

ABSTRACT

Kevin O. Headd, Jr. CORE LITHOLOGIES, VEINS AND FRACTURES OF THE CONCORD GABBRO/SYENITE COMPLEX OF NORTH CAROLINA. (Under the direction of Dr. Richard L. Mauger) Department of Geology, September 1993.

The purpose of this thesis is to study the rocks of the Concord Gabbro/Syenite complex. The Concord Gabbro/Syenite complex lies in the Charlotte Belt of North Carolina. Nine drill cores from the southeastern corner of the complex were studied. Fractures and veins in the syenite consist of mainly quartz and calcite. The gabbro fractures and veins are primarily filled with quartz, calcite, and chlorite. The gabbro cores are riddled with graphic granite, fine-grained gabbroic, and coarse-grained gabbroic dikes. None of the dikes that cut the gabbro were found in the syenite. Three fluid species (CO₂, H₂O, and a sulfur species) circulated through the gabbro fractures. The maximum depth of oxidation and circulation of groundwater is indicated by the maximum depth of oxidation in the mineralized fissures.

CORE LITHOLOGIES, VEINS AND FRACTURES OF THE CONCORD
GABBRO/SYENITE COMPLEX OF NORTH CAROLINA

A Thesis
Presented to
the Faculty of the Department of Geology
East Carolina University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science in Geology

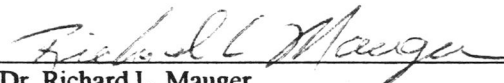
by
Kevin O. Headd, Jr.
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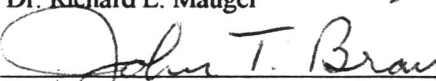
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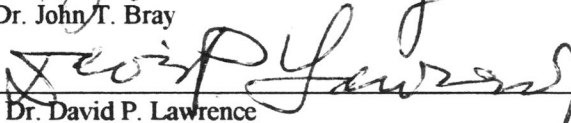
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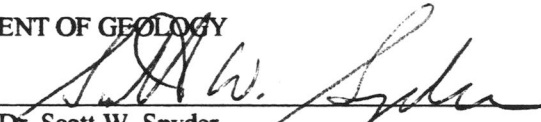
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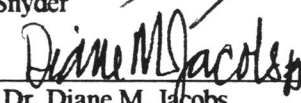
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DEDICATION

In memory of Carl Johnson, who was not as lucky as I was
during the fire in Trenton, New Jersey on February 22, 1985.

ACKNOWLEDGEMENTS

I would like to express my thanks to Dr. Richard Mauger, Dr. Terri Woods, Dr. David Lawrence, and Dr. Bray. Their contributions to this thesis are immeasurable. Mr. Steve Mason, formerly of Engineering Tectonics, donated the cores used in this thesis. Mr. Barry Nelson, of Bain and Palmer, provided additional observations and data on the thesis site. Mr. James Watson lent me an ear whenever a technical problem arose. Dr. William White discussed his field activities in the Concord Gabbro/Syenite Complex with me at his home.

Thank you to all the people who assisted in the preserving of my life after I sustained burn injuries to 50% of my body. Dr. John Remensnyder, emeritus of Shriner's Burn Institute (Boston Unit), directed and was successful in mapping out my recovery. Dr. David Lunney, Dr. Robert Morrison, and Dr. Scott Snyder introduced me to East Carolina University and research, through the Science Institute for the Disabled (SID) program.

I wish to thank my parents, Kevin Headd Sr and Maureen Miller, for staying on my back with the familiar question: "When are you going to finish your thesis?".

Lastly, I wish to thank my wife Lisa and our baby girl Kelly for sacrificing some of their time with me to complete this thesis.

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INTRODUCTION

The Concord Gabbro/Syenite Complex, southwestern Cabarrus and eastern Mecklenburg Counties, is part of the North Carolina Charlotte Belt. Syenite surrounds the gabbro core in a circular pattern, except for a small portion of the southern flank where the syenite is absent. The gabbro is deeply weathered and covered with thick soils. The syenite, because it weathers more slowly, produces slightly higher topography and more outcrops. Few outcrops exist and the best exposures are in quarries. Geophysical data, soil types, and rock float were used in mapping the bedrock geology (Olsen and others, 1983). The exact geologic relations of a small area along the southern edge of the complex are still in question.

Nine 2 1/2-inch, diamond-drill cores were recovered from an area along the Rocky River about 5 miles northeast of Harrisburg, NC, just south of NC Route 49. The deepest hole reached 200 feet. The cores, drilled for a groundwater study in the area, were donated to East Carolina University by Engineering Tectonics, P. A. of Winston-Salem, NC.

PREVIOUS WORKS

The Concord Gabbro/Syenite Complex has been noted by numerous investigators. It was included in a description of the

building and ornamental stones of North Carolina (Watson and Laney, 1906). LeGrand and Mundorff (1952) studied the groundwater in the area and LeGrand and Bell (1966) published a field guide. The first modern map of the complex was by White and Mundorff (1944). Later mapping (Ray, 1960) employed aerial photos, aeromagnetic and aeroradioactivity measurements (Johnson and Bates, 1960), and gravity studies (Morgan, 1963). Morgan also studied pegmatites (graphic granite) in the complex; they range from a few inches to 15 feet wide and are sometimes traceable for up to a thousand feet. Trace element analyses of the syenite and gabbro were performed by Price (1969). A petrologic study was done by Cabaup (1969), and Fullager (1971) dated the syenite at $401 \text{ Ma} \pm 30$ (Rb-Sr). Olsen's (1982) geophysical model of the complex suggests a 6 km-thick gabbro pluton surrounded by a syenite ring dike, dipping outward at an angle of about 78 degrees on the west side and dipping vertically on the east side. Olsen (1982) and Olsen and others (1983) dated the gabbro at $407 \text{ Ma} \pm 36$ (Sm-Nd), described the gabbro/syenite complex in detail, and modeled an inferred magmatic fractionation history. They concluded that the gabbro and syenite were derived from the same parental material and were injected contemporaneously. McSween and others (1984) included the Concord plutonic suite in their comparison of the gabbro-metagabbro complexes of the southern Appalachians, and

they estimated that the gabbroic intrusions were emplaced at depths of 13-17 km. In a comprehensive analysis of the Fe-Ti oxides in the gabbro and syenite, Dobson (1987) described Fe-Ti oxide occurrences and textures. Recently a groundwater study was conducted by Nelson and Stewart (1992) in the same location from which the drill cores were recovered.

OBJECTIVES

The objectives of this study are as follows:

1. Study the lithology of the selected cores and describe any fissures, dikes, veinlets, etc.
2. Describe the mineralogy and textures of the dike rocks and fissure-filling assemblages; interpret the fissures observed in the drill cores in terms of temperature and depth, of origin, fluid interactions and tectonic history
3. Produce a chart and/or map showing the bottom of the oxidized zone and how it relates to the present-day groundwater system

METHODS

Fourteen cores, each 10 feet in length, were selected on the basis of depth, fracture frequency, mineralogy of the fracture fillings, interesting lithology, unusual textures, and/or other

interesting features. Most samples were very fresh; they came from well below the level of oxidation and weathering.

Mineral identification in the fractures and veins was accomplished using investigative techniques ranging from traditional to state-of-the art. These included:

1. Hydrochloric acid tests for calcite
2. Microscope study of thin sections (transmitted and reflected light)
3. X-ray diffraction
4. Electron microscope studies
5. EDX analysis
6. Study of standard mineralogical properties such as refractive index, hardness, cleavage, and magnetism.

The mineral assemblages in fractures are listed in Appendix C. Hand specimen and thin section studies were sufficient for describing core lithologies. Polished thin sections from the gabbro (28) and 2 polished thin sections from the syenite were studied. About 10 polished grain mounts were made from various mineralized fractures in the gabbro and syenite. Polished thin sections and grain mounts were studied in reflected light to identify the opaque minerals. To help in identifying orthoclase, one syenite and three gabbro thin sections were stained with sodium cobaltinitrate (Hutchison, 1974). Minerals in fractures

were easily lost during grinding, so samples were saturated with epoxy before being cut.

Six rock cubes were sent to XRAL Laboratories, where they were powdered for whole-rock major-element and trace-element analyses (See Appendix A).

Hematite or limonite staining indicates modern oxidation. The deepest occurrence of either hematite or limonite, therefore, marks the maximum depth of oxidation for each specific core. These observations were compiled in a contour map showing the maximum depth of oxidation and circulation of oxygenated groundwater.

DESCRIPTION OF THE SYENITE

Olsen (1982) described the syenite in the complex as, "a coarse-grained seriate porphyry with phenocrysts of perthitic feldspar and a groundmass of albite, microcline, clinopyroxene, amphibole, biotite, oxides, sulfides, apatite, zircon, and monazite."

F-7 was the only syenite core recovered in the study area (See Figure 1 and Plate 1). The syenite is coarse-grained, and consists of perthite, plagioclase, microcline, clinopyroxene, hornblende, biotite, oxides, sulfides, apatite, zircon, and monazite. Calcite, chlorite and white mica exist as alteration products. The mineralized fractures are sparse.

