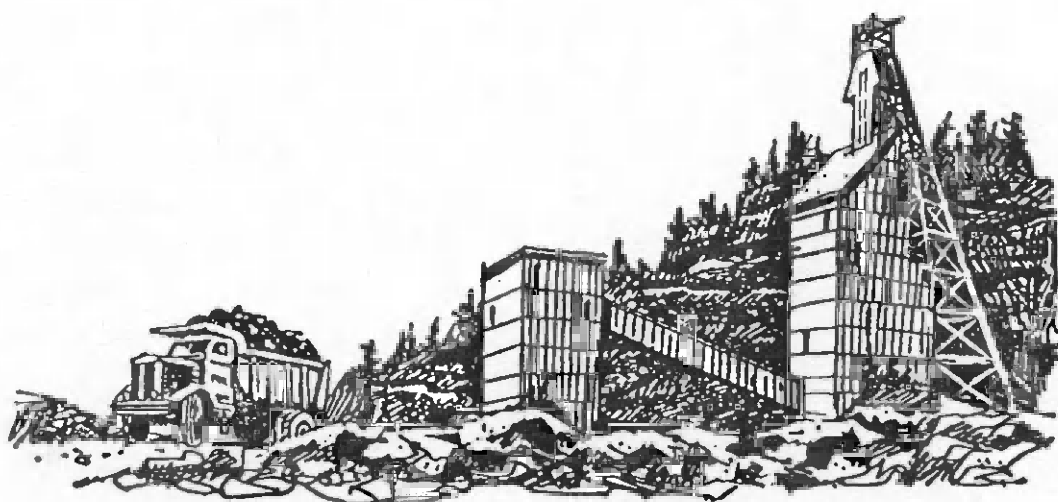


MAGMATIC ORE DEPOSITS OF THE SUDBURY IGNEOUS COMPLEX

**BY
S. A. PREVEC**



**INSTITUTE ON LAKE SUPERIOR GEOLOGY
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SUDBURY, ONTARIO**

Field Trip Guidebook, Volume 43: Part 5

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Field Trip Co-leaders

S.A. Prevec (Laurentian University, Sudbury)
M. Cosec (Resident Geologist's Office, Sudbury)

Conference Co-chairs

R.P. Sage (Ontario Geological Survey, Sudbury)
W. Meyer (Resident Geologist's Office, Sudbury)

ILSG '97
Field Trip Guidebook

Magmatic Ore Deposits of the Sudbury Igneous Complex

S.A. Prevec
Dept. of Earth Sciences
Laurentian University
Sudbury, Ontario
CANADA P3E 2C6

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Frontispiece: Idealized sketch of a mining operation that appeared on some stationery of the former Ontario Department of Mines, circa 1972.

Introduction

Since the initial discovery of copper sulphide ores in the Sudbury area in 1883 during construction of the trans-Canadian railway, and the subsequent discovery of high nickel contents in these ores, Sudbury has remained the single largest source of nickel in the world. For the first half of this century, Sudbury produced approximately 80% of the world's nickel, although this has dropped to less than 20% in recent decades with the development of Ni-deposits elsewhere in the world. In addition to nickel, Sudbury also produces significant quantities of both copper and the platinum group elements (PGE), plus lesser amounts of gold, silver, cobalt, selenium, tellurium and sulphur. This and further historical information is summarized by Giblin (1984).

In addition to its anomalously high abundances of base- and precious-metals, Sudbury is also distinguished by its somewhat unique distribution of silicate and sulphide components, and the resultant enigmatic or at least controversial models for its origin. It has long been recognized that a discrete, igneous-textured noritic phase of the complex occurs in discontinuous pockets along the interface between the Sudbury Igneous Complex (SIC) and the footwall. This is known as the Contact Sublayer, and is characterized by the presence of a high proportion of inclusions of various types (including relatively ultramafic ones), bits of assimilated footwall, and most significantly, represents the residence of the majority of the nickel sulphides. Offshoots of less mafic material which extend out from this interface into the footwall, or which may be emplaced into linear zones in the footwall running parallel to the SIC-footwall contact are known as Offset Dykes. The ore mineralization in Sudbury is largely associated with these three environments, as

summarized by Morrison et al. (1994):

- 1. contact-type deposits that occur at or near the basal contact of the Sudbury Igneous Complex (SIC) with Proterozoic and Archean basement*
- 2. offset dykes of SIC material that extend many kilometres into the basement*
- 3. footwall-type deposits that occur as sheet-like veins and vein stockworks within brecciated basement up to 2 km outside the SIC and/or basement contact*

The emplacement of the SIC was a catastrophic event, involving extensive fracturing and brecciation of the host rocks, including the appearance of shock-induced features such as shattercones (well-preserved on Ramsey Lake Road, west of the Ontario Geological Survey building) and planar lamellae in quartz grains. In the footwall this fracturing has not only provided potential conduits for the introduction of magmas (such as the Offset Dykes) and heated fluids (which may carry sulphides, as may the magmas), but also a distinctive pseudotachylitic-textured rock known as Sudbury Breccia, which has also provided a conduit for later migration of sulphides and other material.

Objectives of this excursion

This excursion will provide access to some of the best aboveground examples of the environments of mineralization in the Contact Sublayer (at Whistle pit), and in the footwall, associated with Sudbury Breccia emplacement (at the Barnet showing).

The trip has been arranged as two one-half day excursions. Part 1 involves a trip to the Whistle mine, an active Inco Limited property located at the northeast corner of the SIC. This is an excellent example of the Contact Sublayer-type mineralization, and displays the transition from the Main Mass to the Sublayer to the footwall environments extremely well. The transition of mineralization styles is also very evident through this sequence. Part 2 of this excursion will take place at the northwest of the SIC, near the town of Levack. Here we will observe the transition, a bit more discontinuously, from Sublayer breccia to mineralized footwall breccia to mineralized Sudbury Breccia within the footwall, courtesy of Falconbridge Limited.

Acknowledgements

Acknowledgements are due first and foremost to both Inco Limited and Falconbridge Limited, without whose cooperation and collaboration this excursion would not be possible. Both these companies have provided access to their properties, logistical advice and assistance, and scientific support and expertise. Specific acknowledgements are due to Andy Bite and Bill Dyck (Inco) and John Fedorowich and Mike Sweeny (Falconbridge) for their assistance in preparing this guidebook and supporting the pre-excursion fieldwork involved.

