CONSOLIDATED SUDBURY BASIN MINES LIMITED

STRUCTURAL GEOLOGY OF

THE ERRINGTON MINE -- THE VERMILION LAKE MINE

Foreword and Acknowledgements

The following paper has been submitted to the Canadian Institute of Mining and Metallurgy for publication in the new edition of the volume "Structural Geology of Canadian Ore Deposits".

The maps and sections accompanying the paper were drawn by S. N. Charteris and J. S. Ross, mine geologists respectively, for the two mines. The underground mapping and setting up of the geological plans and sections was done almost entirely by Phillip Eckman, Chief Geologist, who has been on leave of absence for some time. The writer is indebted to mine geologists Charteris and Ross for reading the paper and for their helpful comments and suggestions.

INTRODUCTION

The company owns two mines, 4 miles apart, near the southwest end of Sudbury basin. The Errington mine lies close to the ~~north boundary of~~ Creighton Township and about 18 miles by car from Sudbury. The Vermilion Lake mine is in Fairbank Township, on the south side of Vermilion Lake.

The first discovery of base metal mineralization within Sudbury basin was made by James Stobie in 1897 at Stobie Falls on the Vermilion River, half a mile west of the Errington mine. A few years later Alphonse Ollier made a discovery of massive pyrite with base metal sulphides near the west end of the present Errington workings.

No work of consequence was done on these discoveries until 1924 when Joseph Errington acquired options on a large acreage of ground which was later taken over by the Treadwell Yukon Company Limited. After considerable diamond drilling this company sank No. 1 shaft in 1926. In the next three years, a large amount of underground development was done, a pilot mill was constructed and operated for two years. All operations ceased in 1931 with the fall in metal prices. While in operation the pilot mill treated 186,172 tons of ore the average grade of which was 1.07% copper; 1.10% lead; 4.60% zinc; 0.03 oz. gold, and 1.70 oz. silver.

Up to the time of closing in 1931 there had been completed at the mine 26,790 feet of lateral work and 75,500 feet of surface and underground diamond drilling. The company records, however, showed no figures on ore reserves, except broken ore in stopes amounting to about 60,000 tons. A study of the plans, prior to re-opening the mine 1952, showed 1450 lineal feet of ore (at 1952 prices) opened up by drifting on the 300-ft. and 500-ft. levels. It is clear that no comprehensive picture of the structure was had at this time. The ore bodies were considered to be very irregular pods scattered through masses of quartz-carbonate in a sheared zone about 800 ft. wide. In some way the ore was believed to be related to the tuff-slate contact zone. With this picture it was impossible to make a reasonable ore estimate or even gauge the tonnage potentialities with any feeling of reliability.

The Errington mine was pumped out to the 500-ft. level in 1952 and an underground drilling campaign commenced to assess the ore indications. Prior to the re-opening, a study of the mine records, together with re-logging of the diamond drill core from the Vermilion Lake deposit, the Errington cores having been lost, had indicated the possibility of at least one good marker horizon above the ore horizon, that is, chert breccia which had been logged as quartz. Using the chert as a guide the strictly stratigraphic relationship of the ore horizon to other formations became apparent and was soon confirmed by underground study. By the end of 1953 the estimated ore reserves at the Errington mine was 7,396,313 tons and at the "lake" deposit, 2,615,412 tons.

The first ore at the Vermilion Lake property was found in 1929 when a diamond drill hole pointed north into the lake, for the purpose of assessment work, cut 81.0 feet averaging 3.08% copper and low values in lead and zinc. Further diamond drilling indicated about 1,000,000 tons of ore. No forther work was done here until the shaft was completed in 1953 initiating the current program of underground development and exploration.

The published ore reserves at the two mines, given in the company's annual report for 1954, are as follows:

Errington Mine: after allowing 15 per cent dilution:

7,513,007 tons 1.02% Cu., 0.75% Pb., 3.24% Zn., 0.017 oz. Au., and 1.49 oz. Ag.

Vermilion Lake Mine: after allowing 20 per cent dilution:

2,819,220 tons 1.43% Cu., 1.10% Pb., 4.56% Zn., 0.020 oz. Au., and 1.78 oz. Ag.

Essentially no exploration work was carried out during 1954. The above tonnages, however, have been substantially increased during 1955 at both properties but the figures have not yet been published.

THE ROCKS

The name Vermilion formation has been given to a small group of rocks, including the ore host rock, which lie between the Onaping tuff and overlying Onwatin slate. Due to the economic importance of this formation, and doubts as to the origin of some of the members, a fairly detailed description of it is given later.

The Onaping tuff stratigraphically underlies the Vermilion formation. The tuff consists of a subaerial deposit of volcanic fragments and ash of mainly acid composition. No lavas have been encountered in the mine areas. In its upper part the tuff becomes fine grained and difficult to distinguish from slate. It generally exhibits a marked schistosity or flow cleavage. It is mostly chloritic and greenish in colour but may become carbonaceous and dark black near the Vermilion formation.

