# SPECIMEN LIST (D.O.)

1 Creighton - Disseminated ore - average sulphide content

2 Creighton - Massive ore - high nickel

3 Creighton - Massive ore - high copper

4 Creighton - Breccia ore - average sulphide content

5 Murray - Disseminated ore - high sulphide content

6 Murray - Breccia ore - average sulphide content

7 Murray - Massive ore - high nickel

8 Frood - Disseminated ore - high nickel

9 Frood - Disseminated ore - high copper

10 Frood - Massive ore

11 Garson - Massive ore - high copper

12 Garson - Massive ore - average copper & nickel

13 Garson - contact sulphide - average copper & nickel

14 Levack - Disseminated ore - average

15 Levack - Breccia ore - average copper and nickel

# SUDBURY DISTRICT ROCK SUITE

Acquaint yourself with the general geology of the Sudbury mining district by reading the pertinent parts (p. 580-626) of the book (1948) entitled Structural Geology of Canadian Ore Deposits. Look over the xeroxed article that follows. Bateman's Economic Mineral Deposits has a brief review of the Sudbury district. The most important reference, however, and the one with which you should spend some time is the book (ordered by the Geology Department in April 1970) by J.E. Hawley (1962) entitled The Sudbury Ores: Their Mineralogy and Origin (Min. Assoc. Canada, 207p.)

Next read the mimeographed material on the Sudbury rock suite. Match the specimens with the maps and the rock description in the above references.

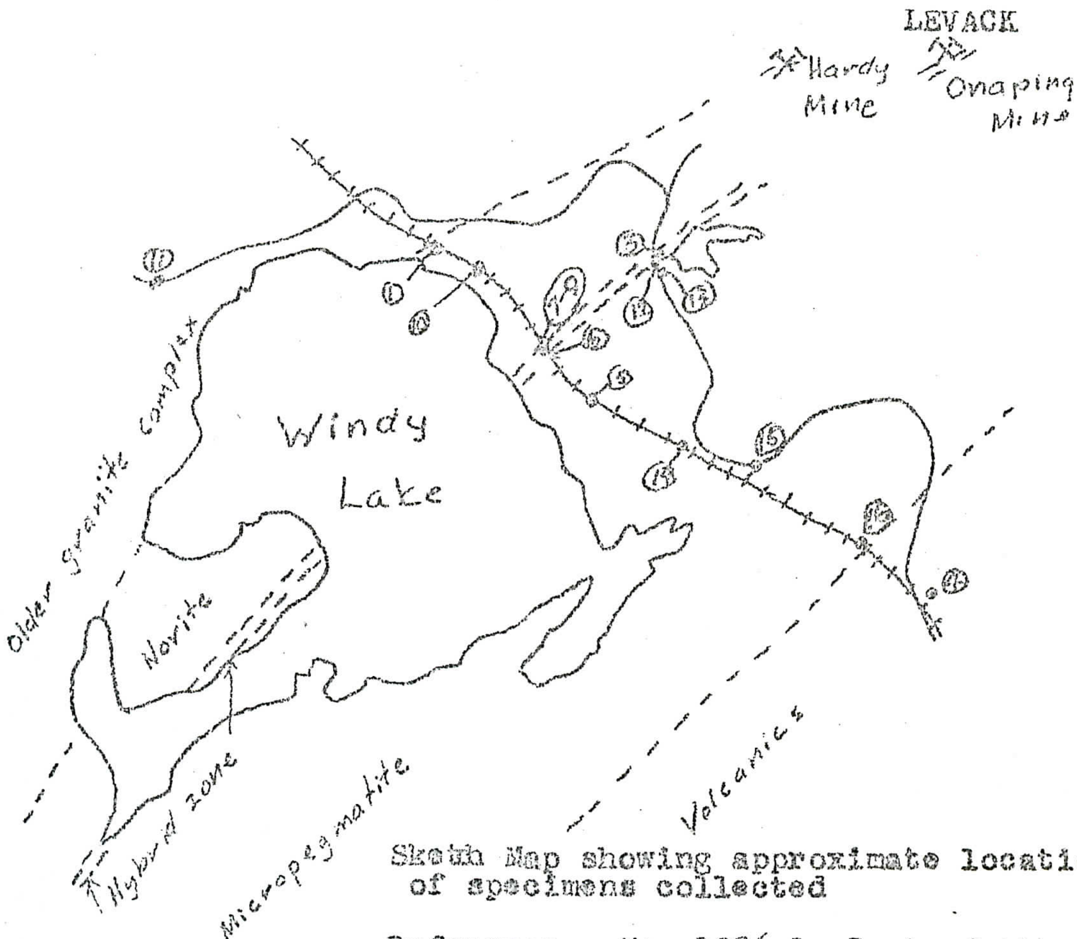
Describe the hand specimens and give them rock names. Next describe how each hand specimen originated (i.e., its petrogenesis); be as specific as you can on the basis of the texture in hand specimen and of what you have read.

P.S. There are addition rock specimens, especially of the ores themselves, from the Sudbury district in this lab. Ask Dr. Henrickson where the specimens, and any information on them, are to be found.

Note that three specimens are missing; there are no numbers "SUD-4", "SUD-6", or "SUD-9." There are, on the other hand, two hand specimens whose numbers have rubbed off; which of the three numbers should be assigned to these un-numbered specimens?

