THE GEOLOGY OF A MINERAL DEPOSIT IN THE SKEENA MINING DISTRICT OF NORTHWESTERN BRITISH COLUMBIA

by

STANLEY GIFFORD TURNER

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INTRODUCTION

The information contained in this thesis was obtained during exploration on four claims in which the ore deposit is located. The exploration work consisted of surveying a topographic map on a scale of 40' = 1" with 50 foot contour intervals; preparing a geological surface map of the ore outcrop area; and of 1866.5 feet of diamond drilling.

The area studied is located near the western contact of the Coast Range Complex and the Ecstall Septum.[1] The Ecstall Septum constitutes a series of well foliated and layered gneisses and minor schists, most of which have been derived from greywackes and some from pelitic sediments.[2] This belt of metasediments lies within the northwestern zone of the Coast Range Complex and has been mapped by others from the Skeena River, south to Hawkesbury Island in the Douglas Channel.

The four claims are situated in an isolated segment of metamorphic rocks and migmatites which are a part of the Ecstall Septum, which is surrounded by intrusive rocks of the Coast Range Complex.

The mineral deposit (See Plate A) occurs in the western limb of a southern plunging anticline which is traversed by a series of simple pegmatitic dykes and sheet-like masses.

1. Padgham, W.A., The Geology of the Ecstall-Quaal Rivers Area, North Western, B.C., Thesis 1958.
2. Read, P.B., Summer Report, 1958.

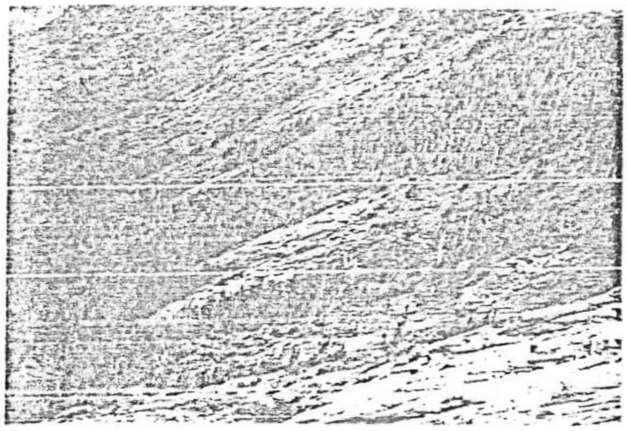


Plate A. The mineral deposit is visible as the orange colored outcrop area in center of photograph. (Looking West).

I PHYSICAL FEATURES

LOCATION AND ACCESS

The thesis area is located in the Skeena Mining District of British Columbia and lies between 54° N and 55°N longitude and 129° W and 130° W latitude. It is situated 30 miles southeast of Prince Rupert and 70 miles northwest of Kitimat. The elevation of the ore deposit is approximately 2800 feet and is about 1 mile northeast of Little Scotia Lake and about 1.5 miles southwest of the junction of the west and main forks of Scotia Creek.

Access to this area is relatively limited as there are no roads or navigable rivers in the area. However, an old trapper's trail follows Scotia Creek to within a few miles of the claim area. Direct access to the ore deposit is possible only by helicopter. A heliport has been constructed within 100 yards of the deposit to accomodate helicopters of the Bell G-2 variety (See Figure 1). The Ecstall River is navigable by fishing boats and scows to within 10 miles southwest of the map area at a location called Big Falls. The Skeena River is navigable to larger sized fishing boats and scows to within 10 miles northeast of the map area at the mouth of Scotia Creek. Small float-equipped aircraft have previously made use of the larger lakes in the region further to the south and have landed on the Ecstall River in the vicinity of Big Falls. The Skeena River would also be suitable for the landing of such aircraft. The nearest suitable lake to the ore deposit is Khtada Lake situated 10 miles to the east. However, an overland route from there to the claim area would prove highly impracticable as three high valleys of 5000 feet relief would have to be traversed.

If direct access to the property should be required in the future for the transport of ore or concentrate the most practical route would be from the Skeena River at the mouth of Scotia Creek, up Scotia Creek to the west fork, then up the west fork to an elevation of 2500 feet, which would be directly south and below the ore deposit.

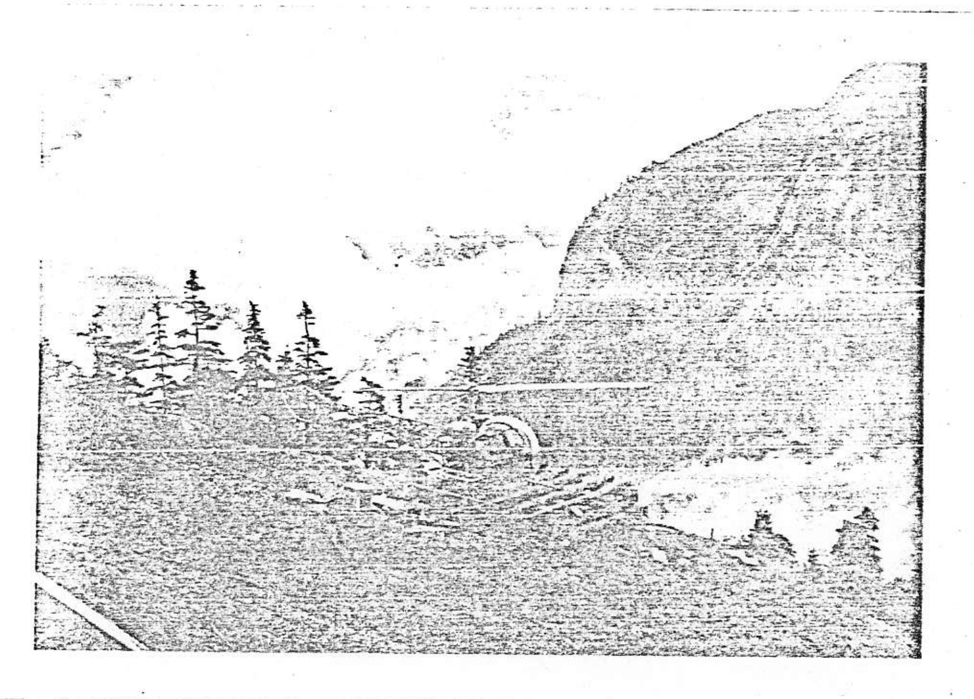


Figure 1. Shows foggy weather often encountered during the summer months. Note heliport with helicopter (Bell G-2) in central foreground.

This would involve an overland distance of 15 miles. The route would be difficult to construct in the lower valley regions of Scotia Creeks as the valley floor is extremely swampy. However, this route would be more feasible than an overland route from Big Falls as precipitous slopes would have to be crossed here. Once the ore or concentrate had reached the Skeena River, it could then be shipped by barge or scow down the Skeena River or it could be shipped across the Skeena River and loaded on the Canadian National Railway. Movement of ore or concentrate might also be accomplished by helicopter transport. However, this procedure would undoubtedly be costly and would depend upon the future development of helicopter transport.

Logging is carried on along both the Ecstall and Skeena Rivers and if further expansion of the logging industry in this area results, roads may be built to within a reasonable distance of the deposit. Perhaps a method of sharing the cost of road construction could be made between the logging and mining companies concerned.

PREVIOUS WORK

Previous work on the ore deposit was done during the summer of 1958. Shortly after its discovery, the showing was mapped on a scale of 1" = 40'. The map was made by traversing the area in six places at intervals of about 120 feet from the top of the outcrop to the bottom, a vertical distance of 300 feet. The map was not contoured as it was made on a rudimentary exploration basis only.

In 1951 extensive development work was done at the Ecstall Mine situated 20 miles further to the south in the Ecstall Septum. At that time geological mapping was done in an area 30 square miles adjoining the mine. Preliminary mapping of the Ecstall Septum was done in the summer of 1957 from the Ecstall Mine south ot the Quaal River. In the summer of 1958 further mapping was done south of the Ecstall Septum and on Hawkesbury Island in the Douglas Channel, and north of the Ecstall River to within a few miles of the Skeena River. All the mapping was done on a scale of 1" = ½ mile. In addition to the giological mapping, a giophysical survey was conducted in several promising areas during the summers of 1957 and 1958.

Work done on the thesis area during the summer of 1960 consisted of detailed geological mapping of a part of the ore outcrop area on a scale of 1" = 10'; (Figure 58) surveying of the area producing a 50 foot contour interval map on the scale of 1" = 40', (Figure 59) and 1866.5 feet of diamond drilling.

The detailed geological map was made with a Brunton compass and a chain and involved 122 strike and dip readings of the rock attitudes whereas the surveyed contour map, which was made with transit and chain, involved 24 strike and dip readings which were the result of averaging some 75 attitudes.

The diamond drilling consisted of a total of 1866.5 feet with 1678.5 feet of AX core and 188 feet of EX core. Eight holes were drilled approximately normal to the strike of the rocks and at angles ranging from -45° to -85°. The longest hole drilled was 273' while the shortest hole drilled was only 30'. Figure 2 shows one man operated packsack drill setup in the thesis area, while in Figure 3 can be seen the larger drill, used most often during the diamond drilling.

Figure 2. Pack-sack drill which was used in primary exploration drilling of the mineral deposit. Site is on upper edge of the outcrop.

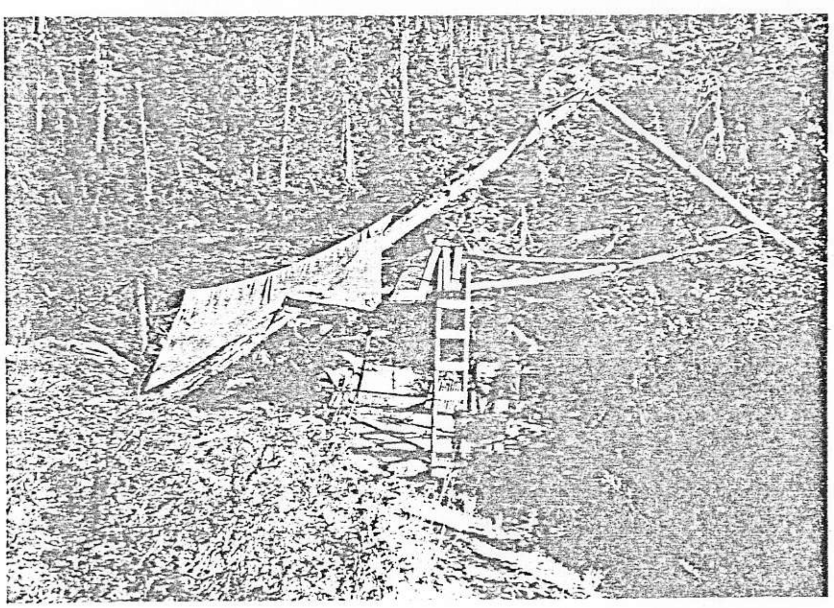


Figure 3. Large AX drill used for major part of drilling. Site is not in thesis area but further south.

CLIMATE, FLORA, AND FAUNA

The Ecstall to Skeena River area, in which the deposit occurs, is characterized by extremely heavy precipitation of the West Coast Marine type of climate. On an average, rain falls one day in three during the summer months and as a result the thick underbrush is almost constantly wet. Fog, accompanying the rain, often covers this mountainous region making flying impossible (See Figure 1). The winters in this area are relatively mild and precipitation, although less than in the summer months, is still moderately high. The mild winters along with the heavy summer rainfall results in a luxuriant plant growth which approaches the thickness and impassability of a jungle in the valley bottoms. Conifers are the most abundant of trees; hemlock, yellow cedar, and balsam fir grow abundantly at lower elevations, while near the ridge tops Engleman spruce, juniper, and heather dominate. (See Figure 4). In places, Sitka spruce grows in large stands with trees over 100 feet in height. In general, the terrain overlying the metamorphic rocks is much more heavily timbered than the terrain which overlies the granitic rocks. This can be seen in Figures 5 and 6 respectively.

In addition to numerous species of birds, bears and mountain goats are frequently seen. (See Figure 7). Smaller animals such as mink, beaver, marmots and squirrels are occassionally seen.

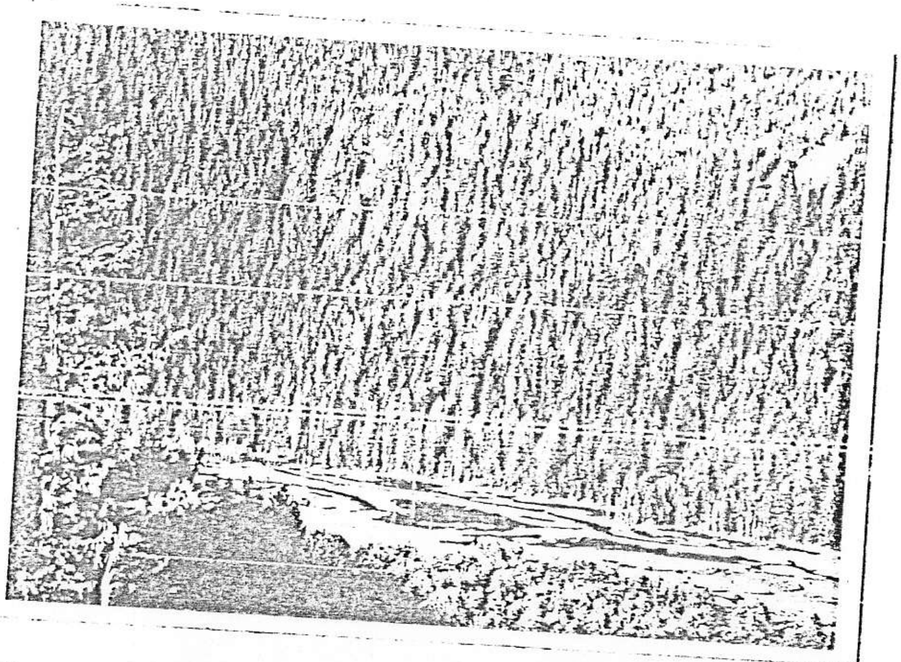


Figure 4. Heavily wooded lower elevations of the Ecstall-Skeena River region. Note swampy nature of the valley floor which is impassable for man on foot.

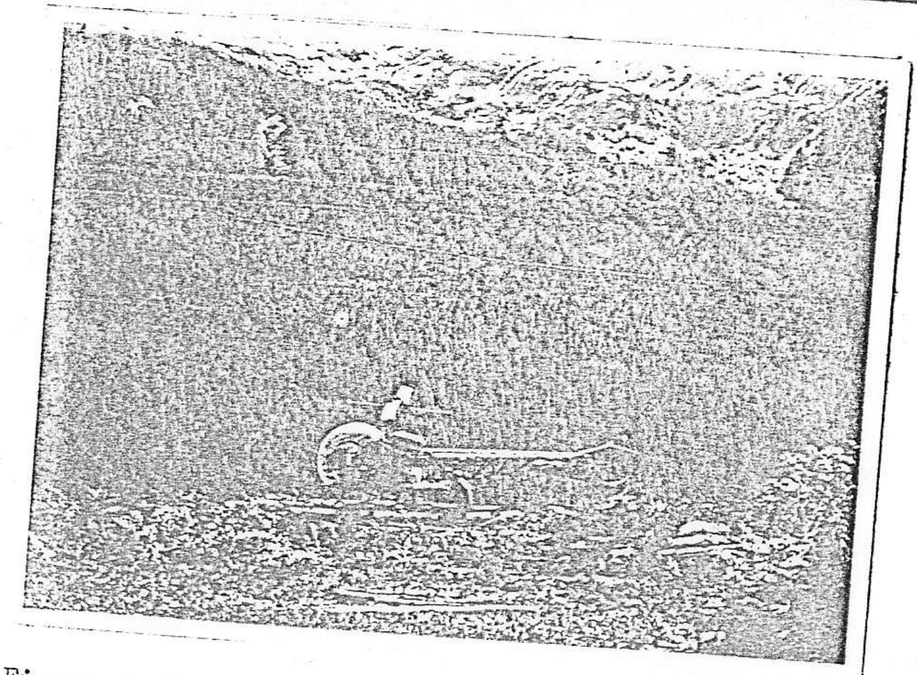


Figure 5. Heavily timbered terrain which is characteristic of regions of metamorphic rocks. Note lineation in upper right hand part of photograph. It shows the strike of the foliation of the metamorphic rocks.

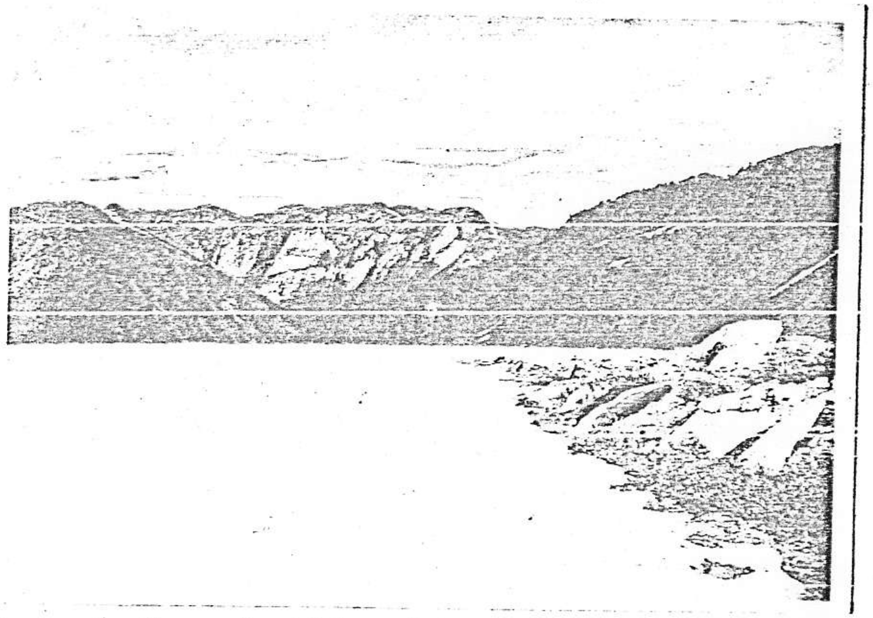


Figure 6. Sparsely timbered terrain of granitic rocks of Coast Range Complex as seen in background of photograph.

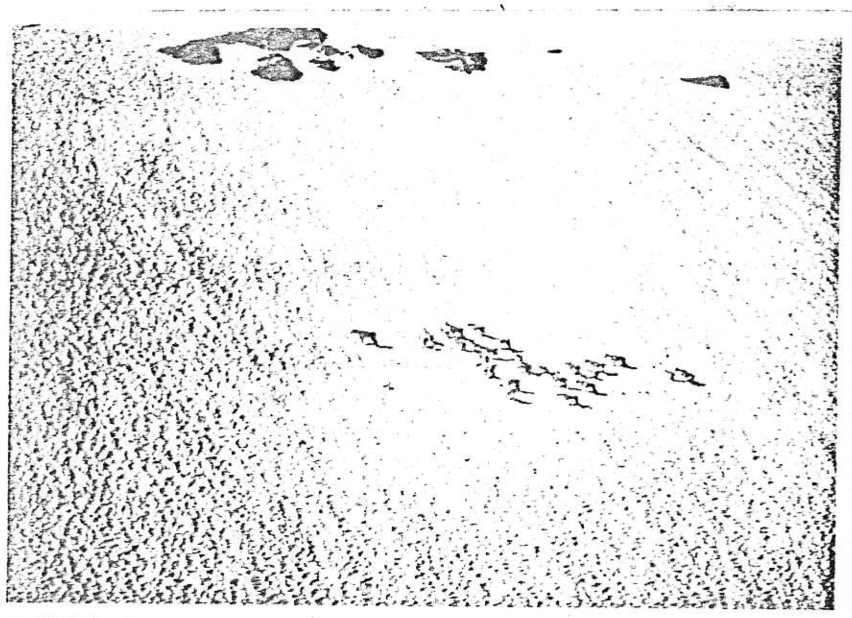


Figure 7. A herd of mountain goats crossing a snow scree.

In the late summer and early autumn, salmon pass up the main streams to spawn. Often during the spawning period, seals can be seen in the rivers and in the larger lakes which feed these rivers.

TOPOGRAPHY AND GLACIATION

The area in which the property is located is in the Pacific Ranges of the Coast Mountain area, part of the western system of the Canadian Cordillera. It is characterized by rugged topography with maximum relief of nearly 6000 feet. The highest peak in the region is Mount Khtada (Figure 8) with an elevation of 6600 feet. The majority of the peaks and ridges are rounded with the northward facing slopes being more precipitious than the southward facing slopes as shown in Figures 9 and 10.

The Ecstall and Skeena rivers are the two main water courses in the area. Each river occupies a major valley system which drains westward into the Pacific Ocean. All the small mountain streams in the immediate vicinity of the ore deposit drain northward into the Skeena River. The ore deposit occurs on a south facing slope of valley containing a branch of West Scotia Creek. This valley runs approximately northeast and southwest and is relatively gently sloping in its long profile. The walls of the valley are gently sloping in the upper half but become more precipitous in the lower half. In fact, remnants of a hanging valley are suggested at the confluence of the valley with the West Scotia Creek valley. Scotia Creek and Big Falls Creek constitute the major drainage of the region surrounding the map-area and flow northward and westward into the Skeena and Ecstall rivers respectively.