The Onwatin slate overlies the Vermilion formation. It consists of more or less uniform thinly bedded slate, grey to black and carbonaceous in colour. In some horizons the slate becomes massive with indistinct bedding and poor cleavage. Small seams of pyrite up to half an inch thick are common away from the ore areas, and possibly represent supergene sulphide. Where altered the slate may be extremely difficult to distinguish from fine tuff.

Except for a diabase dike at the Vermilion lake mine and another similar dike 2 miles east of the Errington mine, no intrusives have been met with on the two propertie If the norite-micropegmatite is a sill injected below the Onaping tuff, the micropegmatite would be the most likely genetic source of the base metal mineralization in the basin.

TABLE OF FORMATIONS

Diabase Dikes.

ONWATIN SLATE

Black carbonaceous slate.

VERMILION FORMATION (Mine terminology)

Argillite and limestone:	Gray to buff argillite with interbedded limestone and dolomite.
Chert breccia:	Black to light grey brecciated chert.
Cherty carbonate:	Gradation zone from carbonate to chert.
Carbonate - Ore horizon:	White to black calcitic carbonate, fine grained to coarsely crystalline, granular pisolitic textures, banding, crustiform banding.
Basal argillite:	Black dense siliceous mudstone, frequently hard and cherty, fine pyrite dust throughout typical, grades into tuff and slate over 6" to several feet.

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ONAPING TUFF

Volcanic fragmentals and tuff.

CHARACTER OF THE MINERALIZATION

The ore sulphides consist of chalcopyrite, sphalerite, galena, pyrite, marcasite and minor pyrrhotite. The sulphides occur in massive or disseminated form principally in the carbonate member of the Vermilion formation. The mineralization is fine grained and generally intimately mixed. The massive pyrite type occurs mainly along the stratigraphic footwall of the carbonate member, or as heavy impregnations near the base. The average pyrite content of the ore is about 30 per cent at the Errington mine and appreciably less at the "lake mine".

The pyritic ore is generally high in zinc and low in copper. Chalcopyrite tends to replace pyrrhotite readily, the latter frequently occurs as small pods in the tuff along the footwall, or the massive pyrite near its footwall may be replaced by pyrrhotite and chalcopyrite. Chalcopyrite without other ore sulphides commonly occurs replacing chert breccia and cherty carbonate, so that the best copper values tend to occur on both the hangingwall and footwall sides or around the margins of the deposits.

Post-ore quartz stringers are common in the ore zone. The stringers may contain splashes of coarse sphalerite, galena and chalcopyrite and near the quartz the ore sulphides may be recrystallized to a coarse grain along with the carbonate of the gangue. Outside the ore zone the stringers are virtually barren of sulphides or carbonate.

VERMILION FORMATION

Basal Argillite:

This is a dense massive fine grained rock which is an extremely dense, fine grained, silliceous, probably ashey, carbonaceous mudstone. It is frequently hard and cherty. It lacks any definite bedding. Typically it contains a dust like dissemination of pyrite or pyrrhotite or both, occasionally this sulphide is concentrated in fine bands which show contortions of slump flowage type.

The rock has a uniform appearance but both contacts are gradational over 6" to 10 ft. It varies from zero to 100 ft. in thickness. Where the overlying carbonate member is thick, the basal argillite may be absent or thin. Carbonate clearly replaces brecciated basal argillite but apparently from the top down. If massive pyrite is present it lies between the basal argillite and carbonate members. Massive pyrite clearly tongues into and replaces basal argillite.

The origin of the basal argillite is puzzling. It occurs in the ore area but is best developed away from the ore areas, it is apparently therefore not a metamorphic rock derived from hydrothermal activity associated with ore deposition. It is possibly a leached volcanic mud rock, product of the alteration by hot acids and weathering of the tuff surface.

Carbonate - Ore Host Rock:

The carbonate gangue of the ore is a crystalline carbonate, mainly calcitic, which looks like typical vein carbonate. However, away from ore it may be dense or fine grained, and granular and pisolitic textures associated with sedimentary carbonate are apparent, but similar textures are reported in vein carbonates (7). The origin of the carbonate is therefore uncertain. No comparable beds of bands of carbonate have been found in the Onaping tuff or Onwatin slate around the basin. Nor have any veins of carbonate, except occasional small stringers, been found cutting these rocks around the basin, but quartz veins with little or no carbonate are fairly numerous. The quartz veins cut all the rocks, including the ore, but excepting the diabase dikes.

