GEOLOGY 409
SECOND TERM REPORT.

SUDBURY IRRUPTIVE,
& BEAVERDELL CAMP.

GINA M. SANTER 1969

THE SUDBURY NICKEL IRRUPTIVE:

The Sudbury Nickel Irruptive outcrops as an oval-ring, the outer part of which is norite, the inner part a granophyre or micropegmatite. This granophyric layer is commonly termed micropegmatite, indicating a granitic material of granophyric texture. The contacts between this and the norite are marked by a transitional zone, and all contacts are gradational. The inner and outer contacts of the Irruptive dip towards the center at 30^{0} to 60^{0}. The unit appears to have intruded along an unconformity at the base of the Onaping Formation.

There are four theories for the formation of the Sudbury Basin and the Nickel Irruptive.

One of the oldest theories considers the noritic magma to be emplaced as a flat lying sill, which differentiated to form the micropegmatite. Later folding produced a synform which now outcrops as the oval ring.

A second theory proposes a ring-dike complex to account for the abrupt mineralogical differences between norite and micropegmatite and the apparent volume of the granophyric material. The norite and micropegmatite are introduced separately, and mixed along the transition zone.

A third proposal considers the body as a funnel shaped intrusion. Paleomagnetic data supports the form of an inverted cone, with original dips of 42^{0} at the north rim, and 30^{0} at the south. The assumptions are that a larger mass of more maric rocks is buried. Xenoliths of peridotite and dunite in younger norites and sulfides may be dragged from the mafic member at depth, since there are no peridotites in nearby formations outside the basin. This hypothesis is supported by

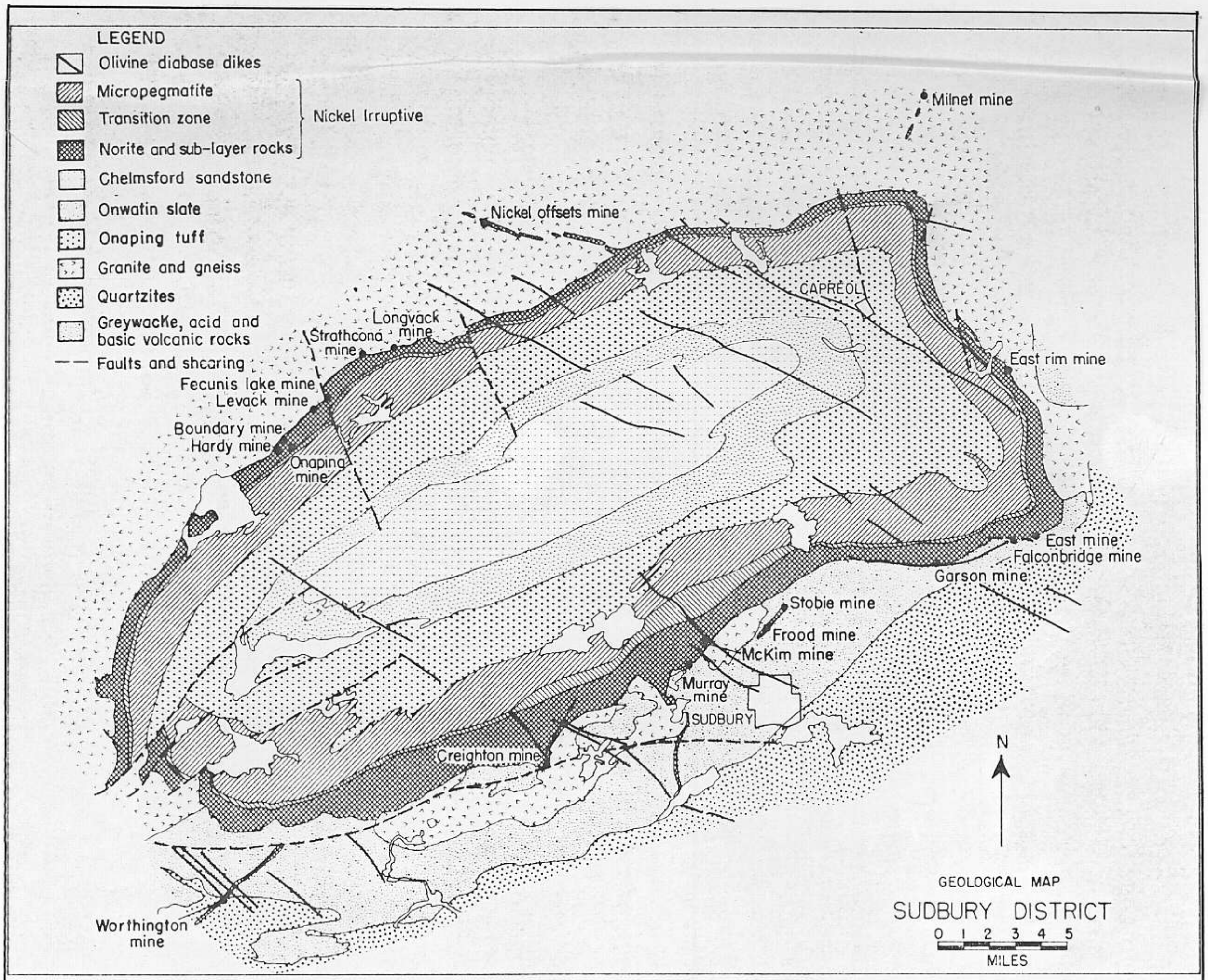


FIG. 1. Geologic map of the Sudbury area, showing the location of some of the more important mines. (Adapted from the map in the guidebook for the Sudbury area, field trip no. 7, Geol. Soc. Amer. Annual Meeting, Toronto, 1953.)

(Naldrett and Kullerud, p. 457)

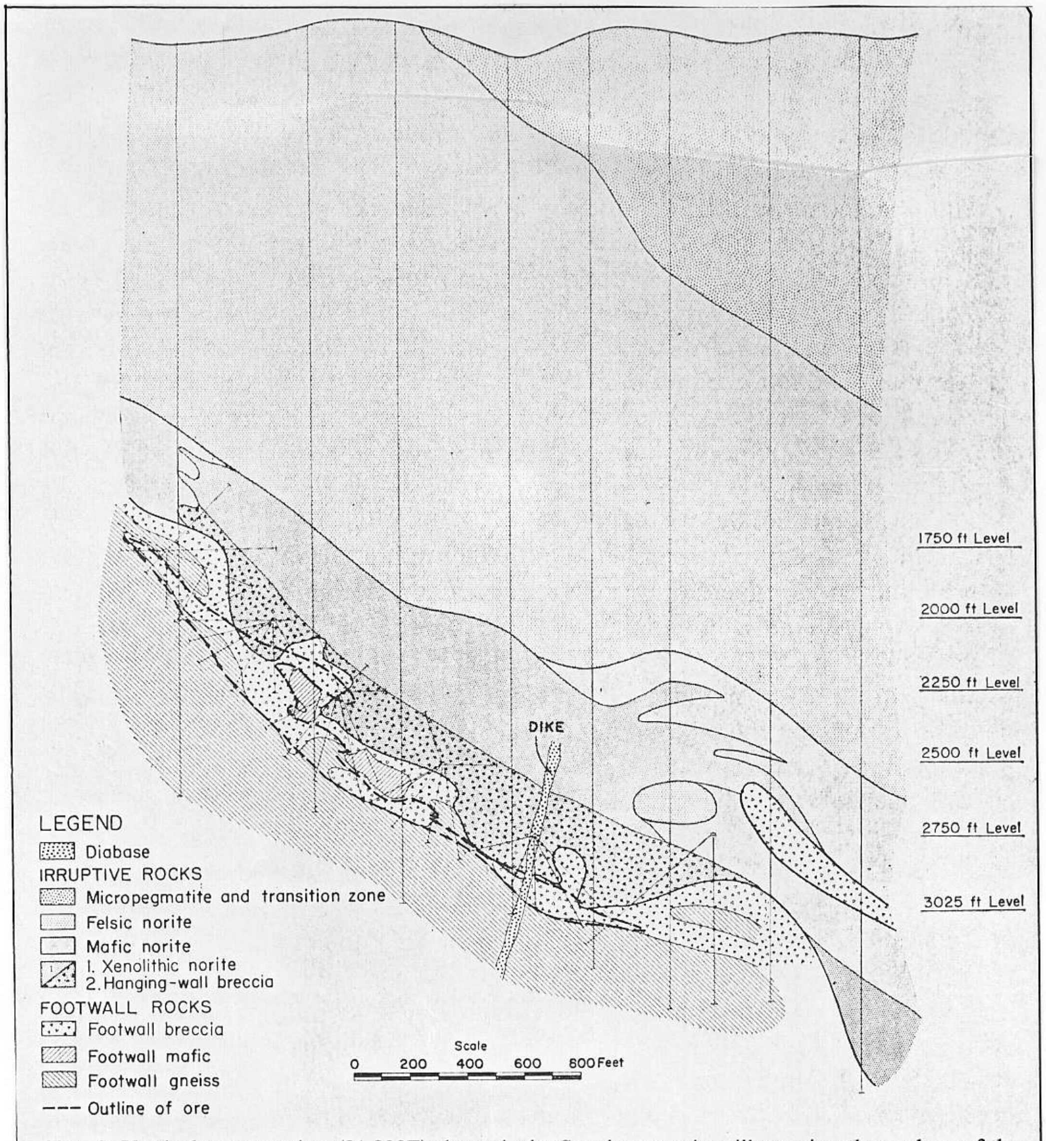


FIG. 2. Vertical cross-section (21,200E) through the Strathcona mine, illustrating the geology of the mine. Information on mine geology from the company geologists, Falconbridge Nickel Mines Ltd.

