GEOLOGY OF THE TULK'S HILL AREA
CENTRAL NEWFOUNDLAND

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by

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ILLUSTRATIONS

ABSTRACT

The thesis area, 3 miles south of the upper end of Red Indian Lake, lies in the Central Mobile Belt of Newfoundland. The rocks consist of schistose sericitic to chloritic acid volcanic flows and pyritic acid volcanics, with massive to schistose acid pyroclastic breccia, intermediate volcanics, minor sedimentary rocks and diabase dykes. All are metasomatized and metamorphosed to the greenschist facies.

The rocks have been folded into a central, south-westerly trending anticline and a northern, south-westerly plunging syncline. A major fault, paralleling the fold axis of the syncline, lies just north of it. Small isoclinal folds parallel the major folds. Two types of drag folds are present.

Four major pyritic horizons with base metal sulphide concentrations of economic interest occur in the area. Three mineralized zones occur within, and are a part of these mineralized horizons. The mineralized zones are principally massive pyrite and sphalerite, with lesser amounts of banded and disseminated sulphides. All three zones are steeply dipping and tabular in shape. The mineralized horizons, excluding the mineralized zones, are largely disseminated and banded sulphides with minor amounts of massive mineralization of the pyritic and sphaleritic types.

Paragenetic studies show that pyrite was the first formed mineral, followed by a group comprising arsenopyrite, unknown "A" and some pyrrhotite. A subsequent group includes the remaining pyrrhotite, chalcopyrite, sphalerite, tetrahedrite and galena, followed by unknown "B". Secondary chalcocite, covellite and digenite were the last minerals to form.

Gangue minerals in both the mineralized zones and horizons are quartz, albite, carbonate, sericite and chlorite. They appear to be later than the sulphides.

Hydrothermal fluids appear to have deposited the sulphides in tabular porous tops of acid volcanic flows on the northwest limb of the central anticline. The deposit may be described as exogenetic and epigenetic.

CHAPTER 1

INTRODUCTION

Purpose of the Thesis:

This thesis describes a field and laboratory study of the Tulk's Hill Area. The principal purpose of this work is to investigate the petrology of the rocks and the nature of the mineralized zones found in this area.

Location, Size of Area, and Access:

The Tulk's Hill area is located in Central Newfoundland between Longitude 57° 10' 75" and Longitude 57° 13' 25", and Latitude 48° 31' 20" and Latitude 48° 25' 00" north. It measures 4000 by 7600 feet and is rectangular in shape.

Access may be had by aircraft from Gander or by American Smelting and Refining Company Aircraft from Buchans. The aircraft lands at the mouth of Tulk's Brook on Red Indian Lake. The area, three miles upstream, is reached either by walking or by muskeg tractor..

An alternate method is to drive to Buchans Landing or Shananditiht's Brook, proceed by boat to the mouth of Tulk's River and thence to the camp.

Previous Work in the Area:

The earliest worker in the area was W. E. Moore who in 1930 first noticed the gossan zone and disseminated pyrite in the rocks.

In 1948, the area was again examined by prospectors of the American Smelting and Refining Company. As a result of their work, a reconnaissance map of the area was completed in 1949.

In 1957, G. C. Riley mapped the Red Indian Lake Sheet, West Half, for the Geological Survey of Canada on a scale of 1 inch to 4 miles. This map includes the area mapped by the writer.

In 1961, geochemical sampling of stream waters in the Tulk's Hill area revealed a copper anomaly at the foot of Tulk's Hill near Tulk's River. Detailed geochemical soil sampling was carried out in 1961 and 1962. This resulted in the discovery of additional copper anomalies.

Diamond drilling was begun in 1963 and continued until 1966.

R. L. Brown carried out mapping in 1963 and extended the work in 1964. In 1965, the writer remapped R. L. Brown's area and extended detailed mapping toward the west. Additional mapping was carried out in 1966.

Method of Investigation:

The area was mapped by the writer during the summer of 1965 and part of the summer of 1966. Mapping was done by traversing along cut and chained lines spaced at 200 foot intervals. The position of outcrops between the lines was located by pacing.

In barren areas, air photographs on a scale of 1 inch to 200 feet were used in conjunction with the lines to locate outcrops.

During the winter of 1965-66, a preliminary map of the area was prepared on a scale of 1 inch to 200 feet. Contours were drawn on the map from information obtained from a level survey of the grid.

Logging of pertinent diamond drill core was also done during this time.

Thin and polished section studies of selected specimens were completed during the 1966-67 term at Memorial University of Newfoundland.

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PHYSIOGRAPHY

Topography:

The area lies in the Annieopsoquotch Mountains of Central Newfoundland and drains into Red Indian Lake.

The area may be conveniently divided into two parts. The southern portion is a plateau-like area, gently rolling with an elevation of about 1,200 feet. The northern edge of this portion is marked by a line of cliffs of varying height and steepness. The elevation of this sector decreases toward the west.

The northern part of the map-area comprises the valley of Tulk's River. The eastern half of this part is covered by talus from the cliffs. A large bog occupies most of the western half of this part.

The maximum relief of the area is around 700 feet. The cliffs vary from 20 to 100 feet in height.

Streams drain the area. Those in the eastern half of the area flow in a north-westerly direction into Tulk's River. The streams in the western half flow in a westerly direction into Tulk's River. The direction is coincidental with the schistosity. Tulk's River, just north of the thesis area, flows north-easterly into Red Indian Lake.

Glaciation:

Evidence of glaciation is seen in the rounded hills, the till and erratics observed in the valley of Tulk's River and the absence of residual soil in the southern half of the area. Striae and small scale glacial features are generally absent even on freshly exposed rock surfaces. The only stria seen was oriented 330° true.

The direction of ice movement is not known with certainty. Granite and granite gneiss boulders and cobbles predominate in the till. Rocks of these types are found in situ to the west and northwest of the thesis area. This suggests that the ice moved in an easterly or south-easterly direction. The orientation of the stria suggests a south-easterly flow.

MacClintock and Twenhofel (1940) have suggested, on the basis of the unweathered till, that glaciation occurred during Pleistocene times.

A carbon 14 age of 7400 ± 15 years was obtained from a peat bog near St. John's (Olson and Broeckner 1958). This gives an idea of time elapsed since glaciation.

CHAPTER 2

PETROLOGY

Regional Geology:

The region is underlain by a series of north-easterly trending acid to basic volcanics and associated sedimentary rocks that have been folded into a north-easterly trending anticline. These rocks have been intruded by stocks of granitic and gabbroic composition. (Map 2 in pocket.)

Bodies of granite and granite gneiss, of batholithic dimensions, lie northwest and southeast of the anticline.

The most prominent structural feature in this region is the above-mentioned anticline. It is open, eroded and plunges gently to the southwest. It is about 15 miles wide just south of Red Indian Lake and dies out 45 miles farther south along its axis. The thesis area is on the northwest flank. (Map 2 in pocket.)

The age of the volcanics and associated sedimentary rocks is not known with certainty. Fossils have not been found in these rocks.

Riley (1957) assigns the rocks of this region to the Strides Group. He considers them to be of Ordovician age because of a lithological similarity to the Buchans Series which, in turn, is similar to the Exploits Group of Ordovician age found in the Bay of Exploits area.

Williams (1966) working to the north of this region, places the Buchans Series in the Silurian, with the Ordovician-Silurian contact along the south shore of Red Indian Lake. This would place the Strides Group in the Ordovician.

The granitic and gabbroic rocks intrusive into the volcanics are probably Devonian in age, but no absolute age determination has been made. The granites and granite gneisses enclosing the flanks of the anticline are Devonian and Precarboniferous (Riley 1957).

VOLCANIC ROCKS

General Statement:

The volcanic rocks comprise both flows and pyroclastics, and range from acid to intermediate in composition. The acid volcanics consist of sericitic, porphyritic and nonporphyritic chloritic, fragmental pyritic and biotitic subtypes. The intermediate volcanics may be andesitic. These rocks have been metamorphosed to the greenschist facies.

Nomenclature:

Low grade metamorphism and metasomatism of the volcanic rocks has obliterated most of the primary minerals and probably altered the plagioclase to albite. The absence of unaltered plagioclase or evidence of its former composition precludes the use of a system of nomenclature designed for unaltered volcanic rocks. The high quartz content of the leucocratic volcanic rocks suggests they are acidic types; hence, these rocks will be named 'acid volcanics'.

The dark green volcanic rocks have been completely altered to secondary minerals, but the percentage of albite (50 percent) in these rocks suggests that they are of an intermediate composition; hence, the term 'intermediate volcanics' will be used.

There are four principal divisions of the acid volcanic rocks:

1. Sericitic acid volcanics,
2. Chloritic acid volcanics,
3. Fragmental acid volcanics,
4. Pyritic acid volcanics.

The first type consists of quartz and albite phenocrysts in a matrix principally of sericite and quartz with amounts of plagioclase and chlorite in small quantities.

The second variety consists of both porphyritic and nonporphyritic subtypes. The phenocrysts when present are quartz and albite, while the matrix is predominately quartz and chlorite with smaller quantities of sericite and plagioclase. One specimen contained a small percentage of biotite.

The third type is made up of angular to lenticular fragments of sericitic acid volcanic rocks in a porphyritic chloritic acid volcanic matrix.

The pyritic acid volcanics consist of nonfragmental acid volcanics with minor amounts of fragmental acid volcanic rocks. This classification, based on a non-primary feature, is used because these rocks have a relatively high pyrite content, are closely associated with the mineralized areas, and the classification of this type as fragmental and nonfragmental would not aid in the structural interpretation of the area.

The intermediate volcanic rocks consist of approximately 50 percent albite, the remainder being chlorite, epidote and carbonate. These rocks are nonporphyritic.

Sericitic Acid Volcanics:

In the field the outcrops range from massive to banded in appearance and are sometimes well foliated. The massive looking outcrops, on closer inspection, show a poorly developed foliation. The banded looking exposures appear gneissic in structure, while the schistose outcrops have a well developed schistosity. In all cases, the rock weathers white to greyish in colour. Quartz eyes, 1 to 2 mm. in diameter, are easily seen on the weathered surface. Limonite stains are common on some exposures.

The more massive varieties are seen to have a banded structure on the fresh surface of hand specimens. This consists of alternating bands of quartz and white mica. The banded looking rocks exhibit a similar structure. Those with a well developed schistosity in outcrops are seen to consist of narrow bands of sericite and quartz. Phenocrysts of quartz and plagioclase, 1 to 3 mm. in size, occur in a fine grained white to blue grey matrix of sericite and quartz.

Under the microscope, quartz and albite phenocrysts occur in a foliated matrix of quartz, sericite, albite and minor chlorite, calcite and clinozoisite.

Quartz phenocrysts are generally anhedral in form. A few grains show bipyramidal faces (Plate 1). Strain shadows are characteristic, as is corrosion of the grains by the matrix (Plate 1). Where the grains have been fractured, the fractures are filled with groundmass minerals. Cores of matrix minerals were observed in several grains.

The quartz of the matrix occurs as irregular masses and bands of interlocking anhedral quartz grains. The size of these grains varies from 0.01 to 0.05 mm., and they commonly contain sericite needles.

The plagioclase phenocrysts are albite, An_6. Their composition was determined by the measurement of extinction angles in sections perpendicular to (010) by means of a Leitz Universal Stage. The subhedral crystals occur either as individual grains or as aggregates of 3 or 4 crystals (Plate 2). Terminal faces have been observed on a few phenocrysts (Plate 2). The borders of the phenocrysts are usually sharp, but in places have been embayed by the matrix. Fractures in this mineral are healed by the groundmass. Broken grains were occasionally noticed. The mineral is twinned on the albite law.

Varying amounts of albite, An_6, also occur in the matrix (Plate 3). The mineral occurs as lath shaped grains, albite twinned, and as anhedral untwinned grains intergrown with quartz. The plagioclase grains range from 0.05 to 0.2 mm. in length. There appears to be a subparallelism of the long axes of these grains.

Sericite is the principal micaceous mineral. It occurs either as stubby needles or flakes disseminated in the quartz of the matrix or in layers of elongate grains several millimeters thick (Plate 4). The sericite exhibits a directive texture and the layers bend around the phenocrysts (Plate 4). Crenulation of these bands occurs in places, but is uncommon (Plate 4).

Chlorite occurs in the rocks as stubby needles and fan-shaped grains from 0.01 to 0.1 mm. long. The mineral is associated with the sericite and the plagioclase phenocrysts. It also occurs in pressure shadows.

Calcite occurs as euhedral rhombs or as irregular masses poikilitically enclosing quartz. It is usually spatially associated with the albite phenocrysts.

Accessory minerals include pyrite and zircon. Small amounts of limonite and clinozoisite are also present.

The modal composition of the rocks, estimated visually, is shown in Table 1.

TABLE 1

Modal Composition of the Sericitic Acid Volcanics

(Average of 20 Specimens)

Percent	Chlor.	Ser.	Plag. Phen.	Plag. Matrix	Qtz. Phen.	Qtz. Matrix	Carb.	Access.
Range	0-10	5-60	1-25	0-50	1-20	10-85	0-35	.5-5
Average	2	20	5	5	10	50	5	1

Alteration:

The degree of alteration of the plagioclase varies. In the sericite-rich rocks, the degree of sericitization and carbonatization of the albite is more intense than in the sericite-poor specimens. Some crystals are altered to calcite along their fractures and around their borders. The sericite is developed along fractures and twin planes, but is disseminated in the plagioclase where sericitization is slight. The slightly altered phenocrysts are dusted with opaque iron oxides.

The pyrite is partly altered to brown amorphous material probably limonite.

Porphyritic Chloritic Acid Volcanics:

In the field, the rock is seen as massive outcrops. Closer inspection reveals that the rock is poorly foliated. Quartz phenocrysts protrude from the dark green weathered surface. Limonite stains of varying size stain some exposures.

In hand specimen on fresh surface the texture is more apparent. The rock is porphyritic with phenocrysts of quartz and plagioclase 1 to 2 mm. in size. The groundmass is dark green and fine grained. Schistosity is poorly developed.

Thin section examination reveals that the quartz and plagioclase phenocrysts occur in a matrix of quartz, chlorite, plagioclase, and smaller amounts of sericite and carbonate.

The quartz phenocrysts are subhedral, and show strain shadows. Ragged edges are common and some grains are embayed by the matrix. Aggregates of quartz grains resembling phenocrysts were also observed.

The plagioclase phenocrysts are albite, An_6, as determined by Universal Stage techniques. It occurs as subhedral grains and grain aggregates (Plate 5).

The quartz of the matrix occurs as angular to rounded grains and grain aggregates distributed throughout. Individual grains range from 0.01 to 0.03 mm. in size.

Corroded laths of plagioclase are found in the matrix. The composition determined by Universal Stage methods is An_6.

Chlorite is found in the rock as irregular layers and masses of stubby needles. The long axes show a preferred orientation parallel to the foliation.

Sericite occurs as narrow bands and irregular masses of stubby grains, often mixed with the chlorite. Minor biotite was observed in one specimen.