The association of black slate with chemical sediments, including chert, carbonate and pyrite, is common in the Huronian rocks of the Lake Superior region, and elsewhere, it would not be surprising therefore to find chemical sediments with the black slate of Sudbury basin. But at Sudbury the restriction of the chert and carbonate, and possibly the thick lenses of massive pyrite of the ore horizon, all to the contact zone between the tuff and slate, points to another possible origin. Abundant hot spring activity, after the deposition of the tuff, could be expected as the last phase of the Onaping volcanism. Some or most of the chert, carbonate and pyrite may be of hot spring origin.

Unfortunately not enough is known about the distribution and quantity of chert and carbonate outside the mine areas, also the trend of these rocks. Facts which might throw further light on the problem of origin. A fair amount of exploration drilling has been done, however, outside the mine areas and a considerable amount of barren chert and carbonate found, enough to suggest that these rocks and the ore sulphides may have had different origins. But no thick bodies or lenses of barren pyrite have been found outside the ore areas.

A good case can be built up for the epigenetic origin of the ore sulphides. All the ore found to date of any consequence occurs on the south dipping limbs of folds, where thrust faults occur at a low angle to the dip and strike. Maximum dragging and brecciation of the Vermilion formation occurs in such locations and the best structural conditions to catch mineralization of epigenetic origin. The carbonate member also appears to be best developed under the same general conditions but it is far more extensive. The conclusion is that some of the carbonate must be epigene, there is evidence of at least two ages of carbonate in the ore zone. See Fig. 5 and 6.

The maximum thickness reached by the carbonate member is about 100 ft.

Cherty Carbonate:

This member marks the zone of gradation from carbonate to chert. There is no doubt that carbonate replaces chert. In places the chert breccia member is gone except for a few fragments scattered through the carbonate. The member reaches a thickness of 50 ft. and averages about 10 ft.

Chert Breccia:

This is a distinctive rock with black chert fragments in a white matrix of recrystallized chert. Fragments are mostly less than 2 inches. The fresher fragments sometimes show a fine wavy banding such as might occur with colloidal deposition. One thin section showed good colitic texture. The problem of the origin of the chert is tied up with the origin of the carbonate which shows similar textures. This member reaches a thickness of 20 ft. but averages about 10 ft.

Argillite and Limestone:

The uppermost member of the formation consists of a pale grey to faintly greenish buff coloured argillite with fine bedding laminae in places. Interbedded with the argillite are sharply defined bands of limestone and dolomite up to 5 ft. thick. The thickness of the member is about 20 ft. but folding and flowage may reduce or expend it greatly. One thin section of the argillite showed it to be extremely dense and textureless.

The member is well developed away from ore areas and it seems unlikely that it is due to replacement by carbonate and bleaching and alteration of the slate. The contact with the black slate is sharp, without bleaching of the slate, except in cases where movement or brecciation is evident at the contact.

REGIONAL STRUCTURE

Sudbury basin, according to the classical hypothesis, is considered to consist of more or less uniformly thick layers of tuff, slate and sandstone underlain by the norite-micropegmatite sill, all dipping towards the centre of the basin. The work done in the basin in the last few years suggests the structure is more complicated.

The evidence at both companys' properties indicates that the Onaping tuff and Onwatin slate have been much folded and faulted and may in large part be dipping south.

At the Errington mine property, where the picture is more complete, at least three parallel anticlines are indicated in a north south distance of about a mile. Overthrusting from the south appears to be concentrated particularly along the south limbs of the anticline where the formations lie at a low angle in dip and strike to the thrust faults. The south dipping formations have been faulted imbricate fashion. The largest individual vertical displacement on these faults in the mine area may not much exceed 500 ft. but their frequency is such as to give the formations a slight apparent dip north.

Unfortunately, detailed information is lacking north and south of the mine areas, but many faults are indicated in the south half of the basin. Assuming these are mostly thrusts dipping south, as in the area investigated,

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the combined displacement of all these faults could add up to a large total. A great enough total to support the hypothesis that the formations of the basin essentially dip south and the shape of the basin is in large part due to dragfolding and overthrusting from the south.

Allowing for repetition and overthrusting, the thickness of the Onaping tuff could be nearer half the 3700 ft. estimated by A. P. Coleman (4).

THE ERRINGTON MINE

The mine is located along an anticline striking North 70° East. A section through the anticline is shown in Figure 2. The south limb and crestal portion of the anticline contain all of the ore found to date. The south limb dips 70° south and north limb appears to dip about 30° north.

Note the Christie orebody on the south limb of the anticline, and the Rheaume No. 1 and No. 2 orebodies near the crest of the anticline in Figure 2. South of the Christie orebody, and parallel to it, but not shown on the section, there is a south facing segment of the Vermilion formation and ore known as the Romig Orebody. South of the Romig again there are indications of more ore but not much is known about its extent. The Christie, Romig and South Romig represent repetitions of the ore zone due to thrust faulting. Further south it is all tuff and it is not known which way it dips.

