T H E

C A M R A Y

D I S C O V E R Y   D Y K E

A N D

A S S O C I A T E D   U R A N I U M

D E P O S I T S

by

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McGill University

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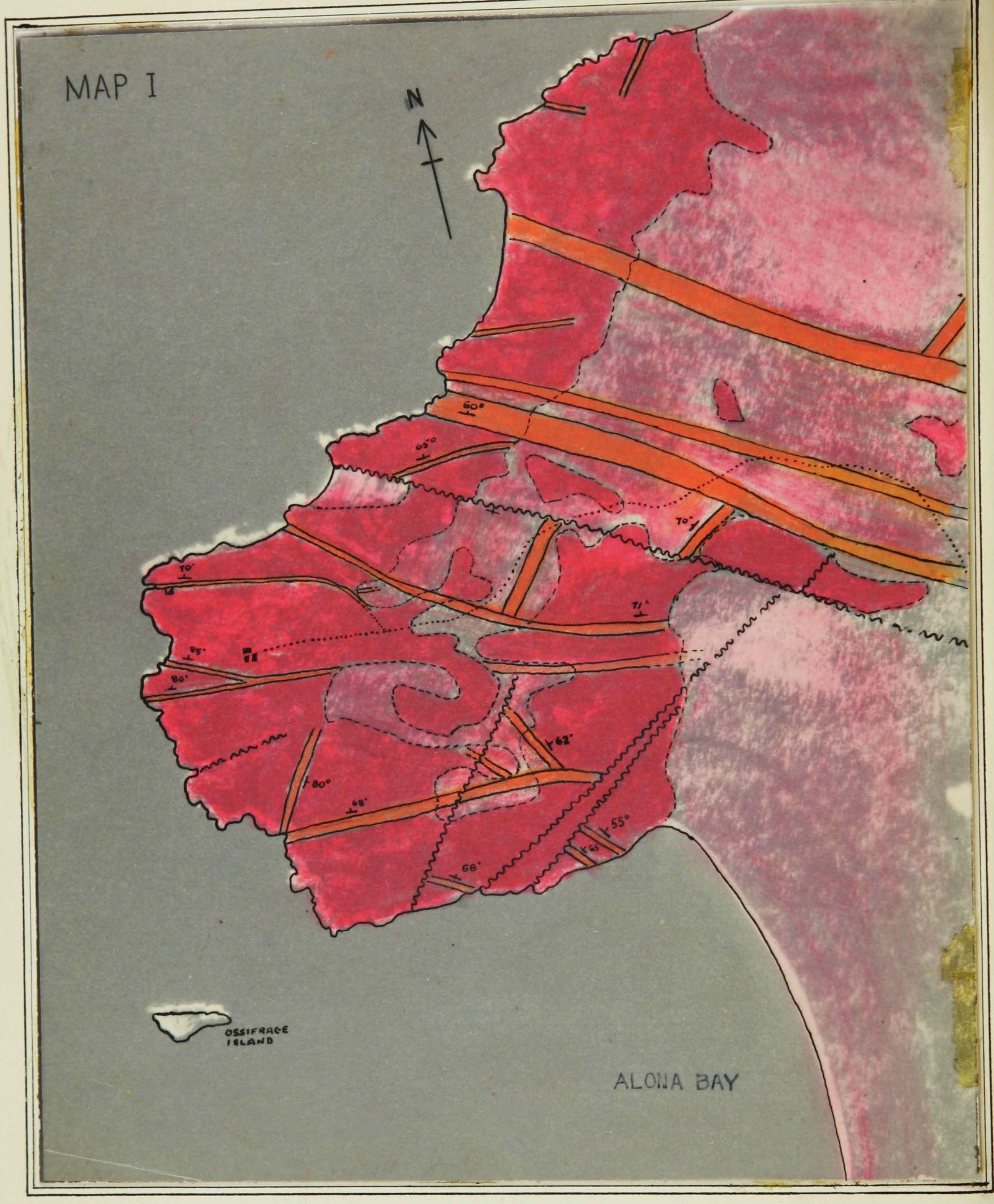
A thesis submitted to the Department of Geological Sciences in partial fulfillment of the requirements for the degree of Master of Science.



THEANO POINT, LAKE SUPERIOR

SCALE 1" = 1000'

LOWER KEWEENAWAN DIABASE

ALGOMAN (?) GRANITE, GRANITE-GNEISS, AND PEGMATITE.
- DRIFT-COVERED

FAULT

70° STRIKE AND DIP OF DYKE

OUTCROP

ROAD

SHAFT

BUILDINGS

AIR PHOTO BY ONTARIO DEPARTMENT OF LANDS AND FORESTS

GEOLOGY BY ONTARIO DEPARTMENT OF MINES

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INTRODUCTION

General Statement and Acknowledgements

During the field season of 1949, the writer was employed as assistant on an Ontario Department of Mines field survey party under Dr. E. W. Nuffield of the University of Toronto. On Dr. Nuffield's suggestion the writer undertook the study of the Camray Discovery Dyke as a thesis problem.

Camray Discovery Dyke is the diabase dyke on the property of Camray Mines, Limited, along which Robert Campbell discovered an earlier-reported deposit of pitchblende. The obvious areal relationship between the pitchblende and the diabase may be genetic and/or structural; and with this in mind the writer secured a fairly complete section of specimens across the dyke near the shaft, and from the granites on both sides. Several specimens of the actual contacts were obtained, as well as a suite of pitchblende ore specimens.

Little attempt could be made to investigate the detailed structural relationships, as surface exposures are poor, and underground workings had hardly been started at the time of the examination.

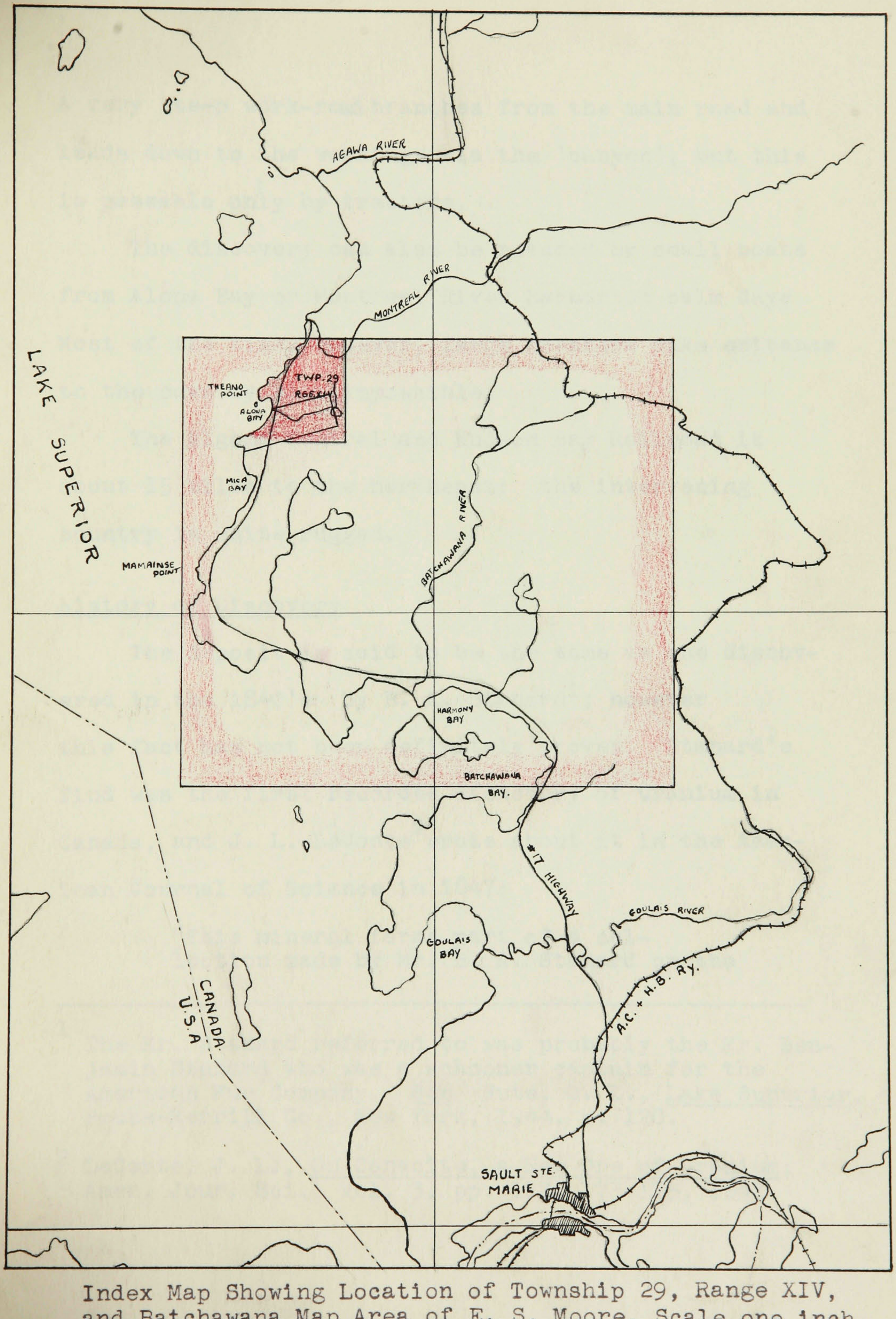
The writer gratefully acknowledges the assistance of Dr. A. W. Jolliffe, and Dr. E. H. Kranck of the

Department of Geological Sciences, McGill University, in the preparation of this report. Dr. E. W. Nuffield of the University of Toronto helpfully identified several minerals by X-ray diffraction pattern methods, and one of the writer's fellow-students, Mr. F. C. Taylor, assisted in photomicrography. To Mr. Thomas Heale, geologist of Camray Mines, Limited, the author is grateful for permission to prepare this report; and to Mr. Frank Clifton for valuable assistance in the field.

<u>Location and Access</u>

The main Camray pitchblende occurrence is at the shore of Lake Superior on the northwest tip of Theano Point, in Township 29, Range XIV, District of Algoma, about 70 miles north of Sault Ste. Marie, Ontario. The workings are about one-and-a-half miles from Highway 17, and are reached by a road built during the summer of 1949. Highway 17 is hard-surfaced for most of the distance from Sault Ste. Marie, and the remainder is a gravel road in good condition. The road to Theano Point is steep in part, and is passable to cars and trucks only in dry weather. It leads to the mine buildings situated on an outcrop about 300 feet above the level of the lake; from this point the showing is reached by a series of ramps and ladders.

Map II



Index Map Showing Location of Township 29, Range XIV, and Batchawana Map Area of E. S. Moore. Scale one inch equals eight miles.

A very steep work-road branches from the main road and leads down to the workings via the 'canyon', but this is passable only by tractors.

The discovery can also be reached by small boats from Alona Bay or Montreal River Harbor on calm days. Most of the time, however, large breakers make entrance to the cove by boat impossible.

The Algoma Central and Hudson Bay Railroad is about 15 miles to the northeast; the intervening country is quite rugged.

History of Discovery

The deposit is said to be the same as one discovered in the 1840's by B. A. Stanard[1]; however this fact has not been definitely proven. Stanard's find was the first recorded discovery of uranium in Canada, and J. L. LeConte[2] wrote about it in the American Journal of Science in 1847:

> "This mineral forms part of a collection made by Mr. B. A. Stanard on the

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1 The Mr. Stanard referred to was probably the Mr. Benjamin Stanard who was a schooner captain for the American Fur Company. See Nute, G. L., Lake Superior, Bobbs-Merrill Co., New York, 1944. p. 120.