Geological Introduction to Sudbury

The "Sudbury Structure" refers to the entire package of igneous-textured, metamorphic and sedimentary rocks which are genetically inter-related or were shaped by the geological episode which produced this complex. These include the Sudbury Igneous Complex (SIC) itself, the Onaping Formation (the later subaqueous sedimentary package which overlies it), and the complex marginal assemblage of igneous and metamorphic textured material between the main body of the SIC and the footwall, which is the area of interest in terms of mineralization and indeed of many other aspects of this complex structure.

The SIC occurs at the southern boundary of the Superior Province, in the granite-greenstone terrains of the late Archean Abitibi Subprovince. The Abitibi has been overlain in this area by a thick pile of volcanogenic and sedimentary rocks known as the Huronian Supergroup (of the Southern Province), sometime between 2480 and 2220 Ma. The SIC was emplaced at 1850 Ma into these two basement types, such that the "north range" of the SIC is hosted by granodioritic to tonalitic, heterogeneous high grade gneisses and granitoids of the Levack Gneiss Complex and Abitibi granitoids, and in the "south range" by more mafic, less evolved low grade metavolcanics, metasediments and granitoids of the Huronian.

The SIC itself may be subdivided into an upper sequence known as the Main Mass, consisting of an upper granophyric sequence which grades downward through a quartz gabbroic transition zone into an igneous, cumulate-textured gabbro-noritic rock known as "Felsic Norite". The sequence from Granophyre down through the Felsic Norite can be broadly viewed in terms of a differentiation sequence (*i.e.*,

becoming more evolved with increasing height in the sequence), although evidence for geochemical discontinuities and other apparent inconsistencies suggest that simple differentiation represents an oversimplified model. At the base of the Felsic Norite, at the contact with the country rock (footwall), the relationships become more complex.

The SIC is geographically described in terms of its three "sides", into the North, South and East Ranges. The North Range is hosted by Late Archean (*ca.* 2710 to 2665 Ma) granitic and heterogeneous gneissic rocks of the southernmost Abitibi Subprovince of the Superior Province. The gneissic footwall suite which borders much of the North Range is called the Levack Gneiss Complex (a "typical" section of which is well-displayed along the Highway 144 roadcut just north of Windy Lake). The South Range footwall consists mainly of volcanics and sediments of the Huronian Supergroup of the Early Proterozoic Southern Province (*ca.* 2480 to 2200 Ma). These include basaltic and rhyolitic volcanics and intercalated sediments, overlain by glacially-deposited sedimentary sequences in a rift environment, and intruded by gabbroic to leucogabbroic dykes and sills of various ages. The South Range has been much more extensively metamorphosed than has the North Range, probably as a result of both Penokean (*ca.* 1950 to 1850 Ma) and later Grenvillian (*ca.* 1100 to 950 Ma) activity. The East Range reflects some characteristics of both environments. In general, preservation of igneous textures and compositions is much better in the North Range rocks than elsewhere.

Introduction to the mineralized environments

The mineralized environments occurring along the margins of the SIC Main Mass can be broadly subdivided into igneous-textured (*i.e.*, therefore of magmatic-origin) Contact Sublayer and Offset dykes, as shown in Figure 1, and the metamorphic-textured footwall rocks which host them. Until relatively recently, the igneous-textured Sublayer matrix ("TSM") and the more felsic equivalents in the Offset dykes, referred to as quartz diorite ("QD"), had been grouped together as Contact Sublayer (*e.g.*, Naldrett *et al.*, 1984). Evidence from petrography (*e.g.*, Pattison, 1979), incompatible trace element geochemistry (*e.g.*, Lightfoot *et al.*, in press), and radiogenic isotope geochemistry (Prevec *et al.*, 1997) suggests that the matrices of the Offsets and the Sublayer represent distinctly different magmas. Thus, although the similarity of their inclusion populations and emplacement styles suggests a close genetic relationship, they will be treated here as separate entities.

An additional subunit of the Main Mass gabbro-norites known as "Mafic Norite" has been identified, occurring below the Felsic Norite (which comprises the bulk of the Main Mass). Mafic Norite is particularly evident in locations where Sublayer and/or Offsets occur below the Main Mass. This relationship is depicted in Figure 2. Mafic Norite is distinguished from Felsic Norite on petrologic grounds; geochemically the two norites reflect a gradationally upwards evolving sequence. Specific distinctions between these two Main Mass subunits will be provided in the descriptions for stops in the Whistle Mine pit.

Sublayer

The most recent formal publication dealing specifically with this subunit of the SIC (Naldrett et al., 1984) used the term "Contact Sublayer" to define that part of the Sublayer adjacent to the Main Mass of the complex and not that included in (Offset) dykes. However, its usage even in that article was ambiguous, and more recent study, as mentioned previously, has indicated a more prominent distinction between Contact Sublayer and Offset Dyke magmas. Therefore, our working terminology will henceforth refer merely to "Sublayer" and "Offset" rocks. The Offsets will be discussed in more detail in the next subsection.

The discontinuous marginal embayments known collectively as the Sublayer, as originally characterized by Pattison (1979), contain the bulk of the Ni-Cu-PGE ores. This unit is characterized by an igneous-textured noritic matrix hosting disseminated to massive sulphides and a relatively large proportion of inclusions. The inclusion populations may be divided into two groups; those obviously derived from the adjacent footwall, and more enigmatic mafic to ultramafic inclusions, the latter of which appear to be spatially associated with sulphide occurrences (*e.g.*, Souch and Podolsky, 1969). Sublayer inclusion types include small-scale felsic/anorthositic blebs (generally cm-scale) which are most abundant in, but not unique to, the Sublayer, cm-scale inclusions of fine-grained, often porphyritic, hornfels-textured material ("anhedral porphyries"), and cm- to metre-scale inclusions of ultramafic material. Although these inclusion populations comprise a significant proportion of the Sublayer (up to 25%), they are not at all well-represented in the surrounding basement.