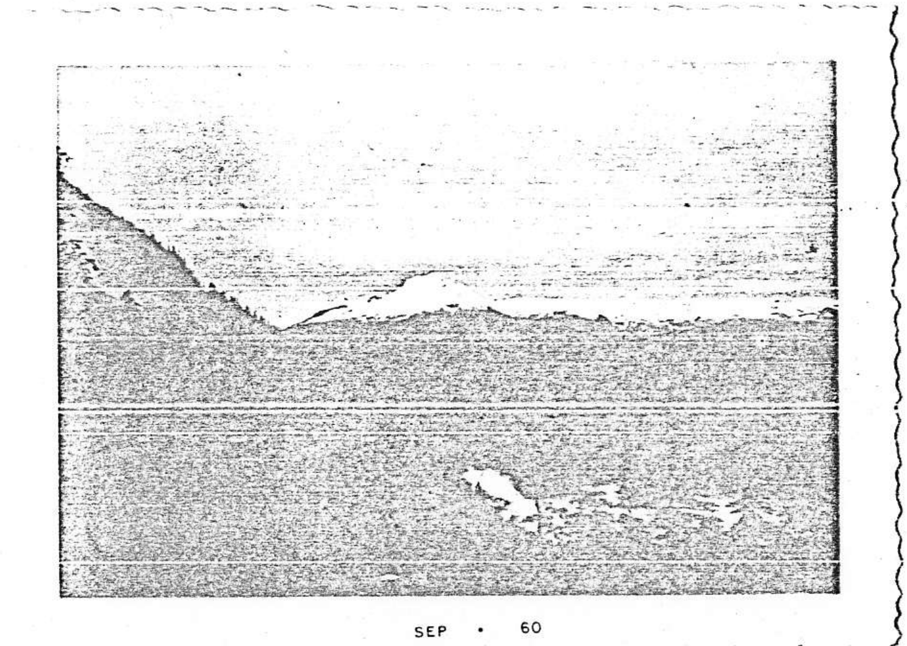


Figure 8. Mt. Khatada as seen from the thesis area looking east. The first snow fall of the season is visible on the summit. (August 28)

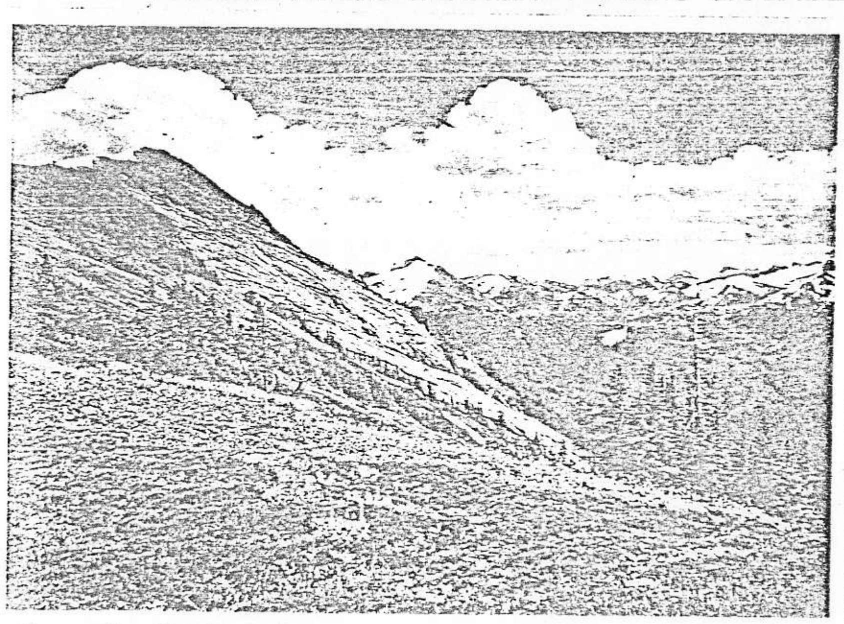


Figure 9. Shows steeper north facing slope of Mt. Khatada in relation to the more gentle south facing slope. (Looking east.)

In general two distinct types of topography can be recognized, especially in the region of the contact between the Coast Range intrusives and the belt of metamorphic rocks. These two types are displayed by the terrain which is underlain by the intrusive and metamorphic rocks as is visible in Figures 10 and 11. The former is characterized by great relief due to abundant steep cliffs, rugged mountain ridges and tops, and relatively little vegetation, whereas the latter terrain is more rolling, hummocky and heavily wooded. Weathering and erosion are much greater in the metamorphic terrain than in the granitic terrain. This is made evident by the steep and narrow canyons of streams which flow along the strike of the metamorphic rocks. Also very prominent in places is a gross lineation paralleling the foliation of the metamorphic rocks caused by differential weathering and erodability of the rocks. This lineation is easily recognized on air photographs and is readily visible from the ground in certain areas. (See Figure 5).

At present, stream erosion and mass wasting are the most important geomorphic processes except at higher elevations where alpine glaciers dominate. Erosion is extreme at times when the mountain streams reach a torrential stage after two or more days of steady precipitation.

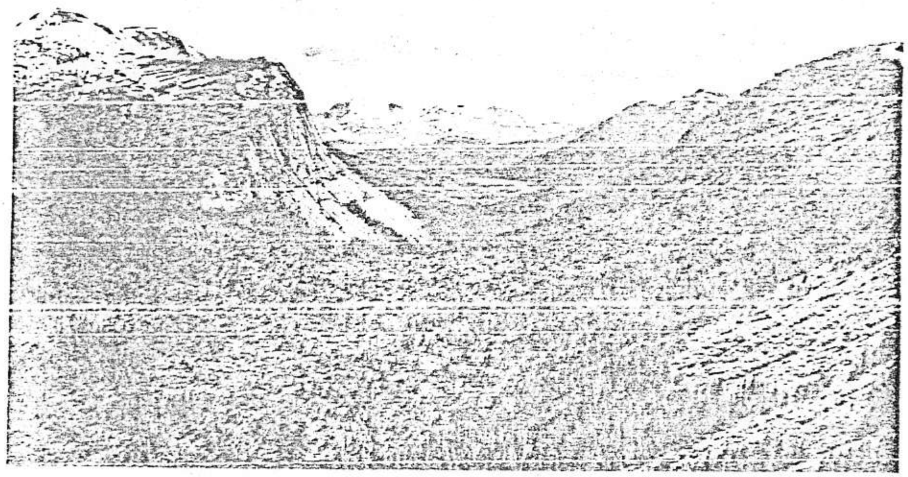


Figure 10. Shows rounded mountain tops, which suggests great thickness (5500') of ice during glaciation. Note precipitous nature of granitic terrain on left side of photograph in contrast with the rolling metamorphic terrain in the foreground.

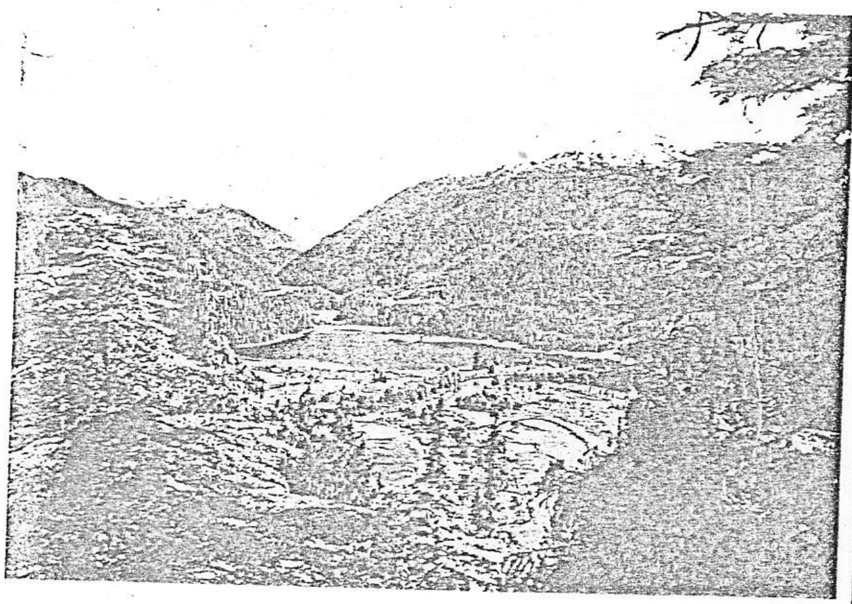


Figure 11. Exhibits very characteristic rolling and hummocky topography of terrain underlain by metamorphic rocks.

Evidence of Pleistocene glaciation is abundant in the region of the thesis area. U-shaped valleys and cirques are common. The generally rounded nature of the mountain peaks and ridges suggests that the ice reached a great thickness in this region. However, few glacial deposits occur. Many of the northern facing slopes of the higher mountains contain alpine type glaciers which exhibit a diminishing or receding nature made evident by the bare walls of the cirques. Glacial striae are abundant at higher elevations where the outcrop is frequent and suggest a north-south sense of movement for the last stages of glaciation.

TABLE OF ROCK UNITS

AGE

Pleistocene and Recent
Unconsolidated deposits, clay, sand, gravel

AGE

Jurassic - Cretaceous
Coast Range Intrusions
Pegmatites
Migmatite
Mineral Deposit

AGE UNKNOWN
Metamorphic rocks

II GENERAL GEOLOGY

The area studied is within the northward extension of the Ecstall Septum which has been mapped in this vicinity to the north and east by others, and as far south as Hawkesbury Island in the Douglas Channel. "This septum is composed of well foliated and layered gneisses and minor schists most of which have been derived from greywackes and some pelitic sediments."[1] The metamorphic rocks are bounded and intruded both on the west and east sides by Coast Range intrusives of quartz monzonite and quartz diorite.[2]

1. Read, P.B., Summer Report, 1958.
2. Ibid.

The thesis area is situated within a zone of metamorphic rocks and migmatites, $\frac{1}{2}$ mile from the western contact of the Coast Range Complex. The metamorphic rocks consist of quartzo-feldspathic biotite and/or hornblende gneisses with minor biotite and sericite schists. Plate B shows the general nature of the metamorphic rocks.

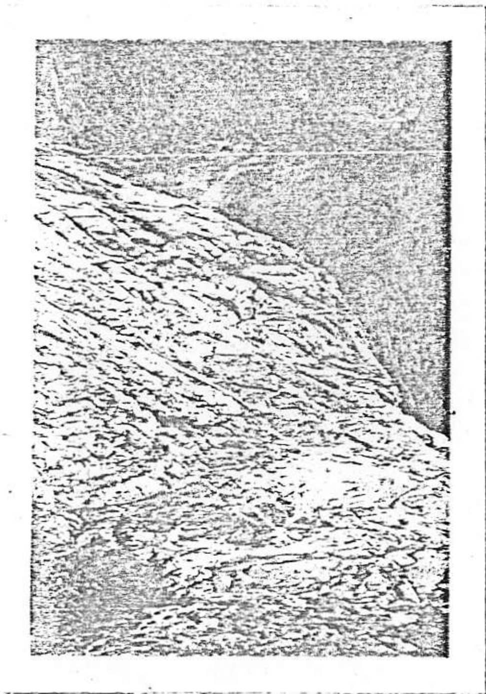


Plate B. Outcrop surface showing eastern limb of anticline composed essentially of metamorphic rocks and migmatites. Note boundinage nature of the mafic rich zones.

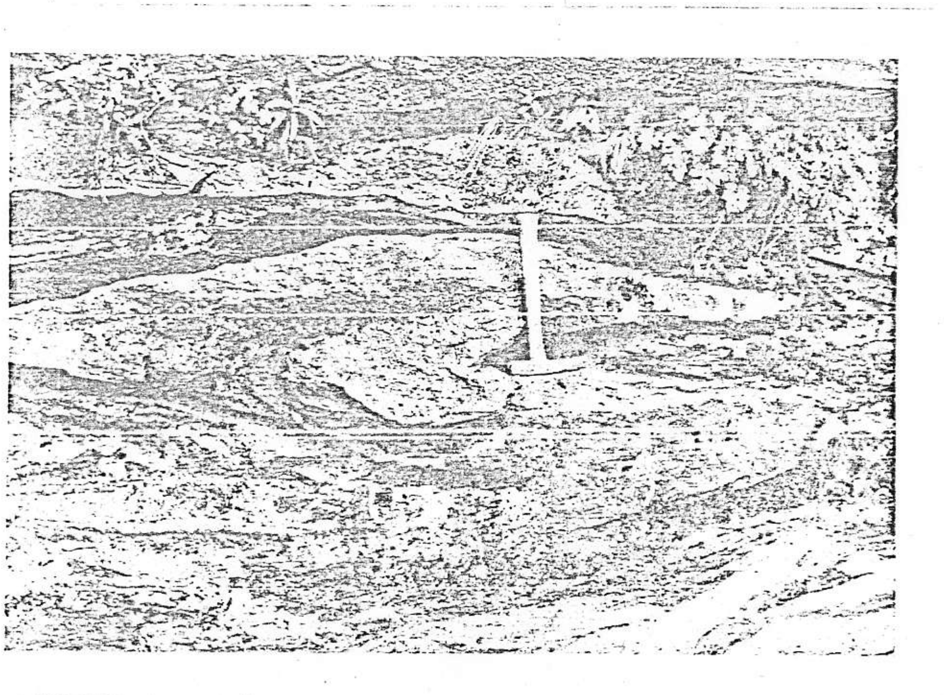


Figure 12. Resistant and irregular lensoid nature of banding displayed by some of the metamorphic rocks.

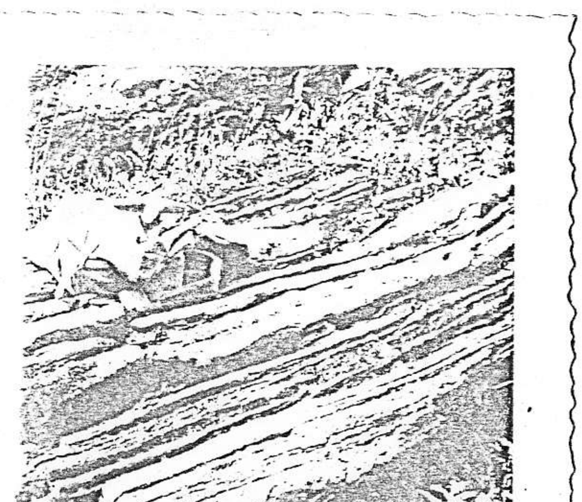
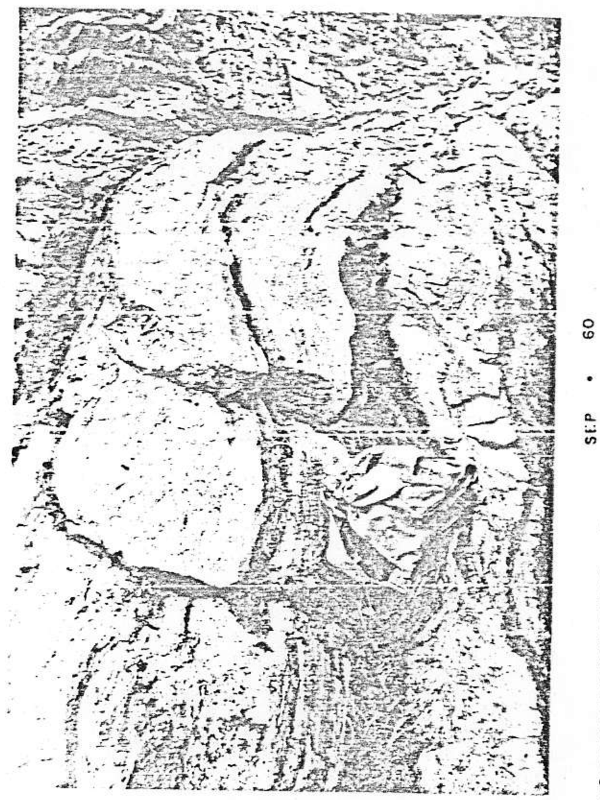


Figure 13. Shows trenched and irregular surface often displayed by the metamorphic rocks as the result of the differential erosion and weathering of the mafic rich layers.

Figure 14.

Local undulations which are common features of the layered rocks.



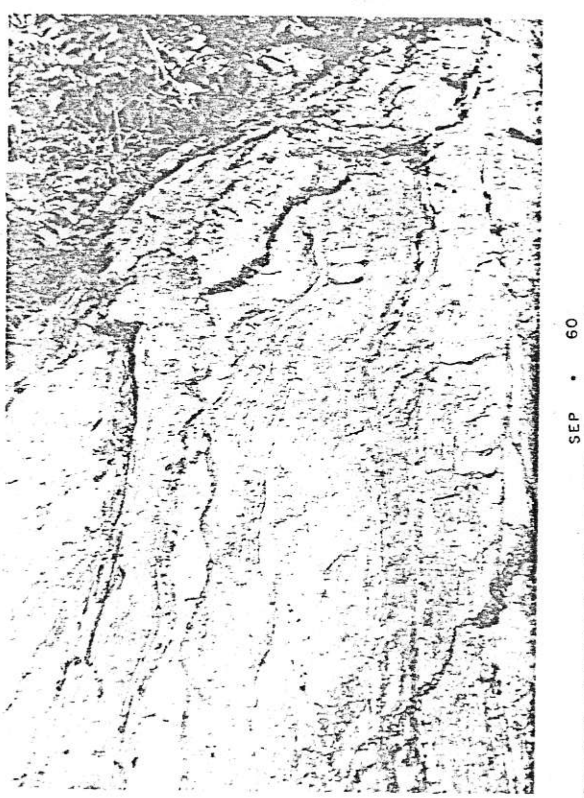


Figure 15.

Lensoid nature, often displayed by granitic component of the migmatites. Note conformable mafic rich layer marking the contact of granitic component and the metamorphic component.

The map-area occurs in the western limb of a northerly plunging [illegible] anticline whose eastern limb is in the contact with (500 foot wide [illegible]) intrusive rocks, 1 mile from the map-area. Beyond this [illegible] of granitic rocks lies the northward portion of the Ecstall [illegible], previously mapped in the summer of 1958.

[illegible] layering of the metamorphic rocks varies in width from [illegible] foot and has an overall general northwest strike and southwest [illegible]. [illegible], the banding results in the formation of irregular lensoid [illegible] (Figure 12). Most of the ore outcrop area of the migmatites [illegible] rocks is slightly trenched and irregular on the surface as [illegible] differential erosion and weathering of the more mafic rich [illegible] 13). Local undulations (Figure 14) are frequent throughout [illegible] the foliated rocks, both along strike and dip. [illegible] be seen from the map showing the attitudes of the rocks. [illegible] drag fold can be interpreted as being congruous from [illegible]. However, three relatively small incongruous drag folds, [illegible] plunges of approximately 20°, were sighted just below the [illegible] same outcrop. The migmatites are often characterized by a [illegible] the granitic component and ptygmatic folding, as seen [illegible] 16 respectively.

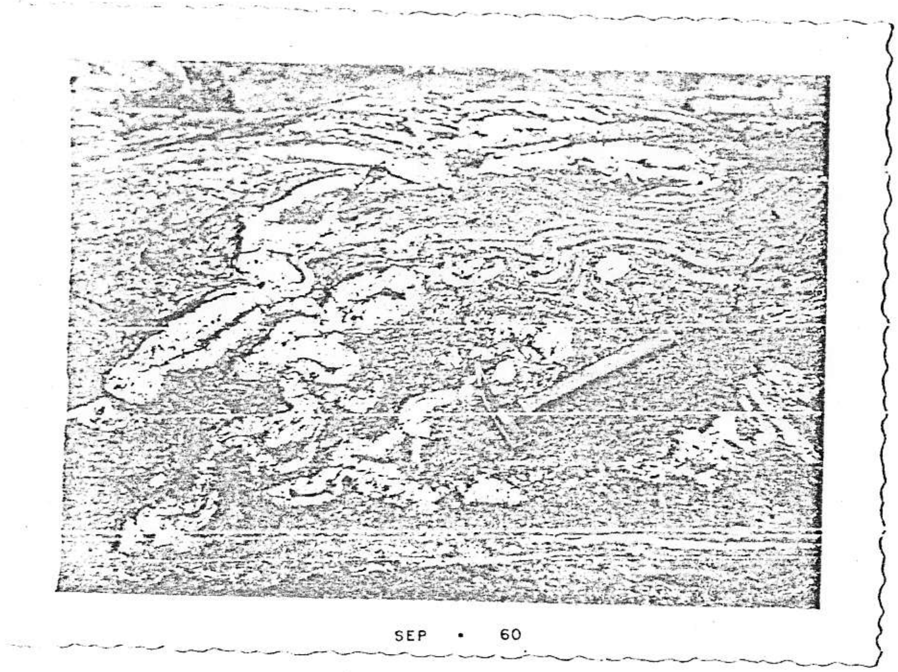


Figure 16. Complex ptygmatic folding of the migmatites.

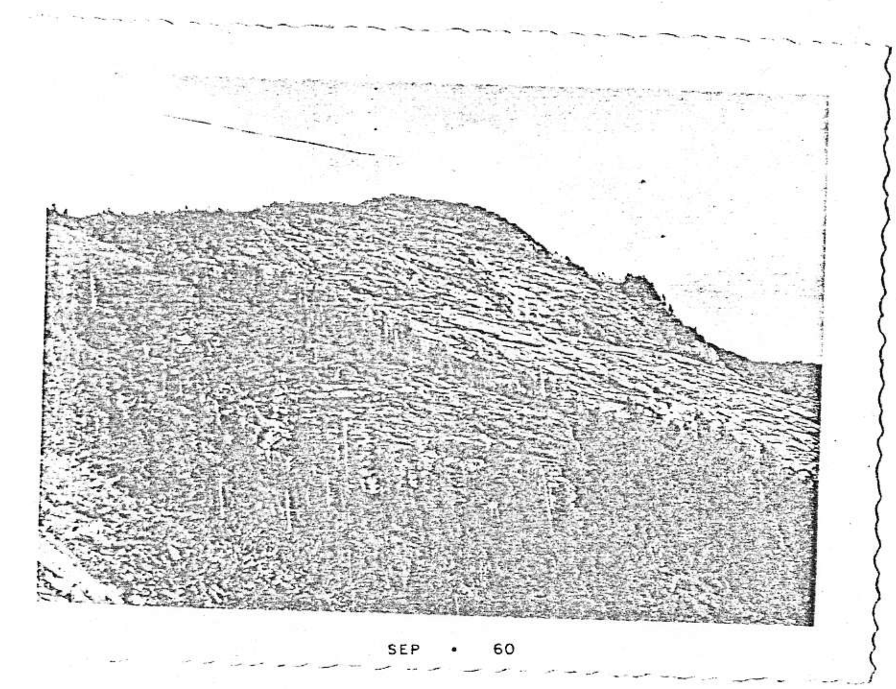


Figure 17. Pegmatite dyke swarm as seen on the outcrop surface to the east of the thesis map-area. Note crestal area of anticline in central portion of the photograph.

