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GEOLOGY OF THE BRENDA COPPER-MOLYBDENUM DEPOSIT

BRITISH COLUMBIA

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Geology of the Brenda Copper-Molybdenum Deposit British Columbia

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The Brenda deposit is 140 miles east-northeast of Vancouver and 14 miles northwest of Peachland, a small town on Okanagan Lake. The deposit is on a ridge between tributaries of Peachland Creek and MacDonald Creek. Elevations range from 5000 to 5600 feet. Glacially rounded outcrops are scattered through the rolling, tree-covered upland.

The earliest record of the deposit appears in Geological Survey of Canada Memoir No. 243 (Rice, 1947) in which are noted the possibilities of a low-grade deposit of large tonnage. In 1954, Bob Bechtel, a part-time prospector from Penticton, rediscovered the deposit and the deposit was then explored by Noranda Exploration Company, Limited, Northwestern Explorations, Limited (Kennco), and by the Brenda Syndicate. The most comprehensive and detailed geological account of the deposit was provided by Charlie Ney of Kenno (1957). Carr of the British Columbia Department of Mines studied the deposit in 1966 and 1967 and provided valuable additions to the geology of the area. This paper is a summary of a study of the Brenda deposit initiated in 1968 by Noranda Exploration Company, Limited. The earlier work by Ney and Carr have been incorporated and is hereby acknowledged.

Published reserves of the Brenda deposit are 177,000,000 tons grading 0.183 percent copper and 0.049 percent molybdenum. Production in the first three years will come from a core of higher-grade mineralization containing 28,000,000 tons of 0.212 percent copper and 0.063 percent molybdenum. The deposit is presently being mined at a rate of 24,000 tons of mill feed ore per day. Mill tune-up commenced in December, 1969 and production was achieved on April 1, 1970. Oxidized capping and waste removed prior to production were used as ballast for water supply and tailings dams.

Geology

The Brenda copper-molybdenum deposit is entirely within the Brenda Stock, a poorly defined body that connects the Okanagan Batholith on the south with the Pennask Batholith on the north. The Brenda Stock was defined by Carr (1967, p. 184) as the "zoned and composite quartz diorite body" in the Brenda Mine area. Overburden and/or Tertiary volcanic rocks mask contact relations between the Brenda Stock and other plutonic rocks in the area.

Nicola Group

Nicola Group sedimentary and volcanic rocks of Upper Triasic age outcrop west of and have been intruded by the Brenda Stock. A band of schistose hornfels (Carr, 1967, p. 185) up to 1500 feet in width was developed in the Nicola tuffs and breccias adjacent to the stock. The hornfels grades westward into porphyritic tuff and volcanic breccia. This hornfels is not developed further north where the stock is in contact with argillites and greywackes. The schistose character of the hornfels in caused by lenticular clots of felted brown biotite crystals in a siliceous matrix.

Brenda Stock

The Brenda Stock as defined by Carr (1967) includes "four gradational units of quartz diorite ..... and a related partly discordant unit named the Fine quartz diorite." These units, which roughly parallel the Brenda Stock-Nicola Group contact, include successively a marginal Medium Quartz Diorite, Speckled Quartz Diorite, Uniform Quartz Diorite, and Porphyritic Quartz Diorite. The units were divided on the basis of slight variations in size, shape, relative distribution and quantity of the contained quartz, plagioclase, potash feldspar, biotite and hornblende.

The Brenda copper-molybdenum deposit occurs almost exclusively in the Speckled Quartz Diorite which is characterized by (Carr, 1968, p. 190):

> "A speckled appearance due to interspersion of small biotite and hornblende crystals with larger ones; the presence of biotite in amounts equalling or exceeding those of hornblende, ...; a prismatic or needle-like shape of most hornblende crystals; and a finely granular appearance of most quartz."