Calcite occurs as either rhombohedral grains or as anhedral aggregates studded with rounded quartz grains.

Accessory minerals are pyrite and zircon, with minor clinozoisite.

The modal composition of the rocks, estimated visually, is shown in Table 2.

TABLE 2

Modal Composition of the Porphyritic Chloritic Acid Volcanics

(Average of 8 Specimens)

Percent	Chlor.	Ser.	Plag. Phen.	Plag. Matrix	Qtz. Phen.	Qtz. Matrix	Carb.	Access.
Range	10-50	1-15	2-20	1-30	1-15	10-65	0-15	Tr.-2
Average	30	5	5	5	5	40	5	Tr.

Alteration:

The degree of alteration of the plagioclase is more pronounced than in the sericitic acid volcanics. Many of the grains are almost entirely a mass of sericite, and the remainder are well sericitized.

The biotite present in one specimen is partly altered to chlorite and most grains are over fifty percent chlorite. The remaining minerals are not altered.

Nonporphyritic Chloritic Acid Volcanics:

The nonporphyritic chloritic acid volcanics are subdivided into green and grey nonporphyritic subtypes. The former is characterized by a dark green colour; the latter is distinctly grey.

In the field the green variety cannot be distinguished from the intermediate volcanics. Outcrops appear massive. The grey type is distinctive. Outcrops are foliated.

In hand specimen on fresh surface the green nonporphyritic acid volcanics are fine grained with a poorly developed schistosity. They sometimes show tiny grains of carbonate. The grey variety is schistose and fine grained with eye-like grains of quartz.

Under the microscope both are similar texturally and mineralogically. They consist of an aggregate of quartz, chlorite, carbonate and minor sericite.

Quartz occurs as aggregates of tiny euhedral grains, bands, or as individual grains depending on the proportion in the rock. A few eye-like aggregates are present.

Chlorite, the most abundant micaceous mineral, occurs as irregular layers and aggregates of stubby needles and platy grains (Plate 6). It is usually mixed with a minor amount of sericite.

Two types of carbonate are found, calcite and dolomite. The dolomite is characterized by a limonite selvage around the periphery and along cleavages. Such features are absent in the calcite. Both occur as either twinned euhedral crystals (Plate 7) or as irregular ragged grain aggregates.

Corroded plagioclase laths are present in accessory amounts. Accessory minerals include pyrite, limonite and clinozoisite.

The mineralogical composition, estimated visually, is shown in Table 3.

TABLE 3

Mineralogical Composition of the Nonporphyritic Chloritic Acid Volcanics

(Average of 10 Specimens)

Percent	Chlor.	Ser.	Plag. Phen.	Plag. Matrix	Qtz. Phen.	Qtz. Matrix	Carb.	Access.
Range	6-65	1-40	0	0-20	0	5-55	5-55	Tr.-1
Average	35	15	0	5	0	25	25	Tr.

Fragmental Acid Volcanics:

In the field, these rocks occur as white weathering fragmental looking outcrops, usually massive. Closer inspection reveals that this rock consists of angular to lenticular fragments of white weathering acid volcanic rock in a dark green matrix. The lenticular fragments are arranged en echelon. The size of these fragments ranges from 1/10 inch to 12 inches in length and up to 4 inches wide. The matrix is poor to highly schistose.

On fresh surface in hand specimen the nature of the rock is more clearly seen. The fragments are white to grey in colour, aphanitic, and contains scattered tiny quartz eyes. The groundmass of the fragments is chloritic, fine grained and contains scattered plagioclase grains approximately 1 mm. in size.

The rocks from the northeast sector of the area appear to be least deformed. Here the fragments are sharply angular, and the matrix of the fragments is poorly foliated. This rock has the appearance of a pyroclastic breccia. Those specimens with lenticular fragments seem to be more highly deformed varieties since the fragments are rounded off on the sides and the matrix of the fragments is schistose.

Under the microscope the fragments, both angular and lenticular, consist of phenocrysts of quartz and plagioclase in a matrix of quartz, minor sericite and chlorite.

The quartz and plagioclase are similar in all respects to those observed in the sericitic acid volcanics (Plate 8).

The texture and mineralogy of the groundmass is again similar to that of the sericitic acid volcanics.

The groundmass is largely quartz. The grains are anhedral and range from 0.01 to 0.1 mm. in size. They form an interlocking mosaic. The percentage of quartz is higher than in the sericitic acid volcanic rocks.

A small percentage of albite laths are found in the matrix. The borders of these laths are corroded.

Sericite and chlorite occur in varying amounts. Where the percentage of these minerals is high, they occur as felty masses of stubby needlelike grains. Where the percentage is low, the grains occur in layers or are disseminated in quartz. There appears to be a preferred orientation of the long axes of the grains in the layers.

Accessory amounts of calcite, clinozoisite and pyrite are present.

The mineralogical composition, estimated visually, is shown in Table 4.

TABLE 4

Mineralogical Composition of the
Fragments of the Fragmental Acid Volcanics

(Average of 10 Specimens)

Percent	Chlor.	Ser.	Plag. Phen.	Plag. Matrix	Qtz. Phen.	Qtz. Matrix	Carb.	Access.
Range	0-60	0-25	1-10	0-10	0-5	20-90	Tr.	0-2
Average	10	10	5	5	2	65	Tr.	1

In thin section the matrix is seen to differ mineralogically from the fragments. The main differences are in the higher percentage of chlorite and sericite, and a resulting lower percentage of quartz.

Plagioclase occurs as phenocrysts ranging from 0.5 to 1 mm. in size. The composition is albite, An_6. The phenocrysts are sometimes fractured and usually occur as individual crystals (Plate 9).

Corroded laths of plagioclase occur in the matrix, ranging in size from 0.1 to 0.5 mm. in length. The composition is estimated to be albite from maximum extinction angles perpendicular to (010).

Quartz phenocrysts in the groundmass are strained and corroded. Fractured individuals have the fractures healed by matrix material. Some appear to be crushed.

In the matrix of the rock, aggregates of tiny quartz grains are characteristic. The size of these aggregates depends on the percentage of quartz in the rock.

Sericite and chlorite, intimately associated, appear as stubby needles and plates. They are arranged in layers of varying width, or as irregular masses of crystals. The minerals sometimes form separate layers.

Accessory carbonate, pyrite and amorphous material are present.

The mineralogical composition, estimated visually, is shown in Table 5.

TABLE 5

Mineralogical Composition of the Matrix of the Fragmental Acid Volcanics

(Average of 10 Specimens)

Percent	Chlor.	Ser.	Plag. Phen.	Plag. Matrix	Qtz. Phen.	Qtz. Matrix	Carb.	Access.
Range	1-50	1-50	0-10	0-20	0-5	15-84	Tr.	0-1
Average	20	20	5	5	2	45	Tr.	Tr.

Alteration:

The degree of alteration of both the phenocrysts and the laths of plagioclase in the fragments is about the same degree as in the sericitic acid volcanics . The phenocrysts and laths are slightly sericitized and are dusted with opaque iron oxides.

Sericitization of the phenocrysts and the laths of plagioclase in the chloritic matrix of the fragments is more intense than that of the fragments. It is about the same in degree as in the porphyritic chloritic acid volcanics . Some clear grains are present and are clouded with opaque finely divided iron oxides.

Pyritic Acid Volcanics:

In the field, this rock forms large areas of rusty weathering outcrops, especially in the vicinity of the mineralized zones. Elsewhere rusty weathering outcrops are interspersed with exposures of sericitic and fragmental acid volcanics. These areas have a 'patchy rusty' appearance, quite noticeable in the field. Outcrops of this rock type appear to be sheared, but this is probably an accentuation of schistosity by weathering because the fresh rock is no more schistose than the other volcanics.

On the fresh surface in hand specimen the rusty colour appears to be due to limonite. This apparently results from the oxidation of pyrite as some partly oxidized pyrite grains are present. Some hematite stains are found.

The rock is white to yellow to light grey in colour and is banded. The bands vary from 1/10 to 10 mm. in width and consist of sericite layers alternating with quartz bands. Where these bands are narrow, the rock is schistose, but the wide bands give the rock a gneissic structure. Few quartz phenocrysts are present.

Various amounts of pyrite give the rock its name. The pyrite occurs both as fine disseminated grains or as lenticular to tabular layers of fine grained pyrite and quartz up to 2 mm. thick. Occasional layers of sulphides, usually pyrite and sphalerite in a quartz gangue, are found.

In thin section the banding is more apparent. Alternating layers of quartz and sericite and occasional bands of pyrite and quartz are characteristic.

Subhedral quartz phenocrysts are rare. Such as were observed are strained, fractured and embayed by the matrix (Plate 10). The fractures are healed by the matrix minerals. Quartz also occurs as eye-like aggregates presenting an eye-like appearance in hand specimen.

The remainder of the quartz occurs as bands of tiny interlocking grains (Plate 11). Quartz grains are present in the sericite layers in varying amounts. Quartz veins cutting these rocks are made up of much larger interlocking grains 0.3 to 0.5 mm. in diameter.

The sericite bands consist of an aggregate of stubby needle-like grains. The long axes show a preferred orientation parallel to the banding (Plate 11). The bands are often crenulated and bend around the quartz phenocrysts. Disseminated sericite occurs in the quartz layers.

Pyrite occurs as euhedral grains and grain aggregates varying from 0.01 to 1 mm. in size. This mineral forms layers and lenses in the rock up to 2 mm. wide associated with fine grained quartz. Minor sphalerite is also present and is associated with pyrite.

Minor amounts of chlorite and calcite are also found in these rocks.

The mineralogical composition, estimated visually, is shown in Table 6.

TABLE 6

Mineralogical Composition of the Pyritic Acid Volcanics (Average of 10 Specimens)

Percent	Chlor.	Ser.	Plag. Phen.	Plag. Matrix	Qtz. Phen.	Qtz. Matrix	Carb.	Access.	Sulph.
Range	Tr.	5-40	0	0	0-5	45-95	0-3	0-1	0-10
Average	Tr.	20	0	0	1	75	0.5	Tr.	3

Biotitic Acid Volcanics:

This rock type was only observed in diamond drill core. It occurs in bands up to 20 feet wide.

In hand specimen it consists of biotite phenocrysts in a dark fine grained groundmass. The rock is schistose.

In thin section the rock is distinctly porphyroblastic. Porphyroblasts of biotite occur in a matrix of biotite, quartz and calcite.

Biotite porphyroblasts are anhedral with ragged edges and are partly chloritized. Many grains are bent and most contain tiny zircon grains with pleochroic halos.

A different type of biotite with less intense pleochroism occurs in the matrix as uneven layers partly altered to chlorite.

Quartz porphyroblasts of a lenticular shape are uncommon. The grains show strain shadows. The remainder of the quartz occurs as aggregates of tiny grains in the matrix sometimes forming lenses or irregular bands. Rhombs and irregular grains of calcite are also present.

Accessory pyrite and zircon are scarce.

Intermediate Volcanics:

In the field, this rock weathers dark green in colour. The outcrops appear to be massive. In many outcrops, oval and lenticular carbonate masses have weathered out giving the rock a vesicular appearance. No pillows or pillow-like structures were seen.

Pseudovesicular zones seem to form definite horizons in the intermediate volcanics in the northern part of the area.

In hand specimen on fresh surface the rock is a typical 'greenstone'. It is fine grained and appears to be largely chlorite with minor plagioclase. The pseudovesicles observed on weathered surface are filled with carbonate, giving the rock an amygdaloidal appearance. These 'amygdules' are lense shaped and the long axes are parallel. Some parts of the rock contain no 'amygdules'. A few white phenocrysts were observed in those rocks from the southeastern part of the thesis area.

Schistosity is well developed in the rocks from the southeast sector, but is poorly developed elsewhere.

Under the microscope, the rock is a mass of chlorite, carbonate, plagioclase and sometimes epidote.

The phenocrysts of plagioclase are subhedral, and usually occur as aggregates. The composition is albite, An_6.

Corroded laths of albite 0.05 to 0.1 mm. long, are found in all specimens. The long axes of these laths are subparallel, giving the rock a trachitic texture (Plate 12).

Both dolomite and calcite are found in this rock type. Euhedral rhombs and irregular aggregates of anhedral grains are typical. The latter are poikiloblastic.

Stubby needles and plates of chlorite crystals occur as crude layers or irregular networks. The epidote is clinozoisite, found only in abundance in the rocks from the northeast intermediate volcanic zone. It is found as anhedral clouded grains, associated with quartz and carbonate.

A small amount of quartz is interstitial to the plagioclase laths in a few sections.

Minor amounts of biotite and sericite were noted in some specimens.

The mineralogical composition, estimated visually, is shown in Table 7.

TABLE 7

Mineralogical Composition of the Intermediate Volcanics (Average of 6 Specimens)

Percent	Chlor.	Ser.	Plag. Phen.	Plag. Matrix	Qtz. Phen.	Qtz. Matrix	Carb.	Epi.	Access.
Range	10-50	0-5	0-10	30-70	0	0-Tr.	2-20	0-30	0-2
Average	33	1	1	54	0	Tr.	5	5	1

Alteration:

The plagioclase laths appear to be altered to sericite. Minor biotite is largely chloritized.

SEDIMENTARY ROCKS

Black Slate:

In the field, this rock occurs as low outcrops with a well developed slaty cleavage.

In hand specimen the slaty cleavage is seen to be poorly to well developed. Crinkles are sometimes present on cleavage planes. Pyrite, pyrrhotite and quartz form layers and irregular masses in the slate giving it a poorly banded appearance. Some disseminated pyrite and pyrrhotite are present.

Under the microscope, the banding is clearly visible. The layers consist of quartz, quartz and sericite with varying amounts of graphitic material, quartz with pyrite, and pyrrhotite (Plate 13).

The quartz layers are made up of a mosaic of tiny anhedral grains. The layers of quartz sericite and graphite consist of tiny quartz grains containing sericite needles and graphite flakes in varying amounts. The veinlets of quartz and pyrite are often zoned consisting of walls lined with quartz crystals with a core of pyrite, quartz and a small amount of calcite.

Pyrrhotite layers were noted in one specimen only. These layers usually contain a small quantity of quartz and pyrite.

Metaconglomerate:

In the field, outcrops of this rock weather light to dark grey and appear massive. No directive texture was observed. The material cementing the fragments is either black or dark grey and is fine grained. The black material is schistose.

In hand specimen two types of metaconglomerate are apparent. The first consists of light grey, rounded to subrounded, fine grained fragments of metasiltstone in a black slate matrix. The second is made up of fine grained medium grey fragments of metasiltstone in a very fine grained matrix of the same material.

In thin section the fragments are seen to consist of a very fine aggregate of quartz grains with minor sericite and tiny graphite flakes. Corroded plagioclase grains are estimated to be albite in composition from extinction angles perpendicular to (010). The fragments are mineralogically similar to the sericitic acid volcanics.

The metasiltstone matrix is of similar composition but is finer grained.

The black slate matrix consists of quartz with varying amounts of graphitic material, and minor sericite.