(Naldrett and Kullerud, p. 464)

THE FACT THAT THERE IS CRYSTAL LAYERING, WITH A DIP SHALLOWER THAN THE CONTACT, WITHIN THE NORITE.

NALDRETT AND RUCKLIDGE, IN STUDYING THE CRYPTIC LAYERING IN THE INTRUSION, DISTINGUISH TWO SEPARATE YOUNGER INTRUSIONS AT THE BASE OF THE NORITE. THE MAIN BODY OF FELSIC NORITE CONTAINS LAYERS OF OXIDE RICH GABBRO, AND GRADES UPWARD INTO THE MICROPEGMATITE. CRYPTIC VARIATION IN THE PLAGIOCLASE IS FROM AN68 AT THE BASE OF THE FELSIC NORITE TO AN50 AT THE OSIDE RICH GABBRO. THE MICROPEGMATITE IS AN4 OR LESS. IN THE PYROXENES THERE IS A COMPARABLE INCREACE IN FE TOWARDS THE TOP. THE CONCLUSIONS ARE;

- -PHASE LAYERING EXISTS
- -THE HORIZONS ARE PARALLEL TO THE BASE.
- -CONTACTS ARE GRADATIONAL THROUGH TO THE MICROPEGMATITE.
- -CRYPTIC VARIATION CONTINUES OVER ALL THE NORITE UNITS.
- -CRYPTIC VARIATION INDICATES GRAVITATIONAL SETTLING.

THE CRYPTIC HORIZONS PARALLING THE BASE FAVOURS THE IDEA OF A FOLDED SILL, BUT THE CRYSTAL LAYERING AND PALEOMAGNETIC DATA FAVOUR THE FUNNEL SHAPED INTRUSION. THE THICKNESS OF THE MICROPEGMATITE CANNOT BE ACCOUNTED FOR BY FRACTIONATION, AND SINCE ITS COMPOSITION IS REGULAR IT IS THOUGHT TO BE AN ACCUMULATION OF DIFFERENTIATED MATERIAL WHICH MIGRATED LATERALLY TO ITS PRESENT POSITION.

THE LATEST THEORY IS THE CONSIDERATION OF THE AREA AS AN ASTROBLEME, OR METEOR CRATER. THE MAIN CONSIDERATIONS IN THIS THEORY HAS BEEN THE UNIQUENESS OF THE OVERLYING ONAPING FORMATION. THIS FORMATION OVERLIES THE MICROPEGMATITE, AND IS SEPARATED FROM IT BY A QUARTZITE BRECCIA. THESE FORMATIONS WERE PREVIOUSLY CONSIDERED AS EXTRUSIVE VOLCANIC BRECCIAS. THEY CONTAIN A LOT OF GLASSY MATERIAL,

AND INCLUSIONS OF BASEMENT ROCKS (GRANITIC). THERE IS A GRADATION IN FRAGMENT SIZE, AND A CONCENTRIC ZONATION OF ROCK TYPES. THEY CANNOT BE DEFINITELY CORRELATED WITH ROCKS OUTSIDE THE BASIN, BUT IT IS GENERALLY AGREED THAT THEY WERE RAPIDLY DEPOSITED.

PETROGRAPHY SUGGESTS THAT THE BASEMENT INCLUSIONS IN THE ONAPING FORMATION SHOW TEXTURES RELATED TO SHOCK PRESSURES WHICH MAY HAVE FORMED BY METEORITIC IMPACT. THE FORM OF THE AREA, AND THE TEXTURES SEEN ARE SIMILAR TO PROVEN METEORITIC STRUCTURES. IF THIS THEORY IS ACCEPTED IT WOULD IMPLY;

- THAT SHOCK FEATURES PERSIST 1.5 BILLION YEARS.
- SHATTER CONES AROUND A DEPRESSION MAY INDICATE A DEFINITE METEORIC ORIGIN.
- METEORITIC IMPACTS MAY PRODUCE OR TRIGGER IGNEOUS PROCESSES.

THE ASSUMPTIONS ARE;

THAT THE UNUSUAL PETROGRAPHIC FEATURES REQUIRE HIGH PRESSURE SHOCK WAVES.

HYPERVELOCITY METEORITIC IMPACT IS THE ONLY WAY OF PRODUCING THESE FEATURES. MOST DISSENTION IS AGAINST THIS LATTER ASSUMPTION, HOWEVER IT IS UNLIKELY THAT VOLCANIC EXPLOSIONS COULD BE CONTAINED UNTIL THE NECESSARY PRESSURES WERE BUILT UP IN A NEAR SURFACE ENVIRONMENT.

THE IRRUPTIVE INTRUDED AGAINST BOTH THE ONAPING FORMATION AND THE GNEISS. THE VOLUME OF MATERIAL IS TOO GREAT TO BE THE RESULT OF FUSION OF THE TARGET AREA. THERE IS NO REASON TO BELIEVE THE ORE IS COMPOSED OF METEORITIC MATERIAL, SINCE THE COMPOSITION IS SIMILAR TO MANY GABBROIC OCCURRENCES OF PYRRHOTITE - PYRITE - CHALCOPYRITE. FRENCH SUGGESTS THE METEORITIC IMPACT TRIGGERED MAGMATIC ACTIVITY. OTHER METEORITIC THEORISTS HAVE SUGGESTED THE NICKEL RICH METEOR IS THE SOURCE OF THE METALS. LATER DEFORMATION HAS ALTERED THE CIRCULAR CRATER TO THE PRESENT ELLIPTICAL FORM.

A STUDY OF THE STRATHCONA MINE BY NALDRETT AND KULLERUD (1967) DISTINGUISHES 3700' OF GRANOPHYRIC MICROPEGMATITE, 300' OF TRANSITIONAL ZONE, AND 1500' OF AUGITE NORITE, AND TWO YOUNGER NORITES, ONE FELSIC AND ONE XENOLITHIC, AT THE CONTACT OF THE HANGING WALL AND FOOTWALL BRECCIA.

THE FELSIC NORITE CONTAINS MAINLY PYRITE MINERALIZATION, (0.1 - 0.5%). THE MAFIC AND XENOLITHIC NORITES CONTAIN PYRRHOTITE, PENTLANDITE, PYRITE, INTERSTITIAL TO SILICATES. THE MAIN ZONE OF ORE SHOWS SMALL SCALE REPLACEMENT TEXTURES. SINCE THE MAFIC AND XENOLITHIC NORITES HAVE A HIGHER PERCENTAGE OF PYRRHOTITE AND PENTLANDITE, AND DIFFERENT TEXTURES, THE HANGING WALL ORE IS CONSIDERED TO HAVE BEEN INTRODUCED WITH THE YOUNGER NORITES.

THERE ARE THREE ZONES OF ORE:

HANGING WALL ORE CONTAINS 2.5 - 3% NICKEL, DISSEMINATED IN THE HANGING WALL BRECCIA AS PENTLANDITE-PYRRHOTITE.

THE MAIN ZONE OR ORE IS MASSIVE IN THE FOOT WALL BRECCIA, AND THE DEEP ZONE ORE IS MASSIVE IN THE FOOTWALL GNEISS, AD CONTAINING 3-5% NICKEL.

THE SULFIDES ARE GENETICALLY ASSOCIATED WITH THE YOUNGER NORITES, AND MAY BE;

PORTIONS OF THE MAGMA WHICH LAGGED BEHIND, AND INTRUDED LATER, OR, YOUNGER INTRUSIONS, ASSIMILATING SULFIDES FROM THE DEEPER SULFIDE RICH LAYERS.

Mineralogy;

From a review of the literature, 40 metallic minerals hav e been identified from the Sudbury ores.