Modal composition ranges are: quartz, 20 to 25 percent; potash feldspar, 10 to 20 percent; plagioclase, 50 to 55 percent; hornblende, 5 to 10 percent; biotite, 5 to 15 percent; plus magnetite, sphene, and apatite. Potash feldspar occurs as poikilitic grains enclosing quartz and plagioclase. Plagioclase composition ranges from An_{36} to An_{42}.

The deposit extends eastward into the Porphyritic Quartz Diorite phase of the stock which is gradational to the Speckled Quartz Diorite. Carr (1968) defines the Porphyritic Quartz Diorite as follows:

> "The rock is lighter colored than others, ... Dark minerals are relatively sparse and scattered and, together with quartz which forms ½-centimeter aggregates, they give the rock a porphyritic appearance. Biotite is typically in well-shaped books..."

The range of modal composition is: quartz, 20 to 30 percent; potash feldspar, 10 to 20 percent; plagioclase, 45 to 60 percent; hornblende, 2 to 5 percent; biotite, 5 to 15 percent; and minor magnetite, apatite and sphene.

Dykes

Several ages of pre-mineral and post-mineral dykes cut the stock. Those observed in the orebody include: aplite, andesite, trachyte porphyry, and basalt. All except basalt are cut by ore-bearing veins. Relative ages of the dykes have not been established.

Aplite: Aplite dykes with widely varying textures consist of aplite and/or graphic intergrowths of quartz and potash feldsper with minor plagioclase and biotite. Narrow dykes generally are aplitic throughout. Some dykes have aplitic borders with granophyric cores while others have granophyric borders and aplitic cores. Aplite dykes range from less than one-half inch to one foot in thickness and rarely persist for strike lengths exceeding a few tens of feet. Color ranges from grey through pink.

Most aplite dykes strike N45°-65°W with dips from 50 to 70°NE. Some strike east-west and dip 65 to 75°S. All aplite dykes are cut by mineralized fractures.

Andesite: Andesite dykes up to two feet wide occur in the pit area. They are dark greenish black with scattered phenocrysts of hornblende. All strike northwesterly, dip 65°S to vertical and have been altered, mineralized and sheared.

Trachyte Porphyry: One dyke of trachyte porphyry up to 15 feet wide has been observed in the Brenda pit. The dyke is characterized by tabular phenocrysts of potash feldspar, some of which exceed one inch in length, set in a grey fine-grained matrix of orthoclase and plagioclase. Larger phenocrysts are pink to white in color with glassy, black turbid cores which enclose small laths of plagioclase. Such phenocrysts comprise up to 50 percent of the rock. Biotite occurs as clots of felted crystals replacing hornblende.

The dyke strikes N60°W, dips nearly vertical and has been traced for more than 1200 feet along strike. Ore-bearing structural features cut the dyke.

Basalt: Irregular and branching basalt dykes, probably related to Tertiary volcanism, have been observed in the pit. These dykes are dark greenish black with chilled margins and rarely exhibit crude columnar jointing. Glassy margins generally have devitrified.

Basalt dykes strike east-west or north-east and dip vertically. Most occupy pre-existing fault zones which cut all phases of mineralization.

Character of Mineralization

Concentrated mineralization is confined to a zone 1500 feet wide and 2600 feet long which is almost entirely within the Speckled Quartz Diorite phase of the Brenda Stock. Ore-grade mineralization is known to extend to depths exceeding 900 feet but has not been explored in detail at depths exceeding 600 feet. Areas of lower grade mineralization extend into adjacent phases of the stock. Veinlets containing chalcopyrite and/or molybdenite have been observed in all phases of the stock.

Primary mineralization is almost entirely confined to fractures, a feature recognized by the earliest workers. Disseminated sulfides are rare, except in altered dyke-rocks and in areas of intense hydrothermal alteration. The grade of the orebody is a function of fracture density.