2 LeConte, J. L., On Coracite, a New Ore of Uranium; Amer. Jour. Sci., Vol. 3, pp. 117, 173-175, 1847.

> north shore of lake Superior... This mineral, as I am informed by Mr. Stanard occurs on the north shore of lake Superior, about 70 miles from the Sault Ste. Marie, at the junction of trap and sienite; the vein in which it is found is about two inches in width; but on account of its position (on the face of an almost perpendicular cliff) only a few specimens were obtained and those with great difficulty."

LeConte distinguished the new mineral as being closely related to pitchblende but having physical and chemical properties slightly different from the typical pitchblende of Joachimsthal in Bohemia. For this reason he called it 'coracite'--deriving the name from the Greek word for raven, apparently in allusion to the black color of the mineral.

In 1849, J. D. Whitney[1] published a short note on the mineral. He considered it to contain uranium of a different valence from that of typical pitchblende and noted that it was more soluble in acids than the pitchblende from Joachimsthal.

In 1857, F. A. Genth[2] gave the following description of the Standard specimen:

> "Dr. John L. LeConte kindly presented me with a specimen of the mineral from about

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[1] Whitney, J. D., A Chemical Examination of Some Minerals; Am. Jour. Sci., Vol. 7, p. 434, 1849.

[2] Genth, F. A., Contributions to Mineralogy; Am. Jour. Sci., Vol. 23, p. 421, 1857.

> ninety miles above Sault Ste. Marie on the north shore of lake Superior, which he described as coracite. Its great resemblance to pitchblende favored the opinion that it was really nothing else....though it is interesting that it is so readily soluble in chlorohydric acid, this fact alone is not sufficient to separate it from pitchblende."

Efforts by the Geological Survey and by various prospectors were made to relocate the occurrence, but these were unsuccessful until 1948, due largely to the conflicting statements regarding location given in various reports. A. H. Lang[1] of the Geological Survey of Canada writes:

> "It....appears likely that the use of the name Mamainse in The Geology of Canada followed an old custom of referring to the entire region as Mamainse, whereas more recent investigators have assumed that it referred to Mamainse Point...."

On September 8, 1948, Robert Campbell discovered an occurrence of pitchblende on Theano Point. He had spent the preceding winter consulting various references to the original discovery, and during the summer had prospected by foot and by boat along the shore of Lake Superior from Point Mamainse northward. Finally, searching alone, equipped with a Geiger counter

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[1] Lang, A. H., The Camray Uranium Discovery; Can. Inst. Min. Met., Vol. 42, No. 442, p. 70, Feb., 1949.

he obtained a strong reaction near the south wall of a gorge on Theano Point. Close investigation revealed that the reaction arose from a stringer of pitchblende near the water's edge. Other stringers were found farther inland along the base of the cliff. Mr. Campbell staked thirty claims and these were recorded on October 30, 1948. A staking rush into the area developed and several thousand claims have been recorded up to the time of writing.

Previous Geological Work

The first geological studies of the area were made by William E. Logan[1] of the Geological Survey of Canada in the 1850's. The results were summarized in the Geology of Canada, issued by the Geological Survey in 1863. The occurrence is reported thus:

> "An ore of this rare metal (uranium) is said to occur at Mamainse."

Actually Mamainse Point is some 20 miles to the south.

A. P. Coleman[2] and A. B. Wilmott examined the northeast shore of Lake Superior for the Ontario Department of Mines in 1898, with special reference to the

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[1] Logan, W. E., Geology of Canada; Geol. Surv., Can., Rept. of Progress, pp. 504, 702, 1863.

[2] Coleman, A. P., Copper Regions of the Upper Lakes; Ann. Rept. Of Ont. Bur. Mines, pp. 121-174, 1899.

copper deposits of the region. The report includes a good general description of the northeast shore, and an excellent account of the Pleistocene geology, especially the abandoned strand lines of glacial lake Algonquin.

E. S. Moore[1] made a geological map and wrote a report on the geology of the region in 1926 for the Ontario Department of Mines.

R. A. A. Johnston and H. V. Ellsworth give summarized accounts of the pitchblende occurrence in later Geological Survey of Canada reports.

After Campbell's discovery in 1948, geological investigations were made of the showing, and of the general area by the Geological Survey, and the Ontario Department of Mines.

J. Satterly and D. F. Hewitt[2] investigated the showing for the Ontario Department of Mines on November 8, 1948, and A. H. Lang of the Geological Survey visited the discovery on November 11, 1948.

The Ontario Department of Mines placed a geological field party in the area during the summer of

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[1] Moore, E. S., Batchawana Area, District of Algoma; Ont. Dept. Mines, Ann. Rept., Vol. XXV, 1926.

[2] Satterly, Jack, and D. F. Hewitt, Report on a Pitchblende Occurrence at Theano Point, Lake Superior, Ontario; Ont. Dept. Mines, Press Release, 1948-49.

1949. Dr. E. W. Nuffield of the University of Toronto was party chief, and the writer acted as assistant. The Preliminary Map[1] of the investigations was issued in March, 1950. Field work by Dr. Nuffield and the writer will be resumed in 1950.

S. N. Kesten, of Eldorado Mining and Refining (1944), Limited, investigated the showing on behalf of the Crown Company during the summer of 1949.

History of Development.

The Camray property consists of a block of thirty claims, and extends for a mile and a quarter eastward from the discovery with a width of about a mile. As was mentioned, the claims were staked by Robert Campbell for the Camray Prospecting Syndicate. They were later transferred to a company called Camray Mines, Limited.

During the summer and fall of 1949, after preliminary diamond drilling, an inclined, one-compartment shaft was sunk to a depth of 120 feet, and several drifts were driven east and west along the south contact of the diabase dyke at this depth. Geological mapping of the claims by the company was completed on

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[1] Preliminary Map of Township 29, Range XIV, District of Algoma; Ont. Dept. Mines, March, 1950.

Fig. 1. View of mine development on Discovery Dyke, September, 1949. Compare with Figure 5.

a scale of one inch equals two hundred feet, and several other occurrences of radioactive minerals were located. One of these, within several hundred yards of the main highway, was promising enough to warrant driving an adit to investigate. An important part of the development work during the summer was the completion of a road from the highway to the mine buildings. In November it became apparent that with the prevailing government price for pitchblende concentrates, the deposits were not of sufficient grade to justify further development on the property, and therefore operations were suspended.

TOPOGRAPHY

Relief

The region is typical of the rugged north and northeast shores of Lake Superior. The total relief within Township 29, Range XIV is about 700 feet, and local relief on Theano Point approaches 600 feet. The hills are composed mainly of granite, granite gneiss, pegmatite, and some schistose rock; the depressions are occupied by diabase dykes, fault zones, and unconsolidated glacial and glacial-lake deposits. At places, however, the diabase is more resistant, and stands higher than nearby granite. Where the diabase has been closely jointed and altered, it erodes easily, and gullies have been formed. Where shearing has been concentrated along the contacts between diabase and granite, the boundaries are usually deeply eroded and covered by many feet of overburden.

Typically, the north slopes of the larger hills are less steep, less rugged, and have fewer outcrops than the southern exposures. Many of the south slopes are precipitous rocky escarpments several hundred feet high.

Fig. 2. View of south side of Theano Point from Alona Bay. Top of hill on right is about 600 feet above the lake.

Fig. 3. View southward from 'Suicide Hill' on north line of township. Note the beach terraces in left background.

Effects of Glacial Lake Algonquin

Progressive lowering of glacial Lake Algonquin, due to the recession of the Wisconsin ice sheet and the opening of new drainage channels to the south and east, has formed a series of beach terraces which extends inland several miles from Lake Superior and occur at various levels up to about 400 feet above the lake. (See Fig. 3) Two abandoned sea-caves, at least 75 feet above the level of Lake Superior, were found on Theano Point, and are undoubtedly due to wave erosion along zones of weakness in the granite.

A glacial lake occupying the Lake Superior basin stood at one time at least 400 feet above the present level of the lake, and below this high water level, the sheet of till that originally covered much of the region has been largely removed by wave erosion and deposited as stratified clay, sand, and gravel in lower terraces and in depressions. Ice and wave action along the shores of Theano Point has kept the rock bare of vegetation for several hundred feet from the shore line, and has carved out many steep-walled gorges along the weaker dykes and fault zones. (See Fig. 4)

Fig. 4. Gorge about 100 feet deep eroded on site of diabase dyke about 300 yards south of Discovery Dyke on Theano Point.

Drainage

The thick deposits of Pleistocene sands and gravels along abandoned beach lines and in depressions permit free underground drainage, and comparatively few lakes and streams occur in the township.

The largest stream in the area is Montreal River, which flows into the township from the northeast, then turns and flows toward the north. It averages 100 to 150 feet in width, with local narrowing and widening. Variations in volume are due to the action of a dam 12 miles upstream which stores and releases water intermittently as required by a hydro-electric plant.

Montreal River is a consequent stream developed mainly on glacial deposits, but where it has cut through these deposits to bedrock, its course is in part determined by rock structure. Rapids or falls have formed where diabase dykes cross the river bed.

A second hydro-electric plant, near the mouth of Montreal River, five miles north of Theano Point, supplies power to the Sault Ste. Marie area.

Vegetation

The area is well-wooded with deciduous trees: maple, dwarf maple, black birch, and poplar; and on the rocky south slopes, with pine and spruce. Cedar is plentiful in swampy areas. A lumber company has a concession in the Alona Bay area and is at present taking out large birch for the manufacture of veneer.

GENERAL GEOLOGY

Table of Formations

In E. S. Moore's report[1] on the Batchawana area (oulined on Map II), which covers the area around Theano Point, the following geological section is given.

QUATERNARY

Recent:	Gravel and sand along lake shore and streams.
Pleistocene:	Drift and stratified gravel, sand, and clay deposited in post-glacial lakes. Clays well varved.

PRECAMBRIAN

Keweenawan:	Upper Keweenawan--conglomerate, sandstone, concretionary shale, and marl.
	Middle Keweenawan--conglomerate and sandstone interbedded with amygdaloidal basalt and felsite. Dikes of olivine diabase and quartz porphyry cut these.
	Lower Keweenawan--diabase, porphyritic and non-porphyritic, quartzose to quartzless, in dykes and bosses.
Algoman(?):	Granite and granite gneiss.
Mamainsean:	Diabase grading into gabbro and diorite. A few lava flows
Batchawana Series:	Banded iron formation, arkose, greywacke, banded slate, acid and basic lavas, and schist equivalents.

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[1] Moore, E. S., Batchawana Area, District of Algoma; Ont. Dept. Mines, Ann. Rept. Vol. XXV p. 59, 1926.

Description of Formations

The only rocks encountered in the vicinity of the Camray claims are: Algoman(?) granite, granite gneiss, and pegmatite, with inclusions of mica schist and amphibolite; Keweenawan diabase, lava, sandstone, and conglomerate; and Pleistocene glacial and glacial-lake deposits.

Pre-Algoman(?)

Some dark-colored schists occur on Theano Point as inclusions in granite. A few miles to the east, on the Bobcam property, schistose amphibolite, and breccia formed of amphibolite fragments in a pegmatitic matrix underlies an area a few hundred feet across. These schists may represent highly metamorphosed remnants of either Mamainsean diabase or, more probably, the Batchawana Series which Moore[1] correlates with the Sudbury Series. They may even be remnants of Keewatin rocks not previously recognized in the district.