The thrust faulting, of which the Christie hanging wall fault and Romig hanging wall fault is typical, may have considerable horizontal displacement as well as vertical with the south side moving west.

The near parallelism of the faults and folds has allowed excellent continuity of ore. The Christie appears to be continuous ore for 2,000 ft. and may be much longer with only slight interruption.

The north limb of the anticline has hardly been explored. The Vermilion formation on this limb appears to consist mostly of basal argillite with little or no carbonate member or ore. West of the mine area all members of the Vermilion formation have been found on the north limb but in lensey form. Ore sulphide mineralization is generally present in the carbonate but no ore shoots of substance have yet been outlined.

The anticline has been traced for a length of about 3,500 ft. where it is interrupted at both ends by northeast striking faults believed to be branches of the Fairbank Lake fault. The north branch appears to dip about 50° south and the south branch is steeper. There appears to be a possible horizontal displacement of 2,000 ft. or more on this fault with south side moving east and up.

Barren white quartz veins and stringers are associated with the faults. The quartz may follow the fault or occur as tension veins dipping flatly in the wallrock. These veins cut the ore and in the ore zone may contain coarse grained sulphide mineralization particularly chalcopyrite.

Figure 1 is a plan of the 500-ft. level where the anticline develops a domical structure. It is in this section, which is about 2,000 ft. long, that the crestal portion of the anticline makes ore, namely the Rheaume orebodies. Beyond the domical section, both ways, the anticline flattens along the crest and there appears to be little or no carbonate member or ore, but exploration has been limited and the picture is far from complete.

No. 3 shaft is located about 9,000 ft. east of the Errington mine. At this shaft an anticlinal structure is evident with its crest about 500 ft. below surface. A substantial orebody is indicated in a probable dragfold on the south limb of the anticline. About 1,000 ft. north of this structure another anticline has been recently located by diamond drilling. It is possibly the easterly extension of the main Errington mine structure but little is known about the intervening ground.

THE VERMILION LAKE MINE

The structure at the "lake mine" is more complex than at the Errington. At the latter mine, the faults about parallel the fold axis and ore bodies have excellent continuity. At the lake there is a marked distortion of the main fold by cross folding.

The main structure is an anticline with axis striking north 60° east. The main faults about parallel this direction and dip slightly steeper than the south limb which dips about 40°. It is not known whether the tuff immediately south of the mine area dips south or north. The north limb is less well known but appears to dip 60° to 70° north, faulting may have steepened the dip.

All of the ore found to date is on the south limb of the anticline but there are indications near the crestal part of the fold about which little is known yet. Many sections through the mine show parallel repetitions of ore due to the imbricate structure produced along the south flank of the anticline by the more steeply dipping thrust faults. As at the Errington mine, the faults are frequently accompanied by quartz veins which cut the ore. The veins are virtually barren except where they cross the ore zone, here they may contain patches of coarse sulphide mineralization particularly chalcopyrite.

The two largest orebodies, No. 4 and No. 6, shown in Figure 3, are located on the south limb of the anticline where it is intersected by a cross syncline whose axis has an apparent trend close to east-west. Faulting complicates the picture, No. 4 and No. 6 orebodies are located in different fault slices and the amount of displacement is not known but is believed to be east on the south side as well as up. Allowing for faulting, the true strike of the cross fold would be nearer northwest-southeast than east-west, or roughly about parallel to the southwest side of the basin. The cross folding is presumably due to the proximity of the mine location to the south-west end of the basin.

In longitudinal section the two largest orebodies are mushroom shaped. The stem of the mushroom is vertical and coincides with the cross syncline. A section through No. 4 orebody at the stem is shown in Figure 4. The stem is about 300 ft. long in horizontal length. The ore in the cap is continuous for a length of close to 900 ft. and it is tilted slightly eastward to correspond with the general plunge of the structure. O.K.

W. C. Martin

January 15th, 1956.