Footwall

The term "footwall" is used as a general term to denote basement rocks underlying the SIC. The footwall within about 1 km surrounding the SIC has been variably thermally recrystallized by the contact aureole of the SIC, producing concentric contact metamorphic zones from pyroxene- to hornblende- to epidote-albite-hornfels, in order of increasing distance from the contact. It has been observed that the mineralization in the footwall is largely associated with the most proximal, highest temperature, pyroxene hornfels aureole (Coats and Snajdr, 1984).

In addition to the thermal aureole, the footwall is extensively fractured, both radially and concentrically around the SIC. These fractures provide conduits for the injection of relatively homogeneous noritic magma bodies known as Offset Dykes and of distinctive shock-induced pseudotachylitic-textured rocks known as Sudbury Breccias, both of which represent environments for hosting significant Cu-rich mineralization. In addition to the Sudbury Breccias, additional breccia-type environments which may host mineralization include "footwall breccia", "late granite breccia" and Sublayer (breccia; see pg. 21). The latter two reflect terminology used mainly by Falconbridge Limited, and will be discussed further in the text for Part II of this excursion.

Offsets

Offset Dykes are intrusive, igneous- to metamorphic-textured bodies occurring as elongate dykes which may extend 10 to 15 km into the footwall, occasionally upwards of 25 km (in the case of the Foy Offset in the North Range). These dykes occur both radiating outwards from the contact with the base of the SIC and also

aligned parallel to the contact, lying out in the footwall, as in Hess and Falconbridge Townships. The silicate mineralogy of the Offset Dykes is dominated by plagioclase, ortho- and clinopyroxenes, quartz and granophyre (*e.g.*, Pattison, 1979). As the dyke extends further into the footwall, this assemblage is replaced by its metamorphic equivalent, whereby the pyroxenes in particular are replaced by amphibole and then biotite, and quartz, feldspar and granophyre are recrystallized.

Sudbury Breccias

Sudbury Breccias also occur in a wide zone surrounding the SIC, where their alignment, as with the Offsets, is a function of the local fault geometries. They have been identified as far as 80 km distance away from Sudbury (both near Lake Temagami to the northeast and Agnew Lake to the west). They consist of a very fine-grained matrix within which blocks of country rock are entrained. The clast size may vary enormously, from xenocrystic grains to outcrop size blocks, where the rotation of regional fabrics (foliations, lineations, etc.) allow these blocks to be identified as breccia clasts. The matrix of Sudbury Breccia is texturally comparable to a low-viscosity liquid in terms of its fluid dynamics, although it appears to consist of the pulverized equivalent of the local country rock, displaying sharp contacts with it but with no thermal contact aureole.

Mineralization

The vast majority of the ores at Sudbury are incorporated into an assemblage dominated by pyrrhotite, pentlandite, chalcopyrite and pyrite. Variation in the relative proportions of these minerals within a given deposit are attributable to the effects of fractionation of a monosulphide solid solution (Mss), such that

fractionated liquids enriched in Ni, Cu, Pt, Pd and Au are differentiated from residual cumulate sulphides enriched in Fe, Co, Rh, Ru, Ir and Os (Naldrett, 1984). Differences in Cu, Ni and PGE tenor between different deposits may be attributed to progressive depletion of these elements from a given batch of magma by segregation of successive batches of sulphide.

While most of the Ni is concentrated into pentlandite, exsolved at low-temperatures (200° to 250°C) from pyrrhotite, pyrrhotite itself may also retain up to 1.2 wt% Ni. Cu is largely concentrated in chalcopyrite, with lesser amounts occurring in cubanite (CuFe_2S_3). PGE are largely concentrated in the platinum-group minerals (PGM) michenerite (PdBiTe), moncheite (PtTe_2) and sperrylite (PtAs_2). A relatively complete list of the metalliferous minerals occurring at Sudbury is provided by Naldrett (1984). Typical average grades of these elements in 100% sulphide are as follows, based on values given in Naldrett (1984), Cochrane (1984), Binney *et al.* (1994) and Naldrett *et al.* (1994).

Unit	Ni (wt%)	Cu (wt%)	Co (wt%)	Pt (ppb)	Pd (ppb)	Au (ppb)	Cu/Ni	(Pt+Pd)/ (Ru+Ir+Os)
Sublayer-	3.8	2.2	0.19	1391	1798	583	0.58	6.8
Offset	4.0	3.6	0.17	2130	3170	868	0.90	5.3
F. Breccia	4.5	2.3	0.16	756	802	122	0.51	25
S. Breccia	4.9	3.8	0.12	1042	1026	105	0.78	93
Cu zones	1.6	30.1	0.06	1753	2994	85	18.8	897

These values are based on arbitrarily chosen data from available literature, and are intended as a very general guide to relative abundances. Sublayer deposits are generally thought to have Cu/Ni ranging between 0.1 and 0.5 (Morrison *et al.*,

1994), which is lower than presented here. The concentrations of PGE and Au in particular may vary by orders of magnitude between deposits, so "average" abundances should be treated with caution. The Cu/Ni ratio of the SIC deposits as a whole is considered to be around 1.0, where Sublayer deposits have $\text{Cu/Ni} < 1$, Offset Dyke and Sudbury Breccia (or Footwall deposits) have $\text{Cu/Ni} > 1$, and the deep copper and stringer zones have $\text{Cu} \gg \text{Ni}$.

Field Trip: Part I - Whistle Mine

The following three page description of the environment and history of the Whistle Mine was written by Inco Ltd. for geological visitors to the mine site. It is here reproduced for this field trip guide courtesy of Inco Limited as of January, 1997, with minor updating courtesy of A. Bite (Inco Ltd.).

WHISTLE MINE

Whistle Mine is located in the extreme north-east corner of the Sudbury Basin, approximately twelve kilometres north-east of the town of Capreol in concession IV of Norman Township.

The orebody lies within the Whistle embayment which plunges to the west south-west at about forty degrees. The ore outcropped in the form of a large hill facing to the south and is reasonably continuous to a depth of about five hundred feet. The ore is of two primary varieties, the most abundant type being disseminated inclusion norite in which the sulphide exists as distinct blebs in a noritic matrix. Also within the norite are large inclusions of greenstone, amphibolite and a variety of ultramafics (generally dark coloured rocks). The second most common type of ore is inclusion massive sulphide. It is characterized by large rock inclusions (as described above) "floating" in a matrix of massive sulphide. The orebody itself is overlain by a thick layer of medium-grained, light grey barren main mass felsic norite.