Intruding this zone of slightly folded metamorphic and migmatitic rocks are a series of pegmatitic dykes varying in width from 4 inches to 10 feet, the majority of which are from 1 foot to 2 feet wide. (Figure 17). These pegmatite intrusions are simple in mineralogy, consisting of plagioclase, microcline, perthite and quartz, with minor sericite and/or muscovite, and in most cases display sharp and steeply dipping contacts with the country rocks. The pegmatite is very coarse grained and is abundant with feldspar crystals of 3 inches by 4 inches. At one locale a feldspar crystal 14 inches by 3 inches was sighted. The intrusions, which are almost all dykes, have an undulating trend but are roughly parallel to each other, as can be seen on the large outcrop area situated east and northeast of the map area as can be seen in Figure 18. Numerous offshoots are characteristic of the dykes and at times they exhibit a radial effect. (Figure 19). These offshoots continue for several feet and then gradually disappear into the surrounding country rocks. (Figure 20). Some of the pegmatite dykes display a "fingering out" nature as shown in Figures 21 and 22. That is, a dyke of 2 feet in width will lense out to a stringer of $\frac{1}{2}$ inch and then gradually continue to increase in size until it reaches its original width. Often times these dykes contain xenoliths of country rock which usually have sharp contacts with the pegmatitic material.

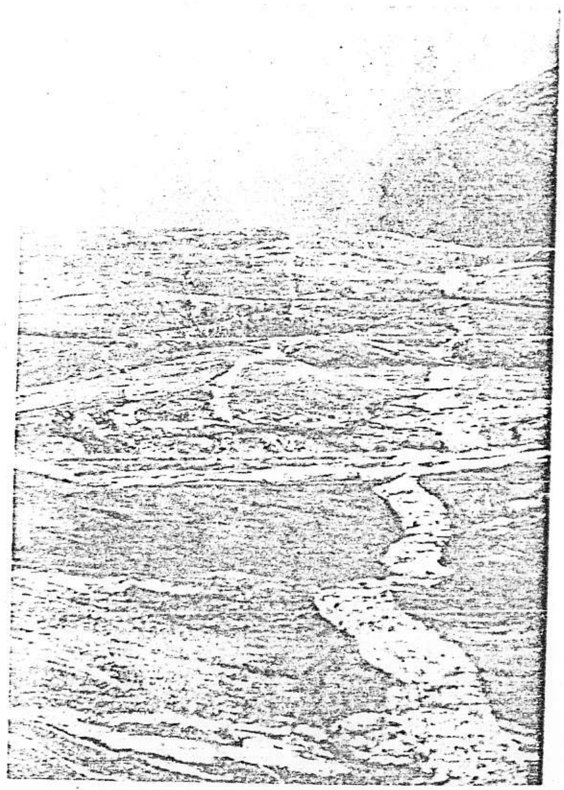


Figure 18. Parallel and undulatory nature of pegmatite dykes. Note sharp contacts of dykes with country rock.

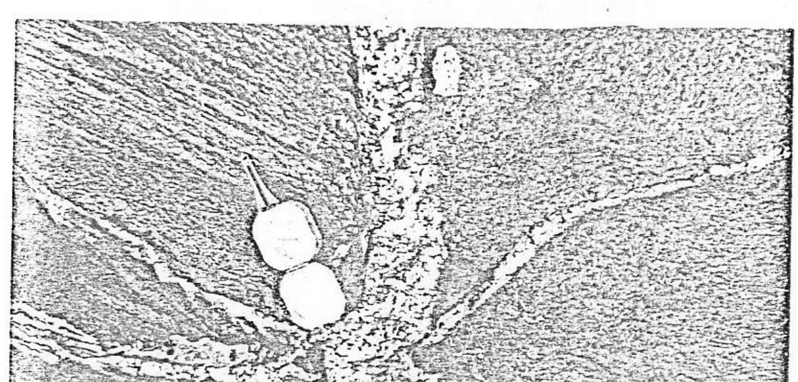


Figure 19. Radial effect commonly displayed by the small [illegible]

Figure 20. Short offshoots, from a main pegmatite dyke, along the foliation of the metamorphic country rock.

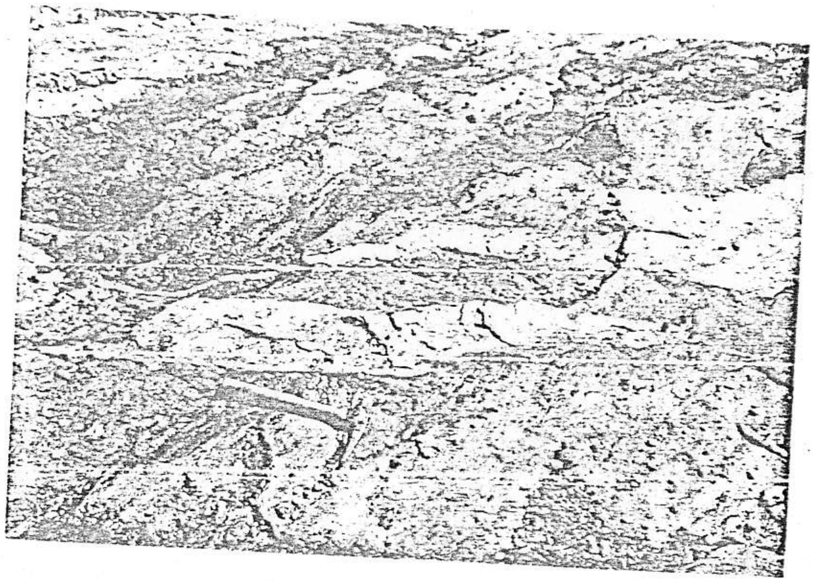


Figure 21.

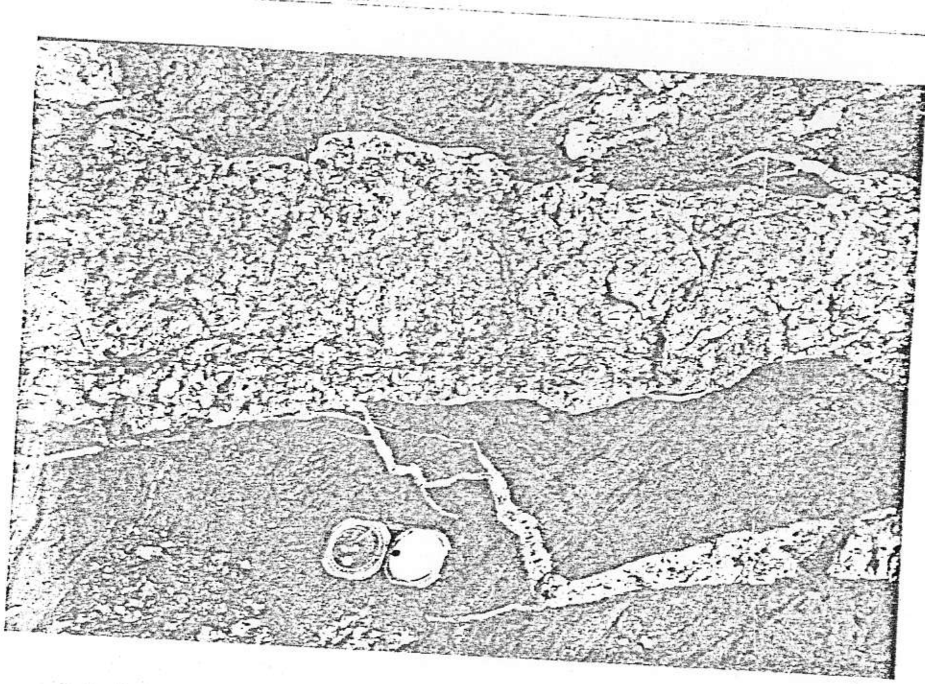


Figure 22.

Figures 21 and 22. Show "Fingering-out" nature shown by some of the pegmatite intrusions. Note sharp contact of pegmatite with country rock in Figure 22.

however, the pegmatite bordering the xenolith often contains coarse grained crystals of hornblende. (Figure 23). Also in some instances the pegmatitic intrusions have caused the country rock to become somewhat domed causing discrepancies in the foliation of the country rock near the contacts of the pegmatite intrusions. (Figure 24).

The largest pegmatite outcrop is situated within the map-area as a sheet-like mass. It is in direct contact with a major portion of the ore and has a maximum width of about 15 feet and appears to have a thickness of from 5 to 10 feet. This particular pegmatite body is approximately parallel to the contours of hillside which further suggests a flat lying type of body. Within the map-area six offshoots of about 1 foot in width can be seen in a vertical section, joining the large pegmatite mass to the lower pegmatite dykes. This suggests a possible origin for the sheet body. Small stringers of pegmatite, 2 inches to 8 inches in width, occur throughout the map-area above the large pegmatite mass from which they originated. Only in one locale can it be clearly seen that one of these pegmatitic offshoots has cut an ore zone. In all other instances the stringers are very irregular in trend and untraceable when traversing an ore zone.

In the crestal area of the anticline the rocks, which are predominantly metamorphic and migmatitic, exhibit a characteristic blocky weathering due to the flat-lying and gently plunging nature of the rocks. This is clearly visible in Figure 25. Local minor undulations in the rocks can also be seen in this region. (Figure 25).

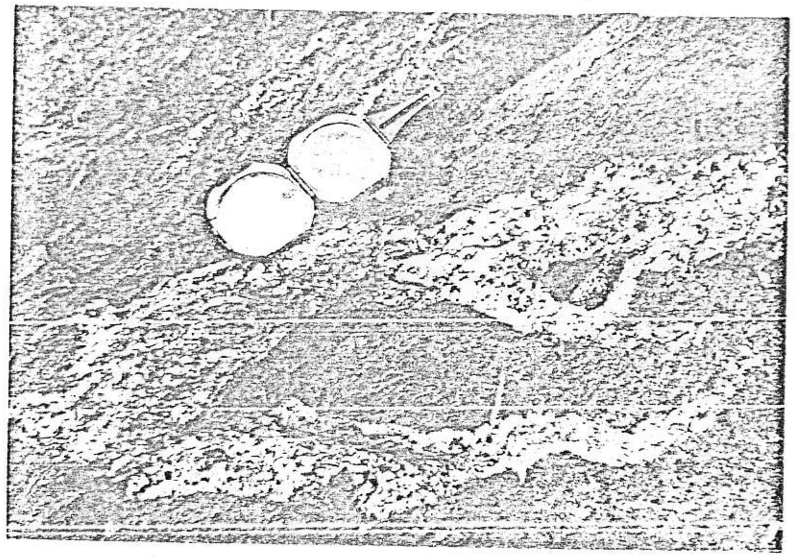


Figure 23. Xenolith of country rock in a pegmatite dyke. Note large hornblende crystals around the xenolith and along the upper contact of the pegmatite dyke.

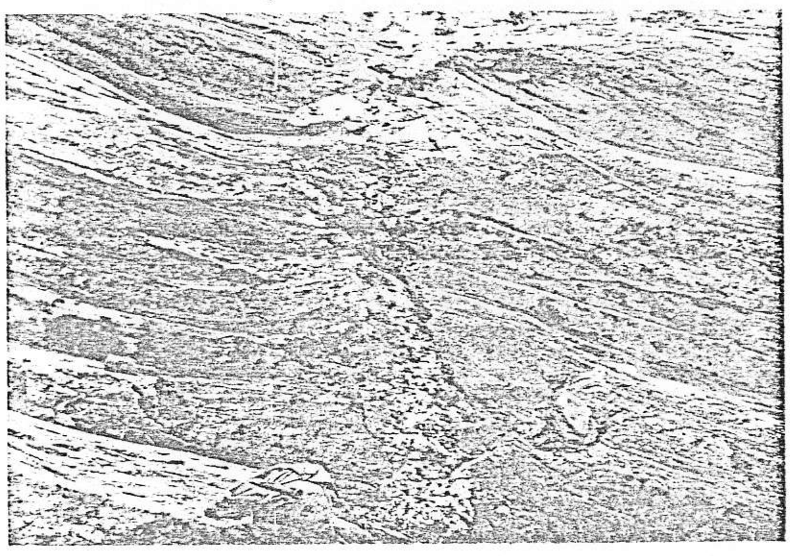


Figure 24. Local bowing of country rocks as caused by intrusion of the pegmatite dyke.

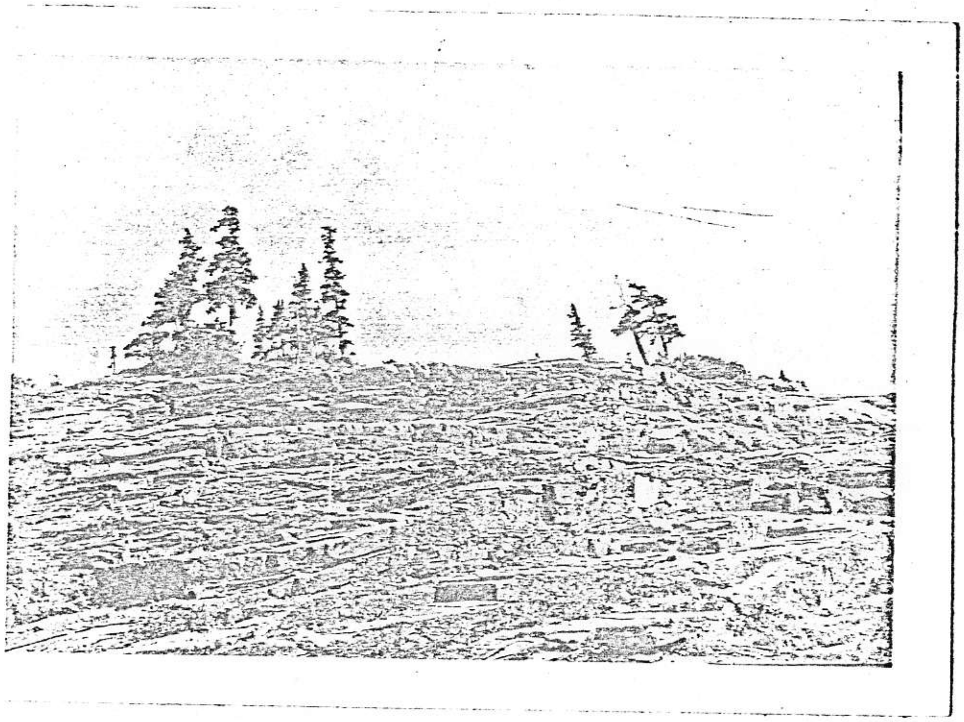


Figure 25. Characteristic blocky weathering of crestal portion of the anticline.
Note minor undulations of the layered rocks.

The ore, which is generally dark in color, has a very irregular outline on the outcrop surface. The majority of the ore on the surface is situated above the large pegmatite mass in the central part of the map-area. It occurs as an almost completely massive body near the pegmatite sheet but then branches into stringers 4 inches to 8 feet in width which continue upwards approximately paralleling the rock foliation. One stringer of ore is visible along the pegmatitic contact down from the main ore mass. Inclusions of metamorphic rock up to 4 feet by 10 feet in size occur within the large ore zone just above the pegmatite contact. Two separate stringers of ore also occur at the lower end of the map-area and appear to be parallel to a pegmatite dyke in that region. All of the ore stringers tend to be lensoid in places and are in most cases parallel to the rock attitude as seen on the outcrop surface. However, as was proven by the diamond drilling the ore does not appear to be conformable to any great depth. In a few places, the ore shows a highly folded nature on a small scale which closely resembles ptygmatic folding. The contact of the ore with the country rock is not sharp and readily distinguishable but appears rather gradual. In general, the ore contact with the pegmatite mass is much sharper than the ore contact with the country rock above the pegmatite mass.

A third rock type occurs in the map-area and is probably the …gest of the rocks mapped. It is an altered sericitized rock which … only occurs in the lower part of the map-area but which at one time …bably covered most, if not all, of the map-area. Its minor occurence …s …ue to erosion which removed it from the higher elevations. …is sericitized rock is slightly gneissic in most part but is schistose [illegible] …0% sericite. The latter occurs at the outcrop surface where the …thering processes have been most extreme. The rock may contain from … to 50% pyrite with the greater percentage obtained in the more …icitized rock.

III PETROLOGY OF THE MIGMATITIC, METAMORPHIC, IGNEOUS, AND ALTERED, SERICITIZED ROCKS

Specimens of the common rock type and ore were collected during the field study. Thin-sections and polished sections were made of the specimens and then studied in the laboratory. A description of each rock type, hand specimen, and thin-section follows:

MIGMATITES

The migmatites of the thesis area may be classified as those which occur in relatively narrow zones bordering granitic bodies[1] and not as those which occur on a regional scale, such as in pre-Cambrian terranes.[2] The granitic component of the migmatites occurs parallel to the foliation of the metamorphic host rocks and at times exhibits a lensoid nature. However, in some instances, discontinuous zones of granitic material occur in the metamorphic rock. The author believes that the majority of the migmatites were formed as a result of injection of magma along foliations or schistosity surfaces of the metamorphic host rock.[3] Some of the migmatites, such as those displaying discontinuous granitic zones, may have formed as the result of metasomatism or differential fusion of the host rocks.[4]

1 Turner and Verhoogen, Igneous and Metamorphic Petrology, Page 371, 1960.
2 Ibid.
3 Op. Cit. P. 373, 1960.
4 Ibid.

MIGMATITES

Specimen - AT

This specimen is from an area about 200 feet southeast of the lower edge of the map of the ore area. The medium grain (3-5 mm.) granitic component of the migmatite is lensoid in nature in two dimensions parallel to the schistosity of the rock. The thickest portion of the lense is 2 centimeters, while the thinnest portion is 2 mm. The composition of the granitic component is mainly quartz and plagioclase, with minor hornblende, biotite, sphene and K-feldspar. The mafics occur in a sporadic distribution throughout the component. The metamorphic component is medium grained (1-3 mm.) and is moderately schistose. It is composed essentially of hornblende, biotite, plagioclase and K-feldspar, with minor amounts of quartz, sphene, apatite and pyrite. Augens and metacrysts of feldspar and/or quartz occur throughout the metamorphic component. Many of the augens display a poikilitic texture as they contain hornblende crystals. The schistosity surface shows a majority of biotite crystals while another surface shows a majority of hornblende crystals which suggests a differential layering of the hornblende and biotite. The contact between the granitic composition and the metamorphic component is irregular but sharp, as it is lined with hornblende crystals. The weathered surface of the rock is dark in the metamorphic zone and light gray in the granitic zone.

Thin-section:

Thin section study shows the granitic component to be composed of; plagioclase 40%, quartz 55%, K-feldspar 4%, hornblende, biotite and sphene = 1%. The plagioclase is $An_{26}Ab_{74}$, section⊥a, $X'_{\wedge}(010) = 9^{\circ}$. Pericline twinning is present in some of the plagioclase. Some of the plagioclase crystals show spherical poikilitic inclusions of quartz and/or K-feldspar. The K-feldspar inclusions are probably the beginning of an antiperthite. Most of the feldspars in the granitic component show a moderate amount of alteration to clay minerals and sericite. In places, especially near the contact of the granitic and metamorphic component, pseudo-cataclastic texture is visible. (Figure 26). Many of the plagioclase grains displayed stressed and curved twin lamellae. The mafic crystals are broken, with irregular to jagged crystal ends, and often have a sutured texture with the grains which they contact.

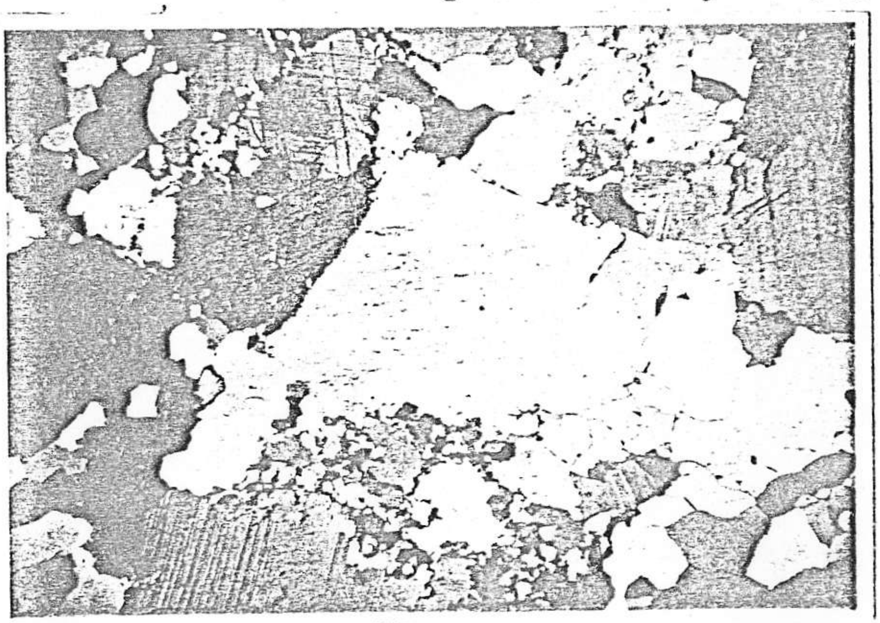


Figure 26. Photomicrograph of AT crossed nicols X 24. Pseudo-cataclastic texture visible near contact of granitic and metamorphic component. Note

The metamorphic component is composed of; K-feldspar 20%, plagioclase 20%, hornblende 45%, biotite 10%, quartz 5%, sphene 3%, apatite less than 1%, and opaque ore minerals 1%. The plagioclase is $An_{27}Ab_{73}$, as shown by the Michel-Levy method of determination. Some of the plagioclase crystals show poikilitic inclusions of apatite, sphene, and quartz. Pericline twinning is present in some of the plagioclase. A plagioclase crystal located on the contact between the metamorphic component and the granitic component showed; section $\perp$ a, $X' \wedge (010) = 3^{\circ}$, $An_{21}Ab_{79}$.

