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ONTARIO GEOLOGICAL SURVEY

Open File Report 5686

Feldspar in the Parry Sound - Huntsville - Haliburton Area

by

C. Marmont

1988

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V.G. Milne

V.G. Milne, Director
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Foreword

The economic importance and value of industrial minerals is continually increasing and a resurgence of interest in industrial mineral commodities is taking place. This resurgence has underlined the need to increase efforts to compile and publish information on the industrial mineral deposits of Ontario.

Industrial mineral and building stone production in the Parry Sound - Huntsville - Haliburton area is currently limited to limestone, aggregate and flagstone, but in the past, small amounts of silica, feldspar, and mica have also been produced. Considerable interest is currently being shown in a number of graphite deposits. The geology of the area is complex and the greater part has not been mapped geologically. Consequently, the mineral potential of the area has not been fully assessed.

The study area has good infrastructure and is favourably located to supply raw materials to the industries of the Great Lakes Basin.

This report presents some of the results of the second year's work of a three year programme designed to evaluate the industrial mineral, rare element and building stone potential primarily in the Huntsville, Parry Sound and Nipissing districts; but one pegmatite occurrence from Haliburton County is also described. It should be of interest to the minerals industry, and to local municipalities and developers.

V.G. Milne
Director,
Ontario Geological Survey.

ACKNOWLEDGEMENTS

The author is indebted to Marcus Johnston, who conducted a large part of the fieldwork, and provided stimulating input to the programme from its inception until his departure in the fall of 1987. Bruce Heitkamp and Nick Walsworth provided very competent and companionable assistance for the summer.

Thanks are due to Dave Villard, Janet Springer, Duncan Ash and Philip Zuberec for reviewing the manuscript and providing useful comments for its improvement. Drafting was done by Marcus Johnston and Philip Zuberec. Kirk Winning and Jack Silva of Roxul Ltd. provided useful information on the rock wool manufacturing process and raw material requirements for that industry. David Frazer provided useful documentation and information on feldspar processing.

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ABSTRACT

This report presents the results of investigations conducted on feldspar in the Parry Sound area during 1987. This was the second year of a three-year programme to evaluate the industrial minerals and building stone potential of parts of the Muskoka, Parry Sound and Nipissing districts. Soda and potash feldspars are found in pegmatites, most of which are relatively small. Soda and potash feldspar find extensive applications in the glass, ceramic and filler industries. Calcium feldspar resources are contained within a number of anorthositic to gabbroic anorthositic bodies which range up to 100 square kilometres in area. Calcium feldspar could find applications in the above named industries but currently is little used. Recrystallized anorthosites appear to represent the best opportunities for locating economic bodies of clean calcium feldspar; and one pegmatite body is described which may warrant further exploration work to establish its potential as source of soda and potash feldspar.

The area has good infrastructure and is well located to service the industrial complexes of the Great Lakes Basin.

SUMMARY

This report describes the results of the second year's work on feldspar (anorthosite and pegmatite) in the Districts of Parry Sound, Muskoka and Nipissing, and one pegmatite occurrence in Haliburton County. This forms a part of a three year progamme to evaluate the industrial minerals and building stone potential of the said area.

Pegmatites are sources of soda and potash feldspar which find extensive use in the glass, ceramics and filler industries. Anorthosites consist largely of calcium feldspar which currently has limited industrial uses, although its composition makes it a potential raw material in a wide range of industrial applications. Its market possibilities have not been fully explored.

Work performed during 1987 concentrated on anorthosites, mainly the Whitestone and Moon River bodies. These were found to differ in significant ways: the Whitestone is structurally less deformed than is the Moon River Anorthosite. As a consequence the feldspars of the Moon River Anorthosite are more completely recrystallised than those of the Whitestone, are whiter, and contain only minor amounts of silicate and oxide inclusions. These factors will probably result in more effective beneficiation and better recovery of feldspar from the Moon

River Anorthosite. In the light of these findings, a review of the petrography of the Arnstein Anorthosite was undertaken, and revealed that its feldspars are also relatively free from inclusions. Further fieldwork is planned to establish the extent and distribution of clean anorthosites in the Arnstein and Moon River bodies, and in other anorthosites in the region not yet investigated. Further research on the processing and industrial applications of high calcium and aluminium feldspar is planned. This will be an important step in making possible the future development of anorthosites.

Only four pegmatites were visited during 1987. All have been tested or exploited early in the century as sources of feldspar, but operations ceased because the presence of graphic intergrowths of quartz and feldspar prevented their separation by hand cobbing methods. Modern flotation methods have overcome this problem, and as a result, some of the past producing mines may yet contain potentially economic reserves of feldspar and quartz. Some pegmatites also contain rare earth elements in allanite, cyrtolite and uranium and thorium minerals. Of the four prospects visited during 1987, only the Frazer prospect in Glamorgan Township appears to be of a size which justifies further exploration work. Work planned for the 1988 field season involves visiting the larger known pegmatite occurrences to assess their feldspar, silica and rare element potential.

CONCLUSIONS

Potential sources of feldspar in the Parry Sound - Huntsville-Haliburton area include anorthosites and pegmatites. Anorthosites present potentially very large resources of calcic feldspar, whereas the pegmatites, which are potential sources of soda and potash feldspar are of small to modest size. The market for calcic feldspar is rather limited at the present time: in Norway some anorthosite is used as a filler and mild abrasive; whereas the glass and ceramics industries provide a major market for soda and potash feldspar.

Using 2% iron as the upper limit for potentially exploitable anorthosite, prospective areas were identified in the Moon River and Whitestone anorthosite - gabbroic anorthosite bodies. These areas contain fairly clean feldspathic anorthosite, with less than 10% non-feldspathic minerals, mainly pyroxene, hornblende and biotite.

An important difference between the Whitestone and Moon River anorthosites is the degree of recrystallization which has occurred during metamorphism. The long and narrow Moon River Anorthosite has an almost pervasive mineral banding, probably produced by shearing and mineral segregation, whereas only the southern tail and marginal parts of the Whitestone Anorthosite

are pervasively sheared: its core retains many primary igneous features, such as oikocrysts up to 30 cm in diameter, remnant plagioclase phenocrysts, and graded igneous layering.

This recrystallization has resulted in further differences which are of economic significance, and which combine to give the Moon River body natural advantages over the Whitestone Anorthosite:

1. The feldspar in the Whitestone Anorthosite is generally a pale grey colour; that in the Moon River body is white or nearly so. Whiteness is a valuable characteristic in industrial minerals.

2. The less recrystallized feldspar in the central part of the Whitestone Anorthosite is grey because it contains many silicate and iron oxide inclusions. In processing, this feature will increase the percentage of waste material, reduce feldspar recovery and impede production of a clean feldspar concentrate. Recrystallization of the Moon River Anorthosite has resulted in the expulsion of such inclusions from all but a few remnant plagioclase megacrysts, and even these contain a much lower density of inclusions than do those in the Whitestone body.

3. The fine banding of the Moon River Anorthosite results in a relatively homogeneous lithology, whereas the large oikocrysts

of the Whitestone Anorthosite produce a less predictable and patchy distribution of mafic and feldspathic minerals. Both bodies contain secondary minerals derived from feldspar. In the Whitestone Anorthosite the most important is scapolite, and in the Moon River Anorthosite sericite is common and locally abundant.

A review of thin sections collected during the previous field season from the Arnstein Anorthosite, revealed that its feldspars are also fairly clean: the body appears to have undergone a greater degree of recrystallization than the Whitestone Anorthosite. Areas of anorthosite with a low colour index do occur within the Arnstein Anorthosite, but their extent and distribution is not known. Hornblende is the main accessory mineral; scapolite is a common alteration product of the plagioclase, but in places it has in turn been replaced by calcite.

While mineral dressing tests will be required to determine how successfully a plagioclase feldspar concentrate can be produced from these anorthosites, initial field and petrographic evidence suggests that the more strongly recrystallized bodies may well be able to supply large tonnages of clean, bright calcium feldspar.

Four pegmatite prospects were visited during 1987, and of these, the Frazer prospect in Glamorgan Township appears large enough to warrant further exploration. This body requires stripping and drilling to evaluate properly its size and grade, but it appears to have the potential to contain several million tonnes of "ore" grading as much as 80% feldspar, with potash spar exceeding soda spar. Silica and rare earth elements may provide marketable by-products.

Early attempts to exploit this and many other pegmatites ceased because the quartz and feldspars were not amenable to hand cobbing. With modern flotation techniques separation of feldspar and quartz is readily achieved.

RECOMMENDATIONS

Silicate and iron oxide inclusions in the feldspars of the Whitestone Anorthosite down grade its economic potential, although metallurgical tests would be required to determine whether acceptable recoveries of feldspar are possible. It has the advantage of favourable topography and exposure.

Further field work is warranted in the Moon River and Arnstein Anorthosites to establish the extent and distribution of the cleanest anorthosites. A number of other pale grey to white-

coloured anorthositic bodies in the Parry Sound - Huntsville-Haliburton area have not been investigated to date. These should be field checked, and their chemical and petrographic characteristics determined.

Beneficiation tests of the cleanest material from sizeable occurrences should be considered.

Further research should be conducted into the potential applications of high calcium feldspar.

The larger known pegmatite occurrences should be visited with a view to establishing whether significant reserves of feldspar or silica remain to be exploited.

FELDSPAR IN THE PARRY SOUND - HUNTSVILLE - HALIBURTON AREA.

C. Marmont. (1).

INTRODUCTION

This report describes some of the results of the second year's work in a three year programme to evaluate the industrial minerals potential of the Huntsville-Parry Sound area. The programme is funded under the terms of the Canada-Ontario Mineral Development Agreement (COMDA). This report discusses work performed on anorthositic rocks (calcic plagioclase/lime feldspar), and pegmatites (potash feldspar and soda spar). Separate reports describe work conducted on limestone (crystalline marble), and building stone (gneiss). The results of the 1986 programme have been presented by Marmont and Johnston (1987).

Feldspars have long been used in the ceramics and glass industries. The alumina content of feldspar increases the resistance of glass to impact, bending and thermal shock; reduces its tendency to devitrify and increases its chemical durability. The alkalies act as a flux in glass making. Soda

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spar finds most application in glass making, while potash spar is preferred in the ceramics industry. Feldspar is also used as a filler in plastics, paint and rubber, and is used as a mild abrasive.

In North America, feldspar is mainly produced from aplite, alaskite and pegmatite deposits in the USA, phonolite and rhyolite are used in West Germany, beach sands and alluvial deposits in Spain, and weathered granite in the United Kingdom. The major competitor for feldspar is nepheline syenite: a rock composed of soda and potash feldspar and nepheline. Indusmin Ltd's Blue Mountain deposit in Methuen Township, Ontario is the largest producer of this product in the non-communist world.

In the Huntsville - Parry Sound area, the most likely sources of feldspar are the large anorthositic bodies located to the north and south of the town of Parry Sound, and northeast of Haliburton (Figure 1). These rocks have a very high alumina content (25-30%), high calcium (10-12%), moderate soda (4%) and very low potash content (>1%). They are not currently exploited as sources of high calcium (lime) feldspar. Here and elsewhere in the world, anorthosites have been considered as sources of alumina, but they are unlikely to be able to compete with bauxites in the foreseeable future. Anorthosite has a chemical composition suitable for use in mineral wool, and this is discussed in a later section of the report. Apart from the glass and ceramic industries, in which anorthosite would have difficulty competing with established producers, anorthosite may find applications where the high calcium rather than soda and potash contents are of benefit, and where a higher alumina content is preferred. (A separate COMDA programme has recently commenced which will evaluate the potential applications of high alumina rocks. This programme is being conducted by the Industrial Minerals Section, Mineral Development and Lands Branch, MNDM, Toronto.)

The objective of the 1987 field programme was to identify the distribution of the "cleanest" (most feldspathic) areas within the major anorthosite-gabbroic anorthosite bodies, such that future exploration efforts might be conducted most effectively.

The Huntsville - Parry Sound area also contains numerous pegmatites, several of which have been exploited in the past for potash feldspar, soda spar, mica and silica, but none has sustained more than a few thousand tonnes of production. These bodies also contain minor amounts of uranium and rare earth element - bearing minerals which have been explored in the past. Further work on this aspect will be conducted in 1988. During the 1987 field season three pegmatite bodies were investigated; these are described in a later section of this report. No overview of pegmatite occurrences in the project area has previously been undertaken. It is the objective of the present study to gain such an overview in the hope of identifying the systematics of pegmatite distribution and mineralogy *; and identify prospective areas of silica, and possibly rare earth elements, in addition to feldspar. Outside of the main project area, a visit was made to a potash spar pegmatite at Gooderham, south of Haliburton, and this interesting prospect is also described in the text.

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* Detailed studies on pegmatites are presently being conducted by Bruce Goad, Geologist, MNDM, Bancroft, Ontario.

RESULTS OF 1987 WORK

ANORTHOSITE

The Huntsville-Parry Sound area contains four large anorthosite bodies: Arnstein, Whitestone, Parry Island, and Twelve Mile Bay; and many smaller and minor occurrences (Figure 1). The general geology of these bodies has been described by a number of workers listed at the end of this report, and whose work is summarized by Marmont and Johnston (1987). During 1987 another body, the Raganooter Lake body, was found to contain a significant proportion of anorthosite in its central part (McRoberts and Tremblay, 1987). A similar body is known in the Haliburton area, but has not been described in the published literature (S.B. Lumbers, Geologist, Royal Ontario Museum, Toronto; pers. comm. 1987; Davidson et al., 1986).

In the Huntsville-Parry Sound area the largest bodies lie within the Parry Sound Shear Zone at the base of the Parry Sound Domain, the middle of three major tectonic thrust sheets identified in the Central Gneiss Belt of Ontario (Davidson et al., 1982). They are variably deformed, and display textures ranging from relict primary to ultramylonitic.

Smaller bodies are commonly narrow (a few metres to tens of metres) and long (up to 40 km), or are stretched and disaggregated into separate pods lying along the same structural horizon. Such bodies may be seen in many ductile shear zones, including the aforementioned Parry Sound Shear Zone where they occur below the major anorthosites, and also further to the east near Magnetawan where the zone re-emerges in contact with the Algonquin Domain; in the Moon River Synform (including the Moon River and Twelve Mile Bay anorthosites); and within the Go Home and Rosseau subdomains.

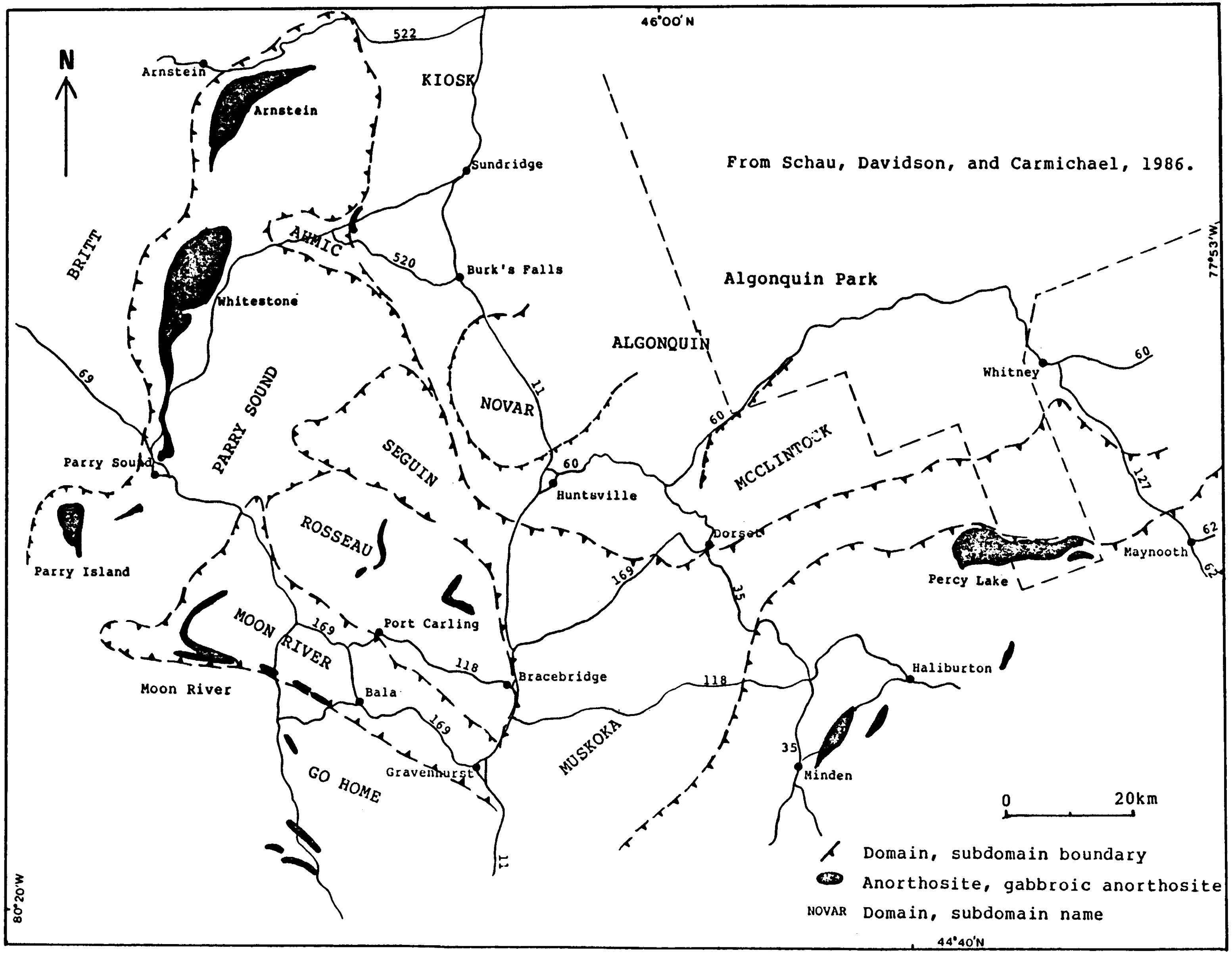
The current study has concentrated on the larger bodies, primarily the Whitestone Anorthosite and the Moon River Anorthosite. The Arnstein body has not been examined in as much detail because it is not as favourably located as the Whitestone and Moon River Anorthosites (Marmont and Johnston, 1987). However, recent petrographic data reported below suggest that the Arnstein Anorthosite may represent a better source of calcium feldspar than the Whitestone Anorthosite, and accordingly, it will be reviewed during 1988; and the Raganooter body will be reconnoitred.

A brief visit was made to the Percy Lake body but only dioritic phases of the complex were seen. Both S.B. Lumbers (Geologist, Royal Ontario Museum, pers. comm., 1987) and A. Davidson (Geologist, Geological Survey of Canada, pers. comm., 1988) report that this body contains very clean anorthosite, and further work on that body is planned during 1988.

Permission to visit the Parry Island Anorthosite (Satterly, 1942), located on the Parry Island Indian Reserve, was not granted.

As is the case with many industrial minerals, anorthosite is a potential resource with a low unit value. This factor has been taken into consideration in this study, so that only reasonably accessible areas, preferably with positive topography to reduce mining costs, have been investigated.

The following sections of the report describe the geology, mineralogy and chemistry of the Whitestone and Moon River Anorthosites, and the main features of the Arnstein body are reviewed.



From Schau, Davidson, and Carmichael, 1986.

Figure 1. Location of Major Anorthosite Bodies in the Parry Sound-Huntsville-Haliburton Area.

WHITESTONE ANORTHOSITE

The Whitestone Anorthosite was the main feldspar body studied during 1987. It was given priority because of its size and easy access; because good geological information was available (Lacy, 1960; Kretschmar, 1968; Mason, 1969), and because reasonably extensive areas of clean anorthositic material had been observed during the 1986 field season (Marmont and Johnston, 1987).

For most industrial applications, the iron content is one of the most critical concerns. Consequently the material having the greatest economic potential is that with the lowest iron content. A clean plagioclase product should also be obtenable without the processing of an undue amount of waste minerals. The most desirable material then, would be an anorthosite containing the lowest possible amount of mafic minerals.

Mason (1969) indicated that the cleanest anorthosite occurs near the centre of the body, and that it becomes progressively more mafic towards the margins, but he subdivided the body on a textural rather than compositional basis. Consequently, as the body has an area of some 100 sq km, some means of selecting the most prospective areas was necessary. This was attempted by using the 300 modal estimates included in Mason's (1969) thesis, and converting these modes to estimates of the total

Photo 1. View of Blue Lake area, Whitestone Anorthosite. Note high relief and good exposure.

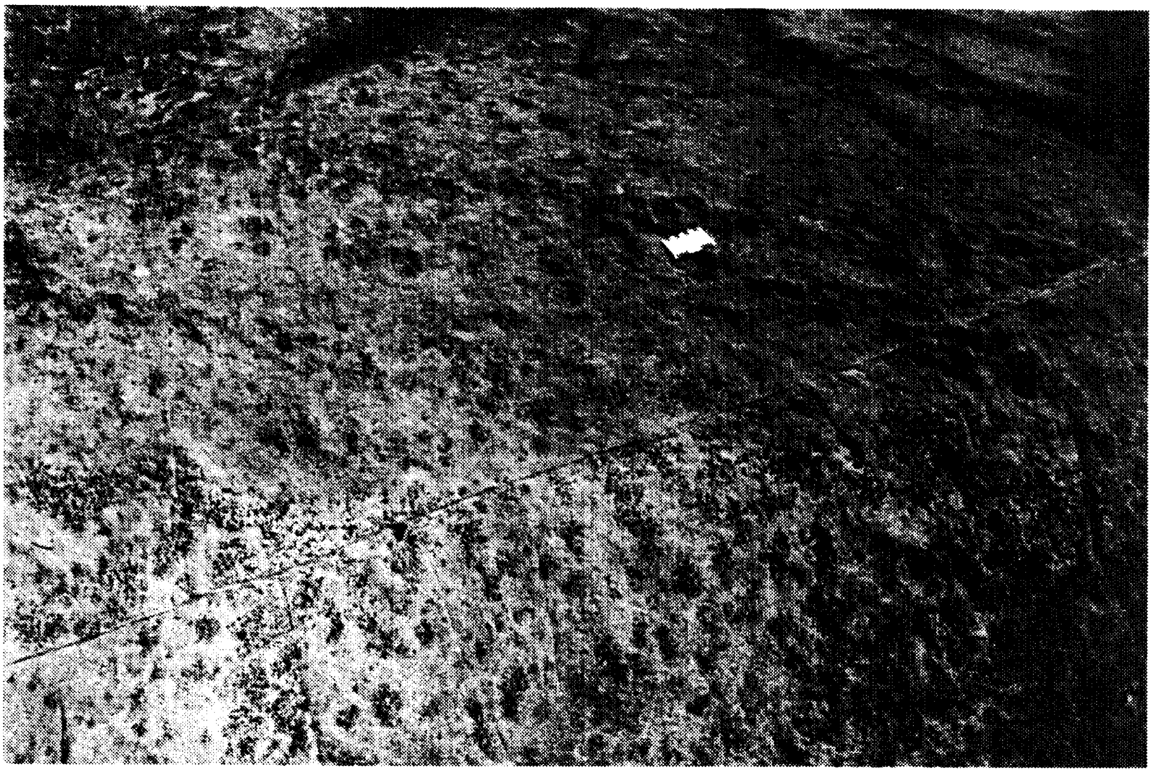


Photo 2. Typical outcrop of oikocrystic anorthosite and gabbroic anorthosite, Highrock Lake, Whitestone Anorthosite.

iron content of the anorthosite. The method employed in this conversion is explained in Appendix 1, and the results shown on Map No. 2 accompanying this report. Map No. 2 indicates two broad zones of low iron content (<1%) which trend at 020 degrees on either side of Mason's Green Feldspar Facies (Map No. 1). Most of the work performed during the 1987 field season focussed on the eastern zone in the vicinity of Blue Lake because of better accessibility and outcrop exposure than the western area. This area is outlined on Map No. 2.

COLOUR INDEX AND IRON CONTENT OF ANORTHOSITE.

Having thus identified the general areas of low iron content, a means was devised of estimating the iron content of the anorthosite in the field. The data of Mason (1969) which was manipulated as explained in Appendix 1, indicates that in the cleanest parts of the anorthosite, consisting essentially of plagioclase and clinopyroxene, a colour index of 9 represents an iron content of approximately 2%. These are taken as the upper limits for potentially economic material (see page 70 et seq.).

Detailed surveys in the Blue Lake area took note of the textural, mineralogical and compositional variations of the anorthosite and gabbroic anorthosites. However, it was soon

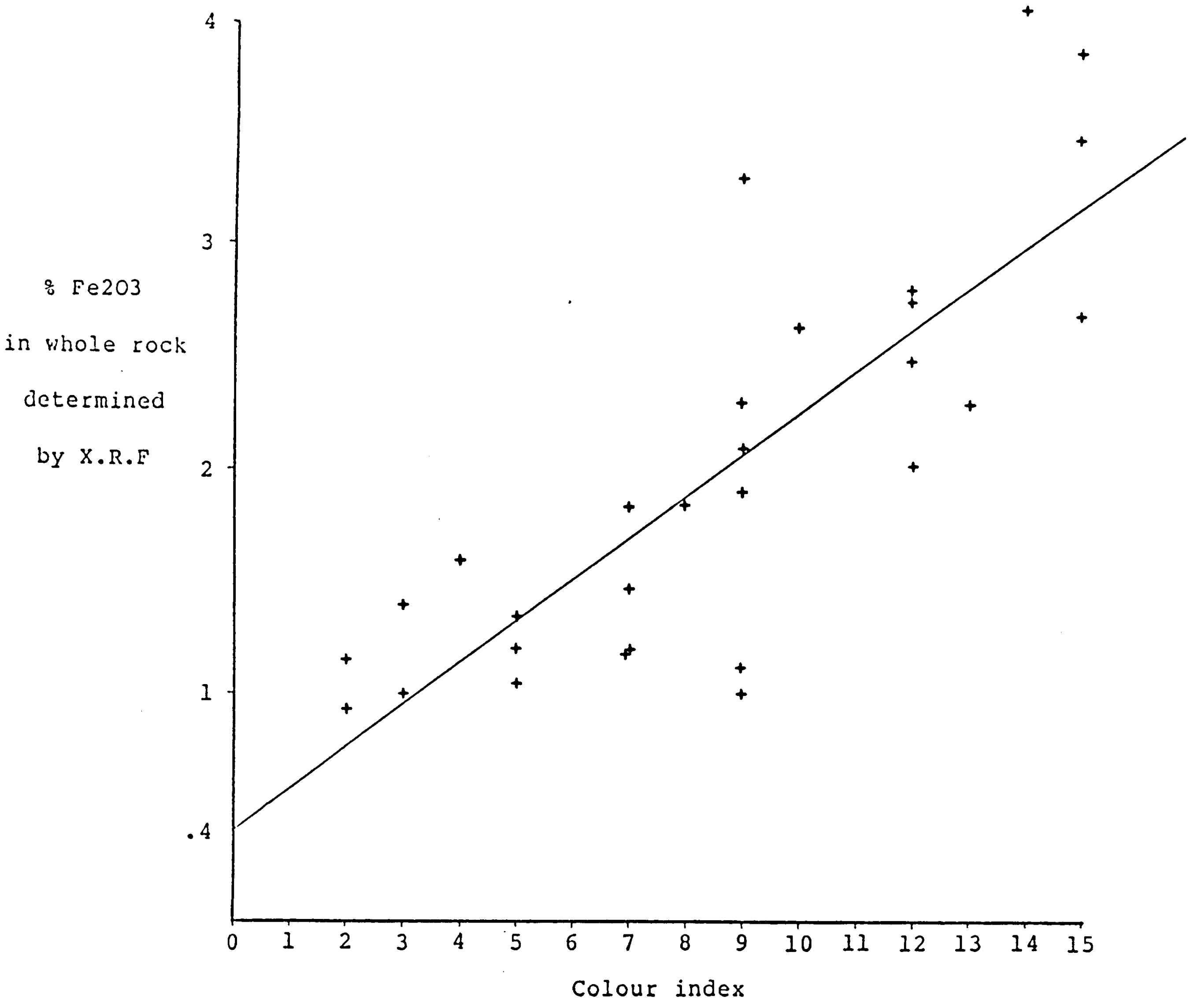


FIGURE 2 Correlation of Colour Index and Iron Content, Blue Lake Area, Whitestone Anorthosite.

found that visual comparisons of rocks with colour charts was too imprecise, and not consistent between different workers. Therefore colour indices were measured as a series of point counts on representative exposures of each outcrop. This was facilitated by the colour contrast between pale grey plagioclase and the mafic minerals. The presence of garnet and magnetite was noted, but not factored into the colour index, since they occur as much finer grains than the major minerals, and are therefore difficult to quantify when counting. Scapolite is included with plagioclase.