The footwall of the Sudbury Igneous Complex (SIC) comprises partly barren sublayer and/or inclusion basic norite. However, the true footwall to the ore body is a pink granite breccia which is well exposed on the north wall of the pit.

The ore is made up predominantly of copper plus nickel with minor amounts of cobalt and precious metals. The copper/nickel ratio is approximately 0.3:1 while the pyrrhotite/nickel ratio is 23.5:1.

There are no major offsetting structures transecting the ore zone; however, strong localized joints are encountered and many are quite rusty in appearance, indicating significant historic water movement. This may be due in part to the fact that the area had previously been developed as a mine near the turn of the century.

To date, some 4.5 million tons of rock and 2.7 million tons of ore have been mined from the pit.

January 15, 1991

WHISTLE MINE

HISTORY and STATUS

-LOT #6, concession #5 - Norman Township - 12 km north of Capreol

- 1897 - Isaac Whistle discovers the property
- 1900 - A mining patent is issued
- 1903 - Property ownership is transferred from Dominion Nickel Copper Company to British American Nickel Company.
- 1910 - Exploration begins in the form of diamond drilling and drifting along ore veins accessible through an adit.
- 1912 - Whistle is abandoned in favour of the Murray prospect.
- 1912 - 1929 - The property stagnates
- 1929 - The property reverts to INCO through the merger.
- 1928 - 1988 - The ore body is delineated by several series of diamond drilling programs.
- 1988 - INCO develops an open pit in January, 1988 contractually mined by MacIsaac Mining and Tunnelling.
- 1991 - Pit production ceases and the mine is placed on standby after 3,285,000 tons of ore are extracted along with nearly 4,868,000 tons of waste. Approximately 1.3 million tons of ore remain to be extracted from the open pit. Additional mineral below the pit could become mineable if economic conditions become favourable.
- 1993 - Exploration diamond drilling in the footwall of the pit locates a small occurrence of high grade copper with substantial precious metals between 1500 and 2000 levels.
 - Closure plans are being formulated to be ready for submission by 1995.
- 1994 - Exploration diamond drilling continues
- 1994 - In November plans are established to reopen Whistle. The mining contract is let to Carman Construction with the intention to mine approximately 1.3 million tons to the 12th bench.
- 1995 - Plans are finalized for an expansion which will access an additional 1.0 million tons of ore and development begins. Mining will now go to cut #14.
 - The mine closure plan is completed and submitted.

- Canmet initiates a project to attempt to characterize a living growing waste pile.
- A rare earth magnet is purchased to facilitate ore cobbing in an attempt to remove significant volumes of "floatable rock" and enhance the mine feed grade.
- 1996 - Mining is planned for the full year at a rate of 2500 tons per day. The magnetic separation circuit is in place and about 70% of the ore is being treated.
- 1997 - Reserves indicate that we will be able to mine until September of this year at a rate of 2500 tons per day. This will take the pit to a depth of 14 benches.

Summary (as of June 1, 1996):

Total rock removed to date	-	6.11 million tons
Total ore shipped to date	-	4.80 million tons

At the Whistle mine, the geology exposed in the pit includes both felsic and mafic Main Mass norites at the southwest, the Sublayer in its various forms, and finally the footwall contact at the northeast corner. The trip will traverse these units in this order, in theory, depending on pit logistics, as depicted in Figure 2.

Stop 1: Introduction to Whistle Mine

This stop is technically not a geological stop, as it will not involve looking closely at the rocks, but will provide a geological and historical overview of the mine, courtesy of Inco Limited, much of which has been provided in the previous text, for your convenience.

Stop 2: Main Mass norites (south ramp)

This stop includes the two Main Mass norites and the contact between them. The felsic norite is distinguished from the mafic norite on the basis not only of colour index (and therefore a modal mineralogical change), but also by inclusion content and sulphide content. The felsic norite is a two-pyroxene-plagioclase-granophyre rock, which is relatively massive and homogeneous. Towards the base, the proportion of ortho- to clinopyroxene increases from roughly equal (about 20% and 15% of the rock, respectively), to orthopyroxene-dominant. The mafic norite underlying it does not contain clinopyroxene at all, and consists of approximately 35-45 modal% orthopyroxene, which becomes progressively more poikilitic-textured with depth. The proportion of quartz and granophyric-textured quartzofeldspathic material also decreases from about 10% in the felsic norite to less than 2 or 3 modal% in the mafic norite. The mafic norite contains cm-sized felsic clasts thought to represent anorthositic melt droplets, which have subsequently

been recrystallized and hornfelsed. Inclusions of dark, fine-grained massive "gabbro-hornfels" comprise the other main inclusion population here. Minor (2 wt%) disseminated sulphides appear in the mafic norite, consisting of pyrrhotite.

Stop 3: Sublayer: upper contact

At this stop the contact between the base of the mafic norite and the uppermost Sublayer is observed. The contact is irregular, and is represented by a decrease in grain size, significant decrease in the abundance of coarse-grained feldspar, and an increase in sulphide content. The mafic norite here is characterized by the presence of coarse-grained interstitial biotite, as well. The Sublayer here may be broadly described as *opx-rich Sublayer*, and consists, at the top, of a medium-grained rock containing about 40% plagioclase plus two pyroxenes (ortho>>clino). Granophyre is also present again, but decreases with depth and disappears. Sulphide consists of five to ten percent disseminated pyrrhotite, grading about 250 ppb Ni, plus associated pentlandite.