Chalcopyrite and molybdenite are the principal sulfides in the deposit and generally are accompanied by minor quantities of pyrite and magnetite. Pyrite is especially abundant in altered andesite dykes. Bornite, galena and sphalerite are rare constituents. Pyrrhotite has been reported in drill core.

Structure

The structural features of the deposit include ore fractures, faults, and joints. Joints, other than those which reflect ore fractures, have not been studied in detail.

Ore Fractures:

Ore fractures have been divided into categories based upon the mineralogy of the filling material. Most ore fractures are displacive with sharp boundaries. Some, especially those with potash feldspar and/or epidote, have replaced the host rocks, adjacent to the veins.

Ore fractures have been divided into the following groups:

1. Quartz-potash feldspar-sulfide.
2. Biotite-chalcopyrite.
3. Quartz-molybdenite.
4. Epidote-magnetite-molybdenite.

1. Quartz-Potash Feldspar-Sulfide

Veins in this category form the bulk of the mineralization in the Brenda deposit. Two ages of veins with different characteristics have been recognized. Veins range in thickness from ¼ inch to 2 feet with an average between ¼ and ½ inch. Mineralization within the veins is patchy.

Older veins in this category consist of quartz and potash feldspar with highly variable quantities of chalcopyrite, molybdenite, and pyrite. Magnetite occurs as rare octahedra in chalcopyrite and more rarely as bands at veins walls. Pyrite occurs as euhedral cubes enclosed by chalcopyrite. Potash feldspar content varies from less than one percent to as much as 20 percent in local parts of some veins. Some molybdenite commonly occurs as veinlets cutting other minerals in the veins and some may have been introduced during a later stage of mineralization. Bornite was observed in one vein.

The older veins have the following attitudes:

a) N60-75°E/55°S to 80°N:

These are the most abundant veins and are remarkably persistent throughout the deposit. Veins with this attitude, which include the original high-grade vein showing, comprise 60 percent of the total number of veins mapped in the pit.

b) N65-75°W/vertical:

c) N35-45°W/vertical:

Veins b) and c) comprise a combined 9 percent of the total veins. They are highly subordinate in number and rarely exceed 3/4 inch in thickness.

Younger quartz-potash feldspar-sulfide veins clearly cut the older veins and have several distinctive characteristics. The younger veins are always vuggy with sulfides occurring as discrete crystals and crystal groups in interstices between subhedral quartz and potash feldspar crystals. Biotite occurs as a minor constituent of all veins as does epidote. Chalcopyrite is the principal sulfide and is accompanied by minor quantities of molybdenite and pyrite.

These younger veins range in thickness from 1/8 to ½ inch but rarely exceed ¼ inch. Two attitudes have been recognized:

a) N0-25°W/80-85°SW:

This more dominant set comprises 11 percent of the total veins.

b) N30-45°E/15-25°NW:

Veins with this attitude comprise 2 percent of the total.

2. Biotite-Chalcopyrite

Biotite-chalcopyrite veins which occupy narrow fractures up to 1/8 inch wide, transect the quartz-potash feldspar-sulfide veins. Most biotite-chalcopyrite veins do not exceed 1/32 inch in thickness and are difficult to recognize in unfractured pitwalls. Biotite commonly shows evidence of some slippage along the fracture after or during deposition. Minor and sporadically distributed grains of molybdenite and potash feldspar occur in some veins. Quartz is notably absent.

The veins occupy two fracture sets which show some difference in distribution. Both sets constitute about 16 percent of the veins in the pit. However because they are very narrow and mineralization within them is patchy, their importance in the overall grade of the deposit is minimal.

a) <u>N5-20°W/45°E to vertical</u>:

These are most abundant in this category and occur throughout the deposit.

b) <u>N40-60°W/15-30°N</u>:

Veins in this orientation are most abundant in the north part of the pit.

3. Quartz-Molybdenite

Banded veins of quartz-molybdenite with disseminated cubes of pyrite and chalcopyrite on fractures range from 1 to 8 inches in thickness. Banding is caused by veinlets of molybdenite within the quartz. The wall rock adjacent to most veins contains hydrothermal biotite.

