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GEOLOGY OF THE ECSTALL MINE

ECSTALL RIVER, B.C.

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I. INTRODUCTION

During the summer of 1952 a geologic study was made of the region around the Ecstall River and of the mine itself. The chief purpose of the investigation was to extend the known ore reserves and to determine those areas which might be favorable for mineralization, as well as a general prospecting of the area. Such a study, in the detail in which it was undertaken, had not been done before.

The greater part of the regional geology was mapped by W. Holyk with the assistance of Messrs. D. Lowrie and D. Webster of the University of British Columbia. Mr. Holyk has submitted his report on the geology. I assisted also in the regional mapping and undertook a detailed study of the mine.

This report, then, concerns the results of this study and my conclusions regarding mineralization and structure in the setting of the regional geology.

The regional geologic map enclosed with this report has been compiled from the field sheets of W. Holyk and my own notes. The map of the east plateau is based on the work of Messrs. Lowrie and Webster. All other maps and diagrams are my own.

The work of W. Holyk and these two men is gratefully acknowledged.

Mr. E. E. Mason, through his long knowledge of the Ecstall River, provided valuable assistance and advice.

II. GEOGRAPHY

The area of the Ecstall River, British Columbia, lies in the belt of Coast Range mountains bordering the Pacific Ocean. These mountains are high and rugged and are divided by many deep U-shaped valleys and fjords. The slopes are long and steep and rise almost vertically to sharp peaks and ridges. On the floors of the valleys and partially up their flanks, underbrush and tall conifers grow in abundance due to the annual rainfall of 180 inches.

Outcrops in the valleys do not exist, and on the plateaus immediately below the uppermost peaks, where the vegetation is not so plentiful, the moss, grass, and soil further obscure the geology. In a few cases errosion has laid bare the outcrops on these plateaus. The only rock exposures remaining, therefore, are the steep bluffs, which are largely inaccessible, the beds of small creeks and streams, the shores of small lakes, and the upper ridges.

Geologic interpretation is, therefore, difficult.

III. GEOLOGY

A. General geology of the Coast Ranges.

The main rocks in the Coast Ranges are those of the large batholithic intrusions composed chiefly of quartz-diorite and granodiorite. They range in age from Upper Jurassic to Upper Cretaceous. The batholiths have intruded sediments and volcanics of unknown age and left them as residual roof pendants. These intruded rocks have been intensely metamorphosed and folded; as a rule the older formations are more deformed and have dips exceeding 60°, whereas the younger formations are less deformed and altered. Also, as a general rule, those sediments which are nearest to the batholiths are more metamorphosed and disturbed than those farther away.

The general strike of all the rocks is northwest, and the elongation of the batholiths conforms to this direction (Armstrong, 1946).

B. The Ecstall River.

1. Distribution and character of the rocks.

a. General.

The rocks of the Ecstall River consist of a complex of metamorphic rocks believed to be sedimentary in origin. They form a narrow belt approximately four miles wide between batholithic intrusions of quartz-diorite and granodiorite. The belt strikes in a northerly direction and has been mapped as far as Red Gulch Ridge to the north and Balan Creek to the south, but the metamorphics are known to extend farther in both directions.* These rocks probably represent a roof pendant characteristic of the Pacific Coast Ranges.

It should be mentioned in the beginning that in this part of British Columbia there is a paucity of outcrops except in the few places mentioned in the geographic description of the area. This must be kept in mind when any extrapolation is done on the continuity of various rock units from exposure to exposure. In

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* W. Holyk's report contains good descriptions of all the rock types found in the area, and are to be found in his Appendixes A and B.

most areas where there is a high degree of metamorphism, the exposures are more plentiful and the structure of the region, if any, is more apparent. It should be further emphasized that the regional geology was mapped on a scale of 1000 feet to the inch, and that the largest outcrops averaged about five feet in width. On this basis, therefore, an exposure on the map would be represented by .005 of an inch, or very much less than the width of a thin pencil line. Of course, this is inherent in any geologic mapping on a large scale, but at the Ecstall River this point assumes more importance. Geologically it is extremely difficult to extend single formations over any great distance.

Holyk points out that, broadly speaking, the belt of metamorphics can be divided into two units: The Johnson Lake group and the Mine group. The Johnson Lake rocks are largely confined to the drainage of that lake and to the south of it, and the Mine group of rocks lie on the western side of the belt.

The Johnson Lake rocks are more easily mapped in the field because of the small number of lithologic units. Quartzite, argillite and hornblendite are the predominate rocks. They form well-defined bands and do not vary a great deal from their normal appearance. The structure, therefore, is more apparent in the aerial photographs and is more easily discernible in the field.

The Mine group of rocks has a decidedly different character. The main rock types are chlorite schist and quartz-chlorite schist (both with varying amounts of biotite, hornblende and garnet), quartzite, argillite and limestone. In addition to these are a host of rocks which are varieties of the standard types. They are difficult to place in any one group. Furthermore, these varieties occur as a banded complex with the basic units. The result is to make the geology difficult to interpret.

One example will point out this problem. Examination of the regional geologic map shows that there is a fairly continuous outcrop across the strike on Red Gulch Ridge. The lithology and sequence of rocks are easily identified. However, on the west plateau and on the slopes south of the ridge, the same rocks and their relationships to each other cannot be found.

Igneous rocks, mainly basic in composition, are intruded into the Johnson Lake and

Mine groups. One set is parallel to the strike of its host rock and has been metamorphosed to the same degree. The other set cuts across the cleavage and schistosity of the host rock and is unmetamorphosed. This latter group, therefore, is the younger, and antedates the regional metamorphism and deformation.

A group of rocks, which can neither be placed in the Johnson Lake rocks nor the Mine rocks, is located around the contact areas of the batholithic intrusions. The sediments appear to have been "granitized." The texture is strongly gneissic and the rocks are crosscut with a network of pegmatite dykes. Large limestone lenses with no continuity are frequent. The impressive thing about the rocks is that they have been folded, contorted and bent into such a variety of shapes and forms that the mapping of them would be almost impossible. The schistosity of the rocks is parallel to the axial planes of the folds, and since the folding has no regularity, neither has the direction of schistosity.

b. The "granite" gneiss.

Two theories on the origin of the "granite" * gneiss have been advanced. The rock was originally either igneous or sedimentary. Thin sections of the rock from various localities indicate that the rock is sedimentary. Examination of the hand specimen finds proponents for both theories, while the field relationships are equally uncertain. I favor a sedimentary origin for the rock.

The bearing the origin of the rock has on the geology is found in the structural implications. Should the rock be igneous in origin, then its shape, size and extent can be accounted for. However, if the rock is sedimentary, then its form must be derived through deformation. Since all of the metamorphics at the Ecstall River are, in my opinion, highly deformed, the granite gneiss, being sedimentary, is no exception.

The rock is gneissic in texture, and has varying amounts of biotite and chlorite.

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* Although the adjective "granite" alludes to an igneous origin for the rock, it will be retained in this report but with the quotation marks deleted.

These platy minerals have a rough parallelism. Quartz is the predominate mineral and feldspar is found in small quantities.

The granite gneiss is easily distinguished in the field and for this reason can readily be traced from exposure to exposure. It lies off the hanging wall of the two main sulphide lenses and continues erratically some 500 feet north of the northern pyrite body. South of the Third outcrop it begins again, and near the headwaters of Red Gulch Creek it swells to an enormous size. On the high bluffs farther north it completely disappears for no trace of it can be found on Red Gulch Ridge.

Discordant strikes and relationships are noted. Immediately below the Third outcrop the gneiss strikes N. 40° E. whereas the neighboring schists strike N. 05° E. On the north fork of the second creek north of the Third outcrop on the west side of Red Gulch, the granite gneiss was found to alternate with bands of chlorite schist; on some of the exposures the bands were up to 5 feet in width. The contacts were fairly well defined and had a strike of N. 10° W. On Swinerton Creek the gneiss occurred as large irregular lenses with chlorite-biotite schist "flowing" around the lenses. Directly north of the North Lens, on the floor of Red Gulch Creek, the gneiss had been broken into large blocks and the chlorite schist folded around the pieces (Illustration No. 6). Other exposures of granite gneiss were noted in the area of Thirteen Mile Creek, but these are more likely associated with the contact areas of the batholith and are not exactly the same in appearance as the gneiss described above.

c. The "blebbed" gneiss.

A rather curious digression from the usual granite gneiss was observed below the Third outcrop and near the regular granite gneiss. "Blebs" or eye-shaped pieces of gneiss lie in the biotite-chlorite schist like a school of fish. The schist "flowed" around the pieces and they became more numerous closer to the solid granite gneiss.

Such occurrences have been described elsewhere. Vayrynen (1939) writing on the Outokumpu region in Finland describes a "blebbed" gneiss in rocks very similar to those found at the Ecstall. He ascribes its formation to strong tectonic movements where the mobility is great, and where there is a connection with pegmatite and aplite injections. His rock is partially igneous in origin and this rather favors an igneous theory for the granite gneiss. Other writers have reasoned that this type of rock is purely tectonic in origin (the Alpine school), has been formed from phyllites through igneous injection (V.M. Goldschmidt) and is created by the shearing of porphyritic rocks (C.W. Carstens). I favor the tectonic origin for the rock and believe that it was formed through strong movements while the rocks were in the process of metamorphosis.

2. Structure.

a. Shearing and alteration.

In the field of structural geology there are two types of shearing recognized: first, shear breaks; and second, fracture and brecciation.

Shear breaks result where the rock is under such pressure that it does not expand readily and deformation approaches flow.

Fracture and brecciation result where the rock fails under stress and expands; the rock breaks under light load.

The shear zones at the Ecstall River belong to the first type-shear breaks.

The sericite shears find their greatest development in the Mine group of rocks. They are often localized along argillites, but this is not a general rule. They are composed of sericite principally, and pale green mariposite (identified by W. Holyk). The widths and strike lengths vary. The widest zone mapped is the so-called Red Bluff shear found on the south flank of the west plateau; it is 100 feet wide but has a strike length of only a few hundred feet. It cannot be correlated across the Ecstall River, nor can it be located northward on the west plateau.

The schistosity within the shear zones parallels the cleavage in the neighboring rocks, but it is thought that in some cases the zone may cut across the schistosity of the other rocks at a very small angle, although there is no evidence for this. More usually the sericite schist is highly foliated: small drag folds, z-folds, and large folds up to five feet across the limbs are found, and within the main bodies of sulphide, bands of sericite schist have been folded and contorted.

The sericite is an alteration product, and not only do the zones represent areas of stress but also alteration. Alteration and shearing appear to be interdependent. The shear zones represent lines of high pressure and they have provided suitable channelways for ascending hydrothermal solutions which altered the rocks. The alteration process was undoubtedly complicated and resulted in a thorough sericitization and the formation of sericite schists with small percentages of pyrite. In the formation of the sericite, FeO, MgO, and CaO were liberated and partly migrated into the surrounding rocks to form additional plagioclase, hornblende, and basic feldspar. This would account for the higher concentration of these minerals in the rocks around the main orebodies.

During alteration the zones remained under pressure and it was through these same channels that the ore solutions travelled. It is possible that the tectonic forces shifted and the sulphides favored only certain shears, or the solutions favored a sericitized host rock in conjunction with a change in structural deformation.

From the relationships of the massive sulphides to the sericite schists it is evident that the altered rock was formed before the solutions deposited the ore, although further alteration took place during the ore emplacement.

b. Structural features.