Black Chert Breccia:

The black chert breccia was observed only in diamond drill core. In hand specimen it is seen to consist of angular fragments of black chert cemented by quartz stringers. The fragments are aphanitic and contain disseminated pyrite.

Under the microscope, the breccia fragments consist of a fine grained interlocking mass of quartz grains peppered with tiny graphite flakes. A little sericite and pyrite are present.

The mineral cementing the fragments is quartz. This mineral forms grains about 0.1 mm. in size.

Metasiltstone Breccia:

The metasiltstone breccia consists of angular fragments similar to those of the conglomerates cemented by a quartzose matrix.

In thin section the fragments are seen to consist of fine quartz grains, sericite and chlorite in an interlocking mass. Graphite is present in varying amounts.

The interfragmental material is predominately quartz with minor carbonaceous matter, pyrite and sericite.

DYKE ROCKS

Diabase Dykes:

In the field, the diabase dykes occur as dark, almost black, massive outcrops. Closer inspection shows that the dykes have chilled borders.

In hand specimen the rock is massive and dark green to black in colour. The grain size ranges from very fine at the margins to coarse in the central part of the dyke. This rock appears to be mainly chlorite and white plagioclase.

Under the microscope, the diabase exhibits a diabasic texture. The plagioclase appears as saussuritized corroded laths 0.05 to 1 mm. long. The degree of saussuritization varies and the crystals contain inclusions of magnetite. Their composition is albite.

Chlorite, clinozoisite and calcite are interstitial to the plagioclase laths. Minor brown biotite is largely chloritized.

Accessory minerals are apatite and magnetite.

Quartz Veins:

Quartz veins are found throughout the area, but are most abundant in the pyritic acid volcanics.

In hand specimen it is milk-white in colour and massive. In places it contains inclusions of sericitic acid volcanics.

In thin section the rock consists of interlocking grains of quartz up to 0.5 mm. in size. An occasional sericite grain was also seen.

DISTRIBUTION AND FIELD RELATIONS OF THE ACID VOLCANICS AND ASSOCIATED ROCKS

The sericitic acid volcanics are the most common rock type and are equally abundant in all parts of the thesis area (Map 1 in pocket). All rock types subsequently described occur as elongate bodies in the above acid volcanics.

The sericitic acid volcanics both across strike and parallel to strike are in sharp contact with the intermediate volcanics. Gradational contacts between the former and the chloritic acid volcanics were observed both in the field and in diamond drill core. The contacts between these rock types along strike were not observed.

The gradational contact between the fragmental acid volcanics and the sericitic acid volcanics, both across and parallel to strike, is marked by a gradual decrease in the amount of 'matrix' in passing from the sericitic to the fragmental acid volcanics over some 10's of feet. The transition from the predominately sericitic rock to the predominately chloritic matrix appears to be relatively abrupt.

The contact between the black slate and the sericitic acid volcanics is sharp. This was seen in both the diamond drill core and the outcrop.

Both the porphyritic and nonporphyritic chloritic acid volcanics are sparsely distributed throughout the map area. The green variety of nonporphyritic chloritic acid volcanics cannot be distinguished from the intermediate volcanics in the field. The porphyritic type of chloritic acid volcanics is associated with both the intermediate volcanics and the green nonporphyritic chloritic acid volcanics. The former can be distinguished from the latter two rock types by the presence of quartz eyes. The two types of chloritic acid volcanics are not separated in the field because of the small number of exposures of the porphyritic subtype.

Contacts between the porphyritic chloritic acid volcanics and the green nonporphyritic chloritic acid volcanics, observed only across strike, appear to be gradational. The number of quartz eyes gradually decreases over a distance of about 50 feet in passing from the porphyritic to the nonporphyritic type.

The grey nonporphyritic chloritic acid volcanics occur as narrow horizons in the sericitic acid volcanics up to 300 feet long and 100 feet wide. It is not associated with the other chloritic acid volcanics. These horizons parallel the regional strike. The contacts with the enclosing sericitic acid volcanics are sharp, the change taking place across strike within a distance of several millimeters.

The fragmental acid volcanics are found throughout the area. The largest single body is in the southern sector where it forms several conspicuous hills and ridges (Map 1 in pocket).

The contact between this rock type and the chloritic acid volcanics was not observed. The contact between the former and the intermediate volcanics was not seen. Contacts between the pyritic acid volcanics and the fragmental acid volcanics are marked by a decrease in the amount of pyrite in passing from the former to the latter, both across and along strike.

The pyritic acid volcanics form conspicuous rusty weathering outcrops in the central portion of the area. Such rusty zones form an elongate zone parallel to the trend of rocks (Map 1 in pocket). Much smaller zones are scattered through the rest of the map-area. Passage from the rusty weathering (pyritic) acid volcanics to other rock types is marked by a gradual decrease in the amount of limonite stain on the weathered surface. In diamond drill core the change from the pyritic to the other types is marked by a gradual decrease in the pyrite content over 10's of feet.

The intermediate volcanics and associated green non-porphyritic acid volcanics are for the most part restricted to the southeast, northeast and southwest sectors. These bodies vary in size, but are approximately 2000 feet long and 500 feet wide on the average.

Contact relations with the sericitic acid volcanics have been previously described (Page 36). Contacts of the intermediate volcanics with the other rock types were not observed.

Black slates, metasiltstone breccia and metaconglomerate are usually found in the same horizon. The exception is a zone of metaconglomerate found on the eastern boundary of the area. The two largest zones occur in the eastern and western ends. Both are approximately 1000 feet long and 100 feet wide. Several smaller bodies occur elsewhere.

A horizon of black chert breccia of indeterminate length and about 500 feet wide is found just north of the thesis area, underlying Tulk's River.

Diabase dykes from several inches to 100 feet wide are confined to the southern border and the north-central part of the area. The dykes parallel the regional schistosity.

Surface mapping and diamond drilling reveal that the dykes cut the other types of acid volcanics. The borders of the dykes are chilled and the contacts with the enclosing rocks are knife-sharp.

ORIGIN OF THE ACID VOLCANICS AND ASSOCIATED ROCKS

The sericitic and fragmental acid volcanics constitute the bulk of the rocks in the thesis area. They are intimately associated in the field.

There appears to be three possible origins for the sericitic acid volcanics:

1. These rocks are a series of flows.
2. These rocks are a series of tuff beds.
3. These rocks are a series of minor intrusions.

Field and laboratory examination favour the first. Field examination and diamond drill core logging reveals that these rocks are uniform throughout the area.

Examination of these rocks in hand specimen showed a similar textural uniformity. No tuffaceous fragments were observed in hand specimens or outcrops.

Thin section studies furthur reveal that these rocks are texturally similar. The plagioclase phenocrysts are usually subhedral and often in groups. Few broken phenocrysts are present and some show terminal faces. A subtrachytic texture is found in many specimens. In addition, few broken quartz phenocrysts can be seen and several grains display bipyramidal faces. This rock has the texture of a typical flow rock. Fragments of glass and of other rocks are entirely absent.

The above evidence indicates that these rocks could also be a series of minor intrusions. However, the gradational contact of these rocks with the fragmental acid volcanics precludes such an origin for this rock type. It is, therefore, concluded that this rock comprises a series of flows.

The origin of the fragmental acid volcanics is obscured by later metamorphism. There are several possibilities for the origin of this rock:

1. The rock is a pyroclastic breccia,
2. A flow breccia,
3. A tectonic breccia,
4. A volcanic conglomerate formed by wave action on acid volcanic flows.

Field and laboratory studies indicate that it is a pyroclastic breccia.

Field study reveals a wide range in the sizes of fragments and a difference in composition between the fragments and the matrix. This work shows that the fragments, in all cases, are sericitic acid volcanics, usually massive, while the matrix is high in chlorite giving it a green appearance.

Hand specimen study confirmed the above observations and reveals that the matrix of the fragments contains grains of plagioclase 1 to 2 mm. in size. There is a wide range in size of fragments (from 1/10 to 12 inches long), but the average size is small in the order of 2 or 3 inches. The shape also varies. Where the rock has been stressed, the shape is lenticular. Where foliation is poorly developed, the fragments are angular in shape.

Thin section studies show that the fragments are quite uniform and, in all cases, are typical sericitic acid volcanics as suggested above. The matrix of the fragments is made up of subhedral grains of plagioclase of varying size. Some are broken. The matrix of these grains consists of chlorite and quartz.

The dissimilarity of the fragments and the matrix indicate that it is not a flow breccia. The above evidence combined with the very irregular shape and distribution of the fragmental acid volcanic bodies indicates that it is not a tectonic breccia. The angularity of the broken plagioclase grains and the angularity of the fragments in the poorly foliated area indicates that it is not a volcanic conglomerate derived by wave action on acid volcanic flows.

It is, therefore, concluded that this rock type is a pyroclastic breccia.

Textural similarity between the porphyritic chloritic acid volcanics and the sericitic acid volcanics suggests that the former is a series of flows. This is supported by the observation that these rocks are associated with the intermediate volcanics.

The nonporphyritic chloritic acid volcanics are devoid of primary structures and contain no visible plagioclase. The association of these rocks , with the porphyritic chloritic acid volcanics and the intermediate volcanics coupled with the absence of tuffaceous fragments, indicates that this type is volcanic in origin, probably a heavily altered flow.

Examination of the intermediate volcanics revealed the absence of pillow structures, amygdules and vesicles. These features, which commonly survive the greenschist type of metamorphism and which were found south of this area by Coward (1965), suggests that these rocks were deposited on land.

There is good evidence to suggest that these rocks are a series of flows. The first is the absence of fragments of intermediate volcanics or other rocks in hand specimen and in outcrops. In the field, the rock is distinctly massive in appearance.

Under the microscope, these rocks show a definite trachytic texture and there is no suggestion of fragments in any of the specimens. It is, therefore, concluded that the intermediate volcanics are a series of flows and that they are subaerial.

The metasedimentary rocks occur in relatively small elongate masses, sometimes lenticular. The presence of graphitic slates indicates that the rock, in part, was deposited in a restricted basin where anaerobic conditions were present (Pettijohn, 1957). The small size of the black slate zones indicates that the basins may have been small or may have been partly eroded after uplift. It is noteworthy that such black slate zones are common throughout the region described under Regional Geology.

The metaconglomerates and breccias, invariably associated with the black slates, suggest that at some time in the history of the area the volcanics were undergoing erosion into the above-mentioned basins. This is supported by thin section study which shows that the fragments of the metaconglomerates and breccias are mineralogically similar to the sericitic acid volcanics.

The black chert breccia associated with the Tulk's River Fault is also associated with black slates. The highly sheared condition of the slates suggests that the black cherts are probably a tectonic breccia. The black chert may be a primary precipitate in a sedimentary basin, or could represent silicification of certain portions of the black slate horizon.

Chilled borders and much coarser grained interior indicate that the diabase dykes are intrusive into the foregoing rocks.

METAMORPHISM AND METASOMATISM

The rocks of the thesis area have, in all cases, been metamorphosed to the greenschist facies.

The sericitic acid volcanics are now an aggregate of quartz, albite, calcite, chlorite, clinozoisite and sericite. The chloritic acid volcanics, both the porphyritic and nonporphyritic types, are similar in composition to the sericitic acid volcanics. The composition of these rocks indicates that they belong to the quartz-albite-muscovite-chlorite subfacies of the greenschist facies.

The intermediate volcanics are members of the greenschist facies consisting of an aggregate of chlorite, clinozoisite, carbonate and albite. Thus they are of the albite-chlorite-epidote-biotite subfacies.

The sedimentary rocks are now slates, metaconglomerates and metasiltstones, typical of this grade of metamorphism.

There appears to have been several types of metasomatism in the area, namely hydrous, carbon dioxide and silica.

The widespread formation of hydrous minerals from anhydrous ones indicates that hydrous fluids were active during the period of metasomatism. Large quantities of sericite and chlorite probably formed during this time.

The sericite appears to have formed as result of the alteration of potassic feldspar. Staining of 20 specimens with sodium cobaltinitrite showed that potassic feldspars are absent. These feldspars are normally present in acid volcanics. Alteration of biotite has given rise to some chlorite since partly altered grains of biotite were seen in several specimens. The rest of the chlorite probably formed from other ferromagnesian minerals, formerly present in the rock.

The abundance of carbonate, both calcite and dolomite, indicates that carbon dioxide bearing fluids permeated the rock during the period of metasomatism. The source of calcium for the calcite was probably the plagioclase and possibly hornblende. Veinlets and irregular masses of calcite are intergrown with pyrite suggesting that the source of the bulk of the calcium was the plagioclase.

Dolomite is restricted to the chloritic acid volcanics and intermediate volcanics. The source of most of the calcium was probably the plagioclase and the alteration of ferromagnesian minerals was possibly the source of the magnesium.

Quartz veins occur throughout the area, but are most abundant in the pyritic acid volcanics.

In thin section in the pyritic acid volcanics, quartz stringers of varying sizes can be seen, some containing pyrite and fluid inclusions. This suggests that silica bearing hydrous solutions were active during metasomatism and especially affected the pyritic acid volcanics. The complete absence of chlorite and plagioclase suggests that these fluids may have removed these materials or converted them into other minerals.

CHAPTER 3

STRUCTURAL GEOLOGY

Folds:

There appears to be two principal types of folds in the area. These are:

1. Isoclinal folds on both a large and small scale
2. Drag folds.

The evidence for isoclinal folding is found in the northern part of the thesis area. The first is an exposure in a brook in the northeast sector (Map 1 in pocket). At this location, a distinctive black slate horizon is repeated three times over a distance of 200 feet. The similarity in lithology among the three exposures indicates that it is the same bed repeated three times, not three different beds. Coward (1965), who examined the same exposures, reached a similar conclusion.

A second exposure, not examined by Coward, is found in the north central part of the area. In this instance, a horizon of intermediate volcanics was repeated three times by folding over a distance of approximately 300 feet. The intermediate volcanic-acid volcanic contacts on the limbs are steeply dipping toward the northwest.

On a larger scale there appears to be at least two larger folds.

Mapping in the northeast sector of the map-area, combined with subsequent interpretations, suggests that a plunging syncline or anticline is present in this sector. Studies of minor structures in the area by Coward (1965) suggest that it is a syncline with almost vertically dipping limbs plunging toward the southwest (Map 1 in pocket).

Two distinct types of drag folds were observed during mapping of the area. The first is the normal type, while the second is a variety known as a kink fold.

The first type of drag fold is found only in areas of quartz veining. Some of the veins have been drag folded. They are most abundant in the central part of the area near the mineralized zones. Observations indicate that they plunge toward the northeast at a high angle. The axial planes strike northeast and dip steeply southeast and northwest.

The kink folds were closely examined by Coward (1965), who made the following observations:

> "Acid tuffs are thinly foliated and show kink folds on the north side of the hill. The folds form a conjugate set. In this set the overall dominant couple is magnetic north-south."

He furthur states:

> "The amount of outcrop on top of the hill is quite high, which enables the kink folds to be traced out quite readily. They tend to die out rapidly, and the length over which displacement takes place is quite short. The axial planes often follow a curved path. The kink folds generally group together, although not en echelon."