Quartz-molybdenite veins strike N70-80°E and dip 75°S to vertical. These veins comprise only 1.5 percent of all veins, but may be more important than this figure suggests. The attitude of these veins overlap the attitude of some quartz-potash feldspar-sulfide veins and the quartz-molybdenite period of mineralization may have provided much of the molybdenite now found in the earlier veins. Many post-mineral faults with attitudes parallel the quartz-molybdenite veins contain abundant molybdenite on shear planes.

4. Epidote-Magnetite-Molybdenite

Veins of epidote and magnetite with some molybdenite occur throughout the deposit, but they are nowhere abundant. The veins are generally less than one inch in thickness and have highly irregular walls resulting from replacement of the wall rocks by epidote. Calcite and locally biotite and chalcopyrite occur in epidote-rich areas.

These veins strike N45-55^{o}W and have vertical dips. They comprise only 0.5 percent of the veins. Their relationship to the other veins has not been observed.

Faults:

Faults are expressed as shear zones in which the rocks have been intensely altered to clay minerals, epidote and chlorite. These shear zones range from a few inches to 30 feet in width. Most strike N55-90^{o}E and are vertical. North-westerly striking shear zones (N40-60W) are less numerous and seldom exceed three feet in width. Both sets of shear zones exhibit left-lateral movement. A few narrow shear zones strike N5^{o}E to N15^{o}W and exhibit right-lateral movement. Maximum lateral displacement on all appears to be a few tens of feet.

The number of shear zones per unit area and the width of the zones increases toward the north edge of the pit. This area was expressed as a topographic low with little outcrop. A N70^{o}E zone of shearing through this area can be traced for several miles on aerial photographs. Other photo linears can be correlated to dykes and mineralized structures.

Alteration

Four phases of alteration have been recognized in the Brenda deposit:

1. Potassic
    a. Potash feldspar
    b. Biotite
2. Propylitic
3. Argillic

1. Potassic Alteration:

Two phases of potassic alteration have been recognized; a potash feldspar phase and a biotite phase. Sulfide mineralization accompanies both phases.

a) Potash Feldspar: Potash Feldspar is almost entirely confined to quartz-sulfide veins, but locally, in areas of pre-mineral fracturing, the potash feldspar has replaced part of the host rock adjacent to the veins. Such areas seldom exceed two or three feet in diameter and most are but a few inches in width. Most zones of this kind are elongate parallel to vein walls.

b) Biotite: Biotite shows some overlap with the potash feldspar phase. Biotite forms a minor part of vuggy quartz-potash feldspar-sulfide veins and occurs in veins as previously described. Adjacent to some quartz veins, especially those with high molybdenite content, biotite has replaced the mafic minerals and plagioclase in the host rock for widths ranging from a fraction of an inch to several inches. Locally, in areas of intense fracturing, biotitization of the host rock has been so intense that the hydrothermal biotite forms up to 50 percent of the rock. Such areas generally are irregular in distribution and of unknown size. Most are not exposed for more than a few feet. Andesite dykes have been especially susceptible to biotite alteration.

2. Propylitic Alteration:

Weak to moderate propylitic alteration is irregularly distributed throughout the deposit. Characteristic features of this alteration are: a) chloritization of mafic minerals (hydrothermal and magmatic); and b) the plagioclase becomes waxy in appearance and greenish in color. The alteration is most intense in areas with a high density of quartz veining.

3. Argillic Alteration:

Argillic alteration is locally extreme and is confined to shear zones and small fractures ranging from a few inches to greater than 30 feet wide.

The shear zones cut all phases of mineralization and all other phases of alteration. Molybdenite and other minerals have been smeared on the fractures in many of the northeasterly trending shear zones. Clay, sericite and epidote are the characteristic minerals of this alteration assemblage and they impart a light greenish to brownish color to the rock.