Stop 4: Inclusion Sublayer

This "stop" is a sequence of stops as we move progressively into the more mineralized Sublayer down towards the footwall rocks. The Sublayer can be discriminated petrographically into a variety of sub-groups, including olivine-opx-rich Sublayer, porphyritic opx-Sublayer and variations thereon, as distinguished from the opx-rich variant at the top of the Sublayer. The presence of porphyritic-textured pyroxene distinguishes Sublayer rocks from mafic norite, which is characterized by poikilitic textured pyroxene. As the footwall contact is approached, a relatively thin subunit of the Sublayer referred to as *inclusion basic*

norite is present, characterized by a "salt and pepper" texture. This is a somewhat more leucocratic variant of the Sublayer, and has been thought at one time to be representative of a possible parental composition for the Sublayer (*e.g.*, Morrison *et al.*, 1994). The inclusion basic *norite* may also reflect differentiation of Sublayer rock into the "root" of the Offset Dyke which extends outwards from the Whistle Sublayer to the northeast (forming the Whistle and Parkin Offsets). The application of terminology such as inclusion basic *norite* and quartz diorite to Offset rocks becomes somewhat subjective at this point. Many workers apply the term "quartz diorite" to Offsets in the South Range only.

Sulphide textures vary through the Sublayer from the *interstitial pyrrhotite* observed at the top to progressively more interconnected, higher sulphide content equivalents towards the core of the Sublayer (above the inclusion basic *norite*). These include *disseminated (blebby) sulphide*, *ragged-textured sulphide*, *gabbro-peridotite inclusion sulphide* (GPIS) and *inclusion massive-sulphide*. The inclusions in inclusion massive sulphide tend to consist of locally derived footwall material, whereas those in gabbro-peridotite inclusion sulphide are thought to represent potentially more exotic material. This interpretation depends on knowing the source of these more ultramafic inclusions, which is unclear. Alternatives include derivation from the Main Mass (*i.e.*, cumulates), a pre-existing Proterozoic mafic-ultramafic body, Archean footwall, or picritic mantle. The source of these inclusions therefore has further potential implications regarding the origins of the metals and the sulphur.

Stop 5: Footwall

The footwall exposed along the north side of the pit consists of granitic material of the Levack Gneiss Complex, cut by mafic dykes locally. *[Note that the cliff face in the pit at the footwall in particular is relatively unstable, due to the extensive fracturing in this brecciated rock, so particular awareness and caution should be exercised at all times in this area.]* Blocks of footwall rock are present within the adjacent inclusion basic Sublayer, and may contain Cu-enriched sulphides dominated by chalcopyrite. Pyrite-rich sulphide may also be observed, particularly associated with the more "granitized" Sublayer and footwall granite breccias. Sudbury Breccia, hosting "*gash-type*" copper mineralization, can also be observed amongst and below the footwall breccias. The presence of well-defined Sudbury Breccia can be used to imply that the host footwall rock is (probably) insitu, and is not, itself, a breccia block.

LUNCH - Onaping Falls

Field Trip: Part II - Strathcona Footwall Breccia

In contrast to the Sublayer-hosted, pyrrhotite-dominated ores at Whistle mine, the deposits along the northwest margin of the SIC are dominantly footwall-hosted, copper-rich deposits. The following table, modified from Coats and Snajdr (1984), summarizes the mining activity in this 10 km wide belt.

Deposit	Ownership	Depth (feet)	Production
Hardy	Falconbridge	1427	1954 to 1978
Boundary	Falconbridge	952	1961 to 1973
Onaping	Falconbridge	5348	1961 to 1982
McCreedy West	Inco	1600	1973 to present
Craig	Falconbridge		not developed
Levack	Inco	3915	1913 to present
Fecunis	Falconbridge	3993	1957 to 1977
North	Falconbridge	4430	1964 to present
McCreedy East	Inco		not developed
Fraser	Falconbridge	5250	1981 to present
Strathcona	Falconbridge	3205	1968 to present
Coleman	Inco	2278	1970 to 1982
Lower Coleman	Inco		not developed
Longvack	Falconbridge	open pit	1956 to 1961
Longvack South	Falconbridge	1289	1968 to 1977
Big Levack	Inco		not developed

Following initial discovery of sulphides in the area in 1888, production of Ni-Cu ores began in 1913, and production and reserves for the deposits in this area exceed

200 million tons. A summary of the so-called "North Range deposits" located in Levack Township is provided by Coats and Snajdr (1984), from whom the following information has been derived.

The Sublayer, as characterized previously, along with its corresponding mafic noritic protrusion from the Main Mass, is relatively poorly developed at the surface in this area, although well-developed in the subsurface. No Offset Dyke projects outwards into the footwall, although offset rocks hosted by Archean granitoids do occur parallel to the footwall contact about 15 km to the north in Hess and Harty Townships (Fig. 1). The footwall in Levack Twp. consists of a heterogeneous high-grade Archean gneiss complex (the Levack Gneiss Complex), in its type location (or near enough). This complex includes a mixture of granitic, tonalitic, mafic and occasionally ultramafic rocks which have seen granulite grade metamorphism (and subsequently retrogressed to amphibolite facies, for the most part). The complex is exposed at surface to a width of about 2.5 km out from the SIC, beyond which more heterogeneous, greenschist-grade granitoids occur.

The stops on this section of the excursion will pass from basal Sublayer into Footwall Breccia and then into the footwall proper, where mineralization is associated with a Sudbury Breccia zone.

Stop 1: Sublayer (garbage dump outcrop)

The Sublayer here is inclusion-rich Sublayer between the base of the Main Mass and the footwall proper. It is broadly equivalent to undifferentiated inclusion Sublayer between the opx-rich Sublayer and the inclusion basic norite described

previously. This rock type may be considered a breccia, given that a large proportion of the inclusions may have been derived from the Main Mass above it (as it is interpreted by Falconbridge, as opposed to the Inco perspective which treats the inclusions as largely potentially exotic). As the proportion of footwall increases, this becomes analogous to the footwall breccias observed at Whistle. Inclusions identifiable here include fragments of footwall gneiss, iron-rich pyroxenite, and a variety of mafic inclusions in a variably crystalline felsic matrix. The granitic footwall proper is evident in the cliff face, about 100 m to the north.