The structural history of the Ecstall River has followed closely the intrusions of the large batholiths. Originally there was a series of unmetamorphosed sediments. The sediments may have been disturbed prior to the intrusion of the batholiths, but it is more likely that they were tilted, folded, metamorphosed and intruded at the same time. The important point is that at the Ecstall River <u>all</u> the intruded rocks were metamorphosed and deformed. In no case can they be divided structurally according to the two lithologic groups outlined.

This deformation is most apparent in the contact gneisses previously described, and more easily seen because of the lack of vegetation on the upper ridges.

The Johnson Lake group, as has been pointed out, is easily identified because of the simplicity of the lithologic units. At the top of Red Gulch Ridge the group is narrow and has a north strike. Extending to the south it fans out to a greater width and complexity and strikes northwest. On the top of the east plateau, where there are numerous outcrops, the rocks are complicated by drag folding (see map of east plateau). On the east side of the plateau the rocks dip to the east and folds plunge to the north; on the central part of the plateau the dip is west and the plunge north; and on the west side, or Red Gulch Creek, the rocks dip east and the structure plunges south. The structure around the orebodies follows this latter pattern.

Farther south from the plateau, following the Johnson Lake group across the shores of the Lake and into the mountains south of it, the strike of quartzites vary widely. On the edge of the intrusive a large fold has been mapped that measures several hundreds of feet across its limbs. In the first creek south of the Lake, a wide argillite band is seen expanding to the south and decreasing to the north.

These are but a few examples to bring to the attention of the reader that the Johnson Lake group has been deformed and folded to a high degree.

Although folding in the Mine series is not as readily apparent, nevertheless, there are discordant strikes, evidences of folded structures, and obvious folding in the orebodies and in the rocks surrounding them (refer to the underground sheets and the surface map of the two lenses).

A few localities in the Mine group will serve as examples of deformation in the series. The granite gneiss has already been discussed.

Small drag folds bearing east-west have weathered out immediately above the Falls, but the schistosity in the rock is north. On the footwall of the Five Foot vein lying to the east of the two lenses, the chlorite schist is contorted. On an exposure of quartz-biotite schist on the west side of Red Gulch Creek a faint lineation in the rock strikes N. 40° E., but the cleavage strikes north. In Phoebe Creek a large fold was visible on the wall at elevation 665 feet, and the rock exposures in the Creek varied from N. 05° W. to N. 40° W. A folded quartz vein striking east lies to the east of the South Lens and similarly folded quartz veins are found throughout the area (Illustration No. 7). Although these quartz veins are clearly younger than their host rock, they are still indicative of a differential movement which produces folding.

The cleavage or schistosity in all the rocks vary widely. In some cases it actually follows the folded contacts of the different rock units, but usually it is parallel to the axial planes of the folds. Underground, where the mapping was done in greater detail, shearing occurred parallel to these axial planes (Illustration No. 5).

Shearing and schistosity are more highly developed in the Mine group of rocks, since they are generally more incompetent than the Johnson Lake group. It is in this rock group, therefore, that ore deposits are likely to occur.

I suggest that the Mine series of rocks were folded at the same time as the Johnson Lake group, although perhaps not to the same degree. It is likely that the Mine group, under continued pressure, folded, but was more likely to shear through failure of the rocks, and that the schistosity has been superimposed on an already folded structure.

This does not in any way give a clue to the over-all structure. There is a suggestion, however, that the Johnson Lake group has been folded in a tight syncline with its eastern limb plunging to the south and its western limb plunging to the north; the Mine group, which should repeat to the east of the axis of the syncline, has been taken away by the intrusion of the diorite. Whether this is the case or not would most easily be determined by further mapping to the north across Lockaby Creek-a valley almost impossible to get into from Red Gulch Ridge.

The over-all structure becomes further obscured by the question of whether the drag folds seen are, in fact, flowage folds. If this were the case, the folds would pitch in the opposite direction from the major structure.

The mapping was done on only a reconnaissance basis. The rocks are exceedingly complex in their structure, and there is, at present, no way of determining the larger picture without further detailed study; but, even then, I doubt, with the outcrops as few and far between as they are, that a definite conclusion could be reached.

Therefore, no relationship can be found, at this time, between the ore deposits and the regional structure. The structural interpretation of the two main lenses is only local in scope and will be dealt with in the following section.

IV. ORE DEPOSITS

A. General Character and Situation.

The relationship of the two main orebodies at Ecstall River are best shown by the accompanying isometric diagram. The average strike is N. 05° E. and the dip about 80° E. The red color represents the North Lens, and mauve its hanging wall stringers; the limits of the North Lens are accurately shown to scale, but the orebody has been arbitrarily cut off at 500 feet above sea level whereas some of its outcrops lie at over 600 feet above sea level. The South Lens is shown in orange; it extends farther to the south than drawn and its depth is unlimited; however, the southward plunging north pinch-out has been determined by diamond drilling and structural interpretation. Near the surface the two lenses have a considerable overlap, but with depth they become farther apart.

Other mineralization of interest includes the Third outcrop, a five-foot vein of massive sulphides exposed at the surface and to the east of the two main lenses, and the Frizzell outcrop.

The Third outcrop, lying near the headwaters of Red Gulch Creek, showed up to 7 feet of sulphides exposed at the surface. The outcrop was drilled extensively within the capabilities of the small X-ray drill and mineralization proved to be spotty and intermittent. However, it should be remembered that drilling intersections were around 1000 feet above sea level and the South Lens is known to extend 1000 feet below sea level. The depth-range for mineralization in the shear zone has hardly been explored therefore.

The five-foot vein was explored underground with two drill holes, but only sericite shear and disseminated pyrite were found. The shear at the surface dies out to the north against the granite gneiss which lies between it and the North Lens, but continues to the south.

Small stringers of sulphides were found throughout the area mapped; some, however, were not associated with sericite schist. Of particular note is a 10 inch sulphide vein in sericite schist located west of the South Lens. This same mineralized shear is found in the large bend in the main adit and was picked up again in Drill Hole No. 60 drilled 500 feet south and downward from the No. 1 Crosscut.

The Frizzell outcrop was found, after a great deal of difficulty, by W. Holyk near the headwaters of Hanna Creek. The mineralization was weak and erratic and the assays of the sample taken were disappointing. The sulphides strike northwest and the surrounding quartzites strike due east. This anomalous situation cannot adequately be explained.

B. Metamorphics around North and South Lenses.

The rocks adjacent to the two lenses include quartz-chlorite schists, chlorite-biotite schists, with hornblende or garnet as accessory minerals, highly hornblendic schists, granite gneiss with chlorite or biotite being the predominate mineral, quartzites, argillite and sericite schist.

The granite gneiss lies off the hanging wall of the two lenses. Other rocks are not easily correlated through the mine for any great distance. Quartzites predominate in the southern end of the mine but give way to dominantly chloritic rock around the North Lens. For greater detail the reader is referred to W. Holyk's underground map and my underground sheets found in this report.

Of special interest is the so-called crumpled chlorite schist. The name accurately describes it. Sericite is sometimes highly developed. It lies on the hanging wall side of the South Lens, cuts between the two lenses and continues on the footwall of the North Lens. At the surface the zone is close to the North Lens, but underground it bears sharply away from and to the west of the North Lens. Small zones of crumpled chlorite schist are developed locally elsewhere. These will be discussed under the structure of the orebodies.

The sericite schist is developed around the two lenses, but is not always present. The North Lens sericite shear disappears with depth and to the south, but not northwards. The South Lens sericite shear joins with the North Lens to the north and dies out at its most southerly end.

C. Mineralogy and Classification.

The sulphides at Ecstall include pyrite, chalcopyrite, small amounts of sphalerite and pyrrhotite, in a gangue of calcite, quartz and sericite.

The highest copper values are confined to the footwall of the North Lens (Illustration No. 10); zinc is largely found in the South Lens.

The sulphides occur as bands of equigranular minerals ranging from coarse to extremely fine and massive. The sulphides produce no gossan or oxide, other than a local staining of rocks in the creeks, and it weathers to a sand made up of sulphide mineral crystals. Sulphides lying on the dump for nearly twenty years show no sign of oxidation.

The nature of the banding, which in some places is contorted and folded, and the massiveness of the sulphides, indicate that the deposit is a replacement of a favorable rock. Bateman (1951) lists the criteria for a replacement as follows:

(1) Unsupported nuclei (if the deposit is a cavity filling then such residuals tend to lie on the floor of the deposit).

(2) Bedding planes in alignment with the wall rock.

(3) Pre-existing rock structures that continue on either side of the orebody, and especially if they continue into the ore.

The Ecstall deposit meets all these requirements, but the last point is not so readily discernible and examples of this are not common.

There is some evidence that the banded sulphides form apophyses in the sericite schist, thereby indicating that the schist had been "displaced" (Illustration No. 4). This process, as well as replacement, is part of the ore deposition.

D. Structure.

1. North Lens.

The dominant structure in the North Lens is a southward plunge with the axis migrating in a southeast direction (Illustrations Nos. 8, 9, 10). Small striations or undulations on shear walls, the plunge of folds, and an isograd of the thickness of the lens, and of the copper values follow the same southerly pattern (Illustrations Nos. 8, 9, 10). Only the south end of the North Lens, which plunges northward, is the exception.

With regard to the striations and undulations seen on shear walls, I do not regard these as indications of a dip-slip movement. For example, the crest of the undulations may plunge 80° S. measured in the plane of the shear wall dipping east and striking north. Here the movement is not up and down in the plane of the shear, but rather in a direction at right angles to the striations. These small folds are produced by rotational forces much like the making of ripple marks on a beach. When the rotational stresses become more pronounced, folding, more particularly drag folding, results, and this is in evidence throughout the mine.

Folding is evident, especially on the surface of the deposit. Going across the North Lens the folds in the sericite schist waste bands reverse themselves several times across the deposit. Folds are observed in the sericite schist on the hanging wall and footwall of the sulphides and in unreplaced quartzite (surface map and underground sheets). This unsystematic direction of folding leads me to postulate that the favorable replaced host rock, or sericitic rock, had doubled over on itself.

The bottoming of the North Lens is particularly perplexing. Drill holes under the lens contacted neither mineralization nor shearing. The lens had completely disappeared. Those holes which were blanks have been plotted on semi-logarithmic paper (Illustrations Nos. 1, 2, 3), the angle of hole dip against the depth. None of the holes deviated more than 3° in strike so that this is a constant factor. Also plotted is the angle of schistosity of the rock in the drill core against the hole depth.

In the ideal case, in uniformly dipping or striking schists, the schistosity curve should change with the curve for the dip of the hole. As can be seen from the graphs, this is not the case.

Either the dip or strike in the rocks underneath the North Lens is changing markedly. As elsewhere in the mine, this is indicative of disturbed or folded rocks.

The probable cause of bottoming in the North Lens is two-fold: first, the ore deposition is dependent on the development of the sericite schist; these shears are zones of maximum stress where rocks have approached flowage and allowed altering solution to migrate; second, shearing is regarded as the end product where the rocks could no longer be deformed. Folding controlled and caused the thickening in the North Lens, and conversely, the lack of folding, shearing and deformation has been responsible for the pinch-out in the North Lens.

It is my belief that just as shearing and folding may reappear along the strike it can also do so with depth. The North Lens could reopen with depth and would most likely be found to the southeast of the orebody.