The major sulfides and oxides are;

Pyrrhotite
Pentlandite
Pyrite
Chalcopyrite
Cubanite
Magnetite
Ilmenite

In addition;	Marcasite	Arsenides of Fe, Ni, Pt, Pd.
	Bornite	Sulphosalts of Fe, Co, Ni, Cu.
	Galena	
	Sphalerite	

Nickel values are mainly in pentlandite, which occurs in rims or lamellae in pyrrhotite.

Pyrrhotite is the dominant sulphide, and occurs in interlocking irregular grains, which are intergrowths of hexagonal and monoclinic pyrrhotite. These intergrowths are visible only when etched with a solution of ammonium dichromite and HCl, (Naldrett and Kullerud, p. 497). In ordinary polished sections, the two forms are indistinguishable.

Chalcopyrite is usually in irregualr blebs, and pyrite is irregularly distributed throughout the pyrrhotite and chalcopyrite.

Geothermometry;

The pyrite-pyrrhotite association is used as a temperature indicator for the formation of the sulphide ores.

From a consideration of the pyrite-pyrrhotite phase diagram, the temperature of formation of the pyrite pyrrhotite assemblage is just below 750°C. Pyrrhotite saturated with sulphur at 743°C. will

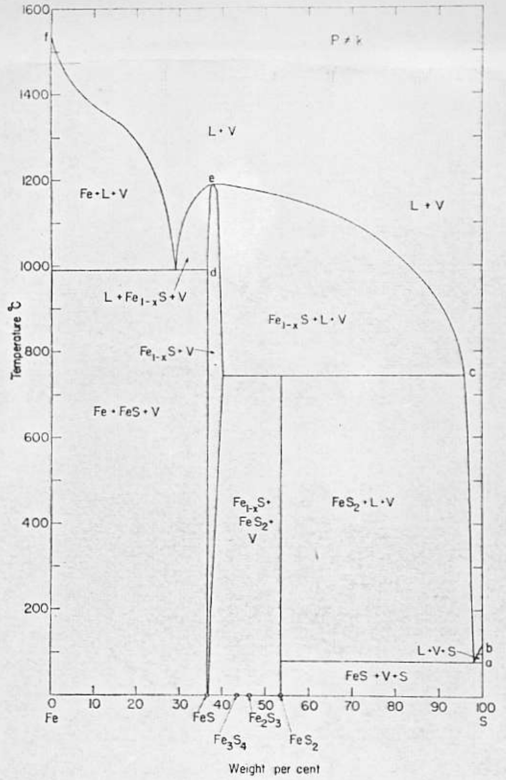


FIG. 11. The so-called "condensed" diagram of the system Fe–S. Vapor is present in all assemblages, and the pressure of the system is not constant.

(Naldrett & Kullerud p. 563)

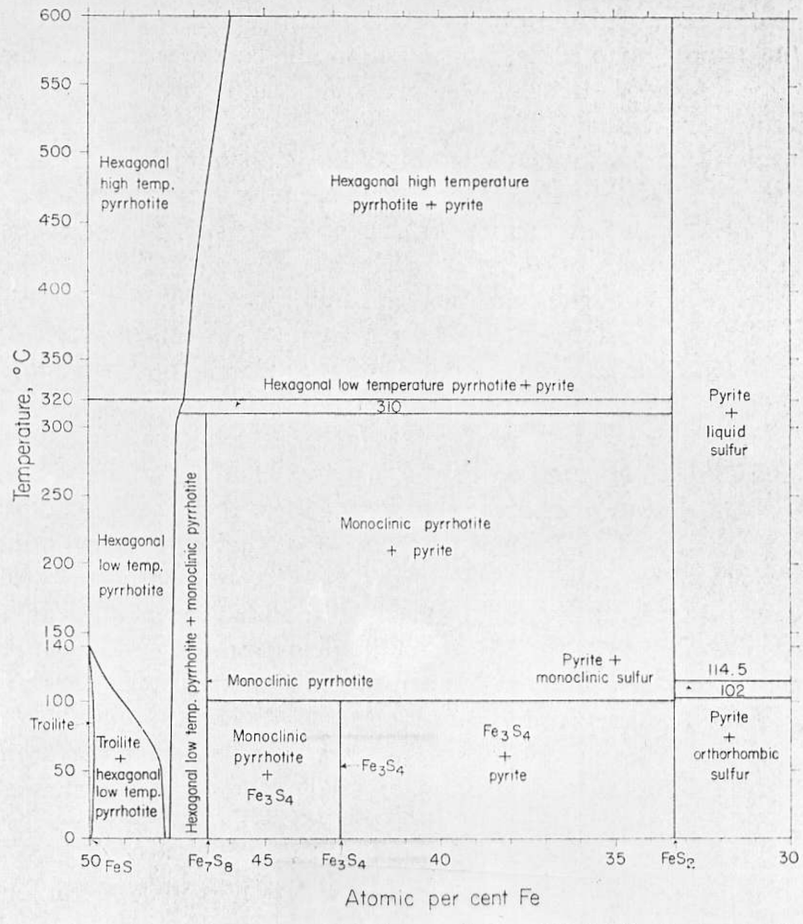


FIG. 16. Portion of the condensed Fe–S system below 600° C (after Kullerud, 1967).

(Naldrett & Kullerud p 502)

EXSOLVE 10% PYRITE AT 320°C. THE PERCENTAGE OF PYRITE PRESENT, AND THE LOCALIZATION OF SMALL EUHEDRAL GRAINS AROUND PYRRHOTITE SUPPORTS THE THEORY OF EXSOLUTION OF PYRITE FROM PYRRHOTITE.

THE ASSOCIATION OF MONOCLINIC AND HEXAGONAL PYRRHOTITE INDICATES LOW TEMPERATURE EQUILIBRIUM WAS REACHES AS THE MAGMA COOLED. AT 320°C. THERE IS AN INVERSION OT HEXAGONAL LOW TEMPERATURE PYRRHOTITE. AT 310°C., HEXAGONAL PYRRHOTITE + PYRITE REACTS TO FORM NOMOCLINIC PYRRHOTITE. THE HEXAGONAL PYRRHOTITE-PYRITE ASSEMBLAGE SEEN AT SUDBURY IS THEREFORE CONSIDERED TO BE A METASTABLE ASSEMBLAGE. THERE IS ABUNDANT MONOCLINIC PYRRHOTITE, WITH NO EVIDENCE THAT IT FORMED FROM REACTION WITH PYRITE. THE MECHANISM SUGGESTED FOR ITS FORMATION IS THE ADDITION OF SULPHUR FROM FLUIDS FROM THE MAGMATIC BODY, ALTERING THE HEXAGONAL PYRRHOTITE TO THE MONOCLINIC FORM.

MUCH OF THE EVIDENCE FOR EXSOLUTION AND REACTIONS HAVE BEEN OBLITERATED BY LATE REWORKING AND RECRYSTALLIZATION OF THE MINERALS. FROM THE FE-NI-S SYSTEM, THE PENTLANDITE IS CONSIDE4ED TO BE THE RESULT OF EXSOLUTION FROM NI PYRRHOTITE BELOW 300°C.

CHALCOPYRITE IS ALSO AN EXSOLUTION ASSOCIATION, ALTHOUGH THE TEXTURE IS MAINLY MASSIVE BLEBS WHICH HAVE BEEN REMOBILIZED OR RECRYSTALLIZED. SOME OF THE BLEBS APPEAR TO BE PRIMARY, AND NEVER OF AN EXSOLUTION ORIGIN. PYRITE, AT ABOUT 700°C. WILL HOLD 4 - 5% COPPER, WHICH, IF EXSOLVED EARLY, WOULD RECRYSTALLIZE AS IT COOLED, FORMING THE BLEBS.

THE CONCLUSIONS DRAWN FROM THE STUDY BY NALDRETT AND KULLERUD ARE THE EMPLACEMENT OF THE ORE AT GABBROIC TEMPERATURES, WITH CRYSTALLIZATION OF THE SULFIDES AT ABOUT 700°C.

ORE GENESIS:

THREE MAJOR THEORIES HAVE BEEN PROPOSED;

1. THE DEPOSITS ARE TRUELY MAGMATIC.

2. HYDROTHERMAL FLUIDS CONCENTRATED SULFIDES FROM THE MAGMA, AND TRANSPORTED THEM TO THE SITE OF THE ORE BODIES.

3. SULFUR AS A FLUID PHASE, FROM AN EXTERMAL SOURCE, HAS MOVED THROUGH THE GABBRO AND REACTED WITH IT.

THE MAGMATIC THEORIES ARE DIVIDED BETWEEN TWO SOURCES FOR THE ORE.

THE ORES MAY HAVE BEEN INTRODUCED IN SOLUTION IN THE MAGMA WHICH FORMS THE MAIN MASS OF THE NORITIC INTRUSION, AND SEGREGATED AS AN IMMISCIBLE SULFIDE-OXIDE LIQUID, THEN SETTLED TO THE BASE OF THE IRRUPTIVE, EITHER DIRECTLY, OR AS INFECTIONS ALONG THE BASAL CONTACT.