Figure 2 shows the correlation between colour index measured in the field and analytical values. The regression line intersects the "y" axis at a value of 0.4% Fe_2O_3. This means that a "pure" anorthosite consisting of 100% plagioclase would still contain 0.4% Fe_2O_3. While this method is obviously imprecise, it should be noted that the plagioclase does contain inclusions of iron bearing silicates and oxides: this is discussed in the following sections.

Some 30 rock samples were collected in order to verify field observations. Where possible composite samples were collected in an attempt to obtain samples representative of the whole outcrop. This is often difficult, and is somewhat subjective given the "leopard spot" nature of much of the rock. Analytical results are presented in Appendix 4, and summarized in Table 3. The iron values of these samples are also shown on Map No. 3.

Map No. 3 shows the outlines of outcrops visited in the Blue Lake area, lithogeochemical sample locations, and total iron contents estimated from measured colour indices. While it is difficult to contour these results, it can be seen that iron contents may vary by a factor of two over fairly small areas. However, several areas of a few hectares exist which appear to have consistently low levels of iron. The largest is about 400 metres west of Blue Lake, and is a well exposed area. Other reasonably large areas having low colour indices are immediately east of Blue Lake, 800 metres north-northwest of Blue Lake, and in the extreme northeast corner of Map No. 3.

MINERALOGY

A number of samples were collected for petrographic examination. The mineralogy of the Whitestone Anorthosite is described at some length in order to provide a basis for comparison with other anorthosites. As will be seen later, mineralogical differences between the various bodies may have a significant bearing upon mineral processing and the recovery of calcium feldspar concentrates, and hence upon the relative economic potential of each body.

The mineralogy of the Whitestone Anorthosite is fairly simple: in order of decreasing abundance the minerals are plagioclase, clinopyroxene, hornblende, scapolite, garnet, epidote, magnetite-ilmenite, orthopyroxene, titanite, biotite, muscovite and calcite. This order of abundance is approximate, and varies more or less systematically within the body as described by Mason (1969).

In brief, the primary minerals are plagioclase, clinopyroxene, orthopyroxene and magnetite-ilmenite. Garnet may also be a primary phase in the least altered and deformed areas in the central parts of the body. The distribution of the other minerals is controlled by deformation and metamorphism, both in the marginal and internal parts of the body.

The following section describes the petrographic characteristics of the rocks in the Blue Lake area surveyed in detail during 1987.

PLAGIOCLASE

Most of the thin sections examined from the Blue Lake area can be classified as anorthosites, that is they contain less than 10 modal percent of mafic minerals. The balance of 90% consists largely of plagioclase, with variable amounts of scapolite.

The plagioclase crystals are usually 2.0 - 3.0 mm in size and are equidimensional. However, laths up to 15.0 mm were observed in some sections, and crystals up to eight centimetres long have been observed in the field. The plagioclase is mainly labradorite, ranging up to about An66.

Inclusions within the plagioclase are the rule rather than the exception. Silicate minerals are abundant, but opaque minerals are common also; most are euhedral. Table 1 lists the minerals identified as inclusions in the plagioclase.

Because of the small size of the inclusions, definitive optical identification is often difficult. Epidote was identified in a slide which contained a complete range of grain sizes from inclusions to large discrete crystals. Amphiboles and pyroxenes may not be distinguishable in some sections. Commonly, the mineral phases found in inclusions are also represented as discrete, readily identifiable grains elsewhere in the same section.

Within a given thin section, the distribution of inclusions is not uniform. One plagioclase crystal may contain inclusions of magnetite, while an adjacent grain contains inclusions of pyroxene. In some plagioclase crystals the inclusions are

TABLE 1. Mineral Inclusions Hosted by Plagioclase, Blue Lake Area, Whitestone Anorthosite.

Species	Habit	Size Range (microns)
Magnetite	Opaque black needles and cubic equidimensional specks	dusting 1-2 rods 1 x 80 cubes 5-20
Ilmenite	Purplish semi-opaque rectangular plates	10 - 50
Garnet	Pink isotropic euhedral cubes and dodecahedra. Usually sparsely and randomly dispersed, sometimes weakly describing trains parallel or sub-parallel to the albite twin plane.	<0 - >300 Av ~ 40
Clino-pyroxene	Pale green, barely pleochroic, stumpy to slightly elongate prisms.	2 - 200 mode 30 - 50
Hornblende	Medium green pleochroic prismatic crystals	<20 - >300
Epidote	Colourless to v. pale yellow-green	<40 - >300
Amphibole? Sillimanite?	Bluish pleochroic, long needles	<1 x up to 300
K-Feldspar? (anti-perthite)	Colourless rectangular to subhedral exsolutions crudely aligned parallel to albite twin planes.	20 - 60
Cavities?	Colourless rhombs, with strain haloes in enclosing plagioclase, randomly distributed through large plagioclase laths. High negative relief.	20 - 30
Titanite	Rounded, high relief, pleochroic; sparse lamellar twinning not uncommon.	30 - 300

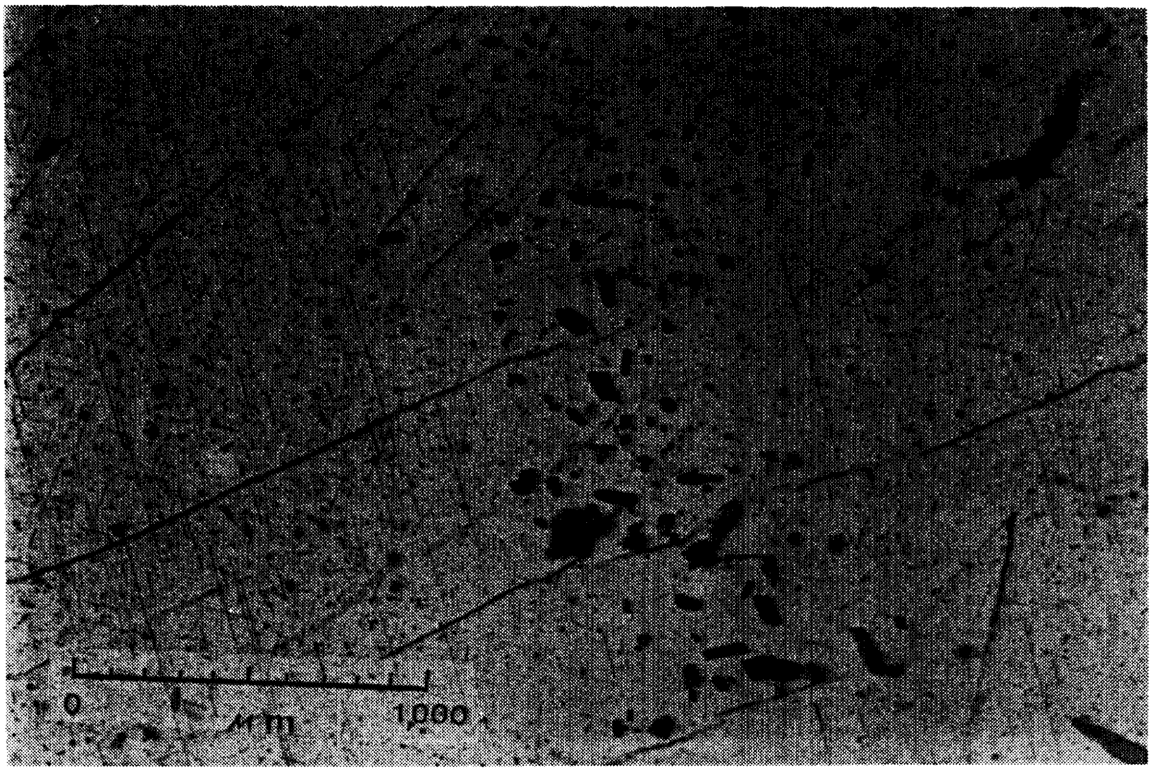


Photo 3. A single crystal of plagioclase containing an area of 10-75 m sized prismatic amphibole inclusions, surrounded by fine acicular and very fine grained silicate inclusions, Whitestone Anorthosite.

Photo 4. Inclusions of epidote in plagioclase, Whitestone Anorthosite.

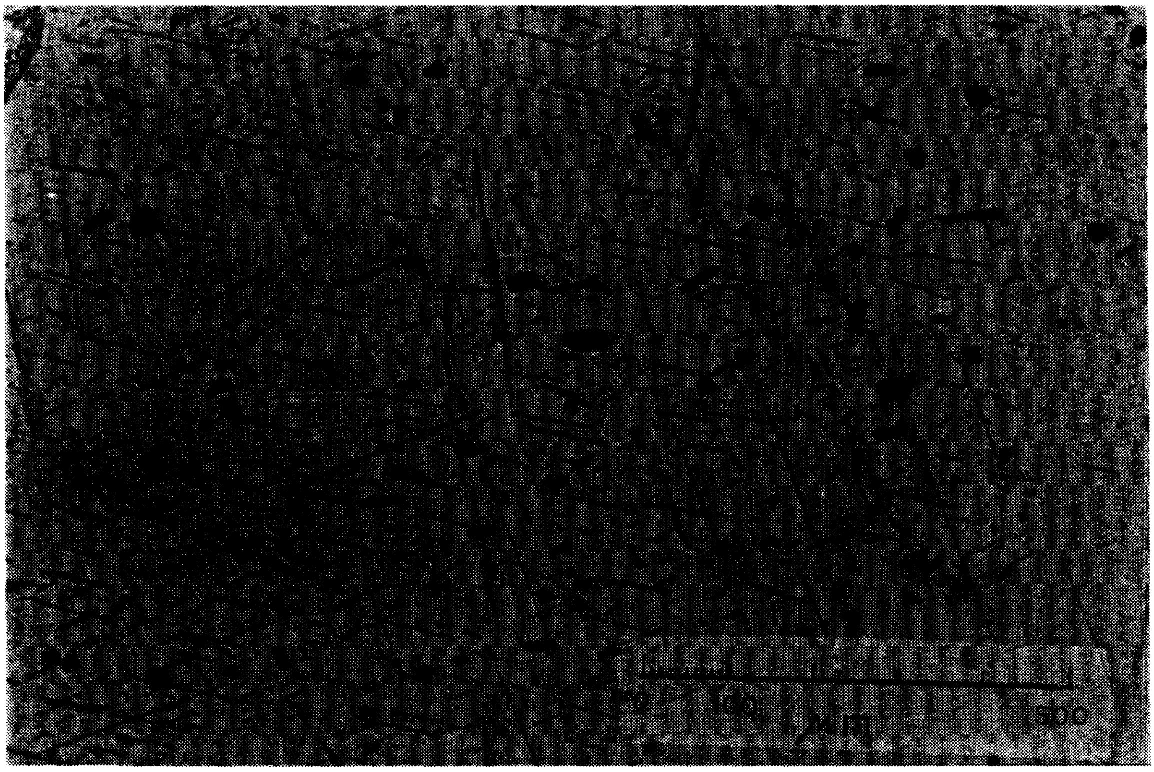


Photo 5. Acicular magnetite and platey ilmenite inclusions in plagioclase, Whitestone Anorthosite.

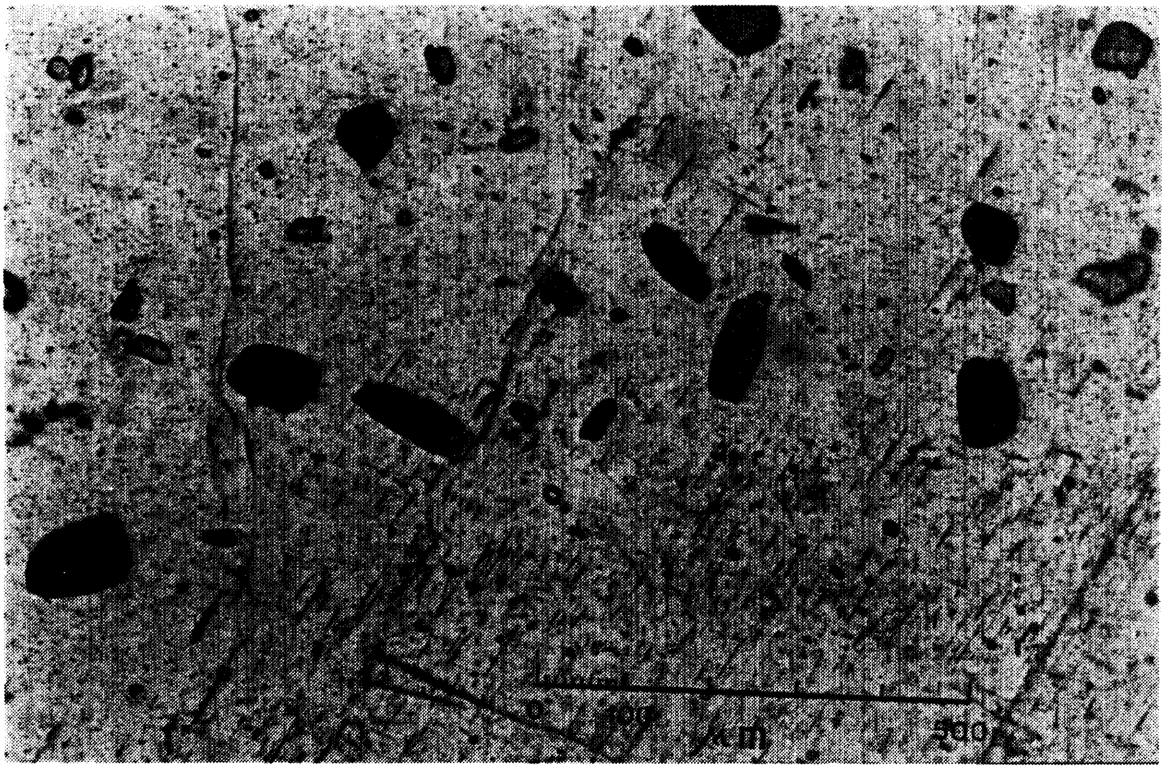


Photo 6. Train of large clinopyroxene inclusions adjacent to a mass of acicular opaque minerals, in a single plagioclase grain, Whitestone Anorthosite.

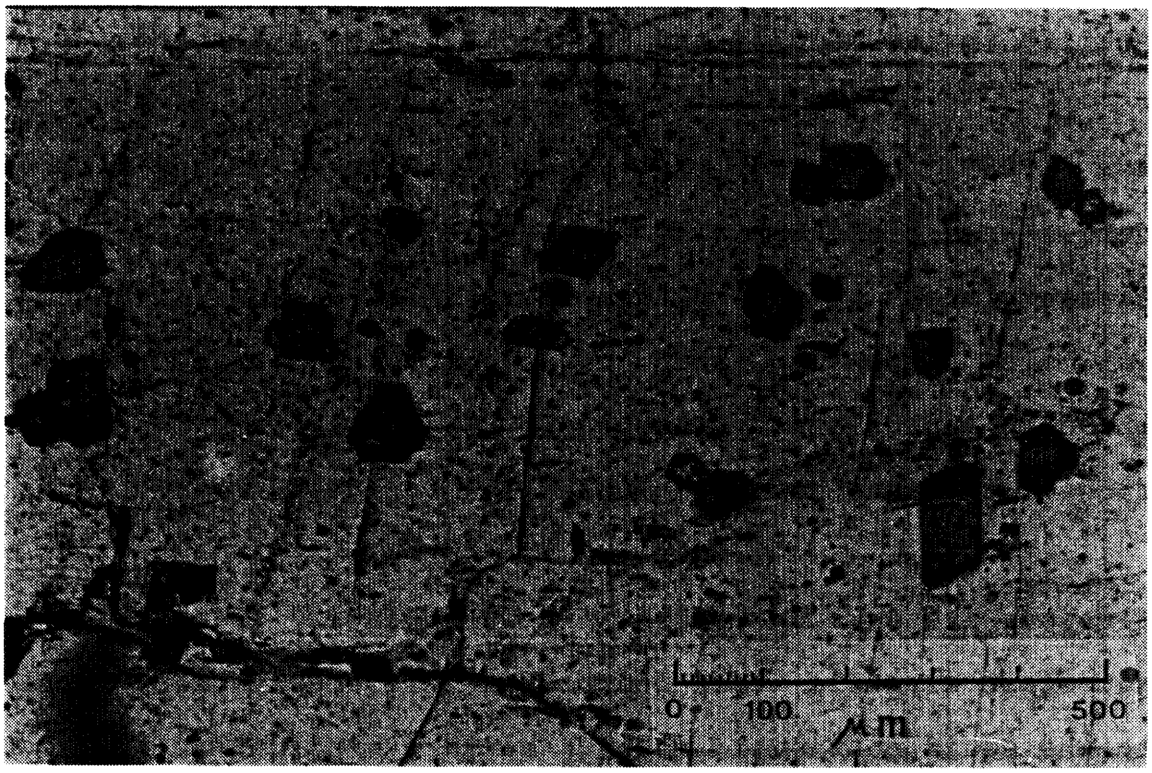


Photo 7. Inclusions of garnet in plagioclase, Whitestone Anorthosite.

segregated; for example a large plagioclase lath in sample 87MMJ-3022 contains a cluster of garnet inclusions at one end, magnetite in the middle, and amphibole at the other end.

Mason (1969) observed that rods of magnetite and silicate minerals were preferentially oriented along the (100) and (010) cleavage planes of the plagioclase; this is shown in photo 5, which also shows an area of clear plagioclase containing amphibole inclusions. Photographs 3 to 10 and 14 show the various inclusions noted in Table 1.

Inclusions are usually absent in the outer fringes of the plagioclase crystals (see photo 8). This observation, coupled with the equidimensional mosaic texture indicates that some recrystallization has occurred. Mason noted that the rims of plagioclase grains were more sodic than the cores. This might be due to recrystallization during metamorphism or it may be that the original plagioclase crystals were zoned. Whether the inclusions are the result of exsolution from the plagioclase (as suggested by Mason, 1969, for the magnetite) or are the result of material entering the more calcic core of the plagioclase structure during metamorphism is not clear. However, inclusions in plagioclase are of much lesser importance in the Arnstein and Moon River anorthosites, both of which are more severely recrystallized than is the Blue Lake area of the Whitestone Anorthosite. It is also possible that pyroxene, magnetite, and possibly garnet, are crystallites trapped in co-crystallizing plagioclase. The origin of the inclusions is beyond the scope of this report, but any interpretation must bear in mind the complex structural and metamorphic history of the anorthosite, of which Mason was not cognisant.

SCAPOLITE

Scapolite is a common alteration product of plagioclase. It ranges in habit from an almost imperceptible brownish - grey dusting along plagioclase grain boundaries, through wormy intergrowths eating into, or embayed in, the edges of grains, to discrete, equidimensional, anhedral crystals up to 1 mm in diameter, occurring between plagioclase crystals, especially at triple junctions (photos 8 and 9). Where abundant, it forms strings of crystals, which define a local structural foliation, within areas where the size of plagioclase crystals is smaller than usual, as a result of deformation. In some of the less altered anorthosites, scapolite occurs as local clusters of equant 1 mm-sized crystals.

Vermicular scapolite such as that shown in photo 10 has also been observed by Moecher (Geologist, University of Michigan, pers. comm., 1988). In other anorthosites similar textures composed of potash feldspar and bytownite have been described by Jaffe (Friends of the Grenville, Program with Abstracts, Gananoque, March, 1988); and of quartz and plagioclase (S.B. Lumbers, ibid., pers. comm., 1988).

In the field scapolite is not obvious, and large amounts may occur in what otherwise appears to be a fairly clean, pristine anorthosite. It generally displays fairly high birefringence as would be expected, indicating a composition towards the meionite (calcium-rich) end of the Na-Ca series. Locally, high third order interference colours can be seen, representing extremely calcium rich compositions. Scapolite is usually devoid of inclusions, but rarely magnetite rods can be seen oriented parallel to cleavage traces.

Photo 8. Incipient scapolite alteration between plagioclase grains. Feldspar on left has 20-30 μm inclusions of amphibole or pyroxene; the felspar on the right has oriented inclusions of a pleochroic acicular silicate mineral up to 250 μm.

Photo 9. Early vermicular scapolite alteration of plagioclase and well developed scapolite crystals.

CLINOPYROXENE

Clinopyroxene is the major primary mafic mineral of the Whitestone Anorthosite. In the field it is most conspicuous as sub-spherical ophitic clusters or oikocrysts, enclosing tabular and equant chadacrysts of plagioclase. In the "cleanest" anorthosites, clinopyroxene appears to occur as sparsely distributed sub-ophitic crystals. In thin section, however, the clinopyroxene "oikocrysts" are seen to consist of clusters of equant crystals, commonly about 1.0 mm in diameter, with different optical orientations. Ophitic textures are evident as wedge shapes and straight contacts between clusters of plagioclase and pyroxene crystals. Some clinopyroxene clusters contain a central crystal containing exsolved laths of ilmenite, surrounded by smaller crystals of clear clinopyroxene. These are probably primary and recrystallized/metamorphic pyroxenes respectively. The primary clinopyroxenes range up to 7.0 mm. The secondary pyroxenes are generally in the range of 0.5 to 2.0 mm. Hornblende is a common alteration product of clinopyroxene, and forms rims around the pyroxene, commonly in association with garnet, magnetite and titanite. Within the area surveyed in detail in 1987, hornblende alteration is relatively minor, but it increases in amount towards the margins of the body, and within local deformation zones in the central portions. An increase in the amount of hornblende is usually, but not necessarily accompanied by an increase in the amount of scapolite.

Within the orthopyroxene-bearing facies (green feldspar facies of Mason, 1969) some large, primary clinopyroxenes are cored by orthopyroxene which is weakly pleochroic, whilst they are rimmed by more strongly pleochroic secondary orthopyroxene and hornblende.

HORNBLENDE

In the Blue Lake area, hornblende is far less abundant than clinopyroxene. Hornblende occurs in greater amounts in the more mafic anorthosites and gabbroic anorthosites towards the margins of the body. Hornblende usually occurs as narrow (50-200 m) alteration rims which are in optical continuity around clinopyroxene. It is distinctly pleochroic from dark green to light greenish brown, and usually occurs as anhedral crystals. It may completely replace clinopyroxene in local shear zones, associated with the other secondary minerals: scapolite, biotite and epidote. It forms ragged crystals, commonly with feldspar inclusions, sometimes as a myrmekitic intergrowth with feldspar. In shape it ranges from wedge-shaped ophitic pseudomorphs after clinopyroxene to rudimentary hornblende outlines.

Where alteration is less severe, garnet and magnetite accompany hornblende in the rims around clinopyroxene.
In one thin section (87 MMJ-3037), hornblende and clinopyroxene coexist as discrete anhedral crystals, commonly contiguous. Weak alteration rims of hornblende occur around some clinopyroxene crystals, but most clinopyroxenes are fresh, showing no sign of alteration to hornblende, are inclusion-free, and are probably themselves recrystallized.

Hornblende also forms alteration rims around magnetite, and in this instance it is commonly brown coloured.

Hornblende inclusions are abundant in the plagioclase of anorthosites which display considerable hornblende alteration of clinopyroxene.

GARNET

Garnet occurs in all facies of the Whitestone Anorthosite, but is most abundant in the eastern marginal foliated facies (see Map No. 1).

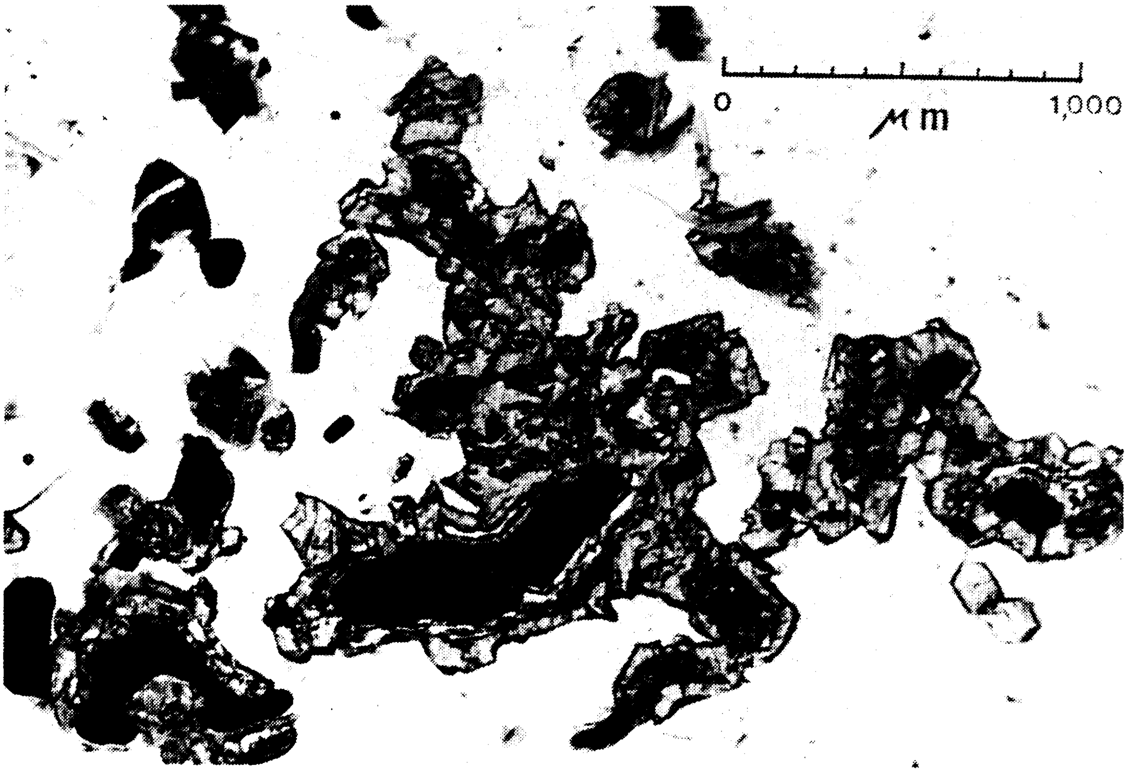


Photo 10. Garnet rims around magnetite.

In the Blue Lake area it is a minor component of the anorthosite, probably accounting for less than 0.5 modal percent overall. It commonly occurs as euhedral crystals up to 1 mm in diameter. While many are randomly disposed as inclusions throughout the plagioclase, and could be primary, the most usual locus for garnet is between hornblende (after clinopyroxene) and plagioclase. Thus, although the crystals are well formed, they are almost certainly a co-product of the reaction between clinopyroxene and plagioclase.

Garnet also forms reaction rims around magnetite grains, some of which are quite broad (up to 300 m), and may display complex intergrowths (see photo 10).

Garnet inclusions in plagioclase are euhedral cubes and dodecahedra. They are usually sparsely and randomly dispersed, sometimes weakly describing trains parallel, or sub-parallel, to the albite twin plane. They range in size from a few microns to more than 200 microns, with the mean estimated at 40 microns.

ORTHOPYROXENE

Orthopyroxene occurs mainly in the core of the Whitestone Anorthosite, in the Green Feldspar Facies (Map No. 1), although

Photo 11. Primary orthopyroxene with thin exsolution plates of pigeonite, with clinopyroxene and plagioclase.

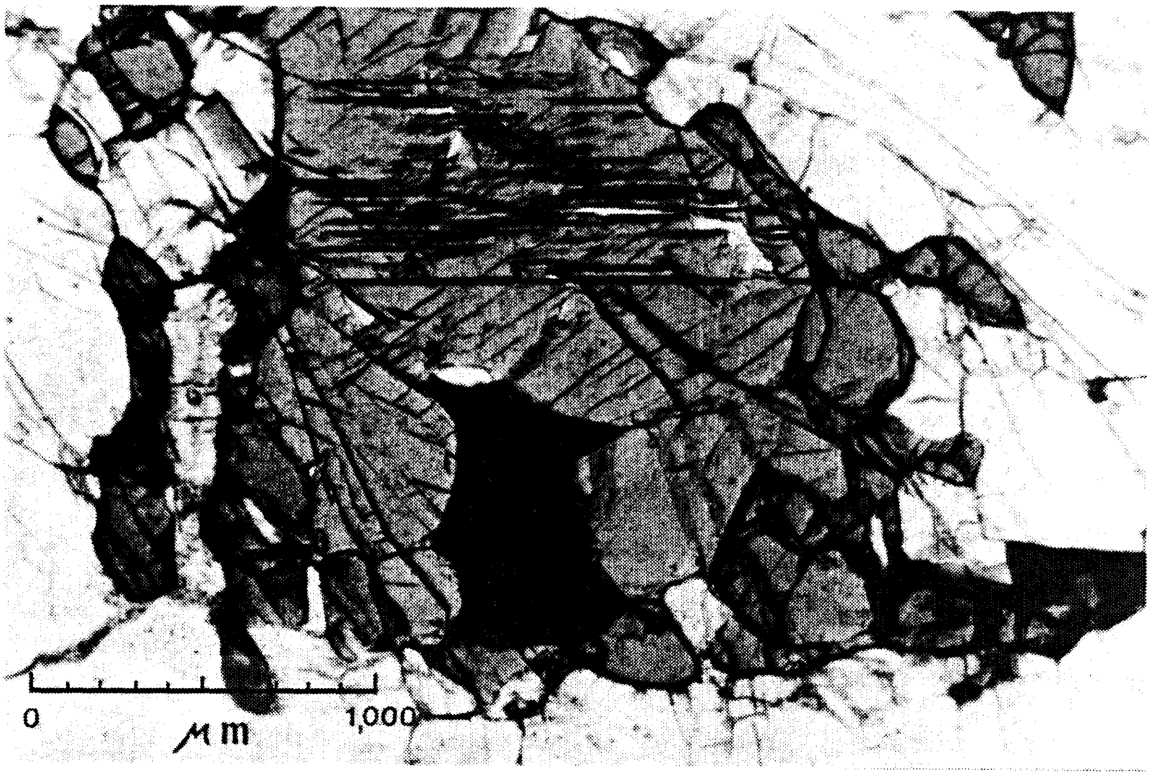


Photo 12. Secondary orthopyroxene rimming clinopyroxene, Whitestone Anorthosite.

scattered occurrences are noted elsewhere in the body (Mason, 1969, p.159). Mason believed that the orthopyroxenes were of secondary (late magmatic) origin. However, in the Blue Lake area, two distinct habits can be recognized: one probably primary, and the other secondary.