Algoman(?)

The Batchawana.area mapped by Moore (See Map II) is almost surrounded by Algoman(?) granite. The granite is mostly biotitic, but grades into types carrying more hornblende or pyroxene. In most places it is compar-

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[1] Op. cit. p. 59.

atively massive but includes gneissoid facies. On Theano Point the Algoman(?) rocks are represented by pink to red granite, granite gneiss, and poorly-defined dykes and irregular masses of pegmatite.

Lower Keweenawan

A great number of dykes of Lower Keweenawan diabase occur in the area. The widths of most of them range from 10 to 80 feet, but larger ones occur; one exposed in Alona Bay is 300 feet across. The dykes are so numerous on Theano Point that they underlie a considerable proportion (perhaps five to ten percent) of the area. Moore[1] states that the diabase seems to correspond to the quartz diabase so common in the Michipicoten region and elsewhere in Ontario, and which has generally been considered as Keweenawan in age.

Middle Keweenawan

Rocks of the Middle Keweenawan (interbedded lavas, conglomerates, and sandstones) outcrop along the south shore of Alona Bay, and for many miles along the shore southward from Mica Bay four miles farther south. The lavas are mainly altered amygdaloidal olivine basalt,

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[1] Op. cit. p. 65.

commonly called melaphyre, but grade into fairly coarse diabase near the base of each flow. Acid lavas are almost completely lacking in the series. The conglomerates are remarkable for the large boulders up to four feet in diameter which they contain. The pebbles and boulders are composed of granite, greenstone, diabase, quartz, schist, and lava. According to Moore they represent shallow-water deposition, and were derived from highlands to the northeast. Middle Keweenawan sandstones are mostly argillaceous and arkosic, containing much undecomposed volcanic rock and feldspar along with the quartz grains. The sandstones are light grey to red in color, and in many places are mottled. Locally they grade into shaly layers.

Upper Keweenawan

In Alona Bay, conglomerates, sandstones, shales, and marls, believed to be Upper Keweenawan, lie unconformably on the Middle Keweenawan rocks. The conglomerates contain pebbles and boulders similar to those in the underlying formation, but the boulders are generally smaller in size. The sandstone is mainly soft and argillaceous--grading into a concretionary shale.

Dykes of olivine diabase and quartz porphyry cut the conglomerates of the Middle Keweenawan. They have not been found near outcrops of Upper Keweenawan so their age relative to this formation is in doubt. Moore[1] states:

> "....they are the youngest igneous rocks so far known in the Precambrian shield. It seems reasonable to regard them as a late phase of the Middle Keweenawan."

Pleistocene

Pleistocene glacial and glacial-lake deposits occur throughout the township. Glacial till, deposited by the continental ice sheet, is exposed in the Alona Bay area, where a small stream has cut through overlying lake-bottom deposits.

On exposed points, wave erosion by a glacial lake occupying the Lake Superior basin has largely removed the mantle of till. With progressive lowering of the lake, beach terraces of stratified clay, sand, and gravel were developed in sheltered areas. The air-photo (See Frontispiece) shows clearly the scoured zone extending inland along the shores of Theano Point, and two of the lower terraces in Alona Bay.

Cross-bedding is common in the sands exposed along Highway 17, and on the logging road east of Alona Bay.

Some of the beach terraces north of Theano Point

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[1] Op. cit. p. 75.

are composed of rounded, well-sorted boulders of granite from eight to ten inches in diameter. Such terraces are usually bare of any vegetation.

Structural Geology

The only rocks outcropping on Theano Point are Algoman(?) granite, granite gneiss, and pegmatite; inclusions of mica schist; and the Lower Keweenawan diabase dykes. Pegmatite occurs as poorly-defined dykes and irregular masses in the granite. The direction of lineation in the granite gneiss is fairly uniform over the area, plunging at low angles to the northeast.

Diabase dykes form a considerable proportion of the rock formation on the point. (See Frontispiece) The age relationships of the variously striking sets of dykes is rather obscure. It is apparent that the latest dykes strike about S80°E-S60°E and dip steeply northward--in places occupying faults that have offset earlier dykes striking northeast. The relative time of the intrusion of a set of dykes striking about S40°E is obscure beyond the fact that they appear to be earlier than the northeasterly-striking faults.

The rocks on the point are cut by several major faults striking about N55°E, at least one of which is offset by a vertical fault striking S65°E, and traceable for at least four miles on the air photos. What appear to be fault scarps, in places 200 feet high, occur along this vertical fault as southward-facing cliffs. Movement along this fault was apparently the latest tectonic activity in the geological history of the area. Further study in the field may enable the writer to determine the direction and amount of movement on this fault.

Minor cross faults, with movement of seldom more than a few feet, cut the main southeasterly-trending dykes. In some places movement was concentrated along the dykes, producing closely-spaced joints and slickensides throughout the diabase, and brecciation at the granite-diabase contacts.

DISCOVERY DYKE

General Description

'Discovery Dyke' is the name applied to the diabase dyke with which the original discovery of pitchblende on the Camray property is associated. It appears to have been intruded along one of the main directions of jointing in the granite. The pitchblende occurs in the brecciated south contact, and in stringers extending several feet into the granite from this contact.

Discovery Dyke, like many of the other diabase dykes exposed on the shore line, has been deeply eroded by ice and wave action of Lake Superior, and a cove 150 feet in length has formed where it enters the lake. (See Fig. 6)

Near the lake the dyke strikes S80°E, dips from 70° to 80° to the north, and averages 35 to 40 feet in width. Where the specimens were obtained it measures 45 feet wide. Assuming the dip to be 75°, the true thickness of the diabase dyke at this point is 41 feet. At 15 feet West[1], there is a local narrowing to 18 feet, and granite outcrops on the canyon floor.

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[1] Measurements are East and West from zero point on a base-line established in the gully.

Fig. 5. Discovery Dyke viewed eastward from cove, June 15, 1949. Compare with Fig. 1, taken from same location three months later.

Fig. 6. Discovery Dyke at shore of Lake Superior. Diabase outcrops in center foreground.

Inland about a quarter of a mile, the dyke narrows to 20 feet in width and changes azimuth to 125°--the dip remaining fairly constant. At this point it is parallel to a pronounced gully several hundred feet to the east which is occupied by another diabase dyke. A hundred feet or so to the southeast Discovery Dyke disappears under overburden, and its gully becomes too indistinct to trace farther. The elevation of this point is between 250 and 300 feet above Lake Superior.

Along its known length the dyke occupies a distinct gully or gorge--locally called the 'Canyon'--with granite walls rising 50 to 150 feet on the south and 15 to 20 feet on the north. Outcrops of diabase occur intermittently in the gully, but become fewer toward the east where they are confined to selvages along the granite walls of the gully.

The following description relates to the diabase near the pitchblende occurrences.

The diabase has been strongly sheared since its emplacement and is closely jointed. The joint blocks are two or three inches to the side and in many cases show slickensiding on all faces. Several occurrences were noted of joints curving through 20° or 30° in the space of a few inches. Shearing appears to be concentrated at and close to the south contact, but slickensides and closely-spaced jointing occur to within a few feet of the north contact.

Several inclusions of granite occur about eight feet from the south contact; these were probably sloughed off the contact during intrusion of the diabase. A specimen of this rock is described in the following section. Megascopic and microscopic examination of the diabase suggests that Discovery Dyke may be a multiple intrusive.

At least two faults, with displacements of less than ten feet, occur in the area near the pitchblende deposits. The fault at 140 feet East traverses the dyke and the granite on both sides, striking S28°E and dipping 45° to the east. A small shear at 60 feet West appears to cut only the south granite wall and disappears after passing several feet into the diabase. It strikes about N60°E and dips steeply to the south.

These two faults may have some bearing on the narrowing of the dyke between 60 feet West and 150 feet East. It may also be significant that no radioactivity is found (at the surface level) along the south contact between these faults.

Several other indentations in the granite walls may mark the sites of other faults crossing or entering the dyke, but these were not investigated.

Petrographic Description

Specimens of diabase were taken approximately every two feet across the dyke near the shaft. Between 12 and 22 feet from the south contact no specimens were available due to a deep covering of compacted overburden.

Megascopic Description

All specimens except the very fine-grained types, appear considerably altered. On fresh surfaces the diabase is a dark greenish-grey in color, with occasional red tinges. The weathered surface is commonly a light rusty brown or yellow. Most specimens show patches of opaque minerals.

The diabase at the immediate contact with the granite is a massive, greenish-black rock, having a pronounced conchoidal fracture. It is either wholly aphanitic, or has an aphanitic base in which minute, shiny phenocrysts can be detected. From these chilled border phases, the diabase grades to a relatively coarse-grained type with visible ophitic texture in the middle of the dyke.

Magnetic components are indicated by small particles of the rock being attracted by a strong magnet.

Specific gravity determinations of the fine-grained and coarse-grained varieties showed little difference.

coarse-grained:	2.71
fine-grained:	2.70

Both types are considerably lighter than the average fresh, quartz-free diabase which, according to Daly[1], has a specific gravity of 2.98.

A fairly normal gradation in grain size from the contacts toward the center of the dyke is broken by several specimens of a fine-grained type found about ten feet from the south contact. These may be associated with the granite inclusions spoken of previously, or they may suggest that we are dealing with a multiple dyke. Grain size appears to increase more slowly outward from the south contact than from the north contact.

Microscopic Description

General Mineralogy

In all thin sections, except those of the very

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1 Daly, R. A., Igneous Rocks and the Depths of the Earth, McGraw-Hill, New York, p. 47. 1933.

fine-grained type, the diabase shows considerable alteration. The fine-grained variety, close to the contacts with the granite, under the microscope is porphyritic, containing phenocrysts of labradorite, and of alteration products pseudomorphous after pyroxene, set in a very fine-grained groundmass of labradorite microlites, alteration products, iron oxides, and a mat of polarizing and non-polarizing material that may contain glass.

The coarse-grained type from the center of the dyke, although considerably altered, retains the ophitic texture of fresh diabase. The ophitic texture is retained because the plagioclase, not completely altered, is still recognizeable as lath-shaped, and the interstitial chlorite is to a large extent pseudomorphous after the original pyroxene. Thus, textural evidence shows that the hydrothermal alteration occurred after the complete solidification of the diabase.

Only a few crystals of pyroxene were found; in all other instances it is represented by various alteration products--chlorite, tremolite-actinolite, antigorite, quartz, and acid plagioclase(?). The fresh pyroxene was determined as augite. It is clear, colorless, $Z \wedge C = 51^\circ$, low to moderate birefringence. These few crystals may or may not represent the original pyroxene of the rock. The partially altered augite, seen only in two slides is extremely cloudy with a finely-divided alteration product that obscures it from optical examination.

The final alteration product of pyroxene is a lamellar chlorite mineral,,which may occur as pseudomorphs after the pyroxene. Fibrous aggregates of the same mineral and other chlorite minerals occur. In some slides chlorite comprises from 50 to 60 percent of the rock.

Optical properties of the lamellar chlorite mineral are: pale green, slightly pleochroic; relief fair, $\underline{n}$ average 1.57; good cleavage parallel to (001); maximum extinction angle (Z direction from (001)) 6°; uniaxial (or 2V very small), negative; birefringence .004, maximum interference colors first order yellow--occasionally anomalous.