*Another recent reference:*
*Naldrett, A.J., & Kullerud, G., 1967, Journal of Petrology, v.8, no.3, p 453-531*

SUDBURY PETROGRAPHIC SUITE




Sketch Map showing approximate location of specimens collected

Reference: Map 1956-1 Part of the Sudbury Basin Area, Ontario Dept. of Mines

One inch = One mile

The Levack section through the Sudbury nickel irruptive is represented by more chemical analyses of the transition rocks than any other published section. This section was sampled in detail. Thirteen samples were collected in the irruptive at this section with an additional specimen of norite collected from an outcrop about one mile northeast of the Stobie Mine on the southeast side of the irruptive. Representative specimens were collected from the older granite (migmatite) complex and the volcanics below and above the irruptive at Levack are also included. No thin section chip is included for the migmatite.

All irruptive analyses from: W. H. Collins, "Life History of the Sudbury Nickel Irruptive", I Petrogenesis; Trans. Royal Soc. Can. 3d ser. v 28, sec. XV, 1934, p. 139.

Rhyolite at Onaping falls from: A. G. Burrows and H. C. Rickaby, Sudbury Basin Area, Ontario Dept. of Mines vol. 38, 1929, p. 30.

Specimen No. Location and analysis

1. Gabbro, first outcrop on Canadian Pacific RR. Analysis 50W.

2. Gabbro at outcrop 290-300. The analysed specimens were taken 770 and 785 feet from starting point. There are massive outcrops and it was impossible to be sure about the exact location the specimens . The samples for the collection were probably taken between the two analyses. Thus specimen 2 may be closer to 290, but not certainly so.

3. Transition zone, roadcut on highway. Cut on east side of highway opposite bay on unnmaed lake in S½ lot 7 VI dowling township. (no analysis)

4. Rhyolite at Onaping Falls. (analysis)

5. Transition zone, analysis 58W (well located)

6. Transition zone, analysis 25C (well located)

7. Transition zone, analysis 26C (well located)

8. Transition zone, analysis 50C (located to about 10 feet)

9. Transition zone, analysis 27C (located to about 10 feet)

10. Gabbro, analysis 31C. Approximate location.

11. Granite migmatite, 0.85 mi. SW of RR crossing N of Windy Lake. No analysis. No thin section chip.

12. Coarse transition facies (?) 345 feet SE of No. 3. (no analysis)

13. Micropegmatite. (60 feet toward 12, micropegmatite). 180 ft. SE of 12.

14. Micropegmatite, analysis 59W (well located)

15. Micropegmatite, on road opposite 60W. Same zone, but about 100 yards away from locality analyzed.

16. Micropegmatite, 63W. Well located.

17. Norite, near Murray mine on highway 544 just north of the base of the irruptive.

# CHEMICAL ANALYSES

| Specimen# Analysis | 8 50C | 9 27C | 10 31C | 14 59W | 15 60W | 16 63W |
|---|---|---|---|---|---|---|
| $SiO_2$ | 55.51 | 51.92 | 58.58 | 63.97 | 63.29 | 69.38 |
| $Al_2O_3$ | 13.29 | 13.31 | 16.58 | 15.05 | 13.33 | 12.73 |
| $Fe_2O_3$ | 3.04 | 3.53 | 1.51 | 0.70 | 2.10 | 0.70 |
| FeO | 9.06 | 10.38 | 6.02 | 5.48 | 5.47 | 4.64 |
| CaO | 6.21 | 7.72 | 7.64 | 3.05 | 4.06 | 1.63 |
| MgO | 3.31 | 3.78 | 4.68 | 2.15 | 1.87 | 1.25 |
| $Na_2O$ | 3.86 | 3.07 | 2.85 | 3.76 | 3.52 | 2.96 |
| $K_2O$ | 1.65 | 1.29 | 1.04 | 3.44 | 3.73 | 4.12 |
| $H_2O+$ | .91 | .95 | .81 | 1.61 | 1.45 | 1.78 |
| $H_2O-$ | .11 | | .09 | | | |
| $TiO_2$ | 2.00 | 3.26 | 0.41 | 0.84 | 0.79 | 0.74 |
| $P_2O_5$ | 1.24 | none | .33 | .27 | .24 | .20 |
| S | .20 | .17 | .12 | .05 | .07 | .03 |
| MnO | n.d. | .03 | n.d. | .12 | .14 | .11 |
| BaO | n.d. | .05 | n.d. | n.d. | n.d. | n.d. |
| $CO_2$ | none | Tr. | none | .14 | .15 | .15 |
| Less O/S | .15 | .12 | .09 | .03 | .04 | .02 |
| Total | 100.24 | 99.76 | 100.57 | 100.54 | 100.07 | 100.30 |