Stop 2: Footwall Breccia (Strathcona cliff face, water tower)

In front of the Strathcona and Coleman mines, (at the lefthandmost extreme of Figure 3, but not shown), the contact between Sublayer breccia and footwall breccia is well displayed. The two breccias represent a transition from a norite-dominated inclusion-rich breccia into a granitoid-dominated environment with mafic inclusions. Further up on top of the hill (under the water tower, access permitting), *late-granite breccia* is evident. This contains fewer mafic inclusions in a much more granitic matrix and is characterized by a stockwork of relatively fine fractures infilled with granitic material. Mineralization evident at this stop occurs at the base of the cliff in the footwall breccia, consisting of blebby pyrrhotite plus pentlandite, with chalcopyrite present locally.

Stop 3: Mineralized Sudbury Breccia (Barnet showing)

This location, shown in Figures 3 and 4, is an excellent example of footwall (Sudbury Breccia)-hosted mineralization, and has been summarily described by Morrison and Sweeny (1994). It is located approximately 400 m into the footwall

from the SIC contact, and is interpreted to be the up-plunge extension of the Strathcona Copper Zone, characterized by high-Cu, low-PGE contents in the ores. This showing is the property of Falconbridge Limited (since 1979), and the outcrops were stripped in 1987 and 1989 for subsequent detailed mapping and sampling.

The footwall here consists of Levack Gneiss Complex gneisses and migmatites, cut by plagioclase-phyric ("Matachewan-type") mafic dykes, with later Sudbury Breccia cutting both of these units. Sudbury Breccia pseudotachylite occurs as small veinlets at the south end of the outcrop and as a large east-west trending dyke at the north end, where the bulk of the mineralization is hosted. Thin veinlets of pegmatitic feldspathic material, extensively epidotized and hematized, cross-cut footwall, dykes and breccias, and are also associated with Cu-mineralization. This showing is located within the hornblende-hornfels aureole induced in the footwall by the intrusion of the SIC (as mentioned earlier). Both mineralization and alteration are very strongly fractured and/or structurally controlled in the footwall environment.

Mineralization is dominated by chalcopyrite, and occurs as disseminated sulphide, as discrete veins, or as fine stockworks of veinlets. The veins and stockworks evident within the Sudbury Breccia body represent the best-mineralized section, where the distribution of veins and stringers is controlled by two main orientations of fracture sets. The Sudbury Breccia is more prone to extension than is the footwall, providing more zones of weakness and therefore a relatively high sulphide-reservoir potential. This extensional fracture-fill occurrence is equivalent to the

deep-Cu deposits, but does not display the wide mineralized zones required to produce the more massive, higher-grade ores present at depth.

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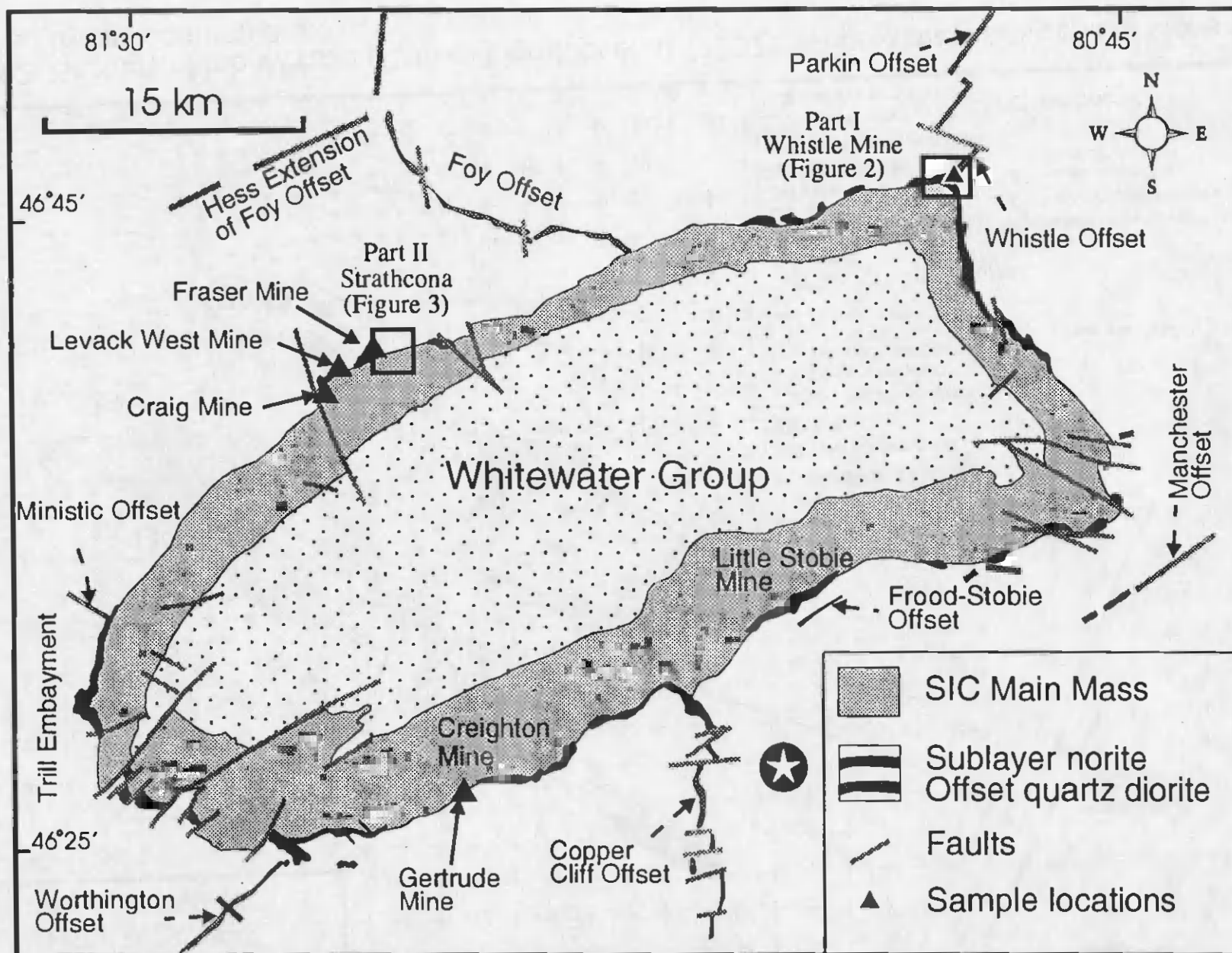


Figure 1: Map of the Sudbury Igneous Complex (SIC) showing Sublayer and Offset locations, plus excursion stop areas (modified from Lightfoot et al., 1997).