Mapping in the southern half of the thesis area indicates that a syncline or anticline may be present in this half. This is suggested by:

1. The repetition of diabase dykes of approximately the same length and distribution across the postulated fold axis (Map 1 in pocket).
2. The repetition of fragmental acid volcanics across the supposed fold axis.
3. The repetition of small bodies of chloritic acid volcanics-intermediate volcanics (Rock Unit 3) on either side of this probable axis in the eastern and western parts of this area.

Swanson (personal communication) suggests that the distribution and length of the diabase dykes indicates that there is a syncline or anticline in the south central part of the map-area.

Coward (1965), based on a structural study of minor structures and foliation of the rocks of this area, suggests that this fold is an anticline, the axis striking parallel to the schistosity.

The writer could not determine whether or not this fold is a syncline or an anticline on the basis of field work. It is, therefore, suggested that on the basis of evidence presented by Coward that there is an anticline in the south central part of the area which strikes parallel to the schistosity.

Faults:

One fault was found by diamond drilling. This lies just north of the northern boundary of the area (Map 1 in pocket) underlying part of the valley of Tulk's River.

Examination of the regional geological map (in pocket) suggests that this fault, hereafter referred to as the Tulk's River Fault, is regional in nature and parallels the trend of rocks. This is confirmed by diamond drilling. One diamond drill hole, collared on the north side of Tulk's River, intersected fault gouge and fault breccia. The gouge consists of highly sheared black graphitic slates. The breccia has been described previously (Page 32-33).

The fault zone is approximately 300 feet wide and the dip appears to be vertical. The strike of the fault trace is about 50° true and the movement appears to have been largely strike slip, since the rocks are similar on both sides of the fault.

Joints:

Jointing is well developed in the rocks. The most prominent set is at approximately 90° to the foliation. The strike of these joints varies from 130° to 160°, and the dip from steep east through vertical to steep west. The joint surfaces are sometimes coated with a thin layer of white quartz.

A particularly prominent linear separates T-1 and T-2 mineralized zones from T-3. It forms a conspicuous notch in the cliffs in the north central part of the area.

The lack of horizontal separation across this feature and the absence of slickensiding on its walls indicate that it is probably a joint. However, two diamond drill holes that penetrated the plane of this lineament showed that it was filled with a rusty stained breccia made up of pyritic acid volcanic fragments cemented by hydrous iron oxides.

The above indicates that movement may have taken place along this feature after metamorphism of the pyritic acid volcanics, but was not repeated to any great extent.

CHAPTER 4

ECONOMIC GEOLOGY

General Statement:

Four mineralized horizons, designated 1, 2, 3 and 4 (see Map 1 in pocket), are found in the area. They are predominately pyritic, but in places they pass laterally into zones consisting mainly of massive to disseminated chalcopyrite, sphalerite, galena and pyrite. These mineralized zones, which are of varying dimensions and tenor, are designated T-1, T-2 and T-3 (see Map 1 in pocket).

Although the mineralized zones are part of the mineralized horizons, they will be considered under separate headings for the following reasons:

1. The mineralized zones are much more intensely mineralized, consisting largely of massive sulphides. The mineralized horizons are largely banded disseminated sulphides.
2. The mineralized zones are much thicker and have much shorter dimensions than the mineralized horizons.

(It is to be emphasized that all subsequent descriptions of, or reference to, the mineralized horizons do not necessarily pertain to the mineralized zones.)

Large Scale Features of the Mineralized Zones:

T-1 mineralized zone, which lies at the same stratigraphic level as horizon 1, is the smallest of the three zones. It is approximately 500 feet long with a maximum true width of 30 feet in the central part.

The shape varies. The eastern portion is shaped like a drag fold (Figure 1); the western half is lens shaped (Figure 2). This zone pinches out at depth and at each end.

The dip varies from 45° northwest to 90° because of the variation in shape and the overall dip of the zone is 70° northwest. The strike of the long axis is 40° true.

The sulphide mineralization of this zone consists of interlayered massive and heavy disseminated sulphides. There is no apparent regular zoning. Pyritic mineralization is most abundant in the eastern half of this zone, while sphaleritic mineralization is characteristic of the western half.

The hanging wall comprises acid volcanics. The footwall consists of pyritic acid volcanics at the extreme western end but elsewhere the footwall is sericitic acid volcanics.

The contacts between the wallrocks and massive sulphide parts are sharp. The contacts between the heavy disseminated sulphides and wallrocks are gradational over a short distance. Preliminary thin section study reveals that the sericitic acid volcanics adjacent to the massive sulphides are similar to those seen elsewhere in the area.

T-2 mineralized zone is intermediate in size. It is about 900 feet long, and attains a maximum true width of 45 feet in the central part (Figure 3).

Diamond drilling reveals that this zone is wedge-shaped, pinching out at the western end and at depth. The eastern end extends into mineralized horizon number 2.

The dip of this zone is quite constant throughout its length, ranging from 60° to 70° northwest. The long axis is oriented in a direction of 50° true.

The sulphide mineralization is entirely of the massive type. Pyritic mineralization predominates, with minor sphaleritic mineralization in some parts of the zone.

Both the hanging wall and footwall are predominately sericitic acid volcanics, with minor chloritic varieties. Disseminated pyrite is concentrated in the western half of the hanging wall.

The contact between the massive sulphides and wallrocks, as seen in diamond drill core, is sharp. Preliminary studies of the wallrock adjacent to the mineralized zone indicate that these rocks are similar in all respects to the sericitic acid volcanics seen elsewhere.

T-3 mineralized zone is about 700 feet long and has a maximum true width of 25 feet in the central part of the zone.

The shape is that of a narrow wedge pinching out at depth and at the western end. The eastern end extends into mineralized horizon number 3.

The dip varies slightly, from 60° to 70° northwest. The strike of the long axis of this zone is 50° true.

This mineralized zone consists mainly of massive sulphides with some zones of heavy disseminated sulphides. There is no apparent regular zoning. Massive pyritic mineralization is most common, followed by the sphaleritic type. Heavy disseminated sulphides are found in the central part of the zone.

The hanging wall in the eastern half of this zone comprises pyritic acid volcanics and minor chloritic acid volcanics. The western half is characterized by sericitic acid volcanics and lesser amounts of the pyritic variety. A diabase dyke cuts the above rocks parallel to the foliation.

The footwall is entirely of the pyritic acid volcanic type. A narrow diabase dyke cuts these rocks.

The contacts between the massive sulphides and the wallrocks are sharp but the heavy disseminated sulphides grade out into the wallrocks over a short distance.

MEGASCOPIC AND MICROSCOPIC DESCRIPTION OF THE MINERALIZATION

General Statement:

The textural and mineralogical similarity among the mineralization of all three mineralized zones makes it redundant to describe the mineralization of each one separately. Therefore, the nature of the mineralization will be described under a single heading.

Two main types of sulphide mineralization occur in these zones; namely, the pyritic and the sphaleritic types.

The pyritic type may be divided into:

1. The massive to heavy disseminated subtype.
2. The banded pyritic subtype.

The sphaleritic type is subdivided into:

1. The massive to heavy disseminated sphaleritic subtype.
2. The banded sphaleritic subtype.

Both the pyritic subtypes contain pyrite and minor other sulphides. The massive to heavy disseminated sphaleritic subtype contains sphalerite and lesser amounts of other sulphides, but the banded type consists of bands of the pyritic type in the sphaleritic variety.

Massive to Heavy Disseminated Pyritic Subtype:

In hand specimen this subtype ranges from massive to heavy disseminated fine to medium grained pyrite with patches of chalcopyrite, arsenopyrite and pyrrhotite in a sericite-quartz gangue.

Under the microscope, the sulphides are seen to consist of cubes of pyrite with lesser quantities of sphalerite, arsenopyrite, chalcopyrite, pyrrhotite, galena, tetrahedrite, and two unknown minerals.

Pyrite occurs as euhedral to subhedral grains, either as individuals or grain aggregates (Plate 14). The grains vary from 0.02 mm. to 0.5 mm. in size, and in some specimens there are two distinct sizes of crystals. The crystals are corroded to varying degrees by the other sulphides, and contain angular to rounded inclusions of sphalerite, galena, chalcopyrite, unknown "B" and sometimes tetrahedrite.

Anhedral grains of chalcopyrite are intergrown with pyrite. This mineral both embays and veins the pyrite. The chalcopyrite contains angular scalloped inclusions of sphalerite, tetrahedrite and pyrrhotite. It seems to form replacement rims around some of the pyrrhotite grains and incompletely replaces it. Chalcopyrite is poorly intergrown with pyrrhotite, tetrahedrite and sphalerite and embays these minerals. Arsenopyrite grains are corroded by the chalcopyrite. The latter rim replaces unknown "A" besides occurring as rounded islands in this mineral. The degree of replacement varies. Sometimes almost the entire mineral is replaced, leaving remnant islands of unknown "A" in the chalcopyrite grains.

In the upper part of T-2 mineralized zone, chalcopyrite has been very slightly oxidized to chalcocite, covellite and digenite. These minerals fill fractures in, and form rims around, chalcopyrite and fill fractures in sphalerite. A small amount occupies the interstices of the pyrite grains.

Euhedral wedge to blade shaped crystals of arsenopyrite are characteristic. This mineral occurs as either individual crystals or as grain aggregates (Plate 15). It is sometimes intergrown with pyrite and corrodes it. The grain aggregates often contain angular inclusions of galena and sphalerite. Large wedge-shaped crystals, relatively uncommon, contain wormy masses of sphalerite and galena, and sometimes unknown mineral "A".

Pyrrhotite usually occurs as anhedral grains intergrown with pyrite, filling the interstices of the grains and corroding the mineral (Plate 16). The former embays chalcopyrite, unknown "A" and sphalerite, and contains scalloped islands of sphalerite and chalcopyrite. Lamellae and irregular masses of unknown "B" occur in many grains of pyrrhotite. Anhedral grains also occur independant of other minerals.

Much of the sphalerite is intergrown with pyrite and corrodes the latter. It contains occasional embayed inclusions of pyrrhotite, galena and minor tetrahedrite. Sphalerite corrodes unknown "A", and veins and replaces arsenopyrite.

Galena usually occurs as inclusions in other minerals. The remainder is intergrown with pyrite and sphalerite. Minor amounts of galena occurs as stringers in sphalerite and arsenopyrite, and corrodes pyrite, sphalerite and arsenopyrite.

Tetrahedrite occurs as anhedral grains in a few sections. It is intergrown with pyrite and contains angular inclusions of sphalerite and galena. Tetrahedrite embays sphalerite, chalcopyrite, pyrite and galena. The relations with pyrrhotite are unknown.

Two unidentifiable minerals are present in the massive sulphides. The first is designated unknown "A", the second unknown "B".

Unknown "A" is characterized by the following optical properties:

1. It is greyish-yellow in colour (slightly greyer than pyrite).
2. It is isotropic.
3. There are no internal reflections.

Other properties include:

1. No cleavage is visible.
2. The scratch hardness is medium (harder than sphalerite, but softer than pyrite).
3. The polish hardness is moderate (harder than sphalerite, but softer than pyrite).

The X-ray pattern from the unknown is very similar to chalcopyrite. Table 8 shows a comparison of the X-ray powder pattern of chalcopyrite and unknown "A".

Unknown "A" occurs as anhedral grains intergrown with pyrite, pyrrhotite, and sphalerite. It corrodes pyrite, and contains inclusions of the latter. This unknown is usually replaced by chalcopyrite to varying degrees. Rim replacement is most common, and sometimes almost the entire grain is replaced, leaving islands of the unknown in chalcopyrite. Anhedral grains also occur independant of other minerals.

TABLE 8

Comparison of X-ray Powder Patterns of Chalcopyrite and Unknown "A"

Chalcopyrite (A.S.T.M. 9-423)		Unknown "A" (CuKa Radiation)	
d (Å)	I/I_1	$d_{obs.}$ (Å)	$I_{obs.}$
3.03	100	3.04	100
2.63	5	2.61	10
1.865	40	1.857	80
1.854	80	1.588	50
1.591	60	1.295	10
1.573	20	1.206	20
1.518	5		
1.323	10		
1.303	5		
1.214	10		
1.205	30		
1.077	60		
1.069	30		
1.018	20		
1.014	10		
1.005	5		

Although there is a strong similarity between the X-ray powder patterns, the optical properties indicate the unknown is not chalcopyrite.

Examination of determination tables for the microscopic identification of ore minerals by Uytenbogaardt (1951) and Schouten (1962) suggests that the mineral is pentlandite on the basis of optical and physical properties. However, the X-ray powder pattern of pentlandite shows no similarity to the unknown.

Bravoite is a second possibility, but the difference in colour indicates that this is improbable. This is confirmed by the X-ray powder pattern.

Colusite, a third possibility, is suggested by the X-ray powder pattern. However, the rarity of this mineral suggests that this is highly unlikely. Observed optical and physical data indicate that the unknown is not colusite.

This unknown is intergrown with pyrite, embaying the latter slightly. It also embays pyrrhotite, sphalerite and galena, and contains inclusions of sphalerite, galena and scattered pyrite cubes. It is replaced by chalcopyrite to varying degrees (Page 60).

The second unidentifiable mineral is designated unknown "B".

It has the following optical properties:

1. The colour is pale yellow with a greyish tint.
2. It is strongly anisotropic in dark brown and medium to dark blue.
3. There are no internal reflections.

Other properties of this mineral are:

1. The scratch hardness is similar to pyrite.
2. The polish hardness is high (similar to pyrite).
3. It has a characteristic 'lacy' structure.
4. No cleavage is visible in the grains.

Examination of determination tables (referred to on Page 64) indicates that this unknown is probably marcasite. This is suggested by both the optical and physical properties. The minute size of the grains made it impossible to obtain a sample pure enough for X-ray determination.

This unknown is nearly always intergrown with pyrrhotite and sometimes pyrrhotite and pyrite. It occurs as lamallae in the pyrrhotite grains, but more often both lamallae and irregular masses are found in the same grain. Where the unknown constitutes a high percentage of the intergrowth, lamellae are usually absent (Plate 17). Unknown "B" partially rim replaces pyrrhotite in a few grains and flame-like embayment of pyrrhotite is sometimes seen. Remnant islands of pyrrhotite occur in some intergrowths.

<u>Banded Pyritic Subtype</u>:

Several types of banded pyritic mineralization are present. In all mineralized zones, the banded ores form a minor amount of the drill core examined.

The three most common types are as follows:

1. A type with bands of fine grained and very fine grained pyritic mineralization of the massive type.
2. Thick layers of massive pyritic mineralization alternating with relatively thin layers of sphaleritic mineralization (Plate 18).
3. Alternating bands of massive pyritic mineralization and much thinner layers of quartz gangue (Plate 19).

The first two types are found in all three mineralized zones. The third is restricted to zone T-2. Other minor varieties consist of bands of fine grained pyrite and pyrite-arsenopyrite, and bands of fine grained pyrite interlayered with pyrite-pyrrhotite bands. The bands range from 1 to 10 mm. thick.