2. <u>South Lens.</u>

The South Lens is regular in shape and continuity, and roughly resembles a parallelogram with its sides plunging 70° to the south. This is conformable with the structure underground and on the surface; striations, undulations and folds generally plunge 70° southward, although there is a tendency for the angle to be steeper at the north end than at the south end.

Of particular note is the wide-scale folding around the No. 2 Crosscut-the widest part of the South Lens. As in the case of the North Lens, the folding has been responsible for this expansion in the lens.

Further on the matter of folding, drawings of structures on the backs and walls of the drift strongly indicate highly disturbed strata, and in the mid-portion of the mine the pinching-out of the quartzites to the north is evidence of tight folding.

Small shears where there is a development of gnarled and rolled-up quartz, pyrite and "creamy" swirled chloritic rock might represent rupture down the axial plane of tight folds; in a few cases this is very apparent, but more usually the rock is so textureless as to make any determination of the lineation impossible.

The crumpled chlorite schists might represent this axial plane shearing; from the highly folded and distorted nature of the large shear zone around the No. 6 Crosscut, one can observe the limbs of folds sliced off by the shearing (Illustration No. 5 and underground sheets).

3. Summary.

Mapping of the two lenses on a scale of 30 feet to the inch shows that all the rocks-the wall rocks and sericite schist-and the massive pyrite ore are greatly disturbed. Rock units are difficult to trace through. The crumpled chlorite schists appear to represent breaking along the axial plane of folds and might be due to a different structural phenomenon from the sericite shears which are largely an alteration product. The sericite is folded in the same manner as unaltered rocks.

The juxtaposition of the two lenses is regarded as fortuitous, although the three alteration zones-North Lens, South Lens, and the Southwestern shear with small mineralization-have an en echelon pattern which may indicate a greater overall structural pattern not yet perceived.

E. Comparison with Other Deposits.

A search through the geologic literature for pyrite replacement deposits was not too fruitful. Such deposits have not, in the past, been economic in North America, but in Europe some reports have been written on such ores, especially those in Sweden.

Per Geijer (1924) has summarized the Swedish pyrite replacement deposits. The orebodies were formed during an epoch of folding and are a replacement in pronounced schistose layers in steeply inclined formations and fissure zones. The minerals formed by replacement show schistosity by crystallization and pronounced banding. Folding in the orebodies and pre-mineralization folding in the host rock can be seen; the folding continued until gradual solidification made the mass rigid. There are places where anticlinal and synclinal structures have controlled the form of the orebodies which generally follow the pitch of the folds.

George Hanson (1920) compared the pyrite deposits in metamorphic rocks in Northern Manitoba, Weedon, Stratford and Capelton in Quebec, and Kyshtin, Russia. The degree of schistosity is of primary importance in determining the size of the orebodies which are generally parallel to the country rock. Ore was formed after the development of schistosity and the degree of foliation determines their size.

Bateman (1951), in speaking of replacement type deposits, states that "the chemical character of the host rock alone may be the controlling factor in localizing ore, but the structural features generally operate in conjunction with other factors ..... Pitching folds and drag folds have been important in localizing ore in many places."

The Boliden deposit (Odman, 1941) in northern Sweden is particularly interesting; to me, it closely resembles the deposit at Ecstall River.

In this case the bedrock is Pre-Cambrian in age and consists of phyllites, greywackes and greenstones. Granite has been intruded and lies south of the mine. The rocks are strongly folded and strike east-west and dip steeply south. There are two orebodies 600 meters long and maximum 40 meters wide and are en echelon position and overlap to the right. There are three types of ore. A drag fold lies between the contact of the sediments and volcanics. The structure is caused by shearing stresses, and the axis of the fold pitches 50°-60° E.

In the drag fold the stress formed suitable channelways for ascending hydrothermal solutions which altered the volcanic rocks, and resulted in their sericitization. Further shearing along alteration zones produced a schisted rock which was replaced by ore solutions. Alteration continued after ore emplacement. The pitch of the ore follows the axis of the drag fold. Folding in the sericite schist probably formed by local movement during the mise en place of the ores.

Banding in the ores does not always correspond to the foliation in the schists and often forms apophyses.

The Melanas deposits in Sweden (Gavelin, 1939) occur in the same age and type of rocks. All have been intensely folded and regional metamorphism and shearing have altered the rock so that often the original texture is indiscernible. The ores are replacements of sericitic schists and consist of pyrite, pyrrhotite with chalcopyrite, galena and sphalerite. The ores are contorted and folded with the schists, and the shape conforms to, and is controlled by, the degree of folding. Gavelin alludes to an over-all structure, but he states that the lack of outcrops in the region makes its identification impossible.

Further research in the literature would undoubtedly produce more examples similar to those outlined, and to the numerous pyrite deposits not herein described. I have visited many pyrite prospects and nearly all conform to the same pattern. Replacement deposits invariably occur in folded metamorphics along zones of alteration; the shape, size, and control of the orebodies are determined by the folding, and its structural attitude in space.

The point is made, therefore, that all the evidence at Ecstall River indicates that the deposits there are similar, and that their geologic and structural history conform, in essence, to the general pattern of pyrite replacement deposits.

V. CONCLUSIONS

A. Geologic and Structural Features.

1. All the metamorphic rocks in the roof pendant have been folded. Metamorphism and structural deformation were contemporaneous. The marginal gneisses, because of their proximity to the batholiths, are more contorted. The swelling of the granite gneiss in the headwaters of Red Gulch Creek is probably due to folding.

2. Shear zones developed in areas of high pressure; the regional schistosity and cleavage are parallel to the axial planes of the structures.

3. Shear breaks provided suitable channels for hydrothermal solutions; the rocks were thereby altered to sericite.

4. The ore solutions migrated through the same zones and both "replaced" and "displaced" the sericitic favorable host rock.

5. Folding and sericitization continued until the sulphide mass was too rigid.

B. Ore Controls.

1. Shear zones are confined to the Mine group of rocks; other ore deposits are, therefore, likely to be found with the association of these two features.

2. Folding has controlled the size and shape of the North Lens, and, to a lesser extent, the South Lens.

3. The juxtaposition of the granite gneiss possibly caused the doubling up of the North Lens and the thickening in the South Lens. It is not a controlling factor in the deposition of ore, but merely over the shape of the orebodies.

4. A determination of the over-all structure should yield a further control over the location of the orebodies much in the same manner as the other pyritic replacement deposits which have been described in the report.

C. Practical Applications.

1. Since the shape of the North Lens has been determined by the folding, those forces which caused its pinching-out with depth may reopen the lens with depth. This would have to be accompanied by shearing and the development of sericite. The structure of the North Lens is plunging 70° at about S. 40° E., and any new orebody would lie along this direction.

2. The South Lens should continue farther in depth. However, the folding about the No. 2 Crosscut could either thicken the lens or reduce it in width.

3. The Third outcrop is favorably located along a shear and near the granite gneiss (if this is a control), and an orebody could develop along the strike and with depth.

4. The shear to the southwest of the South Lens is well developed with depth and could show mineralization either along the strike or down the dip.

5. This makes the flat ground between Red Gulch and the Ecstall River south of the mine a favorable prospecting area. It is not felt that the South Lens will continue southwards at its present levels. Rather the lens will continue its plunge in the southeasterly direction and will be at greater depth.

D. General Considerations.

The underground workings have been fully utilized both in diamond drilling and in mapping the geology. If the orebodies are to be extended in depth, the workings will have to be further developed for there is no longer any practical way to drill deeper from the present locations. Most of the underground geology lies along the main adit-which does not give much of a cross section-and the crosscuts which give an average section of about 60 feet. The geology is extremely limited in scope therefore.

When the underground workings are extended, the utmost practicability should be used for the mining of the ore, the situation of future drill hole stations for deep drilling, and for the use of the geologist, in that order.

No further geologic work is recommended until the mine comes into operation. At that time, as the workings are extended, it would be practical to work in further detail on the surface and underground geology.

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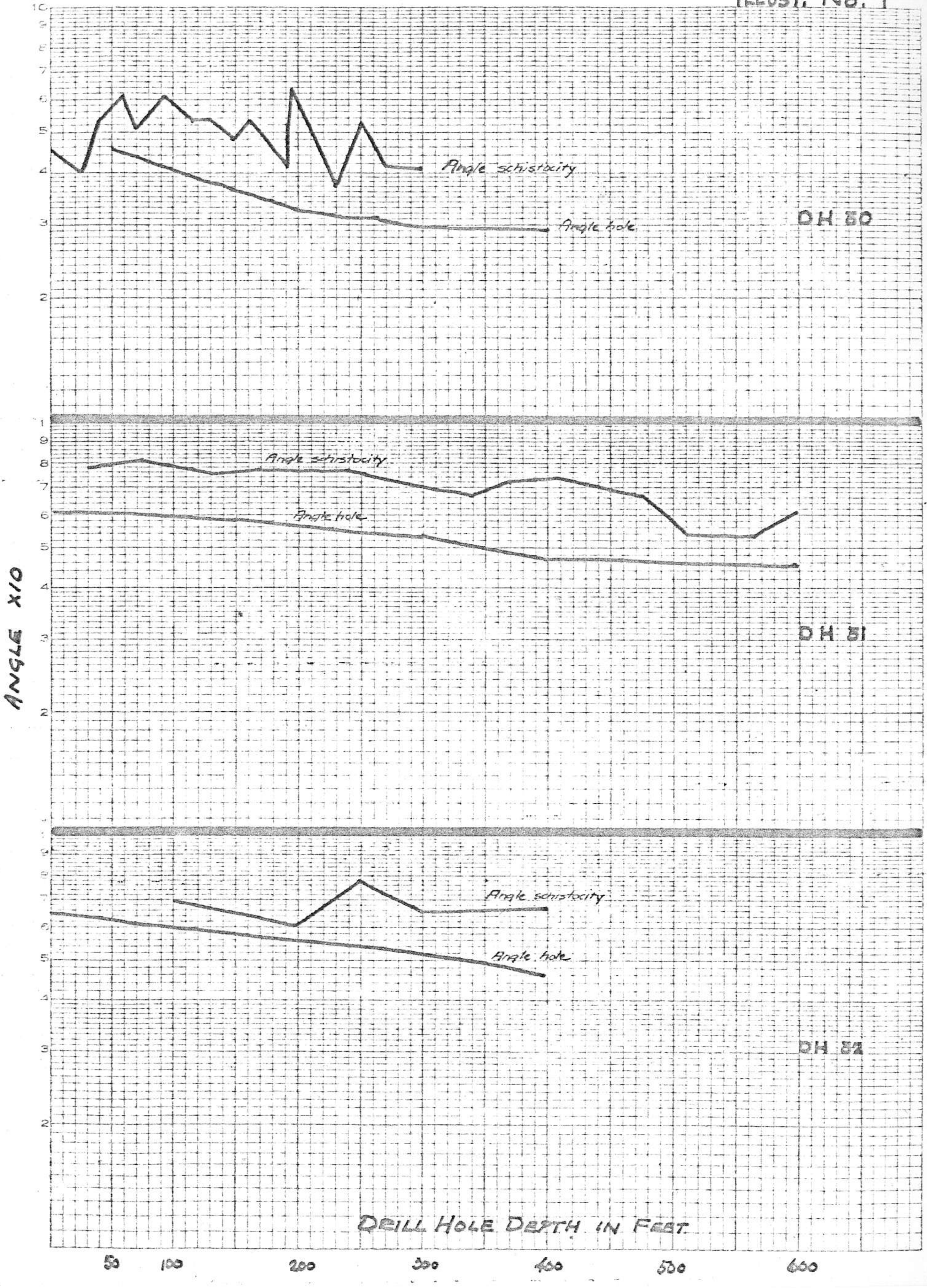
Hugh Douglas
20 April 1953
New York, New York