Primary orthopyroxenes occur in varying states of preservation. The least altered form equant crystals up to 3.0 mm in diameter which are weakly pleochroic from pink to green. Some display fine, discontinuous exsolution lamellae, probably of clinopyroxene. They are usually mantled by aggregates of primary clinopyroxene crystals (see photo 11). Slight alteration is visible in some as a golden brown amorphous to micaceous mineral invading cleavages, fractures and grain boundaries. When more advanced, this material may wholly replace the orthopyroxene. This alteration is highly visible in thin section and is a good indication of the presence of orthopyroxene.

Clinopyroxene is commonly altered to hornblende, but in the "Green Feldspar Facies" it is altered to hornblende + orthopyroxene +/- garnet (see photo 12). This secondary orthopyroxene is strongly pleochroic from salmon pink to pale green, and displays similar golden brown alteration products to those described for primary orthopyroxene. The secondary orthopyroxene grains are commonly of the order of 0.5 mm in diameter and are anhedral. Where primary orthopyroxene has been severely altered, there is commonly abundant secondary orthopyroxene mantling the clinopyroxene, suggesting growth of one at the expense of the other.

A few measurements taken with a Berek compensator indicate that the primary orthopyroxene has a significantly lower birefringence than the secondary orthopyroxene, indicating a higher iron content for the latter.

EPIDOTE

Mason (1969) noted that epidote is most commonly found in the foliated gabbroic anorthosite in the western part of the body (see Map No. 1). However, epidote was noted in several parts of the Blue Lake area, occurring as large porphyroblasts, as myrmekitic intergrowths with plagioclase, and as coronas rimming hornblende.

East of Snakeskin Lake, on the western side of the orthopyroxene-bearing facies, epidote occurs as conspicuous crystals up to 10 mm in length in a strongly foliated, sheared gabbroic anorthosite. It forms distinct tabular porphyroblasts, associated with titanite, in discrete folia between more mafic bands. It is also found in relatively pristine, sparsely oikocrystic anorthosite just north of Dunchurch Lake as myrmekitic blebs up to 3 mm in size. The epidote is intergrown with the adjacent plagioclase, and it includes hornblende and scapolite. Plagioclase is locally recrystallized to smaller equant grains, indicating some structural perturbation.

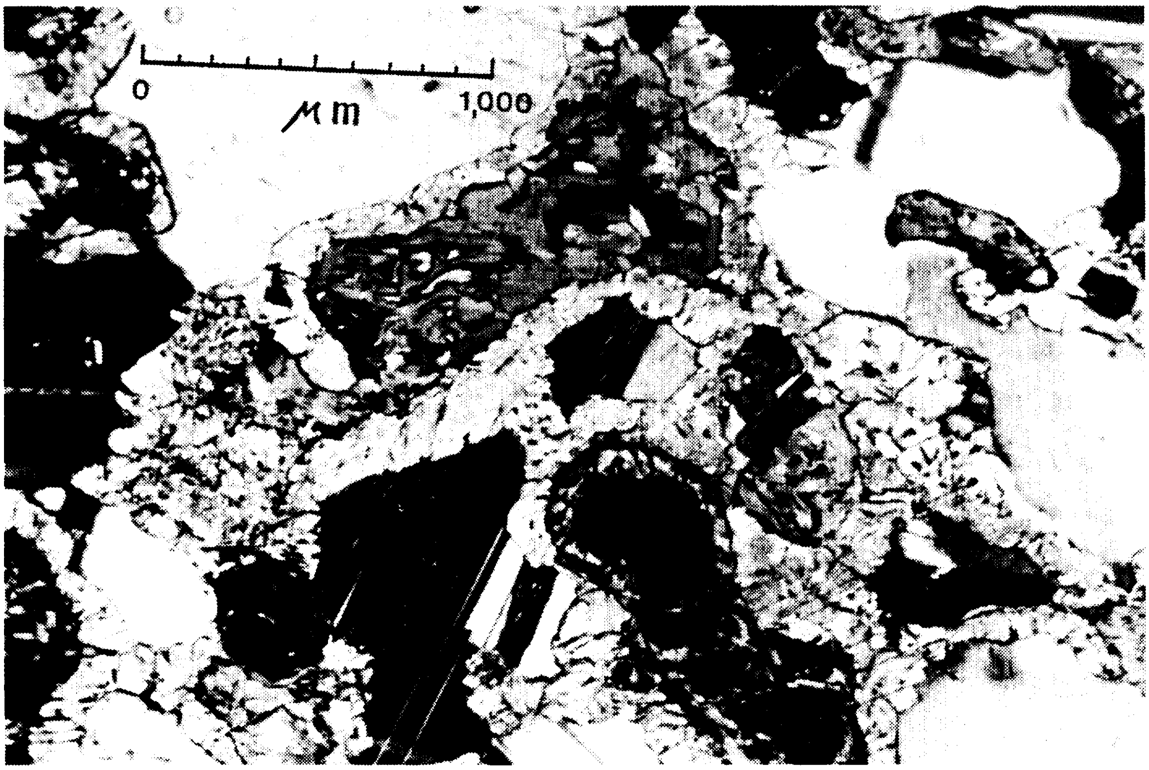


Photo 13. Corona of epidote around secondary hornblende after clinopyroxene, Whitestone Anorthosite.

In an area just northwest of Dunchurch Lake, the epidote occurs as distinct coronas rimming hornblende, within which remnant cores of pale green clinopyroxene can be discerned. The entire epidote corona is a single crystal with optical continuity (see photo 13). Mason (1969, p.184) did not analyse the epidote, but estimated its composition as being halfway between epidote and clinozoisite yielding an iron content of approximately 8%.

In some sections epidote, with or without hornblende, forms rims around opaque minerals.

It is likely that epidote can be found in zones of shearing and deformation throughout the anorthosite.

MAGNETITE

Much of Mason's (1969) discussion on the opaque minerals relates to the foliated garnetiferous facies along the eastern margin of the Whitestone Anorthosite where they are most abundant. He noted that magnetite was rarely in contact with plagioclase, but rather was rimmed by garnet or hornblende, or less commonly, scapolite. In the central part of the body around Blue Lake, however, magnetite occurs most commonly as rounded blebs about 100 - 200 m between plagioclase grains, and less commonly within them. Finer grained magnetite occurs as inclusions within plagioclase. It occurs as rods up to 80 m long along plagioclase (010) and (100) cleavage traces, and as a fine dusting of euhedral to subhedral cubes a few microns in diameter. Magnetite also occurs as rods and lamellae exsolved from un-recrystallized clinopyroxene.

Magnetite is common in the reaction rims of hornblende and garnet which surround clinopyroxene. It occurs in epidote and garnet-bearing anorthosites, and is most likely a product of alteration associated with the development of these and other secondary minerals.

Garnet may form complex intergrowths rimming magnetite (see photo 10), and brown hornblende can also be found rimming magnetite.

Kretschmar (1968) noted that a certain amount of pyrite, chalcopyrite and pyrrhotite occurred within magnetite in the marginal foliated garnetiferous facies of the Whitestone Anorthosite.

ILMENITE

Ilmenite was identified as a purplish to brownish lamellar exsolution product in some clinopyroxene, and as similarly coloured fine-grained plates within plagioclase crystals. It appears to be a minor phase in the core of the anorthosite.

Kretschmar and McNutt (1971) note that in the eastern foliated garnetiferous facies of the Whitestone Anorthosite magnetite comprises 5 to 22 modal percent of the oxide minerals, the balance being hemo-ilmenite with a composition of Ilm90 Hm10 to Ilm50 Hm50.

TITANITE

Titanite is also a minor component in the Blue Lake area in the core of the Whitestone Anorthosite. In some of the cleaner anorthosites it occurs as small (100-300 m) rounded inclusions widely dispersed through plagioclase crystals. It is usually pleochroic, and lamellar twinning is not uncommon. Minor amounts of titanite occur with hornblende in the alteration rims around clinopyroxene. It is more abundant in the tail of the Whitestone Anorthosite, and in the Arnstein body locally attains concentrations of several percent.

BIOTITE

Biotite is not restricted to severely uralitized rocks as stated by Mason (1969), although its occurrence in the less deformed core of the body is relatively minor. It occurs in rocks which also contain significant secondary mineralization. It displays a very dark brown to straw-coloured pleochroism, and has generally formed at the expense of hornblende, which it rims or selectively replaces along cleavages. It also rims some magnetite grains.

MUSCOVITE

Muscovite and amorphous sericite can be seen in a few thin sections of very "clean" anorthosite with colour indices of 1 or 2. It is the alteration product of scapolite.

CALCITE

Calcite was observed in trace amounts in a number of thin sections from the Blue Lake area. It occurs in rocks which have suffered considerable alteration, occurring in cracks between plagioclase grains with biotite, muscovite, scapolite and epidote, but when enclosed within plagioclase grains, it most commonly occurs alone. It forms irregularly - shaped grains up to 300 m across.

QUARTZ

Quartz occurs in a few slides in amounts up to 1% or 2%, notably in rocks which have undergone a degree of deformation or alteration. It occurs as irregularly shaped blebs and stringers along plagioclase grain boundaries. It is also included within plagioclase and hornblende.

APATITE

Apatite generally occurs as small subhedral to rounded grains up to 300 m across, included in plagioclase. Its abundance is variable, but it always occurs in trace amounts. Mason (1969, p.143) notes that apatite concentrations are low in the Whitestone Anorthosite, compared with anorthosites in the Adirondacks.

PYRITE

Pyrite is rarely seen in the Whitestone Anorthosite. The low sulphur values indicated in appendix 4 and table 3 may reflect trace amounts of pyrite, minor amounts of sulphides included in the iron oxide minerals (Kretschmar, 1968), and the sulphate molecule in scapolite.

OTHER INCLUSIONS

An acicular bluish pleochroic mineral is a common inclusion phase in plagioclase in the Blue Lake area. It has not been identified, but may be an amphibole or rutile, or perhaps, sillimanite (see photo 8).

Photo 14 shows rhombohedral to rectangular inclusions in plagioclase. Most are about 15 to 30 microns across but lath shaped ones reach 50 microns in length. All have a high negative relief. No gas bubbles or crystals occur within them. The plagioclase immediately surrounding the inclusions displays strain haloes. It is most likely that these inclusions are actually cavities. Guillet (1962) has noted similar features in nepheline from the nepheline syenite body at Nephton, Ontario.

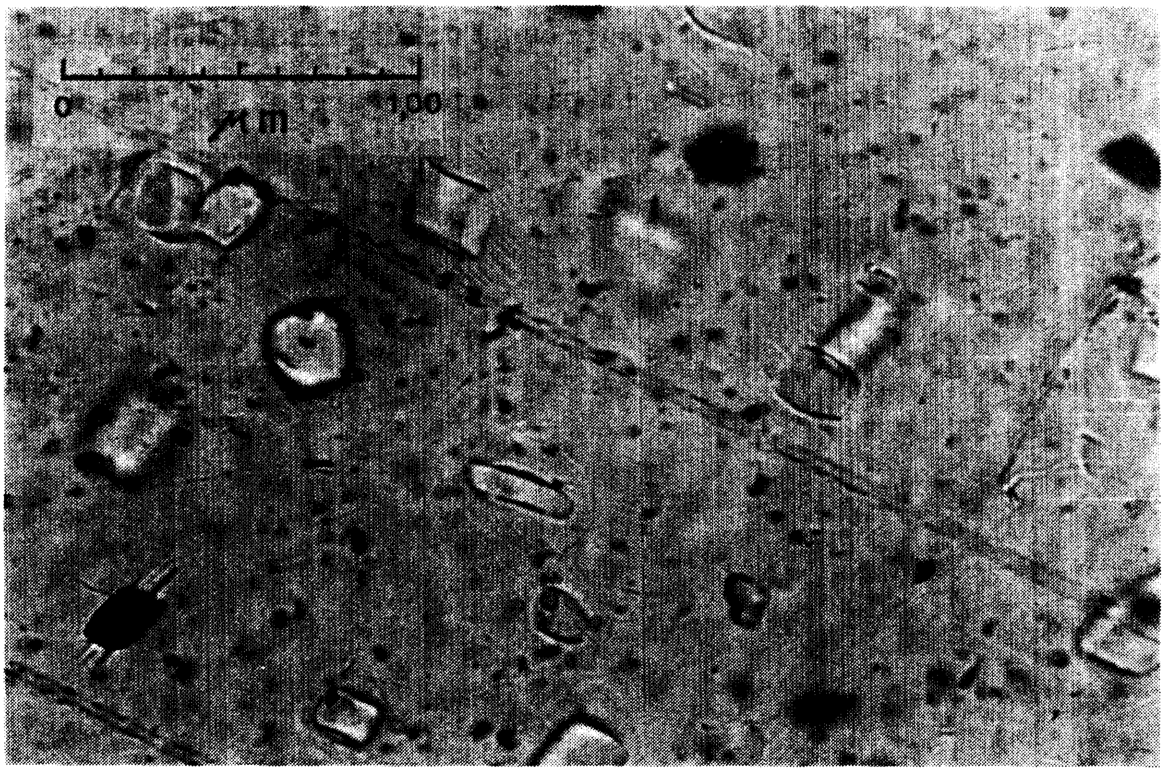


Photo 14. Negative relief inclusions in plagioclase, Whitestone Anorthosite. Appear to be cavities. Note strain haloes in surrounding plagioclase.

Table 2.

CHEMICAL ANALYSES OF MINERALS FROM THE WHITESTONE ANORTHOSITE

	Plag	Scap	Garnet	Cpx	Hbde
SiO_2	52.77	45.2	38.7	47.98	42.65
TiO_2	0.02		0.11	0.84	1.18
Al_2O_3	30.16	27.7	20.93	6.74	13.33
Fe_2O_3	0.18		1.16	3.56	4.24
FeO				8.55	11.98
MnO			0.64	0.21	0.20
MgO			5.19	9.84	10.33
CaO	11.48	17.5	8.83	21.71	11.91
Na_2O	4.05	2.6	0.04	0.77	1.28
K_2O	0.49		0.03	0.13	1.31
SrO	0.072				
Cr_2O_3	Tr			Tr	0.025
P_2O_5			0.00		
CO_2		3.2			0.02
SO_3		1.8			
H_2O			0.05		1.58
Total	99.7	98.0	100.08	100.33	100.04

All Mineral Analyses from Mason, 1969.

Plagioclase sample #133, p.130, east of Blue Lake, orthopyroxene-bearing facies.

Scapolite Calculated, Mason, p.143 (Meionite 75).

Garnet, one sample only; eastern foliated facies.

Hornblende, Mason, p.169, average of one weakly and one strongly uralitized gabbroic anorthosite from marginal facies.

CHEMISTRY

Thirty samples of anorthosite and gabbroic anorthosite were collected from the area around Blue Lake and their major element chemistry determined. The results of these analyses are shown in Appendix 4 and summarized in Table 3. Sample locations are shown on maps numbers 3 and 1.

Table 3. Typical Analyses of Anorthosite from the Parry Sound Area.

	Whitestone (Blue Lk)	Moon River	Arnstein	Parry Island+
SiO_2	51.55	52.27	50.88	53.16
Al_2O_3	27.15	27.90	27.62	31.64
Fe_2O_3	2.13	1.78	1.94	0.64
MgO	1.03	1.01	1.46	tr
CaO	12.79	11.25	11.51	10.14
Na_2O	3.89	4.36	3.93	3.52
K_2O	0.85	0.68	0.72	0.47
TiO_2	0.18	0.17	0.20	0.11
P_2O_5	0.23	0.20	0.01	
MnO	0.03	0.03	0.01	
CO_2 *	0.32		0.40	
S *	0.03		0.05	
LOI	0.28	0.43	1.1	
No. of samples:	30	11	11	

* CO_2, S values for Whitestone Anorthosite are average of 20 samples collected in 1986, and include samples collected outside the Blue Lake area, see appendix 4.

+ Satterly, 1942; one analysis.

Arnstein values taken from Appendix 6, having excluded gabbroic samples.

Whitestone and Twelve Mile Bay analyses presented in Appendices 4 and 5 respectively.

MOON RIVER ANORTHOSITE

INTRODUCTION

The Moon River Anorthosite is part of a long narrow anorthosite to gabbroic anorthosite body which is located between 20 and 30 km south of the town of Parry Sound. It outcrops over a distance of some 40 km. It lies within the Moon River subdomain of the Muskoka Domain (Davidson et al, 1982), and is thus part of the tectonic layer which overlies the Parry Sound Domain which is host to the Whitestone and other large anorthositic bodies in the area. Its full extent is shown on the Preliminary Geological Map, P.2954, of the Moon River Area by Van Berkel and Schwerdtner, 1986, where it can be seen to follow the outline of the Moon River Synform (figure 1). The body as a whole has previously received only cursory attention in the literature, having been described by Walker (1905), Waddington (1973), Schwerdtner and Waddington (1978), Davidson et al. (1982) and Van Kranendonk (1984).

For most of its length the anorthosite is only a few tens of metres thick, but near the head of Twelve Mile Bay, the outcrop area of the body broadens into a lenticular form up to 2 km wide and 6 km long, at a point where a branch from the synformal unit trends westward along Twelve Mile Bay.

It is possible that, rather than being a branch of the Moon River Anorthosite, the Twelve Mile Bay Anorthosite is a separate body at a lower structural level than the Moon River Anorthosite (Van Kranendonk, Queen's University, Kingston, pers. comm., 1988).

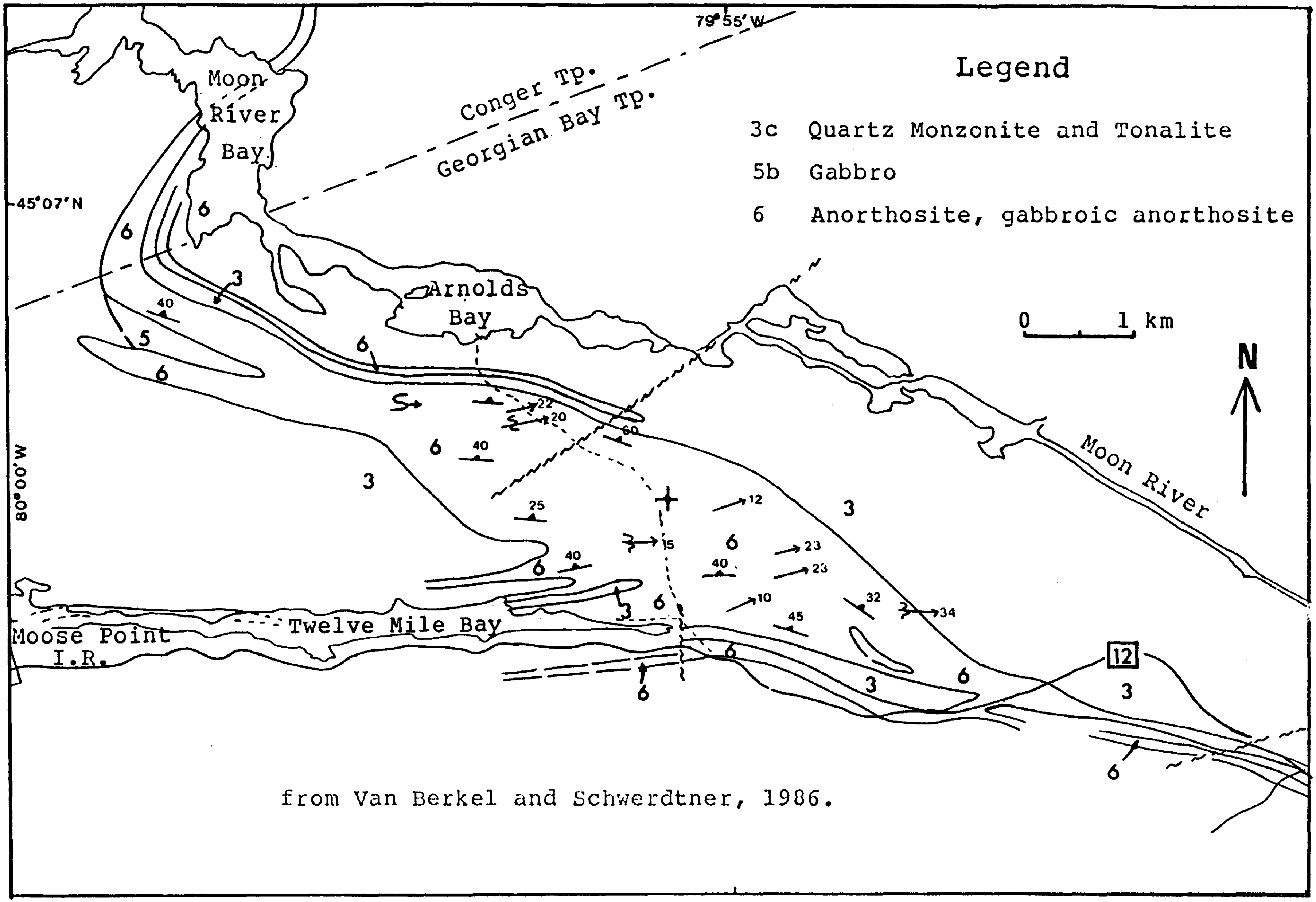
During the summer of 1987, this part of the body was reconnoitred in order to evaluate the purity of the anorthosite.

A bush road to the Arnolds Bay Marina branches off Muskoka Road 12, some 12 km west of Highway 69. This road provides a good cross section through the body (figure 3).

GENERAL GEOLOGY

Relief in the area is low, but numerous small rocky hills up to 20 metres high provide moderate to good outcrop exposure. However, substantial parts of this broad part of the Moon River Anorthosite are covered by swamp. Figure 3 shows the outline and geology of this part of the Moon River Anorthosite.

The body is structurally overlain and underlain by quartz monzonitic and tonalitic gneisses. At the southern contact on the bush road, immediately north of the creek which feeds into Twelve Mile Bay, a pink mylonite with potash feldspar



from Van Berkel and Schwerdtner, 1986.

Figure 3. Geology of the Moon River Anorthosite.

porphyroclasts can be seen, indicating a shear zone at the southern edge of the main body.

In contrast to the Whitestone Anorthosite, the Moon River Anorthosite is pervasively layered. For the greater part, this layering consists of granoblastic white anorthosite layers from 1-25 cm thick with a colour index of less than five, alternating with more mafic layers from 1-10 cm thick, with colour indices of 5-20. The ratio of light to dark bands ranges up to 10, and is commonly of the order of 2-3, yielding a bulk composition just within the field of anorthosite. Less commonly, the mafic layers are gabbroic, and constitute from 8-15% of the bulk of the rock (photo 15). Some mafic bands display "graded bedding".

In the northern part of the body, compositional banding is visible (location 0018, appendix 5), in a gabbroic anorthosite. However, in most places, the banding is probably of tectonic origin. No systematic variation in composition across the body, such as that in the Whitestone Anorthosite was noted in this study, but more detailed work would be required to clarify this impression.

The layering generally strikes at around 100 degrees but may range between 60 and 120 degrees. Dips vary from steep to the north or south, but are mainly gentle to the north; and

Photo 15. Well layered anorthosite with thin gabbroic bands, Moon River Anorthosite, location 0032 (appendix 5).

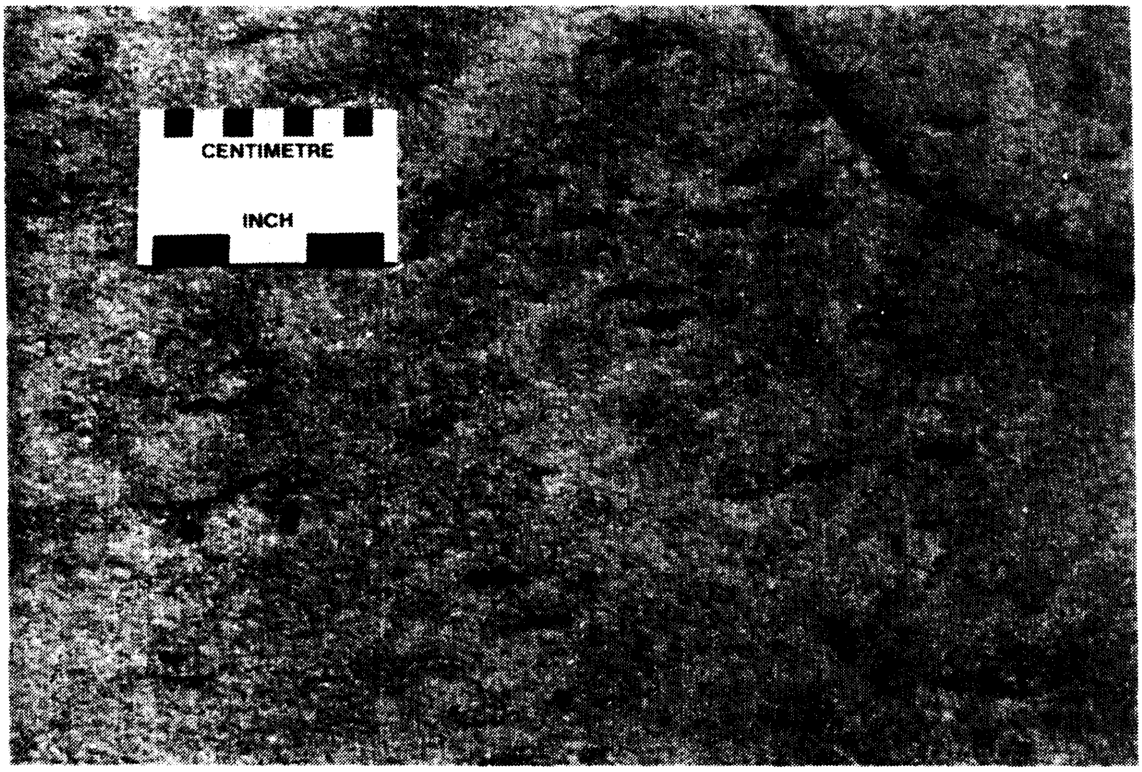


Photo 16. Small oikocrysts in Moon River Anorthosite, location 0035 (appendix 5).

lineations and fold axes plunge gently to the northeast. This variability is probably the result of interference fold patterns related to the branching of the body at Twelve Mile Bay. Locally, for example at the large outcrop 0029 (appendix 5), mesoscopic, overturned, easterly plunging folds are visible.

In places, elliptical aggregates of hornblende grains (oikocrysts?) occur. They are usually only 2-3 cm long, and never show the degree of sphericity which is common in those of the Whitestone Anorthosite (photo 16). At one location (0032, appendix 5), the "oikocrysts" are elongated and define a weak lineation, as if parallel to a cryptic axial planar cleavage, within a fold structure defined by the usual layering. Some are cored by garnet. In some cases the garnet is mantled by chlorite and epidote, which are in turn rimmed by hornblende.

Hornblende is the major mafic mineral, followed by biotite. Less abundant species include magnetite, titanite, epidote, garnet and chlorite. Scapolite and muscovite are visible locally.

Locally, narrow, discordant amphibolite dikes and granitic pegmatites cut the anorthosite.

MINERALOGY

The following section describes salient points of the petrography of the Moon River Anorthosite. In approximate order of decreasing abundance the minerals in the Moon River Anorthosite are: plagioclase, hornblende, biotite, muscovite-sericite, chlorite, epidote, scapolite, titanite, quartz, orthoclase, magnetite, garnet and calcite. Apart from plagioclase and hornblende, the minerals are generally present in amounts which range from trace levels to only three or four percent.

PLAGIOCLASE

As noted above, the feldspar in the Moon River Anorthosite is white, compared with the pale gray of the Whitestone body, suggesting a greater degree of recrystallization in the former. This is borne out by thin section examination which reveals a mosaic of equant labradorite cystals, mainly about 2mm in diameter. Larger lath-shaped crystals are rare, although they were observed in the field reaching a length of 2 cm. The plagioclase is less well twinned than that in the Whitestone Anorthosite, and it displays many irregular fractures.