Perthitic alkali feldspars are much larger than any other mineral grains in the syenite. Grains can be as large as 1 centimeter in length. The perthitic K-feldspar is most easily identified when stained with sodium cobaltinitrate.

Plagioclase is distinguishable from perthite by its albite twinning and lack of staining after treatment with sodium cobaltinitrate. Compositions measured by the Michel-Levy method were in the albite range.

Microcline, readily stained by sodium cobaltinitrate, occurs in 0.2 mm streaks near plagioclase grain boundaries.

Clinopyroxene grains are .6 mm, and can be easily recognized by their green color and 3rd-order birefringence.

The biotite grains in the syenite are brown in color. They are best identified by their cleavage, pleochroism, and "bird's eye maple" appearance when extinguished under crossed polars.

Fine amphibole grains are infrequently found in the syenite; according to Olsen's (1982) microprobe work, they fall into the hornblende range. Oxide minerals consist of magnetite (See Plate 3) and some very fine-grained needles (probably rutile) in localized perthite grains (See Plate 2) (Dobson, 1987); the sulfides are pyrite and chalcopyrite. Apatite appears as hexagonal grains with low 1st-order birefringence. Plagioclase encloses nearly euhedral apatite. Apatite is less abundant in the syenite than in the gabbro. Zircon is an accessory mineral in the syenite. It occurs as colorless, 3rd-order birefringent grains that lack cleavage. Monazite is red to orange in transmitted light and is enclosed in plagioclase. Monazite is rare and easily overlooked; it appears as small blebs or thin polygonal crystals. Calcite occurs as grains showing high-order birefringence and rhombohedral cleavage. It occurs as tiny localized patches throughout the syenite in association with alkali feldspars. Chlorite also occurs in the syenite as a patchy alteration product. White mica occurs as small, birefringent grains which are colorless under plane-polarized light and show parallel extinction under crossed polars. White mica amounts to less than 1 percent of either syenite or gabbro thin sections.

Trace element analyses were performed on the syenite. The results were compared to the elements (Cu, Pb, Zn, Li, V, Cr, Co, Ni, Sr, Zr, Rb) that were analyzed by Price (1969) (See Appendix A). It was found that in the present study there were greater abundances of Zn and Sr, and lesser abundances of Cu, Pb, Co, Ni, Zr, and Rb. The elements Li, V, and Cr had similar values for both studies.

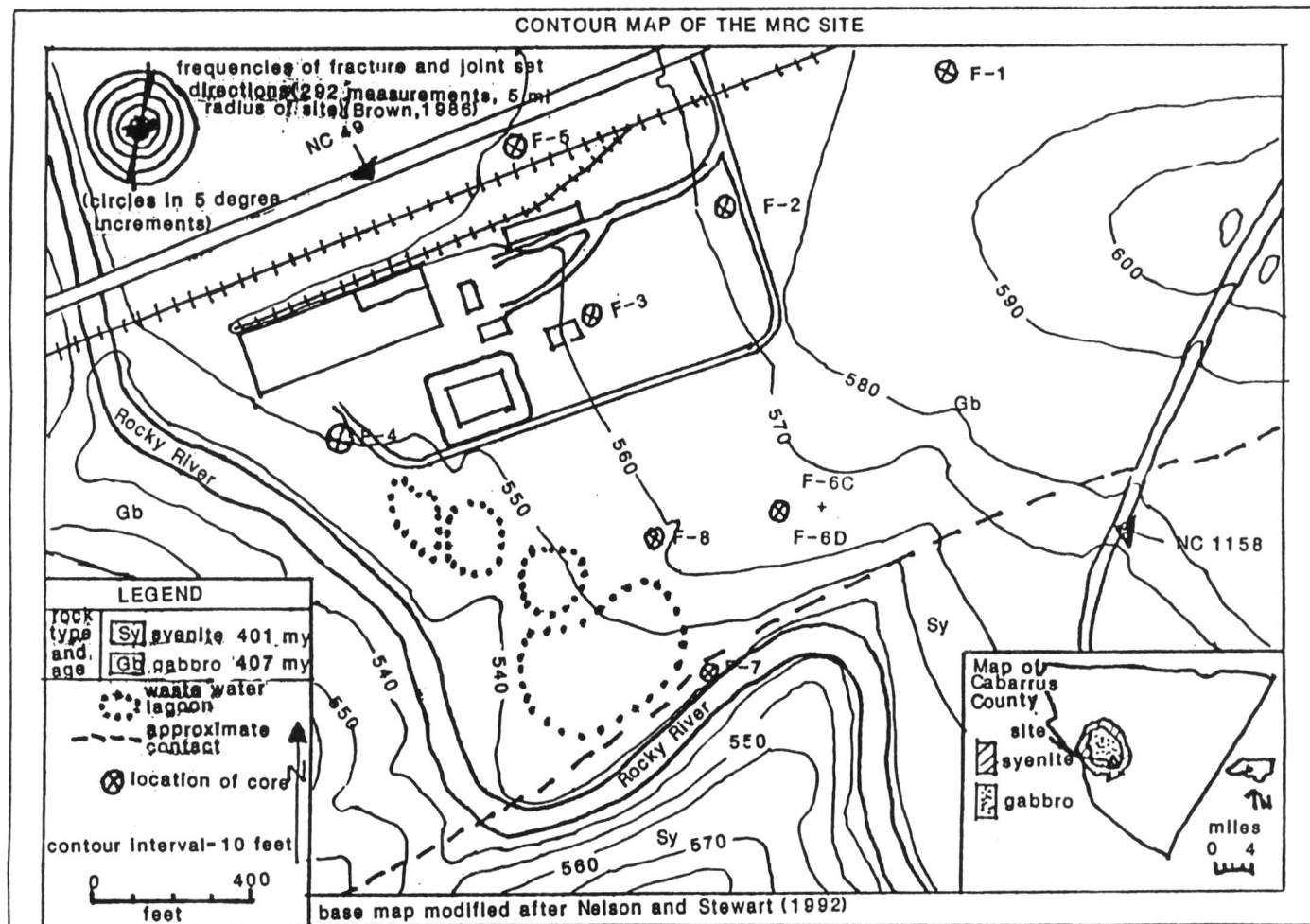


Figure 1. Contour map of the MRC plant, near Harrisburg, North Carolina.



Plate 1. Black and white photo of a wet syenite core (F-7) at depth of 108 feet. A fine-grained area can be seen one quarter length to the left of the quarter. The mineralogy suggests that the fine-grained zone is a concentration of matrix minerals lacking in alkali feldspar phenocrysts (Morgan, 1963).

Explanation of Plate 2 and Plate 3

Plate 2. Photomicrograph (1.07 mm across the top edge of the photo; crossed polars) of tiny rutile or other Fe-Ti oxide needles in a perthite grain from syenite core F-7.

Plate 3. Reflected light photomicrograph (0.62 mm across the top edge of the photo) of magnetite (yellow) and hematite (white) in the syenite.