The texture and mineralogy of the above-mentioned bands is similar to the massive-heavy disseminated mineralization.

Massive to Heavy Disseminated Sphaleritic Subtype:

In hand specimen this type of mineralization consists of fine to very fine grains of pyrite in a sphalerite matrix. The amount of gangue varies.

In polished section the pyrite grains occur as islands in the sphalerite, accompanied by galena (Plate 20).

The euhedral to subhedral pyrite grains occur as corroded islands in the sphalerite host. The former contains angular to rounded grains of sphalerite and galena of varying size, usually around 0.02 mm. The pyrite grains range from 0.05 to 0.2 mm. in diameter.

Anhedral grains of sphalerite form the bulk of the sulphides present, and are intergrown with pyrite. Sphalerite contains equant to elongate scalloped grains of galena, and occasional tiny droplets of chalcopyrite.

Galena fills the interstices of the pyrite grains, corroding the latter slightly.

Chalcopyrite is intergrown with pyrite. Minor corrosion of the pyrite by the former is uncommon. A few of the chalcopyrite grains have been altered to secondary chalcocite along tiny fractures.

Banded Sphaleritic Subtype:

This type constitutes a very small percentage of the mineralized zones.

In hand specimen it consists of relatively narrow bands of pyrite interlayered with sphaleritic bands.

In polished section the texture and mineralogy of both bands is similar to that of the massive to heavy disseminated sulphide mineralization.

RELATIONS BETWEEN THE ORE AND GANGUE MINERALS

The limited number of polished thin sections made does not permit an extensive description of the relations between the ore and gangue minerals. These relations will be considered under a single heading since there is much similarity among all three mineralized zones. The four mineralized horizons were not examined.

The gangue minerals are quartz, chlorite, sericite, calcite and albite.

Quartz is probably the most abundant gangue mineral and is common to all three mineralized zones. It occurs as a mosaic of interlocking grains. It is intergrown with pyrite and contains tiny grains of pyrite and sphalerite. The quartz embays pyrite, pyrrhotite and chalcopyrite. Tiny rounded quartz inclusions are found in the pyrite and pyrrhotite.

Chlorite is common to all three zones. It occurs as aggregates of platy grains, laths or slender needles. This mineral is intergrown with pyrite and embays the latter. Chlorite also embays chalcopyrite and sphalerite. Long slender chlorite needles crosscut pyrite, chalcopyrite and sphalerite grains, often across grain boundaries. Laths of the former occur as inclusions in the foregoing sulphides. Tiny pyrite grains often occur as islands in the chlorite masses.

Sericite is common to all three zones. This mineral occurs as laths forming bands and irregular masses. It corrodes pyrite, sphalerite and chalcopyrite. Long narrow grains of sericite extend across grains of sphalerite and chalcopyrite. Tiny crystals of pyrite and sphalerite are found in aggregates of sericite.

Calcite was observed in zone T-2 and T-3. It occurs as subhedral to anhedral grains 0.5 to 1 mm. in size. It is intergrown with pyrite and embays both pyrite and sphalerite. Inclusions of pyrite and sphalerite occur in the calcite. Minor amounts of the latter are found in chalcopyrite.

Albite grains are restricted to zones T-2 and T-3. This mineral is lath to wedge-shaped and often untwinned. It is intergrown with pyrite and sphalerite, and embays pyrite, sphalerite and chalcopyrite. The plagioclase is often studded with tiny pyrite cubes and anhedral sphalerite grains.

THE MINERALIZED HORIZONS

General Statement:

The four mineralized horizons, consisting of both disseminated and massive sulphide mineralization found in the same vicinity as the mineralized zones, have been designated Numbers 1, 2, 3 and 4.

Horizons numbers 1, 2 and 3 contain mineralized zones numbers 1, 2 and 3 respectively. No major massive sulphide zone of economic interest is associated with horizon number 4. For purposes of this thesis, as outlined on page 54, subsequent descriptions of the mineralized horizons do not include descriptions of the associated mineralized zones.

The mineralization consists mainly of banded disseminated sulphides with minor amounts of massive sulphides similar to that of the mineralized zones previously described.

Number 4 Mineralized Horizon:

The most extensive of the horizons is number 4. It lies some 200 feet north east of horizon 3 and is about 2,400 feet long. This horizon contains two zones of massive and disseminated sulphides 1,300 feet apart, with lengths of approximately 100 feet and thicknesses up to 11 feet. These zones are not of economic interest. The horizon pinches out at either end, but is open at depth. Its maximum thickness is 45 feet.

The average strike of this horizon is about 50° true. The average dip is about 70° northwest.

Both the hanging wall and footwall are sericitic acid volcanics. The banded disseminated sulphides grade out into the wallrocks.

The massive sulphides observed in diamond drill core are similar texturally and mineralogically to the massive pyritic and sphaleritic types of sulphide mineralization of the mineralized zones.

The banded disseminated type of mineralization consists of bands of very fine grained pyrite, bands of chalcopyrite and bands of pyrite and sphalerite in varying numbers ranging from 1 to 3 mm. wide. The sulphides between the individual bands is usually pyrite. The massive sulphide layers are bounded by banded disseminated mineralization.

The gangue minerals appear to be similar to those found in the mineralized zones.

Number 3 Mineralized Horizon:

Number 3 mineralized horizon extends eastward from T-3 mineralized zones for a distance of 900 feet paralleling horizon number 4. In addition to the T-3 zone, it contains a second zone of massive and disseminated sulphides at depth to the east of T-3. The maximum thickness of this zone is 50 feet, while the massive sulphide portion reaches a maximum true width of 8 feet.

The strike of the long axis of the horizon is about 50° true, while the overall dip is 70° to the northwest.

Both the hanging wall and footwall are sericitic acid volcanics with lesser amounts of pyritic and chloritic acid volcanics.

The massive sphaleritic mineralization and the banded disseminated sulphides are similar in all respects to horizon number 4. The gangue minerals are also similar.

<u>Number 2 Mineralized Horizon</u>:

Horizon number 2 is the smallest and has been little explored beyond the limits of the T-2 mineralized zone. The known extent is 200 feet east from T-2. It is poorly defined and consists of banded disseminated sulphides only. Its maximum thickness beyond zone T-2 is 2 feet.

The strike is about 50° true and the dip appears to be 70° northwest.

Both the hanging wall and footwall are sericitic acid volcanics. The mineralized horizon grades out into these wallrocks.

The banded disseminated sulphides are similar to the other horizons.

<u>Number 1 Mineralized Horizon</u>:

Number 1 mineralized horizon, the most easterly of the four, lies on strike with T-1, but is separated from it by an interval of 200 feet of barren acid volcanics. It is about 1,600 feet long. Massive sulphides, 4 inches in thickness, were intersected in one drill hole. The remainder consists of banded disseminated sulphides. The maximum thickness of this zone is 25 feet.

This horizon strikes about 60° true and is inclined at an angle of 80° northwest.

Both the hanging wall and footwall are sericitic acid volcanics. The banded disseminated sulphides grade out into the wallrocks.

The banded disseminated type of sulphides are similar to the other horizons. The massive sulphides are the pyritic type.

PARAGENESIS OF THE MINERALIZATION OF THE AREA

The paragenesis of the sulphides will be considered under a single heading because of the textural and mineralogical similarity among the sulphides in all zones and horizons.

The sulphides observed in the area are: pyrite, chalcopyrite, sphalerite, galena, tetrahedrite, arsenopyrite, two unknown minerals, pyrrhotite, chalcocite, covellite and digenite.

The common cubic form of pyrite appears to have been the first to crystallize. This is suggested by the generally euhedral outline and the observation that the other sulphides fill the interstices of, and embay the pyrite grains.

The second mineral to form in the paragenetic sequence appears to have been unknown "A". This mineral embays pyrite, fills the interstices of the grains of the latter and is extensively replaced by chalcopyrite to varying degrees.

The relations between arsenopyrite and unknown mineral "A" are not known. Both appear to be second minerals to form in the paragenetic sequence. Unknown "A" is younger than pyrite, but older than chalcopyrite. Arsenopyrite corrodes pyrite and is veined by sphalerite. The former is corroded by sphalerite, galena and chalcopyrite, which also fill spaces between the small grains.

The relations among sphalerite, galena, tetrahedrite and pyrrhotite are not clear cut.

In some instances, chalcopyrite seems to form replacement rims around pyrrhotite grains, partly replacing it. However, in sections where there was extensive replacement of unknown mineral "A" by chalcopyrite, little of the pyrrhotite was affected. Pyrrhotite also contains scalloped grains of sphalerite and chalcopyrite and embays both sphalerite and chalcopyrite. The relations among pyrrhotite, tetrahedrite and galena were not observed.

This suggests that the pyrrhotite may have, in part, formed before the chalcopyrite and sphalerite.

Sphalerite contains islands of the galena, tetrahedrite, and chalcopyrite, and embays chalcopyrite and tetrahedrite grains.

Chalcopyrite is host for scalloped grains of galena, sphalerite and pyrrhotite, and in a few sections corrodes sphalerite and tetrahedrite.

Tetrahedrite is uncommon. Where found, it contains angular inclusions of sphalerite, galena and chalcopyrite. It embays galena, chalcopyrite and sphalerite.

The above observations indicate that the foregoing minerals were probably formed about the same time in the paragenetic sequence. Some pyrrhotite probably formed before the others.

Unknown mineral "B" was observed in the first two mineralized zones. It is either intergrown with pyrrhotite and sometimes pyrite, or occurs as independent grains in the gangue. Observations in polished section reveal that, although lamellae of this mineral are found in the pyrrhotite, the relative amount of pyrrhotite and unknown "B" varies widely from grain to grain. This indicates that the unknown "B" is not exsolved from the pyrrhotite.

Observations in thin section show that this unknown partially rim replaces pyrrhotite. In addition, the unknown was observed forming narrow walls along fractures in the latter.

The above evidence suggests that the unknown "A" may have developed from the pyrrhotite at some stage in the formation of the mineralized zones. It is, therefore, probably later than pyrrhotite, but the paragenetic relations with the other minerals are unknown.

Chalcocite, covellite and digenite fill fractures in sphalerite and chalcopyrite. The relations with unknown "B" are not known, but the location of these minerals in the upper part of T-2 and T-3 mineralized zones indicates that they are products of oxidation and would, therefore, probably postdate unknown "B" which appears to be primary. They are, therefore, the last minerals to form in the paragenetic sequence.

TABLE 9

Paragenetic Sequence of the Tulk's Hill Mineralization

Py.	Asp.	Unknown "B" (?) ---	Unknown "B"	Cc.
	Po. ---------	Po.		Cov.
	Unknown "A"	Gn.		Dig.
		Tet.		
		Cp.		
		Sp.		

Time ⟶

ORIGIN OF THE TULK'S HILL MINERALIZATION

The lack of geochemical data and the probability of metasomatism affecting the mineralization precludes a positive statement on the origin of the mineralization.

There are four possible origins for the sulphides in both the mineralized zones and mineralized horizons:

1. Exogenetic - syngenetic,
2. Exogenetic - epigenetic,
3. Endogenetic - syngenetic,
4. Endogenetic - epigenetic.

A number of features of the mineralized zones and horizons indicate that the sulphides were deposited by hydrothermal fluids. The definition of hydrothermal fluids adopted in this dissertation is any hot watery fluid with no genetic implications (after Park and MacDiarmid, 1962).

The evidence for replacement by hydrothermal fluids has been listed by Park and MacDiarmid (1962). Three of the items listed have been observed in polished sections of the sulphides from this area. They are:

1. Islands of unreplaced host minerals in the replacing minerals,
2. Unmatching walls of a fracture,
3. Surfaces of the replacing mineral concave into the host.

Islands of unreplaced host minerals in the replacing mineral is best illustrated by the replacement of unknown "A" by chalcopyrite. Other instances of this structure include the islands of pyrite in sphalerite, tetrahedrite, chalcopyrite, and islands of pyrrhotite in unknown "B".

The second feature was observed in only a few cases since veining of one mineral by another is limited. The best example is the veining of pyrite by chalcopyrite, and other examples are shown by the veining of arsenopyrite by chalcopyrite and galena.

Surfaces of replacing minerals concave into the host are well shown by the replacement of pyrite by sphalerite, chalcopyrite and pyrrhotite.

The banded sulphides of the type with alternating pyritic and sphaleritic bands is also strongly suggestive of replacement by hydrothermal fluids since the sphalerite is clearly later than the pyrite.

The source of these fluids in not known with certainty. Metasomatism has probably obliterated or obscured much of the evidence. The observation that the volume of material replaced appears to have been larger than the space available from initial porosity suggests that the hydrothermal fluids may have been exogeneous.

Two possible exogeneous sources of these mineralizing fluids are the Tulk's Pond Granite Stock about 7,000 feet south of the mineralized area, and metamorphism during which hydrothermal fluids may have been produced. There is no evidence to indicate which of the two is more probable.

The nature of the locus of deposition is not apparent. The tabular shape of T-2 and T-3 and the mineralized horizons do not indicate deposition in the crests, troughs or noses of folds. The drag fold-like shape of the western half of T-1 seems to indicate structural control by folding. However, this structure is located on the flank of an anticline and is not the true shape of a drag fold.

The overall tabular shape and the lack of structural control by folding suggests that the control may have been present in the original rocks. The above evidence combined with the observation that the mineralized zones and horizons are localized within the acid volcanic flows suggests that some feature of the flows may have provided the structural control.

The writer submits that the porous tops of the acid volcanic flows could have provided structural controls that localized deposition from the sulphide bearing liquids. The initial permeability may have been increased by folding. The massive portions of the flows probably remained impermeable.

This would explain the variation in shape of T-1 mineralized zone. The lenticular part probably represents a particularly thick part in the flow top, while that portion with the shape similar to a drag fold may be the result of a variation in shape of the flow top.

The absence of crushing of the sulphides in the mineralized area, especially the brittle pyrite, suggests that the mineralization is post-folding in age.

The time of deposition in relation to metamorphism and metasomatism is not clear. The gangue minerals observed in polished thin section are definitely later than the sulphides since they crosscut and embay the latter. The composition of albite, similar to that associated with the quartz veins, supports this contention. This indicates that metasomatism probably took place after deposition of the sulphides.

Lack of exsolution textures in the sulphides, especially sphalerite and chalcopyrite, indicates that the temperature of deposition may have been low. Edwards (1952) states that a solid solution of sphalerite and chalcopyrite will form experimentally at a range from 350° to 400° centigrade. Other minerals found in this deposit form solid solutions at higher temperatures.

Metasomatism may have, however, destroyed these textures by causing the component minerals to segregate completely during metamorphism and metasomatism. Fyfe, Turner and Verhoogen (1955) state that the minerals of the greenschist facies form below 300° centigrade. The lower limit is not stated. Edwards (1954) makes the following statement on experiments carried out on exsolution textures in sulphides:

> "Another feature of unmixing, revealed by experimental studies, is the rapidity at which exsolution bodies will segregate to the grain boundaries if the specimens are annealed or cooled slowly."