In contrast to the Whitestone body, inclusions within the plagioclase are rare, and they appear to be limited to the remnant unrecrystallized laths. Photo 17 shows inclusions of hornblende and a clear acicular mineral and a fine dusting of unidentified silicates in one such grain. Inclusions in the recrystallized feldspars are limited to a dusting of silicate minerals smaller than 2 microns.

The plagioclase usually displays some degree of alteration to sericite, but this is not uniform. In some thin sections sericitic alteration is greatest in plagioclase within the "clean" layers, whereas plagioclase in the more mafic (hornblende-bearing) layers is fairly fresh. Elsewhere, the more mafic layers are the more strongly sericitized (photo 18). In the latter case, the mafic minerals are chlorite and epidote, with only remnants of hornblende. In still other cases, zones of sericitization cross-cut the layers. Usually the degree of sericitization is weak to moderate but local patches occur in which the plagioclase has been almost completely destroyed. In one thin section of a rock with a colour index of 12, it was estimated that some 20% of the rock was sericite. A more usual amount is about 5%.

Locally flakes of muscovite up to 3 mm in diameter are developed between plagioclase grains, but they constitute only 1-2 modal percent.

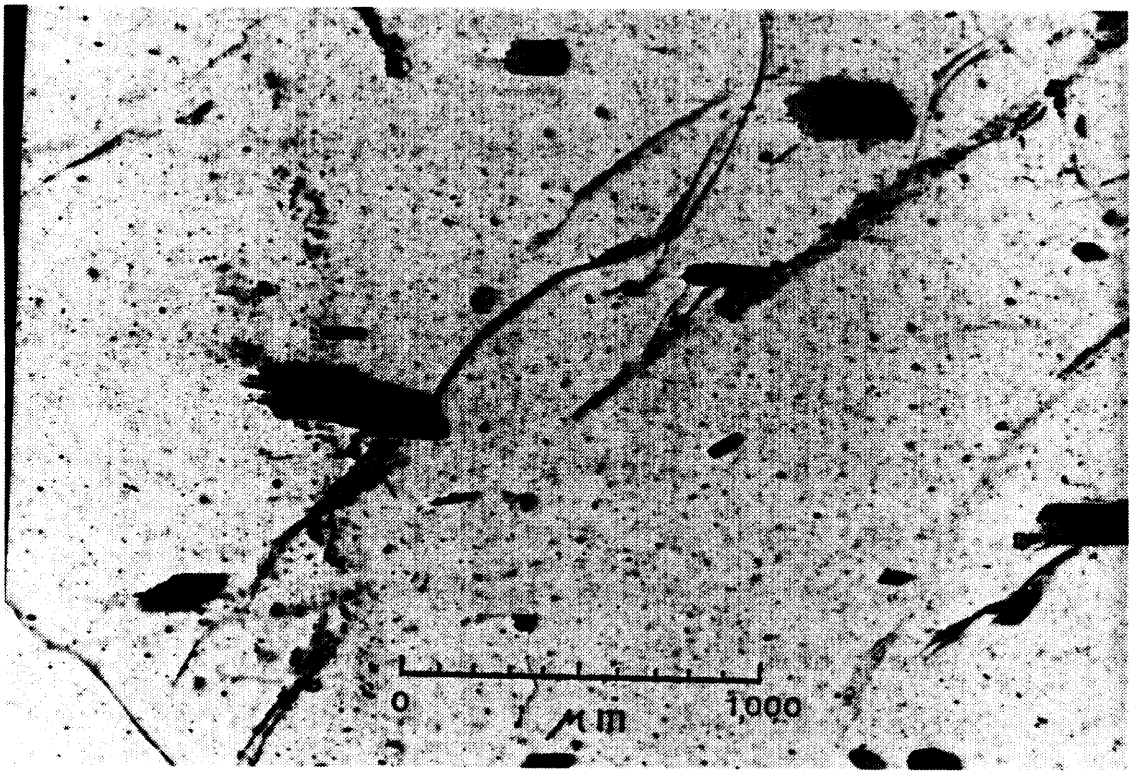


Photo 17. Unrecrystallized grain of plagioclase with inclusions of prismatic hornblende, and needles and dust of unidentified non-opaque mineral, Moon River Anorthosite.

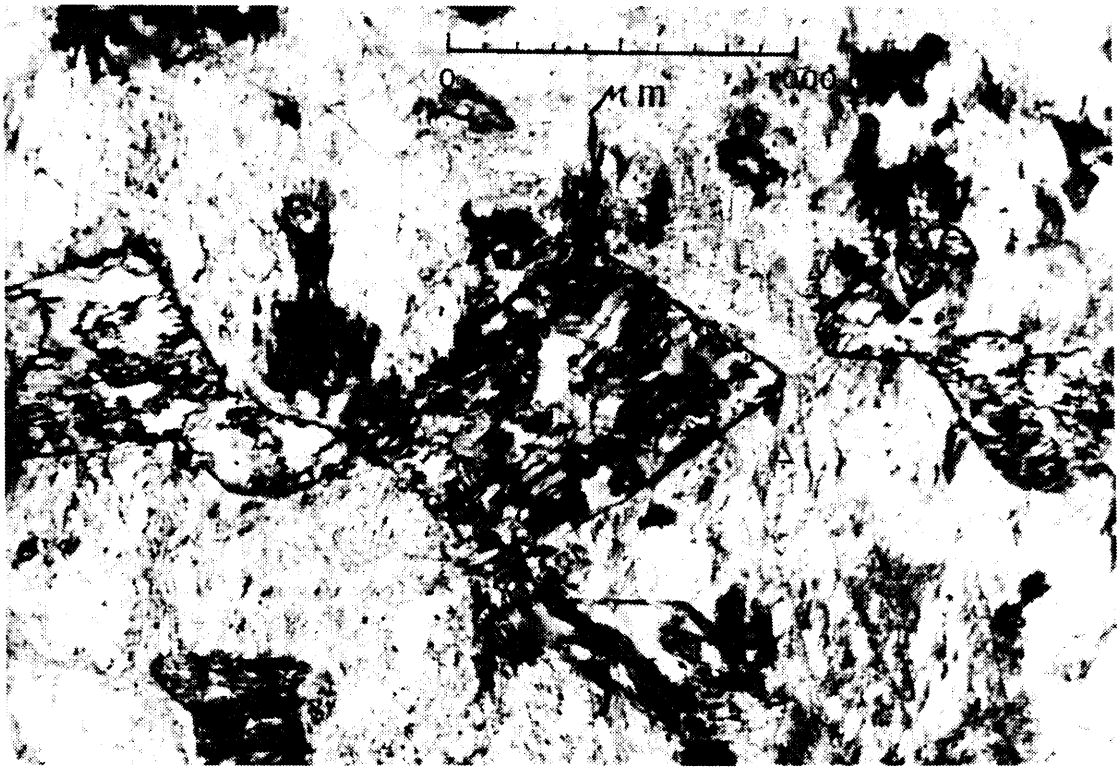


Photo 18. Epidote and chlorite alteration of hornblende, and sericitized plagioclase, Moon River Anorthosite.

HORNBLENDE

Hornblende is the most abundant mafic mineral in the Moon River Anorthosite. It occurs as isolated grains scattered throughout the rock, or as clusters of grains up to one centimetre in diameter. It forms clean, equant, subhedral to anhedral grains free of inclusions; or it may be severely uralitized or replaced by chlorite and epidote. Both habits may occur within the same thin section. Hornblende usually forms grains 1-2 mm in diameter, but ranges up to 5 mm. No good evidence was seen of its having replaced pyroxene, although one grain displayed an imperfect octagonal outline more typical of pyroxene than of hornblende.

BIOTITE

Biotite occurs as thin flakes up to 3 mm in diameter, and is pleochroic from dark brown to a pale straw colour. It usually occurs within the darker bands associated with hornblende, with which it appears to be in equilibrium. In only one instance was hornblende seen to have a margin of biotite which could be interpreted as an alteration product. Like hornblende it may be subject to replacement by chlorite and epidote.

EPIDOTE

Epidote is commonly seen as rectangular to elongated porphyroblasts up to 2 mm long replacing hornblende. In this situation it is associated with chlorite. There appear to be two types of epidote: one a very pale straw coloured, non pleochroic type; the other a strongly pleochroic golden yellow type which usually occurs marginal to the first type.

CHLORITE

Chlorite has been described in the preceding section as an alteration product of biotite and hornblende, commonly occurring with epidote. In some sections, aggregates of chlorite flakes, apparently pseudomorphous after hornblende, form wispy trains (probably flattened discs in three dimensions) up to 2 cm long. As an alteration product of biotite, chlorite forms large well formed pleochroic green flakes, but when replacing hornblende it appears as a jumble of randomly oriented microcrystalline flakes.

MUSCOVITE

Sericite has been described above as an alteration product of plagioclase. Muscovite forms irregularly shaped grains up to 3 mm long between plagioclase crystals. It also occurs as fine intergrowths with chlorite.

SCAPOLITE

Scapolite is not abundant in the Moon River Anorthosite, but where seen forms clusters of equant grains about 1 mm in diameter, or rims between biotite and plagioclase giving the appearance of having flooded selected areas of the thin section. This is most noticeable in a section which was otherwise little altered, and in which biotite and hornblende form large grains showing no sign of disequilibrium.

TITANITE

Titanite occurs locally as anhedral scattered grains about 0.5 mm in diameter. Less commonly it rims ilmenite/magnetite.

MAGNETITE

Magnetite is not common, but occurs as scattered, rounded grains about 0.5 mm in diameter. Some grains are rimmed by titanite.

CALCITE

Calcite occurs in trace amounts as small intergranular fillings associated with muscovite and sericite, and also as irregularly shaped specks and patches within plagioclase grains.

QUARTZ, POTASH FELDSPAR AND GARNET.

Up to 2% quartz was seen in several thin sections. It occurs as rounded grains about 0.5 mm in diameter, commonly with a poorly developed rim of sericite alteration separating it from the surrounding plagioclase grains.

Orthoclase was identified in only two thin sections where it occurs as untwinned crystals about 0.5 mm in diameter.

No garnet was seen in thin section, but it was observed in the field where it formed the cores of some mafic mineral clusters, being rimmed by epidote and/or hornblende.

CHEMISTRY

Appendix 5 lists the analytical results and shows sample locations of anorthosite samples collected from the Moon River Anorthosite. Table 3 summarizes these results.

ARNSTEIN ANORTHOSITE

The Arnstein anorthosite was not visited in the field during 1987, however some of the more important petrographic and chemical characteristics of the anorthositic parts of the body are reviewed here. Aspects of the general geology are described by Marmont and Johnston (1987). As a whole, the Arnstein body is more strongly deformed than the Whitestone Anorthosite, and texturally is more pervasively gneissic than the latter, which still retains many primary mineralogical and textural features.

PLAGIOCLASE

Plagioclase grains are generally about 2 mm in diameter and form a mosaic of equant polygonal grains. A few scattered grains up to 5 mm remain. Many grains exhibit undulatory extinction, bent and kinked twin planes, and the whole rock is pervaded by fractures, all of which indicate late brittle deformation. Irregular zones of grains of less than 0.5 mm in diameter attest to grain size reduction. Oxide inclusions in the plagioclase are rare, and acicular silicates up to 300 m long are sparsely distributed within the cores of some of the larger, unrecrystallized laths. Scapolitization is moderate, and sericitization minor.

Both albite and periclase twinning are present, and the composition of the plagioclase is about An 62.

MAFIC MINERALS

Hornblende is more abundant than clinopyroxene in the Arnstein Anorthosite. It commonly occurs as well formed crystals whereas the clinopyroxene looks very unstable, forming ragged anhedral grains. The rimming of clinopyroxene by hornblende, a regular feature in the Whitestone Anorthosite is not so evident in the Arnstein body. The two minerals commonly coexist in the same rock, often, but not necessarily, in separate bands.

Biotite occurs as well formed porphyroblasts up to 2 mm long and is pleochroic from a pale straw colour to very dark brown.

In some thin sections a twinned chlorite mineral, probably clinochlore, is common.

GARNET

Garnet forms equant crystals up to 5 mm in diameter. It too is ragged, commonly fractured, and has irregular, scalloped contacts with plagioclase. It is a common constituent, exceeding 20% modal volume in some of the more gabbroic phases.

SCAPOLITE

Scapolite is erratically developed along grain boundaries, forming grains up to 1 mm in diameter. It is usually altered to sericitic material, but is completely replaced locally by calcite. Uncommonly it contains rod shaped inclusions of opaque minerals

EPIDOTE

Epidote appears to be more abundant in the Arnstein Anorthosite than in the Whitestone. It occurs as well formed laths up to 1 mm long and as myrmekitic intergrowths with quartz around hornblende.

CALCITE

Calcite is a minor component, but in some thin sections reaches 3-4% and appears to have replaced scapolite, which it pseudomorphs along plagioclase grain boundaries.

TITANITE

Titanite is a minor constituent of the Arnstein Anorthosite. It usually occurs as discrete grains about 0.3 mm in diameter, but may rim opaque minerals.

MAGNETITE

Magnetite is less common than in the Whitestone Anorthosite, and occurs as irregularly shaped grains up to 0.5 mm long. Less commonly it occurs as rods within scapolite grains, but does not appear to be a significant inclusion mineral in plagioclase.

COMPARISON OF THE WHITESTONE, ARNSTEIN AND MOON RIVER ANORTHOSITES

Table 3 indicates that the chemistry of the three bodies is comparable. The plagioclase in the Whitestone Anorthosite is probably slightly more calcic than in the other two bodies, and this reflects the lower degree of recrystallization in the former. Other minor differences can probably be attributed to sampling bias as much as any other factor. The results from the Whitestone Anorthosite shown in Table 3 are from samples collected from a restricted area of the body, whereas the Arnstein Anorthosite and Moon River Anorthosite results are from widespread anorthositic sites.

There are mineralogical differences between the three bodies. These are summarized in Table 6.

The plagioclase, as mentioned above, is most calcic in the Whitestone Anorthosite. The fact that it is also the least recrystallized of the three also accounts for the greater abundance of plagioclase megacrysts, and probably the abundance of mineral inclusions.

Orthopyroxene is limited to the Whitestone Anorthosite.

The amount of deformation appears to have determined the abundance of secondary minerals. Scapolite is patchily distributed in the Blue Lake area of the Whitestone Anorthosite, but is most strongly developed within localised shear zones, where grain size reduction is apparent. In these zones epidote is common, and calcite, muscovite, biotite and magnetite are more abundant. The Moon River Anorthosite appears to be the most highly deformed of the three bodies, and contains virtually no pyroxene: hornblende and biotite are the dominant mafic minerals. In the Whitestone Anorthosite hornblende and garnet are major components of the strongly foliated marginal facies. Plagioclase in the Moon River Anorthosite is commonly sericitized, whereas sericite is a minor constituent in the Whitestone and Arnstein bodies. In the latter, sericite is an alteration product of scapolite.

Textural differences can be recognized between the three bodies. Relict primary igneous textures are common in the Whitestone Anorthosite, less common in the gneissic Arnstein Anorthosite, and dubious in the Moon River Anorthosite which texturally approaches a "straight gneiss" (in which parallel compositional banding induced by shearing has replaced the original texture). The average grain size of the feldspar is about the same in each body - about 2 mm, but the mafic and accessory minerals are probably coarsest in the Whitestone Anorthosite. Many of the mafic minerals in the Moon River

Anorthosite look very unstable and uralitization of hornblende is more common. This may result in poorer liberation of feldspar from the other minerals if mineral separation is attempted.

Table 4. Comparison of Mineralogy of the Whitestone, Moon River and Arnstein Anorthosites.

	Whitestone Blue Lake	Moon River	Arnstein
Plagioclase	M	M	M
Scapolite	X	o	X
Calcite	t	o	o-x
Sericite	t-o	x-X	o
Muscovite	t-o	x	o
Clinopyroxene	M	o-t	X-M
Hornblende	X	X	M
Biotite	o-x	X	x
Garnet	o	o	x-X
Epidote	o-x	o	x
Orthopyroxene	x	_	_
Magnetite	o	o	o
Titanite	t	t	t

M = Major
X = Common
x = Moderate
o = Minor
t = Trace
_ = Absent

ECONOMIC CONSIDERATIONS, USES AND BENEFICIATION

Accessibility, ease of quarrying, infrastructure (roads, hydro power, transportation) are not serious concerns for potential operators of an anorthosite property in the study areas: the main problem is one of markets.

Anorthosite is unlikely, in the near term, to constitute an alternative raw material for the glass and ceramic industries, as these markets are already well supplied by Ontario nepheline syenite.

Tables 5 and 6 (pages 79, 80) compare analyses of feldspathic materials currently used in the ceramics and glass industries, with typical values of anorthosite and pegmatitic sources described in this report.

An immediate user might be the insulation industry, where anorthosite could substitute for silica and nepheline syenite in higher temperature rock wool fibre. Guillet and Joyce, 1987, describe current mineral wool producing operations in Ontario. It might also substitute for some of the slag currently used, compared with which it has a lower sulphur content. However, the demand from mineral wool producers in Ontario is not sufficient to justify the opening of a new pit. It appears that diverse uses for anorthosite would have to be identified before a commercial operation could be contemplated.

In addition to identifying markets for high Ca-Al feldspars, mineral processing tests will have to be performed in order to determine whether a usable calcium feldspar product can be recovered economically from local anorthositic sources.

Different industrial applications require different product specifications. Higher value products such as those required by the glass industry have stringent specifications, and raw materials may require a greater amount of processing to achieve those specifications.

At the lower end of the market, there is potential to use blocks, rubble and crushed anorthosite as aggregate and fill, although it is not known to possess any particular advantage over other materials in current use.

For mineral wool production the preferred composition would contain less than 2% $Fe2O3$. This places a severe constraint on the nature of the raw material, since the industry uses a 2 to 3 inch lump feed which is not beneficiated. A raw material containing more than 2% iron could be used if it were beneficiated, but this might involve crushing the rock to sizes smaller than those acceptable to the industry.

Furthermore, the amount of anorthosite which would be used in each charge is only about 200 kg. Thus the requirement for homogeneity of feed is critical. This could be a problem for material such as the "leopard-spotted" Whitestone anorthosite, where individual oikocysts (which are relatively high in iron) may weigh several tens of kilograms, while the adjacent, enveloping anorthosite might have only a small fraction of one percent Fe2O3. The thinly banded Moon River Anorthosite or the gneissic Arnstein Anorthosite would provide a much more homogeneous feed for this purpose. More mafic sections of the anorthosite bodies can be used for production of higher temperature mineral wool products.

Appendix 2 shows the results of melting point tests performed on a suite of anorthositic rocks from the Whitestone and Arnstein bodies.

The glass, ceramic and filler industries require a finely ground or pulverized product. For these purposes the mesoscopic inhomogeneity of oikocrystic anorthosites is less of a problem, since the whole rock would be crushed, ground, classified and purified to a clean feldspathic product by magnetic, high intensity magnetic and flotation techniques. These proven techniques are employed by current feldspar producers and are likely to work on anorthositic material; although no bench tests have been performed as a part of this study.

Where the mineral phases are sufficiently coarse grained and are not intergrown, magnetic and high intensity separation techniques are capable of selectively removing magnetite, ilmenite, pyroxene, hornblende, garnet, biotite, muscovite and epidote. Titanite can be separated by gravity, and much is likely to be removed in the course of grinding and classifying. Calcite, and quartz which occurs in amounts of up to 2% in the Moon River Anorthosite and in trace amounts in the Whitestone Anorthosite can be removed by flotation. Scapolite might be separated by flotation, but further research on separation of this mineral is in progress.

The main concern in the beneficiation of anorthosite from the study area is the presence of minute inclusions of magnetite and, more commonly, silicate minerals in the feldspar of the Whitestone Anorthosite which range from less than 1 to more than 300 microns. The glass industry uses feed within the size range of 40-140 mesh (425-106 m), and the ceramics industry requires feed at -200 mesh (Minnes, 1975). Given the particle sizes required by industry and the sizes of inclusions in the

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Footnote:

Canadian Standard Sieve Size 30 = 600 m
40 = 425 m
140 = 106 m
200 = 75 m

feldspar (see table 1), it may be difficult to obtain complete separation of the feldspar from the included silicates. This will result in the loss of some feldspar to the magnetic tailings. The degree to which this can be minimized will have an important bearing upon the economic viability of the anorthosite. Pilot studies would need to be performed to establish the degree of liberation of feldspar from other minerals at various size fractions.

The calcium feldspar concentrate from the Whitestone Anorthosite might contain some percentage (likely less than five) of scapolite. Most of the scapolite in the Whitestone Anorthosite is clean and free from inclusions, but magnetite was observed in a few grains. Bench testing of scapolitic anorthosite would be required to determine whether scapolite can be readily separated from plagioclase, probably by flotation, and if not, whether its presence in the plagioclase concentrate has beneficial, neutral or detimental effects for various applications.

In the Moon River and Arnstein anorthosites, inclusions in the feldspar appear to be of lesser importance, but the feldspar is variably sericitized. Again, it will have to be determined whether this is a negative, positive or neutral factor for given applications.

The presence of trace amounts of certain elements can be critical in certain applications. For example, the glass industry has stringent specifications for trace levels of metals such as copper, cobalt, nickel, lead, zinc, selenium manganese and carbon. The current study has not tested for these deleterious elements, because it would be pointless before beneficiation and separation of different size fractions of feldspar from the whole rock. It is known, for example that trace amounts of pyrrhotite, pyrite and chalcopyrite occur in magnetite in the Whitestone Anorthosite (Kretschmar, 1968), but these would probably be almost entirely removed from the feldspar concentrate by magnetic separation.

CONCLUSIONS

On the basis of the chemical and petrographic evidence presented above, it seems likely that a plagioclase (high Ca-Al feldspar) concentrate could be obtained from parts of any of the three anorthositic bodies discussed. In the case of the Whitestone Anorthosite, scapolite may accompany the feldspar sericite in the Moon River Anorthosite, and possibly both in the case of the Arnstein Anorthosite. Pilot processing tests would be necessary to establish the degree of purity obtenable in each case. The Whitestone Anorthosite may be less prospective as a source of clean, pulverized feldspar than the other two bodies by virtue of the abundance of silicate, and to a lesser extent oxide, inclusions in the feldspar. Incomplete liberation of feldspar from the inclusion minerals will result in the loss of plagioclase during milling.

Be that as it may, the most prospective part of the Whitestone Anorthosite appears to be in the Blue Lake area where the anorthosite is cleanest, exposure greatest, and topography favourable for ready exploitation. It is likely that additional large tracts of the Whitestone Anorthosite have the same degree of purity, but the topographical and exposure factors are not as favourable. The latter in particular hampers, or at least increases the cost of, exploration for a commodity which has a low unit value.

The extent and distribution of clean anorthositic phases in the Arnstein Anorthosite and Moon River Anorthosite are not known at present, since neither has been mapped in sufficient detail. Access to both is fair, with the exception of the southern part of the Arnstein Anorthosite which is poorly accessible.

Future work should attempt to determine the distribution of clean anorthosites in the Arnstein Anorthosite, Moon River Anorthosite, Raganooter Anorthosite and Percy Lake-Haliburton Lake Anorthosite and several smaller bodies in the Minden and Rosseau areas. Field work should be supported by petrographic study in order to determine the presence and nature of inclusions within the feldspar.

More advanced studies such as pilot beneficiation tests should await the results of research presently conducted by the Industrial Minerals Section, MNDM, Toronto, into the potential applications of high alumina and lime rocks such as anorthosite.

Table 5.

Typical Analyses, Feldspathic and Aluminous Materials.

	Soda Flotation Feldspar, Spruce Pine, NC.	Potash Flotation Feldspar, Kings Mtn., NC.	Dry Ground Feldspar, Custer, SD
SiO_2	67.54	67.07	71.84
Al_2O_3	19.25	18.02	16.06
Fe_2O_3	0.06	0.04	0.09
CaO	1.94	0.38	0.48
MgO	Tr	Tr	Tr
K_2O	4.05	12.10	7.60
Na_2O	6.96	2.12	3.72
Loss	0.13	0.30	0.20

	Feldspathic Sand, Bessemer City, NC	Low Iron Aplite Montpelier, VA	Nepheline Syenite Nephton, Ontario.
SiO_2	79.20	63.71	61.4
Al_2O_3	12.10	21.89	22.74
Fe_2O_3	0.06	0.09	0.06
CaO	0.52	5.70	0.07
MgO	Tr	Tr	Tr
K_2O	2.62	2.37	4.95
Na_2O	4.80	5.60	9.54
Li_2O	0.35		
TiO_2		0.43	
Loss	0.35		0.60

	Steel Mill Slag
SiO_2	38.8
Al_2O_3	10.5
Fe_2O_3	0.3
CaO	38.5
MgO	8.3
K_2O	0.5
Na_2O	0.4
MnO	1.4
Sulphur	1.1

From: Industrial Minerals and Rocks, AIME, 5th. Edition, 1983.

Table 6.

Typical Analyses of Feldspathic Materials, Huntsville-Parry Sound-Haliburton Area.

	Whitestone Anorthosite	12 Mile Bay Anorthosite	Arnstein Anorthosite
SiO2	51.70	52.48	50.88
Al2O3	27.08	28.15	27.62
Fe2O3	2.13	1.78	1.94
CaO	12.58	11.34	11.51
MgO	0.45	0.80	1.46
Na2O	4.03	4.45	3.93
K2O	0.70	0.64	0.72
LOI	0.28	0.43	1.06
No. of samples:	30	11	11

	Frazer Prospect Pegmatite	Frazer Prospect Potash Feldspar *	Frazer Prospect Flotation Feldspar **
SiO2	67.93	65.70	65.76
Al2O3	17.24	18.87	21.56
Fe2O3	0.32	0.23	0.04
CaO	0.26	0.25	Tr
MgO	0.07	0.04	Tr
K2O	8.43	8.13	6.56
Na2O	5.09	5.32	5.10
Loss	0.33		

	Potash Feldspar, Besner Mine.	Soda Feldspar, Besner Mine.	Soda Feldspar, Ambeau Mine.
SiO2	64.38	63.41	65.07
Al2O3	18.30	21.32	21.12
Fe2O3	0.12	0.43	0.03
CaO	0.20	2.59	2.60
MgO	0.04	0.19	0.02
K2O	14.70	2.35	0.89
Na2O	2.26	9.01	9.34
Loss	0.26	0.46	1.03

* Courtesy of Bruce Goad, Geologist, MNDM, Bancroft.

** Analysis by TSL, Toronto, 1962.

All other analyses by Chemex Labs. Ltd., Mississauga, Ontario.

PEGMATITE

INTRODUCTION

Pegmatites are widely distributed through the Huntsville-Parry Sound area: 137 occurrences are recorded in the files of the Resident Geologist, Algonquin District, Dorset, of which 37 are listed as past producers of silica, mica and potash or soda feldspar. Many have been described by previous workers, notably Satterly (1943, 1956, 1976), and Hewitt (1961, 1967a,b,c). An overview of previous work and the geological setting of local pegmatites is provided by Marmont and Johnston (1987).

AMBEAU MINE, HENVEY TOWNSHIP, Con. A, lot 3.

The former Ambeau mine has been described by Satterly (1943), Rose (1960) and Hewitt (1967a). It was operated by Wanup Feldspar Mines Ltd. during 1926-27, producing 1,000 tons of feldspar. Its location is shown on figure 4 and a geological plan of the pit area is attached as Map No. 4. The open pit is some 50 metres long, 6-8 metres wide and 4-5 metres deep. Much of the pit is now water-filled.