Surface Weathering

Surface weathering leached significant molybdenite from the upper oxidized part of the orebody. This weathering extends from zero to 90 feet below the ground surface with an average thickness of 20 feet. Deeper areas of oxidation generally correspond with intensely faulted areas.

A comparison between shallow drilling (20 to 60 feet) in 1957 and deeper development drilling indicates up to 50 percent loss in molybdenum in the weathered part of the deposit. Copper values show a difference of 0.008 percent. The loss in molybdenum values may not be as much as suggested by these figures, but visual comparison of the oxidized part of the pit indicates that some loss did occur.

Minerals developed during weathering include: limonite, malachite, azurite, hematite, ferrimolybdite, powellite and cupriferous manganese oxides with rare occurrences of cuprite, covellite, chalcocite, native copper, tenorite, and ilsemannite. Limonite is by far the most abundant product of weathering.

Exploration Summary

Geology, soil sampling, and induced polarization combined with diamond drilling were used to effectively explore the Brenda deposit. Ground magnetic, electromagnetic and self-potential surveys provided little aid in exploring the property possibly because of the limited area covered by the surveys.

Soil sampling provided a valuable tool in outlining the general area of interest. Anomalous copper values ($\gtrsim$ 200 ppm total copper) coincide with the area of known mineralization. Molybdenum values in the soil ($\gtrsim$ 20 ppm) show almost identical distribution.

Stream sediments draining the deposit range from 250 to 1340 ppm total copper and 50 to 250 ppm molybdenum. Background values are 30 to 50 ppm copper and 0 ppm molybdenum.

The results of an induced polarization survey conducted in 1965 and 1966 by McPhar Geophysics of Toronto show a close coincidence with mineralization (Fountain, 1968).

Initial diamond drilling consisted of three EX holes drilled in 1956 by Noranda Exploration Company, Limited. These holes indicated a grade of 0.21 percent copper and 0.03 percent molybdenum. A series of short EX holes were drilled the following year by Kenno, but did not penetrate the leached zone. Ney (1957) suggested that surface leaching might explain the low values in the holes. His fracture overlay map of the mineralized area closely resembles the proposed boundaries of the Brenda pit.

In 1965 Chapman Wood & Griswold began an evaluation of the Brenda deposit for the Brenda Syndicate which led to a detailed feasibility program in 1966-67. A program of grid drilling on 400-foot centers was conducted to evaluate the area of interest defined by the induced polarization, geochemical and fracture density surveys. A total of 74 BQ wireline diamond drill holes totalling 42,573 feet and 19 percussion-rotary holes totalling 7,323 feet were used to evaluate areas of interest. In June, 1966 an underground bulk sampling program began to compare bulk and diamond drill grades. Noranda started providing major financing at this time. Management control was assumed by Noranda in 1967 and was formalized by agreement in January, 1968.