HD:GMO

0+5

ILLUST. No. 1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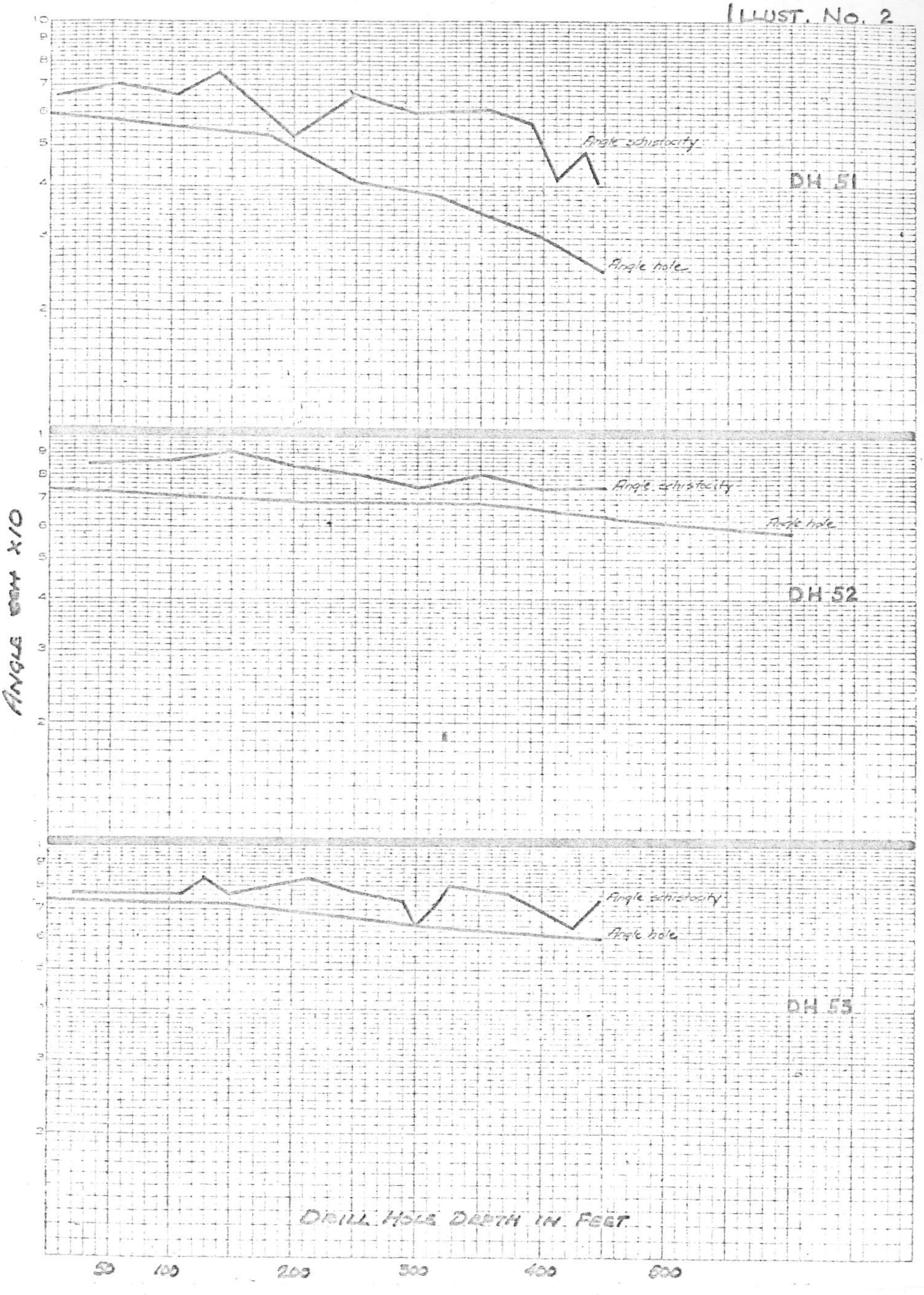
Angle schistocity
Angle hole
DH 80
Angle schistocity
Angle hole
DH 81
Angle schistocity
Angle hole
DH 82
DRILL HOLE DEPTH IN FEET
50
100
200
300
400
500
600
10
9
8
7
6
5
4
3
2
1

ILLUST. No. 2



ANGLE X/10
DH 51
Angle schistocity
Angle hole
DH 52
Angle schistocity
Angle hole
DH 53
Angle schistocity
Angle hole
DRILL HOLE DEPTH IN FEET
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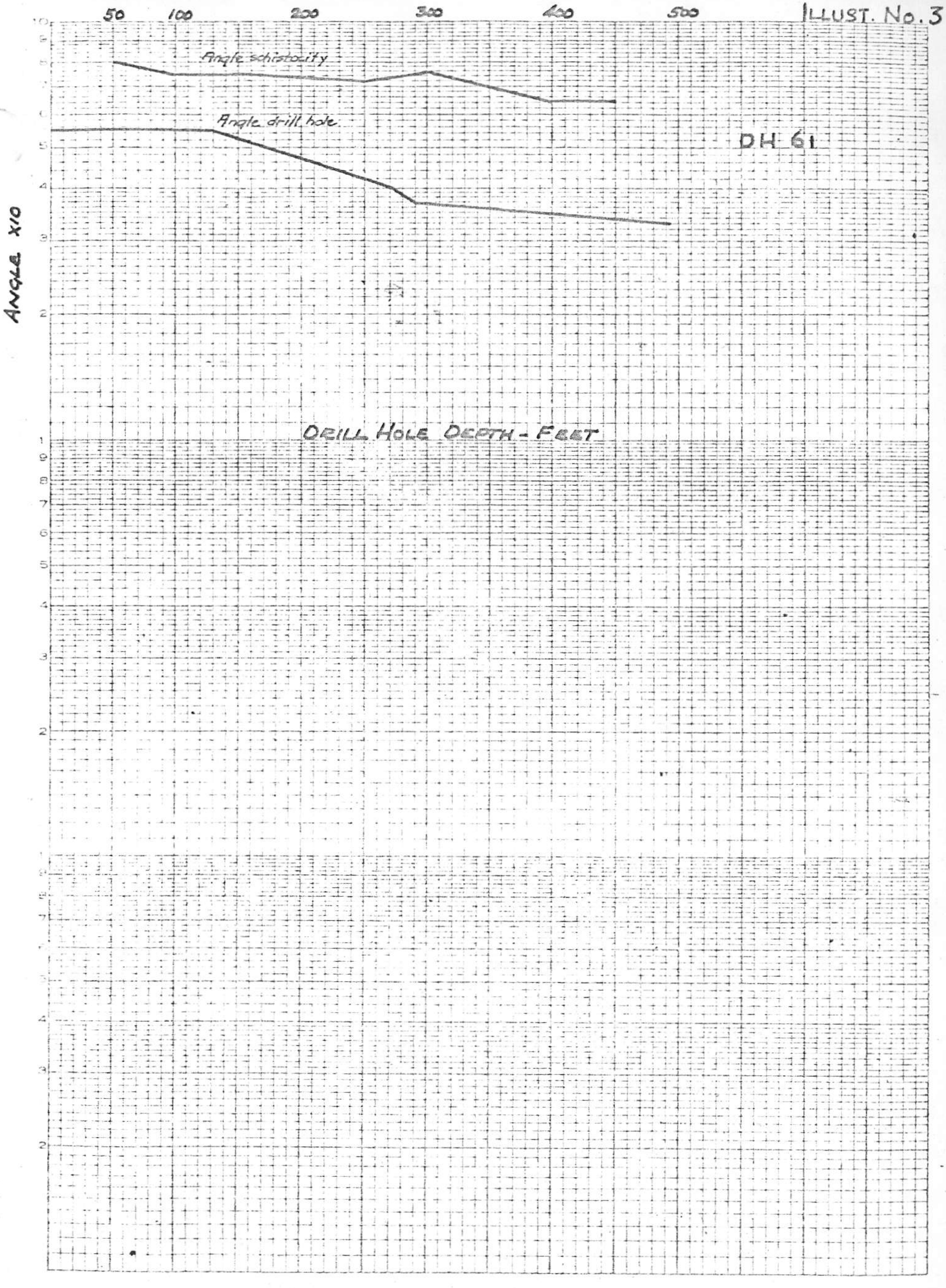
100
200
300
400
500
1
9
8
7
6
5
4
3
2
10

ILLUST. No. 3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100
200
300
400
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Angle schistocity
Angle drill hole
DH 61
ANGLE X10
DRILL HOLE DEPTH - FEET
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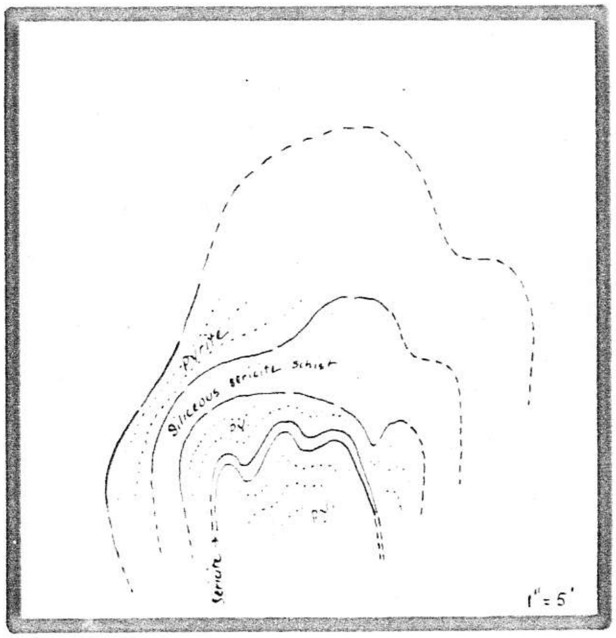
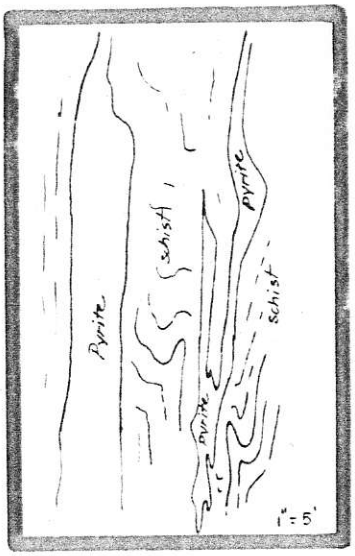
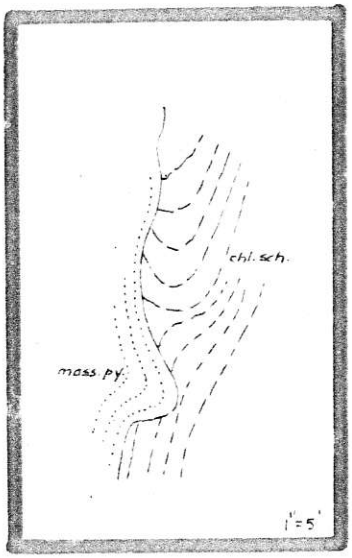
2
3
4
5
6
7
8
9