OR; MAY

THE ORES WERE INTRODUICED IN SOLUTION OR SUSPENSION IN THE LATER NORITIC MAGMA, ALONG THE LOWER CONTACT, AFTER THE MAIN MASS C CONSOLIDATED.

THIS HYPOTHESIS IS SUPPORTED BY THE RESTRICTION OF THE PYRRHOTITE AND PENTLANDITE TO YOUNGER MARGINAL INTRUSIONS. THE MAIN ZONE OF ORE IS A CATACLASTIC BRECCIA, BUT THE BRECCIATION COULD BE POST ORE OR PRE ORE. SULFIDES IN THE MATRIX SURROUND XENOLITHS, BUT RARELY OCCUR WITHIN THEM.

THERE IS MORE EVIDENCE AGAINST THE HYDROTHERMAL THEORIES OF ORIGIN FOR THE MAIN MASS OF SULPHIDES THAN FOR IT. THERE IS LITTLE SILICATE REPLACEMENT, AND FLUIDS WOULD HAVE TO BE EXTREMELY SELECTIVE TO REPLACE THE BRECCIA MATRIX WITHOUT ALTERING THE XENOLITHS. ALTERATION IS LACKING, ALTHOUGH IT IS ARGUED THAT THE TEMPERATURE OR THE CHEMISTRY OF THE SOLUTIONS MAY NOT HAVE BEEN SUITABLE FOR THE

DEVELOPMENT OF TYPICAL HYDROTHERMAL ALTERATION.

THE MAIN ZONE OF ORE MAY BE COMPOSED OF SULPHIDES FROM THE NORITE WHICH HAVE BEEN CAUGHT IN A BRECCIATION AND RE-EMPLACED, OR MAY BE A SEPARATE SULPHIDE MAGMA. THERE IS A DIFFERENT RATIO OF MINERALS IN THE ZONE, WHICH IS BEST EXPLAINED BY A SEPARATE INTRUSION FROM DEPTH WITH DIFFERENT CONCENTRATIONS OF METALS.

CONSIDERING THE PREFERRED HYPOTHESES, THE HISTORY OF THE BASIN COULD BE;

- THE FORMATION OF THE BASIN, EITHER AS AN UNCONFORMITY OR BY A METEORITIC IMPACT.
- INTRODUCTION OF THE FUNNEL SHAPED INTRUSION ALONG THE BASIC STRUCTURE.
- BASAL INTRUSION OF MAFIC NORITE, WITH REWORKING OF SULPHIDES SETTLED OUT FROM IMMISCIBLE SILICATE-SULPHIDE LIQUIDS.
- XENOLITHIC NORITE INCORPORATING BRICCIA NAD DEEP SULPHIDE MAGMA.
- BRECCIATION OF THE CONTACT, WITH INTRODUCTION OF THE MAIN ZONE ORE PERHAPS AS A SULPHIDE RICH MAGMA.
- LATER DEFORMATION, WHICH MIGHT BE RELATED WITH THE GRENVILLE OROGENY, WITH REMOBILIZATION OF DEEP MINERALIZATION SUCH AS GALENA, AND EMPLACEMENT OF THESE ORES ALONG FRACTURES.

POLISHED SECTIONS:

SAMPLE #1.

THE SECTION IS COMPOSED OF MASSIVE PYRRHOTITE WITH SMALL AMOUNTS OF CHALCOPYRITE, AND TWO STRINGERS OF GERSDORFFITE.

MINERALOGY:

GERSDORFFITE; (NI, CO, FE,) AS S. - 10-15%

- H.M., LESS THAN PO.
- WHITE, BRIGHTER THAN PO., SLIGHTLY YELLOWISH.
- ANISOTROPIC, INCOMPLETE EXTINCTION.
- SHOWS PERFECT CUBIC CLEAVAGE - TRIANGULAR PITS CHARACTERISTIC.
- THE INTERFACE OF GERSDORFFITE AND PYRRHOTITE IS ROUNDED TO IRREGULAR, THE APPEARANCE IS VERY SIMILAR TO THAT DESCRIBED BY HAWLEY, P.133, WHO INTERPRETS THE TEXTURE AS PYRRHOTITE REPLACING EUHEDRAL GERSDORFFITE. THE GRAIN BOUNDARIES OBSERVED IN THE SECTION WOULD INDICATE THE OPPOSITE, THAT IS GERSDORFFITE REPLACING PYRRHOTITE;

- ASSOCIATED WITH CHALCOPYRITE AT THE BOUNDARY OF GEBSDORFFITE AND PYRRHOTITE.
- OCCURS AS TWO LARGER BLEBS (1MM. X 1CM.) AND NUBEROUS SMALL BLEBS, (LESS THAN 1MM.)

- DISTINGUISHED BY ANISOTROPISM AND CLEAVAGE.

CHALCOPYRITE; ($CuFeS_2$) - 2%

- H.M., LESS THAN GERSDORFFITE.
- OCCURS AS 0.1MM. BLEBS IN GERSDORFFITE, MAINLY AT THE BOUNDARIES OF GERSDORFFITE-PYRRHOTITE., ALSO WITHIN PYRRHOTITE, BETWEEN GRAINS;

PYRRHOTITE; $Fe_{(1-x)}S$; 75 - 80%

- H. H. , GREATER THAN GSD, CPY.
- MASSIVE - GRAINS ABOUT 1.5MM.
- WHITE TO GREYISH PINK.
- ANISOTROPIC, STRONG, GREY TO BROWN.

GANGUE; 5%

OCCURS IN STRINGERS, ROUGHLY PARALLEL TO THE LINEATION MARKED BY THE LARGER BLEBS OF GERSDORFFITE WITHIN THE PYRRHOTITE;

SAMPLE #2.

THE SAMPLE APPEARS, IN HAND SPECIMEN, TO CONSIST OF PYRITE WITH MINOR CHALCOPYRITE, WITH QUARTZ GANGUE.

MINERALOGY;

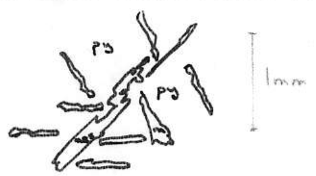
PYRITE; FeS_2, 60%

- MASSIVE ANHEDRAL GRAINS, A FEW EUHEDRAL GRAIN BOUNDARIES.
- WHITE, H.H.
- HOST FOR MARCASITE
- GOOD CLEAVAGE TRACES, OUTLINED BY MARCASITE.

MARCASITE; FeS_2, 15-20%

- OCCURS AS FEATHERY INTERGROWTHS, RIMMING, AND WITHIN PYRITE.
- YELLOW WHITE
- H. H.
- ANISOTROPIC, DISTINCT AND STRONG, BLUE GREY TO REDDISH.

- ELONGATE ALONG CLEAVAGE DIRECTIONS OF HOST PYRITE;



- DISTINGUISHED BY ANISOTROPISM.

CHALCOPYRITE - $CuFeS_2$, 5%

- LARGE GRAINS AT BOUNDARY OF QUARTZ-PYRITE. HAS AN INCLUSION OF SUBHEDRAL OR EUHEDRAL PYRITE.
- DISTINGUISHED BY COLOUR, HARDNESS. (M.L.)

GANGUE - QUARTZ - 20%

SAMPLE #3.

ROUNDED BLEBS OF SILICATE WITHIN A MASSIVE CHALCOPYRITE-PYRRHOTITE - PENTLANDITE? MATRIX.

MINERALOGY:

CHALCOPYRITE; ($CuFeS_2$) - 60%

- DISTINGUISHED BY COLOUR, HARDNESS.
- MASSIVE, IRREGULAR GRAINS.

CUBANITE? - $CuFe_2S_3$ -

- HARDNESS, @= CHALCOPYRITE
- WHITE
- HIGHLY ANISOTROPIC, GREY TO BROWN.
- OCCURS AS ANHEDRAL BLEBS, OR EXSOLUTION LAMELLAE, IN CHALCOPYRITE.

- FIG.1, 3A AND 3B.

SPERRYLITE?-$PtAs_2$

- EXTREMELY HARD.
- BRIGHT WHITE
- EUHEDRAL GRAINS
- ISOTROPIC, COMPLETE EXTINCTION;

PYRITE; FeS2 1%

-H.M., WHITE
-SUBHEDRAL GRAINS

PYRRHOTITE Fe(1-x)S - 10%

-ANISOTROPIC, WHITE TO PINKISH,
-TAKES A BAD POLISH.