Map No. 4 shows that the body is discordant within strongly deformed country rocks of grey tonalitic gneiss and pink granitic gneiss. Small pegmatitic stringers at the eastern end

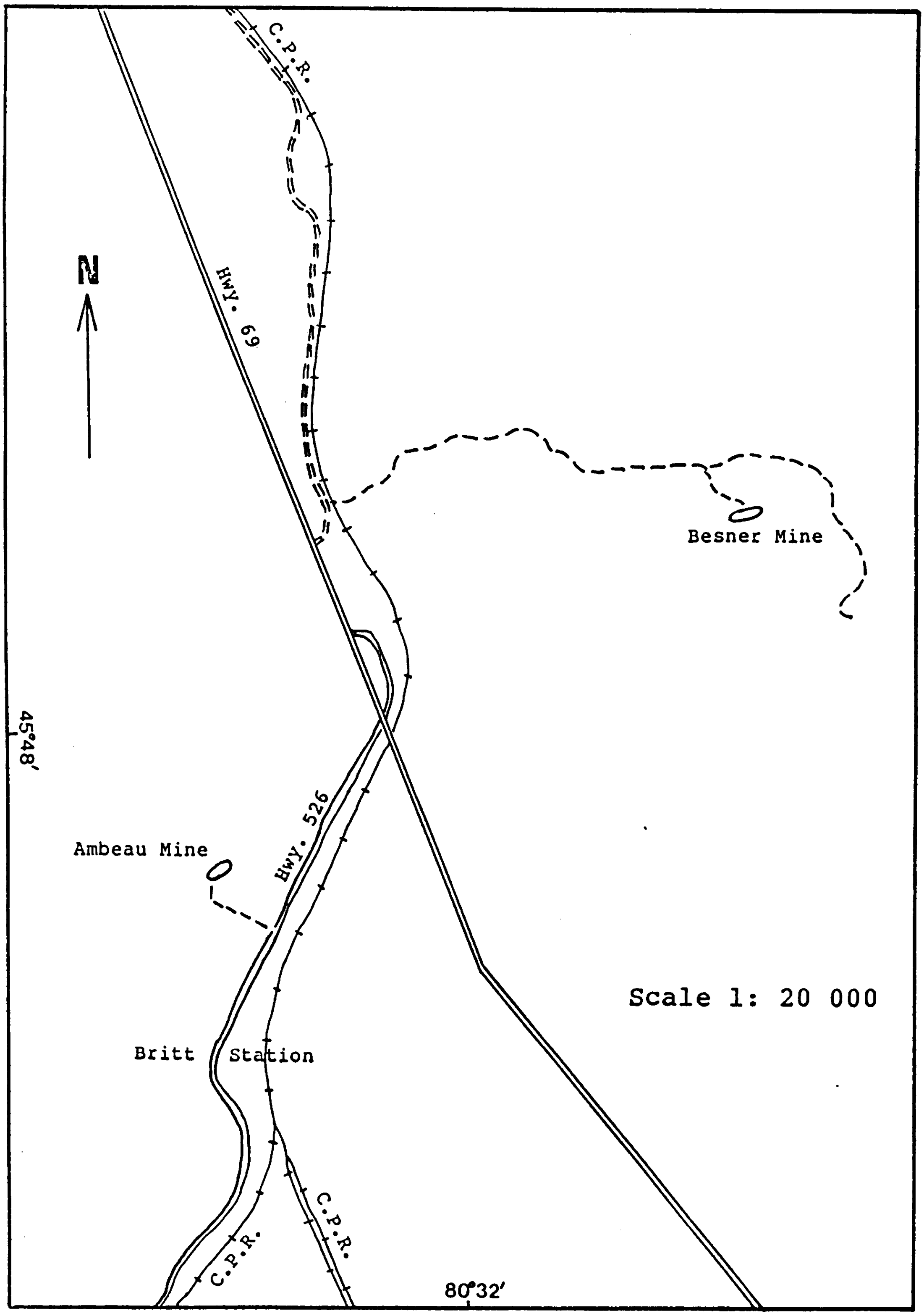


FIGURE 4 Location Map of Ambeau and Besner Mines, Henvey Township, Ontario

of the mapped area are conformable to the gneissic foliation. The large area of pegmatite exposed between 10 and 40 metres east of the pit shows signs of deformation and granulation. It consists of an unzoned mass of potash feldspar, graphic intergrowths of potash feldspar and quartz, quartz-plagioclase intergrowths, quartz and minor biotite. The main body which was mined appears to have been pinched out at its eastern end by a cross-cutting fault which can be seen displacing gneissic foliation immediately southeast of the pit.

No distinct zoning pattern could be discerned in the pit since the pegmatite has been largely removed. However the mineralogy varies along the southern face of the pit: plagioclase being more abundant at the western end, potash feldspar more abundant at the east. Between the two water-filled sections muscovite is common in a section of greenish plagioclase.

In the central part of the south face local spots of radioactivity indicate the presence of euxenite (Rose, 1960).

The fact that much of the potash spar is graphic, and contains a considerable amount of quartz and biotite is noted by Satterly (1943) and is reported in the Mines Branch Report, Vol.731, p.55-56, 1932.

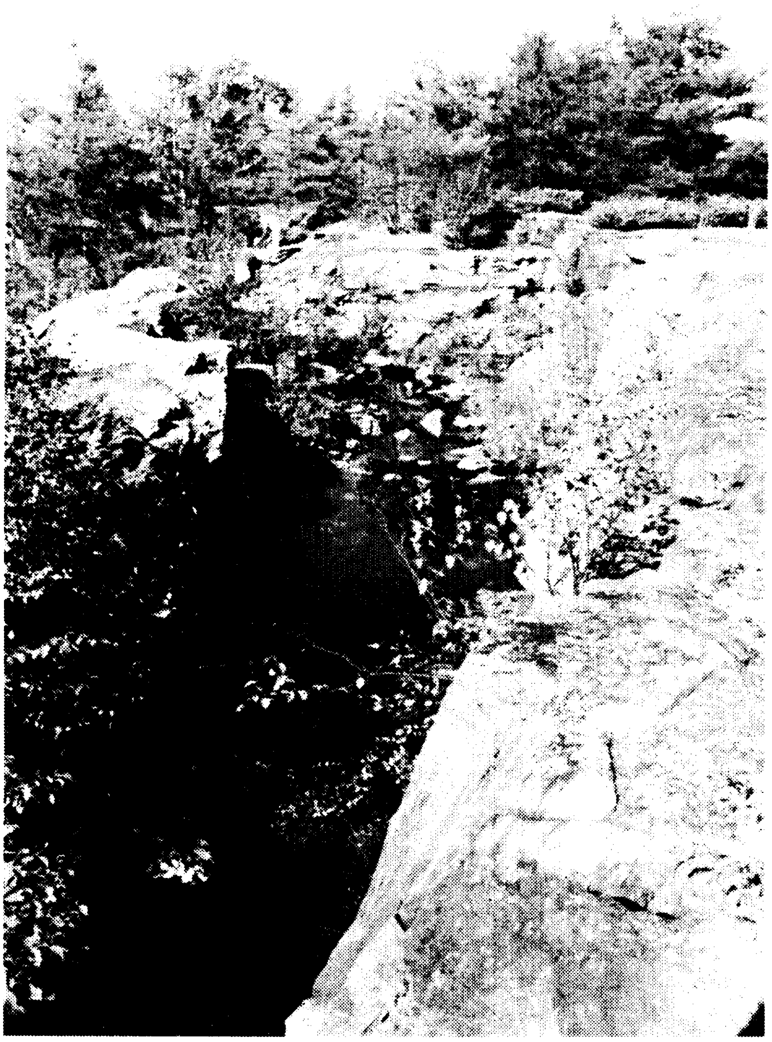


Photo 19. Ambeau Feldspar Mine, Henvey Township, Con. A, lot 3.

Photo 20. Besner Mine, Henvey Township, Con. B, lot 5.

Samples were collected of potash feldspar, plagioclase and quartz. Results of these analyses are shown on table 7.

BESNER MINE, HENVEY TOWNSHIP, Con. B, lot 5.

The former Besner Mine is located on the farm of Tom Besner, some 2,000 metres northeast of the Ambeau Mine (figure 4). It was worked by Wanup Feldspar Mines Ltd. between 1926 and 1929, producing some 2,500 tons of feldspar. In 1955, the deposit was tested by Trio Uranium Mines Ltd., which completed 16 diamond drill holes for a total of 560 feet, encountering from 0-31 feet of pegmatite (Assessment Files, Resident Geologist's Office, Dorset).

The body is very poorly exposed and the pit filled with water (photo 20). The deposit has been described by Spence (1930), Ellsworth (1932), Satterly (1943), Rose (1960), Lang et al., (1962) and Hewitt (1967c).

The pegmatite strikes at 065 degrees within a hornblende granite gneiss and dips steeply to the southeast. The pit is 45 metres long, 18 metres wide and 9 metres deep.

The spoil heaps contain rubble of potash feldspar, graphic intergrowths of potash spar and quartz, oligoclase, minor allanite and trace amounts of uraninite. Also recorded from this location are cyrtolite (metamict zircon), thucolite, hornblende, biotite, chlorite alteration of hornblende and biotite, garnet, magnetite, pyrite and hematite stain.

Satterly (1943) estimated that graphic intergrowths of potash feldspar and quartz constituted 25-50% of the feldspar masses. Ellsworth (1932) mentions that minor amounts of beryl were found in the pit. He also recorded the presence of a heavy yellow oil in two parallel fracture zones about one foot wide and 70 feet apart. Uraninite and thucolite are intimately associated. A panned concentrate contained 8.09% Pb, 79.3% U3O8, 1.73% ThO2 and 2.87% rare earth oxides.

Pough (1934) reported the occurrence of anatase as an alteration product of titanite, which was intimately associated with the uraninite and thucolite in oligoclase zones.

RICHORE PROSPECT, CONGER TOWNSHIP, Con. VIII, lot 5.

The location of the Richore prospect is shown in figure 5. The pegmatite outcrops on the eastern side of Payne Lake, cutting irregularly across pink biotitic monzonite gneiss and black biotite tonalite gneiss. Satterly (1943) records that, "The prospect was worked by the Standard Feldspar and Silica Company

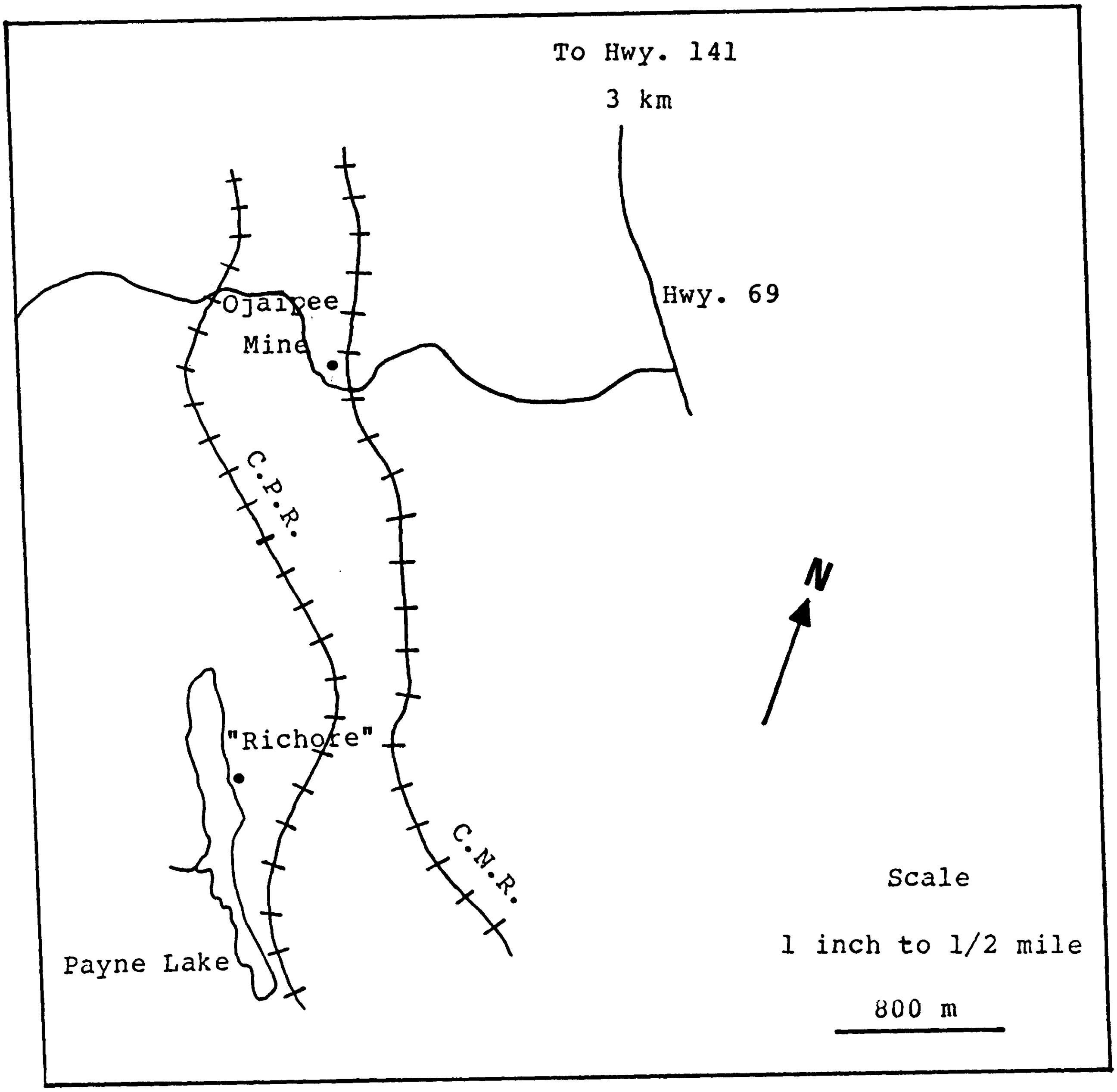


FIGURE 5 : Location of "Richore" feldspar prospect, Concession VIII, Lot 5, Conger Township, District of Parry Sound.

in 1911-12, but there was no production as the deposit is too small and there is very little clean spar present". There was a resurgence of exploration activity in 1970-71 when Richore Gold Mines Ltd. performed airborne and ground radiometric surveys, sampling and trenching for uranium in the area (Assessment Files, Resident Geologist's office, Dorset, Ontario).

Small pits have been excavated at the shore of the lake and some fifty metres to the east, at each end of the meandering body. The country rock is mainly an "augen granite" (cf Ellsworth, 1932), probably a deformed and recrystallized plutonic rock, with lesser grey biotite tonalite gneiss. Pegmatite occurs as several irregularly shaped shoots, consisting of pink potash feldspar crystals up to 30 cm, white plagioclase crystals up to 20 cm, granulated smokey quartz, and books of biotite up to 15 cm thick. It contains inclusions of mafic gneiss and has a cataclastic appearance. Quartz is intergrown with potash feldspar in the marginal parts, and white quartz forms irregular masses in the core. Plagioclase envelopes the quartz cores and contains scattered books of biotite. Samples of the plagioclase and potash feldspar were collected and analysed: results are shown in table 7.

Table 7.

ANALYSES OF FELDSPAR AND QUARTZ FROM PEGMATITES IN THE HUNTSVILLE-PARRY SOUND AREA

SAMPLE NUMBER	SiO2 %	Al2O3 %	Fe2O3 %	MgO %	CaO %	Na2O %	K2O %	TiO2 %	P2O5 %	MnO %	BaO %	LOI %	TOTAL %
Potash Feldspar													
87 CCM 0256	64.19	18.58	0.12	0.05	0.15	1.63	15.65	<0.01	0.02	<0.01	0.05	0.22	100.70
87 CCM 0263	64.38	18.30	0.12	0.04	0.20	2.26	14.70	<0.01	0.04	<0.01	0.15	0.26	100.45
87 CCM 0273	64.97	18.64	0.02	<0.01	0.04	2.82	13.35	0.01	<0.01	<0.01	<0.01	0.25	100.15
Plagioclase													
87 CCM 0260	60.38	23.37	0.26	0.12	5.38	7.65	1.06	0.01	0.05	<0.01	<0.01	0.25	98.56
87 CCM 0262	63.41	21.32	0.43	0.19	2.59	9.01	2.35	<0.01	0.04	<0.01	<0.01	0.46	99.84
87 CCM 0276	65.07	21.12	0.03	0.02	2.60	9.34	0.89	0.01	<0.01	<0.01	<0.01	1.03	100.15
Quartz													
87 CCM 0264	98.63	0.30	0.13	0.05	0.10	0.21	0.05	0.03	0.06	<0.01	<0.01	0.13	99.73
87 CCM 0277	99.72	0.21	0.04	0.01	<0.01	0.16	<0.01	<0.01	0.02	<0.01	<0.01	0.13	100.35
Whole pegmatite													
87 CCM 0364	67.93	17.24	0.32	0.07	0.26	5.09	8.43	0.05	0.02	<0.01	0.07	0.33	99.83
87 CCM 0365	57.50	21.24	4.87	0.37	1.56	4.99	7.04	0.28	0.05	0.10	0.14	0.91	99.06
87 CCM 0366	51.68	18.41	12.15	0.89	3.32	4.41	5.80	0.62	0.21	0.16	0.20	0.55	98.41

Table 7 (continued).

Potash Feldspar	
87CCM-0256	Richore Prospect, Conger Township, Con 8, lot 5.
87CCM-0263	Besner Mine, Henvey Township, Con B, lot 5.
87CCM-0273	Ambeau Mine, Henvey Township, Con A, lot 3.
87BEG-0379	Frazer Prospect, Glamorgan Township, Con 6, lot 31. (Average of 6 samples)
Plagioclase	
87CCM-0260	Richore Prospect, Conger Township, Con 8, lot 5.
87CCM-0262	Besner Mine, Henvey Township, Con B, lot 5.
87CCM-0276	Ambeau Mine, Henvey Township, Con A, lot 3.
Quartz	
87CCM-0264	Besner Mine, Henvey Township, Con B, lot 5.
87CCM-0277	Ambeau Mine, Henvey Township, Con A, lot 3.
Whole pegmatite	
87CCM-0364	Cataclastic pegmatite, Frazer Prospect, Glamorgan Township, Con 6, lot 32.
87CCM-0365	Biotite syenite, Frazer Prospect, Glamorgan Township, Con 6, lot 32.
87CCM-0366	Biotite Monzonite, Frazer Prospect, Glamorgan Township, Con 6, lot 32.

FRAZER PROSPECT, GLAMORGAN TOWNSHIP, Con. 6, lot 31.

The Frazer feldspar prospect is indicated on ODM Map 2173, and is described by Satterly (1944) and Hewitt (1967).

Early work (1918) consisted of the excavation of two small pits into the northwest face of the pegmatite which outcrops along a ridge some 20 metres high and 400 metres long. The pits contain abundant potash feldspar, but it has been cataclastically deformed with the result that the potash feldspar is granulated and mixed with soda spar and quartz. A certain amount of hornblende is also present. Consequently the material was entirely unsuited to hand cobbing and no further development took place until the late 1950's. The following extract is taken from a private report by H.R. Morris commissioned by Mr. Frazer in 1966.

> In 1946, Mr. Frazer acquired the property and in 1957, investigated the narrow lead of radioactive ore and rare earths that nearly coincides with the south boundary of the feldspar development. Before the uranium and rare earth grade and tonnage could be determined, the slump in the uranium market occurred and Mr. Frazer's interest turned to the possibilities of utilizing the large amounts of potash feldspar as indicated by the various outcrops along the hogsback. As the average grade of ore consisted of 80% feldspar, 10% quartz and 10% mafic mineral, the problem became one of separating the feldspar from the gangue minerals. Because of the rigid specifications for potash feldspar, it was feasible to consider only flotation as the possible means of reducing the iron content to less than 0.1%. In 1957, however, the flotation of feldspar was still in its infancy

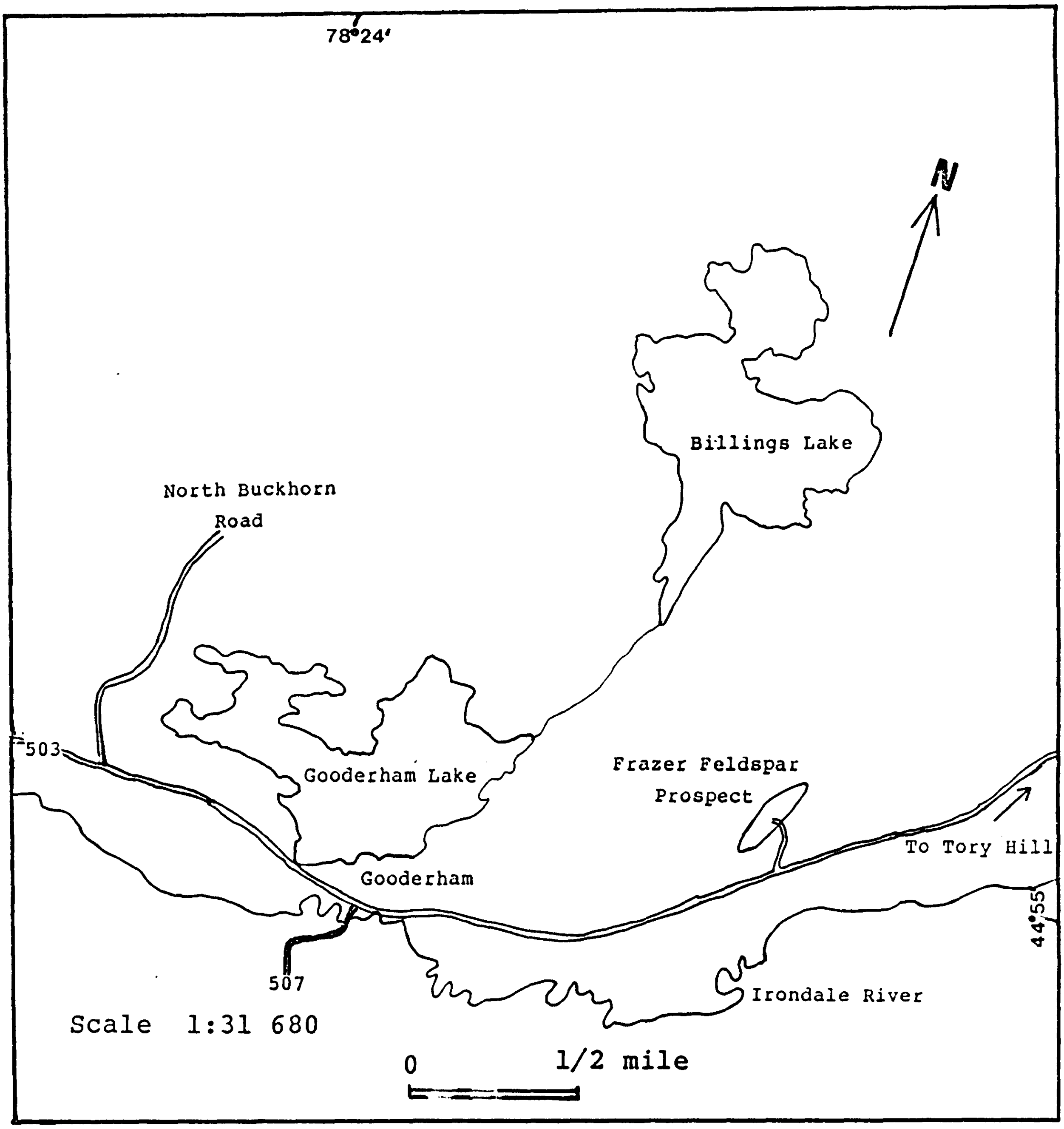


FIGURE 6 Location Map of Frazer Potash Feldspar Prospect, Glamorgan Township, Haliburton County, Ontario

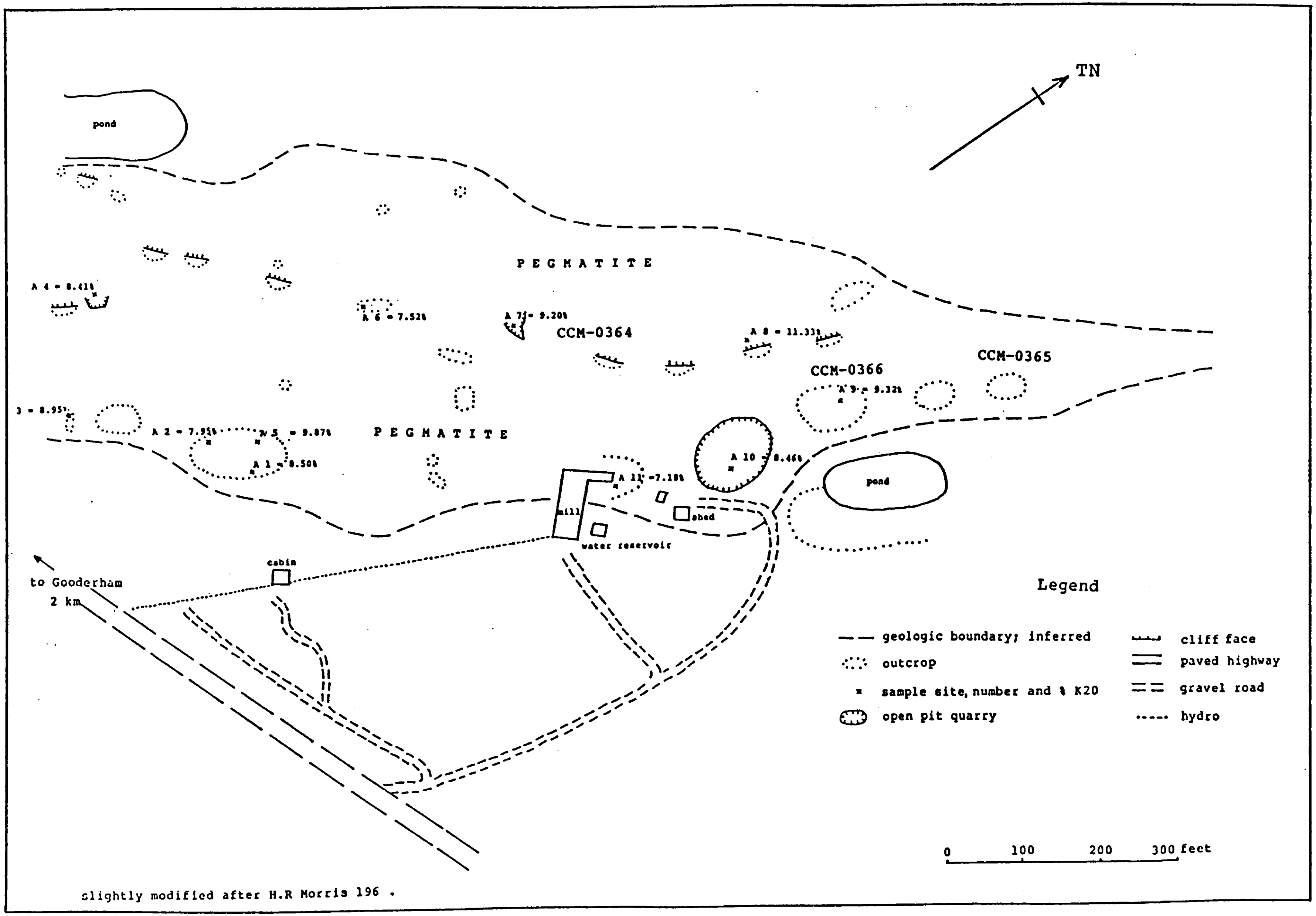
> and the ordinary flotation equipment and techniques did not prove adequate on the feldspar from the Frazer property. Consequently, Mr. Frazer invented a flotation unit that would make an adequate separation of his feldspar from the gangue minerals and patented his invention in The United States and Canada in 1967.
>
> Mr. Frazer felt sufficiently confident of the results he was obtaining from his flotation units to begin the construction of the mill in 1963. Working almost alone, Mr. Frazer has almost completed the construction of the mill buildings and the installation of the machinery to handle approximately 40 tons per 24 hour day.

Unfortunately the mill was vandalized shortly afterward and Mr. Frazer's venture came to a premature end.

Analyses of eleven samples of pegmatite tested by Mr. Frazer revealed K_2O values ranging from 7.95 to 11.33%, averaging 8.79% (Figure 7). An analysis of the feldspar concentrate he obtained from his flotation circuit is shown below, along with a crushed, finely hand cobbed potash-feldspar and a composite two feldspar-quartz sample collected by the author during 1987.

	Flotation Concentrate	Cobbed K-fsp*	Composite Pegmatite
SiO_2	65.76	65.7	67.93
Al_2O_3	21.56	18.87	17.24
Fe_2O_3	0.04	0.23	0.32
CaO	Tr	0.25	0.26
Na_2O	5.10	5.32	5.09
K_2O	6.56	8.13	8.43
MgO	Tr	0.04	0.07

* Courtesy of Bruce Goad, Geologist, MNDM, Bancroft, Ontario. Average of six samples from sites 20 m southeast of A4 (figure 7), A7 and A10. Analyses by Barringer Magenta Ltd., Rexdale, Ontario.



slightly modified after H.R Morris 196 .

Figure 7. Frazer Feldspar Prospect, Glamorgan Township, Con. 6, lot 31. Haliburton County.

These values compare favourably with the specifications of similar materials currently in commercial use (see Table 4). It is apparent that the potash feldspar is highly perthitic.

In addition, Mr. Frazer reports the following analysis of a grab sample of radioactive hornblende rich material from the southern part of the pegmatite:

	%
Nb_2O_3	0.04
Ta_2O_3	nil
U_3O_8	0.059
ThO_2	0.68
CeO_2	0.08
La_2O_3	0.05
Nd_2O_3	0.06
PrO_2	0.02
Y_2O_3	0.05

(Samples analysed by Technical Services Laboratories, Toronto, 1955, by spectrogaphic analysis).

The deposit has not been diamond drilled.

During the fall of 1987, the author visited the Frazer property and collected samples. Pegmatite was seen to outcrop widely over the entire hill, which trends at about 050 degrees. This is an area of up to 120 metres or more in the northwest - southeast direction, and 400 metres along its length. A strongly developed joint system in the pits on the northern edge of the body suggest that a southerly dip of about 45 degrees may obtain for the northern contact. A small outcrop of impure crystalline marble occurs at or near the southern contact of the pegmatite at the mill site.