FOLDED STRUCTURES, NORTH LENS
NEAR ADIT BELOW FALLS

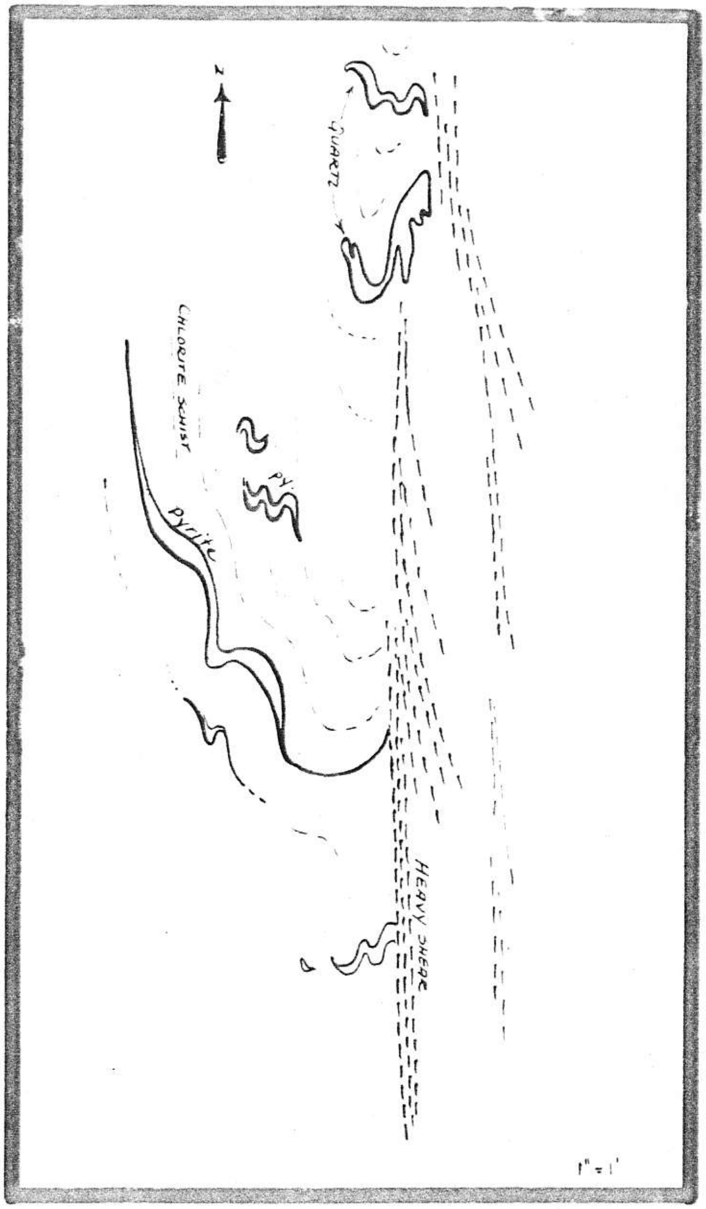


NORTH END
OF THIRD OUTCROP

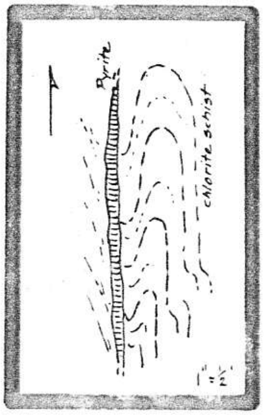


APOPHYSIS OF
PYRITE IN SCHIST

ILLUST. NO. 5



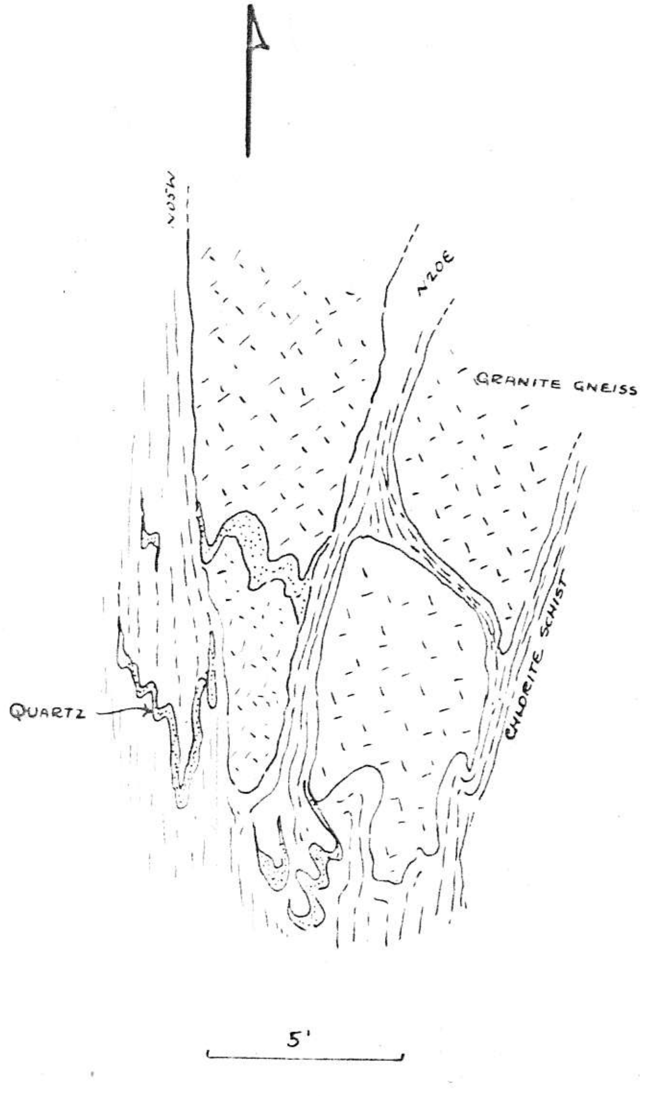
Back main adit, 25' south No. 6 crosscut.



First stream N. of Falls

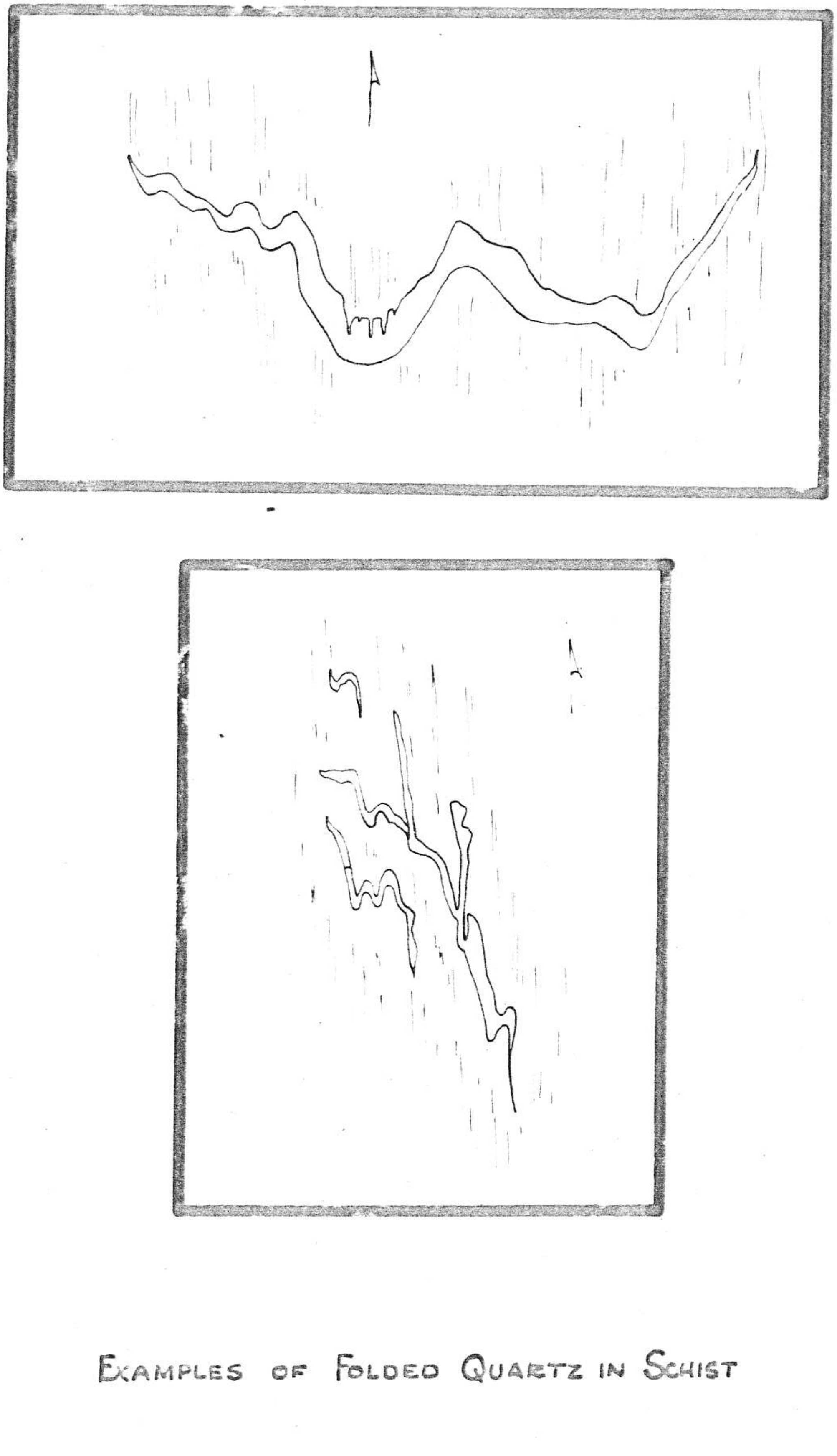
EXAMPLES OF SHEARING ALONG AXIAL PLANE OR LIMB OF FOLDS, UNDERGROUND AND SURFACE.