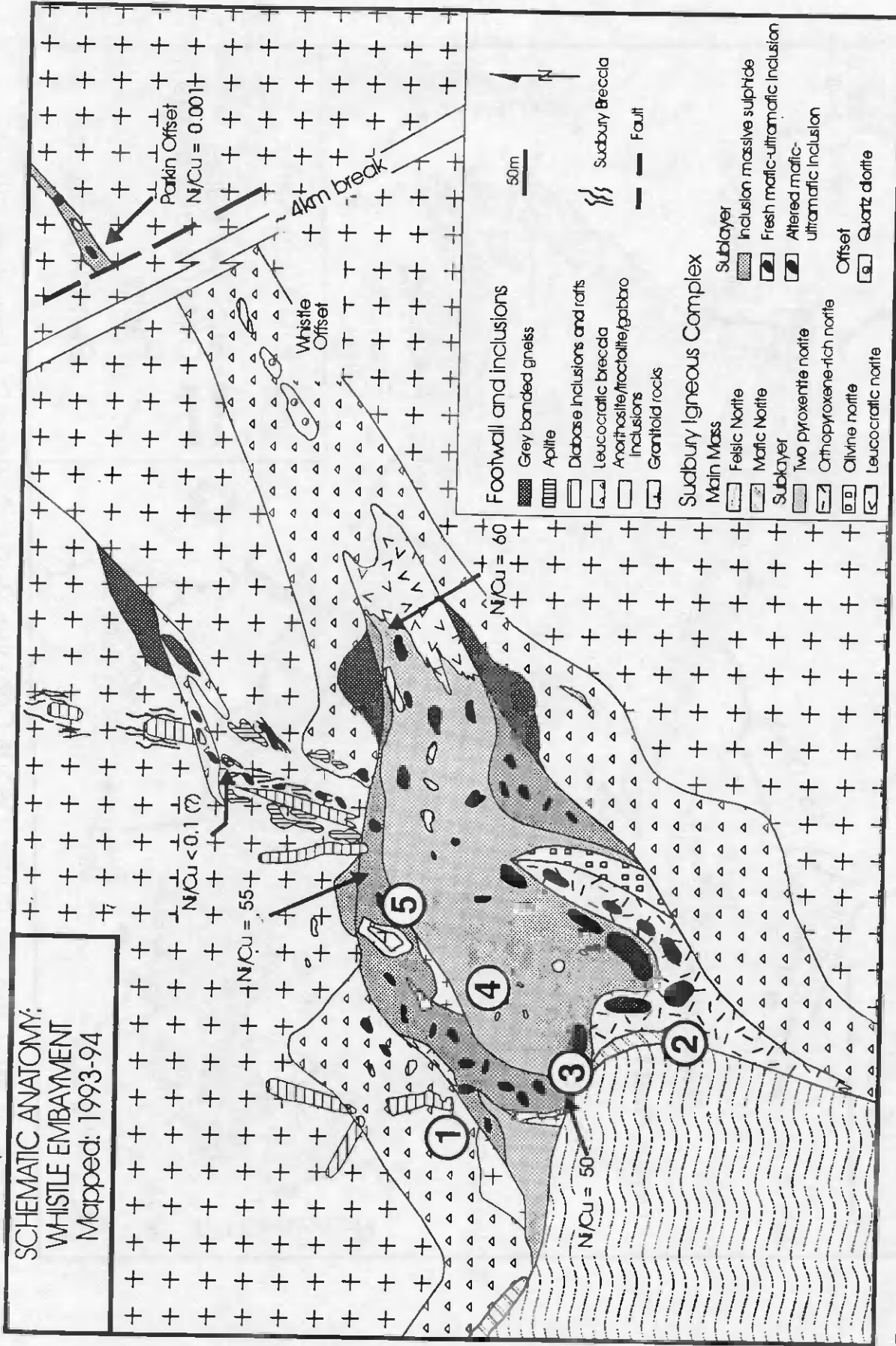


Figure 2: Geology of the Whistle pit, from Lightfoot et al. (1997). Approximate positions of stops are indicated by circled numbers.