Photo 21. Frazer Prospect, Glamorgan Township, Con. 6, lot 31.
View of ruins of part of former mill.

Photo 22. Frazer Prospect, Glamorgan Township, Con. 6, lot 31. Stripped and pitted area.

Pegmatite outcrops as a series of low rises within the larger ridge. The coarse grain size makes estimation of the bulk composition of the pegmatite difficult, but it appears to be approximately 10% quartz, 10% hornblende and 80% feldspar, with potash spar exceeding soda spar.

The radioactive zone appears to be located near the southern contact of the body. Within a stripped area east of the mill (the area which supplied feed for the mill in the early 1960's) hornblende occurs as coarse dendritic growths within the potash feldspar, and small mafic inclusions within the feldspathic pegmatite have rusty weathering radioactive rims (Photo 23). Thin section examination of this material reveals a bright green amphibole, possibly a sodic variety, uranothorite, fluorite and cyrtolite (W.D. Hicks, Mineralogist, Ontario Geological Survey, Toronto).

Toward the eastern end of the body a low rise of pink biotitic feldspathic gneiss occurs, apparently within the outline of the pegmatite as defined by Morris. Petrographic examination of this rock indicates that it consists of syenite and monzonite with 7-10% biotite. Whole rock analysis indicates about five percent soda and 6-7% potash (see table 7). Although some of the potassium will reside in the biotite this rock may also represent a potential source of recoverable feldspar.

Stripping would be necessary to determine whether the scattered pegmatite outcrops represent a single body which has been differentially eroded, perhaps along minor faults, or is a series of echelon pegmatite pods separated by screens or inclusions of country rock.

If the pegmatite is continuous within the area outlined by Morris, then a total area of approximately 450,000 square feet (41,805 sq m) is available. This is equivalent to something in the order of 100,000 tonnes per vertical metre. Diamond drilling will be necessary to establish continuity to depth.

The potential size of this pegmatite combined with technological advances in high intensity magnetic separation and flotation since his earlier tests, and a currently reasonable demand for potash feldspar, have prompted Mr. Frazer to renew his attempts to develop the property.

ECONOMIC CONSIDERATIONS AND CONCLUSIONS.

Most of the pegmatite occurrences visited by the author in the Huntsville-Parry Sound area, and those described in the literature of the same area, are relatively small. All are in the Central Gneiss Belt with the exception of the Frazer Prospect, which is in the Central Metasedimentary Belt. Apart from their small size, many ceased to operate because of the presence of graphic material which could not be hand cobbed economically. This is even the case with the Frazer Prospect, although it is bigger than most.

However, since the 1950's the development of flotation techniques to separate feldspar from quartz and other impurities has rendered the cobbing problem obsolete. Consequently some of the larger pegmatite bodies may warrant further investigation for alkali feldspar. Silica and rare earth elements are also potentially economic constituents of these bodies.

During the 1988 field season, it is planned to investigate the larger pegmatite bodies in the Huntsville-Parry Sound area, in order to assess their economic potential for these minerals.

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APPENDICES

APPENDIX 1.

Estimation of iron content from modal analyses.

ESTIMATION OF IRON CONTENT FROM MODAL ANALYSES

Map number 2, showing the concentration of iron (expressed as Fe2O3) was prepared from modal analyses presented by Mason (1969 Appendix B, p.289-299). Mason's modes were estimated from thin sections (area ~1000 mm2), counting 1000 points per slide. He used visual estimates of modes for slides having >95% plagioclase.

The following notes explain the conversion of modes to weight percent iron (expressed as Fe2O3).

The iron content and density of the major iron bearing phases (garnet, hornblende, clinopyroxene, magnetite) were estimated using averages of microprobe analyses presented by Mason (1969) and densities of mineral species of similar composition presented by Deer, Howie and Zussman (1970). Mineral densities were corrected to the estimated rock density which was taken as 2.72 g/ml; a reasonable value since the major phase in the Whitestone Anorthosite, particularly in the "cleanest" parts is plagioclase.

Clinopyroxene

The average Fe2O3 content of Whitestone pyroxene is 11.83 wt% (average of 5 microprobe analyses Mason, 1969, p.146, table 5-6). Approximate density 3.54 g/ml (Deer, Howie and Zussman, 1966, p.105).

Density correction (11.83wt% x 3.54/2.72) = 15.40

Therefore 1% modal cpx = .154 wt% Fe2O3

Hornblende

The Fe2O3 content of hornblende is 17.28 wt% (average of two microprobe analyses Mason, 1969, p.169, table 5.7).

Approximate density 3.25 g/ml (Deer, Howie and Zussman,1966 p.152).

Density correction (17.28wt% x 3.25/2.72) = 20.64

Therefore 1% modal hornblende = 0.206 wt% Fe2O3.

Garnet

The Fe2O3 content of garnet is 30.71 wt% (average of two microprobe analyses Mason, 1969, p.183, table 5-9)

Approximate density: 4.08 g/ml (Deer, Howie and Zussman, 1966, p. 24).

Density correction (30.71wt% x 4.09/2.72) = 46.19

Therefore 1% modal garnet = 0.462 wt% Fe2O3.

Magnetite

The mass ratio of FeO:Fe2O3 = 0.31 : 0.69. The ideal magnetite composition, expressed in terms of Fe2O3, is 103.72 wt % Fe2O3.

Density = 5.20 g/ml.

Density correction (103.72wt% x 5.20/2.72) = 198.28

Therefore 1% modal magnetite = 1.98 wt% Fe_2O_3.

Other iron bearing phases (epidote and orthopyroxene) occur locally in small amounts but were not included in the estimate of iron contents shown on the map.

Sources of Error

Calculation of the iron content of sample sites based on modal analyses is subject to several sources of error.

1) Sampling bias: Generally speaking one seeks to identify mineral phases and grain relationships from thin sections. Emphasis is placed on selecting a sample for thin section which appears to contain all the mineral phases visible in hand specimen. This will generally result in selecting samples which are more mafic than those truly representative of an outcrop or group of outcrops.

2) Small sample size (1000 mm^2) in comparison to grain size (most rocks in the Whitestone anorthosite are medium or coarse grained). Furthermore, most rocks are very heterogeneous because of the oikocrystic nature of much of the body.

3) Opaque phases: magnetite and ilmenite are not differentiated in the modal analyses: small modal amounts of magnetite have a

large influence on the calculated iron content. Calculated iron contents were made assuming all the opaque phase is magnetite (leading to overestimate of iron contents).

4) Assumptions made regarding the composition and density of the iron bearing phases and the densities of the rocks.

APPENDIX 2

Melting Points of Anorthositic Rock Samples.

MELTING POINTS OF ANORTHOSITIC ROCK SAMPLES.

As a part of the programme of evaluating the suitability of anorthosite for various industrial applications, the melting points of a suite of samples was determined. Rock samples were pulverized to -170 mesh, and melting points determined with a thermocouple by Dr. J. Toguri, Department of Metallurgy, University of Toronto, Toronto, Ontario. The results are as follows:

Sample No.	86MMJ-3010	86CCM-0109	86MMJ-2054	86MMJ3023
% Fe2O3	0.96	5.29	7.26	12.5
M. Pt. (C)	1482	1349	1277	1389
Mineralogy:				
Feldspar	87	70	35	50
Clinopyroxene		1	35	
Hornblende	2	20	6	30
Scapolite	8	9	10	5
Garnet		<1	10	4
Titanite		Tr	5	
Magnetite	<1	<1		5
Epidote		<1		6
Biotite	1	<1		1
Muscovite	2			

These results are in general agreement with phase diagram data for the system anorthite-diopside-albite (Ehlers, 1972, see attached). However, the mineralogy of the samples appears to have an important effect on the melting temperature, and so further tests would need to be performed on the most prospective material, since, even within areas of low colour index (high feldspar content) the proportion of hornblende to clinopyroxene and of feldspar to scapolite may vary significantly. Furthermore, no viscosity tests were performed on these samples, and this property is also very important in determining the suitability of anorthosite for various applications.

The melting zone temperature in mineral wool-producing cupolas is 1550 degrees celcius (Guillet and Joyce, 1987).

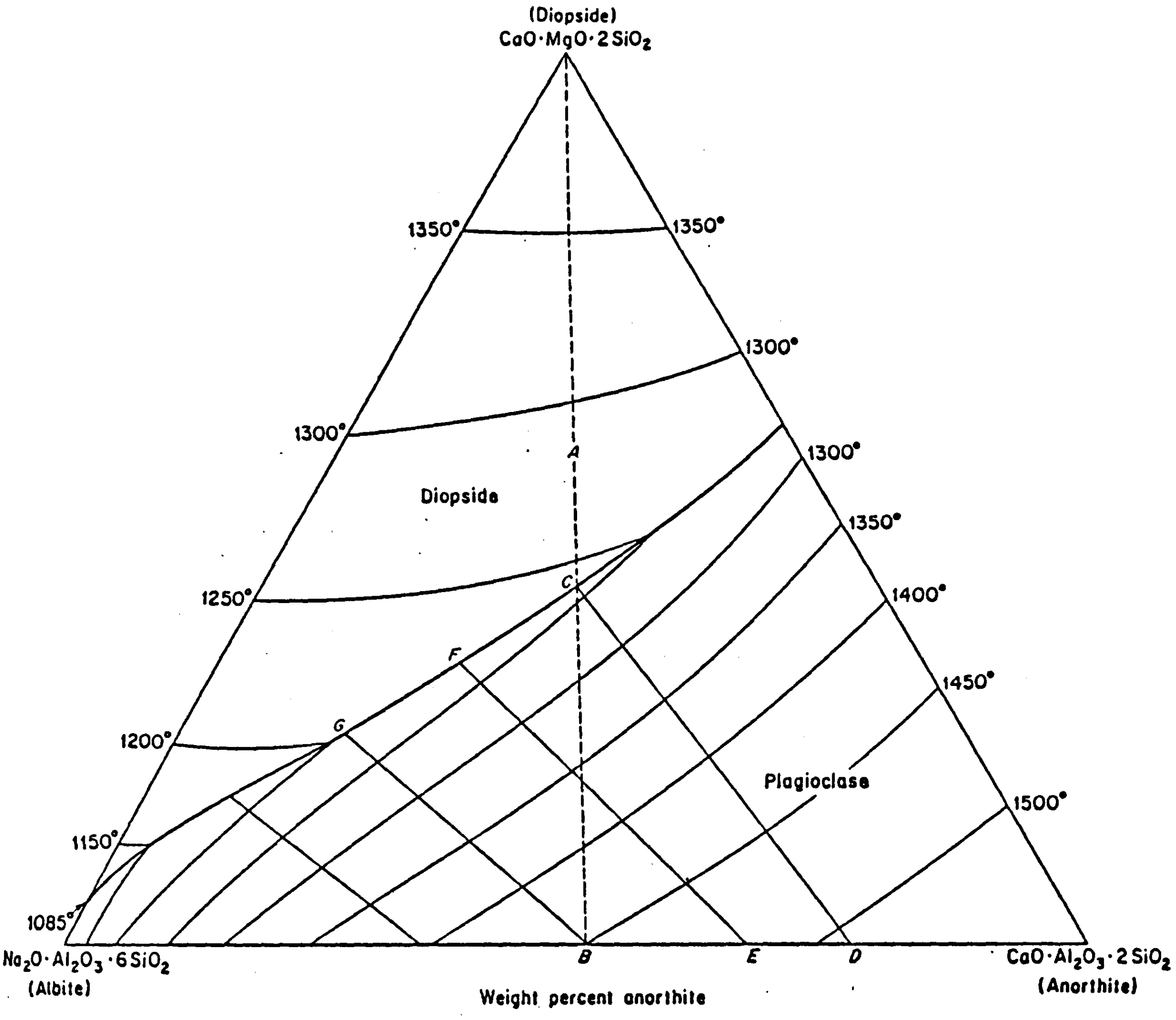


FIGURE 71
Crystallization of a liquid of composition *A*, above the primary field of diopside. The initial plagioclase composition is at *D*. The final plagioclase is at *B*, and the final liquid at *G*.

(From Ehlers,1972)

APPENDIX 3

Major Element Chemistry, Whitestone Anorthosite, Mason, 1969.

ANALYSES OF SAMPLES FROM THE WHITESTONE ANORTHOSITE

FROM MASON, 1969

SAMPLE NUMBER	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	FeO %	Fe_2O_3(T) %	MgO %	CaO %	Na_2O %	K_2O %	TiO_2 %	H_2O %
2	51.73	20.53	2.86	6.46	10.09	1.99	9.76	3.21	0.92	1.51	nd
13	53.81	22.46	1.28	4.70	6.54	1.99	9.69	4.03	0.56	0.92	0.51
17	54.00	21.99	1.10	3.81	5.36	2.07	11.03	3.60	0.81	0.72	nd
20	51.68	22.71	1.50	5.14	7.26	1.56	10.37	3.88	0.52	1.12	0.48
24	48.87	21.11	3.24	7.45	11.58	3.09	10.06	3.07	0.33	1.73	nd
30	52.19	27.35	0.61	1.46	2.24	1.00	11.55	3.80	0.44	0.25	nd
79	51.42	22.19	1.06	2.80	4.20	2.45	12.32	3.90	0.69	0.37	nd
134	52.51	27.11	0.66	1.81	2.69	1.37	11.57	3.92	0.45	0.26	nd
144	52.16	27.86	0.64	0.92	1.67	1.06	12.03	4.06	0.61	0.14	nd
168	52.04	23.83	1.17	2.16	3.59	2.14	13.44	3.83	0.57	0.40	nd
181	53.92	29.10	0.27	0.27	0.57	0.27	12.34	4.24	0.37	0.08	nd
206	49.74	24.06	1.50	5.13	7.24	1.55	11.30	3.81	0.36	1.03	nd
213	52.52	29.07	0.46	0.40	0.91	0.35	11.86	4.07	0.43	0.12	nd
214	51.17	23.97	1.42	2.21	3.90	2.84	13.32	3.30	0.44	0.43	nd
218	52.57	27.82	0.49	0.88	1.47	0.78	12.84	4.05	0.39	0.16	nd
222	50.20	21.37	1.22	5.52	7.40	2.41	10.82	3.58	0.46	1.95	nd
241	52.06	25.91	1.03	1.96	3.23	1.21	12.35	3.98	0.50	0.42	0.39
248	51.17	22.99	1.65	4.62	6.82	2.64	11.26	3.37	0.53	0.98	nd
250	50.55	24.75	0.83	3.50	4.75	2.12	12.07	3.81	0.55	0.49	nd
260	51.85	26.90	0.71	2.03	2.98	2.08	11.80	3.74	0.24	0.22	nd
261	53.12	28.59	0.27	0.48	0.81	0.53	12.02	4.39	0.42	0.11	nd
274	52.35	26.63	0.67	1.64	2.50	1.94	12.06	3.69	0.28	0.17	nd
283	52.11	25.03	1.00	2.00	3.24	2.05	12.82	3.89	0.49	0.36	nd
297	51.99	26.63	0.66	1.39	2.22	1.87	13.21	3.81	0.30	0.23	nd
344	53.11	19.51	2.25	5.55	8.47	2.02	9.87	3.60	0.66	1.54	nd
352	51.98	25.82	0.82	1.38	2.37	2.07	12.27	3.71	0.47	0.18	nd
357	52.93	24.02	1.17	3.09	4.63	1.66	10.22	3.74	0.92	0.64	nd
372	52.67	26.09	1.14	2.00	3.38	1.53	11.15	3.65	0.80	0.41	nd
376	51.44	25.66	1.32	2.68	4.32	1.06	10.92	3.77	0.74	0.68	nd

For sample locations see Map Number 1

Fe_2O_3(T) = Fe_2O_3 + FeO normalised to Fe_2O_3 (Factor 1.1113)

ANALYSES OF SAMPLES FROM THE WHITESTONE ANORTHOSITE

FROM MASON, 1969

SAMPLE NUMBER	SiO2 %	Al2O3 %	Fe2O3 %	FeO %	Fe2O3(T) %	MgO %	CaO %	Na2O %	K2O %	TiO2 %	P2O5 %	MnO %	CO2 %	S %
90	51.12	21.10	1.72	6.40	8.83	2.57	10.50	3.30	0.60	1.43	0.11	0.12	0.56	0.04
106	48.08	26.60	0.89	1.90	3.00	2.39	16.19	2.15	0.42	0.31	0.02	0.04	0.35	0.02
107	48.62	19.50	1.52	3.55	5.46	5.22	17.96	1.79	0.20	0.51	0.03	0.08	0.48	0.02
105	52.29	28.21	0.67	0.68	1.43	0.82	11.97	3.91	0.56	0.14	0.01	0.02	0.21	0.01
140	50.90	22.04	1.34	4.02	5.81	3.97	10.80	4.07	0.59	0.41	0.04	0.10	0.50	0.02
142	52.57	25.85	0.75	1.70	2.64	2.03	11.86	3.89	0.47	0.22	0.04	0.04	0.13	0.02
336	53.15	22.74	1.97	3.18	5.50	2.48	10.76	3.36	0.55	0.62	0.07	0.08	0.52	0.04

For sample locations see Map Number 1
Fe2O3(T) = Fe2O3 + FeO normalised to Fe2O3 (Factor 1.1113)

APPENDIX 4

Major Element Chemistry, Whitestone Anorthosite, 1986, 1987.

REPRESENTATIVE WHOLE ROCK ANALYSES OF SAMPLES FROM THE WHITESTONE ANORTHOSITE, 1986.

SAMPLE NUMBER	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %	CaO %	Na_2O %	K_2O %	TiO_2 %	P_2O_5 %	MnO %	S.G. %
86 CCM 0082	51.2	22.5	4.46	2.25	13.8	3.99	0.48	0.41	0.02	0.04	2.83
86 CCM 0085	51.6	29.3	1.09	0.14	12.1	4.14	0.44	0.15	0.01	0.01	2.71
86 CCM 0086	51.7	29.3	1.06	0.05	12.1	4.19	0.47	0.05	0.01	0.01	2.71
86 CCM 0089	52.0	25.0	3.17	1.32	12.0	4.39	0.53	0.34	0.03	0.02	2.75
86 CCM 0090	50.6	23.2	4.47	2.18	13.4	4.04	0.44	0.39	0.01	0.04	2.79
86 CCM 0095	52.0	27.6	1.50	0.64	11.8	4.32	0.50	0.14	0.07	0.01	2.79
86 CCM 0105	51.3	28.7	1.02	0.39	11.9	4.66	0.36	0.19	0.01	0.01	2.71
86 CCM 0106	51.1	27.7	1.73	1.30	12.4	4.23	0.32	0.27	0.00	0.01	2.77
86 CCM 0108	49.5	25.8	3.97	3.51	10.5	4.06	0.64	0.16	0.01	0.03	2.80
86 CCM 0109	51.6	22.0	5.29	3.19	10.8	3.92	0.68	0.71	0.04	0.06	2.83
86 CCM 0110	51.3	28.9	1.23	0.40	12.6	4.25	0.32	0.12	0.01	0.01	2.75
86 MMJ 3003	50.9	26.6	2.02	1.58	12.1	3.69	0.64	0.21	0.01	0.01	2.77
86 MMJ 3005	55.9	24.2	1.97	1.34	6.2	5.69	1.83	0.55	0.25	0.01	2.90
86 MMJ 3006	51.0	27.8	2.68	1.22	12.2	4.04	0.33	0.30	0.02	0.01	2.79
86 MMJ 3008	52.1	29.1	1.03	0.29	11.5	4.05	0.47	0.17	0.01	0.02	2.69
86 MMJ 3010	51.5	29.2	0.96	0.58	11.3	4.00	0.52	0.23	0.01	0.01	2.70
86 MMJ 3015	51.5	28.8	1.13	0.18	12.1	4.22	0.45	0.14	0.01	0.02	2.73
86 MMJ 3018	51.7	29.4	1.05	0.00	11.9	4.27	0.71	0.15	0.03	0.02	2.71
86 MMJ 3023	47.3	19.3	12.5	2.63	10.2	3.91	0.48	2.12	0.15	0.14	2.95
86 MMJ 3030	50.2	26.0	2.42	1.91	12.1	3.91	0.52	0.46	0.01	0.02	2.73
86 MMJ 3033	50.1	22.5	5.27	2.31	11.8	3.22	0.61	0.82	0.27	0.06	2.80

SAMPLE NUMBER	V (ppm)	Cr (ppm)	Pt (ppb)	Pd (ppb)	CO_2 (wt.%)	S (wt.%)	LOI (wt.%)
86 CCM 0082	76	25	<1	<1	0.32	0.06	0.60
86 CCM 0085	2	<10	<1	<1	0.19	0.02	0.30
86 CCM 0086	<1	<10	<1	2	0.35	0.02	0.20
86 CCM 0089	44	12	<1	<1	0.71	0.07	0.60
86 CCM 0090	76	29	<1	<1	0.48	0.02	0.40
86 CCM 0095	11	<10	<1	<1	0.31	0.04	0.20
86 CCM 0105	5	<10	<1	<1	0.46	0.02	0.50
86 CCM 0106	24	42	<1	<1	0.37	0.02	0.40
86 CCM 0108	7	<10	<1	<1	0.36	0.02	1.70
86 CCM 0109	95	71	<1	<1	0.53	0.06	0.70
86 CCM 0110	11	18	<1	<1	0.36	0.01	0.60
86 MMJ 3003	35	46	-	-	0.16	0.01	0.70
86 MMJ 3005	41	15	-	-	0.32	0.01	0.70
86 MMJ 3006	58	15	<1	<1	0.16	0.01	0.40
86 MMJ 3008	6	<10	-	-	0.16	0.01	0.40
86 MMJ 3010	3	<10	-	-	0.26	0.03	0.70
86 MMJ 3015	7	<10	-	-	0.19	0.01	0.10
86 MMJ 3018	3	<10	-	-	0.20	0.01	0.20
86 MMJ 3023	304	<10	-	-	0.72	0.04	0.80
86 MMJ 3030	49	61	-	-	0.43	0.02	0.90
86 MMJ 3033	96	23	-	-	1.15	0.10	1,00

Analyses by the Geoscience Laboratory of the Ontario Geological Survey.

Major and minor oxides by X-ray fluorescence

V by ICP - MS

Other trace elements by AA

REPRESENTATIVE WHOLE ROCK ANALYSES OF SAMPLES

FROM THE WHITESTONE ANORTHOSITE, 1987

SAMPLE NUMBER	SiO2 %	Al2O3 %	Fe2O3 %	MgO %	CaO %	Na2O %	K2O %	TiO2 %	P2O5 %	MnO %	LOI %	TOTAL
87 CCM 0040	52.05	25.74	3.29	2.35	12.85	3.69	0.5	0.23	0.21	0.06	0.31	101.30
87 CCM 0042	50.94	27.71	2.02	1.12	12.11	3.84	0.6	0.13	0.21	0.04	0.61	99.33
87 CCM 0043	51.92	24.37	4.10	3.46	12.23	3.68	0.9	0.21	0.24	0.08	0.42	101.60
87 CCM 0048	52.18	28.44	1.48	0.43	13.00	4.11	1.3	0.13	0.26	0.02	0.26	101.60
87 CCM 0054	52.61	24.80	2.63	1.63	13.53	4.03	1.8	0.20	0.28	0.03	0.26	101.80
87 CCM 0055	51.84	25.46	2.75	1.68	13.44	3.96	1.0	0.22	0.22	0.04	0.25	100.85
87 CCM 0056	46.47	19.32	6.79	4.60	14.75	2.39	2.0	0.82	0.84	0.05	0.61	98.64
87 CCM 0057	49.63	24.27	2.49	0.99	13.42	3.37	3.4	0.17	0.41	0.03	0.32	98.50
87 CCM 0059	51.29	29.36	1.60	0.28	12.21	4.25	0.6	0.19	0.22	0.02	0.24	100.25
87 CCM 0060	50.91	28.58	1.25	0.20	11.95	4.14	0.66	0.15	0.02	0.01	0.03	98.31
87 CCM 0061	51.06	26.10	3.91	2.19	12.40	3.57	0.4	0.36	0.19	0.06	0.18	100.35
87 CCM 0063	51.29	25.73	3.53	2.28	13.12	3.58	0.5	0.27	0.21	0.06	0.25	100.80
87 CCM 0064	52.82	29.67	1.35	0.32	12.18	4.21	0.8	0.17	0.24	0.02	0.16	101.95
87 CCM 0066	52.01	27.26	2.30	1.31	12.89	3.81	0.5	0.19	0.20	0.03	0.26	100.75
87 CCM 0068	51.43	29.89	0.93	0.20	13.20	3.88	0.2	0.10	0.19	0.01	0.20	100.25
87 CCM 0069	51.55	29.41	1.21	0.40	13.34	3.78	0.6	0.10	0.21	0.01	0.21	100.80
87 CCM 0070	50.97	27.39	1.93	0.81	13.30	3.80	0.8	0.18	0.22	0.02	0.30	99.72
87 CCM 0071	52.92	28.81	1.00	0.16	11.94	4.43	0.9	0.13	0.21	0.01	0.19	100.70
87 CCM 0073	52.33	28.16	1.18	0.21	12.09	4.35	0.7	0.10	0.20	0.01	0.18	99.51
87 CCM 0074	51.21	26.97	1.85	0.70	12.81	4.03	0.6	0.19	0.20	0.02	0.10	98.68
87 CCM 0094	51.15	27.67	1.87	0.92	12.62	3.93	0.7	0.18	0.21	0.02	0.41	99.68
87 CCM 0113	51.97	26.38	2.66	1.91	12.31	3.88	0.6	0.17	0.21	0.04	0.29	100.40
87 CCM 0115	51.92	28.43	1.20	0.34	12.59	4.17	0.7	0.09	0.21	0.01	0.19	99.85
87 CCM 0121	52.00	28.46	1.07	0.43	11.66	4.11	0.57	0.12	0.02	0.01	0.64	99.11
87 MMJ 3011 C	51.80	27.73	1.14	0.44	11.78	4.39	0.8	0.09	0.22	0.01	0.72	99.12
87 MMJ 3016 C	51.84	25.67	2.31	1.21	12.98	4.05	0.8	0.17	0.21	0.02	0.23	99.49
87 MMJ 3017 C	52.44	25.02	2.79	1.62	13.89	3.96	0.8	0.24	0.22	0.03	0.13	101.15
87 MMJ 3018 C	51.40	28.95	1.04	0.34	12.94	3.76	0.7	0.09	0.21	0.01	0.24	99.68
87 MMJ 3022 C	51.67	29.11	1.41	0.63	13.21	3.71	0.7	0.14	0.23	0.02	0.25	101.10
87 MMJ 3023 C	50.98	29.09	1.05	0.38	13.13	3.70	0.6	0.08	0.21	0.01	0.31	99.54
87 MMJ 3033 C	53.13	26.67	2.10	1.15	12.77	4.12	0.9	0.19	0.22	0.03	0.14	101.40
87 MMJ 3041 C	52.00	28.82	1.15	0.38	12.84	3.92	0.6	0.09	0.20	0.01	0.22	100.25

APPENDIX 5

Major Element Chemistry, Moon River Anorthosite.