Specimen - 9T

This specimen is from an area about 2 feet northwest of Point C on the ore map-area. The rock type is a migmatite having a coarse grained granitic component and gneissic metamorphic host. The granitic component is composed essentially of plagioclase and quartz. Some of the large plagioclase crystals show poikilitic inclusions of quartz and other feldspar which are readily recognized with a hand lens. Pyrite, chalcopyrite, and galena are disseminated throughout the granitic component and constitute approximately 1%. Biotite crystals, partially altered to chlorite, make up less than 10% of the granitic component. The quartz is mostly interstitial and appears in concentrated zones.

The metamorphic component is a medium grained (1-3 mm.) biotite - hornblende - plagioclase - K-feldspar gneiss. The layering of the gneiss varies in size from 2 cm. to less than 1 mm. Little, if any, quartz is visible in the metamorphic component. Sparsely disseminated pyrite (less than 1%) also occurs throughout the gneissic portion of the migmatite. The contact between the granitic and metamorphic component in most places, is sharp but irregular and is lined by biotite crystals. The weathered surface is dark brown to black and exhibits slight oxidation.

Thin-section:

The thin-section shows the metamorphic component to be composed of plagioclase 40%, K-feldspar 15%, biotite 25%, hornblende 10%, quartz 5%, chlorite 4%, sphene 1%, and apatite less than 1%. The plagioclase shows; section⊥a, $X'\wedge(010) = 12^{\circ}$ (average of three determinations), $An_{29}Ab_{71}$. Both pericline twinning and curved twin lamellae are visible in the plagioclase crystals. Much of the feldspar is partially altered to sericite and clay minerals. The alteration seems to occur mainly in the central portions of the crystals. The mafics in the metamorphic component exhibit a preferred orientation, and show crystal ends that are jagged. (See Figure 27). Most of the mafic crystals are partially altered to chlorite.

The sphene and apatite occur in no particular relationship with any other minerals. Commonly the contacts between two or more felsic minerals are sutured suggesting an origin by recrystallization. Some pseudo-cataclastic texture is visible near the contact of the granitic and metamorphic components.

The granitic component shows the following composition; plagioclase 50%, K-feldspar 30%, myrmekite 8%, quartz 5%, perthite 5%, sphene and chlorite 1%, ore minerals 1%. The exact plagioclase composition was not determinable because of alteration and curved nature of the twin lamellae. Some of the plagioclase crystals appear to have been replaced partially by K-feldspar. Myrmekite wart-like zones occur at the contacts of some of the plagioclase and K-feldspar. The quartz appears as an interstitial mineral. The majority of the minerals in the granitic component display sutured contacts. The feldspars are moderately well altered to clay minerals and minute flakes of sericite. One of the perthite crystals exhibits a rapakivi type of texture in which the border of the crystal is rimmed with small grains of quartz and feldspar. (See Figure 28). The perthite crystals display a replacement type texture rather than an exsolution texture. The ore minerals of pyrite and sphalerite appear interstitial in nature.

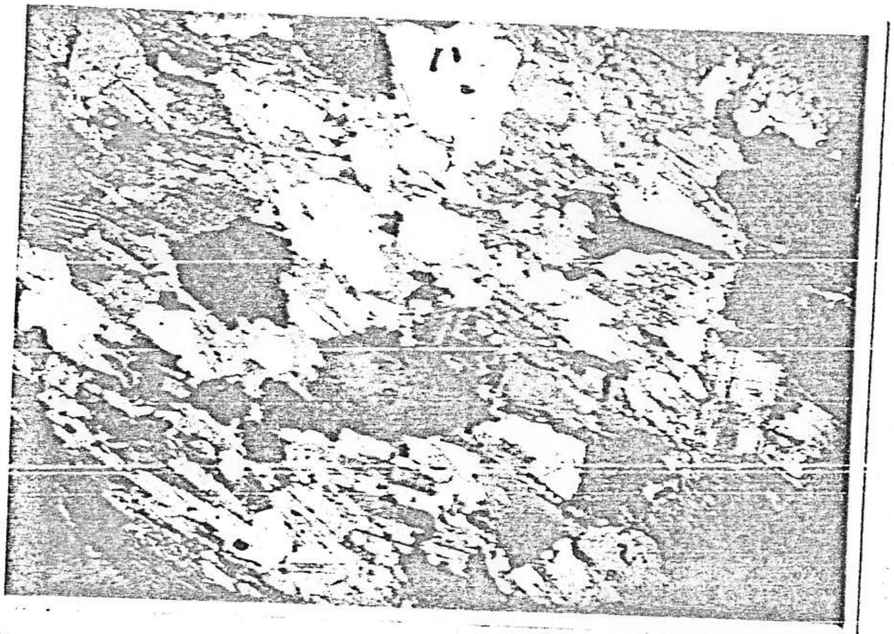


Figure 27. Photomicrograph of 9 T Crossed nicols X 24. Optical orientation (preferred) shown by the biotite crystals which also display ragged end sections. Note pyrite crystals (dark) at edge of feldspar grain in center of the photomicrograph.

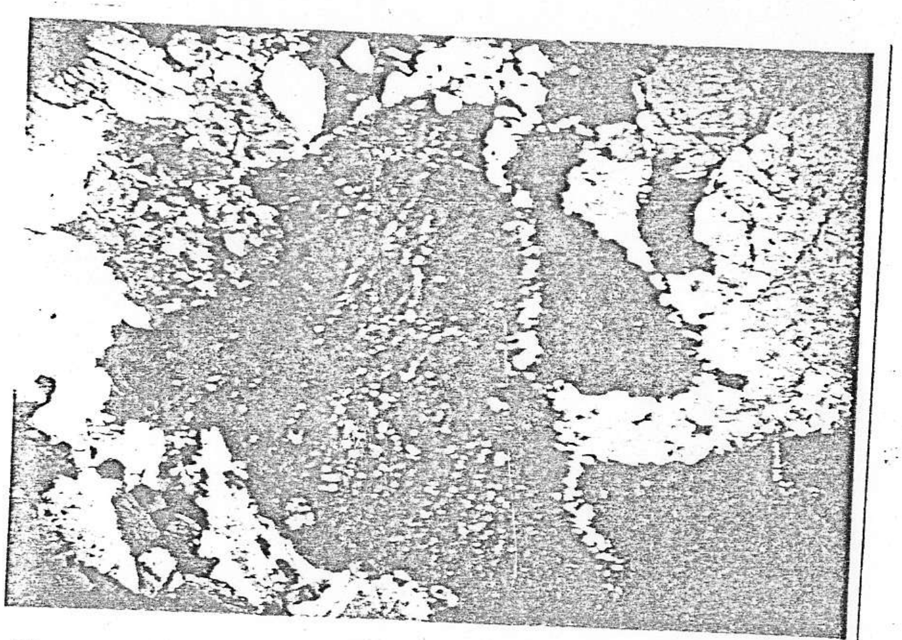


Figure 28. Photomicrograph of 9 T Crossed nicols X 24. Rapakivi type texture around a perthite crystal. Note large size of the perthite crystals in comparison with grains in lower left corner.

Specimen - 10T

This specimen is from the same area as Specimen - 9T, and represents a migmatitic rock type. This rock specimen does not show much of a distinction between the granitic and metamorphic component as the previous specimens. Only one, presumably metamorphic mafic rich band which varies in width from 1 cm. to 2.5 cm., and one granitic layer of 1.5 cm. in width, is visible in the rock. The rest of the rock consists of a slightly layered foliated zone with 70% felsic minerals and 30% mafic minerals. This zone probably represents an intermediate stage of migmatization. The metamorphic zone consists mainly of medium grained (2-4 mm.) moderately schistose biotite rock. The granitic portion shows medium grained (305 mm.) and coarse grained feldspar with interstitial quartz and sparsely disseminated pyrite, pyrrhotite, and galena. In places the contact between the granitic and metamorphic zones which are irregular but sharp, show coarse grained hornblende crystals which exhibit poikilitic inclusions of feldspar. The "intermediate" zone contains aligned medium grained (3-4 mm.) hornblende crystals which give the zone a gneissic appearance. Finely disseminated pyrite and pyrrhotite are also visible in this zone. The weathered surface of the granitic portion is light in color and slightly pitted. The rest of the rock shows a dark brown weathered surface. The rock as a whole definitely exhibits a banded appearance.

Thin-section:

The thin-section shows an area of the contact between the metamorphic zone and the "intermediate stage" zone, and shows the following composition; plagioclase 35%, K-feldspar 15%, hornblende 15%, biotite 20%, quartz 5%, perthite 5%, myrmekite 2%, sphene 2%, apatite less than 1%, opaque ore minerals 2%, and chlorite 1%. The biotite crystals of the metamorphic zone show a preferred orientation as represented by their optical continuity. The crystals are very irregular and jagged and as a result have a sutured contact with other mineral grains. About 2% of the biotite is altered to chlorite, and rarely to sphene. One large hornblende crystal on the contact boundary contained poikilitic inclusions of plagioclase, sphene and biotite. The intermediate or more felsic rich zone contains the ore minerals sphalerite, pyrite and galena disseminated throughout the zone and often within feldspar crystals, The plagioclase showed; section $\perp$a, $X' \wedge (010) = 11^{\circ}$, $An_{26}Ab_{74}$, and section $\perp$X, $Z \wedge (010) = 85^{\circ}$, $An_{21}Ab_{79}$. The majority of the plagioclase crystals show stressed and curved twin lamellae. Wart-like myrmekite zones often occur at the contacts of the K-feldspar and the plagioclase, and in some instances are visible within the plagioclase crystals. (See Figure 29).

Few large perthite crystals show albite in a K-feldspar host. The K-feldspar is mainly interstitial with the quartz and in places occurs as a replacement of the plagioclase. In one instance, a fracture in a plagioclase crystal has been filled with quartz and K-feldspar, and one small biotite crystal. (See Figure 30). On either side of the vein the plagioclase crystal is most highly altered. As was previously mentioned the quartz is interstitial. In general, the minerals in the "intermediate zone" are much more altered than those in the metamorphic zone. This is probably due to the ore minerals in the "intermediate zone". Another characteristic of this zone is that many of the interstitial spaces and fractures in the crystals are filled with an iron oxide (limonite). The mafics in the metamorphic zone are unaltered, or only slightly altered, while those in the "intermediate zone" show partial or complete chloritic alteration.

Specimen - 11T

This is a float specimen found on the ore outcrop surface in the vicinity of Point 2. Although it is a float specimen it is characteristic of the migmatitic rocks. The metamorphic component is a medium grained (2-9 mm.) poorly schistose hornblende-biotite schist. The contact between the metamorphic component and granitic component is lined with coarse grained hornblende crystals.

The granitic component is medium grained (3-5 mm.) to very coarse grained (2.5 cm.) and consists essentially of plagioclase, K-feldspar, and quartz. Patches of hornblende crystals occur throughout and constitute about 10% of the granitic component. Once again the quartz tends to be interstitial in manner. The weathered surface of this zone is light in color with a few rusty areas, whereas the metamorphic component shows a dark weathered surface.

Thin-section:

The metamorphic component of the thin-section is composed of hornblende 50%, plagioclase 40%, K-feldspar 5%, sphene 3%, biotite 1%, apatite 1%. The plagioclase shows section⊥a, $X' \wedge (010) = 10$ (average of three determinations), $An_{27}Ab_{73}$. Some of the plagioclase crystals exhibit curved twin lamellae (See Figure 31) and pericline twinning. Partial alteration of the feldspars to sericite and clay minerals is visible in the thin-section. The hornblende crystals are very large and one of them displays a poikilitic texture with inclusions of quartz, feldspar and sphene. Some alteration of the hornblende to biotite has occurred but there is no chlorite alteration visible. Limonite is visible along fractures through some of the mafic crystals.

The granitic component shows the following composition; plagioclase 60%, K-feldspar 20%, quartz 15%, and myrmekite 5%. The plagioclase was determined to be $An_{26}Ab_{74}$. Pseudo-cataclastic texture is well developed in the thin-section (Figure 31). Wart-like zones of myrmekite are visible at the contacts of plagioclase and K-feldspar. The quartz is interstitial in nature and appears in concentrated zones. Limonite stains occur at the contacts between the crystals and is easily distinguishable in plane plarized light. Partial alteration of the feldspars to clay minerals and minute sericite flakes is present in the thin-section.

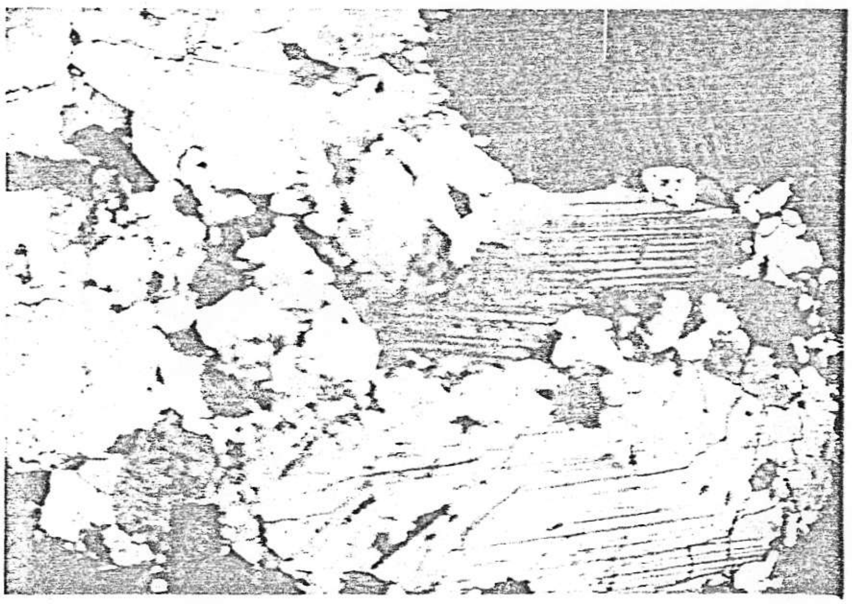


Figure 31. Photomicrograph of 11T crossed nicols magnification X24. Pseudo cataclastic texture between large feldspar grains. Note curved twin lamellae of plagioclase crystal in central portion of photomicrograph.

METAMORPHIC ROCKS

The metamorphic rocks of the thesis area consist mainly of moderately schistose to poorly schistose hornblende-biotite schists. Quartzo-feldspathic, biotite-hornblende gneisses occur in the general outcrop area but none are visible in the map-area of the ore deposit. Some of the gneissic rocks contain almandine garnets, but never greater than 2% of the rock. The layering of the gneissic rocks varies from 2 mm. to 2 inches in width. Some of the diamond drill holes located gneisses containing garnets. The metamorphic rocks of the Ecstall Septum north of the Ecstall River are thought to be regional metamorphic rocks of medium to high grade (belonging to the almandine-amphibolite facies; W.S. Fyfe, F.J. Turner, and J. Verhoogen (1958).

In general, the metamorphic rocks exhibit good foliation and layering. The layering is often traceable along strike for hundreds of feet. Sericite schist also occurs but will be discussed later under the heading of altered rocks. These metamorphic rocks have been derived essentially from quartzo-feldspathic sediments, such as greywackes. Some have probably been derived from pelitic sediments and tuffaceous rocks.

Specimen - 6T

This specimen was obtained 6 feet northwest of Point 2 on the ore map. The rock is a medium grained (1-3 mm.) moderately schistose hornblende-biotite schist. A few augens, the largest measuring 4 mm. by 1.5 mm., occur throughout the rock. The weathered surface is dark in color, and some of the biotite crystals on the surface appear partially sericitized. It should be noted here, that due to the relatively fine grained texture of the rock, the hornblende cleavage surfaces are often improperly identified as biotite crystals under megascopic identification.

Thin-section:

The components of the rock are hornblende 35%, biotite 15%, myrmekite 5%, K-feldspar 20%, plagioclase 20%, quartz 2%, sphene 2%, and apatite less than 1%. The plagioclase shows; section $\perp$a, $X' \wedge (010) = 12^{\circ}$, $An_{28}Ab_{72}$. Some of the plagioclase crystals exhibited moderate alteration to clay minerals and minor sericite. Some of the feldspar crystals are almost entirely unaltered. Small wart-like myrmekite zones occur at the contacts between the K-feldspar and the plagioclase (See Figure 32). In places, the plagioclase crystals exhibit poikilitic inclusions of sphene and apatite, and rarely K-feldspar.

The K-feldspar inclusions may suggest the beginning of an antiperthite. The mafic minerals display a preferred orientation as the result of optical continuity.

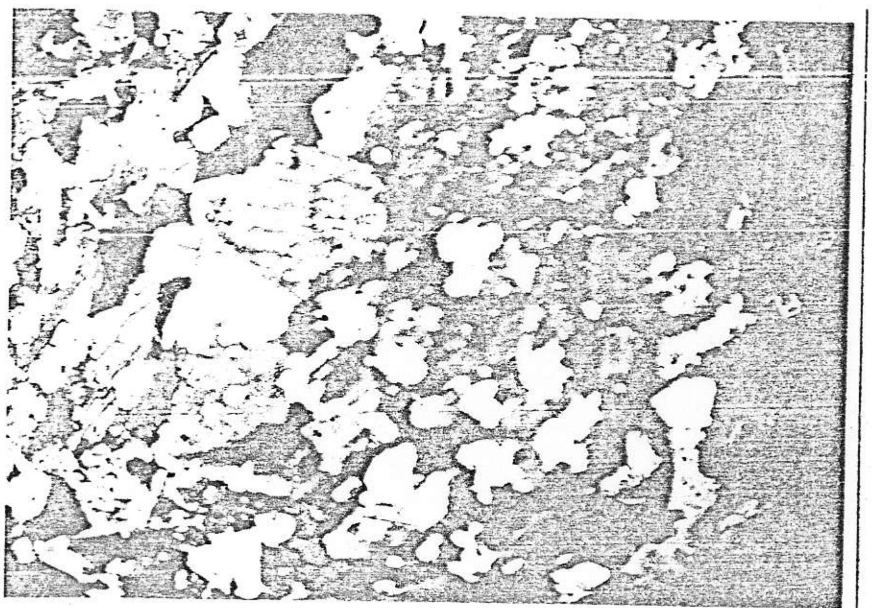


Figure 32.
Photomicrograph of 6T. Crossed nicols magnification X 76. Small wart-like myrmekite zones at contacts of K-feldspar and plagioclase. Note jagged ends of the mafic crystals.

Specimen 13T

This specimen is from the outcrop area just below the ore map-area. It is a part of the metamorphic rock which contains discontinuous zones of granitic material.

The rock is a medium grained (0.5 - 3 mm.), poorly schistose, hornblende-biotite schist. The weathered surface is dark in color with a few areas of iron oxidation. Sericitization of the biotite crystals is visible on the fractured and weathered surfaces.

Thin section:

The rock is composed of; hornblende 40%, plagioclase 40%, K-feldspar 10%, biotite 2%, sphene 2%, and apatite 1%. The plagioclase shows; section⊥a, $X' \wedge (010) = 8^{o}$, $An_{26}Ab_{74}$. The Michel-Levy method gives $An_{28}Ab_{72}$. The albitic twinning is rather poorly developed, and some of the crystals exhibit curved twin lamellae. In places, the plagioclase crystals show poikilitic inclusions of hornblende and apatite. A few crystals of microcline with grid twinning are also present. Some of the plagioclase crystals are partially replaced by orthoclase and/or microcline. The feldspars seem to display a sutured texture at the contact between the crystals. There is relatively little alteration of the feldspars to clay minerals. Approximately one half of the mafic crystals are in optical continuity. (See Figure 32A). The long sections of the mafics display ragged and irregular ends which formed a sutured contact with the surrounding felsic crystals.

The biotite crystals occur in one particular zone of the thin section and are coarser grained than the hornblende crystals. The mafics are generally unaltered. Sphene occurs as crystals in the feldspar and hornblende.

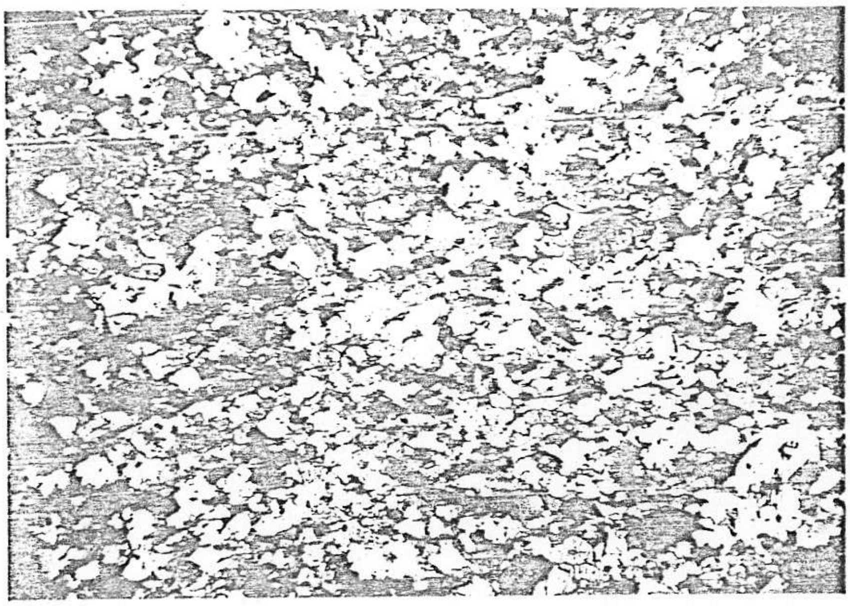


Figure 32A. Photomicrograph of 13T crossed nicols X 24. Optical orientation of the mafic minerals. Note sutured contacts of the mineral grains.

Specimen - 15T

This specimen is from the area about 20' south of Station 7 and constitutes a part of the metamorphic rock which surrounds a more resistant lense of slightly genissic rock.

The rock is a medium grained (1-3 mm.), moderately schistose, melanocratic biotite-hornblende schist. The weathered surface is also dark and displays partial sericitization of the biotite crystals.