PENTLANDITE- (Fe,Ni)5S8 - LESS THAN 5%

- ASSOCIATED WITH THE PYRRHOTITE.
- ISOTROPIC, INCOMPLETE EXTINCTION.
- IRREGULAR PATTERN WITHIN THE PO.

GANGUE - 15 - 20%

- SILICATES.

SAMPLE #4.

MAIN ZONE ORE - SOUTHWALL CONTACT, FALCONBRIDGE.

MASSIVE PYRRHOTITE, WITH ROUNDED SILICATE BLEBS.

MINERALOGY:

PYRRHOTITE - $Fe(1-x)S$ -, 40%

SMALL ANHEDRAL GRAINS, HIGHLY ANISOTROPIC.

PENTLANDITE - $(Fe, Ni)_5S_8$ - 40%

OCCURS AS LARGE PATCHES OR PENTLANDITE 'EYES' IN PYRRHOTITE.
INDIVIDUAL GRAINS MAY BE DISCREET, OR MANTLING PYRRHOTITE.
- ISOTROPIC, COMPLETE EXTINCTION.

GANGUE - 20%

- ROUNDED TO ELONGATE BLEBS OF VARIABLE SIZES WITHIN THE SULFIDE MATRIX;

SAMPLE #5.

BRECCIA ORE - HANGING WALL CHALCOPYRITE ZONE;

MINERALOGY;

CHALCOPYRITE - $(CuFeS_2)$ - 10%

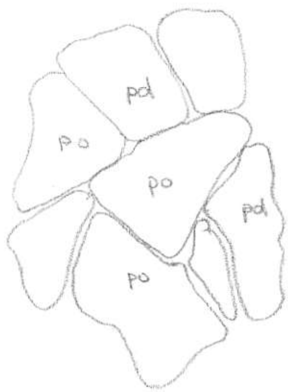
OCCURS IN SMALL BLEBS THROUGHOUT THE SECTION. A FEW LARGER (1CM.) BLEBS.

PYRRHOTITE- $Fe(1-x)S$, 25%

- GRANULAR, 1 - 1.5MM. GRAINS.
- ANISOTROPIC, STRONG, GREY TO BROWN.
- DISTINGUISHED FROM PD. BY ANISOTROPISM.

PENTLANDITE - $(Fe,Ni)_5S_8$ - 15%

- 1MM. GRAINS - OCCUR IN IRREGULAR PATCHES.



SPECIMEN #6.

- A VERY OLD, BADLY POLISHED SECTION.

MINERALOGY;

PENTLANDITE - ISOTROPIC

PYRRHOTITE - ANISOTROPIC

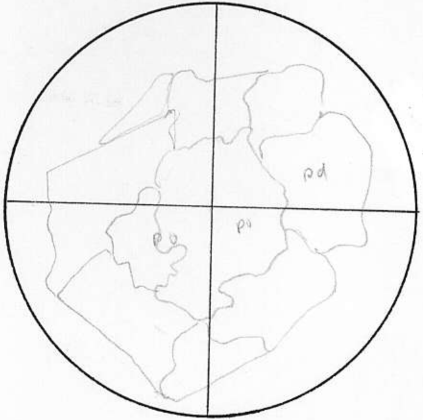
CHALCOPYRITE - SMALL STRINGERS IN SILICATES.

MAGNETITE -

SPECIMEN #7. = EQUIVALENT TO SPECIMEN #2.

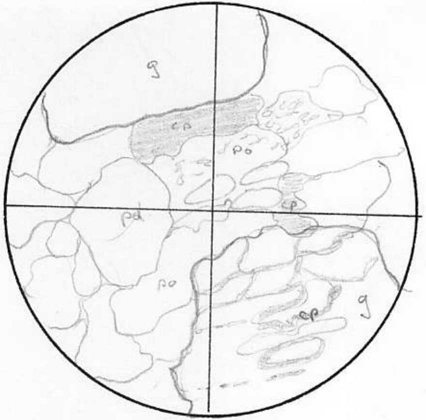
- HAS MAGNETITE IN ADDITION TO THE MINERALOGY OF #2.

SPECIMEN #8 - EQUIVALENT TO SPECIMEN #4.



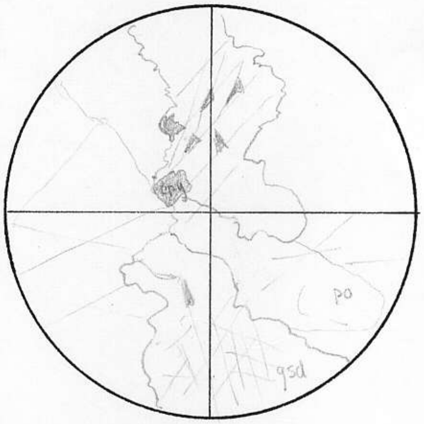
SPECIMEN #5. X20

- PENTLANDITE GRAINS, AROUND PYRRHOTITE



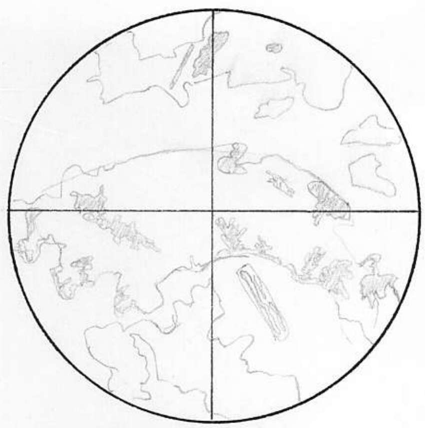
SPECIMEN #6 X5.

- STRINGERS OF CHALCOPYRITE IN GANGUE, ASSC. WITH PYRRHOTITE AND PENTLANDITE.



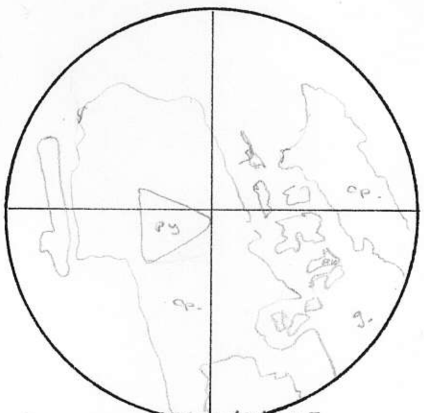
SPECIMEN #1, X20

- GERSDORFFITE IN PYRRHOTITE



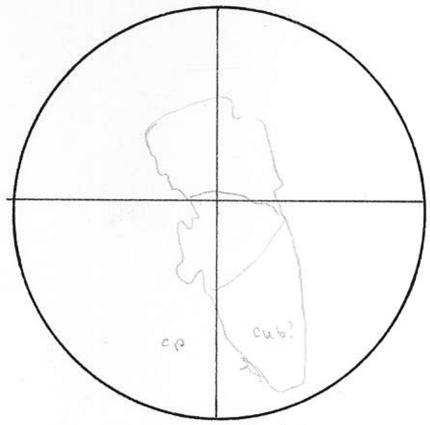
SPECIMEN # 2, (A), X20

- MARCASITE IN PYRITE,
(MARCASITE SHADED HERE)



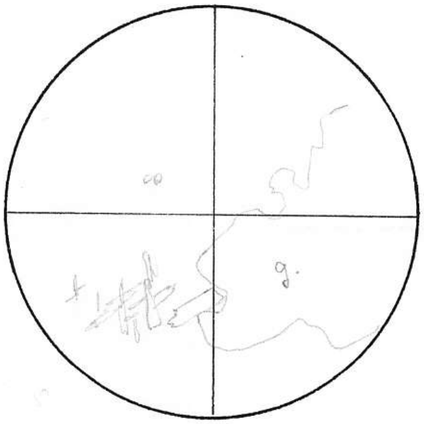
SPECIMEN #2 (B) X5

- CHALCOPYRITE, WITH
EUHEDRAL PYRITE ENCLOSED.



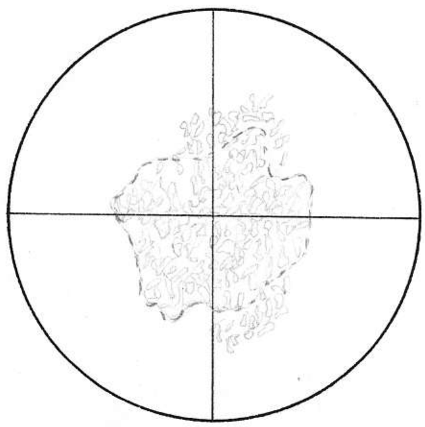
SPECIMEN #3 (A) X5

- CUBANITE? IN CHALCOPYRITE.



SPECIMEN #3 (B) X20

- CUBANITE EXSOLUTION LAMELLAE



SPECIMEN #4 X5

- LIMIT OF PD. 'EYE' IN PO.