Specimens collected by Forbes Robertson

Prepared for shipment by Western Minerals, Inc., Elsah, Illinois

CHEMICAL ANALYSES

| Specimen# / Analysis | 1 50W | 30C | 2 29C | 4 | 5 58W | 6 25C | 7 26C |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 55.32 | 54.46 | 54.04 | 59.02 | 63.66 | 62.81 | 60.03 |
| $Al_2O_3$ | 14.50 | 16.25 | 14.31 | 10.84 | 14.69 | 14.04 | 13.04 |
| $Fe_2O_3$ | 4.34 | 3.80 | 5.27 | 2.56 | 3.65 | 1.61 | 2.31 |
| FeO | 5.39 | 7.03 | 7.88 | 5.83 | 3.52 | 7.74 | 8.53 |
| CaO | 7.97 | 7.94 | 7.68 | 4.09 | 2.04 | 3.80 | 5.20 |
| MgO | 4.82 | 3.16 | 4.05 | 5.50 | 1.76 | 0.17 | 1.83 |
| $Na_2O$ | 3.07 | 3.61 | 2.81 | 3.60 | 3.64 | 3.82 | 3.30 |
| $K_2O$ | 1.60 | 1.58 | 1.52 | 2.72 | 4.04 | 2.96 | 2.45 |
| $H_2O+$ | 2.02 | .90 | .77 | 2.00* | 1.62 | .83 | .69 |
| $H_2O-$ | | .10 | .13 | | | .13 | .30 |
| $TiO_2$ | .75 | .80 | 1.48 | .45 | .77 | 1.24 | 1.23 |
| $P_2O_5$ | .06 | .33 | none | .12 | .34 | .51 | .37 |
| S | .20 | .19 | .61 | .96 | .04 | .13 | .19 |
| MnO | .10 | n.d. | n.d. | .35 | .11 | n.d. | .22 |
| BaO | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | .12 |
| $CO_2$ | .31 | none | none | .36 | .03 | .10 | none |
| Less O/s | .10 | .15 | .46 | n.d. | .02 | .09 | .15 |
| Total | 100.35 | 100.00 | 100.09 | 100.30** | 99.89 | 99.80 | 99.96 |

* Ignition

** Fe Pyrrhotite 1.32

C .58

## INTRODUCTION

Seventy-four years ago the Canadian Pacific Railway was advancing across the continent through the rugged wilderness of the Pre-Cambrian Shield north of Georgian Bay. A short distance west of the town of Sudbury a rock cut exposed an occurrence of copper-nickel sulphides. This discovery later became the Murray Mine.

From this fortuitous beginning the nickel industry has grown to maturity and tremendous mineral wealth has been developed. Past production in excess of 7,000,000 tons of copper-nickel and reserves of more than 8,500,000 tons of copper-nickel give the Sudbury deposits a magnitude that dwarfs any other known occurrence of copper-nickel sulphides.

In 1956, The International Nickel Company of Canada, Limited, mined 15,510,849 tons of ore. In the same period, Falconbridge Nickel Mines Limited mined 1,850,315 tons and Nickel Rim Mines Limited mined 291,842 tons. The 1956 total of 17,653,006 tons of ore mined in one year established a record for this district.

At the present time in the Sudbury area, The International Nickel Company of Canada, Limited, operates five mines, an open pit, two mills, two smelters, an iron ore recovery plant and a copper refinery. (A third INCo mill is under construction at the Levack Mine). Falconbridge Nickel Mines Limited has five mines in production, three mills and a smelter. Nickel Rim Mines Limited, an independent company is currently producing and AER Nickel Corporation is scheduled for production in 1957. Norduna Mines Limited, a copper-nickel property, Consolidated Sudbury Basin Mines Limited, a copper-lead-zinc property, and Lowphos Ore Limited, an iron ore property, are all in the development stage.

As a by-product of smelting, Canadian Industries Limited operates a sulphuric acid and liquid sulphur dioxide plant at Copper Cliff and is constructing a second acid plant adjacent to the iron ore recovery installations of International Nickel. The acid produced by this new plant will be shipped principally to uranium leaching plants in the Blind River area.

The metal industry in the Sudbury district employs more than 20,000 men and has a monthly payroll in excess of $8,000,000.00

## GENERAL GEOLOGY

The Sudbury area may be considered as one part of a large petrologic province that extends over 600 miles (965 KM.) from the west end of Lake Superior easterly through Sudbury and Cobalt and into the province of Quebec. This belt is characterized by the occurrence of a quartz-diabase type of rock with which are associated important metal concentrations. The copper of Michigan, the nickel-copper of Sudbury, and the silver-cobalt of Cobalt are notable examples. The nickel-copper deposits at Sudbury are associated with a formation known as the nickel intrusive.

The nickel intrusive is exposed at surface in the form of an elliptical ring elongated in a north-easterly direction. The long and short axes of the ring have lengths of 37 and 17 miles respectively (59.5 KM. and 27.4 KM.). All the measurable geometry indicates that the nickel intrusive has the shape of an assymmetric basin and the inferences that can be drawn from geophysical measurements are compatible with this shape. The apparent thickness of the nickel intrusive as estimated from surface exposures, deep diamond drilling and mining operations, ranges from one to two miles (1.6 KM. to 3.2 KM.). It consists of an upper layer of micropegmatite separated by transition rock from a lower somewhat narrower layer of norite.

Dike-like appendages known as "offsets" dip steeply and extend outward from the bottom of the nickel intrusive into the surrounding rocks. Some of these offsets have strike lengths measured in miles and widths measured in hundreds of feet. The rock type common to these offset occurrences is quartz-diorite, frequently inclusion-bearing and commonly the host for sulphide mineralization. The quartz-diorite was originally thought to be later than the main norite intrusive but the reasons for a marked age difference no longer appear valid and the quartz-diorite is now generally thought to be closely related to the norite both in time and genesis.

The space inside the nickel intrusive is occupied by a series of volcanic and sedimentary rocks which outcrop in concentric rings thus indicating for this series a basin shape conformable with that of the nickel intrusive. North of the intrusive is an extensive area of pre-nickel-intrusive granite, granite gneiss and highly granitized sediments. Three areas of granitic rocks occur along the south contact of the nickel intrusive. They have been designated as Creighton, Murray and Lady Violet granite. Available evidence indicates that these are not simple granite intrusives but are composite bodies, largely pre-nickel-intrusive in age with some post-nickel-intrusive granite recognized. Most of the area south of the intrusive is occupied by a succession of metamorphic, volcanic and sedimentary rocks highly folded and faulted, striking in general east-northeast and dipping at steep angles mainly to the north. These rocks stratigraphically face south.