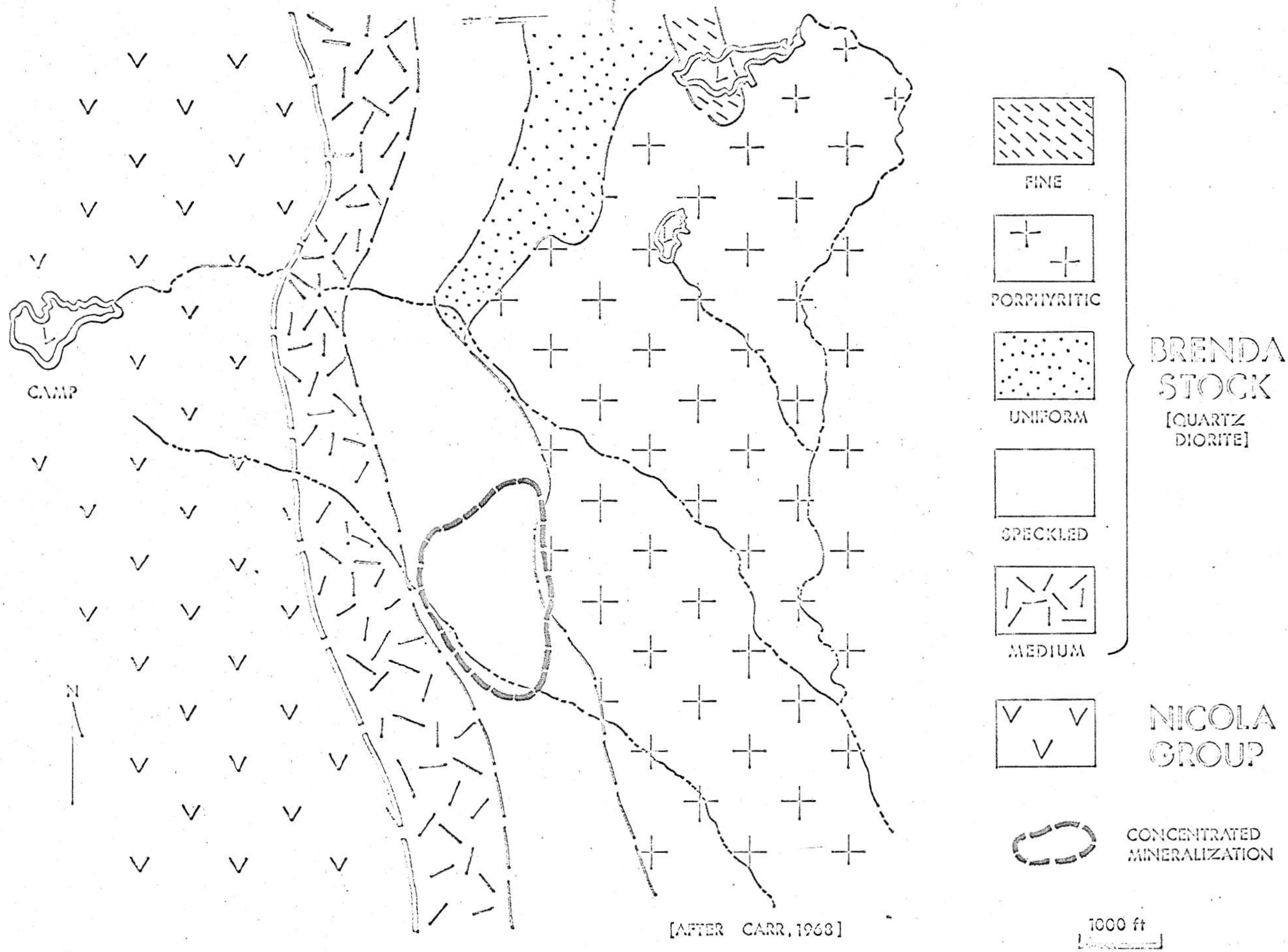
REFERENCES

Carr, J.M., 1967, Geology of the Brenda Lake Area, B.C. Minister Mines, Annual Report, p. 183-212.