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BEAVERDELL AREA:

THE LOCATION OF THE BEAVERDELL CAMP IS SHOWN ON THE ACCOMPANYING MAP, A COMPOSITE DRAWN FROM THE KETTLE RIVER MAPS 15-1961, AND 6-1957. THE VALUE OF THE AREA LIES MAINLY IN SILVER, WITH SOME PRODUCTION OF LEAD, ZINC, GOLD, AND CADMIUM.

THE STRATA AROUND THE CAMP ARE;

PALEOZOIC SEDIMENTS AND VOLCANIC, INTRUDED BY MESOZOIC QUARTZ DIORITE.

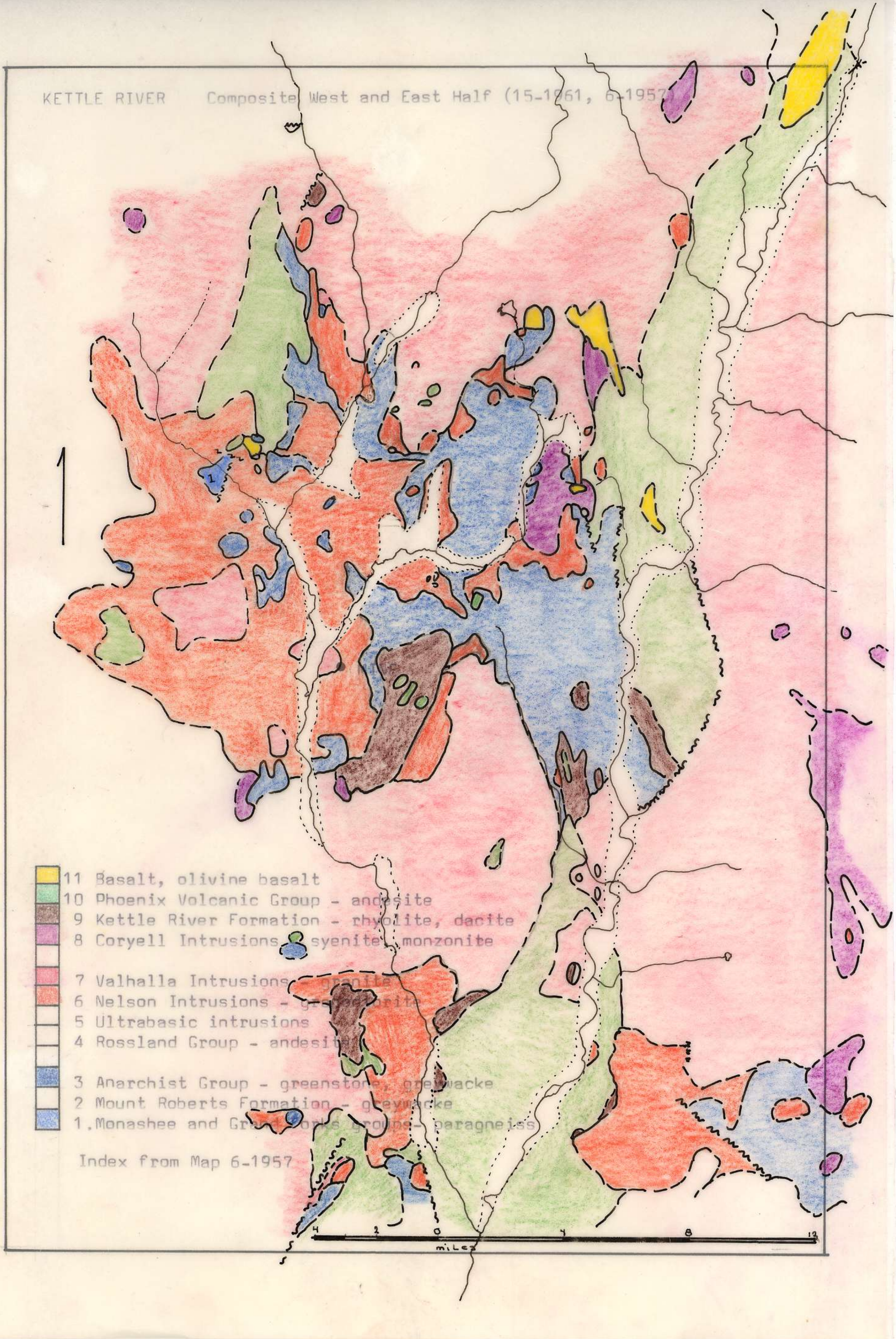
- -WALLACE FORMATION - TUFFS AND LAVAS.
- WESTKETTLE BATHOLITH - QUARTZ DIORITE (JURASSIC)
- BEAVERDELL STOCK - QUARTZ MONZONITE.

THE DEPOSITS ARE WITHIN MINERALIZED SHEAR ZONES WITHIN THE QUARTZ DIORITE, AND DO NOT EXTEND BEYOND ITS LIMITS. THE VEINS ARE ABOUT 1' TO 10' WIDE, AND STRIKE EAST, WITH A DIP S 50 - 90^{0}. THE VEINS CONSITS OF SHEARED BRECCIATED ROCKS AND VEIN MINERALS. DIKES OF ANDESITE ARE PRE-ORE. THERE ARE FOUR TYPES OF FAULTS, WHICH DISPLACE QUARTZ VEINS IN THE LODE. THE ORE STRIKES APPROXIMATELY IN ONE SET OF FAULTS. THE SOURCE OF THE ORE METALS ARE HOT ASCENDING SOLUTIONS FROM THE BEAVERDELL QUARTZ MONZONITE.

THE SULFIDES REPLACE QUARTZ, AND RARELY ARE DISEMMINATED IN THE WALL ROCKS. THE ALTERATION IS WALL ROCK PROPYLITIZATION. THE VALUES OF SILVER DO NOT CHANGE WITH DEPTH, AND MINERALIZATION EXTENDS TO DEPTH WITHIN THE QUARTZ DIORITE.

FROM STAPLES AND WARREN, THE ORE BEARING VEINS ARE ABOUT

40 - 50 % SILICA
10 - 12 % IRON
5 - 7 % ZINC
4 - 6 % LEAD
120 - 150 OZ. SILVER/TON.



KETTLE RIVER Composite West and East Half (15-1961, 6-1957)
11 Basalt, olivine basalt
10 Phoenix Volcanic Group - andesite
9 Kettle River Formation - rhyolite, dacite
8 Coryell Intrusions - syenite, monzonite
7 Valhalla Intrusions - granite
6 Nelson Intrusions - granodiorite
5 Ultrabasic intrusions
4 Rossland Group - andesite
3 Anarchist Group - greenstone, greywacke
2 Mount Roberts Formation - greywacke
1.Monashee and Grand Forks groups- paragneiss
Index from Map 6-1957
4 2 0 4 8 12
miles

MOST OF THE MINERALS REPORTED IN THE LITERATURE WERE OBSERVED IN THE POLISHED SECTIONS.

SILVER MINERALIZATION IS; PYRARGYRITE, FRIEBERGITE, POLYBASITE, (SPHALERITE, GALENA), NATIVE SILVER AND ACANTHITE.

OTHERS ARE QUARTZ, PYRITE, ARSENTOPYITE, CALCITE, RARELY CHALCOPYRITE.

AN ANALYSIS OF THE SPHALERITE BY STAPLES AND WARREN SHOWED THE MN AND FE CONTENT OF THE SPHALERITE SUPPORTS AN EPITHERMAL ORIGIN. THE GALENA IS PRIMARY, DEPOSITION OF TETRAHEDRITE, PYRITE, POLYBASITE OVERLAPS.

POLISHED SECTIONS:

SECTION #1.

SMALL VEIN (1CM.) IN QUARTZ.

MINERALOGY;

POLYBASITE- $(Ag,Cu)_{16}(Sb\ As)_2\ S_{11}$ - 20%

- QUESTIONABLE DETERMINATION, SINCE THIS SPECIMEN SHOWS A LAMELLAR HABIT, PERHAPS IS TWINNING OR ZONING.
- DULL GREY TO GREY WITH A GREEN TINGE
- H. M. TO L., DULL MOTTLY APPEARANCE.
- A. DISTINCT TO SLIGHT.

SPHALERITE - ZNS - LESS THAN 1%

- DEEP YELLOW INTERNAL REFLECTION, OCCURS IN THE GANGUE, SEPARATE FROM THE VEIN.

CHALCOPYRITE - $CuFeS_2$ - LESS THAN 1%

- SHOWS A RELICT OUTLINE - (FIG.1, 1A)- REPLACED?
- OCCURS ONLY AT THE EDGES OF THE VEIN.

SECTION #2.

VERY SMALL GRAINS DISEMMINATED THROUGH QUARTZ.