Breccias are widespread in the rocks that now underlie the nickel intrusive. These breccias are regarded as a manifestation of the volcanic activity that produced the volcanics now lying above the nickel intrusive.

The continuity of the nickel intrusive is interrupted by dikes of granitic material, trap and olivine diabase and by post-intrusive faulting as evidenced by displacements ranging from a few feet (1 M.) to two and one half miles (4 KM.).

An erosional unconformity is thought to have existed between the rocks that now overlie and the rocks that now underlie the nickel intrusive. Some believe that the nickel intrusive was emplaced horizontally along this unconformity, differentiated into its component parts and then was downwarped and infolded to form a basin structure. A second hypothesis favours emplacement in a pre-existing basin-shaped structure. A recent proposal renews suggestions that the elliptical outline of the intrusive at surface is a reflection of the former presence of a ring of volcanoes and the intrusive is a ring dike-and-sill complex.

## GEOLOGY OF THE SUDBURY COPPER-NICKEL DEPOSITS

Mining experience of more than 50 years has established the bottom contact of the norite as the primary structure that determined the location of ore deposition. Feeble mineralization along this locus is present for most of its known area, but ore concentrations occur only where the primary locus coincides with essential but secondary structures. The recognized kinds of ore-bearing structures are (1) depressions in the relatively smooth norite footwall in which the norite penetrates the underlying rocks, (2) shearing that roughly coincides with the base of the norite, (3) contact breccias at the base of the norite. Although it is believed that any one of these structures is capable of controlling an ore deposit, it has been observed that more than one are generally found in any given orebody. It should also be noted that although every known orebody is associated with the kinds of structure described, there are many such structures in which the mineralization is not of ore grade.

Numerous attempts have been made to explain the obviously close relationship of the ore mineralization to the norite. Their invariable association indicates a common source, and adherence of the ore to the base of the norite has led many geologists to believe that the ores must have accumulated from the nickel intrusive during the process of differentiation. Others have given more weight to the apparently contradictory evidence based on the timing of geological events, and have proposed that the ores were introduced after the nickel intrusive was frozen and deformed.

The ores are mined primarily for nickel and copper, but there is also important production of cobalt, iron, the platinum group metals, gold, silver, selenium, tellurium, and sulphuric acid. The principal ore minerals are pyrrhotite, pentlandite and chalcopyrite. Pyrite, magnetite and the arsenides of nickel, cobalt and platinum are the notable accessory minerals. A typical orebody lies astride the norite contact and consists of varying proportions of disseminated ore, breccia ore and stringer ore. Most of the sulphide on the norite side of the contact occurs in the disseminated form, whereas the sulphide below the norite contact is massive. This massive sulphide always contains some associated rock and is named breccia ore or stringer ore, depending on whether the sulphide or the rock is the continuous component.

### The Levack Area

This area, located on the north-west side of the Basin, includes the Levack Mine of International Nickel, and five Falconbridge mines, Hardy, Boundary, Onaping, Fecunis and Longvack.

In this area, the footwall contact of the norite dips southerly at approximately 40°, and the ore deposits are associated with norite penetrations into the footwall. The mineralization usually occurs in the footwall rocks and in a contact — breccia zone found at the base of the norite. There are two principal ore types — disseminated sulphide which occurs in the contact breccia, and massive sulphide which occurs as bodies of essentially massive sulphide and as stringers in footwall rocks.

A prominent structural feature of this area is the Fecunis Lake fault which strikes N 20°W and dips 75°W. Post-ore movement on this fault has offset the east end of the Levack ore zone several hundreds of feet.

### The Frood-Stobie Mine

The Frood-Stobie Mine in the central part of the south range is interpreted as a special example of ore control by a depression in the norite footwall. In this instance, the norite (quartz-diorite) penetration of the underlying rocks, instead of being blunt, is sharp and very deep. It has the shape of a dike-like appendage which apparently projected downward from the bottom of the norite. Erosion has removed the horizons at which continuity would have existed between the appendage and the main body of norite, so that the Frood-Stobie orebody occurs in a pocket of norite (quartz-diorite) now isolated in the basement rocks about a mile (1.6 KM.) from the parent body. At surface, this remnant has an over-all length of 9,600 feet (2.9 KM.). In section, it wedges out downward along a 75° dip and bottoms at about 4,000 feet (1.2 KM.).

Four ore types are found at Frood-Stobie. In order of tonnage represented they are: disseminated sulphide ore, breccia sulphide ore, sulphide stringer ore and siliceous ore.

All of the norite (quartz-diorite) carries disseminated sulphides and barren gabbro inclusions. Although the intensity of mineralization and the frequency of inclusions vary widely, most of the norite (quartz-diorite) is of mineable grade.

Breccia sulphide and stringer ore become more abundant on the lower levels. Breccia sulphide is a rock-sulphide breccia in which fragments of disseminated norite and various kinds of wall rock are contained in a sulphide matrix. Stringer ore is massive sulphide stringers in the wall rocks. These ore types are generally found at the margins of the norite remnant.

The siliceous ore zone lies below the norite at the southwest (Frood) end of the orebody. Siliceous ore is a low grade copper-nickel stringer type ore of commercial importance because of its content of platinum group metals.

### The Garson Mine

At Garson, toward the east end of the south range, the essential secondary structure is shearing that coincides approximately with the norite contact. The dominant shearing strikes east-west and dips at about 75° to the south, away from the centre of the basin. A number of subsidiary shears striking east-west and dipping about 55° to the south diverge upward from the parent structure from successively deeper horizons and terminate in the norite. In cross section, the norite contact traces an irregular course across each of the successively deeper wedges of ground lying between the main shear and its flatter branches. The ore occurs along the main and tributary shears and along the norite contact between them; hence the overall mining pattern is complex. Mineable widths vary from several feet in the vein-like deposits of ore along the shears up to a maximum of about 200 feet (60 M.) where swells of ore occur in the zones of shear convergence.