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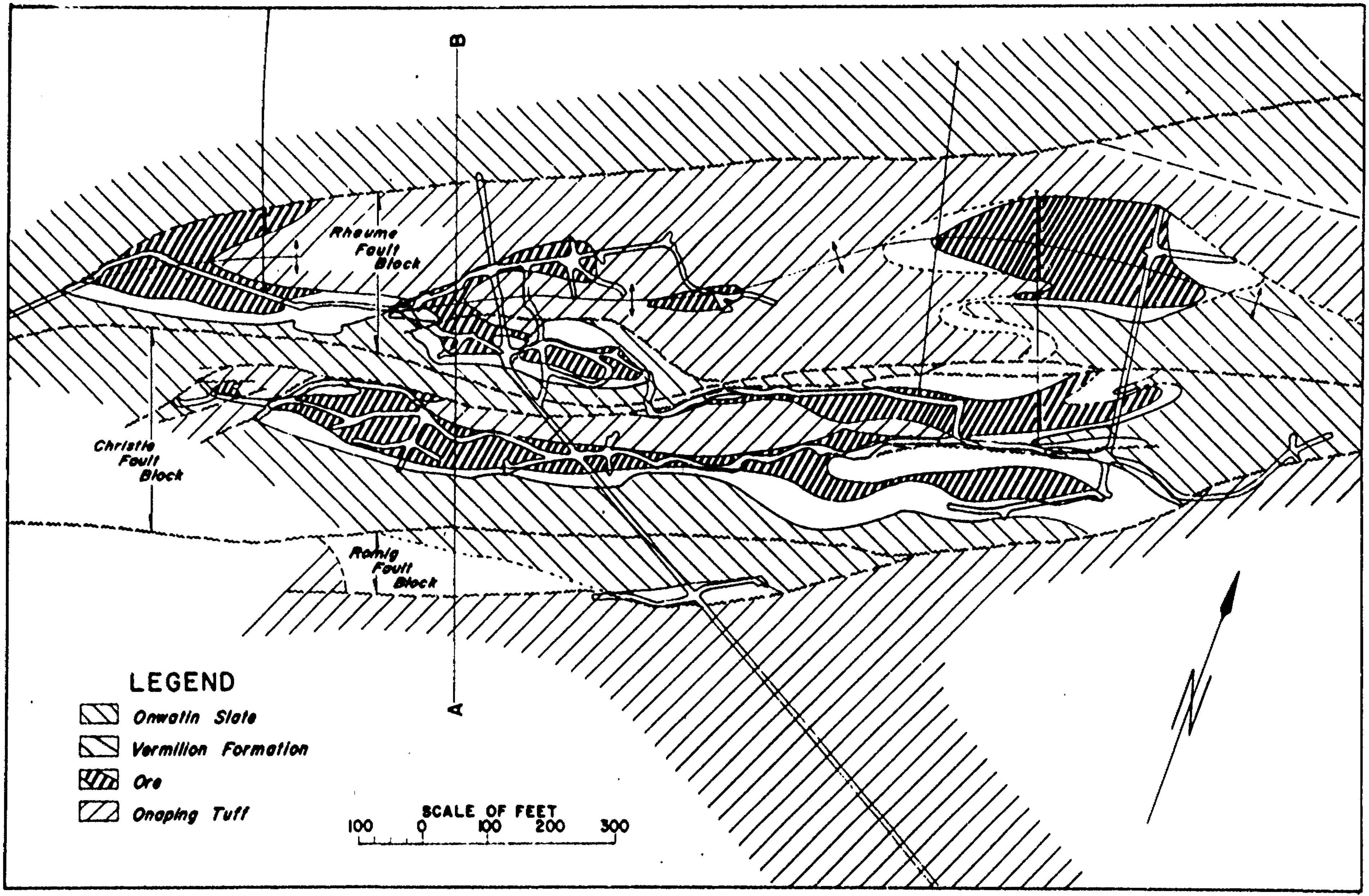
Figure 1 The Errington Mine, plan of part of the 500-ft. level.