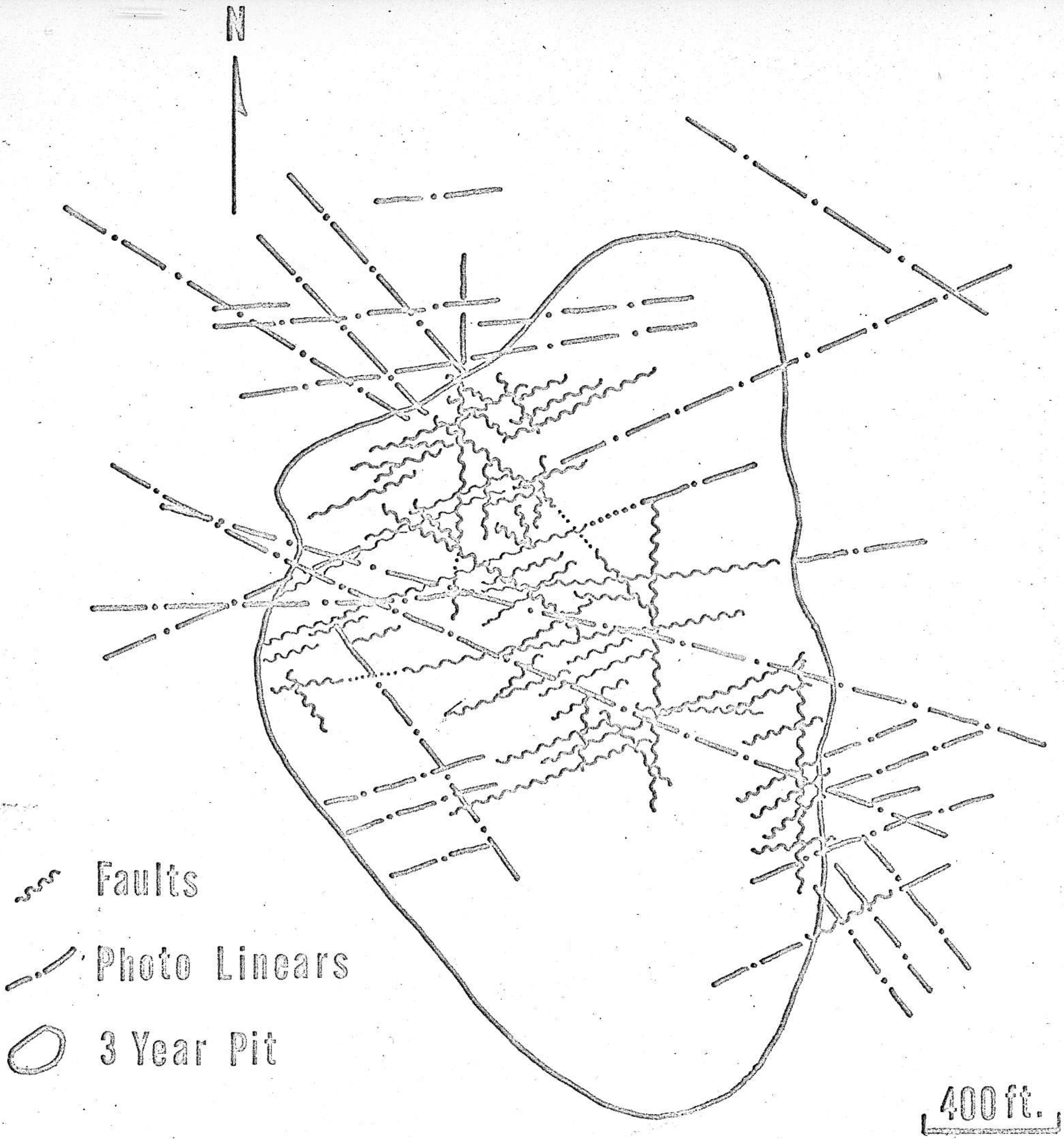
Fountain, D.K., 1968, The Application of the Induced Polarization Method at Brenda Mines, British Columbia, Can. Inst. Min. Met., V, 153-157.

Ney, C.S., 1957, Brenda Prospect, Osoyoos Mining Division, British Columbia, Unpublished report Northwestern Exploration Ltd., 13 p.

Soregaroli, A.E., 1968, Preliminary Report on Geological Studies at the Brenda Mine, Unpublished report, Noranda Exploration Company, Limited, 7 p.