Strathcona-Longvack area Geological Plan map

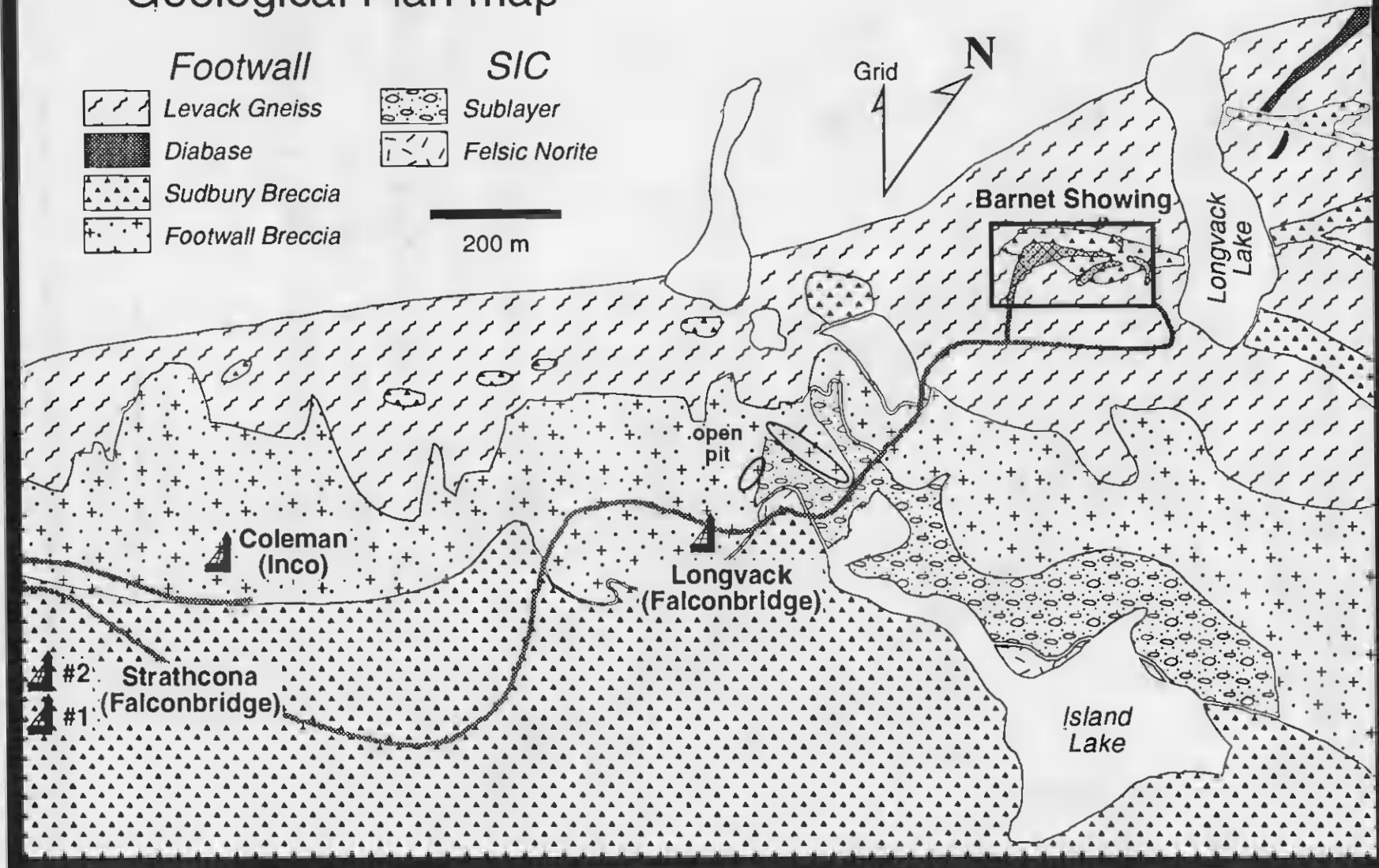


Figure 3: Strathcona to Longvack area geological map, showing mine locations and location of stripped outcrops of the Barnet showing (modified after Morrison and Sweeny, 1994).

Barnet Showing Trench Map

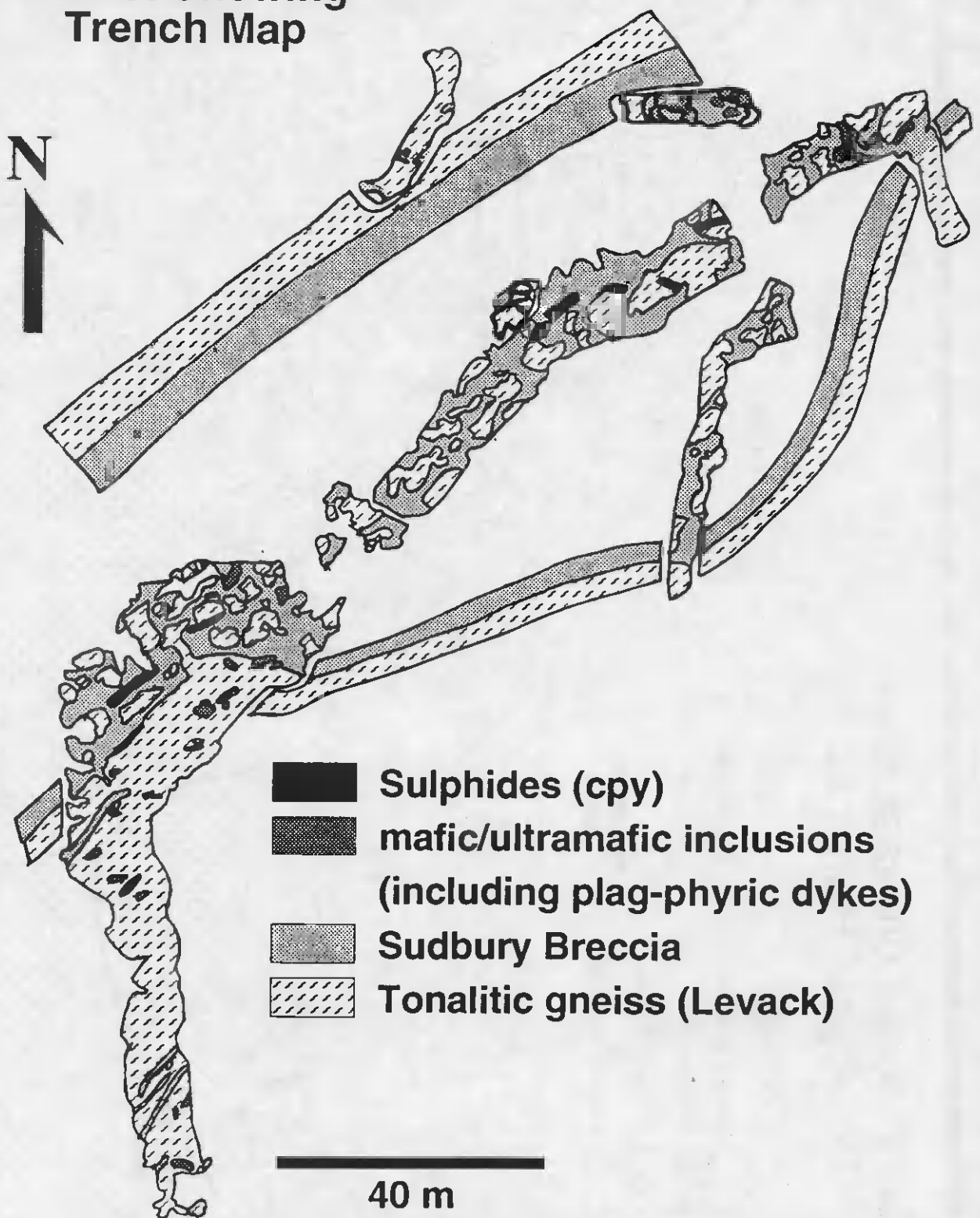


Figure 4: Outcrop map of Barnet showing, displaying mineralized Sudbury Breccia in Archean footwall, modified after Morrison and Sweeny (1994).