ILLUST. No. 6



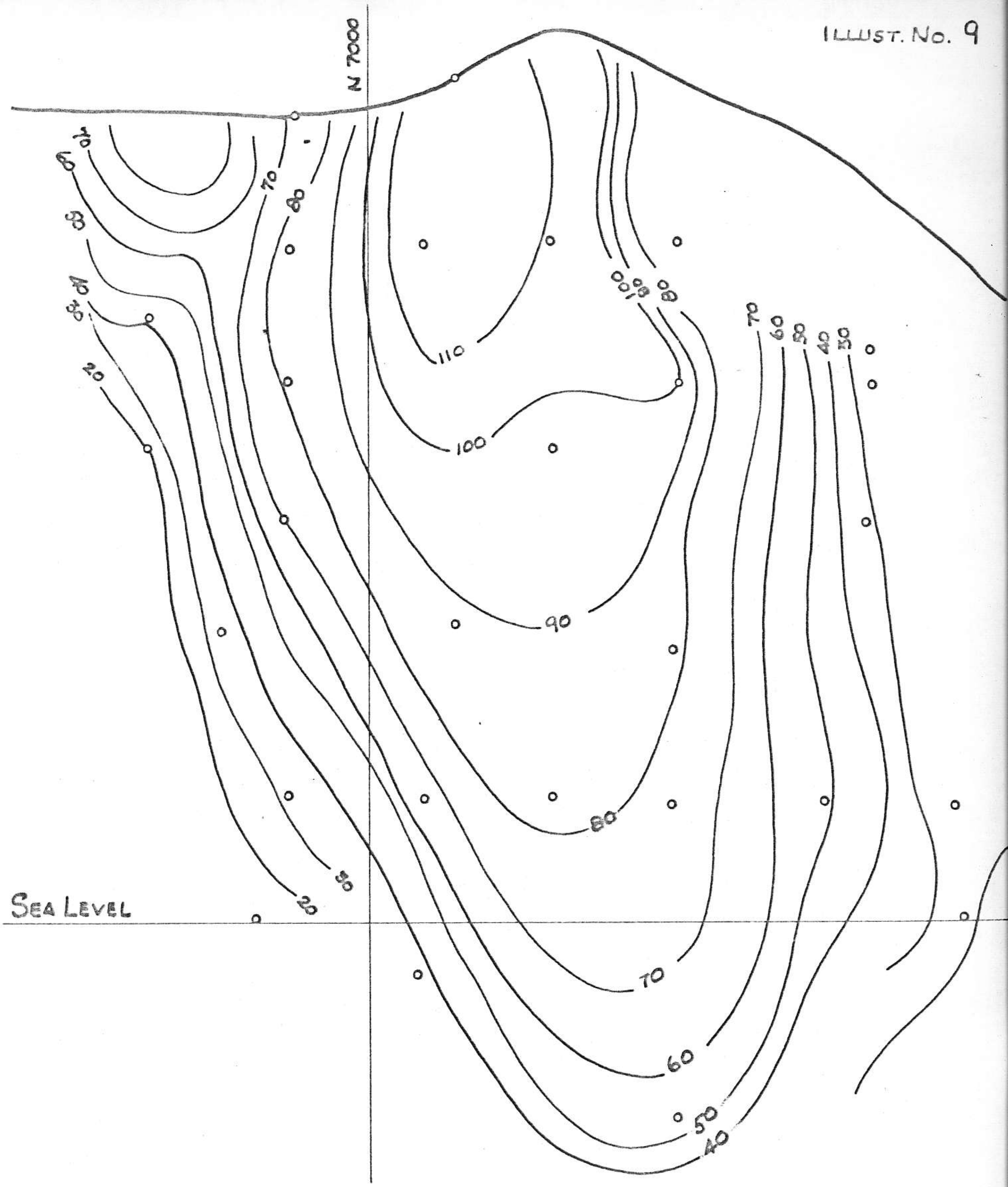
"GRANITE" GNEISS,
NORTH OF NORTH LENS

ILLUST. No. 7

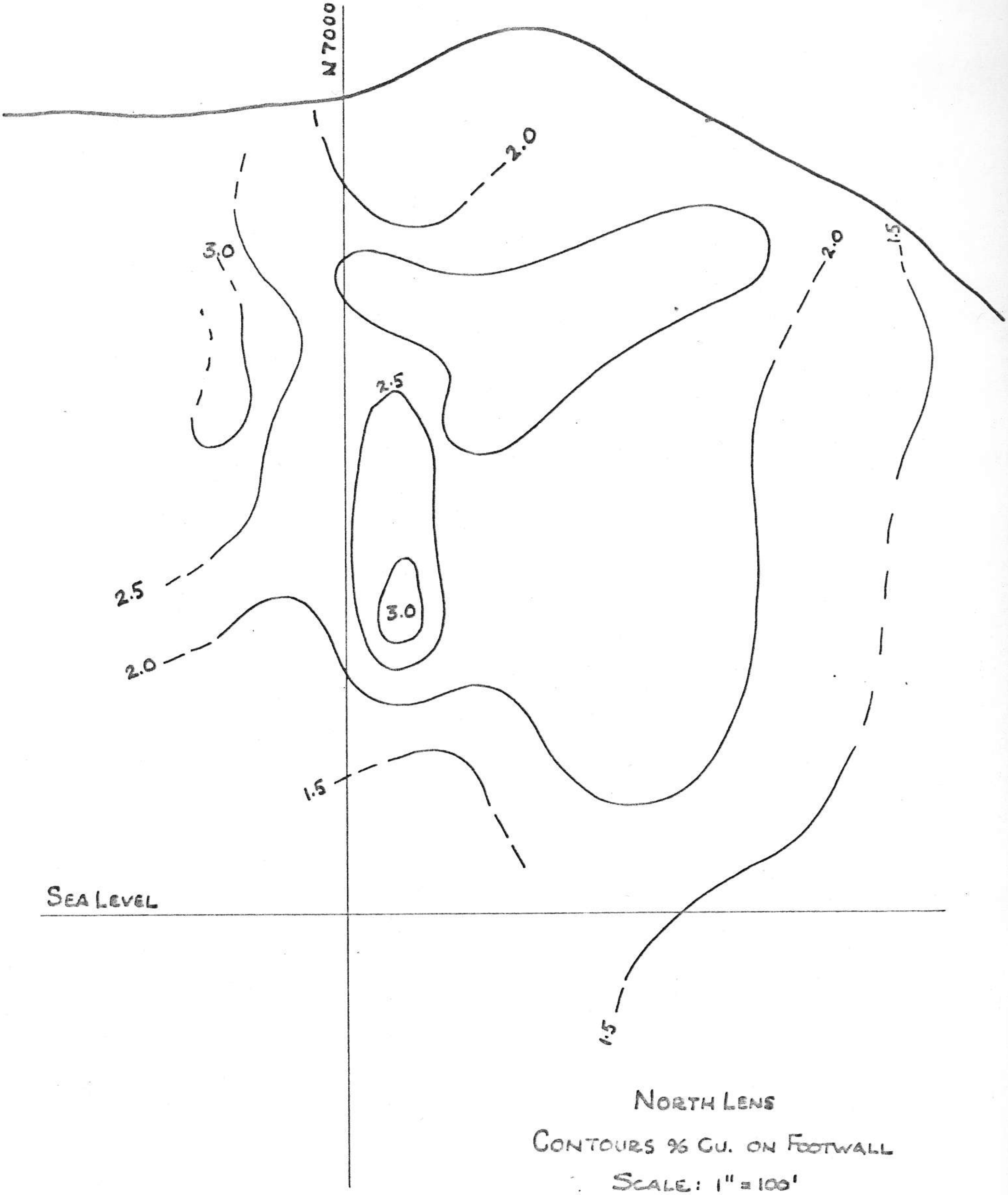


EXAMPLES OF FOLDED QUARTZ IN SCHIST

ILLUST. No. 9



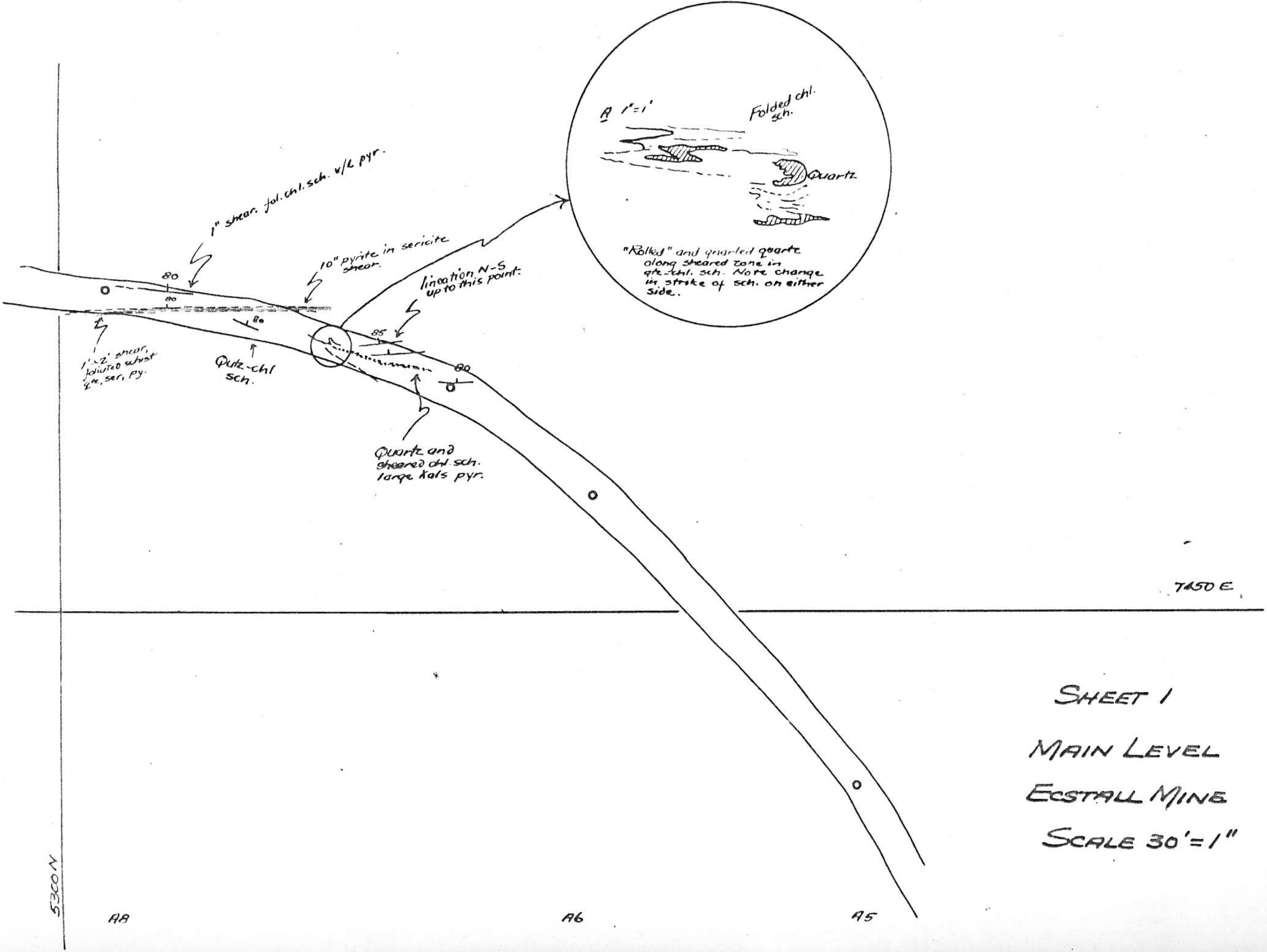
NORTH LENS
CONTOURED THICKNESS
SCALE: 1" = 100'



North Lens

Contours % Cu. on Footwall

Scale: 1" = 100'