Thin section:

The composition of the rock is as follows; biotite 30%, hornblende 10%, pyroxene 5%, plagioclase 50%, apatite 2%, sphene 1%. No quartz of K-feldspar was visible. Since the albitic twins of the plagioclase were curved and poorly developed the determination of the Ab An ratio was not made. However, one plagioclase crystal showed; section $\perp$ a, $X' \wedge (010) = 4^\circ$, $An_{23}Ab_{77}$. Some of the plagioclase crystals show pericline twinning. There is a minor amount of clay alteration of the feldspars. The mafics display optical continuity, and the long sections show ragged ends (See Figure 33). Hornblende appears to have replaced some of the pyroxene, and biotite some of the pyroxene and hornblende (Figure 33). The pyroxene crystals are anhedral and the hornblende crystals subhedral and euhedral. There is slight chloritization of the mafics. The very fine grained euhedral apatite crystals occur as poikilitic inclusions in the mafic and felsic crystals.

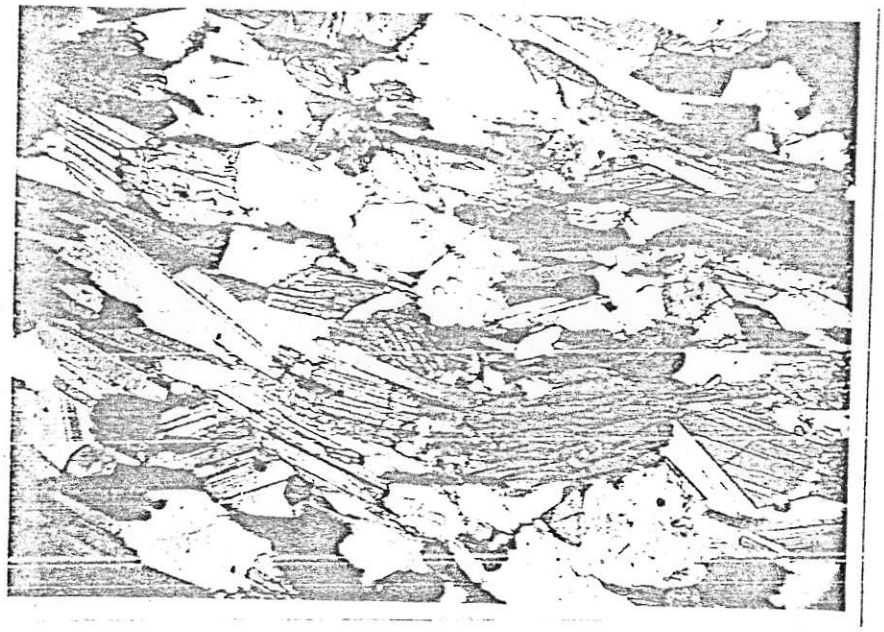


Figure 33. Photomicrograph of 15T crossed nicols, magnification X 76. Hornblende, pyroxene, biotite and sphene in preferred orientation. Some replacement of pyroxene by hornblende, and of hornblende by biotite is visible. Note ragged ends of the mafic crystals.

Specimen - 14T

This specimen is from the same area as specimen 15T and is part of the more resistant lense which is surrounded by the metamorphic rock of specimen 15T. The rock is a medium grain (1-2 mm.), very slightly banded quartzo-feldspathic gneiss. The banding of the rock is due to the slight foliation of the mafics and layering caused by grain size variation. The latter may represent relic graded bedding. The weathered surface is a light grey color. The fresh surface exhibits a few rust colored zones.

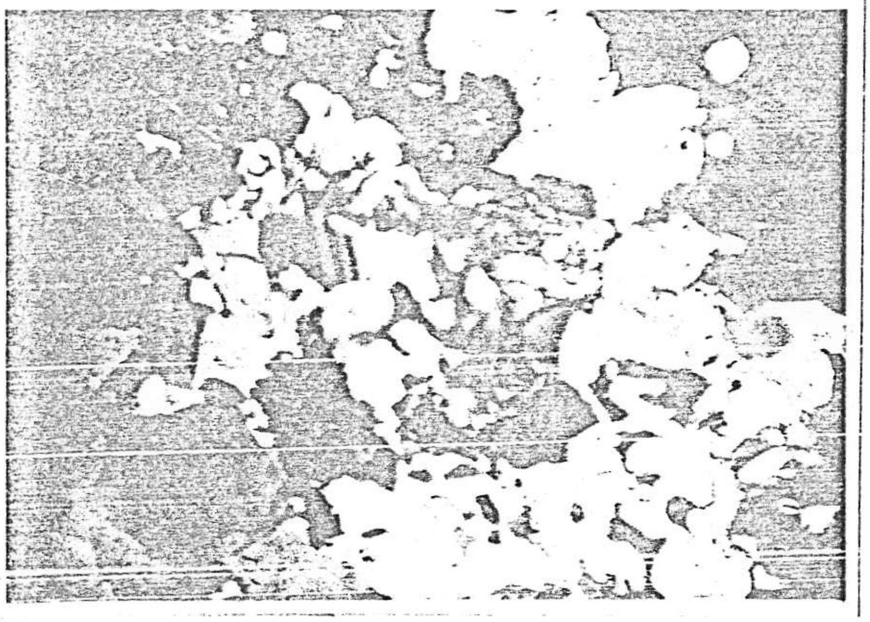


Figure 34. Photomicrograph of 14T crossed nicols magnification X76. Partial replacement of a pyroxene crystal by hornblende. (In center of photomicrograph.)

ALTERED SERICITIZED ROCKS

The altered, sericitized rocks are the youngest of the rocks mapped and represent the top most zone of the anticlinal limb in that area. At the surface, where weathering has been superimposed upon the original alteration, the rocks are very schistose. The sericitization of the rocks is probably caused by hydrothermal alteration accompanying the formation of the ore deposit. The intensity of alteration varies. Some of the rock is nearly 100% sericite, especially near surface specimens, while other rocks contain only 20% sericite.

Kaolinization is also exhibited in the majority of the altered rocks. Much of the less sericitized rock contains from 1% - 50% pyrite which usually occurs in layers and gives the rock a gneissic appearance.

The altered, sericitized rock is only visible in the lower southwestern portion of the ore map-area. This zone of altered rocks has a much greater weathered appearance than the rest of the outcrops in the map-area. This fact and also the position of this rock type as the youngest of those mapped suggests that it originally may have covered more of the outcrop area but has been largely eroded, leaving only the present zone. The position of this altered zone is definitely above the ore. In places, the rock exhibits an exfoliating nature due to the extreme development of sericite. This zone of altered rock continues downward to the southwest and is conspicuous in the area around Station 8 on the contour map.

Specimen - 19T

This specimen is from the altered rock zone of the ore map-area and represents the partially sericitized rock which occurs from 1" to 6" below the surface. The rock is medium grained (1-3 mm.) and gneissic in appearance, and has an oxidized alteration halo varying in width from 3 cm. to 5 mm.

Limonization is visible along the fractures. The gneissic appearance is the result of rather crude, yet distinguishable, layering of coarse grained pyrite and sphalerite. The feldspars in the alteration rim show much pinkish colored kaolinization. The ore minerals constitute about 5% of the rock, with 3% pyrite and 2% sphalerite. This rock has only about 20% sericite, which may be due to the fact that the mafics originally only constituted such a percentage of the rock. The weathered surface of the rock is a reddish-brown color and is pitted.

hin-section:

The components of the rock are as follows; sericite 20%, quartz 5%, plagioclase 10%, perthite 10%, K-feldspar 10%, clay minerals 10%, limonite 5%, pyrite and sphalerite about 1%. Since alteration of the eldspar was intense, (See Figure 35), accurate determination of the agioclase crystals was difficult. However, by the Michel-Levy method the agioclase was found to be $An_{25}Ab_{75}$. Some of the plagioclase crystals owed stressed twin lamellae. Many of the feldspar crystals have limonite ains through them. Myrmekitic zones occur at some of the contacts tween the K-feldspar and the plagioclase. Perthite occurs with both a crocline and an orthoclase host.

The sericite crystals do not show a preferred orientation, and are often highly twisted and bent with jagged ends. The twisted crystals suggest that anticlinal folding may have occurred after sericitization. The large sericite crystals are probably largely the result of biotite alteration rahter than feldspar alteration. However, many of the feldspar crystals contain minute flakes of sericite along with the clay minerals. Marginal corrosion borders are displayed by some of the feldspar crystals as shown in Figure 35. In places some of the large sericite crystals contain inclusions of feldspar.

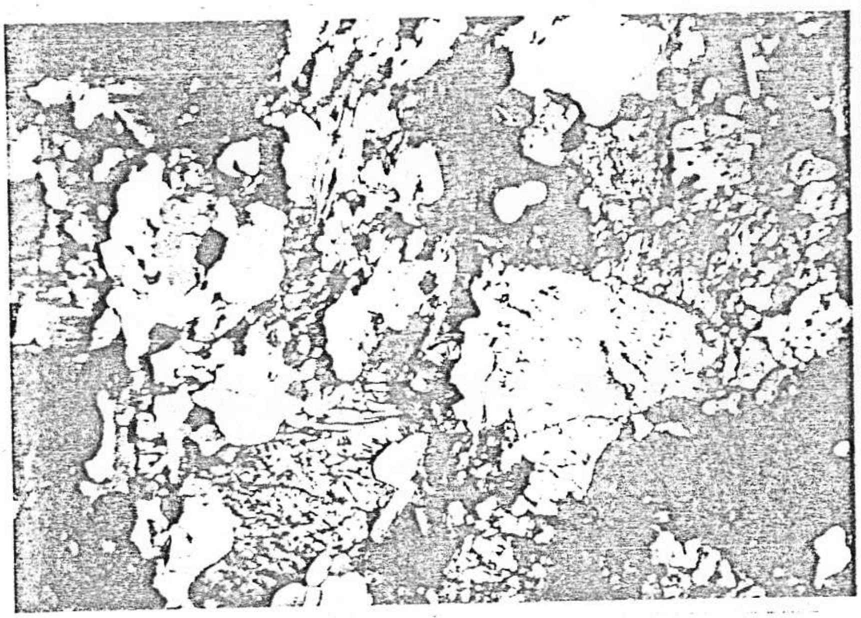


Figure 35. Photomicrograph of 19T crossed nicols magnification X24. Intense alteration of the feldspars. Note pods of quartz crystals as they appear unaltered. Microcline crystal in central upper portion of the photomicrograph containing an inclusion of quartz. The large feldspar crystal (light color) in central portion of the photomicrograph exhibits marginal corrosion texture.

Specimen - ET

This specimen is from the altered, sericitized zone south of the ore map-area around Station 8 as located on the contour map. The rock is medium grained (2-5 mm.), gneissic and leucocratic. The rock is very porous in texture, and displays patches of iron stain where pyrite crystals originally were. The majority of the feldspars appear partially kaolinized. The weathered surface is a light brownish color and is well pitted.

Thin-section:

The composition of the rock is as follows; sericite 30%, plagioclase 35%, quartz 25%, feldspar alteration (clay minerals and sericite) 5%, sphene and apatite about 1%. The plagioclase crystals show; section $\perp$ a, X' (010) = 4° (average of two determinations), $An_{22}Ab_{78}$. The majority of the feldspar crystals are partially altered to clay minerals and minute sericite flakes. Some of the sericite crystals are stessed and broken, (See Figure 36), and in places completely surround quartz crystals. The curved and broken nature of the sericite crystals once again suggests anticlinal folding after, or contemporaneous with sericitization. There was no K-feldspar visible in the thin-section.

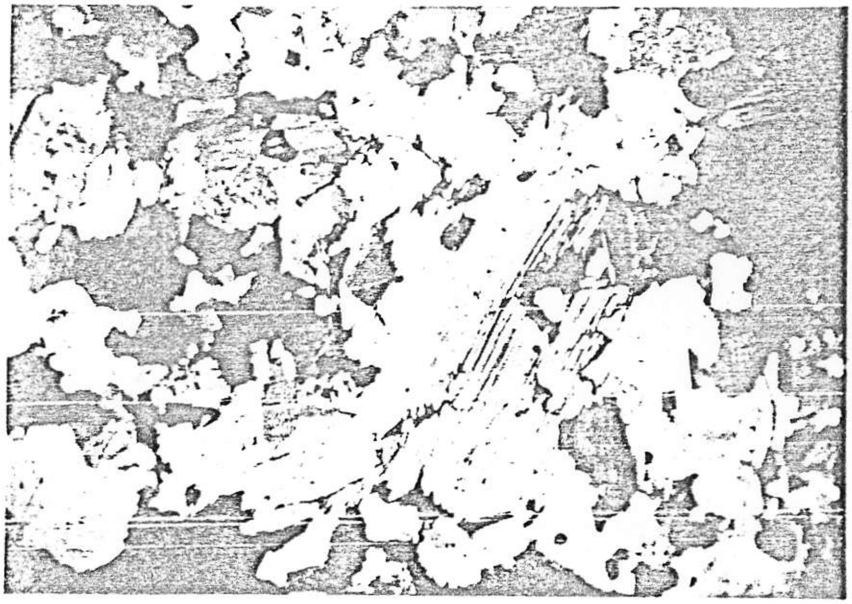


Figure 36. Photomicrograph of ET. Crossed nicols magnification X 24. Curved and broken nature of the large sericite grains.

IGNEOUS ROCKS

The igneous rocks of the thesis area consist of the pegmatite intrusive bodies which traverse the area discordantly as a series of dyke and sheet-like masses (See Plate C). They range in width from a fraction of an inch to 15 feet. The majority of the intrusions occur as 1' to 2' dykes, and have sharp and steeply dipping vertical contacts with the country rock (See Plate D). The pegmatites are coarse grained to very coarse grained in texture and are composed essentially of plagioclase, K-feldspar and quartz. Some of the dykes show a wedging-out or tension effect. The dykes are exposed from the bottom to the top of the ore outcrop area. Smaller off-shoots are a common feature of these pegmatitic intrusions as visible in Plate E.

Only in a few places were there any signs of ore minerals in the pegmatites. Pyrite and chalcopyrite occur in concentrated zones, especially near the contact with ore zones in the country rock. In most instances the pegmatite intrusions are more resistant than the surrounding country rock and so represent local topographic highs. The large sheet-like mass of the ore map-area is on the upper lip of a 15 foot drop in the outcrop and is undoubtedly the cause of this small cliff. The weathered surface of the pegmatite bodies is leucocratic in color, and in the ore area they are reddish in color due to the run off waters from the ore containing rocks above.

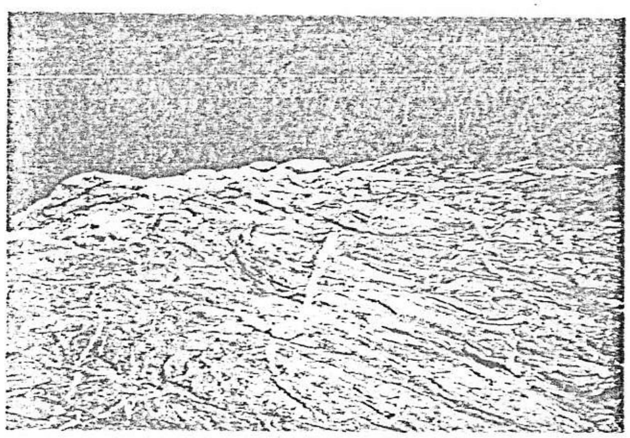


Plate C. Multiple pegmatitic dykes traversing a portion of the eastern limb of the anticline.

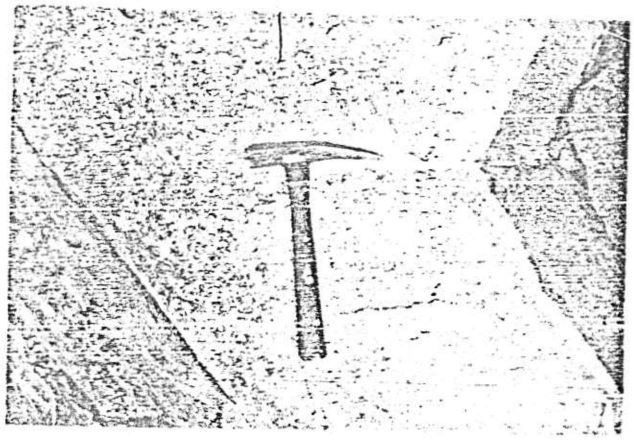


Plate D. Shows sharp contact of pegmatite dyke with country rock.

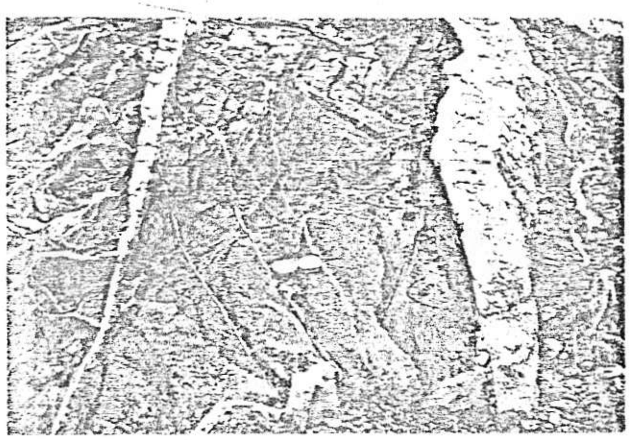


Plate E. Small stringer offshoots from pegmatite dykes. Note "fingering-out" nature of dyke at left, and also the resistant character of the pegmatite dykes in comparison to the topographically lower metamorphic rock.

Specimen - BT

This specimen is from the southeastern portion of the ore outcrop area, about 200' southeast of the lower edge of the map of the ore area. This specimen shows a contact between the pegmatite dyke and the metamorphic rock. The contact is sharp when normal to the layering of the metamorphic rock but parallel to the layering, offshoots of pegmatitic material along the foliation surfaces are visible. The pegmatitic dyke material is composed essentially of coarse grained (5mm. - 1 cm.) feldspar and interstitial quartz. A few patches of medium grained to coarse grained partially chloritized biotite crystals occur in the granitic material. The weathered surface is light grey in color due to lichen, and rough as the result of the feldspar cleavage and the quartz. The metamorphic rock is a medium grained (1-2 mm.) biotite schist with moderate schistosity. The weathered surface of the metamorphic rock is dark in color.

Thin-section:

The thin section shows the contact between the intrusive dyke material, the metamorphic rock and a dyke offshoot parallel to the layering of the metamorphic rock. The composition of the metamorphic rock is follows; biotite 40%, plagioclase 40%, K-feldspar 10%, quartz 5%, myrmekite 4%, sphene 1%, apatite 4%, opaque mineral< 1%.

The plagioclase crystals show section $\perp$a, $X' \wedge (010) = 11^{\circ}$ (average of two determinations), $An_{28}Ab_{72}$. Some pericline twinning is visible in the plagioclase crystals. Myrmekite zones occur in places at the contact between the K-feldspar and the plagioclase. The biotite crystals show an optical continuity and are unaltered. The majority of the biotite mafics have a broken appearance and as a result have a sutured contact with the feldspar crystals. The ore minerals occur disseminated throughout the thin section in no particular arrangement. The granitic portion is composed of; plagioclase 40%, K-feldspar 30%, quartz 15%, perthite 10%, myrmekite 5%, biotite and sericite 1%. The plagioclase shows section $\perp$a, $X' \wedge (010) = 9^{\circ}$ (average of three determinations), $An_{25}Ab_{75}$. Some of the plagioclase crystals are partially altered to clay minerals and minute sericite flakes. Wart-like myrmekite zones often occurrred at the contacts between the K-feldspar and plagioclase. One plagioclase crystal shows larger grained myrmekitic pods of quartz than most (See Figure 38). All the quartz pods display the same optical continuity. The few large perthite crystals show plagioclase in both microcline and orthoclase hosts. A pseudo-cataclastic texture is visible with the large feldspar crystals displaying marginal corrosion structures. The finer grained crystals between the large feldspars consist of quartz and K-feldspar.

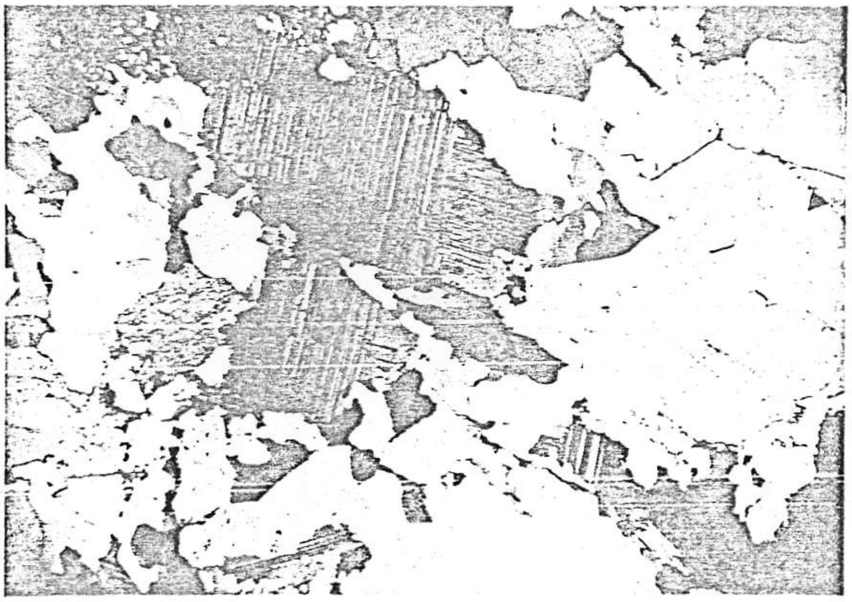


Figure 37. Photomicrograph of BT crossed nicols X24. Shows fracture in large plagioclase crystal filled with quartz. Note broken and cracked nature of the large plagioclase crystal. A partially replaced plagioclase crystal within a grain of K-feldspar is visible in the lower central portion of the photomicrograph.