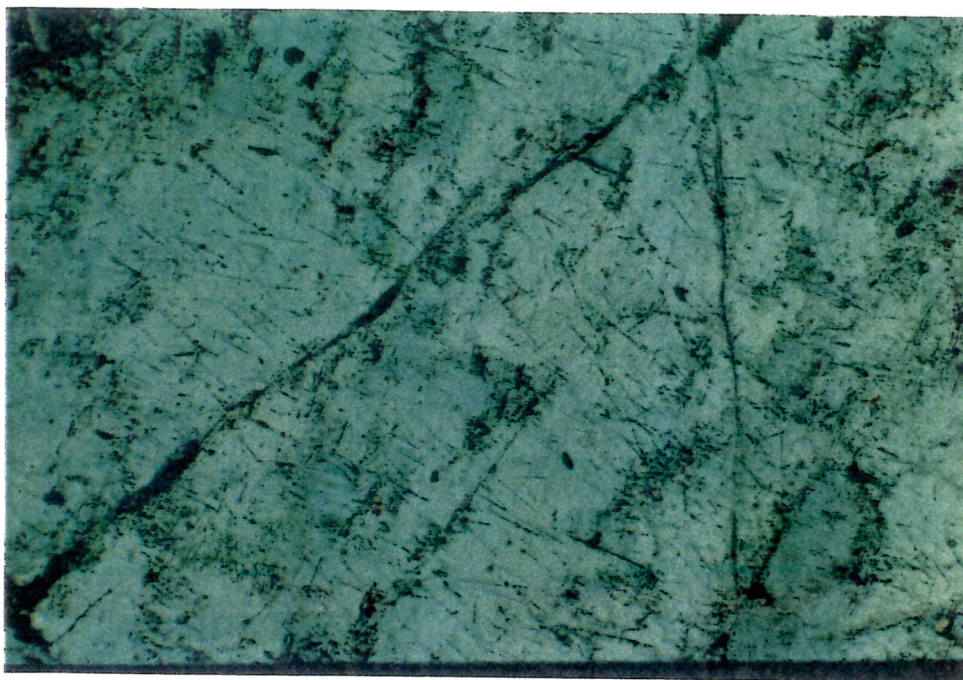


Plate 2

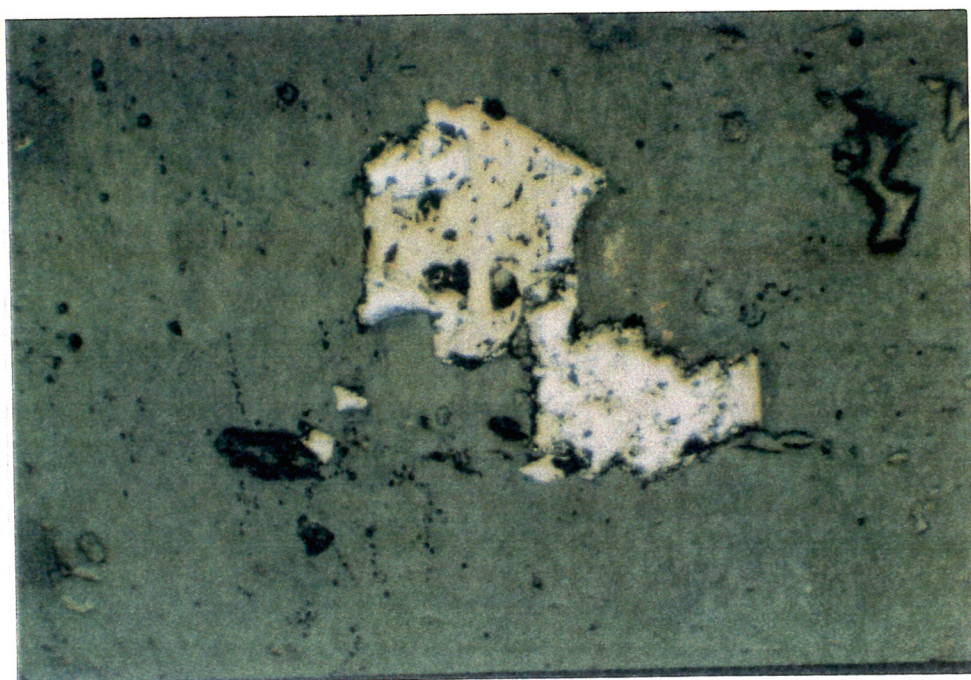


Plate 3

VEINS AND FRACTURES IN THE SYENITE

A few 1/8-inch quartz veins cut the syenite: dips are about 50 degrees. Calcite veins in the syenite are less than 1/16-inch thick with dips ranging from 0-75 degrees. Some of the quartz veins contain scattered calcite rhombs (See Plate 4) and others are cut by calcite veins and/or fractures coated with calcite. Hexagonal pyramidal terminations on quartz crystals in the veins indicate that the crystals grew in fluid-filled open spaces (See Plate 5). Quartz veins in the syenite are thinner and less extensive than those found in the gabbro.

Most of the syenite fractures are coated by calcite. As fluids moved through the open fractures, they precipitated calcium carbonate, possibly derived from decomposition of Ca-rich plagioclase in the nearby gabbro. The calcite-lined fractures eventually were sealed and fluids could no longer circulate, unless a new episode of fracturing opened new fractures or reopened the old ones.

The mineralogy of some fractures suggest a change in fluid composition during mineralization. This is evident in the healed chlorite/calcite fractures found in the syenite (See Plate 6). After the fracture first opened, brown Fe-rich calcite was precipitated, healing the fracture. Next, the healed fracture opened and a chlorite was deposited against calcite walls. The

fracture reopened and chlorite was deposited against the walls of the earlier chlorite.

The fractures filled with calcite, chlorite and other soft minerals break open more easily than those filled with harder minerals, such as quartz. This explains why these veins tend to have multiple episodes of opening, reflected in successive stages of mineral deposition and internal layering; quartz veins do not show such episodes of opening.

Explanation of Plate 4 and Plate 5

Plate 4. Photomicrograph (1.07 mm across the top edge of the photo; crossed polars) of a quartz vein in the syenite. Note the calcite rhombs in the vein.

Plate 5. Photomicrograph (2.66 mm across the top edge of the photo; crossed polars) of a quartz crystal termination in a vein in syenite.