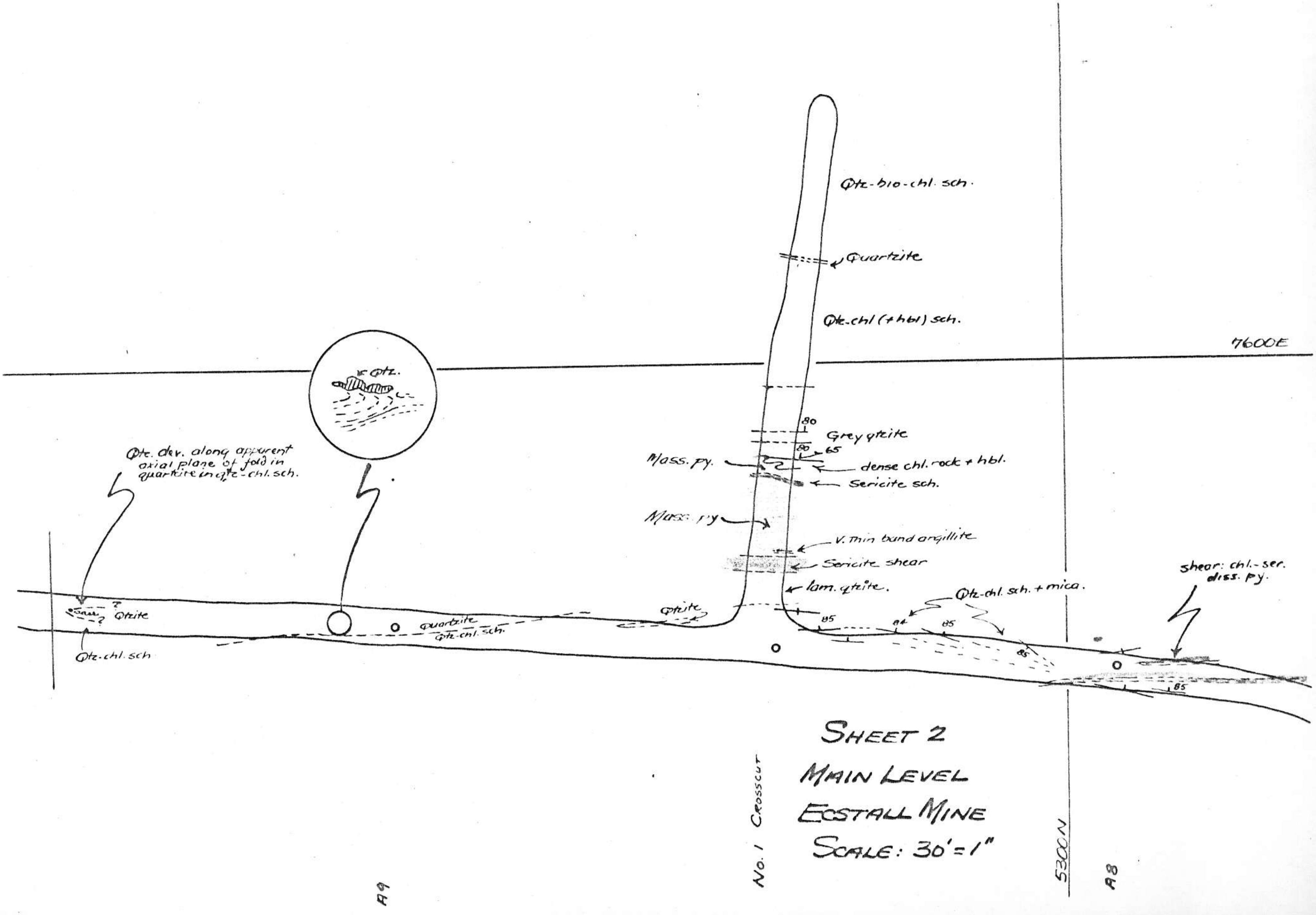


SHEET 1

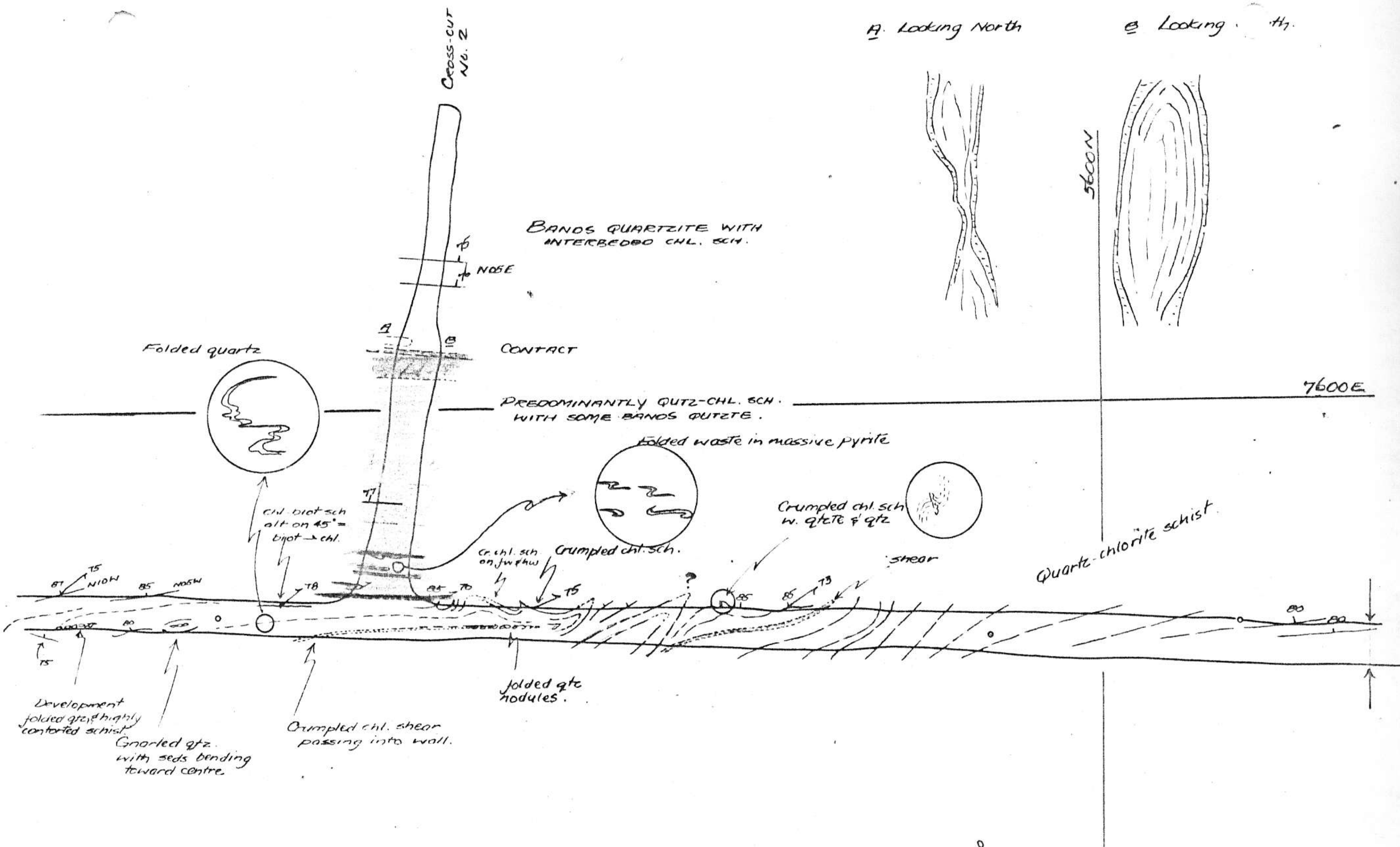
MAIN LEVEL

ECSTALL MINE

SCALE 30'=1"



SHEET 2
MAIN LEVEL
ECSTALL MINE
SCALE: 30' = 1"