Considering the extent of the alteration of pyroxene, the plagioclase is, in most places, remarkably fresh. This factor, as noted above, has resulted in the ophitic texture being largely retained. The measurements of the angles of extinction by the Michel-Levy statistical method indicates that the feldspar is labradorite averaging $Ab_{40}An_{60}$, the most calcic variety, $Ab_{35}An_{65}$, occurring as microlites near the south contact. By immersion in index liquids, measurements of the index of refraction on fragments indicate a value for $\underline{n}_\beta$ of approximately 1.565, confirming the identification of labradorite. In the coarser parts of the dyke, the plagioclase is partly altered to the variety of epidote giving anomalous blue interference colors known as clinozoisite. Plagioclase phenocrysts in the chilled contacts show some sericitization. A notable feature of the plagioclase throughout the dyke is the bending and fracturing of the twin lamellae. The fractures have been healed by sericite and kaolin minerals, and have also acted as foci for alteration processes.

No quartz was found as a primary constituent in the diabase; small particles of a clear, colorless, uniaxial mineral of low relief, occurring as mosaics in the midst of alteration products were interpreted as being secondary quartz resulting from the alteration of the primary silicates. The quartz is present in insufficient quantities--even if primary--to justify calling the rock a quartz diabase.

A clear, colorless mineral of low relief, having an index of refraction less than that of canada balsam, and in particles too small to examine satisfactorily, are considered to be a secondary acid plagioclase, probably albite, resulting from hydrothermal alteration. It occurs in smaller quantities than does the quartz. In one slide, a vermicular, or myrmekitic intergrowth of secondary quartz and feldspar, so minute as to be resolvable with difficulty even under highest power, was observed.

Granular aggregates of sphene are abundant throughout the dyke, forming up to five percent of the rock in places. It is colorless to yellow, with very high relief and strong dispersion. Birefringence is extreme--the interference colors being high order white. Due to the strong dispersion and the small size of the individual grains, the mineral does not generally show extinction. Sphene occurs in the chlorite, elongated along the cleavage traces, but more typically as formless aggregates near crystals of ilmenite and hematite. The creamy alteration product, leucoxene, is almost invariably present.

Minute spicules of tremolite-actinolite occur embedded in the alteration products. These are difficult to examine, their optical properties being obscured by the enclosing mineral. Several occurrences of en echelon and radiating arrangement of these tiny crystals were noted.

In a thin section of a specimen 30 feet from the south contact, a six-sided aggregate of serpentine, one millimeter in diameter, was interpreted as the remains of an original olivine crystal. Magnetite and fibrous antigorite lie along curved fractures in the aggregate, which also contains inclusions of granular sphene and leucoxene. This is the only evidence of the presence of olivine in Discovery Dyke.

Ilmenite, or titaniferous magnetite, occurs in typical forms showing the skeleton-like arrangement, and alteration along crystallographic directions to leucoxene. Yellow and rusty iron staining is derived from crystals of iron oxide, and emanates also from stringers of introduced hematite.

Introduced calcite is disseminated throughout the diabase near the south contact. One section shows a veinlet less than a millimeter wide which also contains a very small amount of flamboyant vein quartz.

The relatively large amounts of ilmenite, leucoxene, and sphene in the rock suggests that at least part of the original pyroxene may have been of the titaniferous variety. The rare, residual pyroxene seen in the thin sections are not of this type, although the extinction angle is large, and pink traces are observable along the cleavages.

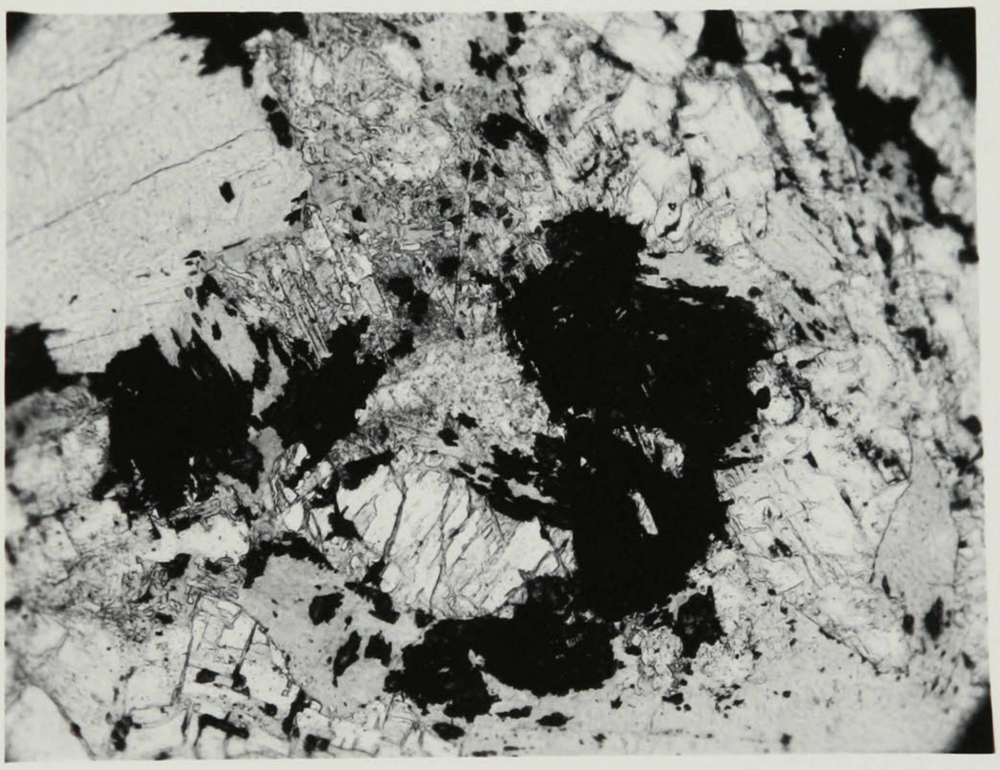

Fig. 7. Specimen No.49-29. Diabase from center of dyke. Photomicrograph shows skeletal crystals of ilmenite; aggregates of sphene; plagioclase altering to epidote. At upper left is crystal of chlorite. Magnification 80X. Uncrossed nicols.

Fig. 8. Specimen No. 49-21. Diabase eight feet from south contact; shows unique occurrence of fresh augite. Magnification 80 X. Uncrossed nicols.

Fig. 9. Specimen No. 49-31. Diabase from center of dyke. Photomicrograph shows aggregate of serpentine representing original olivine crystal. Magnification 80 X. Crossed nicols.

Detailed Descriptions of Rocks

The following is a petrographic description of some of the typical specimens of dyke rock; and short notes on unusual or significant features seen under microscopic examination.

Specimen 49-17. Diabase six inches from south contact.

The diabase is dark bluish-grey, very hard, massive, fine-grained, and has a pronounced conchoidal fracture. It weathers to a reddish-brown surface. No minerals are recognizeable, but small glistening phenocrysts, less than a millimeter long, are visible.

Microscopically, this rock shows a felsophyric-porphyritic texture. Lath shaped and stout phenocrysts, one half to one and a half millimeters long, of labradorite, and pseudomorphs of antigorite after pyroxene, are set in a groundmass of microlites of basic labradorite, alteration products of pyroxene, and a confused mat of polarizing and non-polarizing material. Finely-divided magnetite and ilmenite occur, as well as some leucoxene. Many of the larger plagioclase phenocrysts show fracturing; and some of the fractures are healed by sericite.

A photomicrograph of this thin section is shown in figure 10.

Specimen 49-18. Diabase 18 inches from south contact.

Microscopically this specimen is holocrystalline, and has a fine-grained ophitic texture. Subhedral crystals of labradorite ($Ab_{42}An_{58}$) occur, with lamellae bent and transversely cracked. No pyroxene is present; interstices between feldspar crystals contain chlorite, antigorite, quartz, hematite, sphene, and less than one percent introduced calcite.

In slide 48-19, of diabase four feet from the south contact, calcite comprises from five to ten percent of the rock, occurring as aggregates up to two millimeters across; in places it corrodes and enters along cracks in the plagioclase, suggesting hydrothermal introduction.

Slide 49-21, of diabase eight feet from the south contact, shows a rock of finer-grained texture, and is noteworthy because it contains a group of four or five crystals of fresh augite, about one half millimeter long (<u>See</u> Fig. 8.); and a group of labradorite phenocrysts showing undulatory extinction. A veinlet of calcite, with some vein quartz, cuts across the section.

Slides 49-21, 49-22, and 49-23, of diabase specimens respectively eight, ten, and twelve feet from the south contact, are interesting in that they represent a local reversal of grain-size gradation--number

49-23 having a texture similar to the chilled borders. This group of specimens is associated with the granite inclusions spoken of previously, and the apparent gradation may only be coincidental, but a possibility exists that Discovery Dyke is a composite dyke, and this fine-grained group may mark the north boundary of the southern member.

Unfortunately the section of the dyke from 12 to 22 feet from the contact could not be sampled.

Specimen 49-21A. Rock from small granite inclusion in diabase at eight feet from south contact.

In hand specimen the granite is mesocratic, medium-grained, with all components except quartz stained dark red by hematite.

In thin section the rock is holocrystalline, medium-grained, and has an equigranular, allotriomorphic texture. All minerals except garnet are anhedral. Essential minerals are: quartz, 20 percent; orthoclase, 10 percent; oligoclase ($Ab_{80}An_{20}$), 15 percent; microcline, 35 percent; microperthite, 15 percent. Garnet in euhedral crystals, and kaolin from the alteration of mica are accessories amounting to five percent of the rock. Many minute hematite particles occur, and staining is conspicuous.

This granite closely resembles the granite at the immediate south contact.

Specimen 49-25. Diabase 24 feet from the south contact.

Typical of the coarser-grained central part of the dyke, this rock is a dark greenish-grey in color, with a granular ophitic texture. Plagioclase crystals up to three millimeters in length are visible, as well as reddish patches of hematite.

Under the microscope this sample shows a medium-grained, ophitic texture, although the original minerals are largely altered. Some plagioclase remains, but it is fractured, and partly altered to kaolin and epidote. No pyroxene remains as such. Alteration products are: chlorite (in part pseudomorphous after pyroxene), tremolite-actinolite, sphene, quartz, secondary feldspar, and other minerals in various relationships and textures in the interstices between the plagioclase laths.

From a point 24 feet from the south contact to within a few inches of the north contact, all diabase specimens show a similarity in grain-size, degree of alteration, and mineral composition.

Slide 29-31 shows the presence of biotite and zircon as very minor accessory minerals.

At the immediate contact with the granite hanging-wall on the north side of the dyke, the rock resembles in hand specimen and microscopically the chilled border on the opposite side of the dyke, except that the plagioclase phenocrysts are altered to a greater extent to sericite and kaolin.

Fig. 10. Specimen No. 49-17. Fine-grained porphyritic diabase from chilled border at south contact. Magnification 17 X. Uncrossed nicols.