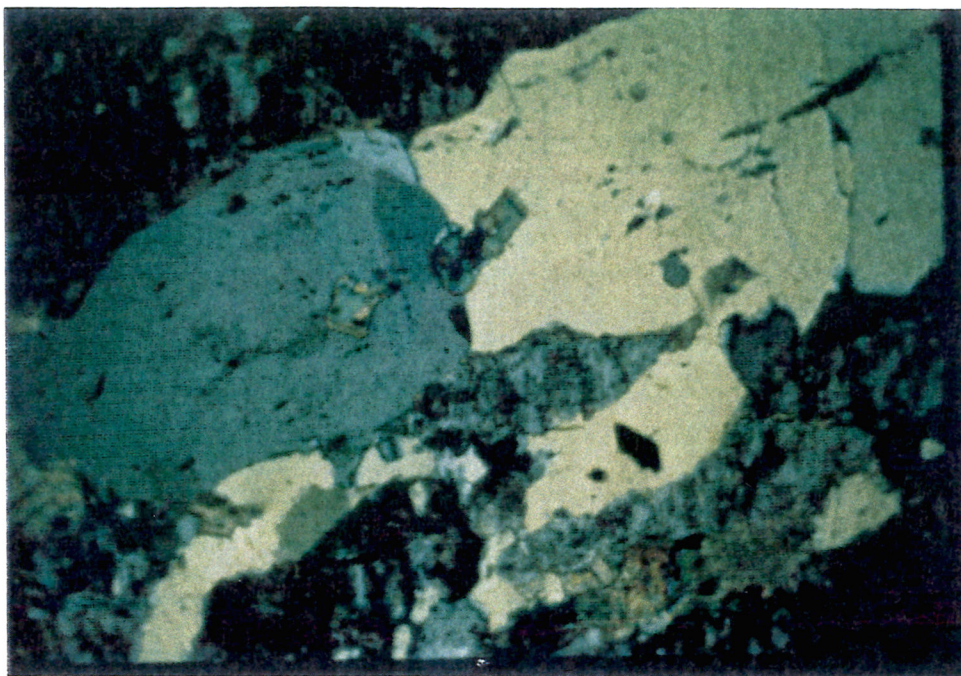


Plate 4

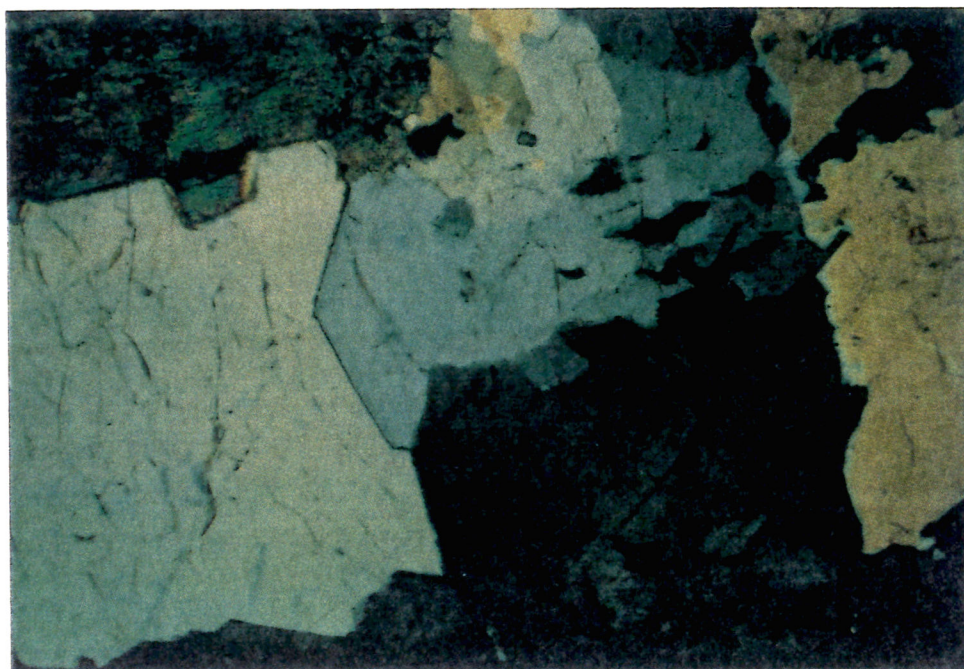


Plate 5

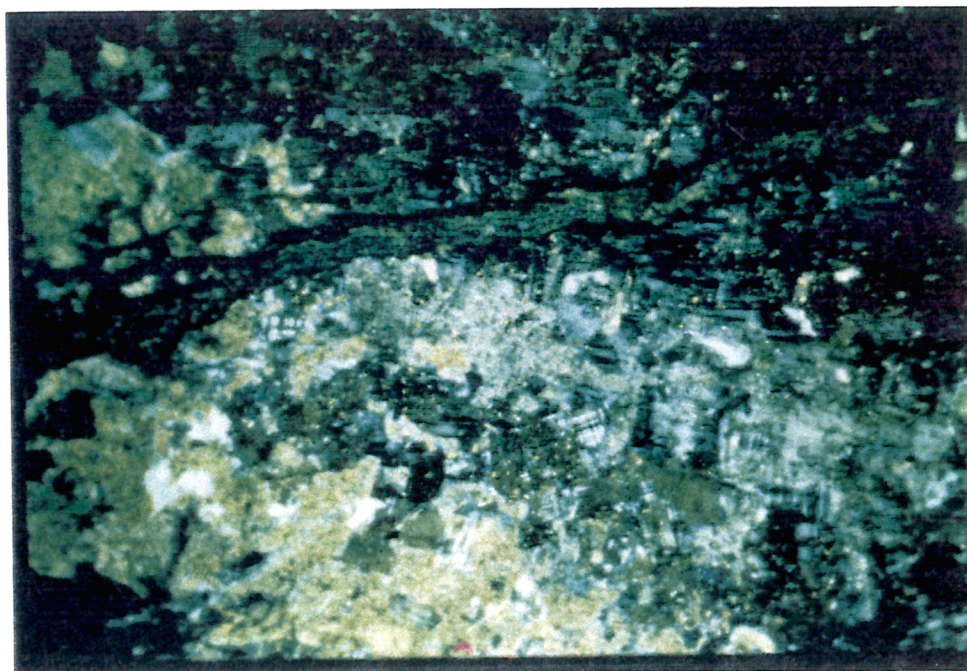


Plate 6. Photomicrograph (2.66 mm across the top edge of the photo; crossed polars) of a layered vein in syenite consisting of Fe-rich calcite walls (dark bands) and chlorite layers.

FINE-GRAINED ZONES IN THE SYENITE

Three fine-grained dikes, xenoliths, or schlieren occur in the core (see Plate 1). One such mass cuts horizontally across the core; at depths between 90 and 100 feet, others dip at about 45 degrees.

Table 1. Fine-grained zones in syenite core F-7

<u>Depth</u> (ft)	<u>Thickness</u> (in)	<u>Shape</u>
91	1	lens
100	6	oblong
108	1	lens

The fine-grained zones contain very fine-grained microcline perthite, plagioclase (An 13), hornblende, and opaque minerals (Morgan, 1963). In this study, a thin section cut from a fine-grained zone at a depth of 91 feet was stained with sodium cobaltinitrate. The mineralogy was found to be microcline perthite, plagioclase (An 4), biotite, hornblende, clinopyroxene, and opaque minerals. These are the same minerals as are found in the syenite, and the fine-grained zones are presumed to be similar to the matrix, without the very coarse alkali feldspar phenocrysts (Morgan, 1963).

DESCRIPTION OF THE GABBRO

The gabbro in the cores I studied is fine to medium grained, and composed of plagioclase, hornblende, clinopyroxene, orthopyroxene, biotite, olivine, apatite, Fe-Ti oxides, pyrrhotite, pyrite, chalcopyrite and zircon. Most of the 28 thin sections from the gabbro were cut through fractures and veins; a few were made to determine the core-rock lithologies.

Albite twinning in the plagioclase grains is common. An contents (measured by the Michel-Levy method) range from An 61 to An 78. Plagioclase twin lamellae are typically straight, but a few bent lamellae were observed. As previously described by Olsen (1982), clumps of hornblende, clinopyroxene, and orthopyroxene tend to surround the plagioclase. A few plagioclase grains are altered to chlorite (see Plate 7 and 8).

Hornblende, tremolite, and actinolite can be found within some gabbro drill cores. Most slides contain both hornblende and tremolite which are easily distinguishable (from the non-amphiboles) by their 60 and 120 degree cleavage traces. In transmitted light, hornblende is brown, tremolite is colorless, and actinolite is green. In the gabbro, Fe-Ti oxides tend to be enclosed in or associated with hornblende. Thin section C-19 was cut from a two-foot thick, bluish-gray zone in core F-6C (see Plate 9). Upon closer examination, abundant fibrous

tremolite and fibrous actinolite were found in this rock (see Plates 10 and 11). There is a distinctive boundary between actinolite and tremolite, and opaque minerals tend to be associated with this boundary. In thin section C-20, also in the bluish-gray region, a tremolite corona can be seen around a hornblende (see Plate 12). The tremolite and actinolite represent low grade hydrothermal alteration of the gabbro along seams or fractures.

Orthopyroxene and clinopyroxene are found together in most thin sections. Biotite is also found in most thin sections. Some biotite grains are bent and a few have been fractured (see Plate 13). There is no recognizable increase or decrease of biotite grain size with depth. Biotite grains as large as 2 inches across occur in certain parts of the cores.

Olivine is found in the majority of thin sections, but is usually partly altered to hydrous Mg-Fe silicates (see Plate 14). Iron-stained fractures through the grains are common, and many grains are enclosed poikilitically in hornblende.

Small, euhedral, apatite crystals with a birefringence lower than quartz are ubiquitous. They are often found enclosed in plagioclase grains.

The opaque minerals found in the gabbro cores include magnetite, ilmenite, pyrite, pyrrhotite, hematite, and chalcopyrite.

Zircon is a very minor mineral usually consisting of small grains associated with olivine.

Hydrothermal alteration in the gabbro consists of unidentified hydrosilicate pseudomorphs after pyroxene (?) (see Plate 23), opaques after hornblende (see Plate 24), and chlorite after plagioclase (see Plate 25).

An alignment of light and dark minerals in gabbro Core F-8, from 106 - 110 feet, was observed (see Plate 26). This area consists of mostly plagioclase with an increase in biotite and sericite. Mafic minerals occur in clusters with ilmenite (with hematite lamellae), magnetite, and pyrrhotite. Chlorite and occasionally epidote also exist in this texture. It is believed the hydrous minerals were formed by hydrothermal alteration along a zone of seams and microcracks in the cooling gabbro.

Trace element analyses were performed on the gabbro (sample CGB6) and the mafic-rich gabbro (sample CM5) (See Appendix A). Compared to the elements (Cu, Pb, Zn, Li, V, Cr, Co, Ni, Sr, Zr, Rb) that were analyzed by Price (1969), my gabbro sample was found to have greater abundances of Zn and V, and lesser abundances of Pb, Cr, Ni, and Zr. Similar values were found for the elements Cu, Li, Co, Sr, and Rb. The mafic-rich gabbro was found to contain greater abundances of Zn and Sr, and lesser abundances of Cu, Pb, Cr, Co, and Ni. Similar results

were found in the mafic-rich gabbro for the elements Li, V, Zr,
and Rb.

Explanation of Plate 7 and Plate 8

Plate 7. Photomicrograph (2.66 mm across the top edge of the photo; crossed polars) of a plagioclase grain in the gabbro altered to chlorite.

Plate 8. Photomicrograph (2.66 mm across the top edge of the photo; crossed polars) of plagioclase grains in the gabbro altered to chlorite rosettes.