REPRESENTATIVE WHOLE ROCK ANALYSES OF SAMPLES
FROM THE MOON RIVER ANORTHOSITE

SAMPLE NUMBER	SiO2 %	Al2O3 %	Fe2O3 %	MgO %	CaO %	Na2O %	K2O %	TiO2 %	P2O5 %	MnO %	LOI %	TOTAL %
87 CCM 0010	52.95	28.12	1.50	0.88	11.57	4.17	0.64	0.14	0.07	0.02	0.54	100.65
87 CCM 0015	52.17	28.16	2.23	1.60	11.63	4.27	0.7	0.16	0.22	0.04	0.57	101.75
87 CCM 0016	51.13	27.17	2.46	1.97	11.15	3.31	1.1	0.23	0.20	0.04	0.80	99.56
87 CCM 0019	52.35	28.39	1.40	0.76	11.05	4.82	0.6	0.13	0.21	0.02	0.51	100.25
87 CCM 0026	51.78	27.64	1.95	1.29	11.43	4.46	0.5	0.11	0.20	0.03	0.32	99.71
87 CCM 0027	52.10	27.92	1.82	1.05	11.22	4.30	0.8	0.15	0.22	0.03	0.49	100.10
87 CCM 0030	52.36	27.97	1.64	1.11	10.88	4.09	0.9	0.16	0.21	0.03	0.68	100.05
87 CCM 0032	53.10	28.72	1.32	0.73	10.91	4.72	0.9	0.11	0.20	0.02	0.62	101.35
87 CCM 0035	51.87	26.10	3.83	1.59	10.39	4.56	0.7	0.61	0.41	0.07	0.53	100.65
87 CCM 0101	52.82	28.75	0.94	0.40	11.85	4.51	0.4	0.10	0.19	0.01	0.27	100.25
87 CCM 0102	52.35	27.97	1.36	0.70	11.23	4.30	0.6	0.12	0.19	0.02	0.51	99.35
87 CCM 0104	52.62	27.71	1.45	0.42	11.16	4.52	0.7	0.12	0.20	0.01	0.33	99.24
87 CCM 0104D	52.03	28.38	1.02	0.36	11.70	4.50	0.59	0.12	0.01	0.01	0.34	99.08
87 CCM 0105	52.30	28.55	1.65	0.85	11.93	4.40	0.43	0.12	0.05	0.02	0.31	100.60
87 CCM 0106	52.50	27.91	1.48	0.64	11.80	4.42	0.6	0.13	0.21	0.01	0.18	99.88

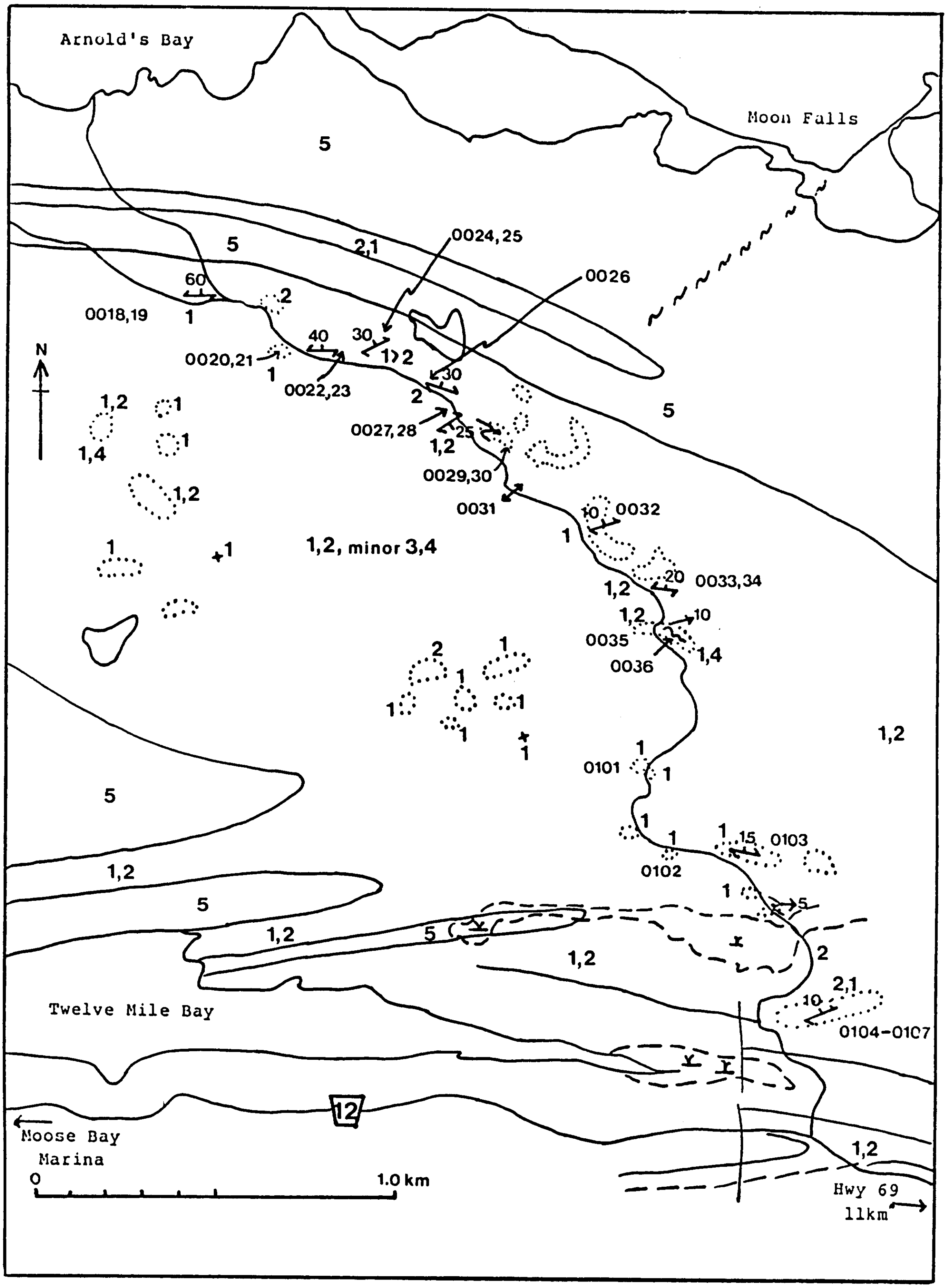
Analyses by Chemex Labs Ltd., Mississauga, Ontario
Major oxides by ICP-AES
LOI - Furnace

LEGEND

1 Anorthosite
2 Gabbroic anorthosite
3 Anorthositic gabbro
4 Gabbro
5 Tonalitic and monzonitic gneiss

Limit of outcrop
Strike and dip of foliation
Azimuth and plunge of lineation
Sample location and number (87CCM-1234 series)

Map traced from air photos numbers:
77-4504-36-12
77-4505-36-116



Appendix 5: Moon River Anorthosite: sample location map. For legend see facing page.

APPENDIX 6

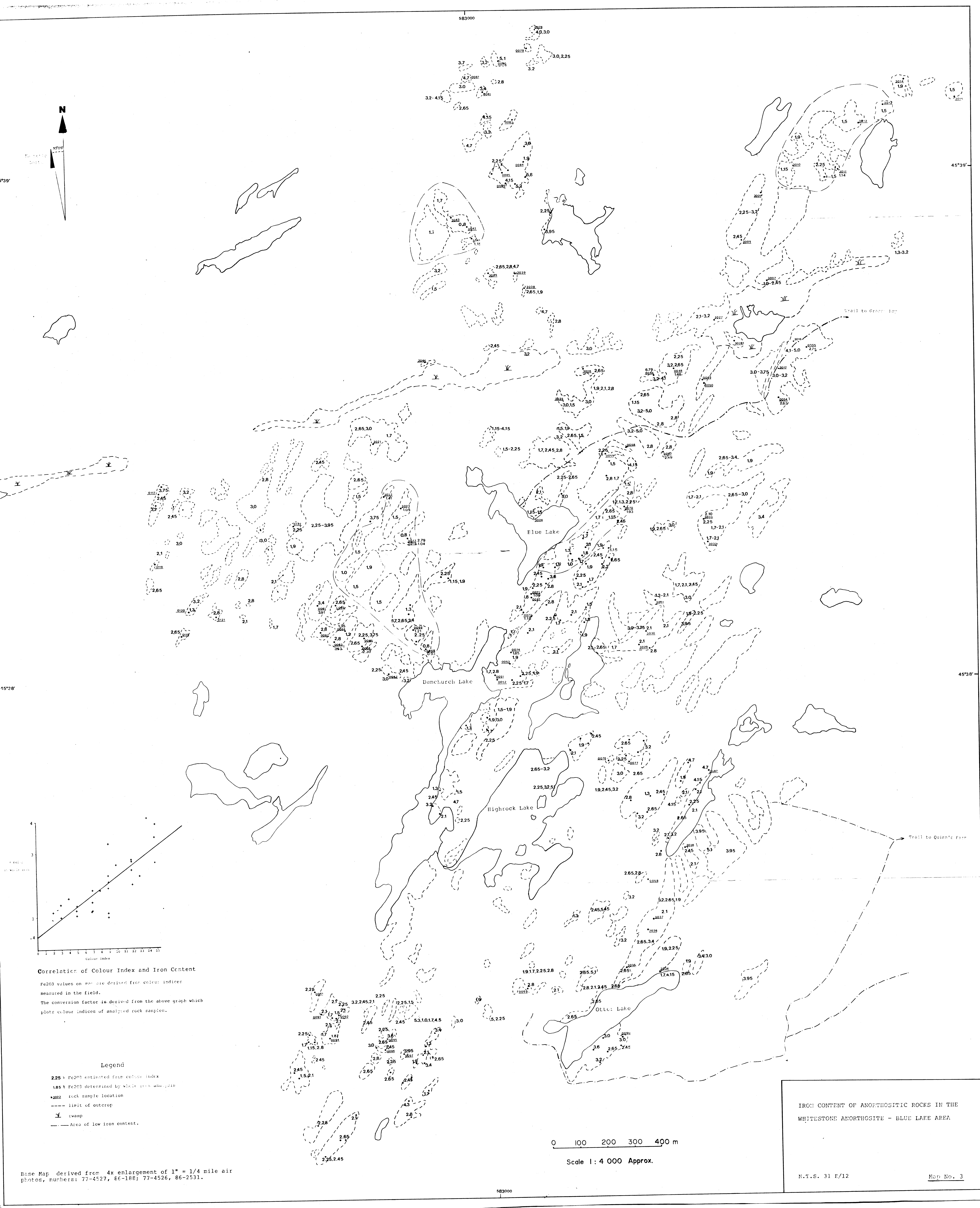
Major Element Chemistry, Arnstein Anorthosite.

REPRESENTATIVE ANALYSES OF SAMPLES
FROM THE ARNSTEIN ANORTHOSITE, 1986

SAMPLE NUMBER	SiO2 %	Al2O3 %	Fe2O3 %	MgO %	CaO %	Na2O %	K2O %	TiO2 %	P2O5 %	MnO %	S.G. %
86 MMJ 2002	48.7	30.2	1.47	0.63	13.7	3.41	0.39	0.14	0.01	0.00	2.78
86 MMJ 2005	50.2	28.5	1.84	0.45	12.7	3.91	0.80	0.16	0.01	0.01	2.80
86 MMJ 2023	53.2	29.0	0.67	0.14	10.5	4.96	0.55	0.20	0.01	0.01	2.70
86 MMJ 2025	51.1	28.7	1.36	1.20	12.4	3.47	0.18	0.17	0.01	0.00	2.78
86 MMJ 2033	54.5	24.0	2.23	1.02	5.71	5.92	2.46	0.13	0.01	0.01	2.78
86 MMJ 2035	47.1	25.8	4.41	5.07	11.1	3.21	0.70	0.10	0.01	0.03	2.81
86 MMJ 2037	51.1	27.0	2.08	1.40	12.6	3.66	0.35	0.27	0.02	0.00	2.75
86 MMJ 2042	51.7	29.7	0.67	0.04	11.4	4.33	0.57	0.12	0.01	0.01	2.66
86 MMJ 2050	51.8	26.0	2.47	2.39	11.9	4.02	0.40	0.30	0.04	0.01	2.79
86 MMJ 2057	51.8	29.0	0.69	0.06	11.2	4.16	1.02	0.18	0.01	0.01	2.69
86 MMJ 2065	48.5	26.0	3.42	3.68	13.4	2.15	0.51	0.45	0.01	0.04	2.79

SAMPLE NUMBER	V (ppm)	Cr (ppm)	Pt (ppb)	Pd (ppb)	CO2 (wt.%)	S (wt.%)	LOI
86 MMJ 2002	10	<10	-	-	0.32	0.02	1.0
86 MMJ 2005	15	<10	-	-	0.36	0.01	1.3
86 MMJ 2023	<1	<10	-	-	0.12	0.01	0.3
86 MMJ 2025	18	39	-	-	0.27	0.01	0.4
86 MMJ 2030	179	17	<1	<1	0.24	0.06	0.4
86 MMJ 2033	14	22	<1	<1	0.48	0.36	2.5
86 MMJ 2035	7	<10	-	-	0.58	0.02	1.8
86 MMJ 2037	49	37	-	-	0.47	0.01	0.6
86 MMJ 2042	<1	<10	-	-	0.32	0.01	0.9
86 MMJ 2048	244	69	-	-	0.32	0.01	0.7
86 MMJ 2050	46	39	-	-	0.36	0.01	0.6
86 MMJ 2052	269	47	2	<1	1.01	0.08	0.6
86 MMJ 2053	201	82	1	<1	1.17	0.02	1.0
86 MMJ 2054	164	36	<1	<1	0.92	0.08	0.2
86 MMJ 2055	294	48	<1	<1	0.36	0.06	0.4
86 MMJ 2056	217	39	<1	<1	0.86	0.01	0.4
86 MMJ 2057	2	<10	-	-	0.12	0.01	1.3
86 MMJ 2065	63	97	-	-	0.37	0.02	1.0
86 mMJ 2073	135	31	-	-	0.62	0.02	0.5

Analyses by the Geoscience Laboratory of the Ontario Geological Survey
Major and minor oxides by X-ray fluorescence
V by ICP - MS
Other trace elements by AA



Correlation of Colour Index and Iron Content

Fe203 values on map are derived from colour indices measured in the field.
The conversion factor is derived from the above graph which plots colour indices of analyzed rock samples.

Legend

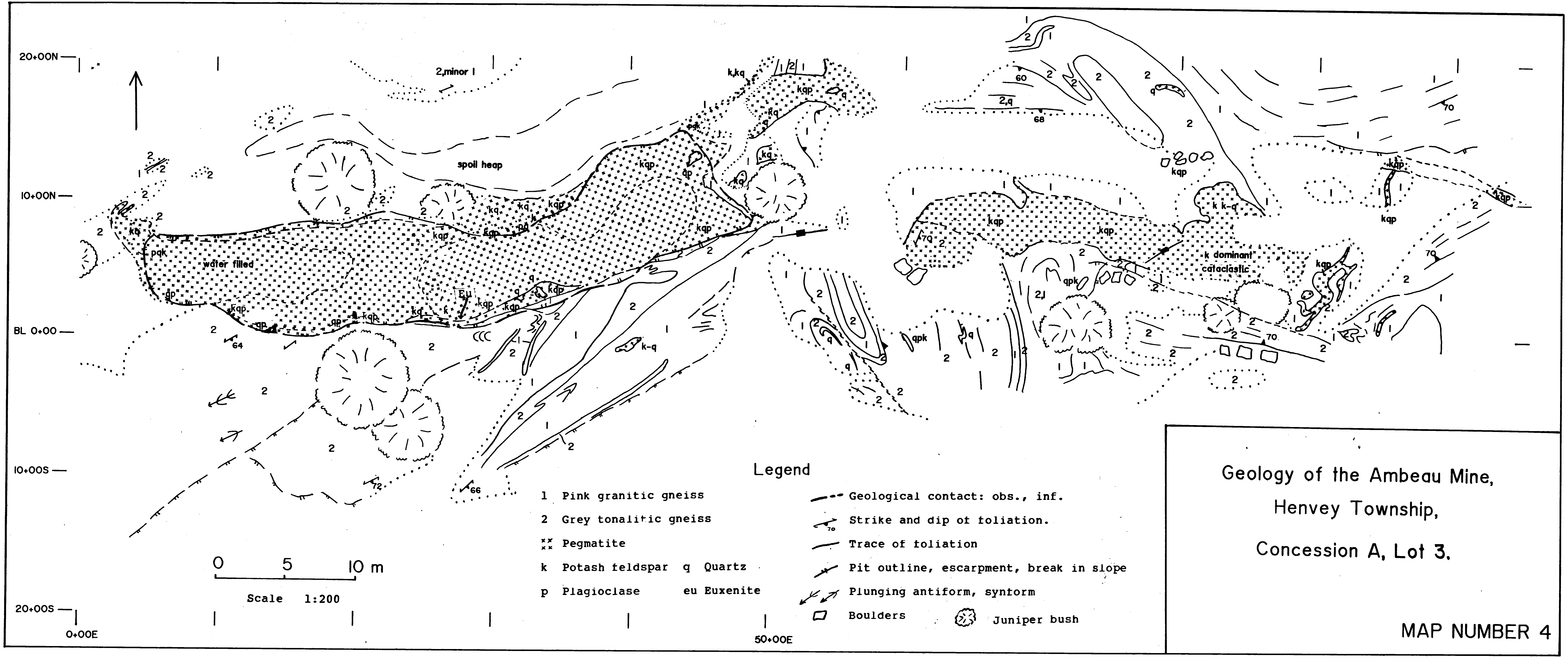
2.25 % Fe203 estimated from colour index
1.85 % Fe203 determined by whole rock analysis
●3022 rock sample location
---- limit of outcrop
swamp
—·— Area of low iron content.

Base Map derived from 4x enlargement of 1" = 1/4 mile air photos, numbers: 77-4527, 86-188; 77-4526, 86-2531.

IRON CONTENT OF ANORTHOSITIC ROCKS IN THE WHITESTONE ANORTHOSITE - BLUE LAKE AREA

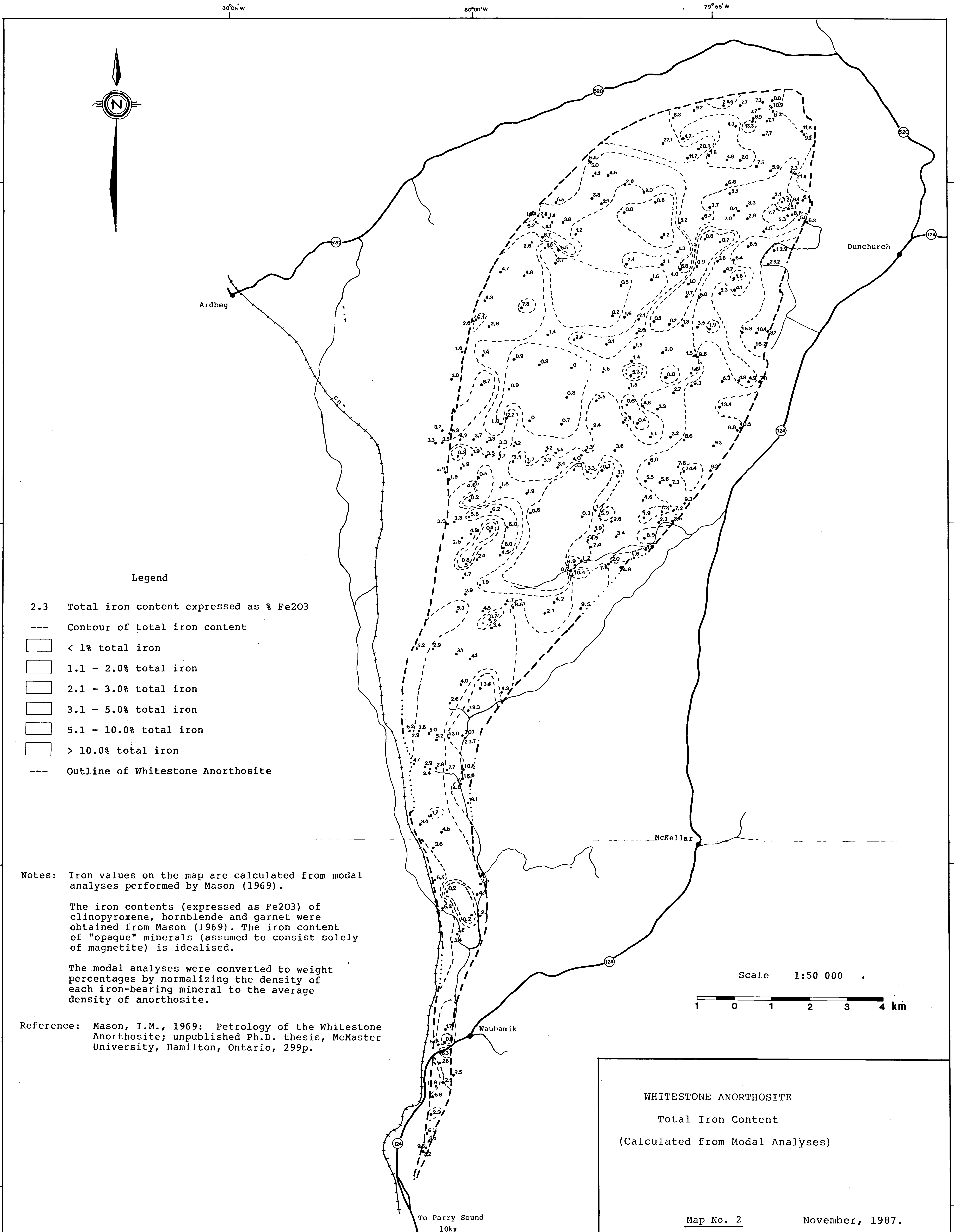
N.T.S. 31 E/12

Map No. 3



Geology of the Ambeau Mine,
Henvey Township,
Concession A, Lot 3.

MAP NUMBER 4



Legend

2.3 Total iron content expressed as % Fe2O3

--- Contour of total iron content

< 1% total iron

1.1 - 2.0% total iron

2.1 - 3.0% total iron

3.1 - 5.0% total iron

5.1 - 10.0% total iron

> 10.0% total iron

--- Outline of Whitestone Anorthosite

Notes: Iron values on the map are calculated from modal analyses performed by Mason (1969).

The iron contents (expressed as Fe2O3) of clinopyroxene, hornblende and garnet were obtained from Mason (1969). The iron content of "opaque" minerals (assumed to consist solely of magnetite) is idealised.

The modal analyses were converted to weight percentages by normalizing the density of each iron-bearing mineral to the average density of anorthosite.

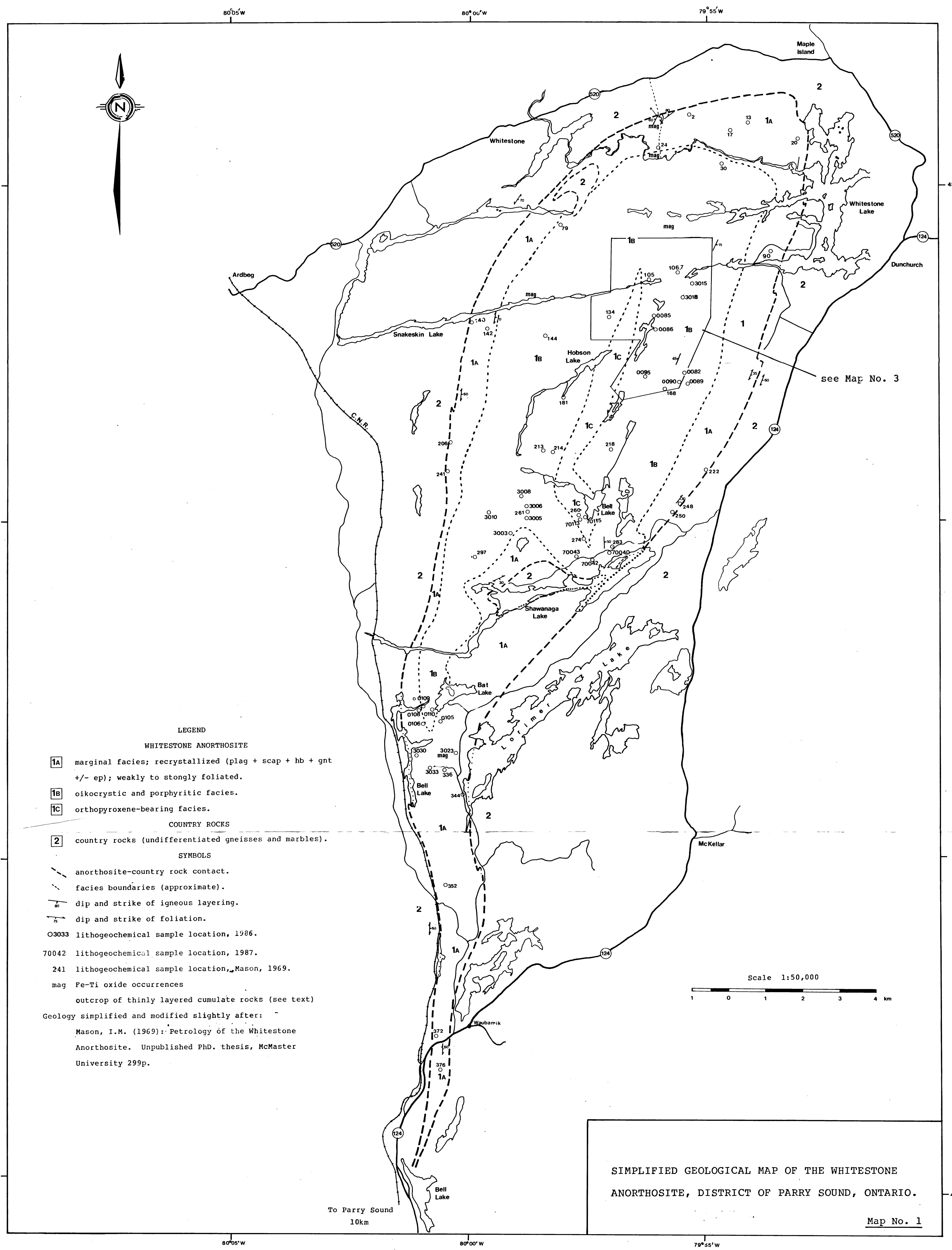
Reference: Mason, I.M., 1969: Petrology of the Whitestone Anorthosite; unpublished Ph.D. thesis, McMaster University, Hamilton, Ontario, 299p.

WHITESTONE ANORTHOSITE

Total Iron Content

(Calculated from Modal Analyses)

Map No. 2 November, 1987.



LEGEND

WHITESTONE ANORTHOSITE

1A	marginal facies; recrystallized (plag + scap + hb + gnt +/- ep); weakly to stongly foliated.
1B	oikocrystic and porphyritic facies.
1C	orthopyroxene-bearing facies.

COUNTRY ROCKS

2	country rocks (undifferentiated gneisses and marbles).

SYMBOLS

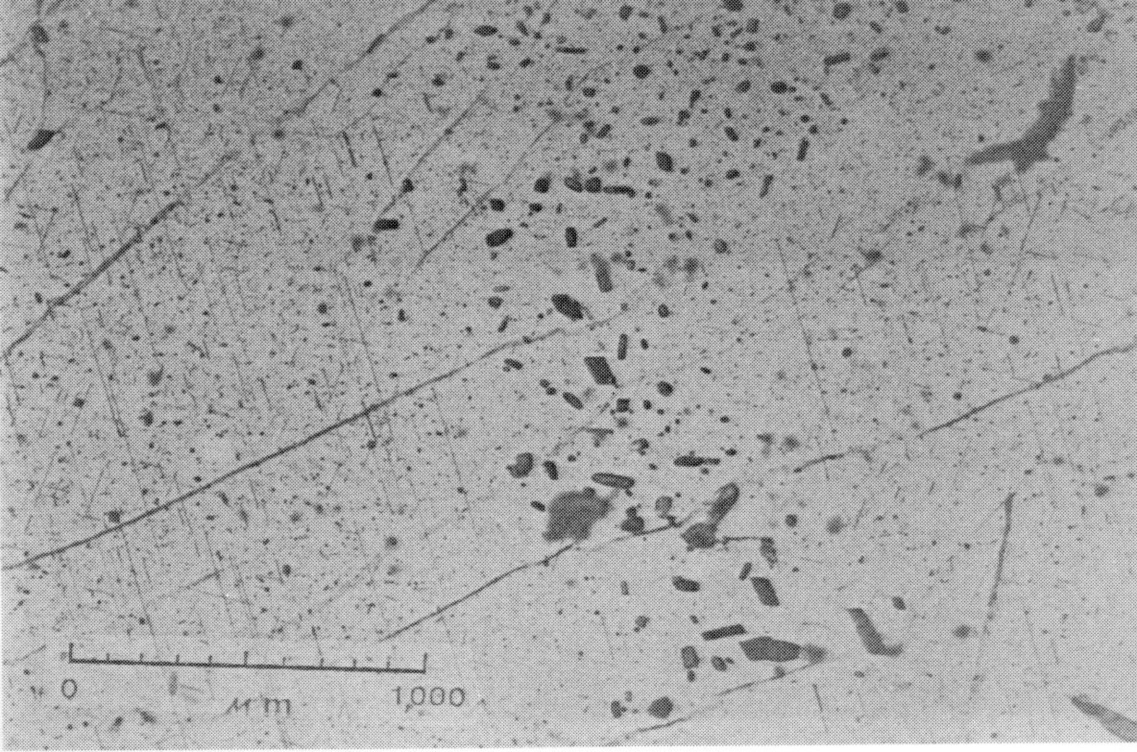
╲ ╲	anorthosite-country rock contact.
⋱	facies boundaries (approximate).
80	dip and strike of igneous layering.
75	dip and strike of foliation.
○3033	lithogeochemical sample location, 1986.
70042	lithogeochemical sample location, 1987.
241	lithogeochemical sample location, Mason, 1969.
mag	Fe-Ti oxide occurrences
·	outcrop of thinly layered cumulate rocks (see text)

Geology simplified and modified slightly after:

Mason, I.M. (1969): Petrology of the Whitestone Anorthosite. Unpublished PhD. thesis, McMaster University 299p.

SIMPLIFIED GEOLOGICAL MAP OF THE WHITESTONE ANORTHOSITE, DISTRICT OF PARRY SOUND, ONTARIO.