It is, therefore, possible that the exsolution textures in the sulphides, if any were present, were destroyed during the period of metasomatism. Thus the temperature of deposition may have been higher than present evidence indicates.

It is tentatively concluded that the mineralized zones and horizons are of the exogenetic epigenetic type.

CONCLUSIONS

It is concluded that the rocks of the area are a series of acid volcanic flows and pyroclastic breccias with minor intermediate lavas. Black shales and associated rocks were deposited in restricted basins. The source of the conglomerate was the acidic flows.

The entire sequence has been metamorphosed to the greenschist facies. Metasomatism resulted in the formation of quartz veins, carbonates and hydrous metamorphic minerals.

The major folds are the central anticline and the northern syncline, which plunges southwest. Two types of drag folds are present. The Tulk's River Fault parallels the regional schistosity.

The tabular steeply dipping mineralized zones and horizons, post folding in age, were deposited in the porous tops of the acid volcanic flows on the northwest limb of the central anticline.

The paragenesis is as follows:

1. Pyrite,
2. Arsenopyrite, unknown "A" and some pyrrhotite,
3. Chalcopyrite, sphalerite, tetrahedrite and some pyrrhotite,

4. Unknown "B",

5. Chalcocite, covellite and digenite.

The gangue minerals are quartz, carbonate, albite, chlorite and sericite. They postdate the sulphides.

The mineralization is of the exogenetic-epigenetic type.

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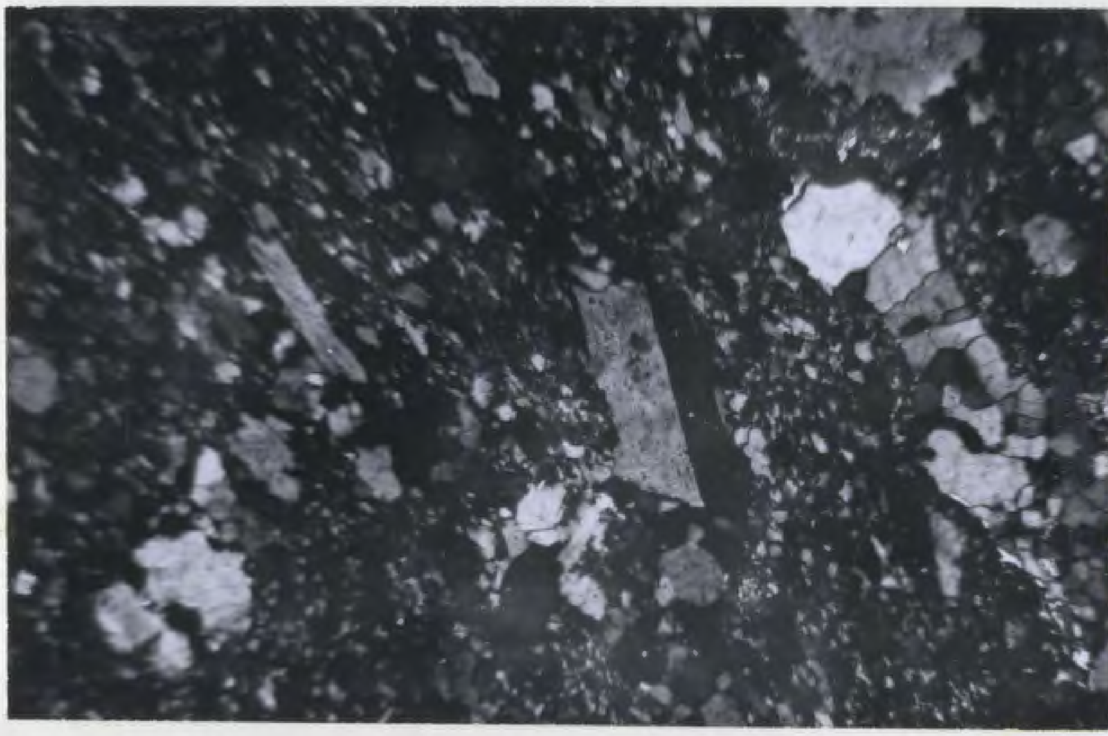
PLATE 1

Sericitic acid volcanics: Corroded quartz phenocryst showing bipyramidal faces. Note inclusion of matrix and matrix-filled fracture. Crossed nicols, X 20. Thin section T-41, 470 feet.

PLATE 2

Sericitic acid volcanics: Aggregate of albite phenocrysts. Note terminal faces on long bent grains. Crossed nicols, X 20. Thin section T-119, 478 feet.

PLATE 3



Sericitic acid volcanics: Corroded plagioclase laths in the matrix. Note parallelism of the long axes of the larger grains. Crossed nicols, X 20. Thin section T-41, 470 feet.

PLATE 4

Sericitic acid volcanics: Bands of sericite (S) and quartz (Q). Note crinkling of the broad sericite band. The bands bend around the plagioclase phenocryst. Crossed nicols, X 20. Thin section T-36, 60 feet.

PLATE 5

Porphyritic chloritic acid volcanics: Plagioclase (albite) phenocrysts in chlorite-quartz matrix. Note terminal faces on central phenocryst. Crossed nicols, X 80. Thin section C-21A.

PLATE 6

Nonporphyritic chloritic acid volcanics: Bands of quartz (Q) and chlorite-sericite (CS). Note elongate strained quartz grain. Crossed nicols, X 20. Thin section T-93, 113 feet.

PLATE 7

Nonporphyritic chloritic acid volcanics: Euhedral carbonate rhombs in a matrix of chlorite and quartz. Crossed nicols, X 20. Thin section C-31A.

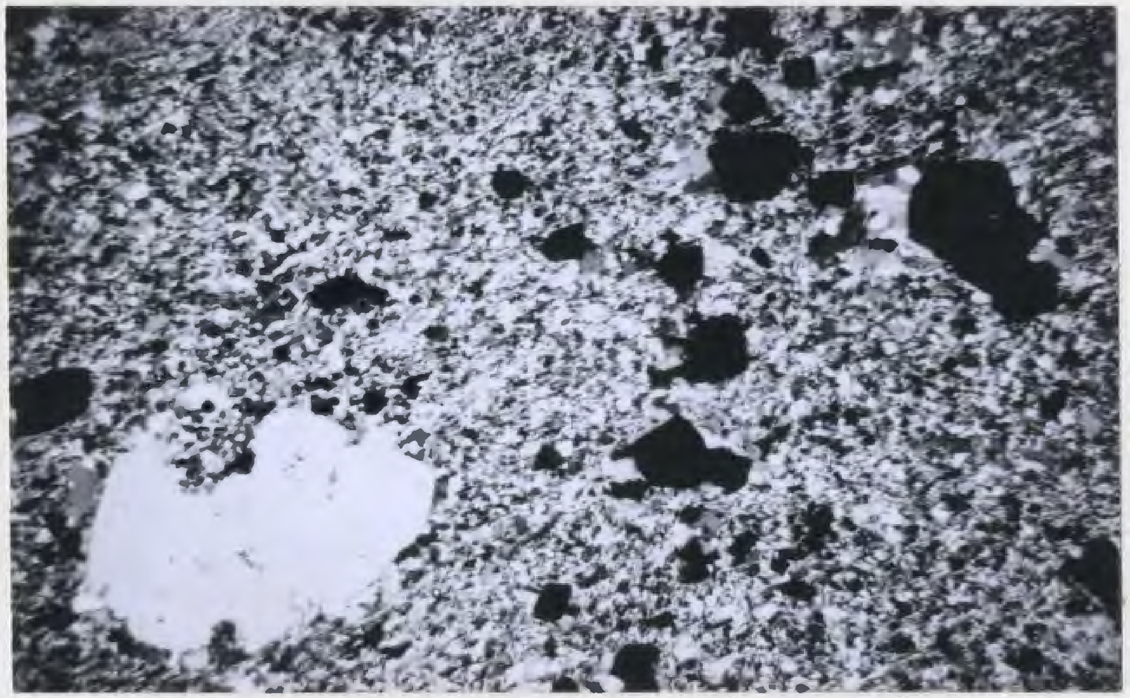
PLATE 8

Fragmental acid volcanics: Fragment showing twinned plagioclase phenocryst in a quartz matrix. Note banding. Crossed nicols, X 20. Thin section C-175.

PLATE 9

Fragmental acid volcanics: Matrix of fragments showing broken plagioclase phenocryst in a quartz-chlorite groundmass. Crossed nicols, X 20. Thin section C-177.

PLATE 10



Pyritic acid volcanics: Corroded quartz phenocryst in a quartz-sericite groundmass. Note black grains of pyrite. Crossed nicols, X 20. Thin section T-134, 206 feet.

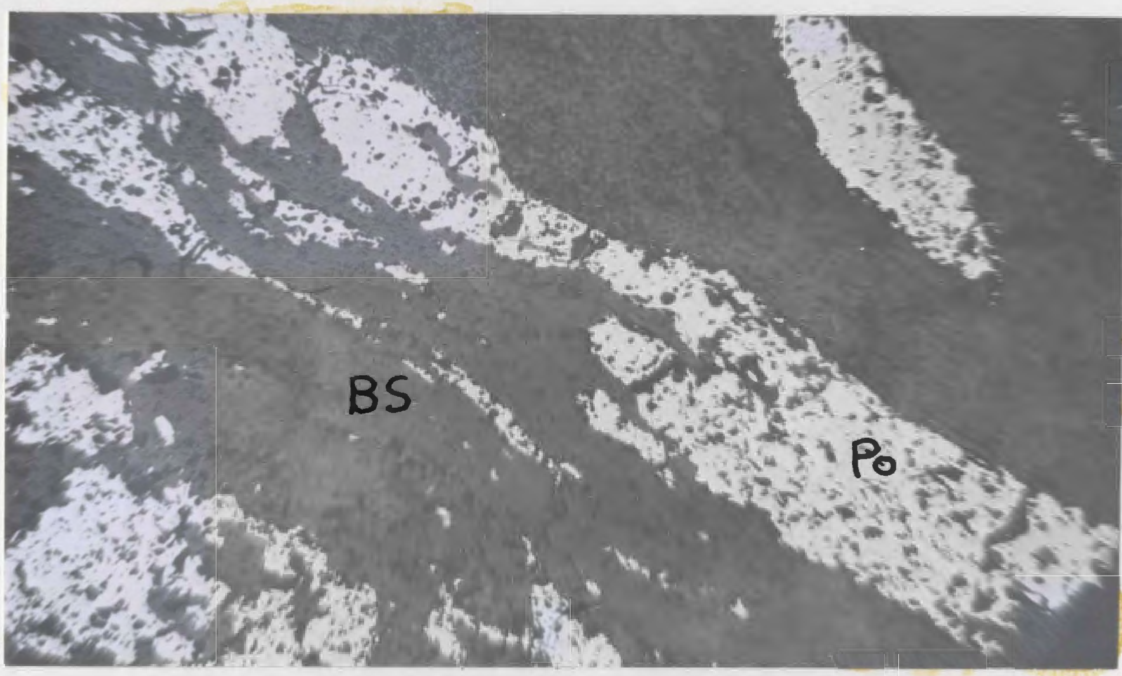
PLATE 11

Pyritic acid volcanics: Bands of sericite (S) and quartz (Q). Note aggregate of quartz grains. Crossed nicols, X 20. Thin section T-96, 151 feet.

PLATE 12

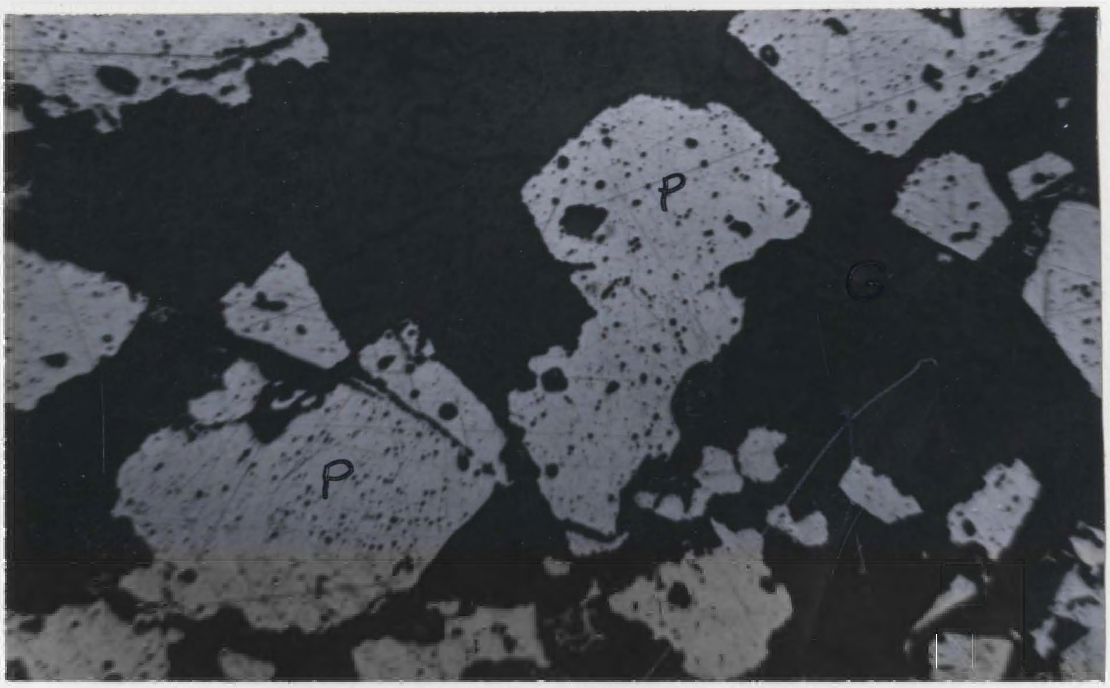
Intermediate Volcanics: Trachitic texture. Crossed nicols, X 20. Thin section C-161.

PLATE 13



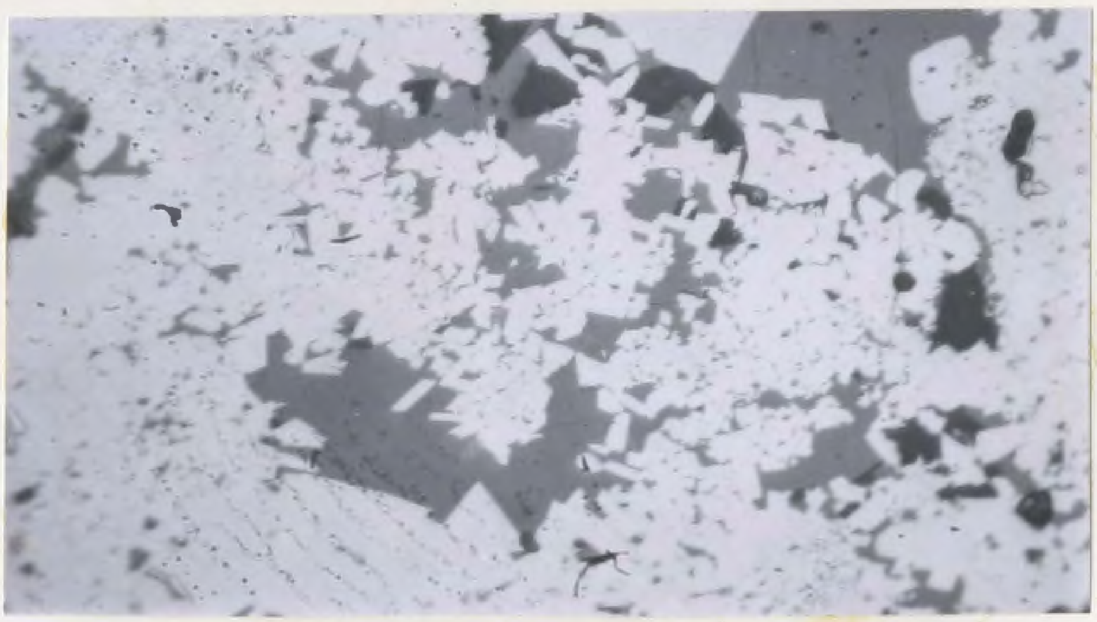
Black slate: Pyrrhotite (Po) bands in a black slate (BS) matrix. Ordinary light, X 20. Polished section T-142, 320 feet.

