic - 3k, biotite - 3b
- Gneiss, Steatite phyllite
- Granitic rocks
- Contact - certain
- - - - - uncertain
- F. Folding
- Fz. Foliation
- Axial plane
- Fault

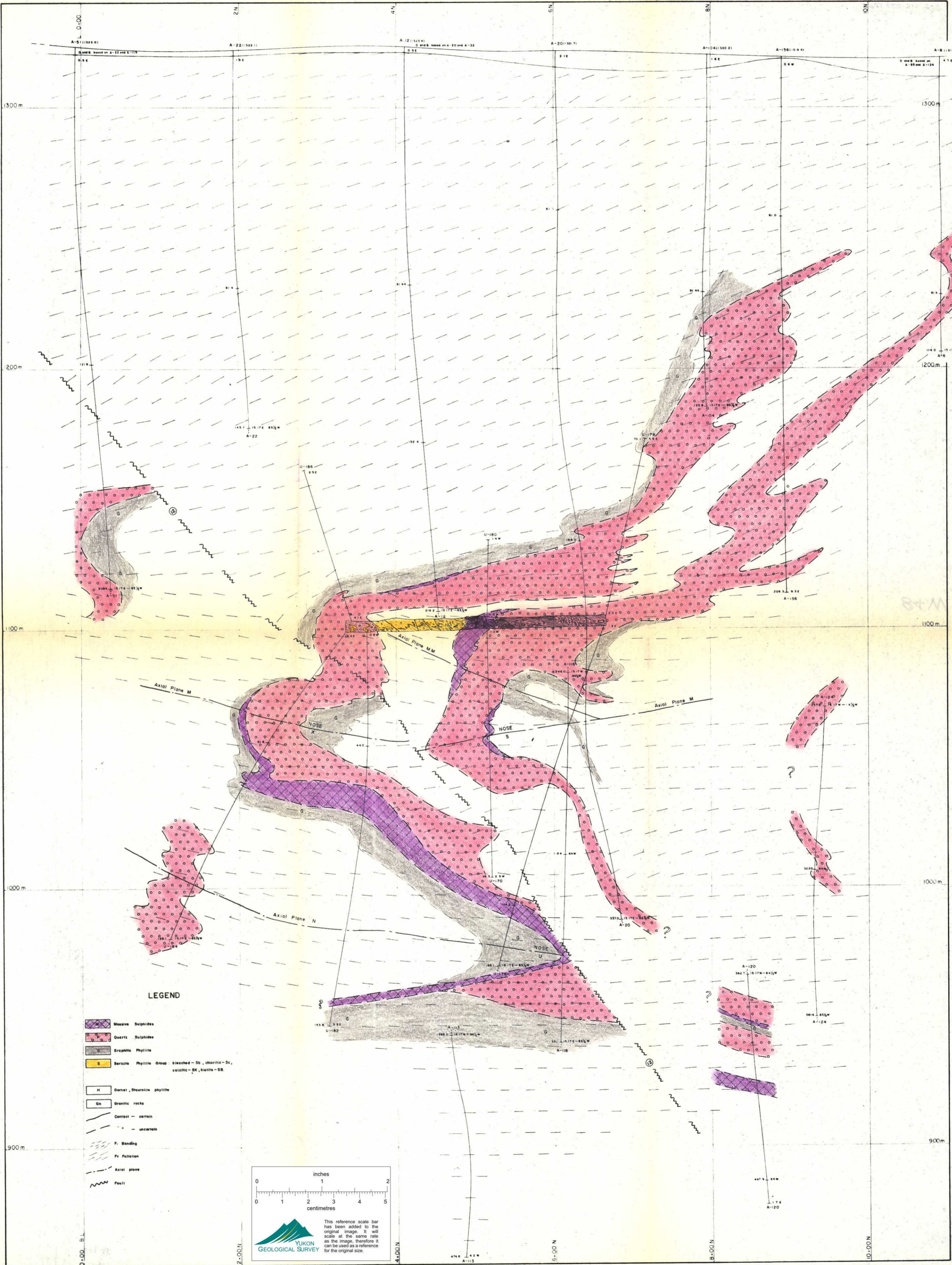


This reference scale bar has been added to the original image. It will scale at the same rate as the image, therefore it can be used as a reference for the original size.



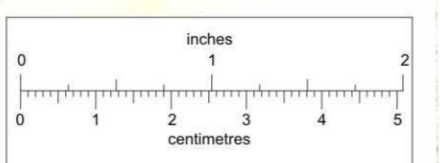
N 43° 47' 58" E →

SCALE: 1:500	KERR ADDISON MINES LTD
DRAWN BY:	GRUM JOINT VENTURE Y.T.
DATE BY:	GEOLOGY
DATE:	SECTION 80W
REVISION:	

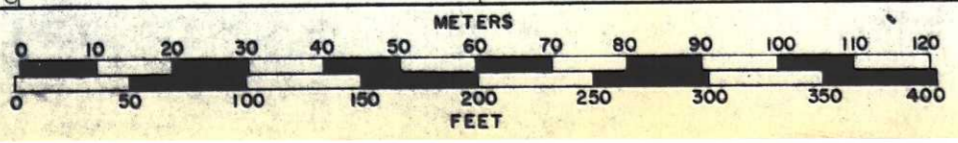


LEGEND

- Massive Sulphides
- Quartz Sulphides
- Graphitic Phyllite
- Sericite Phyllite Group bleached - Sb, chloritic - Sc, calcitic - Bk, baritic - SB.
- Garnet, Schistose phyllite
- Granitic rocks
- Contact - certain
- uncertain
- F. Banding
- P. Foliation
- Axial plane
- Fault



This reference scale bar has been added to the original image. It will scale at the same rate as the image, therefore it can be used as a reference for the original size.



N43°47'58"E

SCALE 1:500
 DRAWN BY
 DATA BY
 DATE
 REVISION STAGE 2

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 GRUM JOINT VENTURE Y.T.

GEOLOGY
SECTION 84 W