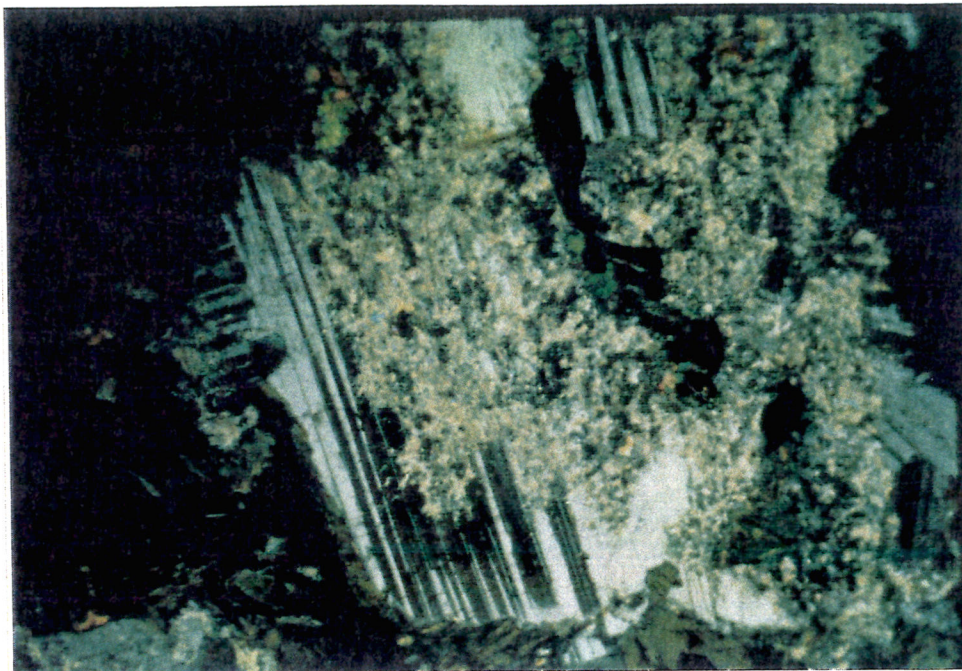


Plate 7

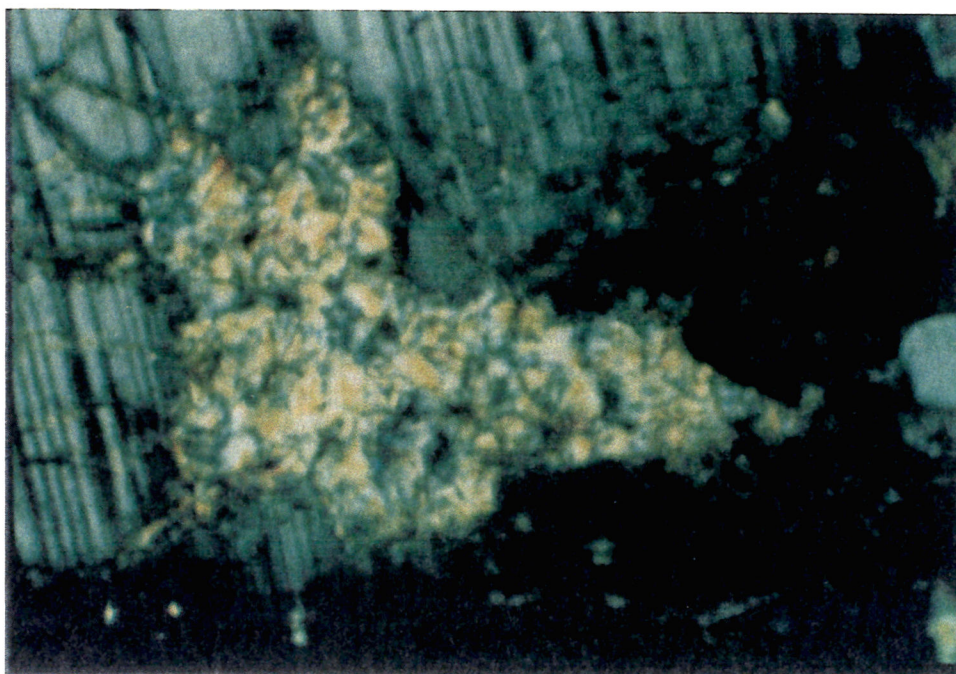


Plate 8

Explanation of Plate 9 and Plate 10

Plate 9. Photograph of the blue-gray hydrothermally altered zone in gabbro core F-6C.

Plate 10. Photomicrograph (2.66 mm across the top of the photo; plane light) of tremolite (colorless) and actinolite (green). These amphiboles are found together in the bluish-gray zone of gabbro core F-6C. Note the boundary between these minerals and that the opaque minerals tend to be associated with the boundary zone.



Plate 9

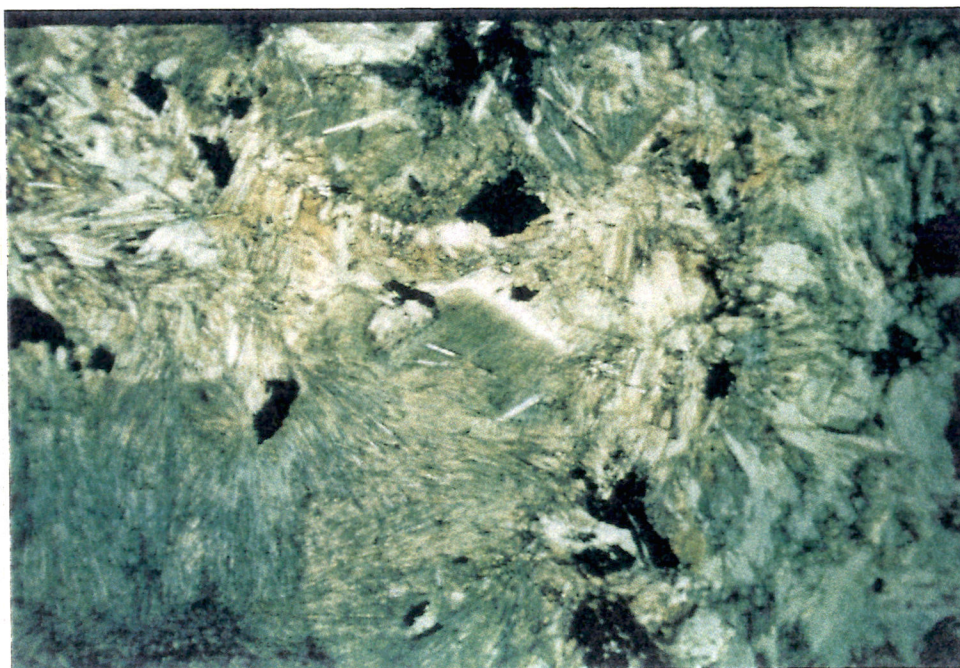


Plate 10

Explanation of Plate 11 and Plate 12

Plate 11. Photomicrograph (2.66 mm across the top edge of the photo; crossed polars) same as Plate 10. The tremolite and the actinolite both exhibit fibrous texture.

Plate 12. Photomicrograph (2.66 mm across the top of edge of the photo; crossed polars) of hornblende (brown and black) with a tremolite corona (blue) in the bluish-gray zone of gabbro core F-6C.

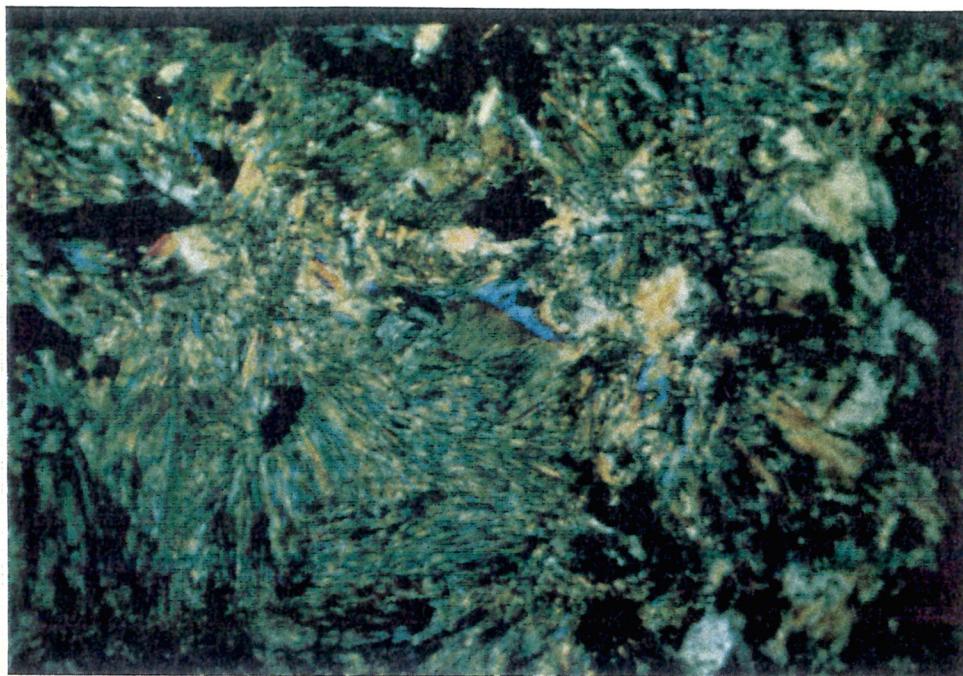


Plate 11

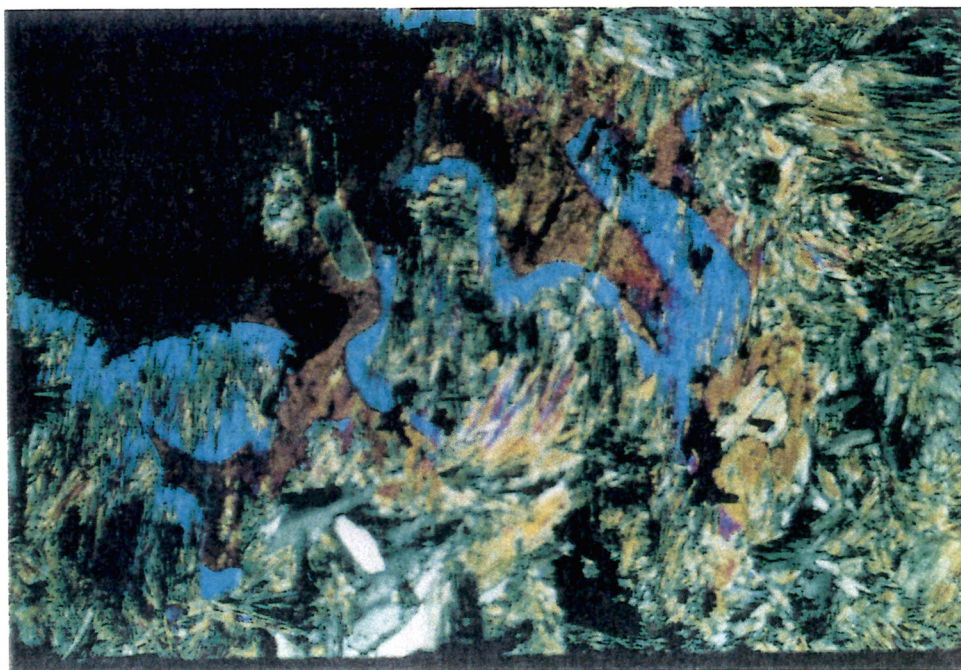


Plate 12

Explanation of Plate 13 and 14

Plate 13. Photomicrograph (2.66 mm across the top edge of the photo; crossed polars) of a fractured biotite grain in gabbro. The feldspars are plagioclase.