### The Creighton Mine

The Creighton ore deposit, located on the south range five miles west of the Copper Cliff offset, is controlled by two structures, a depression in the norite footwall and shearing. At surface, the embayment formed by the depression is about a mile long (1.6 KM.) and one-half mile deep (0.8KM.); it plunges at 45° to the northwest. A northwest dipping shear strikes into the depression from the northeast and there develops a branching pattern so oriented that it coincides with the plunge of the depression. The various branches of the shear cut across the southeast side of the depression where they diverge downward and southwestward. Consequently, each branch, along both the strike and the dip, passes from norite into the footwall rocks and causes displacement of the norite contact which may amount to several hundreds of feet.

The mineralized zone has the shape of an irregular but continuous pipe lying along the plunging structure just described. Most of the zone consists of norite containing disseminated sulphides, the minor portion being breccia and stringer ore located in large and small pockets on the underside of the mineralized norite, and in sheets along the shears. In a general way the intensity of the disseminated mineralization decreases upward from the base of the norite, but heavier than normal dissemination occurs adjacent to the sheets of breccia ore that lie along the shears.

### The Murray, McKim and Mount Nickel Mines

The Murray, McKim and Mount Nickel Mines are located on the south range of the basin, east of the Copper Cliff offset. The control for ore deposition here is a north dipping breccia that lies between the norite and the underlying greenstone and granite. This breccia has an unusually high proportion of inclusions to matrix and because the mineralization is largely confined to the matrix, the overall grade of the orebody is low. Higher grade ore occurs as discontinuous breccia sulphide lenses along the footwall of the low grade mineralization and in places penetrates the footwall rocks.

### The Falconbridge and East Mine

The Falconbridge and East Mine deposits on the southeast margin of the basin are essentially sheets of sulphides lying within an east-west shear zone coincident with the norite-greenstone contact. At the extremities of the mines where the zone of shearing leaves the contact, ore mineralization is lacking.

In the upper workings of the Falconbridge Mine, the ore zone dips steeply north with the norite contact. At a depth of about 1,200 feet (365 M.), the dips of the norite and the ore zone reverse to steep south and drilling data indicate that this attitude is maintained to a depth of at least 6,000 feet (1.8 KM.). Subsidiary fractures branch upward from the main shear into the hanging wall and local widenings of the ore zone occur at the intersections of these branch shears and the main shear. Above 1,200 feet (365 M.), these subsidiary fractures extend into a norite hangingwall. Below 1,200 feet (365 M.), the hangingwall is greenstone and in this hangingwall the branch fractures are responsible for detached ore shoots in addition to widening of the ore zone at the intersection with the main shear.

The norite-greenstone contact at the East mine dips steeply south, being almost vertical in the upper horizons and flattening slightly below 1,750 feet (535 M.). The ore shoots are similar to those of the Falconbridge Mine except that relatively extensive disseminated sulphides, which make low grade ore, occur in the upper horizons.

## GEOLOGY OF THE COPPER - LEAD - ZINC DEPOSITS

The occurrence of the pyritic copper-lead-zinc ore in the southwest part of the interior of the Sudbury Basin was first reported in 1890 by R. A. Bell, an officer of the Geological Survey of Canada. Important deposits have since been located, explored and developed at the Errington and Vermilion Mines of Consolidated Sudbury Basin Mines Limited.

The orebodies are at the contact of fine tuffs and overlying slate of the Whitewater Series of volcanics and sediments, which occupy the interior of the Basin. They are believed to be replacements of a limestone bed at this horizon and the ore consists of very fine grained pyrite, sphalerite, chalcopyrite, pyrrhotite and galena in a carbonate matrix.

Generally around the Basin the tuff-slate contact dips toward the centre at low angles. At the Errington and Vermilion Mines however, the dips are steep and the structure is complicated. Tight folds and thrust faults produce a complex system of ore blocks. The most important faults at these mines are roughly parallel to the thrust faults that are major structural features of the south range of the Sudbury Basin.

## ACKNOWLEDGMENT

The foregoing description of the geology of the Sudbury Basin was compiled from manuscripts prepared by the geological staffs at The International Nickel Company of Canada, Limited, Falconbridge Nickel Mines Limited and Consolidated Sudbury Basin Mines Limited. Their participation was made possible through the courtesy of their respective managements.

## SELECTED READING

This report has of necessity dealt with generalities and those interested in more specific detail should refer to the following list of selected reading:

BELL, R.—"Report on the Sudbury Mining District"; Geol. Surv. Can., vol. V, pt. F. 1890-91.

WALKER, T. L.—"Geological and Petrographical Studies of the Sudbury Nickel District of Canada"; Geol. Soc. London, Quart. Journal, vol. LIII, 1897.

BARLOW, A. E.—"Report on the Origin, Geological Relations and Composition of the Nickel and Copper Deposits of the Sudbury District, Ontario, Canada"; Geol. Surv. Can., vol. XIV, pt. H, 1901.

COLEMAN, A. P.—"The Nickel Industry"; Mines Branch, Dept. Mines, Canada, Bull. No. 170, 1913.

Report of the Royal Ontario Nickel Commission, pp. 105-211, 1917.