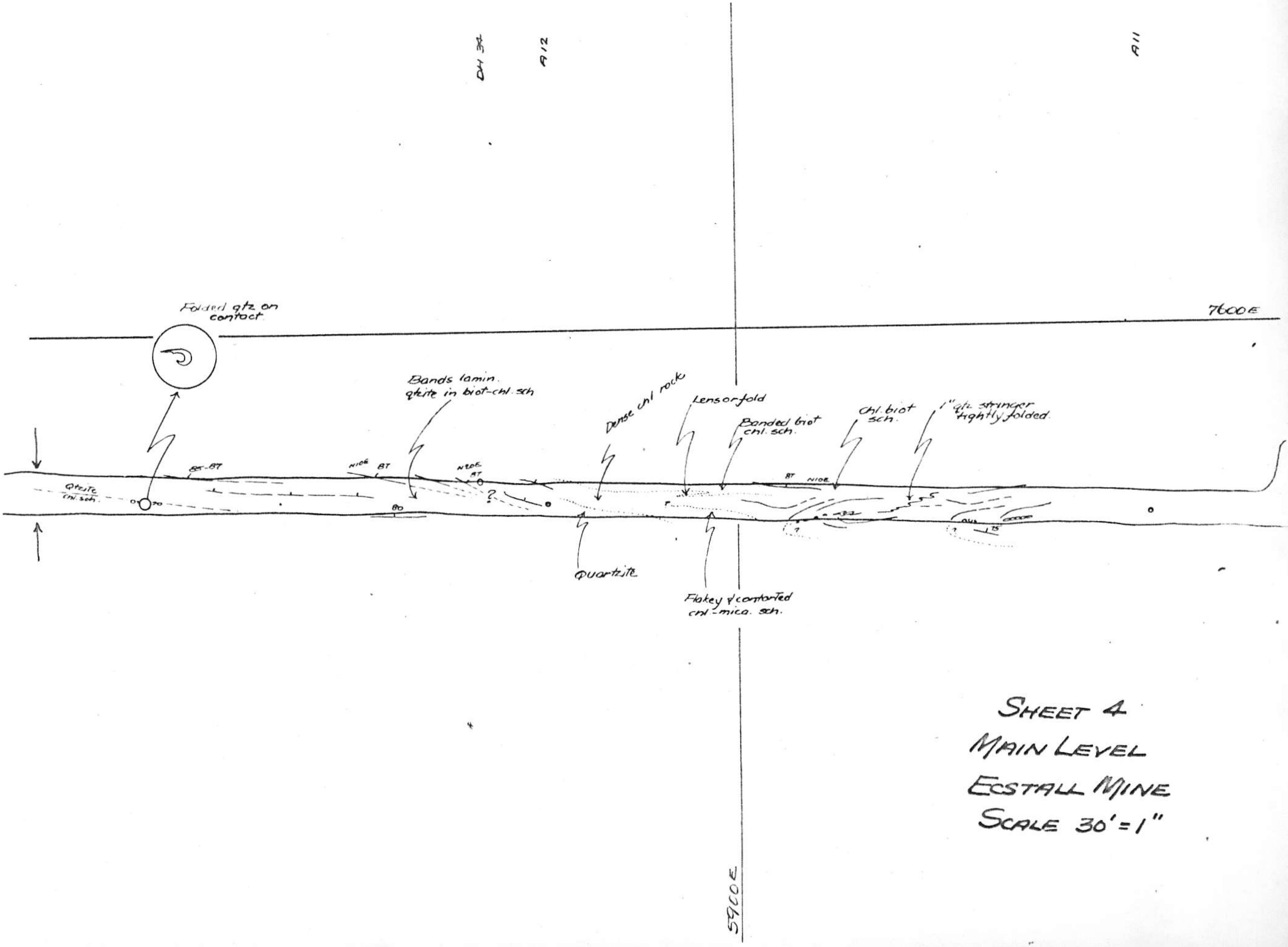


SHEET 3

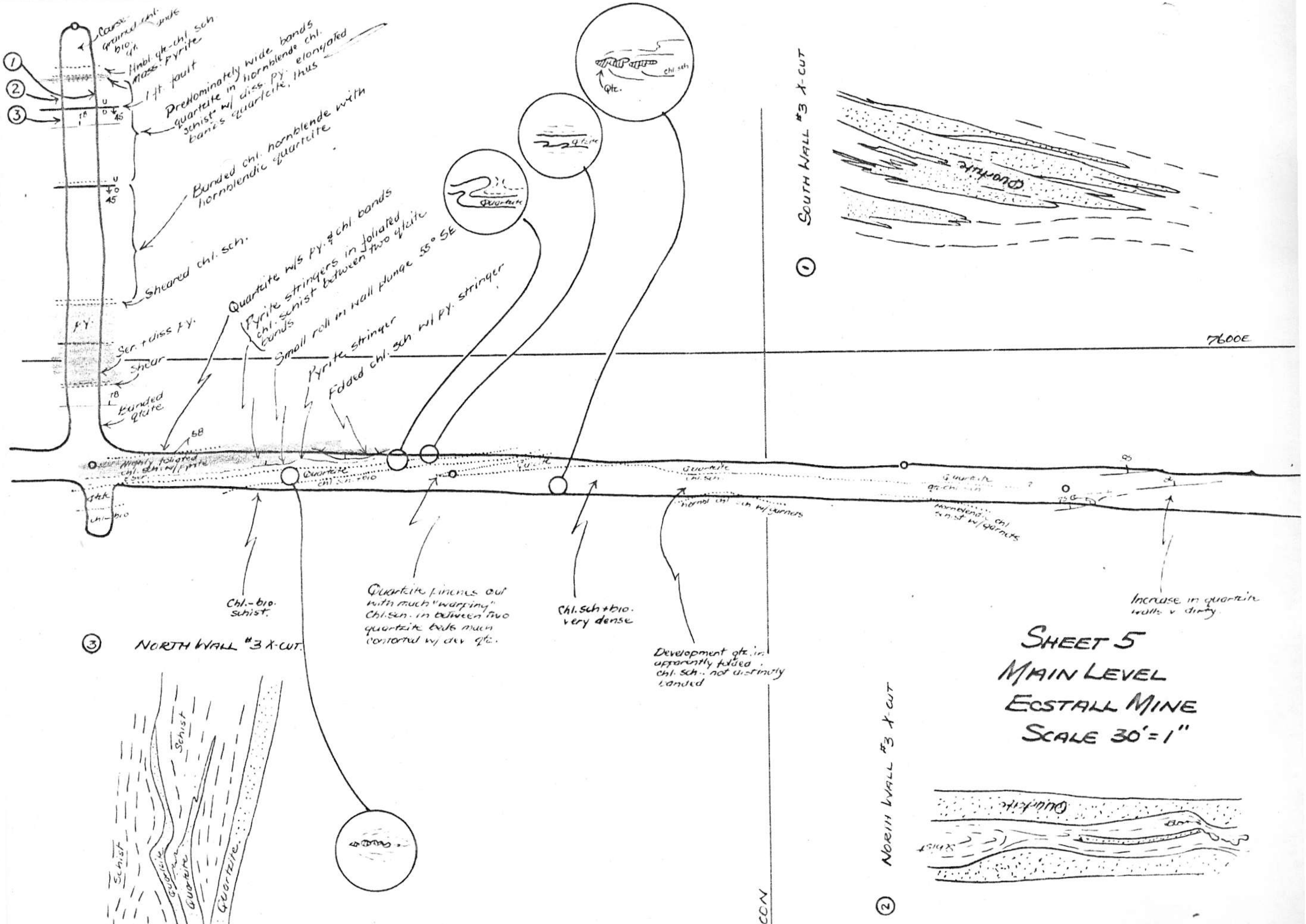
MAIN LEVEL

ECSTALL RIVER MINE

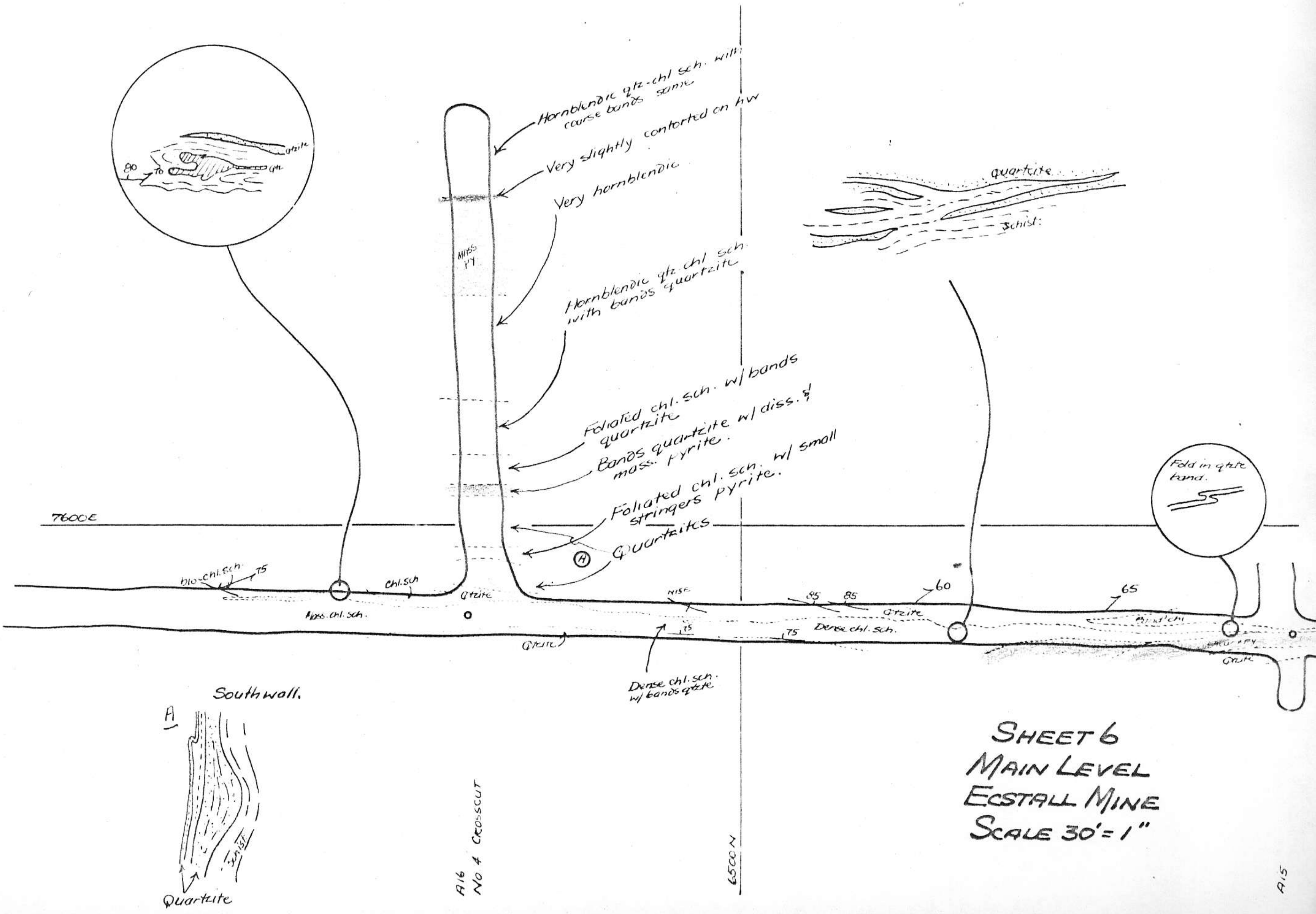
30 FT = 1 INCH



SHEET 4
MAIN LEVEL
ECSTALL MINE
SCALE 30'=1"



SHEET 5
MAIN LEVEL
ECSTALL MINE
SCALE 30'=1"



SHEET 6
MAIN LEVEL
ECSTALL MINE
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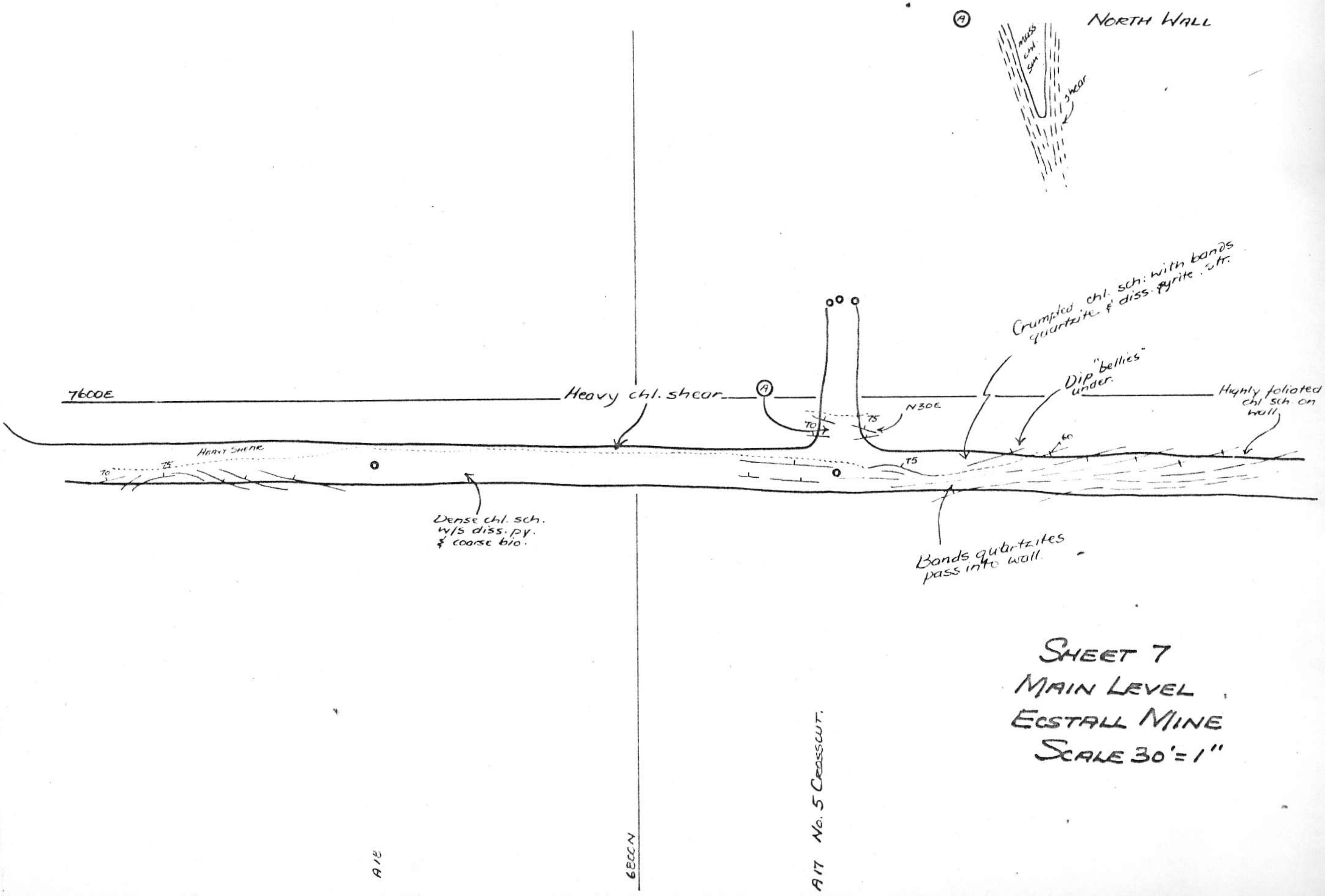

SHEET 7
MAIN LEVEL
ECSTALL MINE
SCALE 30'=1"

SHEET 8
MAIN LEVEL
ECSTALL MINE
SCALE 30'=1"