PLATE 14



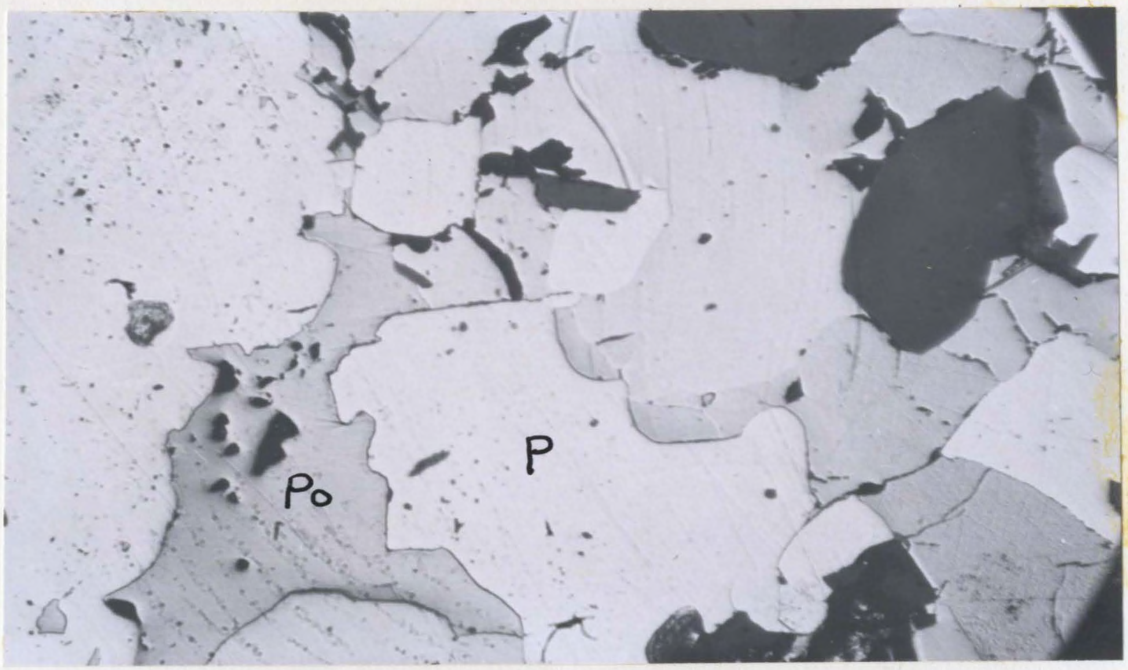
Massive to heavy disseminated pyritic subtype: Pyrite grains (P) corroded by gangue (G). Ordinary light, X20. Polished section T-90, 69 feet.

PLATE 15



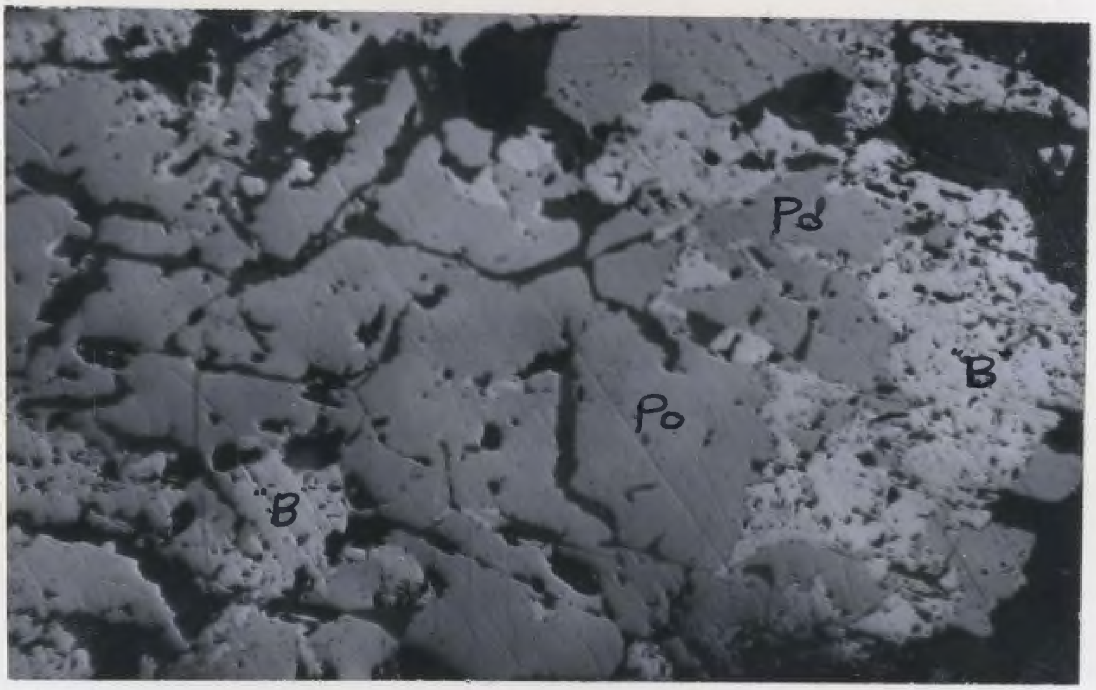
Massive to heavy disseminated pyritic subtype: Aggregate of arsenopyrite grains. Note bladed shape of many single crystals. Ordinary light, X 160. Polished section T-4, 57.5 feet.

PLATE 16



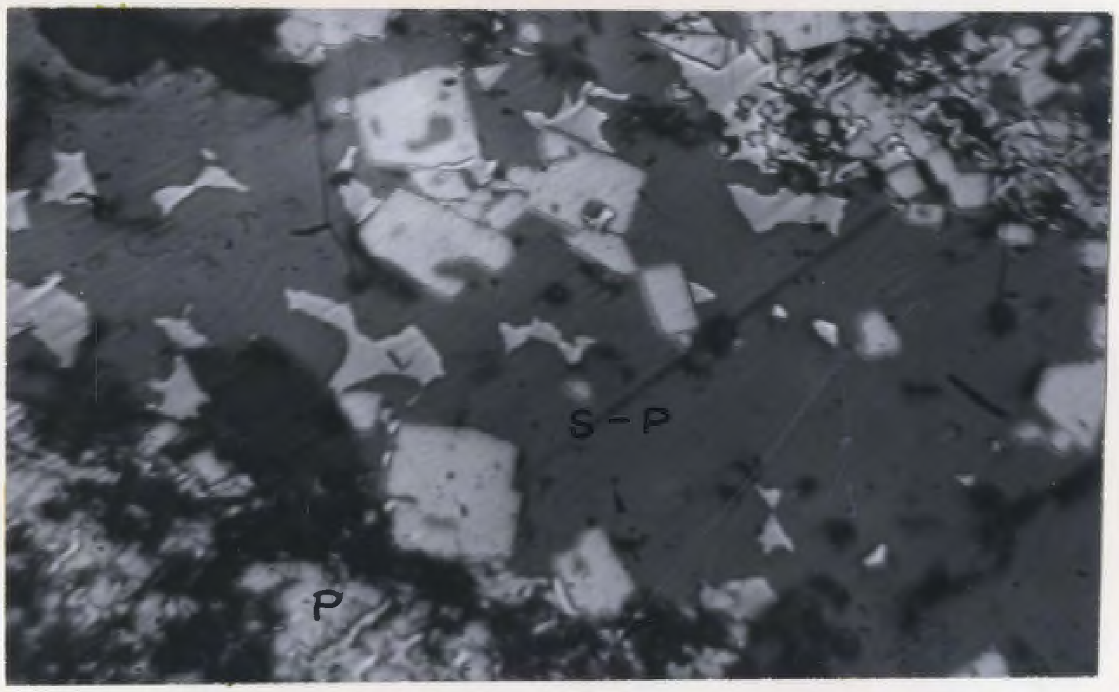
Massive to heavy disseminated pyritic subtype: Intergrowth of pyrite (P) and pyrrhotite (Po). Note embayment of pyrite. Ordinary light, X 80. Polished section T-4, 74 feet.

PLATE 17



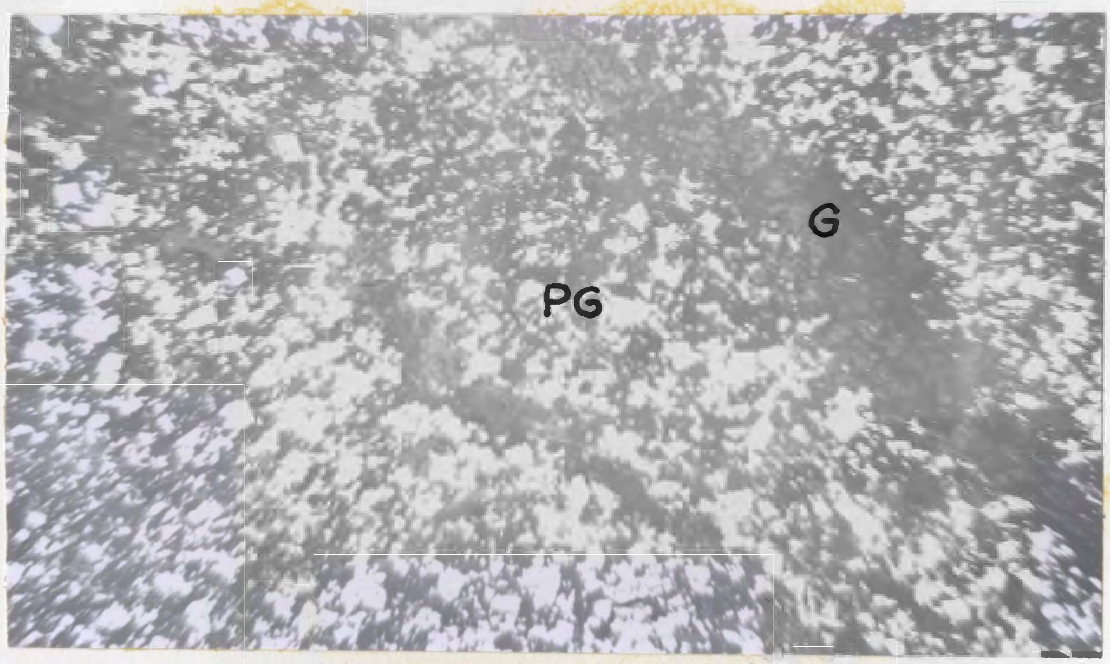
Massive to heavy disseminated pyritic subtype: Unknown mineral "B" (B) intergrown with pyrrhotite (Po). Ordinary light, X 80. Polished section T-4, 74 feet.

PLATE 18



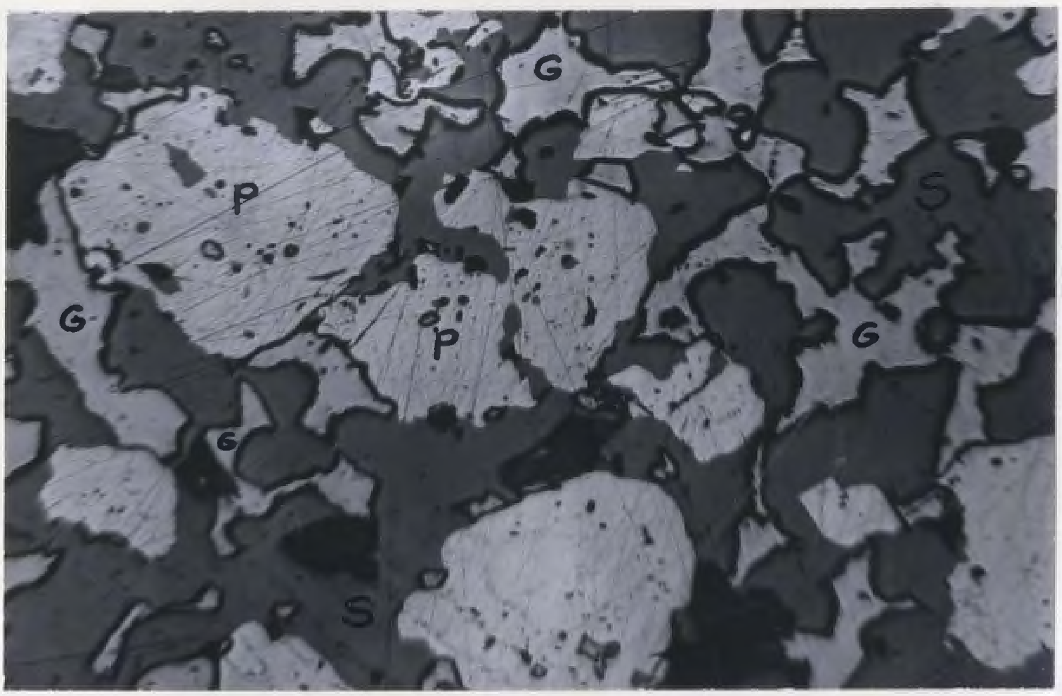
Banded pyritic subtype: Band of sphalerite (S) -pyrite (P) 'ore' enclosed by pyritic bands (P). Ordinary light, X 20. Polished section T-4, 86 feet.

PLATE 19



Banded pyritic subtype: Bands of pyrite-gangue (PG) alternating with bands of gangue (G). Ordinary light, X 20. Polished section T-69, 137 feet.

PLATE 20



Massive to heavy disseminated sphaleritic subtype: Embayed pyrite (P) and galena (G) grains in a sphalerite (S) host. Ordinary light, X 20. Polished section T-111, 213 feet.