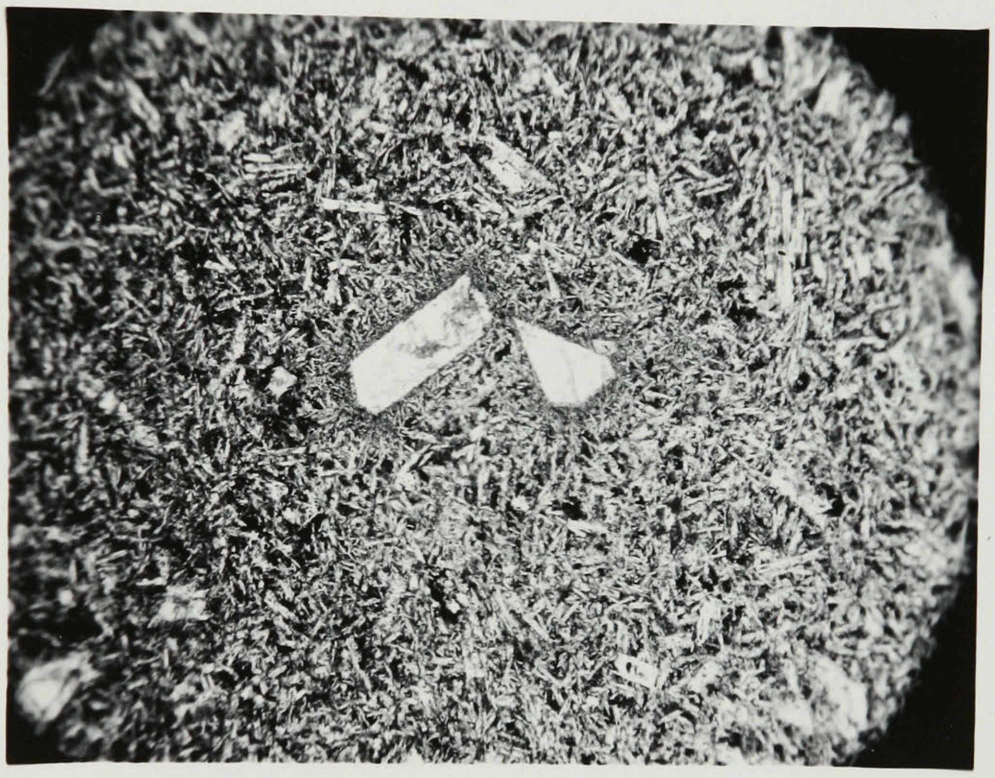

Fig. 11. Fine-grained porphyritic diabase from chilled border at north contact. Photomicrograph shows unusual concentration of small labradorite microlites around plagioclase phenocrysts. Specimen No. 49-45. Magnification 21 X. Uncrossed nicols.

THE CONTACTS

General description

The contact zones of the diabase and granite along Discovery Dyke are important for they appear to have provided the channelways for ore-bearing solutions rising from depth. Faulting has occurred along the dyke, and brecciation is concentrated at the south contact.

The north contact, although sharp and tight, with no apparent brecciation, has acted as a channelway for carbonate solutions and has minor calcite and hematite veinlets extending from it into the granite.

The breccia zone at the south contact near the shaft is from two to three inches wide, and before shaft-sinking started, was exposed for about 15 feet. It is not known how far the zone extends along the south contact beyond these limits.

Petrographic Description

Megascopic Description

The breccia is composed of lens-shaped fragments of fine-grained diabase and of granite in a matrix of pink calcite, chlorite, hematite, and pitchblende. The shapes of the edges of adjacent diabase fragments indicates a simple spreading apart in the formation of the breccia, for the configurations of one edge correspond exactly with the configurations of the side of the closest diabase fragment.

The pitchblende is concentrated on the walls of the calcite veins traversing the portion of the breccia composed of granite fragments. The calcite in this part is more massive and darker than the white and pink 'cross-fibre' calcite forming the matrix in the portion made up of diabase fragments. A green, earthy mineral, probably chlorite, is visible in the matrix. The diabase appear to be partly replaced by hematite, the process forming a rock much like an ironstone in appearance.

Movement in the breccia zone after the introduction of calcite is indicated (Specimen 49-16) by slickensides developed on a surface cutting across the direction of calcite veinlets, and in part formed on the calcite of the matrix.

Microscopic Description

Under the microscope, the breccia of the south contact is seen to be composed of irregular fragments of granite, and lens-shaped fragments up to ten millimeters in length of fine-grained porphyritic diabase in various stages of replacement by hematite. The matrix is formed of calcite and chlorite. The phenocrysts of plagioclase in the diabase have been replaced by chlorite, and the groundmass partly or wholly replaced by minute particles of hematite; in extreme cases the diabase is opaque except for the laths of chlorite set in it.

The feldspar of the granite fragments is completely replaced by chlorite and hematite. The quartz grains are shattered, and are traversed by stringers of hematite and fibrous calcite.

The matrix of the breccia is composed of fibrous and massive calcite, hematite particles, and chlorite. Hematite staining pervades all minerals except solid quartz. No pitchblende was seen in the thin sections.

Fig. 12. Specimen No. 49-15. Breccia from south contact. Fragments are diabase replaced by opaque hematite with laths of chlorite pseudomorphous after plagioclase phenocrysts. Matrix is calcite and chlorite stained with hematite. Magnification 27 X. Uncrossed nicols

Fig. 13. Specimen No. 49-16. Breccia from south contact showing fractured quartz fragments, and partial replacement of diabase by hematite. Magnification 18 X. Uncrossed nicols.

GRANITES AND PEGMATITES

General Description

The walls of the gorge which Discovery Dyke occupies are composed of red and pink granite and pegmetite of probable Algoman age. The south wall of the gorge near the shaft is about 100 feet high; the north wall is from 10 to 15 feet high. Specimens were obtained at 0, 5, and 10 feet (horizontal measurements) from the south contact; and 0, 5, 10, and 15 feet from the north contact. Several representative specimens were taken of the pegmatite, and of a granite breccia occurring at 150 feet West.

Petrographic Description

Megascopic Description

The granite within a few inches of the contacts is dark- to medium-red in color. This color is due to hematite disseminated in feldspar, and due to the great number of veinlets of calcite and hematite which is one of the outstanding characteristics of the granite. Farther away from the contacts the red staining is not as apparent, although hematite stringers are visible; the rocks are normal, light-colored, medium- to coarse-grained granite containing quartz, feldspar, and a small amount of mica. In some instances a coarse graphic texture due to intergrowth of quartz and feldspar is visible.

The masses of pegmatite occurring in the granite contain pink to dark red feldspars; clear, milky, and smoky quartz; light green mica in 'books' and in thin films along minor joints; calcite in veins and stringers; and the ubiquitous hematite as stringers and red staining.

Microscopic Description

The specimens of granite obtained at measured distances from the contacts show under the microscope an allotriomorphic, inequigranular texture. They are composed of microperthite, plagioclase ($Ab_{18}An_{82}$), microcline, orthoclase, quartz, and small amounts of muscovite and garnet. Small veinlets of calcite, quartz, and chlorite occur, and hematite staining is conspicuous.

The plagioclase forms about 20 percent of the rock, and occurs as irregular anhedral crystals usually cloudy with alteration to kaolin and sericite. The composition as determined by optical measurements, is that of oligoclase, $Ab_{18}An_{82}$. This identification was confirmed by measuring the index of refraction by immersion of fragments in index liquids. The highest index obtained for the orientation (010) is approximately 1.545. The oligoclase shows very fine twin lamellae which are in places curved and minutely faulted. Hematite staining occurs along alternate twin lamellae in places. In all thin sections the oligoclase appears considerably corroded by quartz, microcline, and orthoclase, and in many places it is replaced by a microperthite of the 'patch' type. Plagioclase occurs also as lens-like inclusions within the microperthite, and these may show a common optic orientation throughout an area four or five millimeters across.

Microperthite is the most notable feature of this granite, as it makes up from 5 to 70 percent of the rock. The most abundant type is the 'patch perthite', a variety of perthite considered by Anderson[1] to be a typical replacement perthite. Minor amounts of bleb, stringer, and finger perthites also occur. Various combinations of perthitic and non-perthitic feldspars can be seen: the patch perthite may contain inclusions of plagioclase; and the larger areas of microcline may contain elongated inclusions of microperthite.

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1 Anderson, Olaf, Norsk. Geologisk Tidsskrift, B. X, n. 1-2, p. 150, 1928.

(See Figs. 16 and 17.) Some areas of microperthite show faint traces of albite twinning in the arrangement of alteration products (sericite and kaolin). This suggests that the alteration of plagioclase was partially advanced before the attack by pegmatitic solutions that resulted in the production of microperthite.

Quartz comprises from 10 to 25 percent of the granite, and in most places is intergrown with microperthite to form a graphic texture. Several occurrences of myrmekitic intergrowth of quartz and plagioclase are evident. Sutured boundaries are found between many adjoining quartz crystals. Most of the quartz grains show undulatory extinction, and contain a great many solid and liquid inclusions arranged in rows. Tiny bubbles within the liquid inclusions show Brownian movement.

Orthoclase in anhedral crystals comprises about 10 percent of the rock. Microcline averages about 20 percent, although it is entirely absent in some slides and forms up to 55 percent in others. Both potassium feldspars appear to corrode and replace the earlier-crystallized plagioclase. Microcline, especially, seems to invade and replace the oligoclase crystals.

(<u>See</u> Fig. 14.) In many places it is associated with quartz.

Mafic minerals are almost completely lacking in the granite sections studied. Garnet and colorless muscovite form less than five percent of the rock.

The granite at the immediate south contact contains about ten percent muscovite, generally colorless, in anhedral crystals. In a few places the muscovite is stained a blood red by iron solutions that have invaded the rock. A small proportion of muscovite was found in only one other of the seven thin sections of granite studied.

Garnet in subhedral crystals less than a millimeter across occur in the granite at the south contact. It makes up about two percent of the section studied, and is present in two poorly-defined zones. One of these zones, shown in figure 18, appears to form a dividing line between a coarse-grained variety of granite and a fine-grained microcline-rich variety.

All sections of granite show evidence of granulation, minute faulting, and bending of crystals. Veinlets of quartz, calcite, chlorite, and hematite, up to two millimeters wide, traverse the rock. Hematite staining is intense near the contacts, but is also visible in the section of granite 15 feet from the north contact. Botryoidal hematite appears in a few of these veinlets. Quartz is the only mineral remaining relatively free from inclusions of the red hematite.

Near the south contact, two ages of calcite introduction within the same stringer are apparent. The earlier calcite carries considerable hematite and chlorite, the later calcite is relatively clear. In the thin section studied, the veinlet is composed of 25 percent and 75 percent, respectively, of calcite of the two ages.

From study of these thin sections, the tentative conclusion is drawn that the granitic rocks described represent the alteration and replacement of an earlier-crystallized rock by pegmatitic solutions. The latter, bearing silica and potassium, attacked the plagioclase, dissolved part of it, and upon cooling, unmixed and crystallized to form the replacement microperthite that comprises so much of the rock, and to form the graphic quartz-feldspar intergrowth apparent in most of the specimens. The masses of pegmatite occurring in the granite, and containing quartz, muscovite, and potassium feldspars, may mark the places where the pegmatitic minerals completely replaced the earlier rock.

The intrusion of diabase along one of the main directions of jointing in the granite to form Discovery Dyke had little effect on the country rock. Subsequently, movements within the diabase and along its south contact opened tension cracks in the granite, and by brecciation of the contact, formed channelways for the passage of still later solutions. These solutions deposited pitchblende in the tension cracks and breccia openings, and quartz, calcite, and chlorite along the many smaller fissures throughout the granite. They also gave rise to the all-penetrating hematite staining.