BRENDA DEPOSIT — GENERAL GEOLOGY



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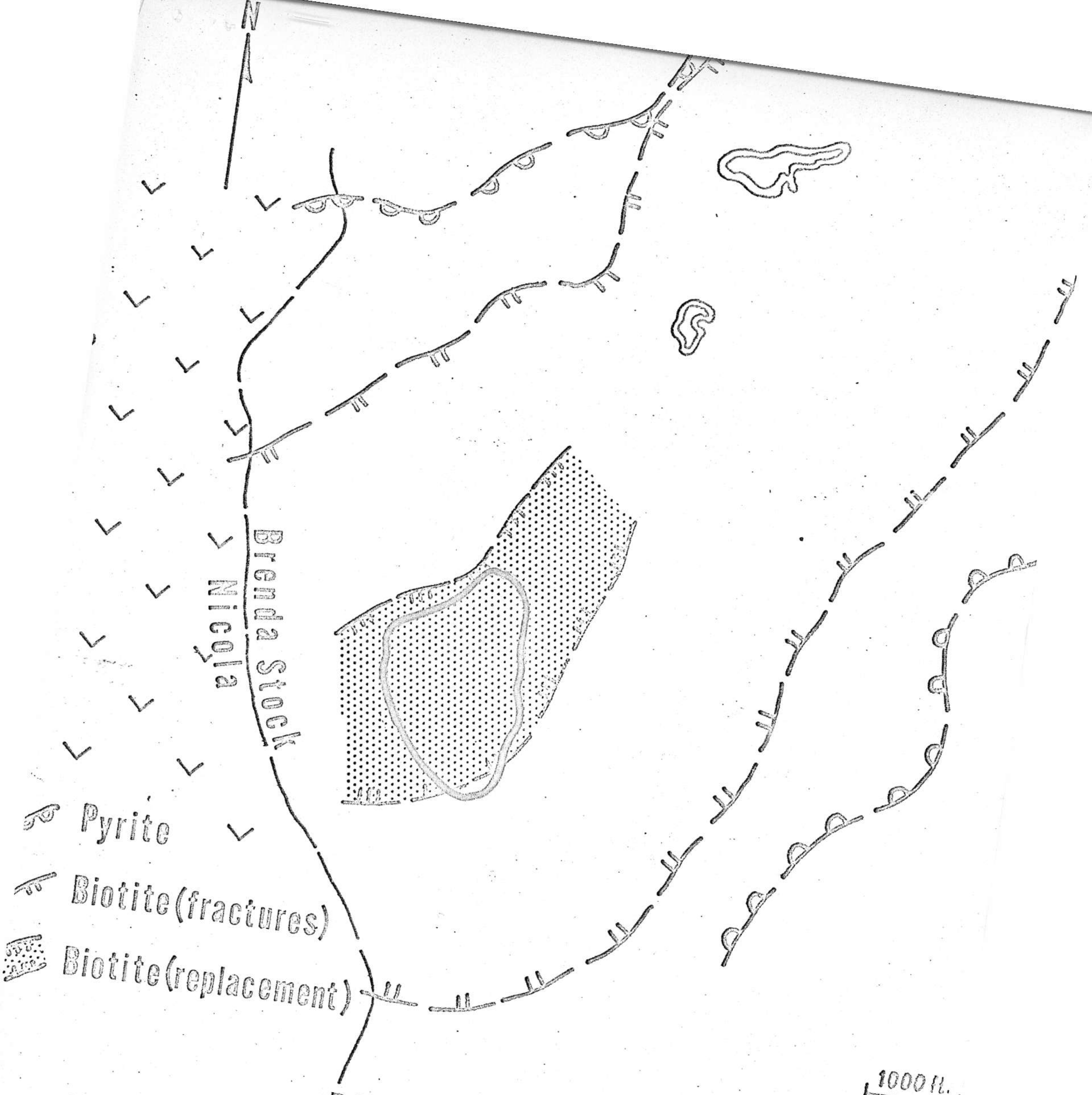

DISTRIBUTION OF
HYDROTHERMAL BIOTITE AND PYRITE