Map No. 1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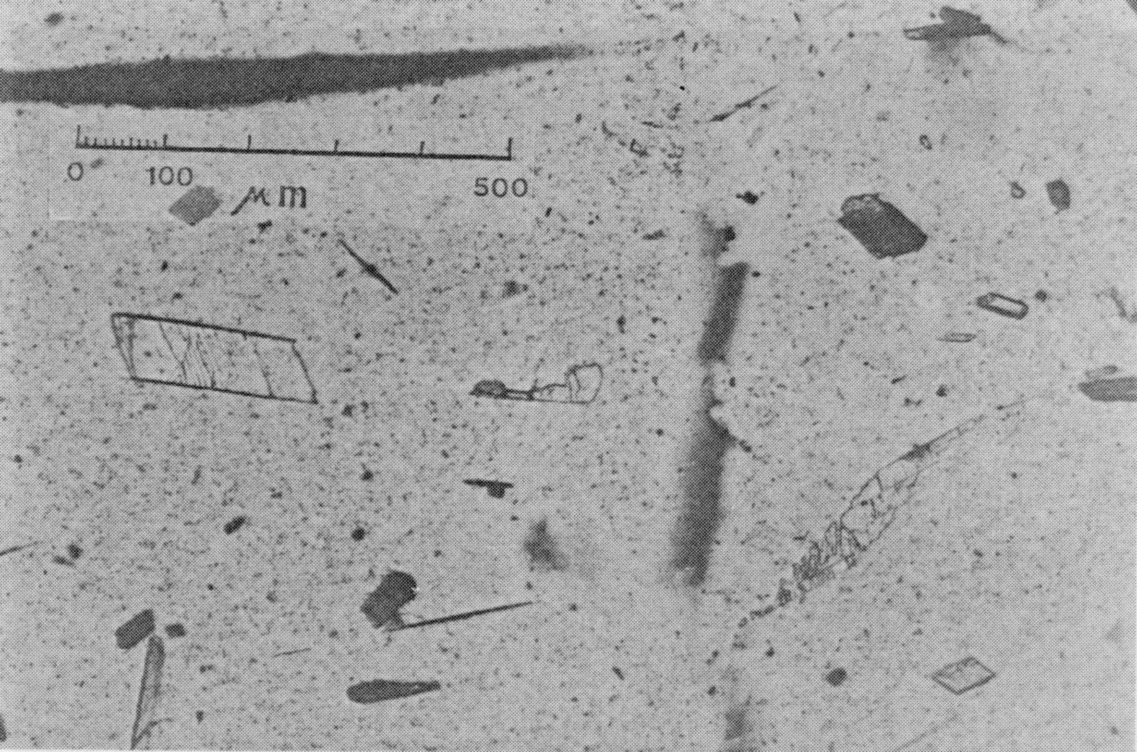
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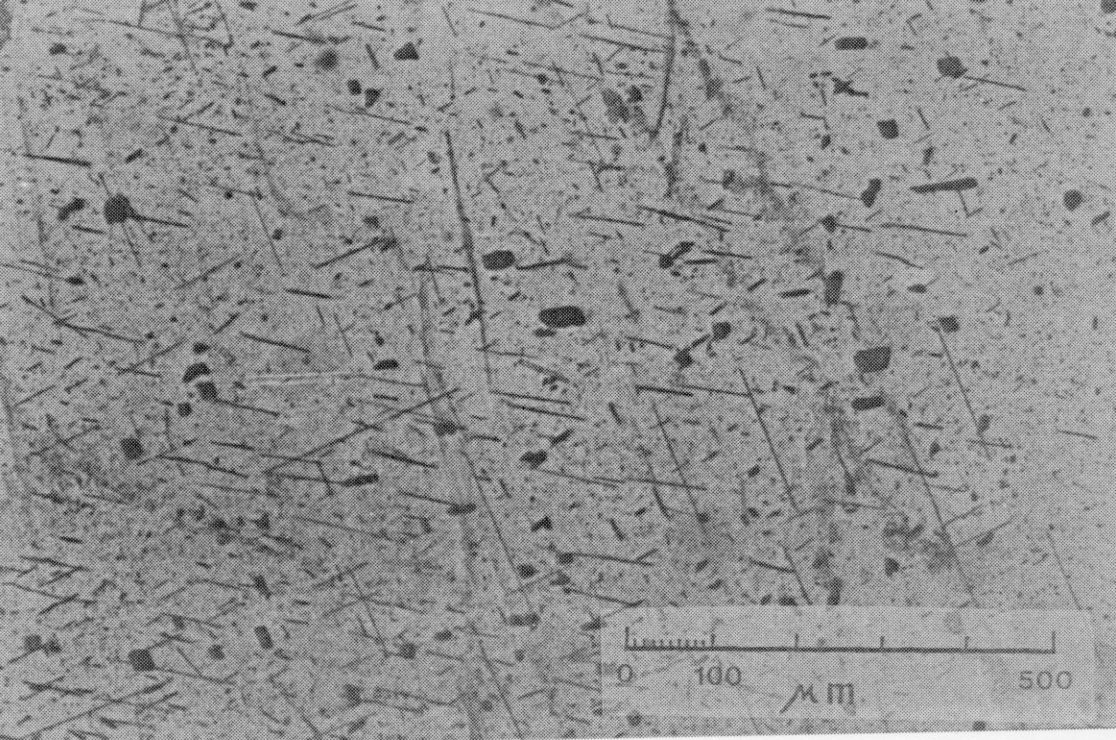
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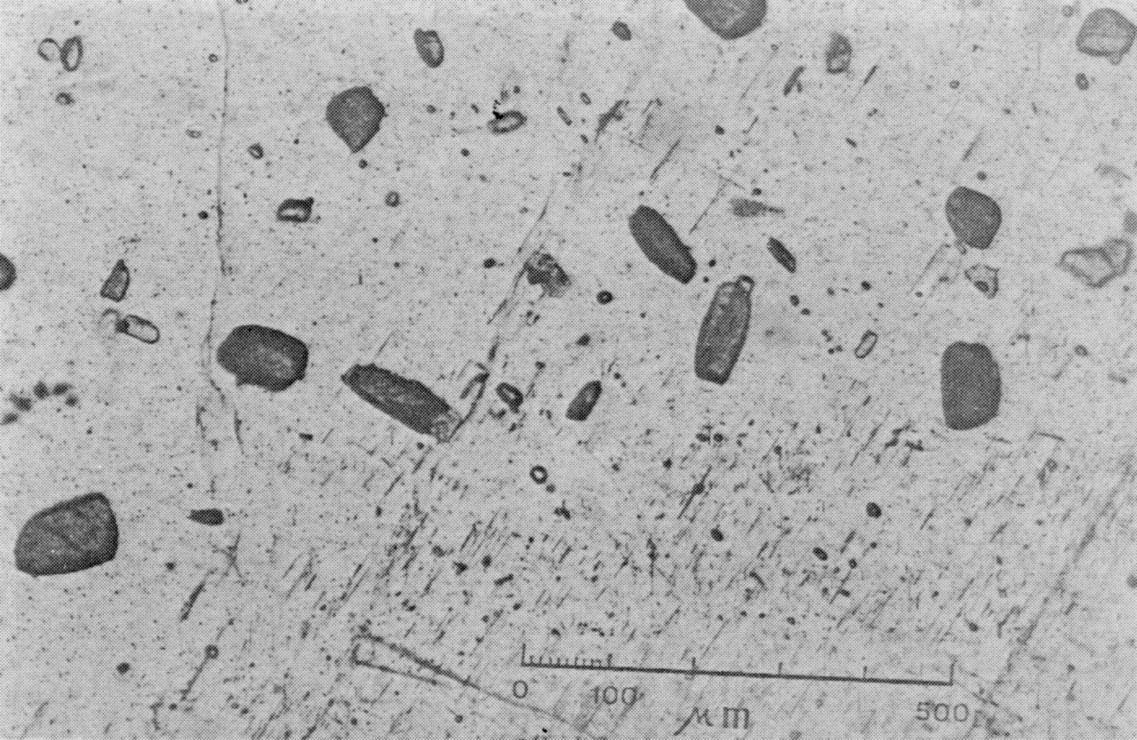
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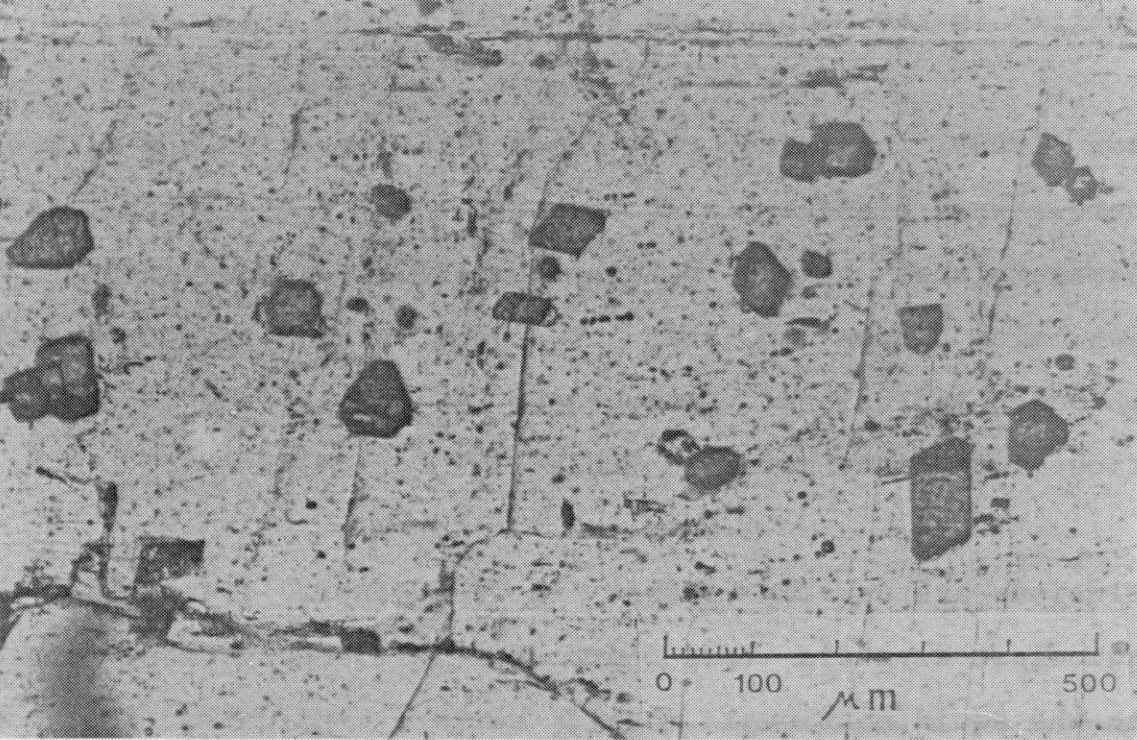
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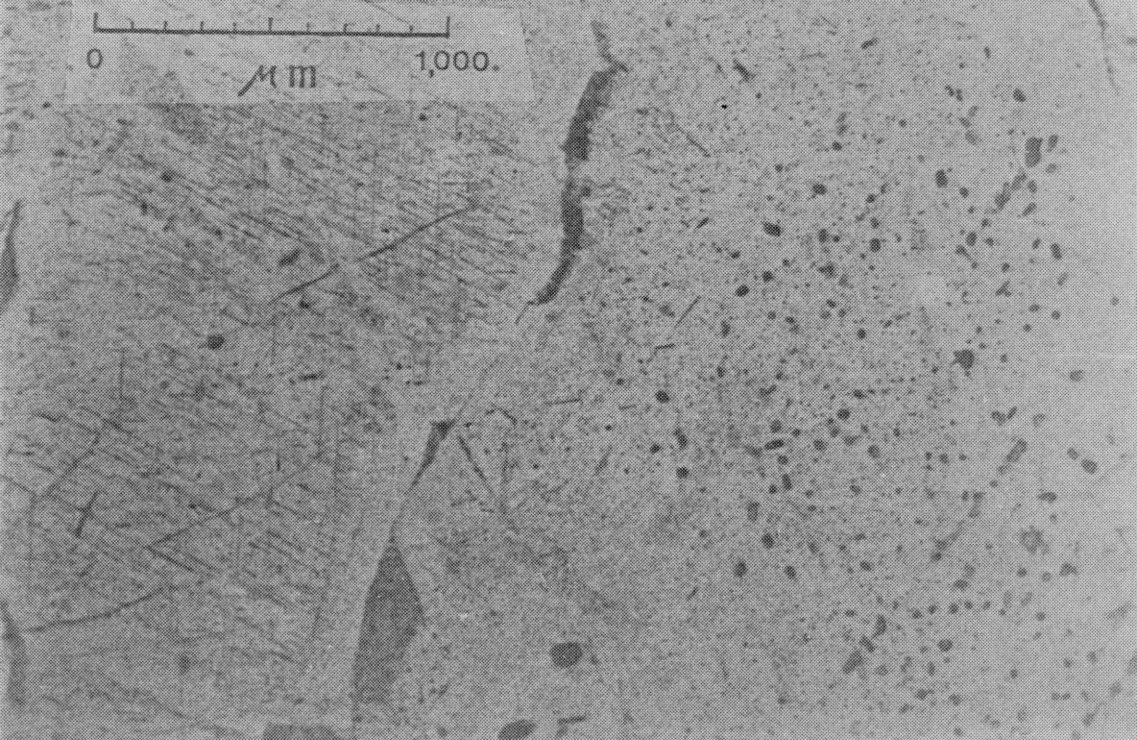
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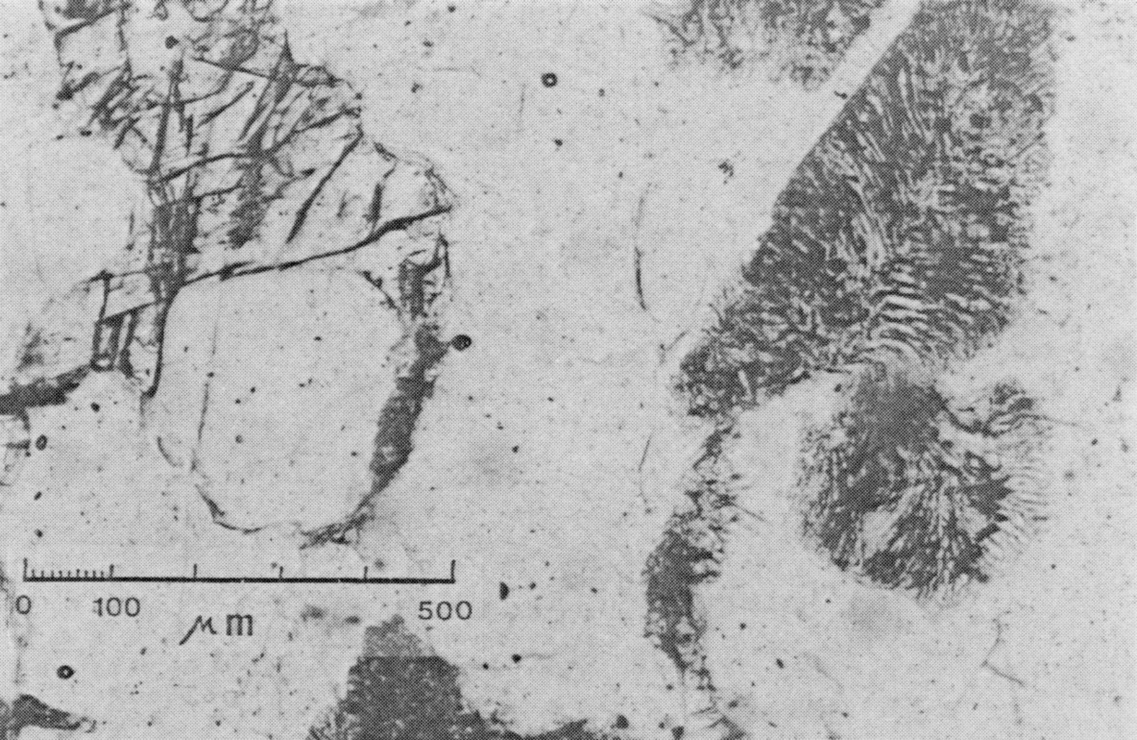
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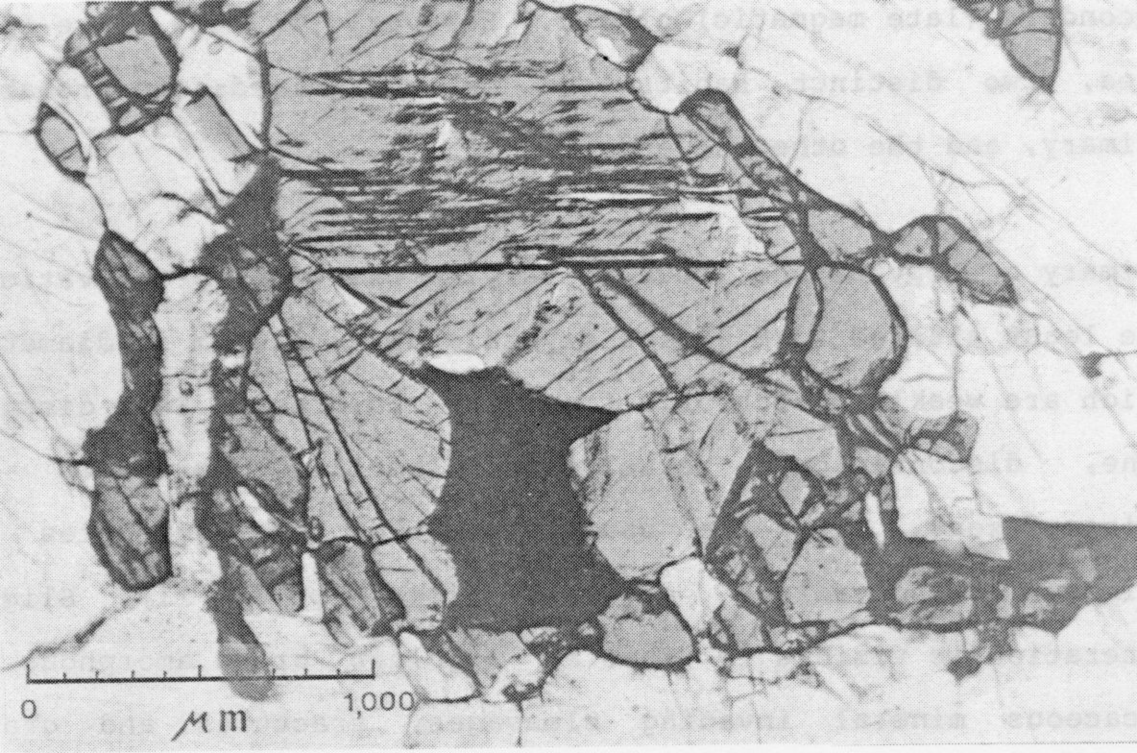
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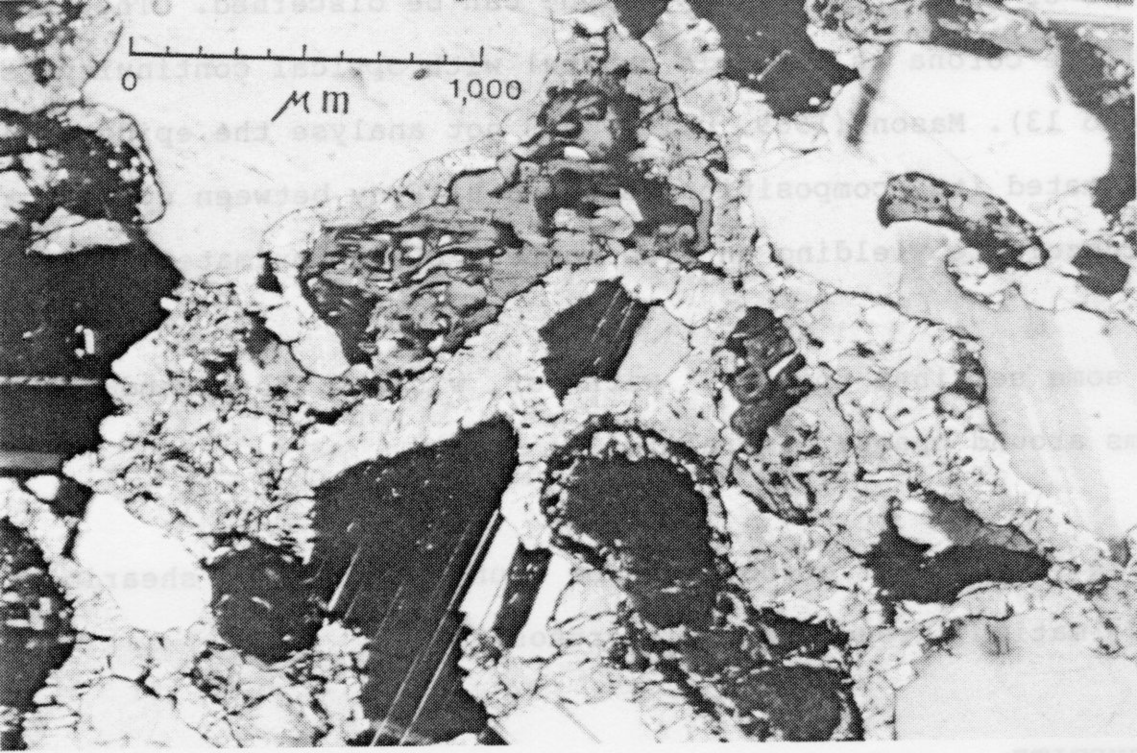
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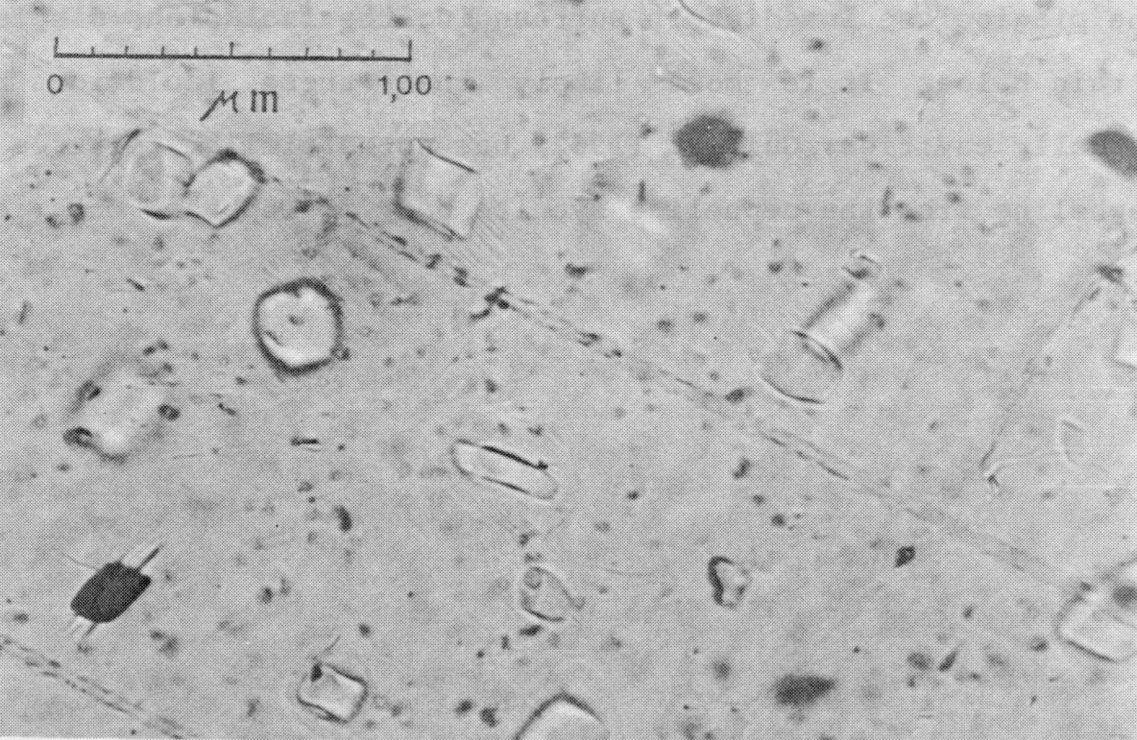
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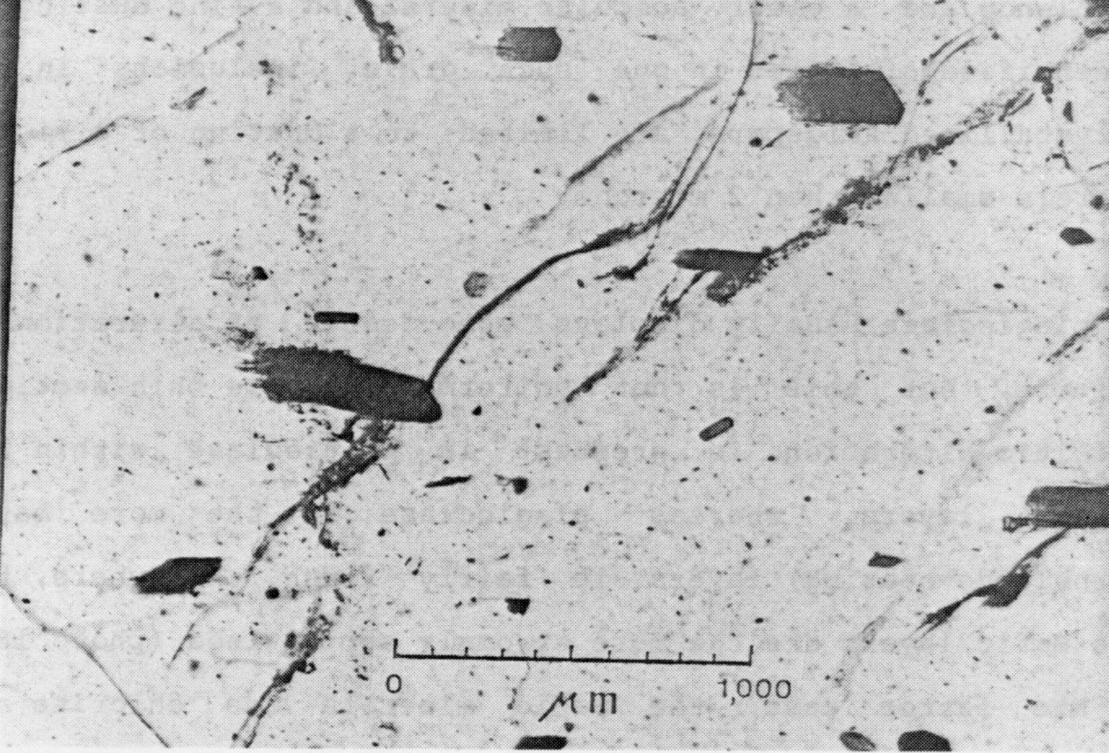
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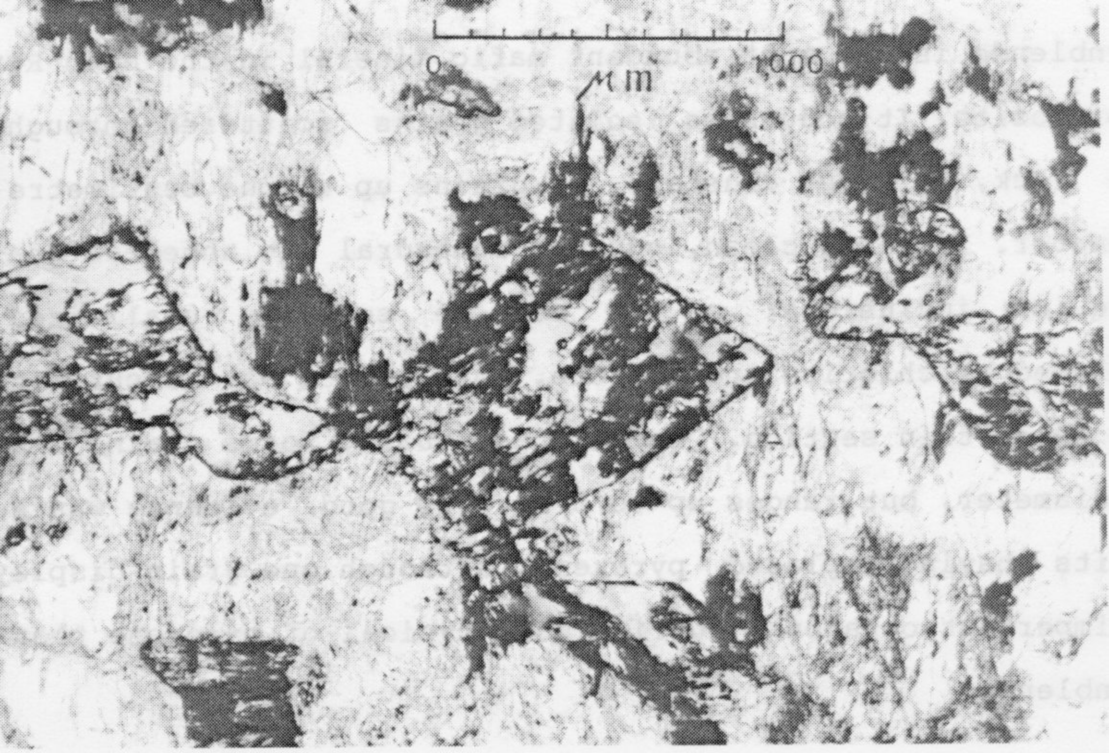
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