Plate 14. Photomicrograph (2.66 mm across the top edge of the photo; crossed polars) of olivine grains in the gabbro. Note low birefringent hydrous silicate-filled alteration cracks.

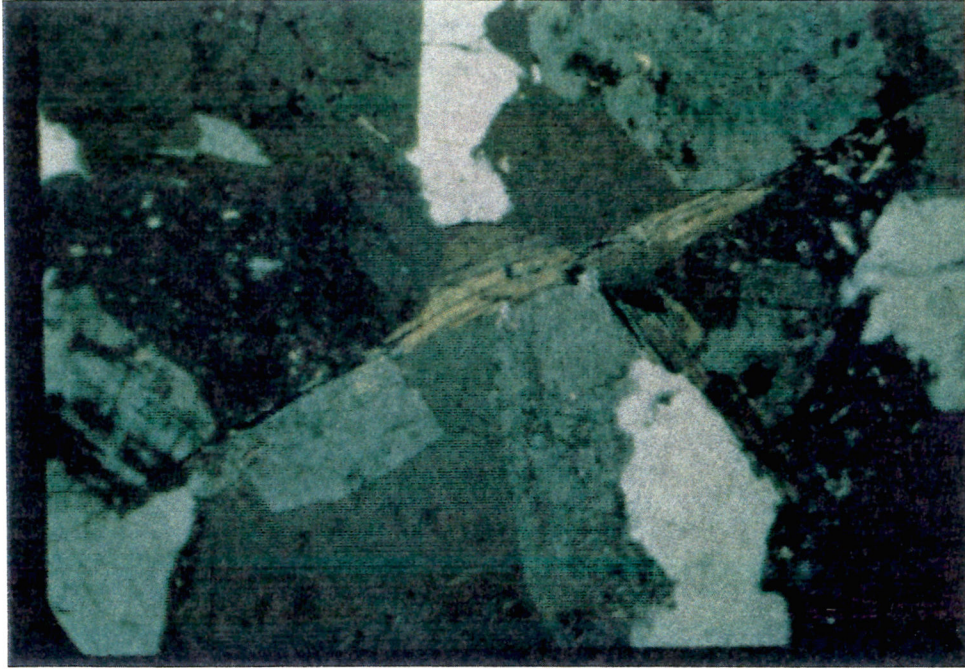


Plate 13

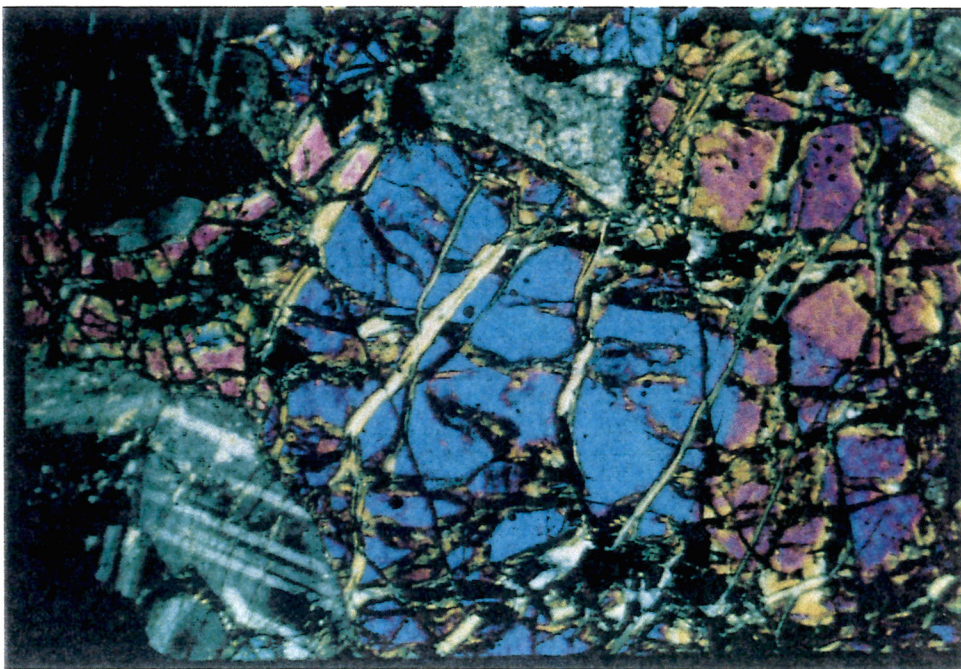


Plate 14

Explanation of Plate 15 and Plate 16

Plate 15. Photomicrograph (1.07 mm across the top edge of the photo; crossed polars) of apatite crystals in the gabbro enclosed by plagioclase.

Plate 16. Photomicrograph (0.62 mm across the top edge of the photo; reflected light) of pyrrhotite (white) with a chalcopyrite lamellae (yellow) in the gabbro; one pyrrhotite grain is partly decomposed to hematite or limonite (red-orange).

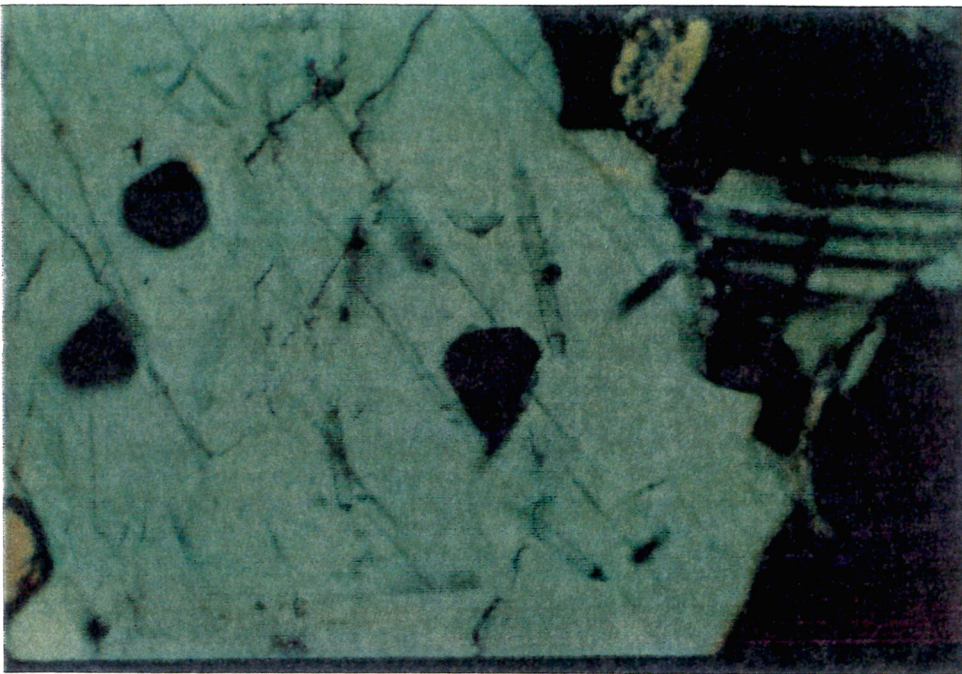


Plate 15

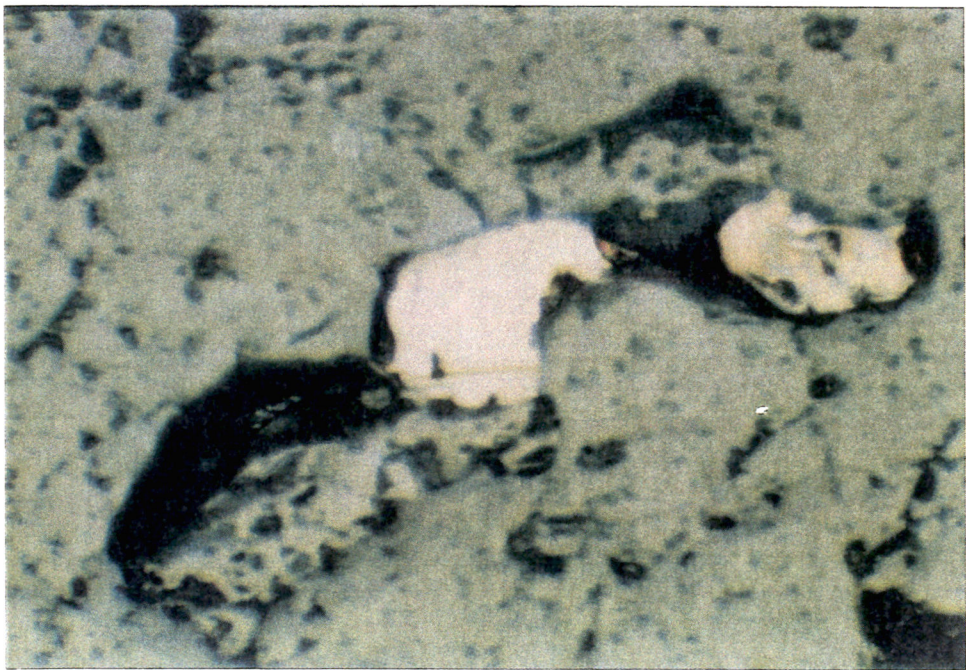


Plate 16

Explanation of Plate 17 and Plate 18

Plate 17. Photomicrograph (0.62 mm across the top edge of the photo; reflected light) of magnetite with exsolution lamellae (dark) in the gabbro.