ROBERTS, Hugh M., and LONGYEAR, Robert Davis—"Genesis of the Sudbury Nickel-Copper Ores as Indicated by Recent Exploration"; A.I.M.E., Bull. No. 134, Feb. 1918.

KNIGHT, C. W.—"The Chemical Composition of the Norite-Micropegmatite, Sudbury, Ontario, Canada"; Econ. Geol., vol. XVIII, 1923.

PHEMISTER, T. C.—"Igneous Rocks of Sudbury and Their Relation to the Ore Deposits"; Ont. Dept. Mines, vol. XXXIV, pt. VIII, 1925.

BURROWS, A. G., and RICKABY, H. C.—"Sudbury Basin Area"; Ont. Dept. Mines. vol. XXXVIII, pt. III, 1929.

BURROWS, A. G., and RICKABY, H. C.—"Sudbury Nickel Field Restudied"; Ont. Dept. Mines, vol. XLIII, pt. II, 1934.

COLLINS, W. H.—"The Life History of the Sudbury Nickel Irruptive"; Roy. Soc. Can., Trans., vols. XXVIII, XXIX and XXX, sec. IV, 1934, -35, -36.

YATES, A. B.—"The Sudbury Intrusive"; Roy. Soc. Can., Trans., vol. XXXII, sec. IV, 1938.

THE EXECUTIVE AND OPERATING STAFF—"The Operations and Plants of International Nickel Company of Canada, Limited"; Canadian Mining Journal, May, 1946.

COOKE, H. C.—"Problems of Sudbury Geology, Ontario"; Bull. No. 3, Geol. Survey of Canada, 1946.

DAVIDSON, Stanley—"Falconbridge Mine"; Structural Geology of Canadian Ore Deposits, Symposium by a Committee, C.I.M., Chapt. III, pt. 7, pp. 618-625, 1948.

COOKE, H. C.—"Regional Structure of the Lake Huron-Sudbury Area"; Structural Geology of Canadian Ore Deposits, Symposium by a Committee, C.I.M., Chapt. III, pt. 7, pp. 580-589, 1948.

YATES, A. B.—"Properties of International Nickel Company of Canada"; Structural Geology of Canadian Ore Deposits, Symposium by a Committee, C.I.M., Chapt. III, pt. 7, pp. 596-617, 1948.

MUTZ, H. J., BROCK, A. F., and TAYLOR, W. J.—"Underground Mining Methods at International Nickel Company"; Mining Engineering, pp. 58-60; January 1953.

LOCHHEAD, D. R.—"Falconbridge Ore Deposit, Canada", Econ. Geol., vol. L, No. 1, pp. 42-50, Jan.-Feb., 1955.

MITCHELL, C. P., and MUTCH, A. D.—"Geology of the Hardy Mine, Sudbury District, Ontario"; C.I.M., vol. 49, February 1956.

THOMPSON, Jas. E.—"Geology of the Sudbury Basin"; Ont. Dept. Mines, vol. LXV, pt. 3, pp. 1-56, 1956.

WILLIAMS, Howel—"Glowing Avalanche Deposits of the Sudbury Basin"; Ont. Dept. Mines, vol. LXV, pt. 3, pp. 57-89, 1956.

PHEMISTER, T. C.—"The Copper Cliff Rhyolite in McKim Township, District of Sudbury"; Ont. Dept. Mines, vol. LXV, pt. 3, pp. 91-116, 1956.

Sudbury District

The Sudbury, Ontario, district is the world's largest producer of Ni and a major producer of Cu. Pt metals, Co, Au, Ag, Se, Te, Fe and S also are recovered. The Sudbury ores are an excellent example of magmatic sulfide deposits and may serve to illustrate magmatic textures. Three general types of ore are recognized in the district: disseminated, massive, and breccia. Disseminated grains of the sulfides, pyrrhotite, pentlandite, and chalcopyrite are found throughout the Sudbury Precambrian intrusive norite-granophyre (micro-pegmatite) lopolith (?) and become increasingly abundant toward the lower portions of the igneous body. Close microscopic examination of the disseminated texture reveals that some of the sulfide grains exhibit nearly rounded shapes (Fig. 1). These rounded shapes are believed to indicate that much of the sulfide formed as sulfide liquid drops which became immiscible in the silicate liquid as the temperature of the magma declined (Hawley, 1962). The converse relationship may also be observed - rounded blebs of silicate minerals within predominantly sulfide areas (Fig. 2). Magnetite is disseminated throughout the norite and its grains may locally show straight crystal borders.

Massive ore occurs at the very base of the Sudbury intrusion where it appears to represent a massive accumulation of gravity settled immiscible liquid sulfide drops. The massive ores exhibit granular texture, one in which grains of pyrrhotite, pentlandite and chalcopyrite are clustered together (Fig. 3). Chalcopyrite occurs along pyrrhotite grain boundaries (Fig. 4) and appears to have locally veined and perhaps replaced pyrrhotite.

The sulfide and oxide grains in all three of sudbury ore may exhibit exsolution textures. Crystallographic orientations of ilmenite in magnetite and cubanite in chalcopyrite are good examples of lattice texture where observed, but they are rare. The most common exsolution relationship is between pyrrhotite and pentlandite, but the pentlandite generally has exsolved completely out of and forms a network around pyrrhotite grains (Fig. 3). What appear to be veins of pentlandite are mostly pentlandite clusters along the grain boundaries of pyrrhotite as can be seen with cross nicols. Only in recent years has it been recognized that exsolution products may lead to granular and veined textures (Brett, 1964). Rare exsolution flame-like lamallae of pentlandite in pyrrhotite, cubanite chalcopyrite, and cubanite in pyrohotite (Fig. 6), attest to original high temperature solid solution relationships (Fig. 6), and indicate minimum temperatures of formation of 425°and 300°C. The phase diagrams in section VI-B-6 and 7 illustrate the exsolution of pentlandite from pyrrhotite. Those in section VI-B-10 and 11 illustrate the exsolution of cubanite from chalcopyrite.