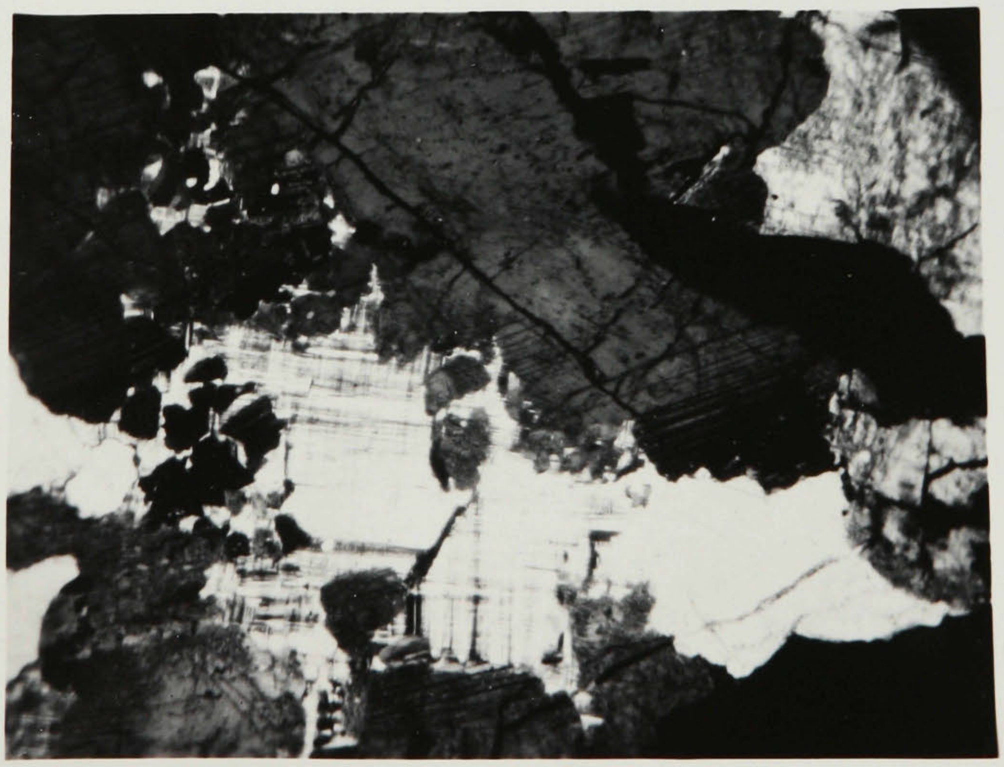

Fig. 14. Specimen No. 49-41. Photomicrograph of granite showing oligoclase invaded and corroded by microcline and quartz. Magnification 27 X. Crossed nicols.

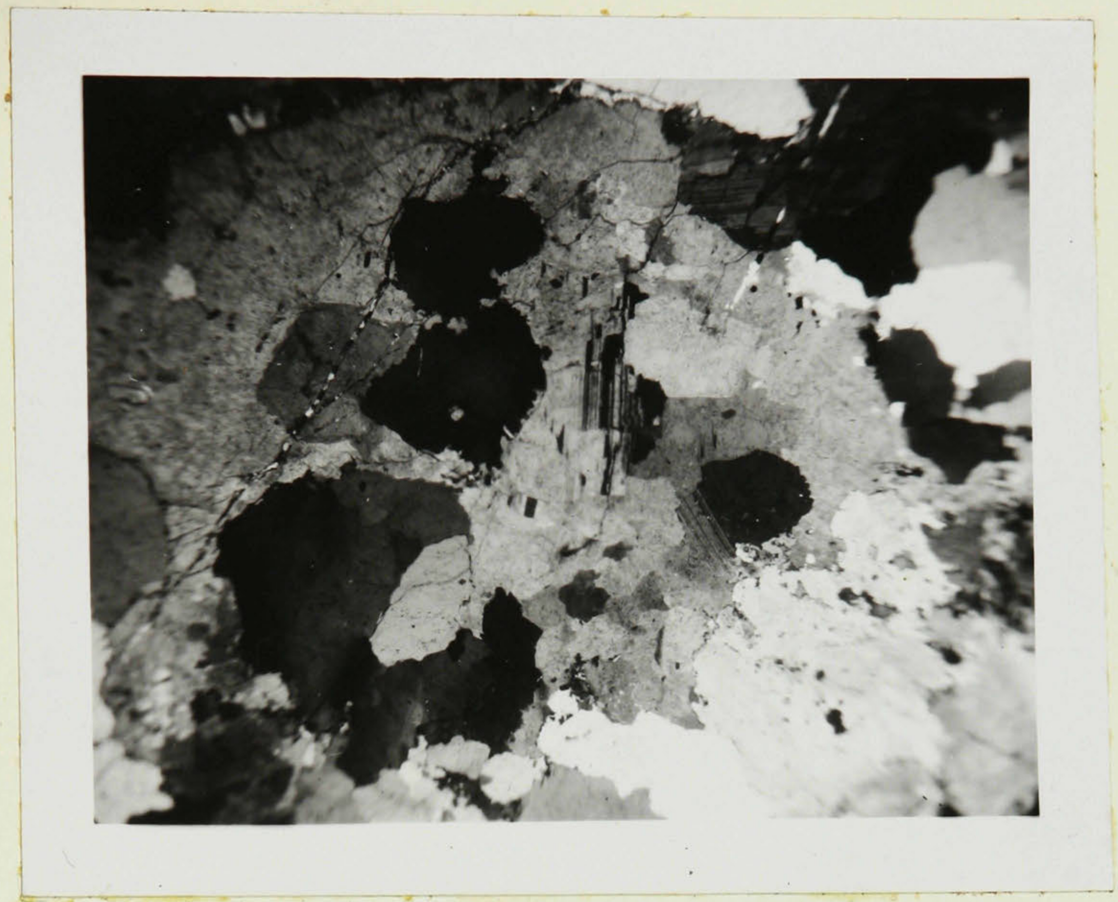

Fig. 15. Specimen No. 49-40. Granite, showing corroded plagioclase; quartz with undulatory extinction, and sutured boundaries; minute quartz stringer. Magnification 18 X. Crossed nicols.

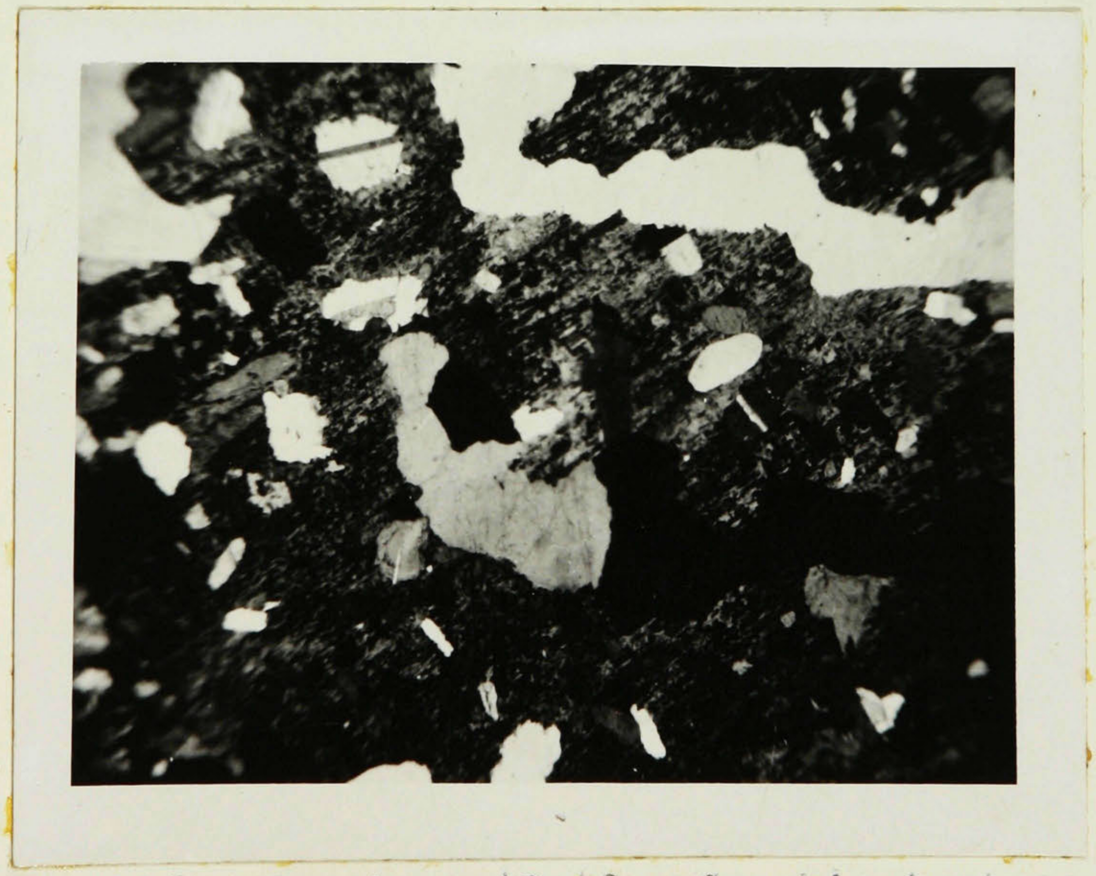

Fig. 16. Specimen 49-42. Graphic texture in granite. Intergrowth of quartz and microperthite containing plagioclase inclusions. Magnification 17 X. Crossed nicols.

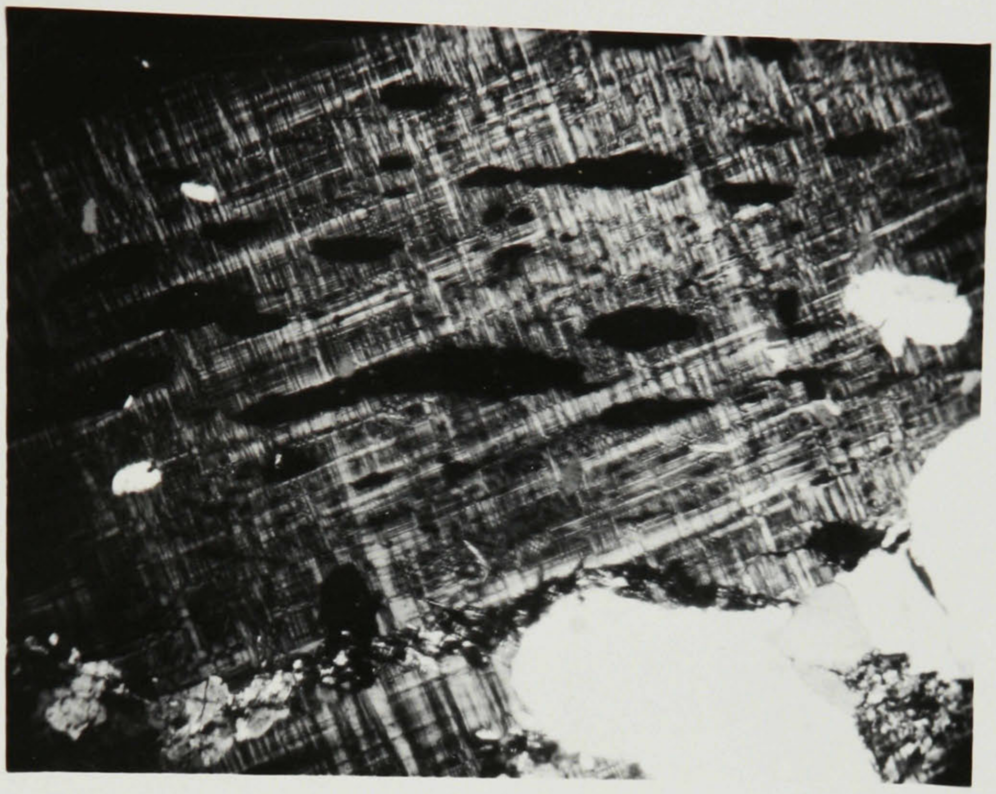

Fig. 17. Specimen 49-43A. Granite showing perthite formed of microcline with intergrowths of patch microperthite. Magnification 25 X. Crossed nicols.