Plate 18. Photomicrograph (0.62 mm across the top edge of the photo; reflected light) of ilmenite (trellis texture) within a magnetite grain in the gabbro.

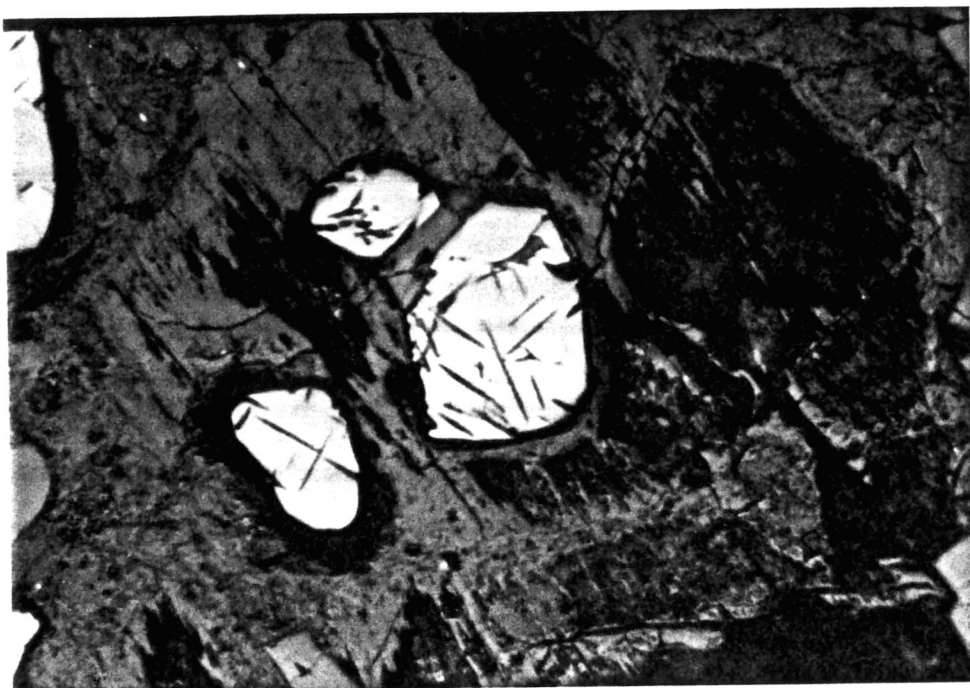


Plate 17

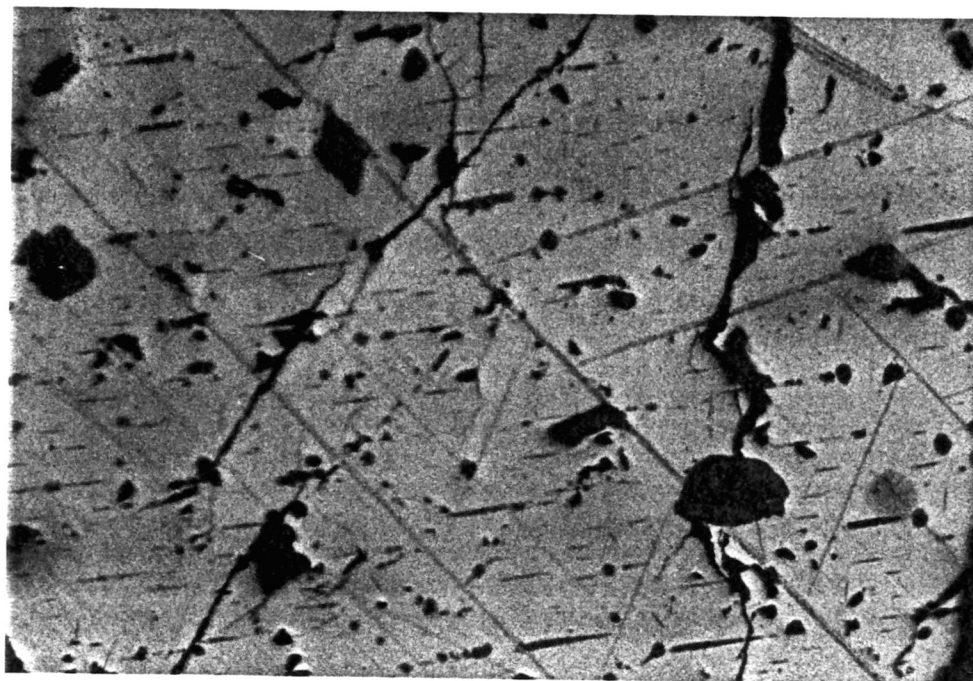


Plate 18

Explanation of Plate 19 and Plate 20

Plate 19. Photomicrograph (0.62 mm across the top edge of the photo; reflected light) of a chain of ilmenite grains in the gabbro. The other highly reflective mineral is pyrite.

Plate 20. Photomicrograph (0.62 mm across the top edge of the photo; reflected light) of hematite lamellae (very white) within ilmenite grains (white) in the gabbro.