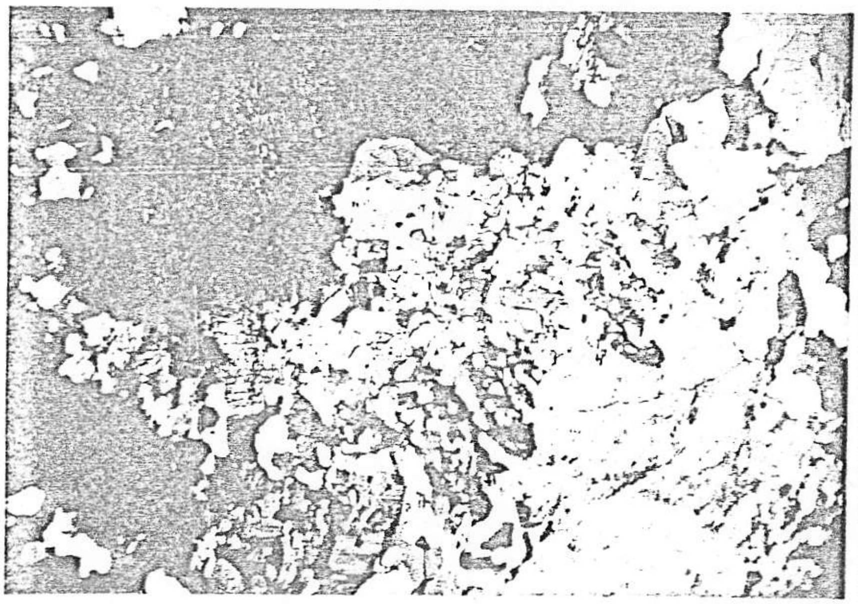


Figure 38. Photomicrograph of BT crossed nicols X24. Large scale myrmekite texture developed in a plagioclase crystal in contact with a perthite grain.

These display mutual or sutured boundaries (Figure 39). The amount of alteration of the feldspars is greater in the part of the thin section containing the main dyke material than in the part containing the offshoot of dyke material parallel to the layering of the metamorphic rock.

Specimen - 16T

This is a specimen from the only pegmatitic dyke which clearly traversed an ore zone in the thesis area. The specimen was obtained from an 8" wide dyke where it cut the ore stringer 5 feet east of the Station A as seen on the ore map. The rock varies from medium grained (2-5 mm.) to very coarse grained (3-1.5 cm.) and is composed essentially of perthite, plagioclase and quartz. The rock has two distinct portions, a medium to very fine grained portion containing the greater percentage of the ore minerals. Sphalerite, pyrite, pyrrhotite and galena are disseminated throughout the rock. The mineralization constitutes about 5% of the rock. Some of the large feldspar crystals can be seen with the naked eye to contain quartz inclusions. A slight bluish tinge is discernable from the feldspar crystals. The weathered surface of the rock is a rusty color and is slightly pitted.

Figure 39. Photomicrograph of BT crossed nicols X 24. Mutual intergrown boundaries of the quartz and feldspar crystals. Note undulatory extinction displayed by some of the quartz crystals.

Thin-section:

The composition of the rock is as follows; perthite 45%, plagioclase 25%, quartz 20%, myrmekite 5%, sericite 2%, sphene 1%, and opaque minerals 1%. The plagioclase crystals show section⊥a, $X'\wedge(010) =$ 5° (average of two determinations), $An_{23}Ab_{77}$. Much of the feldspars are partially altered to clay minerals and minute sericite crystals. The very large perthite crystals show albite in a microline host (Figure 40). One perthite crystal contains a quartz inclusion. Wart-like myrmekite zones occur throughout the thin-section at the contacts between the K-feldspar and plagioclase crystals. (Figure 40). The quartz was mainly interstitial, often occurring with the feldspar crystals to form a pseudo-cataclastic texture. (Figure 41). The contacts of the large crystals were very irregular and often intergrown, which suggests a marginal corrosion structure (Figure 41). The ore minerals occurred disseminated throughout the thin-section and in one instance a sphalerite crystal contained a poikilitic inclusion of feldspar. Many of the minerals displayed irregular contacts with the surrounding crystals. There is a suggestion of replacement by the ore minerals of some of the feldspar crystals.

Figure 40. Photomicrograph of 16 T crossed nicols X 24. Large perthite crystal with inclusions of K-feldspar. Note myrmekite zones at contact of the plagioclase crystal with the perthite grain.

Figure 41. Photomicrograph of 16 T crossed nicols X 24. Pseudo-cataclastic texture and abundant myrmekite pods. Note marginal corrosion texture of the large plagioclase crystal.

Specimen - 20T

This specimen is from the pegmatite sheet-like body of the ore map area. The leucocratic pegmatite sample is a medium (2-5 mm.) to very coarse grained (5-3 cmm.) and is composed of perthite, plagioclase, quartz myrmekite, biotite and sericite. Many of the large felsic crystals show poikilitic inclusions of quartz, biotite, and sericite. Zones of medium grained biotite, sericite, plagioclase and quartz occur throughout the specimen. This particular feature was only noticed in the pegmatite sheet-like body of the ore map-area. These zones may represent partially digested xenoliths or may be ground mass for the larger felsic crystals of the pegmatite. The borders of these zones are not sharp but the area of a particular zone is readily discernable because of its relatively fine grained nature. The biotite and sericite crystals show no preferred orientation in the zones. The rock has rough fracture and the weathered surface is light in color.

Thin-section:

The thin section shows; perthite 45%, plagioclase 15%, quartz 25%, myrmekite 5%, sericite 1%, biotite and chlorite less than 1%, clay alteration products 5%.

The plagioclase shows section ⊥a, $X'_{\wedge}$ (010) = 6^{o}, $An_{23}Ab_{77}$. Perthite crystals are large and show albite in an orthoclase host. Many of the perthite crystals contain a few inclusions of quartz as shown in Figure 42. The plagioclase crystals are highly altered to clay minerals. In places, veinlets of quartz crystals can be seen throughout some of the perthite crystals. These are probably fracture fillings which resulted from the breakage of the large perthite crystals during deformation (folding). Myrmekite pods occur throughout the thin-section at contacts between K-feldspar and plagioclase. Quartz which does not occur as inclusions is interstitial. The biotite crystals are partially altered to chlorite. One biotite crystal exhibits a sagenetic texture.

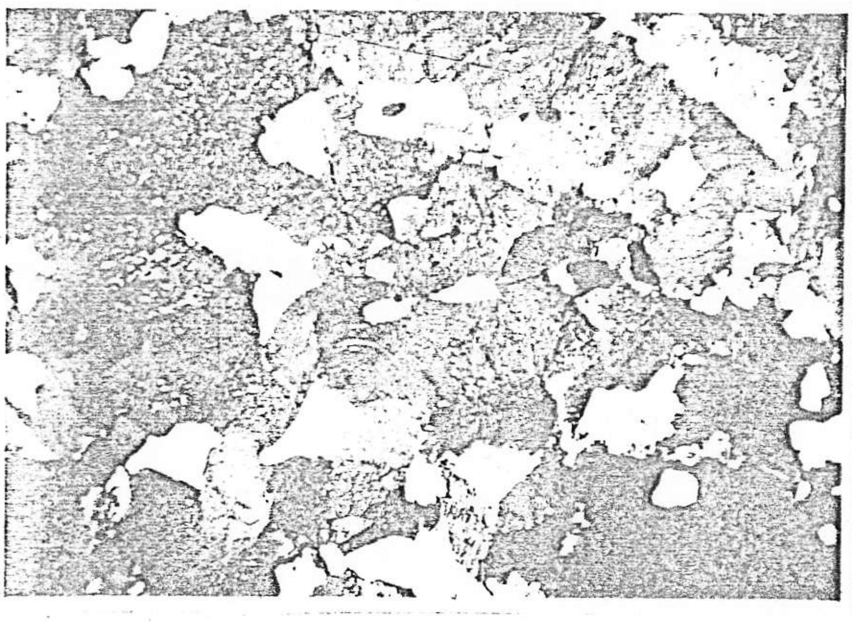


Figure 42. Photomicrograph of 20T. Crossed nicols magnification X 76. Large perthite crystal with inclusions of quartz.

PETROLOGY AND MINERALOGY OF THE MINERAL DEPOSIT

A description of hand specimens and polished sections of the mineral bearing rocks follows:

MINERALOGY AND MINERALOGRAPHY

Specimen - 1T:

This specimen was obtained 10 feet southwest of point 2 as seen on the ore outcrop map. The rock is medium grained (2-5 mm.) to coarse grained (up to 1.5 cmm.) and has the following composition; sphalerite 60%, quartz 25%, feldspar 14%, pyrite 1%, and chalcopyrite less than 1%.
The sphalerite, which is a dark reddish brown, is moderately coarse grained (3-5 mm.). The ore minerals are not evenly distributed throughout the rock. In the more massive sections of the rock the quartz and feldspar occur as poikilitic inclusions in the sphalerite. However, in other parts of the rock, the feldspar and quartz exhibit poikilitic inclusions of sphalerite. The pyrite and chalcopyrite is sparsely disseminated in nature, and often occurs as inclusions in the felsic minerals and the sphalerite. The felsic portions of the rock exhibits a slight porous nature, resulting from the subangular contacts of the quartz and feldspar grains.

In these zones, the ore minerals appear to occupy the pores mentioned above (i.e. interstitially). The majority of the feldspar is partially kaolinized. The weathered surface is a light rusty brown and well pitted due to the leaching of the sulphides and the resistent character of the quartz grains.

Specimen - XT:

This specimen is characteristic of the most massive ore rock and was obtained from the massive central portion of the mineral deposit. The rock is medium grained (3-5 mm) to coarse grained (up to 1.3 cm.) and contains; sphalerite 90%, quartz 5%, feldspar 5%, and pyrite, chalcopyrite, and galena less than 1%. Sphalerite is moderately coarse grained with some crystals up to 1.3 cm. in length, and dark brown in color. The pyrite, chalcopyrite and galena are disseminated throughout the rock. The galena appears most often at contacts of the felsic minerals with the sphalerite, or as poikilitic inclusions in the felsics. In this specimen all of the quartz and feldspar occur as poikilitic inclusions in the sphalerite, and are subangular to subrounded in outline. The feldspar appears well kaolinized. The weathered surface is a dark brown and moderately pitted in nature.

Polished section of Specimen - XT:

The polished section shows; sphalerite 90%, galena 5%, pyrite 1% and felsic minerals 4%. The galena occurs as multi-shaped blebs throughout the sphalerite in no particular orientation or texture. The pyrite occurs in the same manner as the galena but in some instances contains rounded grains of sphalerite as the result of replacement.

Specimen - 3T:

This specimen was obtained about 2 feet from a stringer of ore minerals in the upper portions of the ore outcrop map. It is a medium grained (2-5 mm.) to coarse grained (up to 8 mm.) rock with the following composition; sphalerite 40%, feldspar 35%, quartz 24%, biotite 1%, and pyrite, chalcopyrite, galena less than 1%. In this specimen the ore minerals exhibit a very slight banded appearance, and are intergranular in nature. The pyrite, chalcopyrite, and galena are of smaller grain than the sphalerite. Some of the ore minerals occur as poikilitic inclusions in the quartz and feldspar while most of the pyrite and chalcopyrite occurs within sphalerite grains. When the rock is broken, the quartz and feldspar along the fractured surface are easily separated from the rest of the rock as individual, equant, subrounded to subangular grains. The weathered surface of the rock is dark in the portion of ore minerals and light in portion of felsic minerals.

Specimen - YT:

This specimen is from a quartz pod about 3 feet in diameter located in the country rock above the pegmatite. It consists mainly of clear quartz with a few sporadic zones of galena, chalcopyrite, pyrrhotite, and marcasite which constitutes about 10% of the rock. The ore minerals occur interstitially between quartz grains and in small veinlets of 1 inch in length. A few poikilitic inclusions of the ore minerals also occur within the quartz. Traces of biotite occur throughout the rock and where it is associated with ore minerals it is sericitized. The marcasite is crustiform in nature and occurs as concentric layers around some of the pyrrhotite grains. Most of the quartz is a light brown in color due to iron oxide stains. The weathered surface is pitted and reddish-brown.

Polished section of Specimen - YT:

This polished section of a part of the above mentioned quartz pod shows galena, sphalerite, pyrrhotite and pyrite in sporadic lenses throughout a quartz matrix. Galena occurs in greater amount than the other ore minerals. No marcasite was visible in the polished section.

Polished section of a part of a Galena rich zone (lense):

This polished section represents one of the galena lenses that occurs in minor abundance throughout the thesis area associated with the mineral zone. The polished section shows; galena 95%, pyrite 4%, and sphalerite 1%. The latter minerals occur as subangular to subrounded inclusions in the galena in no particular orientation. The pyrite grains show minute blebs of galena. In general the galena exhibits a zonal texture seen most clearly under low magnification. It is probably a growth zoning texture.

Petrology of the ore bearing rocks

The following are descriptions of five hand specimens and corresponding thin sections of rocks which border ore zones in the thesis area.

Specimen - 2T

This specimen is a sample of the rock which is in contact with a foot wide ore stringer situated about 32' northeast of Point 2 as seen on the ore map-area. The rock is a medium grained (2-5mm.) slightly banded biotite feldspathic gneiss.

The rock is rich in felsic minerals as the mafics constitute only 1/5 of the rock. A few medium grained (3-5 mm.) hornblende crystals occur disseminated throughout the rock. A layer of small equant sized clear quartz crystals occurs in the rock. This layer represents the major portion of quartz in the rock. Sphalerite, pyrite and chalcopyrite, are in general, disseminated throughout the rock but in places occur in more concentrated zones and constitute about 2% of the rock. Some of the black sphalerite crystals show poikilitic inclusions of feldspar. The weathered surface of the rock is a dark rusty color.

Thin-section

The thin-section showed the following composition; plagioclase 50%, biotite 20%, K-feldspar 15%, myrmekite 10%, quartz 3%, apatite 1%, opaque minerals 1%, and sphene 1%. The plagioclase crystals show, sections $\perp a$, $X' \wedge (010) = 11^\circ$ (average of 3 determinations), An_9Ab_{91}, section $\perp x$, $\wedge (010) = 75^\circ$, An_5Ab_{95}. Pericline is present in some of the plagioclase feldspars. Many of the plagioclase crystals show curved twin lamellae (Figure 44). Often the twin lamellae would occur in only one half of a plagioclase crystal. Also the majority of the feldspars are partially altered to sericite and clay minerals.

Some of the plagioclase contained inclusions of K-feldspar, which suggests an antiperthite development. Rims of unaltered plagioclase are at times visible around partially altered plagioclase crystals. Small wart-like zones of myrmekite occur at some of the contacts between plagioclase and K-feldspar. The K-feldspar is mainly interstitial in occurrence. Biotite shows no optical continuity. The majority of the biotite crystals appear broken and display sutured contacts with bordering minerals. One biotite crystal contains an inclusion of plagioclase which was in optical continuity with a larger plagioclase crystal that bordered the biotite crystal. This may suggest partial replacement of the plagioclase crystal by the biotite (See Figure 43). The ore minerals occur in close relation with the biotite crystals. In one instance, a sphalerite crystal contains inclusions of biotite and plagioclase. The biotite inclusion showed the same optical continuity as the biotite crystal which bordered the ore mineral crystal.

Specimen - 4T

This specimen represents rock which is 8 inches from the massive portion of an ore stringer. The rock is felsic and of medium grain (2-5 mm.) exhibiting a slight layering caused by mafic rich bands of biotite with a trace of hornblende.

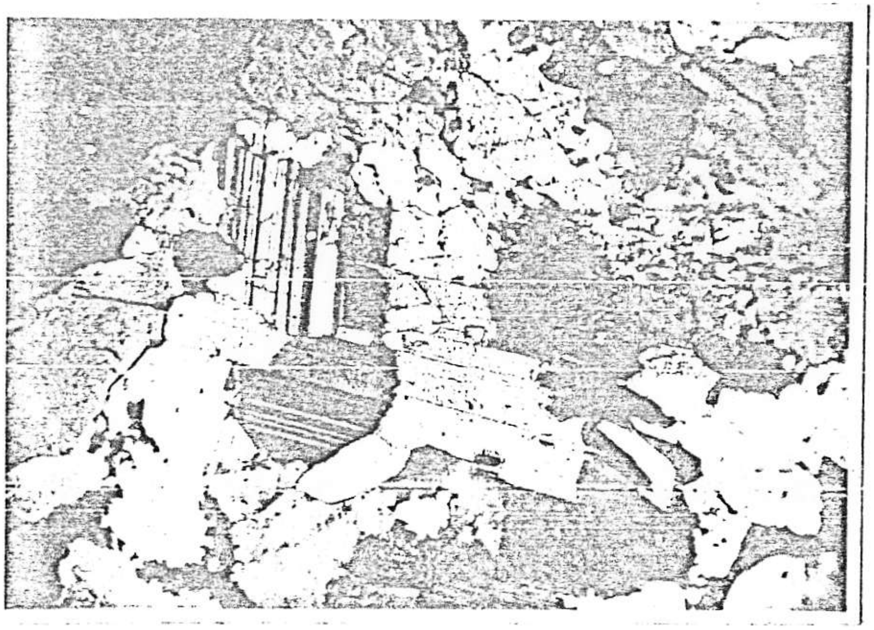


Figure 43. Photomicrograph of 2 T crossed nicols X 26. What might be replacement of biotite by albite as is shown by the albite crystal in the center of the photomicrograph. Note radio active halo around sphene crystal in the biotite crystal.

Figure 44. Photomicrograph of 2 T crossed nicols X 24. Pseudo-cataclastic texture and marginal corrosion texture of the feldspar crystals. Note curved and broken plagioclase crystal in lower left of the photomicrograph.

ny of the feldspars appear partially kaolinized. The ore minerals occur sseminated throughout the rock. The sphalerite is so dark in color, is hard to distinguish from the mafic crystals. The fresh surface of the ck is light grey whereas the weathered surface of the rock is a yellowish-own color and pitted due to the leaching of the sulphides.

n-section:

The composition of the rock is as follows; plagioclase 40%, artz 20%, microcline 15%, orthoclase 15%, myrmekite 4%, perthite 2%, otite 2%, sphene and hornblende 1%, and opaque ore minerals 1%. e plagioclase crystals showed, sections⊥a, X' (010) = 14° (average three determinations), An_3Ab_{97}, section⊥X, $Z_\wedge(010) = 72°$, An_0Ab_{100}. e majority of the feldspars are highly altered to clay minerals and ricite flakes. A few of the plagioclase crystals are almost completely placed by K-feldspar while others show only a few inclusions of K-feldspar d/or quartz (See Figure 46). Small wart-like myrmekite zones occur in aces at the contact between the K-feldspar and plagioclase crystals. e quartz is largely interstitial in occurrence along with the K-feldspar. e perthite consists of plagioclase in a microcline host. The biotite stals show anomalous birefringence colors. A few of the biotite crystals ibit a sagenetic texture (Figure 45).

Figure 45. Photomicrograph of 4 T crossed nicols X 76. Sagenetic texture displayed by the biotite grain in center of photomicrograph. Note large myrmekite pod in upper central portion of the photomicrograph, at contact of the perthite grain and plagioclase.

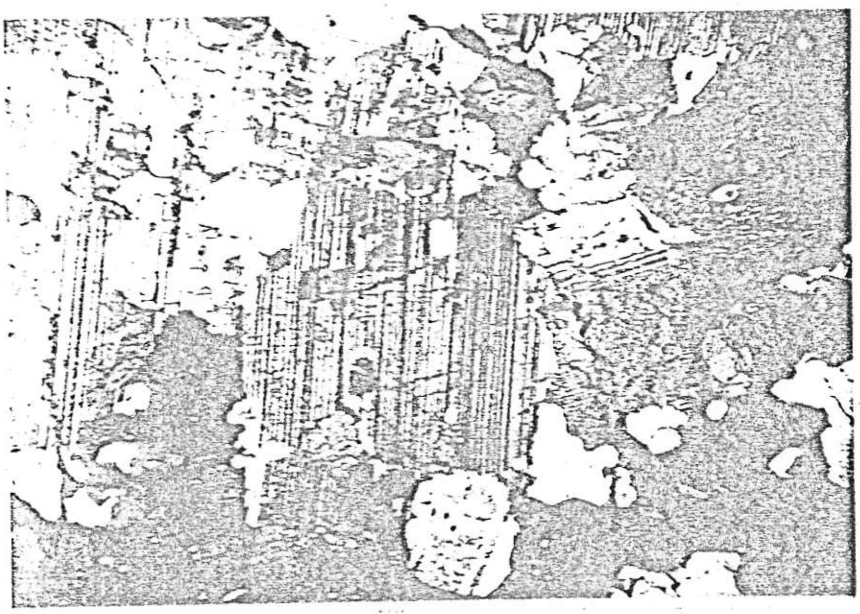


Figure 46. Photomicrograph of 4 T crossed nicols X 24. Plagioclase partially replaced by K-feldspar (grey color) and poikilitic inclusions of quartz (light color) in plagioclase crystals. Note myrmekite pods at contacts of K-feldspar and plagioclase and alteration of the feldspars.

Very fine grained opaque minerals occur along the cleavage planes of many of the biotite crystals. The determination of this very fine grained material is impossible, however, it is probably magnetite or rutite. The ore minerals occur disseminated throughout the thin-section and in places the sphalerite contains inclusions of plagioclase which have the same optical orientation as the plagioclase crystal bordering the sphalerite crystal. Much of the sphalerite displays a "zoned" texture.