Fig. 18. Specimen No. 49-37. Granite from south contact. Zone of small garnet crystals divides area in two parts: left is fine-grained granite with much microcline; right is coarser, shows orthoclase replacing oligoclase. Magnification 35 X. Crossed nicols.

Description of Granite Breccia

At 150 feet East on the base-line, near the cross fault, the south wall of the gorge has been slashed out, exposing fresh granite, and providing good specimens. Examination of these specimens indicates that brecciation of the granite has occurred at this location, possibly related to the movement on the cross fault. The openings thus provided are lined or completely filled with quartz and minor minerals. None of the vugs are more than two millimeters across, and several show the sequence of deposition of the various minerals.

The granite breccia is composed of corroded fragments of medium-grained, pink granite, and coarse-grained, dark red graphic granite, in a matrix of comb quartz. Much of the feldspar of the granite fragments is altered to kaolin minerals.

Microscopically the granite fragments of the breccia are similar to the granite described in the previous section. The dark red, graphic granite is composed of about 75 percent microperthite, 15 percent quartz, and ten percent oligoclase ($Ab_{20}An_{80}$). The microperthite is the 'patch' type, and contains rounded inclusions of oligoclase, commonly with a similar optic orientation over a small area. The lamellae of the plagioclase are bent, fractured, and minutely faulted. The rock is crossed by several quartz and hematite stringers less than one millimeter in width.

In a thin section of a vuggy specimen the granite fragments represent about 25 percent of the rock. They are composed of quartz, sericitized and kaolinized patch and stringer microperthite, oligoclase, and microcline. Comb quartz forms about 75 percent of the rock, occurring in crystals up to a millimeter across. In places where these crystals jut into vugs, at least two stages of deposition are indicated; the earlier stages being associated with hematite staining, the later stage being clear. The original quartz grains of the granite have been corroded, in places to roundness, and then enlarged by addition of quartz in optic continuity--the two zones being separated by a line of 'dust' and minute feldspar particles.

Two hand specimens show a fine development of crested vug linings. The crested surface is composed of nodules, from five to ten millimeters apart, covered by a film of minute quartz crystals which are stained by hematite at the surface to a dark red. In places another layer of clear quartz is deposited on top of the red quartz.

Along a fracture in one specimen, pyrite and quartz have been deposited--the quartz as tiny crystals lining the fracture, and the pyrite as flat, radiating aggregates about 30 millimeters in diameter. One of these pyrite groups has been dissolved out, leaving a mold to show where it formerly existed.

In another specimen, a vug lined with quartz contains several crystals of galena about two millimeters across, showing the typical cubic habit, with minor octahedral modifications. Because of the possibility of this mineral being clausthalite (PbSe), which occurs with the pitchblende in the stringers, Dr. Nuffield of the University of Toronto obtained X-ray powder diffraction patterns of it, and definitely identified it as galena.[1] In other specimens vug crystals of quartz, specular hematite, pyrite, and calcite can be detected, and appear to have been deposited in the above order. Galena is later than the quartz and hematite, but its relationship to the other minerals could not be determined.

The relations of the stringers of pitchblende

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[1] The writer had the opportunity of watching the procedure of taking, developing, and comparing X-ray diffraction pattern photographs when this identification was made by Dr. Nuffield at University of Toronto, Dec. 22, 1949.

which occur in this zone is obscure, but they appear to cut across all the small structures, and this evidence would place the formation of the tension cracks as later than the brecciation and cementation. Pitchblende is not known to occur in the vug linings, and therefore its relationship to the other minerals cannot be determined from a study of deposition in the vugs. Temperature determinations carried out at the University of Toronto[1] suggest that the sulphides are later than the pitchblende, but were deposited from solutions at higher temperature.

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[1] Personal communication from E. W. Nuffield.

URANIUM DEPOSITS

General Description

Stringers consisting of quartz, calcite, hematite, and pitchblende, with associated clausthalite, klockmannite(?), and pyrite, occupy fissures in the granite walls immediately adjoining Discovery Dyke. The ore minerals are also found in the calcite of the breccia which occurs along the contact. Because the stringer material is brittle and easily weathered, many of the fractures in the granite walls show no visible pitchblende, but high Geiger readings at these sites indicate its former presence.

The stringers range in width from one-eighth to two inches, with few exceeding three-quarters of an inch. They are exposed for an average length of three or four feet on the granite face, and seldom extend more than five feet into the granite. They are concentrated in two zones on the south wall of the gorge; the zone near the lake has an overall length of 275 feet, and the other a length of 100 feet. Between these zones, the dyke narrows appreciably and the south contact is barren of radioactive minerals.

Most of the stringers strike about N70° E and dip from 50° to 60° to the southeast. One irregular curving fracture, striking parallel to the dyke and dipping 35° south, is exposed for a length of 60 feet at the east end of the showing.

Assuming that the tension cracks were caused by faulting localized by the dyke (strike S80°E, dip 75°N), the relative direction of movement of the footwall in relation to the hangingwall, as determined from a study of the average attitude of the fissures, is upward and toward the southeast; the line of movement lies in a vertical plane striking S50°E, and dips 59° from the horizontal.

The only occurrence of radioactivity on the north side of the gorge is at 80 feet West, where two stringers one-quarter to one-eighth inch wide are exposed in granite for a length of about four feet. One of these is parallel to the granite-diabase contact, and the other is vertical, and perpendicular to the dyke.

No pitchblende is known to occur in the diabase.

Mineralogy

The stringers are dark brown to black in color, and consist of quartz, calcite, hematite, pitchblende, and the red and yellow alteration products of pitchblende known as gummite.

The radioactive mineral has been classed as pitchblende as it shows no evidence of crystal form. Three samples were submitted by the Provincial Assay Office to Dr. E. W. Nuffield of the University of Toronto for X-ray examination. He reports as follows:[1]

> "I have obtained X-ray powder diffraction patterns of selected pieces of the three Theano point mineral samples submitted to me for study. These patterns are identical. They have been compared with patterns obtained from Great Bear Lake ore and indicate that the mineral is pitchblende, with theoretical composition UO_2. I have noted with interest that the unit-cell dimensions of the Theano point pitchblende are distinctly smaller than recorded cell dimensions for both artificial and natural UO_2. Research on the ore is continuing."

The use of the term 'coracite' has been discontinued.

The pitchblende has a glossy black, resinous lustre, and a subconchoidal fracture. It has a hardness of about six, and is brittle. Because it is partly altered, and crossed by minute calcite veinlets, it crumbles readily.

The specific gravity of a specimen of pitchblende from the contact breccia, measured by means of the Berman torsion balance, is 4.41. This value is much

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[1] Satterly, Jack, and D. F. Hewitt, <u>A Pitchblende Occurrence at Theano Point, Lake Superior, Ontario;</u> Ont. Dept. Mines, Press Release, 1948-49.

lower than the values for pitchblende (6.5) and uraninite (9.0-9.7) given in Dana[1], and is due to the fact that the mineral is shot through with calcite and other impurities. A pure specimen large enough to weigh is almost impossible to obtain. The value is remarkably close to the specific gravity of 4.38 reported by Whitney[2] for the Stanard specimen of 'coracite'.

It is interesting to note here also the analysis of the Stanard specimen made by Whitney[3] in 1849.

silica	4.35%
alumina	0.90%
oxyd of iron	2.24%
oxyd of uranium	59.30%
oxyd of lead	5.36%
lime	14.44%
carbonic acid	7.47%
water	4.64%
magnesia and manganese	tr.
	98.70

A sample of the stringer material, collected by A. H. Lang, and tested in the Radiation Laboratory of the Geological Survey of Canada, indicated a U_3O_8

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[1] Dana, E. S., A Textbook of Mineralogy, John Wiley & Sons, Inc., 4th ed., pp. 745-746, 1946.

[2] Whitney, J. D., A Chemical Examination of Some Minerals; Am. Jour. Sci., Vol. 7, p. 434, 1849.

[3] Idem.

content of 8.72 percent. Satterly and Hewitt[1] quote a radiation assay of 56.3 percent for a specimen from the same stringer as the above, and assays of 61.6 percent and 63.8 percent for material from other stringers. The wide variation may indicate that radiation assays on individual samples which may contain varying amounts of the strongly radioactive secondary minerals cannot be considered reliable indicators of grade. Samples of granite from between the stringers give an average radiation equivalent of 0.006 percent U_3O_8, and the diabase of Discovery Dyke averages somewhat less than 0.001 percent U_3O_8.

The writer attempted to obtain information from government and other sources on age determinations of Theano Point pitchblende, but data promised will arrive too late for inclusion in this work.

Polished Specimens

Some difficulty was experienced in obtaining good polished sections of the ore. The brittleness of the pitchblende, and the presence of hard and soft minerals in the same section prevented the final polish from being satisfactory. Dr. Nuffield kindly loaned two polished sections prepared from the selected pieces

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[1] Op. cit.

mentioned in the quotation on page 61. A description of these and several other polished sections follows.

In reflected light the pitchblende is dull grey, and isotropic. It occurs in typical colloform masses up to four millimeters in diameter, and the outline of these remain even after the mineral is altered to gummite. Ramifying veinlets of calcite, carrying pyrite in minute blebs, cross the pitchblende.

Fig. 19. Colloform pitchblende crossed by ramifying veinlets of calcite. Pyrite (white) in upper left. Magnification 20 X. Plain light.

In several sections the mineral clausthalite (PbSe) occurs as small irregular masses within the pitchblende. It is a silver-white mineral resembling galena, and is isotropic.

Fig. 20. Radial pattern of ramifying calcite veinlets in colloform pitchblende. Magnification 20 X. Plain light.