MINERALOGY;

SILVER - AG - 0.25%

- NATIVE SILVER
- VERY SOFT, WHITE, OCCURS IN IRREGULAR PATCHES, MAY BE A PATTERN IMPOSED BY A WIRE FORM OF NATIVE SILVER.
- I. SCRATCHES ARE A.

GOLD - AU - 0.2%

- NATIVE GOLD
- DEEP YELLOW GOLD COLOUR,
- OCCURS AS SMALL ANHEDRAL BLEBS.
- I., GREENISH UNDER X-NICOLS, SOME ARE SLIGHTLY AN.

ARSENOPYRITE - FE AS S - 0.5%

- WHITE, VERY HARD.
- OCCURS IN SMALL EUHEDRAL TO SUBHEDRAL CRYSTALS WITHIN THE WALL ROCK.

SEC.#2 CONTD.

POLYBASITE-$(Ag,Cu)_{16}(SbAs)_2S_{11}$ - 0.05%

- SMALL GRAINS IN QUARTZ.
- A. STRONG,
- DULL GREY.

CHALCOPYRITE - $CuFeS_2$

- MINOR, SOME CRYSTALS HAVE THE FORM OF ARSENOPYRITE - REPLACEMENT?

GANGUE - 99%

- QUARTZ AND SILICATES.

SECTION #3.

MINERALOGY;

GALENA - PbS - 15%

- H.L.
- SOFT, WHITE - CLEAVAGE ACCENTED BY TRIANGULAR PITS.

SPHALERITE-ZnS - 30%

- DARK REDDISH BROWN IN THE SPECIMEN,
- DULL GREY, WITH ORANGE INTERNAL REFLECTION UNDER X-NICOLS.

CHALCOPYRITE - SMALL BLEBS IN THE SPHALERITE.

GANGUE - QUARTZ.

- BRECCIATED ANGULAR FRAGMENTS ARE ENCLOSED WITHIN THE VEIN MINERALS.
- IN GENERAL, THE WALL ROCK AND PARTICLES ARE RIMMED BY GALENA, WITH THE SPHALERITE IN THE MIDDLE OF THE VEINS.

SECTION #4.

MINERALOGY;

SPHALERITE - ZNS - 75%

- VERY DARK IN THE SPECIMEN.
- DULL GREY, ANISOTROPIC.

PYRITE - FeS_2 - 10 - 15%

- PALE YELLOW
- HARD, MOTTLED APPEARANCE

POLYBASITE - 2%

- DULL, GREY GREEN.
- OCCURS BETWEEN PYRITE AND GANGUE, WITH CHALCOPYRITE

CHALCOPYRITE - 2%

- IRREGULAR BRAINS, INTERGROWN BETWEEN PYRITE AND IN SMALL PATCHES IN SPHALERITE. (0.05 - 0.1MM.)

GALENA - 1 - 2%

- LIGHT GREY, TRIANGULAR PITS.
- ANISOTROPIC.

FRIEBERGITE - (SILVER TETRAHEDRITE) - LESS THAN 5%

- MEDIUM GREY, DARK AGAINST POLYBASITE, GALENA, SLIGHTLY GREEN.
- ANISOTROPIC IN GREY
- BOUNDARIES SMOOTH.

ARSENOPYRITE - LESS THAN 1%

- SMALL(.5MM.) ANHEDRAL TO SUBHEDRAL GRAINS, OCCUR BETWEEN PYRITE

GANGUE - 1%

- SILICATES.

SECTION #5.

MINERALOGY;

PYRITE - 20%

- YELLOW
- MOTTLED, ANHEDRAL TO SUBHEDRAL.

SPHALERITE - 50%

- DULL BROWN TO BLACK
- CONTAINS NUMERAOUS (0.02MM.) GRAINS OF CHALCOPYRITE

GALENA - 8%

- OCCURS AS LARGE INFILLINGS BETWEEN PYRITE, DISTINGUISHED BY CLEAVAGE PITS, ISOTROPISM

POLYBASITE - 5%

- SMALL (0,05 X 4MM.) STRINGERS WITH CHALCOPYRITE, IN SPHALERITE.
- IRREGULAR BLEBS (0.5MM.) IN SPHALERITE, GALENA.

FRIEBERGITE - 2%

- ISOTROPIC, GREY.
- OCCURS IN SAME HABIT AS POLYBASITE.

PYRARGYRITE - 5%

- BRONZE ON SURFACE, TO DULL BLUE GREY.
- ANISOTROPIC
- STRONG RED INTERNAL REFLECTION
- OCCURS IN SAME MANNER, AND IS CONTEMPORANEOUS WITH POLYBASITE AND FRIEBERGITE.

ARSENOPYRITE - 2-5%

- SUBHEDRAL
- BRIGHT WHITE, VERY HARD.
- A. STRONG.

CHALCOPYRITE - 1-5%

- VERY SMALL (0.05MM.) GRAINS IN SPHALERITE.

GANGUE - 5%

- SILICATES.

SECTION #6 = HIGHLAND BELL, ALAN VEIN.

MINERALOGY SAME AS #5.

VEIN CONTAINS PYRITE ON THE QUARTZ, GALEAN IN THE INTERSTICIES. SPHALERITE IS CENTRAL, ON PYRITE, GALENA. SILVER MINERALS INVADE ALONG BOUNDARIIES OF THE GALENA-PYRITE.

SECTION #7.

MINERALOGYYSAME AS #5.

PYRARGYRITE - 20%

- IN FRACTURES ALONG CLEAVAGE IN GALENA;

GALENA - 40%

PYRITE - 5%

POLYBASITE

ARSENOPYRITE

SPHALERITE

GANGUE.

SECTION #8 (SECTIONS 9, 10 AND 11 SHOW ESSENTIALLY THE SAME MINERALOGY)

MINERALOGY;

GALENA - 60%

SPHALERITE - 13%

PYRARGYRITE - 10%

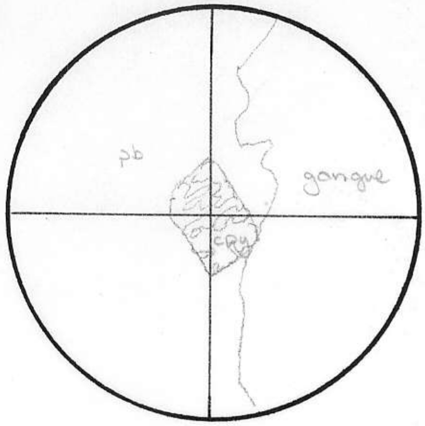
- IN SPHALERITE - (0.5 - 1MM.)
- BRONZE ON THE SURFACE, TO DULL GREY, BLUE.
- A. STRONG, STRONG RED INTERNAL REFLECTION.

CHALCOPYRITE - 2%

ARSENOPYRITE - EUHEDRAL SMALL GRAINS

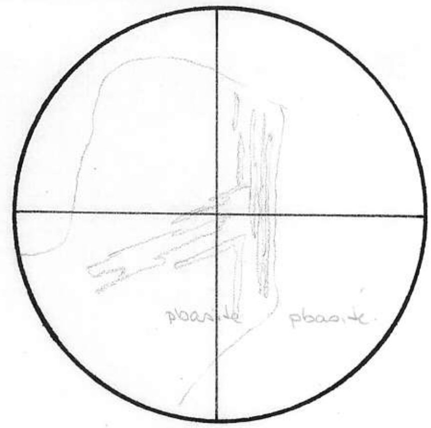
POLYBASITE - SMALL GRAINS IN GRAINS.

GANGUE - 15% - SILICATES



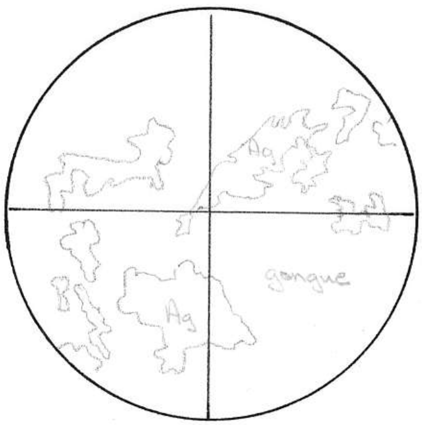
SPECIMEN #1 (A) X20

-CHALCOPYRITE IN POLYBASITE



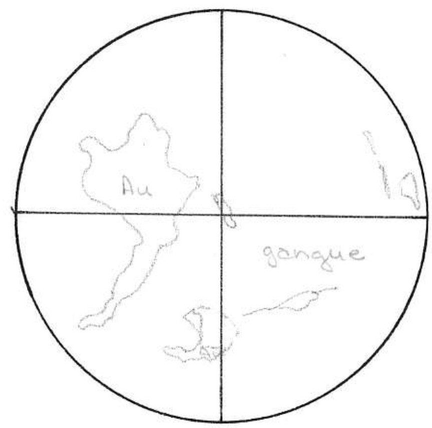
SECTION #1 (B)

- LAMELLAE IN POLYBASITE ?