Specimen - 5T

This specimen was obtained from rock which was 14" from the massive portion of an ore stringer. The rock is a medium grained (2-5 mm.) felsic rich rock which contains about 20% of biotite crystals in random orientation, some of which are very coarse grained (1-1.5 cm.). These large biotite crystals contain multiple poikilitic inclusions of plagioclase. The surface of the rock is nodular in nature due to the equant, subhedral and euhedral plagioclase crystals, Some of the plagioclase crystals are coarse grained (up to 1.5 cm.). The ore minerals occur disseminated throughout the rock and some occur as inclusions in large plagioclase crystals. The weathered surface is very rusty in spots but is otherwise a grey-white color.

in-section:

The rock has the following composition; plagioclase 50%, otite 35%, K-feldspar 10%, myrmekite 4%, opaque ore minerals 1%, apatite d sphene 1%. The plagioclase crystals showed, sections ⊥ a, X'∧(010) = ° (average of four determinations), $An_{30}Ab_{70}$. The feldspar crystals show rly abundant clay mineral and sericite alteration. Curved twin lamellae ur in a few of the plagioclase crystals. Some of the plagioclase crystals tain poikilitic inclusions of quartz and/or K-feldspar. One perthite stal with plagioclase in a microcline host, was visible in the thin tion. The K-feldspar occurs mainly as a deuteric interstitial mineral. ll myrmekite zones occur at some of the contacts between the K-feldspar the plagioclase. The biotite crystals exhibit an anomalous efringence and very rugged end sections which formed sutured contacts h the surrounding crystals. One large biotite crystal shows inclusions plagioclase and sphene (Figure 48). Very fine grained opaque minerals, ssibly magnitite and/or sphalerite, occur along the cleavage planes of of the biotite crystals (See Figure 47). In places, biotite crystals e visible between two fragments of plagioclase which display optical tinuity.

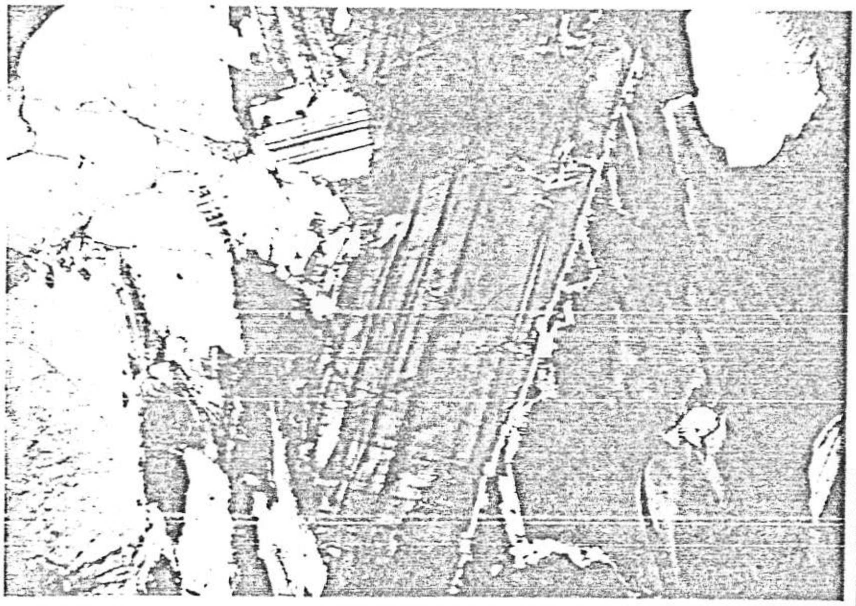


Figure 47. Photomicrograph of 5 T crossed nicols X 76. Very fine grained ore minerals along cleavage planes of large biotite grain. Note that the plagioclase fragment in the perthite crystal, in the upper left corner, has the same optical extinction as the plagioclase crystal to the right.

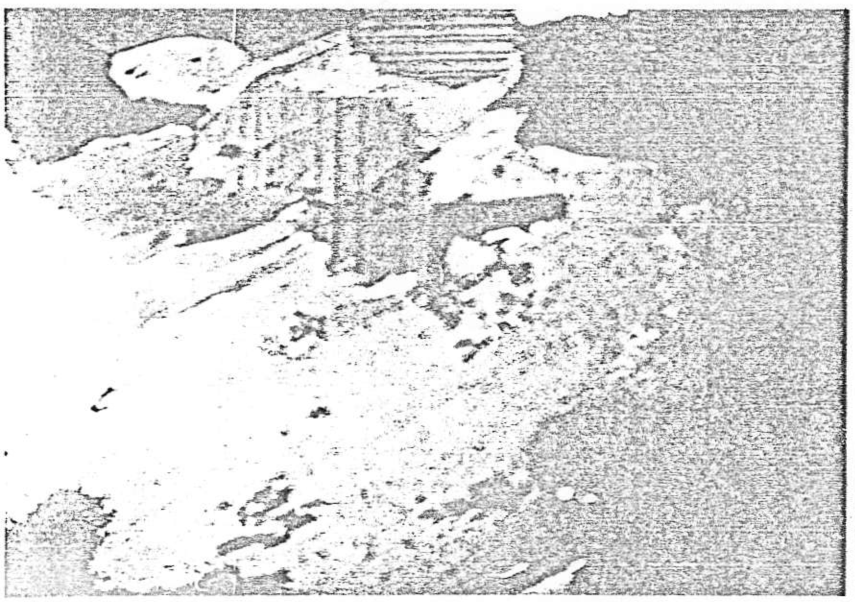


Figure 48. Photomicrograph of 5 T crossed nicols X 24. Ragged end sections of the biotite crystal. The inclusions in the biotite crystal (light grey) are of plagioclase fragments and sphene.

Most of the biotite crystals have radioactive halos around very small crystals of apatite that occur in these biotite crystals. The ore minerals are disseminated throughout the rock and at times appear to have replaced the crystals with which they are in contact.

Specimen - 7T

This specimen represents what is probably the granitic component of a migmatite and was obtained 5 feet from the massive portion of ore stringer. The rock is a medium grained (3-5 mm.) to coarse grained (up to 1.5 cm.) felsic rich rock. The weathered surface shows a banding nature, however, this banding does not continue throughout the whole specimen. It is probably the result of partially digested xenoliths. The mafics, which are biotite, show no preferred orientation and in places have feldspar crystals protruding into them. Most of the plagioclase crystals show a milky-white color due to a kaolinization. A few coarse grained chloritized hornblende crystals occur sporadically throughout the rock. The ore minerals of sphalerite, pyrite, chalcopyrite and galena occur disseminated throughout the rock. The chalcopyrite and the galena usually occur together. The weathered surface is an orange-brown color and pitted in nature. In places the rock is vuggy and some of the vugs are filled with a very soft mineral which may be a zeolite.

Thin-section:

The thin-section shows a composition as follows; plagioclase 40%, K-feldspar 25%, quartz 20%, chlorite 10%, sphene 2%, opaque ore minerals 1%, apatite 1%. The plagioclase crystals show sections $\perp x, z \wedge (010) = 75^{\circ}$ (average of 2 determinations), An_6Ab_{94}. The majority of the plagioclase crystals exhibit curved twin lamellae and in some instances the lamellae do not occur the whole length of the crystals (Figure 49). All of the feldspars show clay minerals and minute sericite flakes as alteration products. Some of the crystals appear 90% altered. Poikilitic inclusions of K-feldspar and/or quartz occur in some plagioclase crystals. Much of the K-feldspar occurs with untwinned plagioclase crystals and together display sutured borders which suggests a recrystallization character. Iron oxide alteration is also visible throughout most of the thin-section. Chlorite occurs with anomalous purple and blue colors and is probably the result of altered biotite. Euhedral shaped sphene crystals are present (See Figure 49) with one crystal containing an inclusion of plagioclase. Once again, the ore minerals appear to have replaced some of the crystals with which they are in contact. The contacts of the grains are lined with iron oxides (limonite) and/or chlorite. One sphalerite crystal contained small inclusions of feldspar. The quartz occurs in pods as is shown in Figure 50.

Figure 49. Photomicrograph of 7 T crossed nicols X 24. Highly altered plagioclase crystal with curved twin lamellae in lower left. A zone of mutual bordered quartz and K-feldspar grains are visible in upper right of photomicrograph Note euhedral crystal of sphene in upper central portion of photomicrograph.

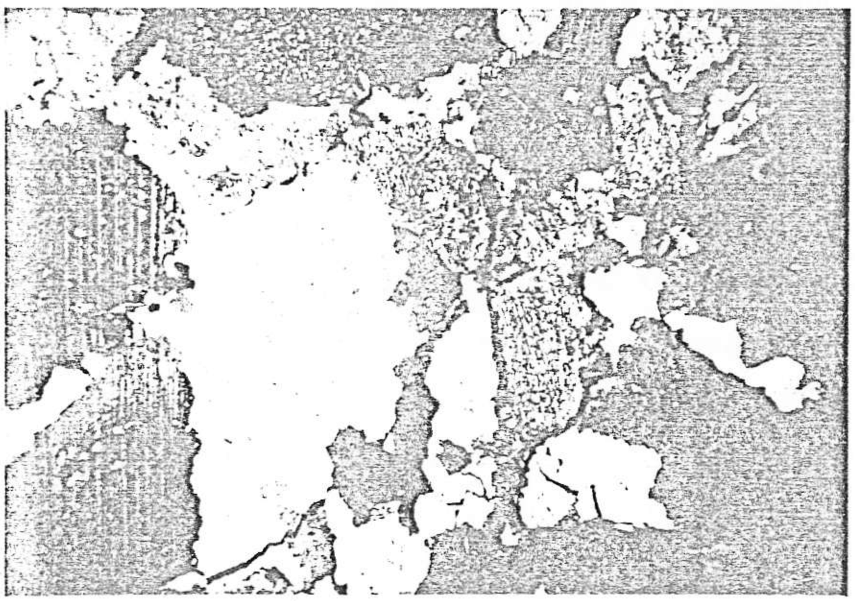


Figure 50. Photomicrograph of 7 T crossed nicols X 24. Quartz pod (light color) surrounded by highly altered plagioclase crystals. Dark grain in upper right of photomicrograph is a grain of sphalerite.

Specimen - 8T

This specimen represents a felsic rich rock occurring within 5 feet of an ore stringer. It is like specimen - 7T in that it is the granitic component of a migmatitic rock. The rock sample is medium grained (2-5 mm.) to coarse grained (up to 10 mm.) in texture and is composed essentially of plagioclase, K-feldspar and hornblende. The mafic crystals occur sporadically throughout the rock in zones of various concentration and often contain poikilitic inclusions of plagioclase. Some of the large plagioclase crystals also contain inclusions of mafic minerals (See Figure 51). The fresh surface of the rock shows patches of iron oxide stains. Finely disseminated pyrite and minor sphalerite occur throughout the rock. The weathered surface of the rock is a rusty to light brown color.

Thin-section:

The composition of the rock is as follows; plagioclase 50%, microcline 15%, K-feldspar 5%, quartz 5%, hornblende 15%, chlorite 5%, sphene 3%, opaque ore minerals 1%, and apatite less than 1%. The plagioclase crystals show sections ⊥ a, $X' \wedge (010) = 10^{\circ}$ (average of three determinations), $An_{27}Ab_{73}$. Some of the plagioclase crystals exhibit twin lamellae which occur only part way along the length of the crystal.

The majority of the feldspars appear relatively unaltered. Poikilitic texture is displayed by some plagioclase crystals which contain crystals of sphene, apatite and ore minerals. The microcline and orthoclase are mainly interstitial in occurrence but occassionally both replace the plagioclase. Quartz is also interstitial in the thin-section and the fractures throughout the crystals are filled with iron oxide (limonite). The ore minerals are disseminated throughout the rock, interstitially and as poikilitic inclusions. The majority of the mafics are moderately chloritized.

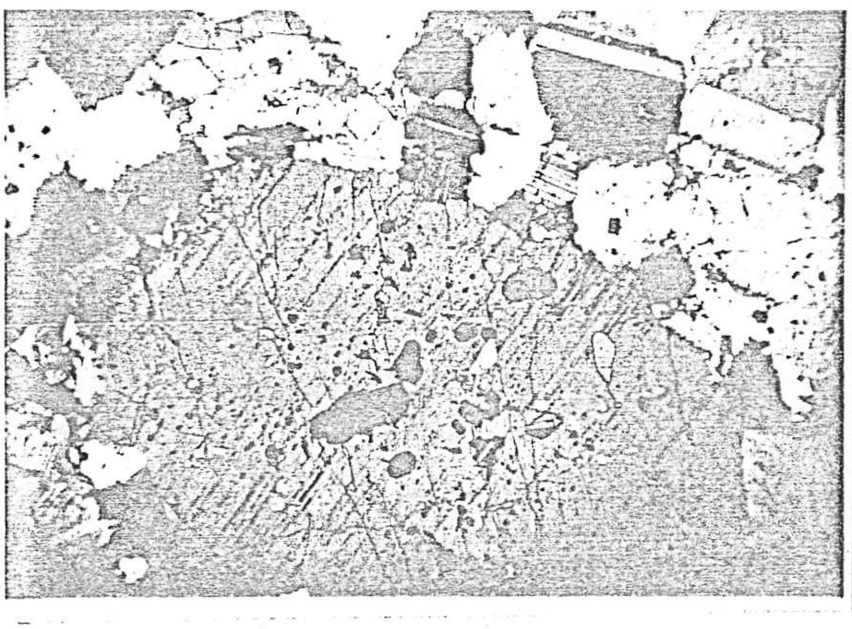


Figure 51. Photomicrograph of 8T. Crossed nicols magnification X 24. Large plagioclase crystals exhibiting sieve texture. The poikilitic inclusions are of; biotite, quartz, sphene, and sphalerite grains. Note marginal corrosion texture of the large plagioclase crystal. Pericline twinning is visible in plagioclase crystal in upper center.

V STRUCTURAL GEOLOGY

The following is a general summary of the structural geology of the northern portion of the Ecstall Septum as reported by P.B. Read, in 1958.

The layered rocks of the Ecstall Septum south of Big Falls Creek, which is 6 miles south of the thesis map-area, dip constantly from 65° to 85° northeast. However, north of Big Falls Creek the structure becomes more complex in part, and going from west to east there occurs a small anticline and syncline (about ½ mile between limbs) the axes of which plunge 30° to 40° southerly. The thesis map-area is located in the western limb of the above mentioned anticline. The anticlinal-synclinal structure is followed to the east by a larger anticlinal structure which was not mapped in its entirety during the summer of 1958. North of the thesis area the anticlinal-synclinal structure dies out and the foliation dips constantly 65° to 85° southwest, as it does for most of the area north of Big Falls Creek. The strike of the foliation in this area is normally 320° to 350°.

The faulting in this region consists of zones of brecciation 10 to 50 feet wide which are epidotized and silicified by the addition of quartz in thin stringers. The largest fault in the area was traced for some 13 miles and consists of an epidotized, and brecciated zone from 10 to 50 feet wide sometimes filled with a brecciated pegmatite.

Most of the faults strike parallel or close to the foliation and dip steeply. The age of the faults is post-granitic intrusions.

FOLDING

Large scale folding

The large scale folding directly associated with the thesis area is a small closed anticline which has an axis that plunges 30° south and an axial plane which is nearly vertical. The ore deposit in question is situated in the western limb of this anticline. In the crestal portions of the anticline the layered rocks exhibit a characteristic rectangular, blocky weathering.

Small scale folding

Small scale folding is represented by drag folds with distances of 2 to 10 feet between limbs. Four such drag folds were seen and measured in the close proximity of the ore map-area. Three of these drag folds produced incongruous results, with regards to the anticlinal folding, which averaged as follows; strike of the axial plane = 300°, dip of the axial plane = 90°, and a plunge of 20° north. The other drag fold gave congruous measurements as follows; strike of axial plane = 012°, dip of axial plane = 090°, and a plunge of o30° south.

Although only one congruous drag fold was seen, the author is convinced that the major structure plunges to the south rather than to the north as do the incongruous drag folds. Close examination of the crestal area of the anticline showed that the layered rocks dipped to the south. This fact along with visual interpretation strongly suggests a southern plunging anticline. The incongruous drag folds are probably post-anticlinal folding in nature and may be related, in part or whole, to the migmitization of the area which produced local and variable forces within the rocks. This would account for the variation in the distance between the limbs of the incongruous drag folds as the rocks in which each occurred were very similar.

FAULTING AND FRACTURING

Faulting

No major faulting was visible in the thesis map-area. However, faulting on a minor scale did occur. Four characteristic fault structures were sighted in the outcrop area below the ore map-area and they resulted in lineations across the outcrop. These fault structures showed a left handed displacement of the rock layering, from 6" to 2'. In most instances there has been no breakage of the rock layering, as it is continuous and readily traceable across the fault (Figure 52).

Other instances show silicification has accomapnied the faulting and in such case the layering of the rocks is not traceable across the fault (Figure 53). These fault zones strike 050° and dip 25° north. In places, dip slips of 2" to 2' were measured. These distances have probably been aided somewhat by weathering processes and are therefore not entirely representative of the actual dip slip movement. Minor horst and graben fault structures were also sighted in on locale and showed movement of 4" to 12" (Figure 54). This was the only occurrence of a relatively complex structure. It is certain that the faults of the thesis area are postmigmitization in age.

Fracturing

Sets of fractures occurred in the thesis area and in the large outcrop area to the east of the map-area. One set of fractures visible in the former area cuts the large pegmatite sheet-like body and is therefore post-pegmatitic in age. The strike of the fractures is 075° and they have a near vertical dip.

A system of prominent fractures was seen in the large outcrop area to the east of the thesis map-area and was traceable for 300' (See Plate F). Once again the fractures cut the pegmatite dykes in the area.

The attitude of the two fracture sets were as follows;

(a) $070^\circ/78^\circ$ SE

(b) 005°/vertical

These fractures displayed no "fracture filling" and little, if any, movement was discernable.

A large fracture which resulted in minor slumpage was sighted in the crestal area of the anticline (See Plate G). It had a strike roughly parallel to the strike of the axil plane of the fold and had a near vertical dip.

Plate F. Vertical fracture set cutting the eastern limb of the anticline. (Looking north.)

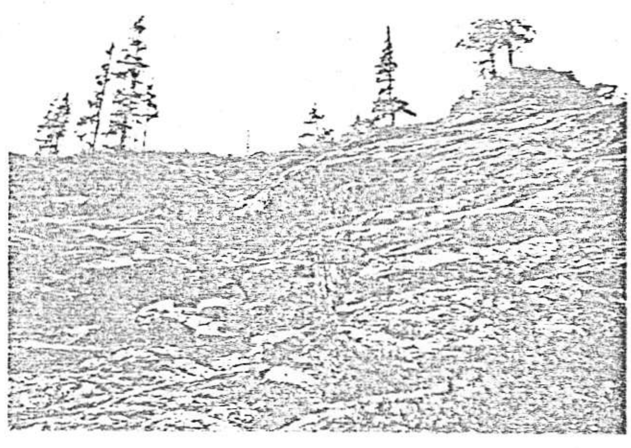


Plate G. Large fracture in crestal area of anticline. Note slumpage of the layered rocks.

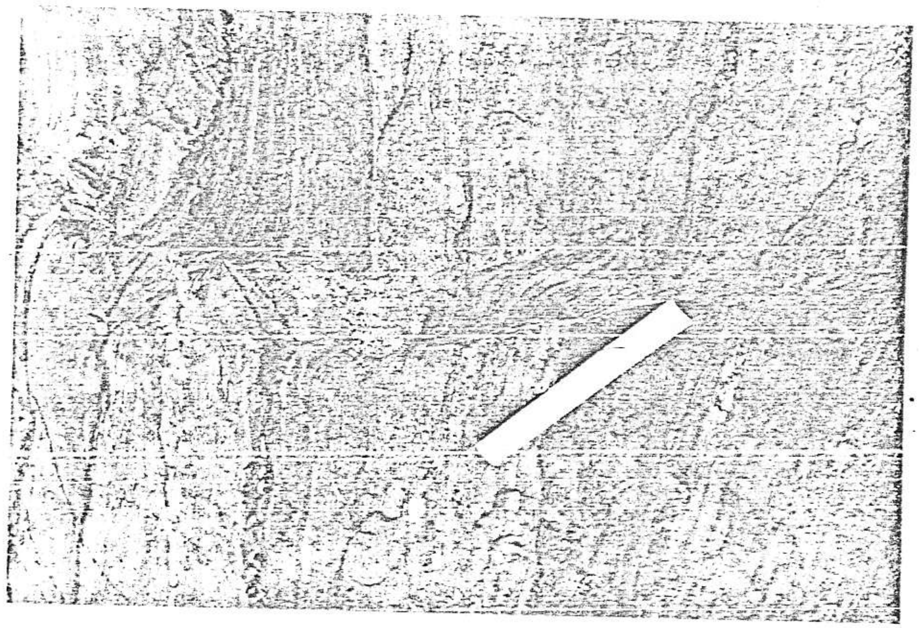


Figure 52. Flowage of rock along a fault zone.

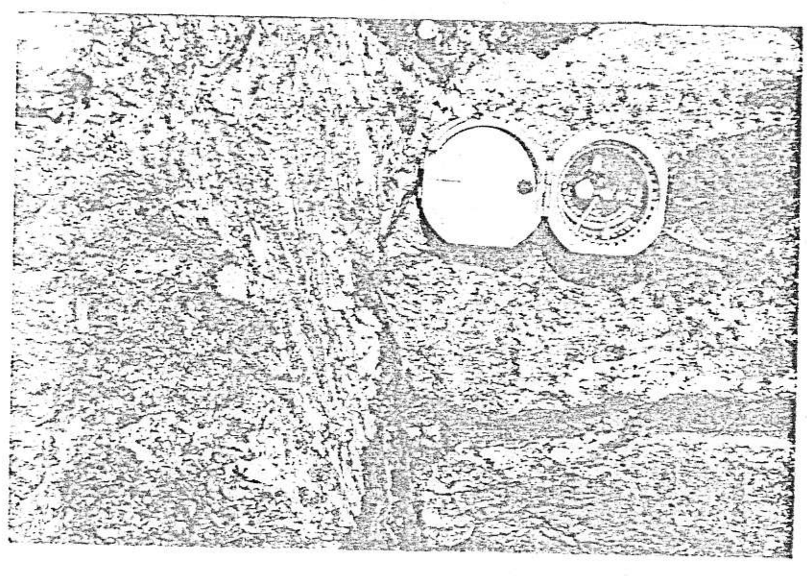


Figure 53. Silicified mylonite along a fault zone. (Fault zone is visible in vertical direction in the photograph.)