Breccia ore occurs at the margins of the Sudbury irruptive. The breccia ores exhibit brecciated texture in which angular fragments of wall rock silicates are cemented by sulfides (Fig. 5). In many places the fragments form a mossaic breccia in which nearby fragments have moved apart only slightly and appear as though they could be put back together again. Where the rock fragments are ground into finer particles they form a granulated texture. Sphalerite and galena locally are present, especially in association with chalcopyrite in massive and breccia ores (e.g., RH-10).

The platinum arsenide, sperrylite occurs as occasional euhedral crystals in the Sudbury ore, but none are present in the laboratory polished section suite.

List of Polished Sections for the Sudbury Suite

Disseminated Ore

RH-4
RH-8
RH-11
RH-12

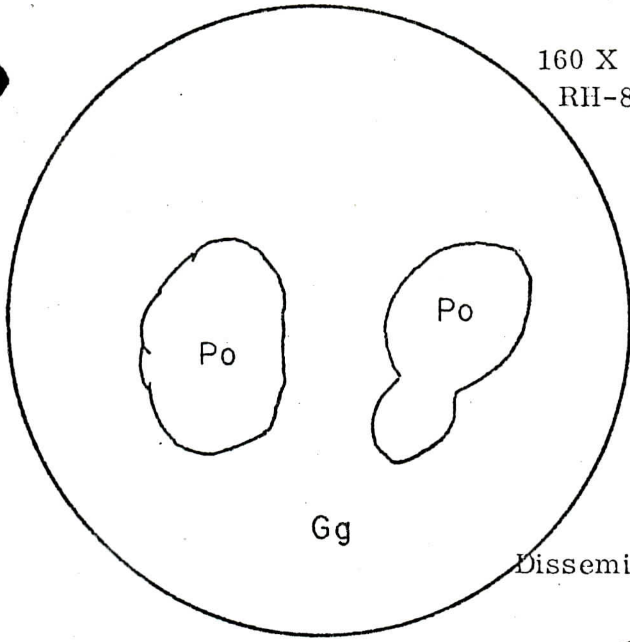
Massive Ore

RH-2
RH-7
RH-9
RH-10

Breccia Ore

RH-1
RH-5

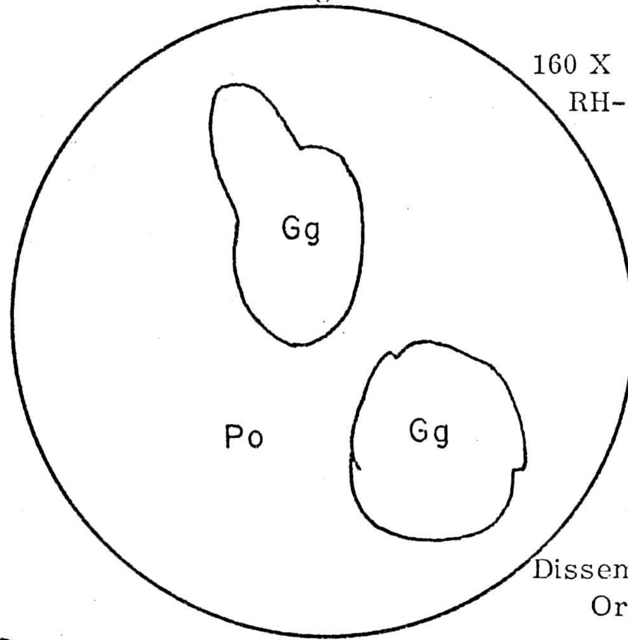
Fig. 1




160 X
RH-8

Disseminated Ore

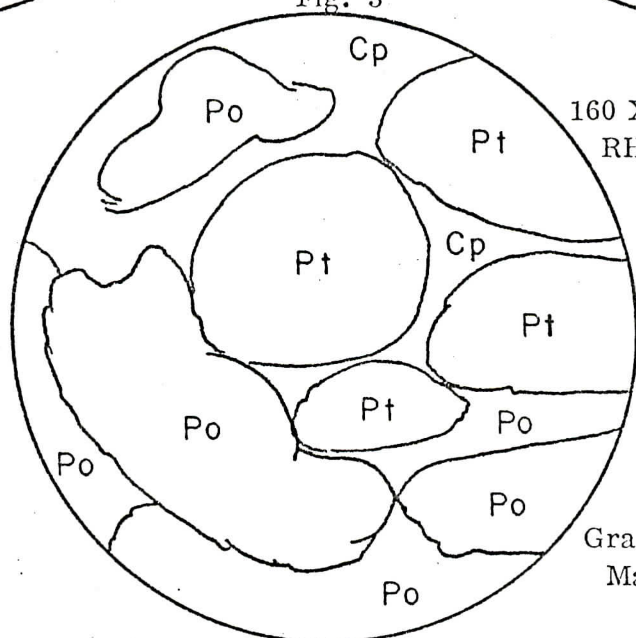
Fig. 2




160 X
RH-12

Disseminat
Ore

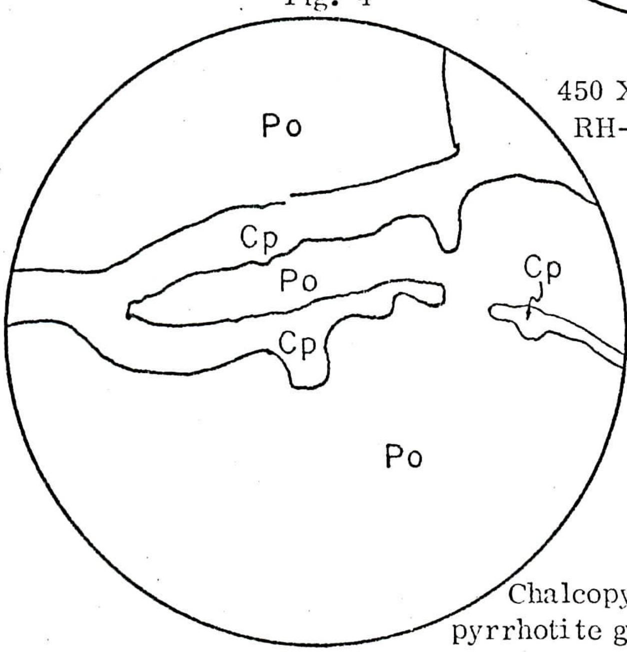
Fig. 3




160 X
RH-10

Granular texture
Massive ore

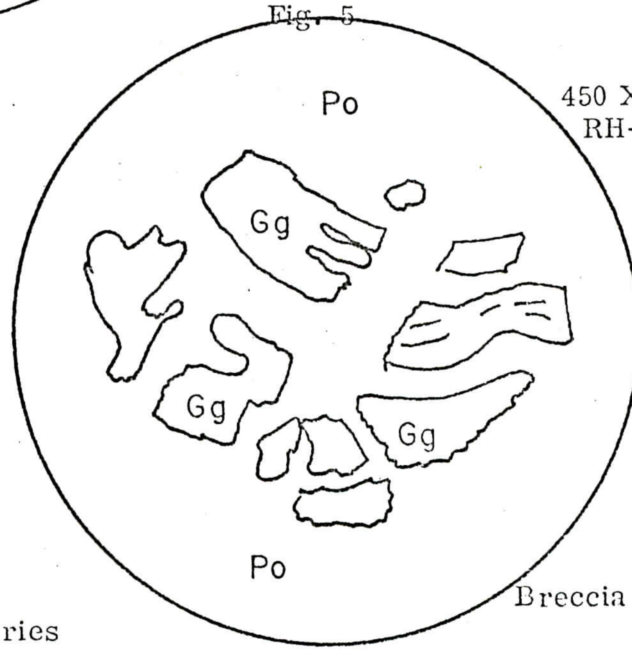
Fig. 4




450 X
RH-10

Chalcopyrite along
pyrrhotite grain boundaries

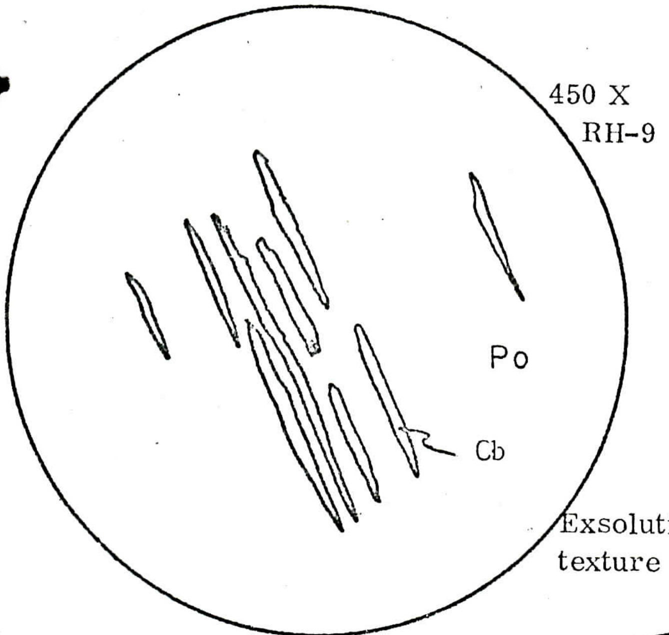
Fig. 5




450 X
RH-

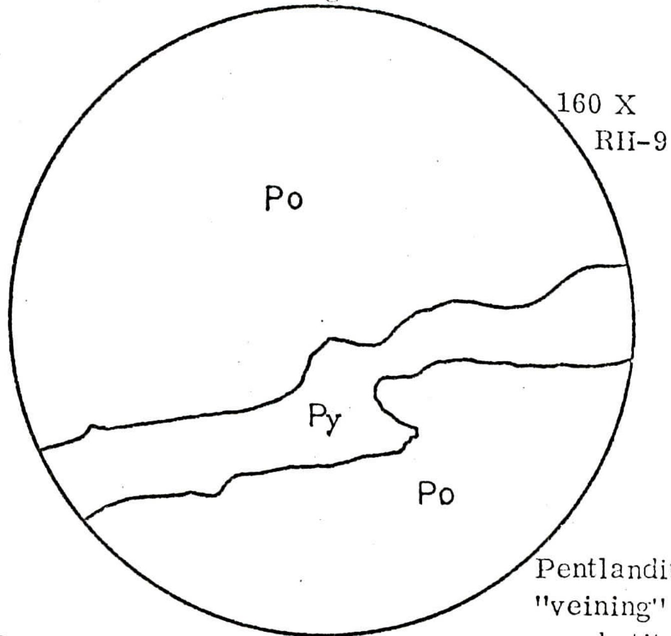
Breccia Or

Fig. 6




Exsolution texture

Fig. 7




Pentlandite "veining" pyrrhotite