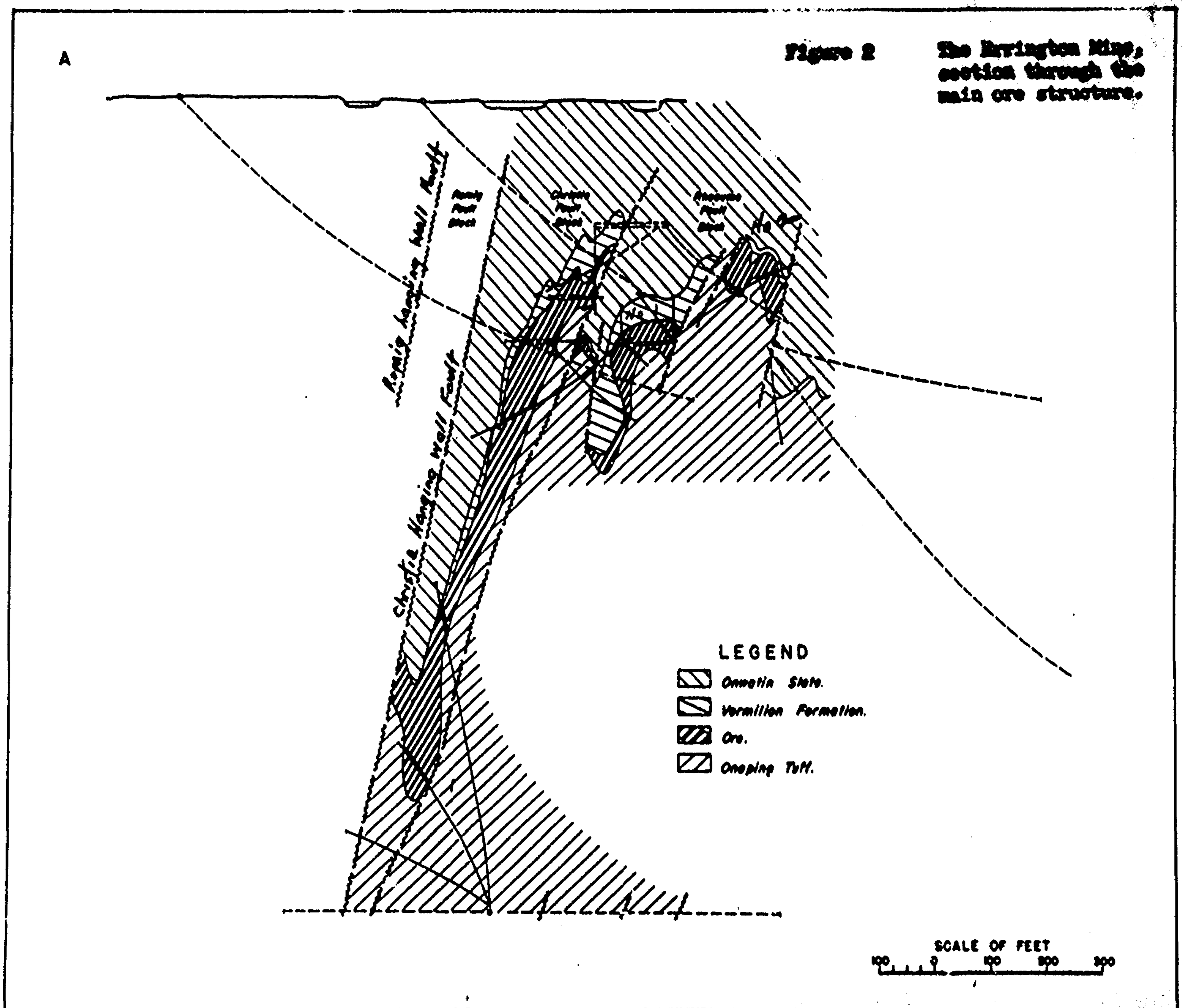


Figure 2 **The Errington Mine, section through the main ore structure.**

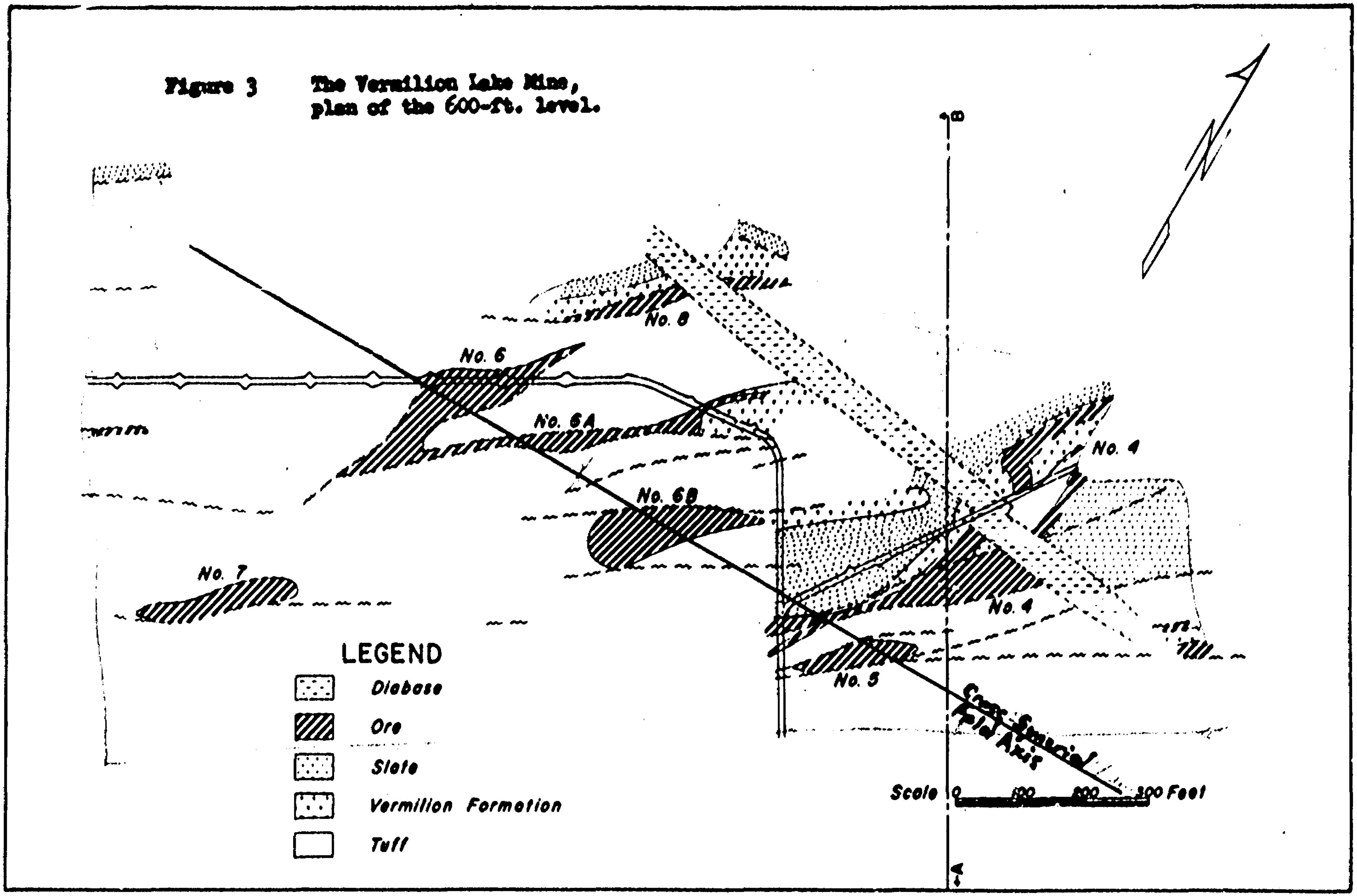
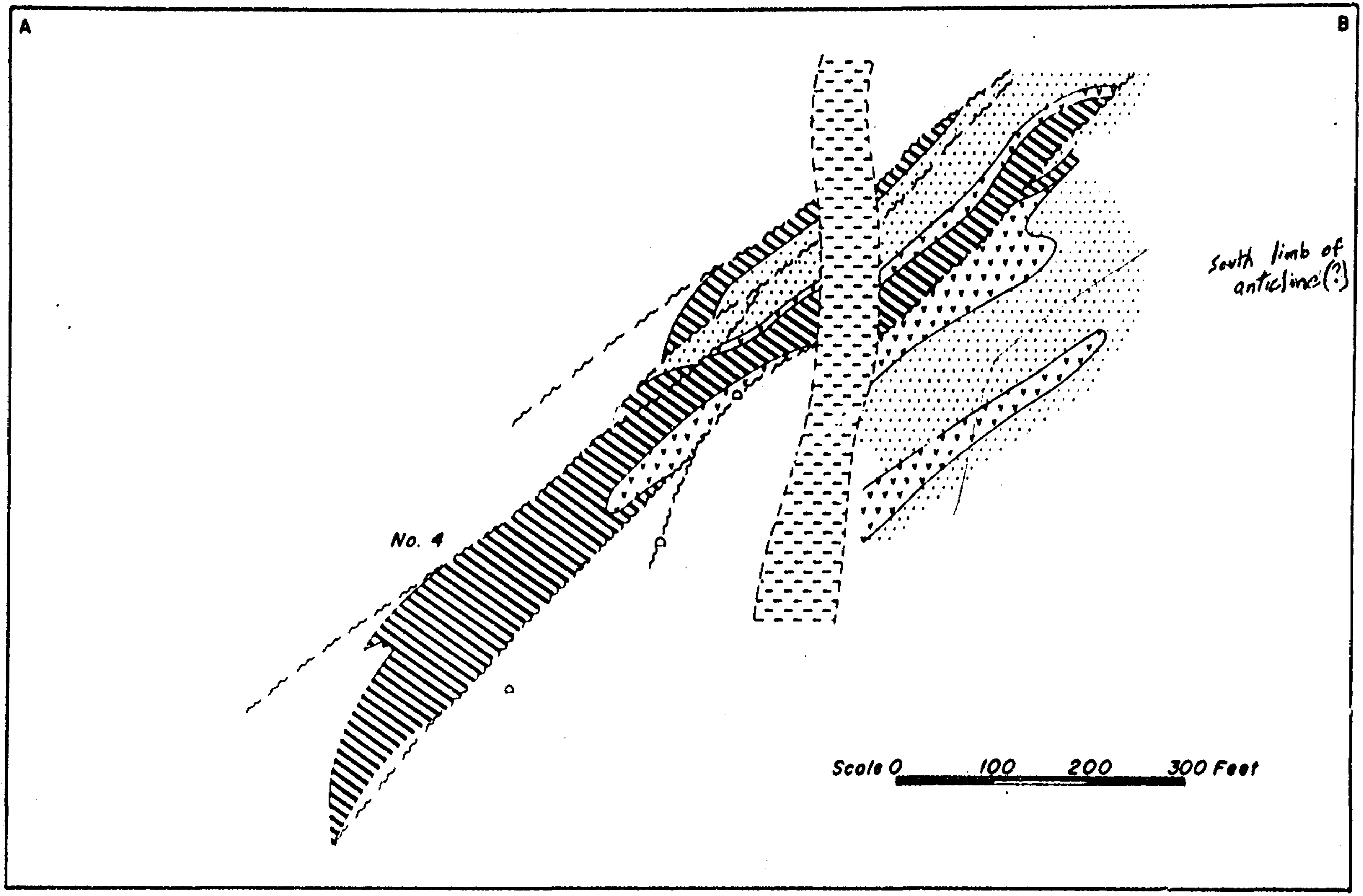