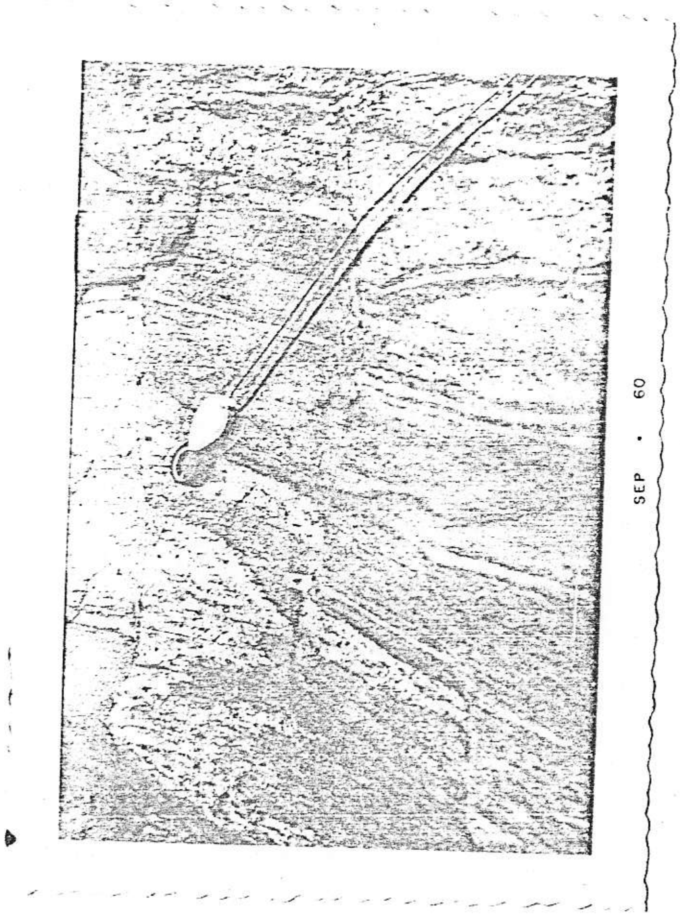


Figure 54. Shows minor horst and graben fault structures.

VI ECONOMIC GEOLOGY

The ore deposit consists essentially of sphalerite and minor pyrite, pyrrhotite, chalcopyrite, galena, molybdenite, and marcasite. Traces of gold and silver were obtained in assays. The sphalerite is dark brown to black in color which denotes a high iron content (See Plate H). The ore body occurs as a nearly massive central zone with stringers branching off from this zone roughly parallel to the layering of the country rocks as seen on the outcrop surface. These stringers vary in width from 4 inches to 8 feet and are composed mainly of sphalerite with minor amounts of galena, pyrite, pyrrhotite, chalcopyrite and molybdenum. Some of these stringers terminate in the upper part of the outcrop area while the rest are traceable into the overburden. The central portion of the ore body, as shown on the outcrop surface, has average surface dimensions of 40 feet by 25 feet. It contains a number of inclusions of relatively unmineralized country rock. The exact dimensions and contact characteristics of these inclusions was not determinable because of heavy oxidation of the outcrop surface in this area (See Plate J). It should be noted here that the northwestern half of the map area is partially covered with minor slide debris and surface runoff water. That, together with the fact that the outcrop surface is also obliterated in places as the result of gessan, made the mapping of the contacts of the ore stringers difficult throughout their length.

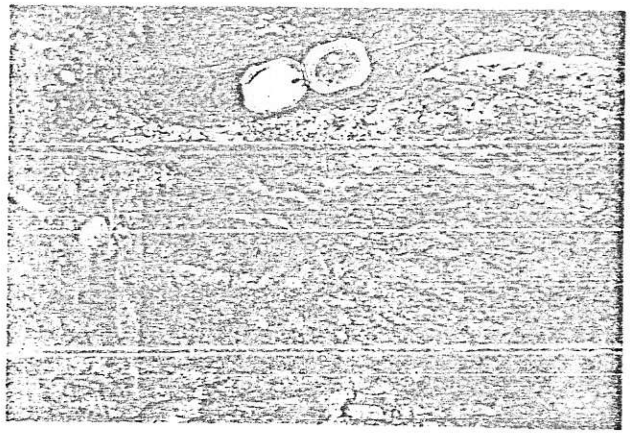


Plate H. Dark color of the sphalerite and formation of gossan on outcrop surface.

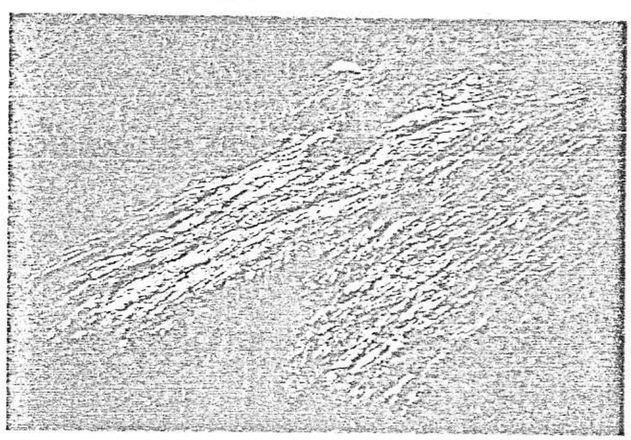


Plate J. Orange oxidation on mineral deposit outcrop area. Actual ore outcrop zone is in upper central right of the photograph (lined with ink). Orange coloured zone denotes the altered, sericite band of rocks.

The eastern contact of the ore zone is, for the most part, against the pegmatite sheet-like body. This is a relatively sharp contact and in a few places patches of pyrite and pyrrhotite are visible in the pegmatite at the contact. In other places, the contact of the ore zones with the country rock varies from sharp to rather diffuse. The rock on either side of the ore stringers does contain minor mineralization which decreases in amount away from the ore stringer. Lenses of almost 100% galena were seen in a few places throughout the ore zones. These lenses were never greater than 4 inches by 2 inches in dimension. Other than these few occurrences of galena, there was none in the more massive sphalerite zones. Most of the galena seemed to be located in the country rocks which bordered the ore stringers and in a quartz lense situated in the lower part of the central ore zone. In general the ore minerals, especially the sphalerite, are relatively coarse grained and always occur in quartzofeldspathic host rocks with the exception of the minor amount of sulphides that occur in the altered sericitized rocks. The feldspars of the host rocks are all partially altered and the quartz grains are rounded to subangular.

From the study of the rocks containing ore minerals it can be ascertained that the mineralization is interstitial in nature. However, in the more massive ore rocks the felsic minerals appear as poikilitic inclusions in the ore.

In certain areas the ore exhibits a banded nature and attitudes were measured from the banding. However, in the majority of cases the ore exhibits a massive texture. The weathered surface of the ore deposit is dark to reddish-brown in color. The unmineralized country rock located below the ore zone shows a yellow-brown to reddish-brown color as a result of the almost continual runoff water which passes over these rocks from the ore zone above. Upon closer inspection of the weathered surface, the felsic minerals (quartz and feldspar) stand out from the surface causing it to have a rough and pitted nature, as the ore minerals have been more easily weathered.

Much of the deposit has probably been removed by weathering and ice action, thus accounting for the short depth of the deposit and perhaps for the present unconformable nature of the deposit as was shown by the diamond drill holes.

The location of this ore deposit seems rather incongruous as according to present literature, few if any zinc deposits occur in the western portion of the Cordilleran Region, most of the zinc and/or lead deposits of the Cordilleran Region are concentrated in the eastern belt, near or beyond the eastern margin of the main zone of the large Coast Range Complex.[1]

II GEOLOGICAL HISTORY

Character of Metamorphism

The mineral assemblage of the metamorphic rocks in the thesis area is typical of medium to high grade regional metamorphism. The Ecstall Septum north of the Ecstall River contains low to high grade metamorphic rocks with a gradual change of metamorphism going northward. This change is gradational showing an interfingering of low and medium to high regional metamorphics.[1]

In the thesis area there is no evidence of contact metamorphism from the Coast Range Complex having been superimposed upon the regional metamorphism.

By thin section study of the metamorphic rocks from the area, it can be inferred that they have undergone medium to high grade metamorphism as the plagioclase normally has a composition of An_{20} to An_{30}. These rocks would then be classified in the almandine-amphibolite facies of regional metamorphism.[2] The mineral assemblage of hornblende-biotite-plagioclase suggests the original rocks were tuffs, tuffaceious sediments,[3] or highly magnesian feldspathic sediments generally lacking in quartz. The more gneissic rock which occur further to the west and east of the ore outcrop map-area suggest their original sediments were psammitic or somewhat feldspathic pelitic sediments.

1. Read, P.B. Summer Report, 1958.
2. Turner and Verhoogen, Igneous and Metamorphic Petrology, Second Edition, pp. 502-560, 1950.
3. Ob. Cit., Read, 1958.

The sericite schist of the thesis area is probably in part associated with the medium to high grade regional metamorphism of the area but has been superimposed upon by hydrothermal alteration relating to the ore deposit.

CHARACTER OF THE MIGMATITES

The migmatites of the thesis area are definitely associated with he Coast Range Complex in origin and time. The author would place the ormation of the migmatites, in accordance with Eskola, in the zone of njection and potash metasomatism. It is in this stage that the major ranitic intrusions may be regarded as mobilized migmatites in an dvanced stage of granitization, injected as mixtures of liquid and ystals, in a mushy condition.[1] The resulting migmatites are mainly terites, such as Sederholm has described from Finland. The general rallelism and straightness of the injected granitic bands indicates that ior to injection of the magma, the dominant characteristic of the rock s fissility rather than plasticity. The probable ease with which the tures of liquid and crystals were injected may be related to the ep dip of the layered rocks into the edge of the Coast Range Complex this particular area. This would account for the presence of the matites on a local basis rather than on a regional basis.

urner and Verhoogen, Igneous and Metamorphic Petrology 1960

Folding of the rocks during the periods when the magmatic solutions and emanations (syntectonic intrusions) were given off and the migmaties developed seems essential, as no contact metamorphism was visible, which would be the result if the magma entered afterwards.[2] Further evidence of folding during migmitization can be interpreted from the common curved nature of many of the feldspar twin lamellae.

The advance of the injection material into the country rock would be attended by phenomena of various sorts, such as impregnation of the wall rock, solution and removal of some of the components of the wall rock, and reactions with the minerals with which the solution comes into contact.[3] In short this may be classed as contact metasomatism. Three principal types of metasomatism were recognized from thin section study of the migmatitic rocks of the thesis area. These were; alkali metasomatism, kaolinization, and sericitization.[4] Alkali metasomatism was seen in the formation of myrmekite and perthite. Both involved metasomatic exchange of alkalis; the myrmekite being formed at the contacts of the K-feldspar and plagioclase where the replacement of the potassium in the K-feldspar by the sodium and calcium of the plagioclase resulted and the liberated silica formed the quartz of the myrmekite;[5] perthite was developed as the result of replacement of the microcline by plagioclase.

2. Barth, T.F.W., Structural and Petrologic Studies in Duchess County, New York, Part II, Geological Society of America Bulletin, Volume 47, pp. 803-832, 1938.
3. Fenner, C.H., The Mode of Formation of Certain Gneisses in the Highlands of New Jersey, Journal of Geology, Volume 22, pp. 544-612, 1914.
4. Turner and Verhoogen, Igneous and Metamorphic Petrology, 1960.
5. Anderson, G.H., Granitization, Albitization, and Related Phenomena in the Northern Inyo Range of California-Nevada, Geological Society of America, Volume 48, pp. 1-74, 1937.

Evidence of alkali metasomatism was also sighted in the field, where mafic rich lenses were lined with feldspars and contained inclusions of same within (Figure 55). The kaolinization and sericitization formed as the result of hydrothermal metasomatism of the feldspars. The exact amount of feldspar alteration related to hydrothermal metasomatism is undeterminable as this may have been superimposed upon as the result of hydrolytic breaking up of the feldspars in weathering processes.[6] Some iron-magnesia metasomatism may also be interpreted from the character of the migmatitic rocks, as the contacts between the granitic component and the metamorphic host rock are often lined by a mafic rich (hornblende and/or biotite) layer (Figure 56). In one instance hornblende pods were seen at the contact between granitic lenses and the metamorphic country rock (Figure 57). Other evidence of metasomatism (replacement) as seen in thin sections are; intergrowths of albite in orthoclase; core-and-rim structures where some of the feldspars, both K-feldspar and plagioclase, are surrounded by rims of albite; marginal corrosion structures, where grains of potash feldspar (microcline and orthoclase) which have the appearance of having been corroded along the margin; and pseudo-cataclastic texture.[7]

6. Ob. Cit., Turner and Verhoogen, 1960.
7. Ob. Cit., Anderson, G.H., 1937.

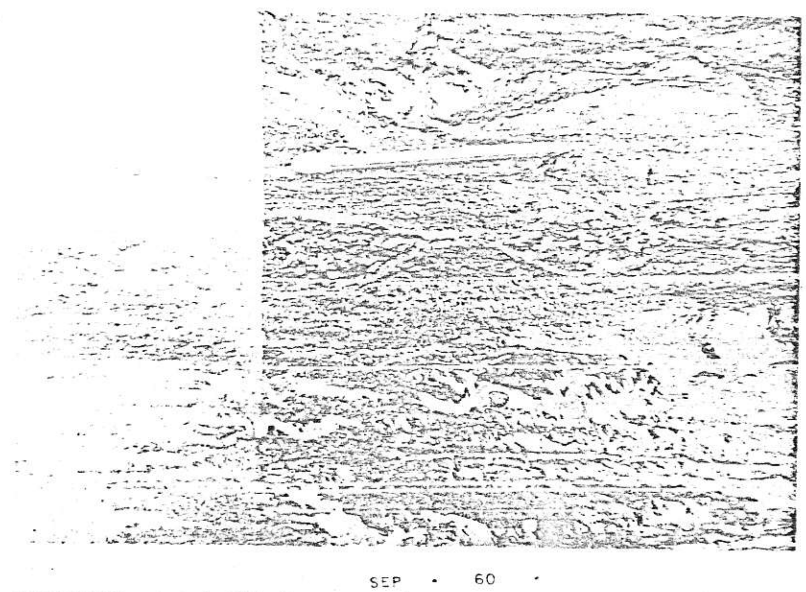


Figure 55. Mafic rich lenses bordered by feldspar and containing inclusions of feldspar.

Figure 56. Mafic rich layer conformable with the granitic component of the migmatites.

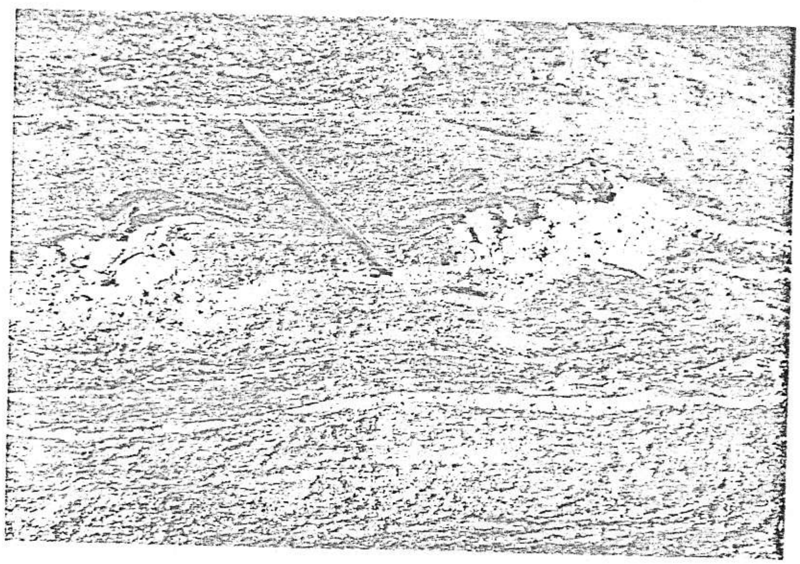


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Figure 57. Hornblende pods at contact of granitic lenses with metamorphic country rock.

In migmatite zones bordering deep-seated plutonic intrusions, there is complete gradation between metasomatic metamorphism and reactive assimilation, in which metasomatism also plays a part but which falls into the category of igneous rather than metamorphic phenomena.[8]

The origin of the ptygmatic folding was primary in origin,[9] as injection occurred during the period of active deformation. This can be further confirmed as the veins are conformable with plications in the country rock, which is in accordance to Buddington. The main occurrence of the ptygmatic folding in the limbs of the anticline is reasonable as these are the high pressure areas of a fold where plastic flow structures are best developed.

CHARACTER OF THE PEGMATITES

The composition of the pegmatite intrusions, K-feldspar, perthite, plagioclase and quartz, with minor muscovite (sericite), shows that they are to be classified as simple pegmatites. All of the pegmatitic bodies were continuous over their entire length as seen on the outcrop surfaces and showed steeply dipping and sharp contacts with the country rocks. Consequently they were not formed by replacement but rather are the result of magmatic intrusions.

8. Ob. Cit., Turner and Verhoogen, 1960.
9. Godfrey, J.A., The Origin of Ptygmatic Structures, Journal of Geology, Volume 62, 1954.

They are definitely post-migmatitic and post defromation in age. Their origin is magmatic and in particular from the residual, water-rich silicate melt of the Coast Range Intrusives.

The pegmatites of the thesis area are the type that commonly occur as swarms of dykes, veins, or flat lenses within or at the margins of batholiths and stocks of granite and granodiorite.[1]

ORIGIN OF ANTICLINAL FOLD

The small anticline of the thesis area was probably formed as the result of the Coast Range Complex intrusions. The west limb of the anticline is in contact with the western edge of the Coast Range Batholith while the eastern limb borders against a narrow Coast Range intrusion. Inward forces from these granitic zones to the west and east accompanied by upward forces from below, as the result of a "rising" batholith, were the most likely components which developed the anticlinal fold, However, the anticline may also have developed as the result of only one of the above mentioned forces. That is, the eastern granitic intrusion may have forced the layered rocks against the western edge of the Coast Range Complex thus causing the rocks to bow upwards. On the other hand, upward force alone of an intruding cupola would also cause an anticline to form in the above layered rocks. The foldi[illegible]wever it occurred, was contemporaneous with mi[illegible]tization and p[illegible]ion in age.

1. Turner and Verhoogen, Igneous and Metamorphic Petrology, 1960.

ORIGIN OF THE MINERAL DEPOSIT

The mineral deposit is probably related to the pegmatitic intrusions and is therefore post-migmatization and post-folding in age. During the late stages of crystallization, associated with the intrusions of the Coast Range Complex, the magma became rich in volatiles and residual liquids which were then intruded, in part, to form the pegmatite dykes. It was during this stage that the mineralizing solutions accompanied the pegmatitic solutions and were deposited in the western limb of the anticline along with the largest pegmatite body, the sheet-like mass. The main central portion of the mineral deposit in contact with the large sheet-like body of pegmatite definitely suggests a direct relationship between the two. Most of the mineralizaing solutions probably travelled upward from this area of the anticline as evidenced by the numerous stringers which project up the outcrop face from the larger central mass. These solutions travelled along the granitic portions of the migmatites as they afforded the greatest porosity and permeability as a result of cataclastic breakage of many of the crystals during crystallization which was contemporaneous with deformation. The passage of the mineralizing solutions through the granitic portions of the migmatite caused many of the felsic mineral grains to become rounded as was displayed by the specimens containing ore minerals.

Hydrothermal alteration (sericitization and kaolinization) was active during the deposition of the mineral solutions. This alteration was mainly the rocks higher up or above the rocks containing the mineralizers. Consequently this would account for the zone of altered, sericitized rocks situated in the "younger beds" portion of the anticline.

It is probable that the mineral deposit was much larger in extent than it is at present. Glaciation was most likely the cause for erosion of much of the deposit.

This mineral deposit is definitely different from other deposits situated in the Ecstall Septum. All of the other deposits of the Ecstall Septum are mainly massive pyritic bodies with minor amounts of copper, zinc, silver and gold, and are associated with sericite schist zones. There is evidence to suggest that these are possibly syngenetic types of deposits. Whereas the mineral deposit in question is definitely hydrothermal in origin.

CONCLUSIONS

The metamorphic rocks of the thesis area, which have undergone medium to high grade regional metamorphism and are classed in the almandine-amphibolite facies, were derived essentially from psammitic sediments (greywackes) and from somewhat feldspathic pelitic sediments. Some possibly were derived from tuffs or tuffaceous sediments. These sediments and volcanic rocks belong to the Pacific eugeosynclinal facies of the great Cordilleran Geosyncline developed during the Paleozoic-Mesozoic time. The orogeny involved in the formation of the above metasediments is that of the emplacement of the Coast Range Complex during two or more tectonic epochs that span an interval of geological time from Early Jurassic to Tertiary.

The migmatites of the thesis area are those of the border zone type and may be classified as arterites or injection gneisses as these terms are descriptive of their origin. Contact metasomatism accompanied the formation of the migmatites and as a result it is probable that some of the migmatites with discontinuous granitic components were formed in this manner. The time of origin of the migmatites was during the late stages of coalescence of the upward-migrating magma of the Coast Range Complex.

Crystallization of the migmatites was at the same time as the folding. This is shown by the induced stress twins of the plagioclase feldspar, the undulatory extinction displayed by some of the quartz crystals, the broken nature of the mafic crystals, and the pseudo-cataclastic texture.

The mineral deposit is classified, according to Lindgren's classification, as a mesothermal deposit and was associated with the ydrothermal stage of the pegmatitic intrusions. Exsolution blebs of halcopyrite in the sphalerite, as seen in a polished section, suggests he temperature of the deposit at the time of formation was in the icinity of 350° - 400° C. The mineralizing fluids were best received the granitic components of the migmatites because of their relatively gh permeability and were deposited interstitially. The pervious nature the migmatites resulted from the development of pseudo-cataclastic xture during deformation which was contemporaneous with migmatization. e anticlinal fold produced a structural trap which localized the ore.

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