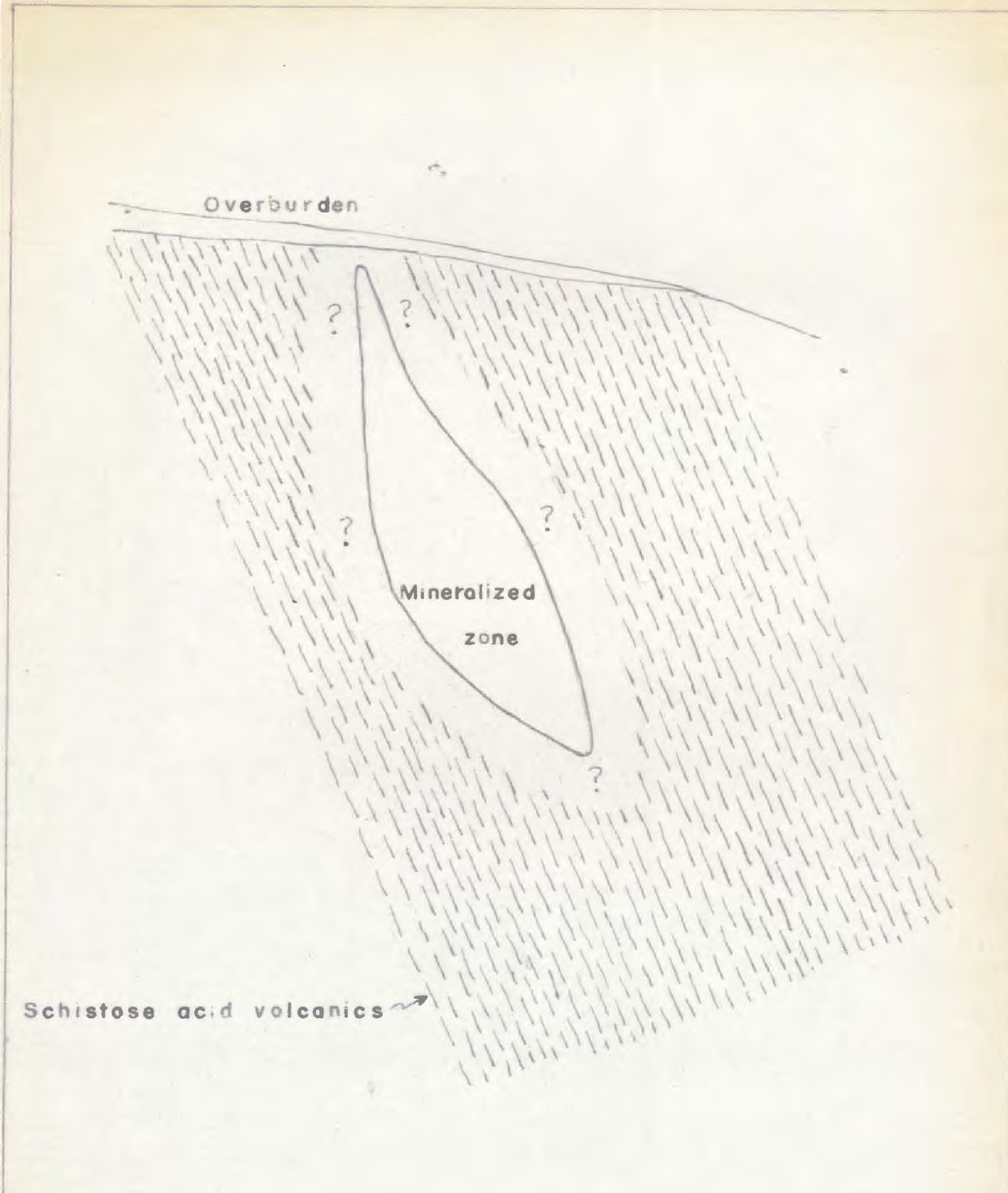


Fig. 1. Generalized cross section of the eastern half of T-1 mineralized zone.

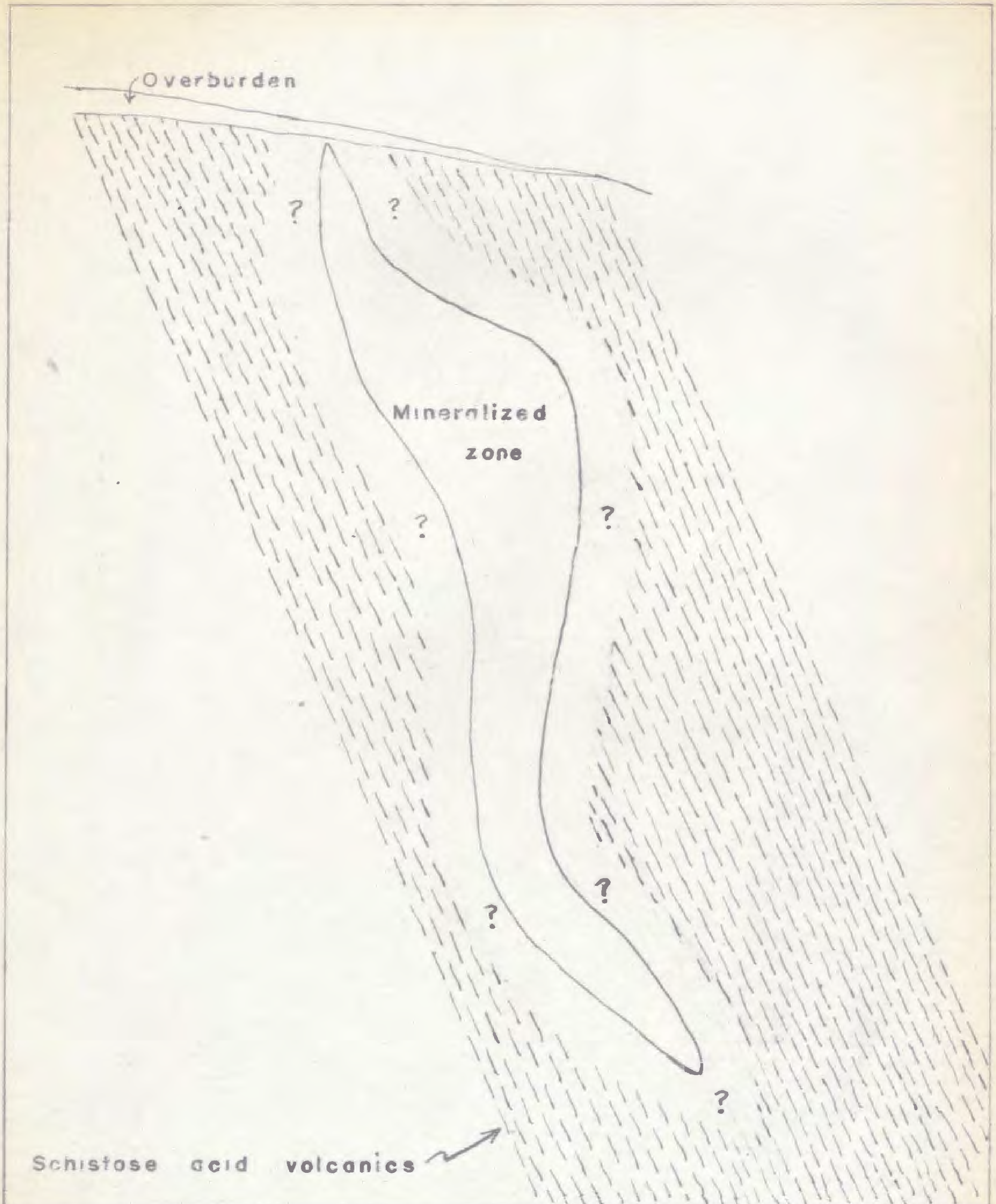


Fig. 2. Generalized cross section of the western half of T-1 mineralized zone.

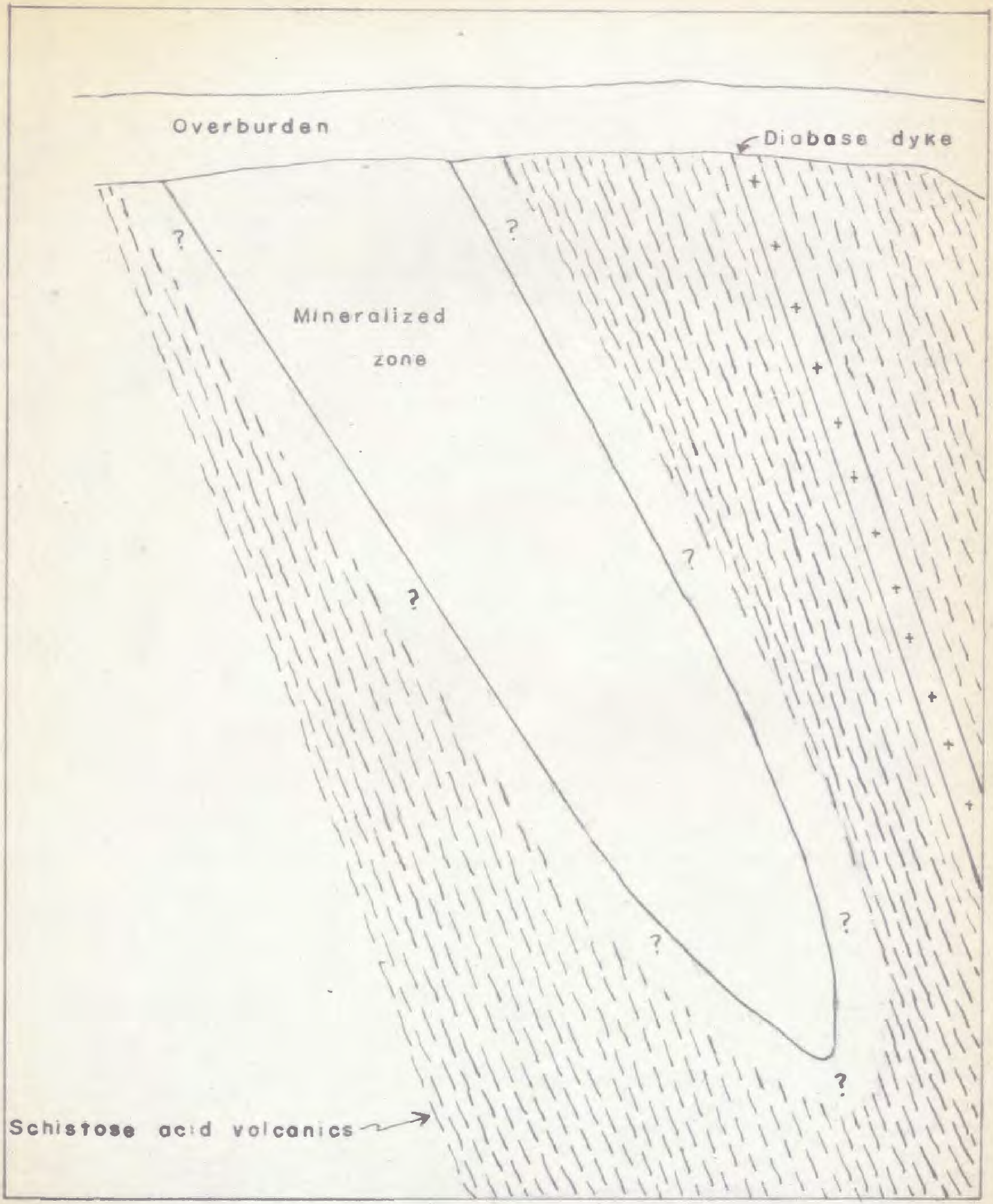


Fig. 3. Generalized cross section of T-2 mineralized zone.

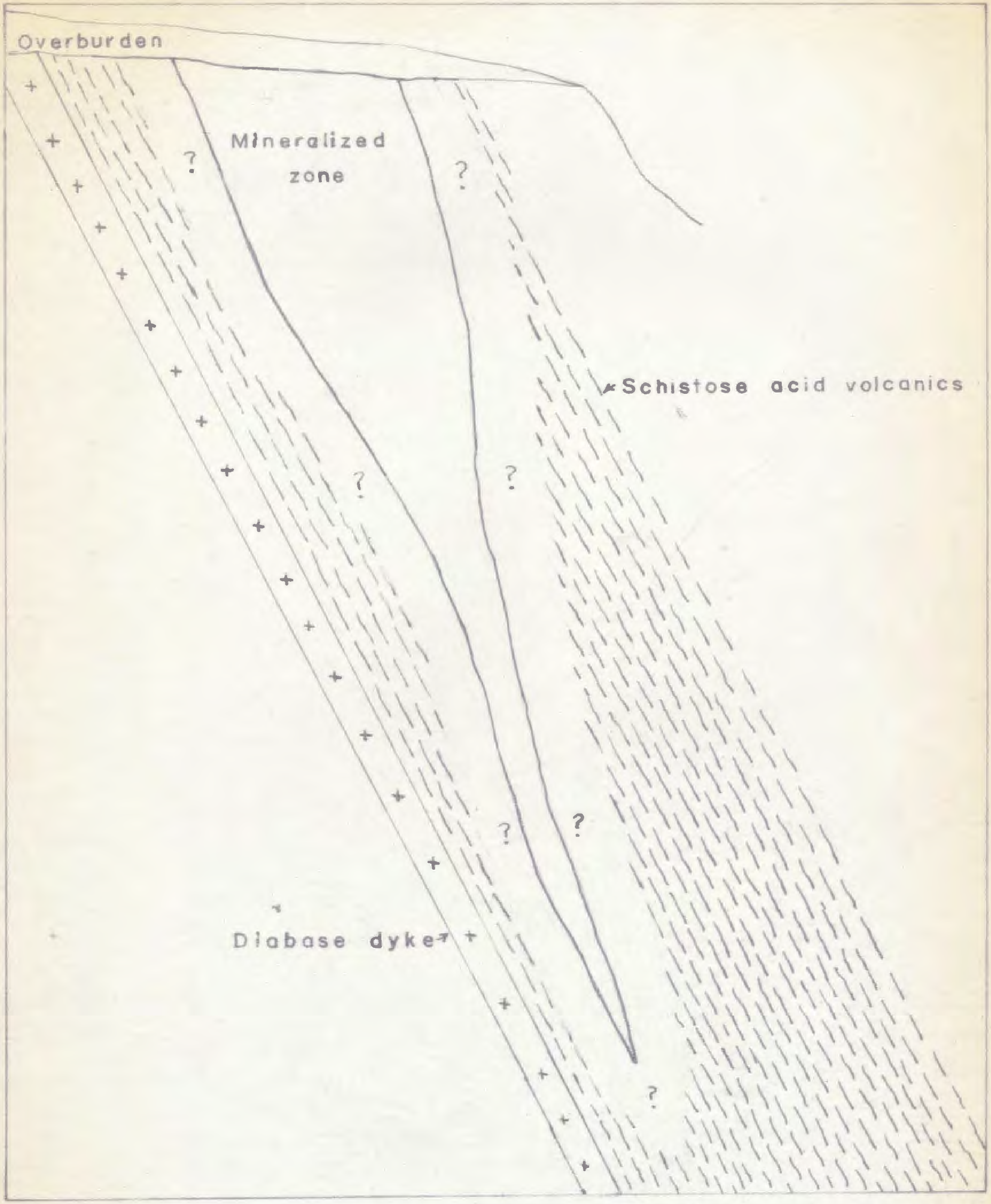


Fig. 4. Generalized cross section of T – 3 mineralized zone.

Map 1. Geology of the Tulks Hill Area.

Map 2. Regional Geology