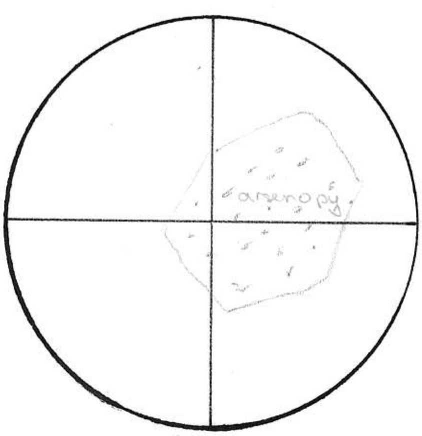
SPECIMEN #2 (A) X20

- NATIVE SILVER

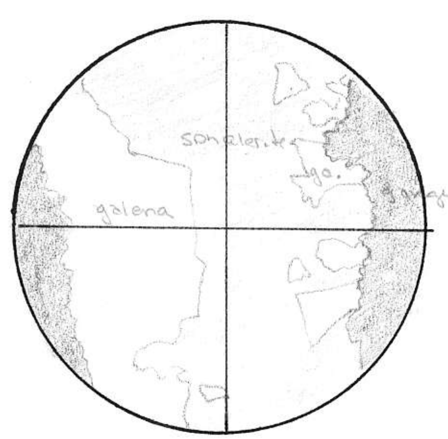


SPECIMEN #2 (B)

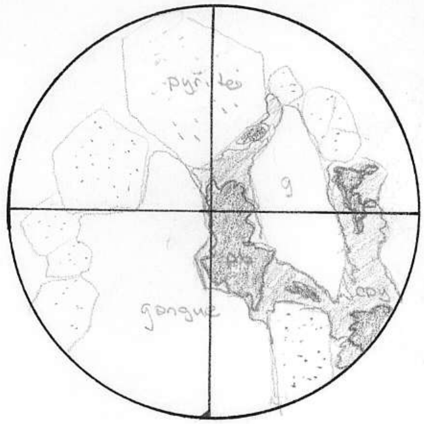
- NATIVE GOLD.



SPECIMEN #3 (A) X20
- ARSENOPYRITE

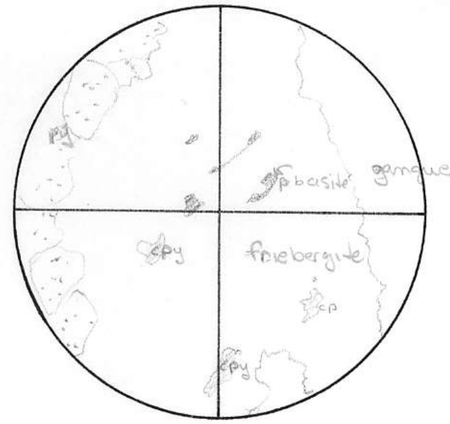


SPECIMEN #3 (B) X5
- GALENA AND SPHALERITE



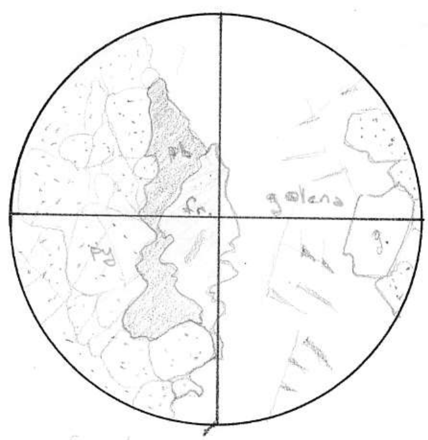
SECTION #4 X5

-POLYBASITE (DARK)
- CHALCOPYRITE (LIGHT GREY)
-PYRITE - MOTTLED.



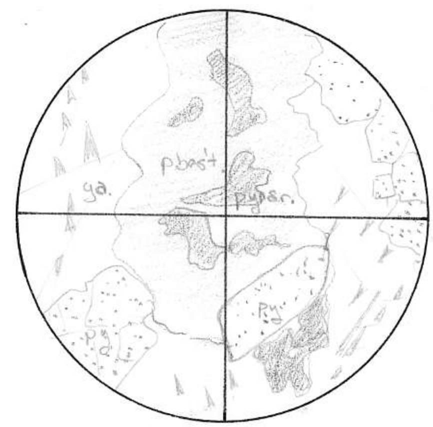
SECTION #4 X5

-FRIEBERGITE, WITH CHALCOPYRITE AND POLYBASITE?



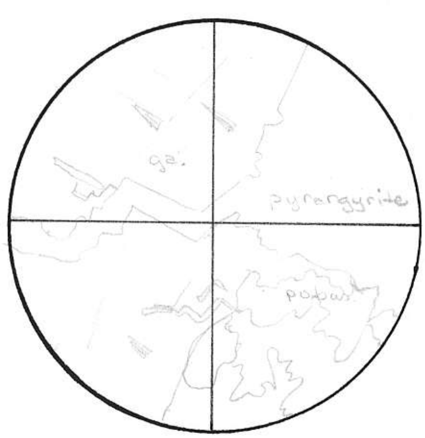
SECTION #5 X5

- POLYBASITE (DARK) WITH FRIEBERGITE AND GALENA

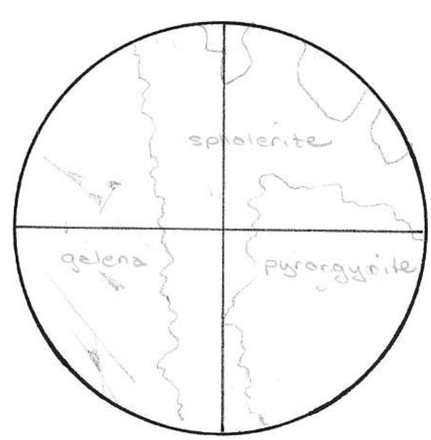


SECTION #5 X5

-PYRARGYRITE (DARK)
- WITH POLYBASITE, GALENA AND PYRITE



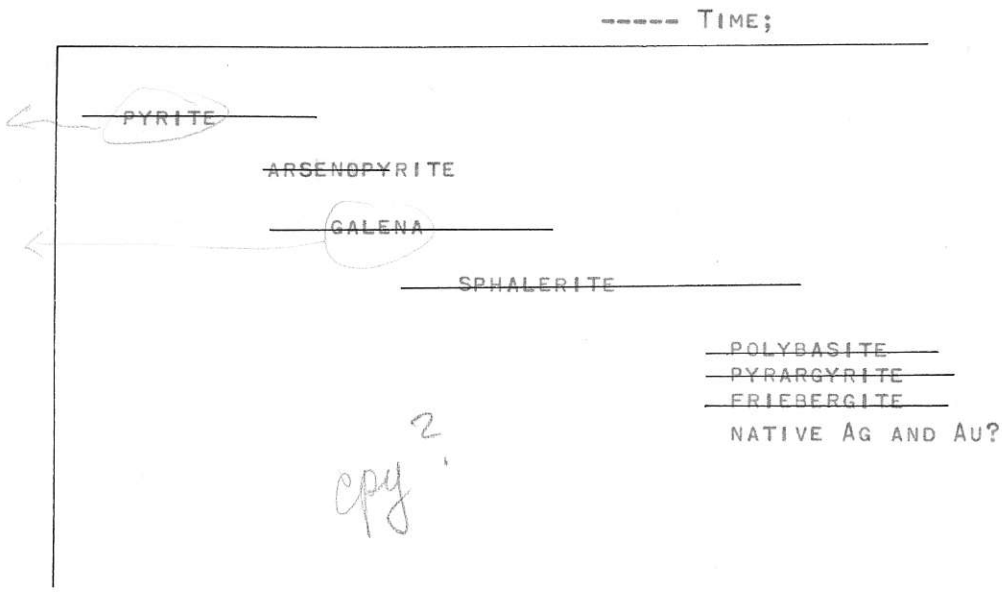
SECTION #7
-PYRARGYRITE IN GALENA ALONG CLEAVAGE.



SECTION #8
-PYRARGYRITE, WITH SPHALERITE, GALENA.

PARAGENETIC SEQUENCE:

THE ORDER OF DEPOSITION OF THE MINERALS IS DETERMINED FROM THEIR RELATIONSHIP IN THE POLISHED SECTIONS STUDIED;



THE MINERALS GENERALLY SHOW SMOOTH BOUNDARIES, THEREFORE THE TIME ELAPSED BETWEEN DEPOSITION OF INDIVIDUSL MINERALS MAY HAVB BEEN RELATIVELY SHORT.

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