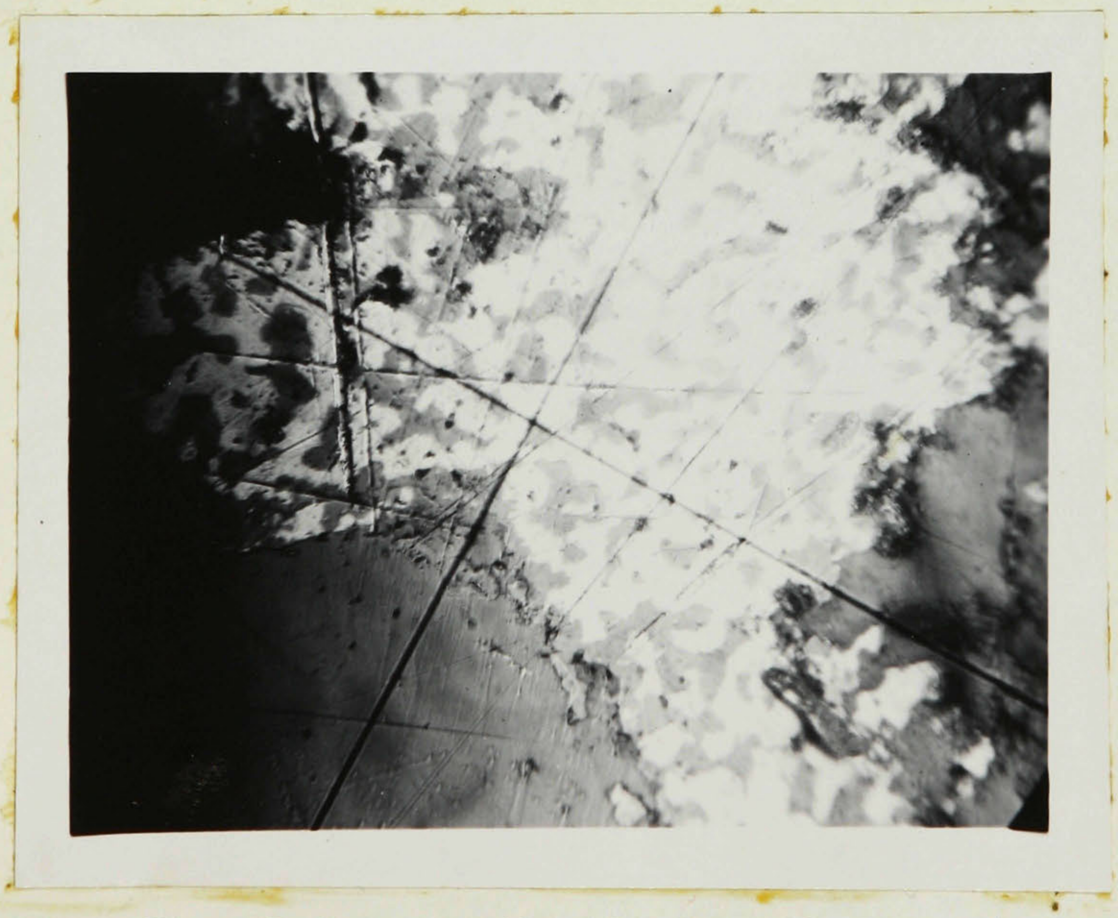

Fig. 21. Intergrowth of clausthalite (white) and klockmannite(?) (light grey) in pitchblende (dark gray). Magnification 90 X. Plain light.

A bluish, anisotropic mineral intergrown with clausthalite, possibly representing a eutectic mixture, remains unidentified because of its limited occurrence and the small size of the individual particles. The writer believes it to be klockmannite (CuSe), because of its association with clausthalite, its fiery orange anisotropism, and its four positions of extinction on complete rotation.

The age relations of the various minerals is relatively simple. Pitchblende and the selenides were deposited in the open fissures during the first age of mineralization. Later, pyrite, and probably also the galena noted in the vugs of the granite, were introduced. Quartz and calcite were deposited during both ages of mineralization.

Conditions of Deposition.

The occurrence of pitchblende in colloform masses gives some indication of the character of the mineralizing solutions, and of the conditions existing at the time of deposition. Lindgren[1] states:

> "Pitchblende is a colloform uraninite of undoubted gel origin found in veins....; it is here one of the early minerals."

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1 Lindgren, Waldemar, Mineral Deposits, McGraw-Hill, New York, pp. 873-874, 1933.

It is reasonable to assume that during the earlier stage of mineralization, the ore mineral was deposited in openings as a colloidal precipitate or a gel, which shrank through syneresis to form the rounded colloform masses seen in polished section. Materials carried in colloidal solution do not readily pass through finely porous material; and this fact may explain why no pitchblende, clausthalite, or klockmannite(?) was seen in the vugs described on page 57. Colloidal solutions do not differ greatly in viscosity from true solutions, and could certainly pass along any visible fissure, provided that this was a member of a continuous system of fissures. Such solutions, however, may not be able to penetrate the wall-rock and deposit pitchblende in an isolated vug.

The pyrite, occurring in radiating fibrous aggregates in fractures, may likewise be a metacolloid; that is, it may have been deposited as a gel and later acquired crystallinity. This form was not noted in the pyrite seen in the polished sections.

The open nature of the contact breccia and the tension cracks, as well as the colloform structure of the pitchblende, indicate a shallow depth for the formation of the deposit. Lindgren[1] states:

> "Colloid minerals form in abundance in open spaces within the oxidizing zone and near the surface, but they may also develop at higher temperatures to a degree formerly not suspected."

This brings us to a consideration of the temperature of the deposition of the pitchblende. Colloidal processes are often thought of as confined to low temperatures, but, in fact, colloform structures are found in deposits ranging from low temperature hot spring deposits to deposits with such high-temperature mineral associations as cassiterite-wolframite. Many high temperature-low pressure deposits showing colloform structure are described by Buddington[2]. Spurr[3] emphasizes the possibility of high temperature deposits at shallow depth, and writes:

> "That shallow depth has meant low temperatures during periods of ore deposition is as fund-

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[1] Op. cit., p. 25.

[2] Buddington, A. F., High Temperature Mineral Associations at Shallow to Moderate Depths; Econ. Geol., Vol. XXX, No. 3, pp. 205-222, 1935.

[3] Spurr, J. E., Review of Geology and Ore Deposits of the Randsburg Quadrangle, California, by C. D. Hulin; Eng. and Min. Jour., p. 463, 1926.

amental an error as has been
made in our recent literature
of ore deposition."

Uraninite is usually considered a 'high temperature' mineral, but when it occurs as pitchblende with colloform structure, the temperature of formation can be deduced from the study of mineral associations. For example, according to Furnival[1], the minerals of the Contact Lake deposits indicate that the pitchblende there was deposited from colloidal solutions between 200° and 270°C.

Recent research at the University of Toronto[2] suggests that the Camray pitchblende was deposited from solutions at 270°C, and that the later sulphides were deposited from solutions at 360°C. However, until more is known about the accuracy of these new methods, and about the melting points of the selenide minerals associated with the Camray pitchblende, the writer prefers to leave the question of temperature of formation open.

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[1] Furnival, G. M., <u>A Silver-pitchblende Deposit at Contact Lake, Great Bear Lake Area, Canada</u>; Econ. Geol., Vol. XXXIV, No. 7, pp. 771-772, 1939.

[2] Personal communication from E. W. Nuffield.

RELATIONSHIP BETWEEN PITCHBLENDE AND DIABASE

The colloform pitchblende represents deposition in a gel form in cavities at relatively shallow depths from hydrothermal solutions presumably of magmatic derivation that were introduced along the south contact of Discovery Dyke. It is unlikely that the solutions were derived from the same magmatic source as the diabase, considering the low radioactive content of the dyke rock, and the fact that uranium is a lithophile element characteristically related to acid igneous rocks.

The reason for the absence of pitchblende in the diabase is obscure--the simplest explanation is that no connected, open fissures existed in the dyke rock at the time of mineralization. At one point a shear zone cuts both the granite and the diabase, and carries pitchblende only in the granite, but the zone appears to have been relatively more open in the granite. However the breccia at the contact, as has been mentioned, carries pitchblende in the calcite matrix between granite fragments, and not in the matrix between diabase fragments. This evidence seems to suggest that the diabase did not act as a precipitant for the pitchblende. A few miles to the north, however, on the property of the Murmac--Lake Athabaska Mines, Ltd., a seam of pitchblende occupies a fissure within a diabase dyke, and yellow uranium oxide staining occurs along many of the joint planes in the diabase; and on Hottah Lake, Northwest Territories, quartz-hematite stringers crossing both granite and gabbro carry pitchblende much more commonly where the wall-rock is gabbro[1]. Similarly, basic wall-rocks appear to favour pitchblende deposition at Lake Athabaska, Saskatchewan.[2]

From the study of the breccia and granite in hand specimen and thin section, and of the ore stringers in polished section, evidence for two periods of quartz-carbonate vein-forming solutions emerges. The first of these introduced pitchblende, selenides, and hematite; the second introduced pyrite, and possibly galena. The lack of radioactive minerals in the diabase could be explained by assuming that during the first stage, no continuously-connected openings were available in the diabase. Following further structural adjustments (including more internal fracturing of the diabase),

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1 Personal communication from A. W. Jolliffe.

2 Christie, A. M., and S. N. Kesten, Goldfields and Martin Lake Map Areas, Saskatchewan; Geol. Surv., Can., Paper 49-17, p. 32, 1949.

the later vein-forming solutions, carrying no uranium, healed these fractures and caused the alteration found in the dyke. Even although Discovery Dyke may be a multiple intrusion as was mentioned on page 38, the veining and alteration suggest that both periods of vein formation postdate the youngest diabase present in the dyke.

CONCLUSIONS

The relationship of the pitchblende to the dyke is structural and not genetic. The reason pitchblende occurs in the dyke area is because movement was localized on the south contact of the dyke; consequent brecciation provided channelways for the passage of solutions from depth; and this breccia at the contact, and tension cracks in the granite, offered favorable cavities for the deposition of pitchblende. The conclusion drawn from the above is that any connected system of openings present at the time of the rise of mineralizing solutions would provide similar channelways and favorable sites for deposition; hence, prospecting need not necessarily be confined to the contacts of diabase and granite, although such contacts would be structurally more favorable than areas of homogeneous granite.

The Camray discovery reaffirms the presence of pitchblende in the Algoma District of Ontario, and, by focussing attention on the area, hastened the discovery of adjacent occurrences. Interest in the possibilities of the area has not been discouraged because of the decision to discontinue development work on the Camray property. Several promising showings have been found to the northeast about six miles.

An important consideration is that the pitchblende in this area is not associated with Precambrian sedimentary or volcanic rocks, and this fact implies that the great areas of the Canadian shield underlain by granites and granite gneisses, crossed by occasional diabase dykes, and hitherto shunned by the prospector, can be considered as potentially favorable for uranium mineral deposits.

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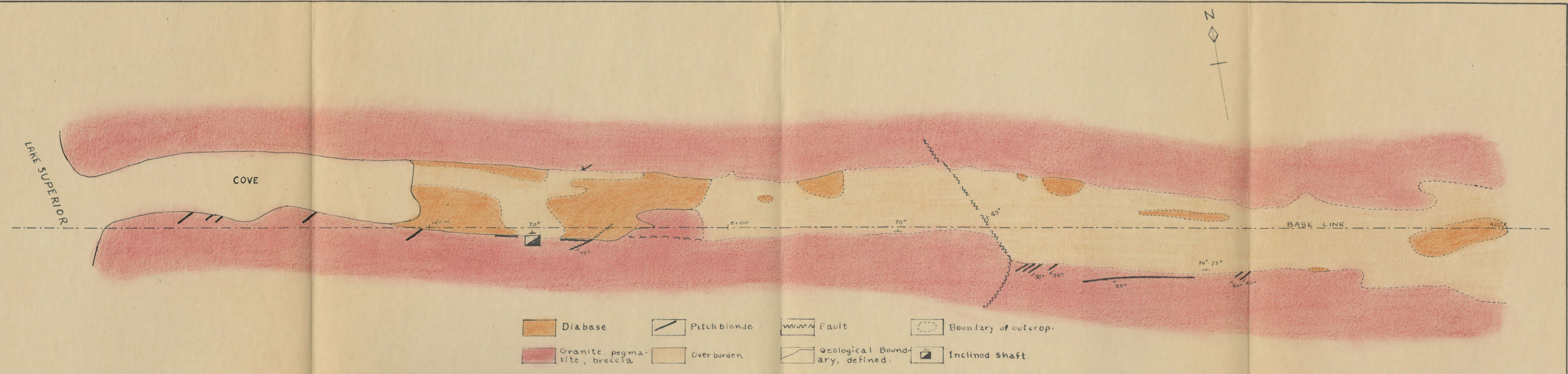

DISCOVERY DYKE

CAMRAY MINES, LTD.

Scale 1 inch to 40 feet.

Modified from Satterly and Hewitt,
Ontario Department of Mines, Press Release, 1948-49