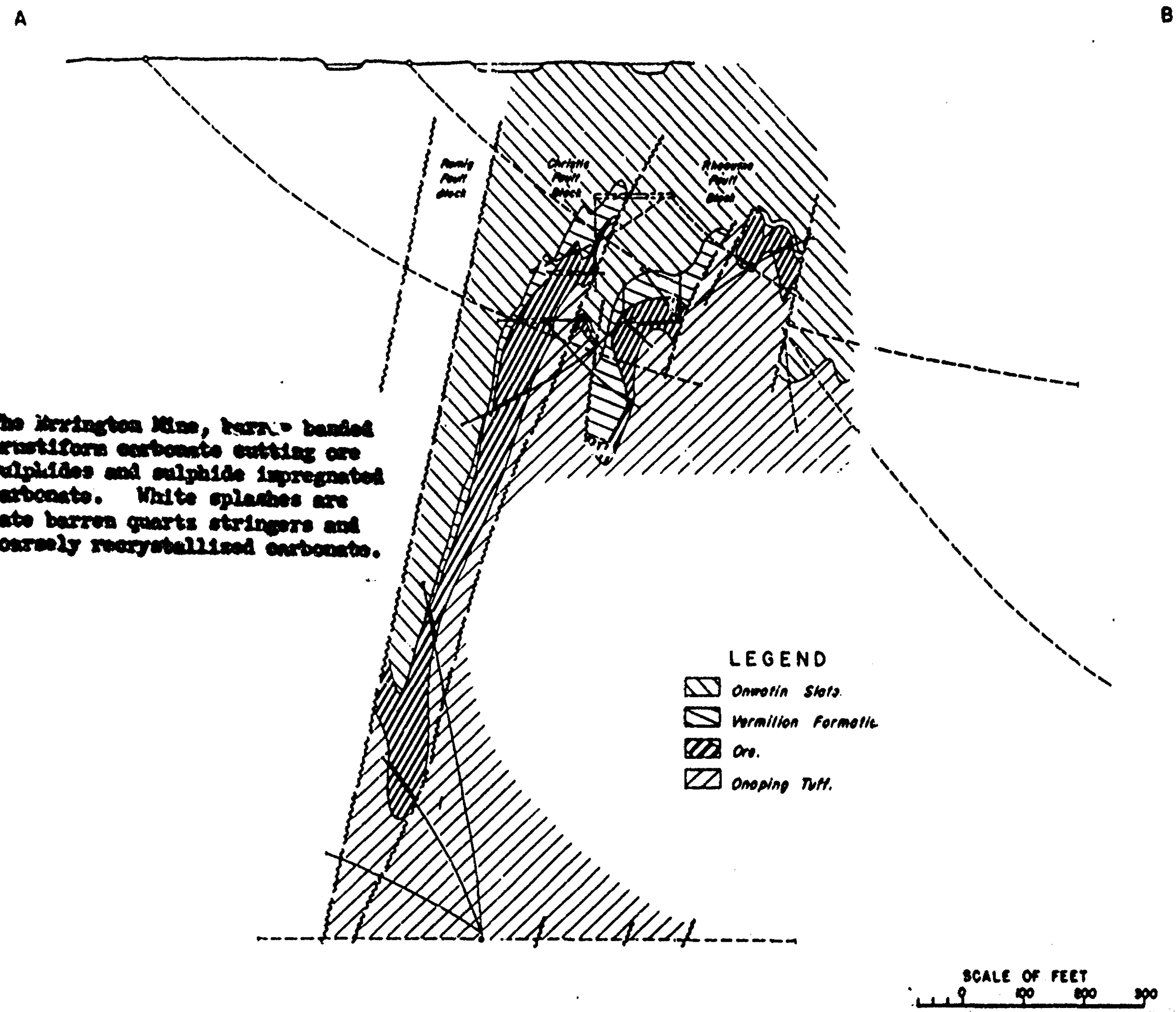


Figure 3 The Vermilion Lake Mine, plan of the 600-ft. level.

plan 600' level Fig. 3.

Figure 4 The Vermilion Lake Mine, section through No. 4 orebody.





The Errington Mine, barren banded crustiform carbonate cutting ore sulphides and sulphide impregnated carbonate. White splashes are late barren quartz stringers and coarsely recrystallized carbonate.