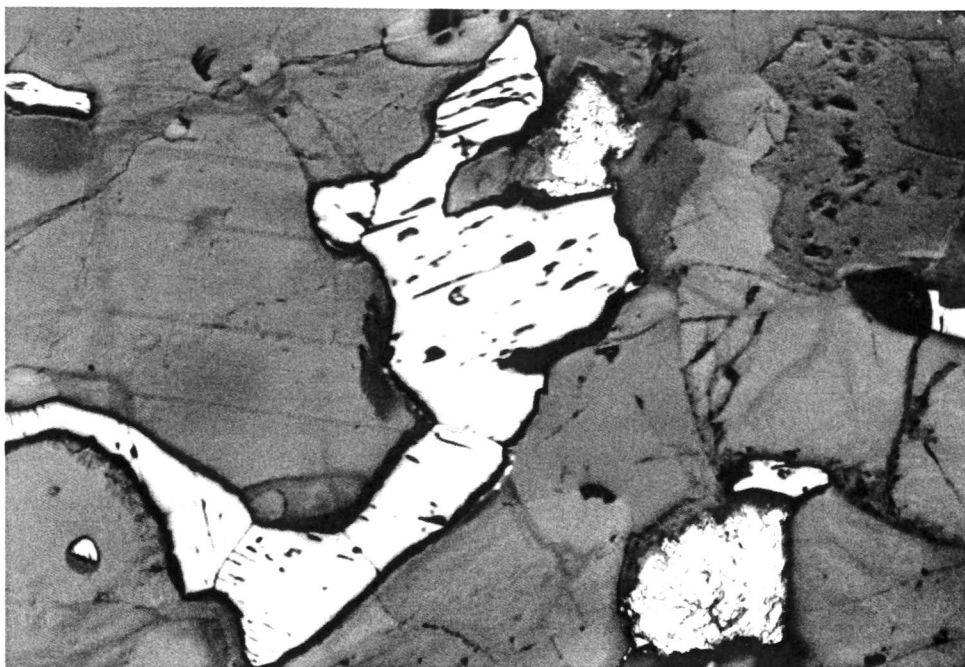


Plate 19

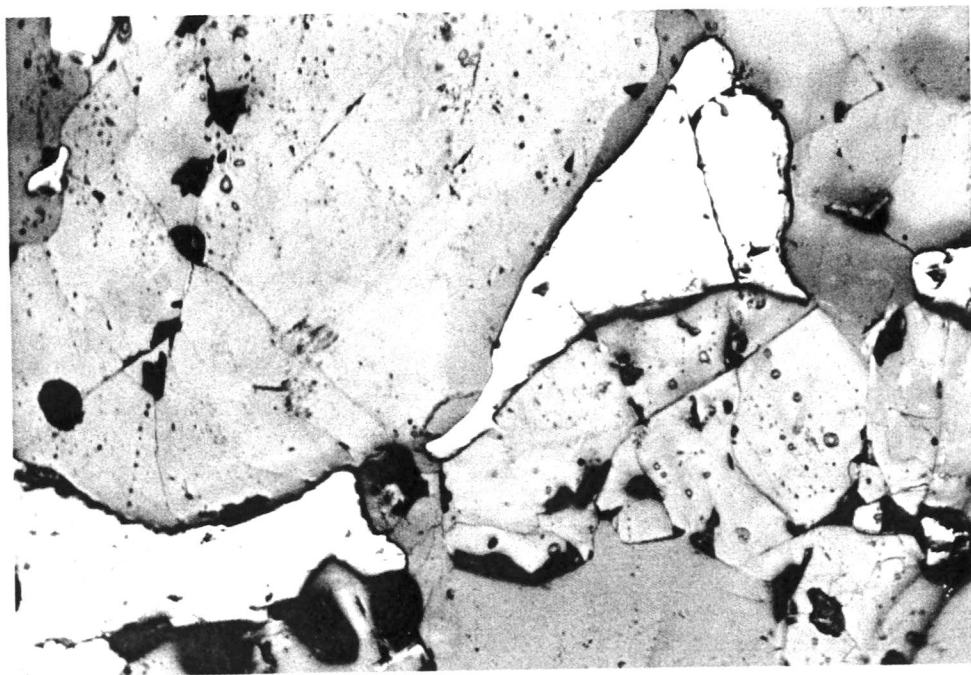


Plate 20

Explanation of Plate 21 and Plate 22

Plate 21. Photomicrograph (0.62 mm across the top edge of the photo; reflected light) of ilmenite with hematite lamellae in the gabbro. Note that the hematite lamellae are oriented in 1 direction inside each ilmenite crystal.

Plate 22. Photomicrograph (0.62 mm across the top edge of the photo; reflected light) of ilmenite with hematite lamellae that terminate near the magnetite in the gabbro (Olsen, 1987). The bright white crystal in the magnetite grain is pyrrhotite.

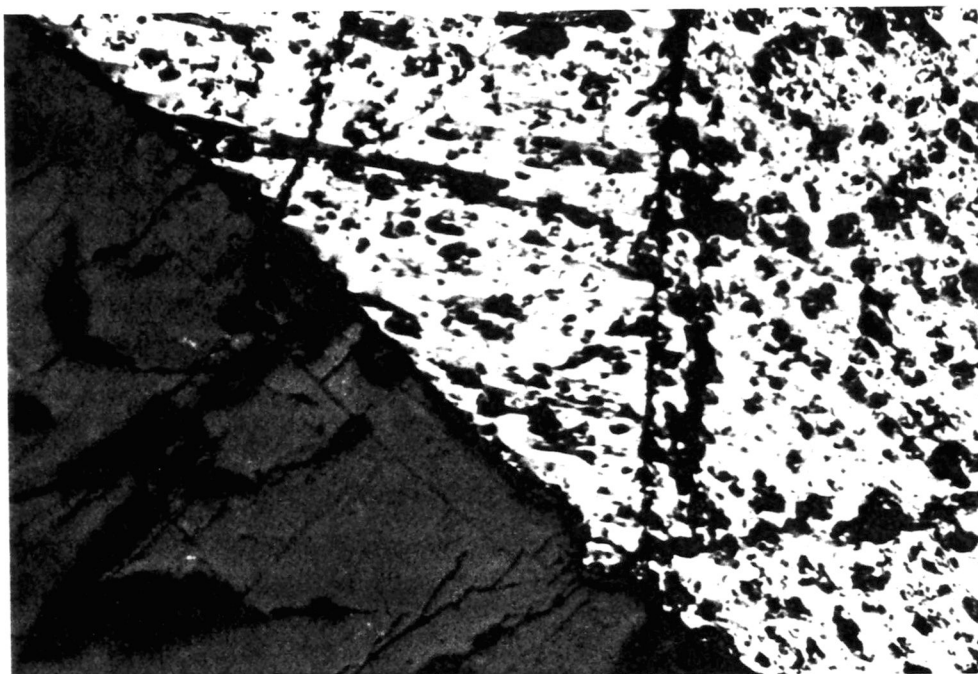


Plate 21

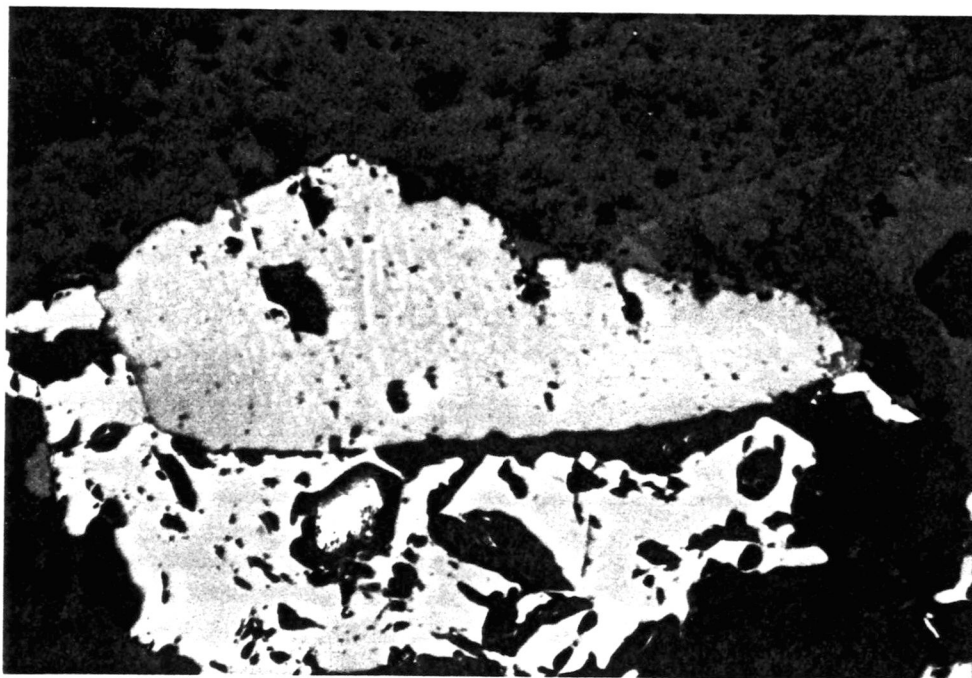


Plate 22

Explanation of Plate 23 and Plate 24

Plate 23. Photomicrograph (2.66 mm across the top edge of the photo; crossed polars) of very fine-grain mica or chlorite pseudomorph (yellow rectangle) after pyroxene (?) in the gabbro. Other minerals include plagioclase (white), biotite (green), and opaques (black).

Plate 24. Photomicrograph (2.66 mm across the top edge of the photo; crossed polars) of hornblende (dark reddish brown) in the gabbro altered to opaques and birefringent very fine-grained mica or chlorite pseudomorphs after pyroxene (?).

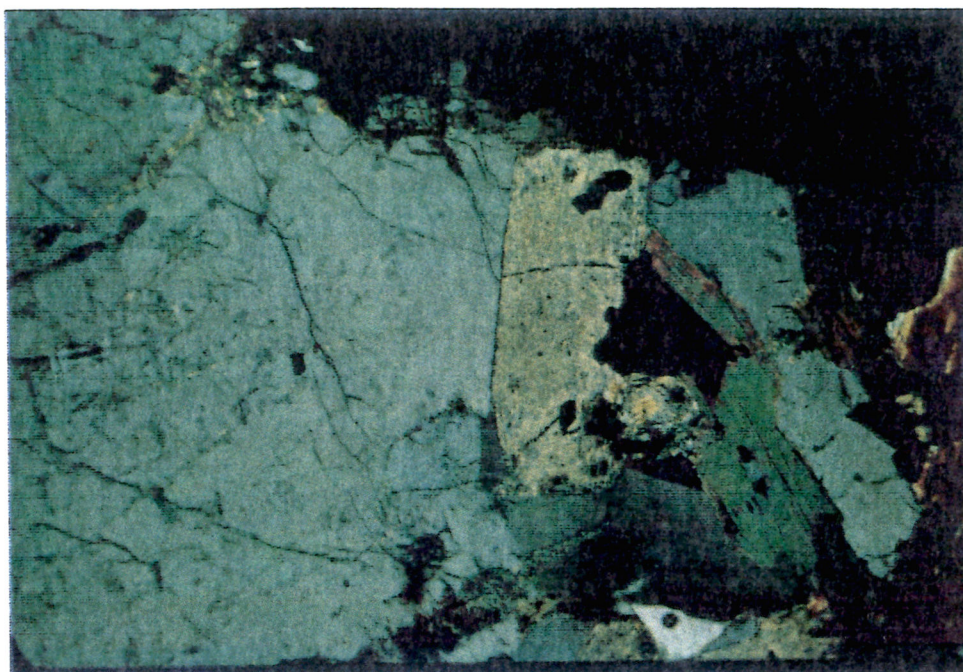


Plate 23

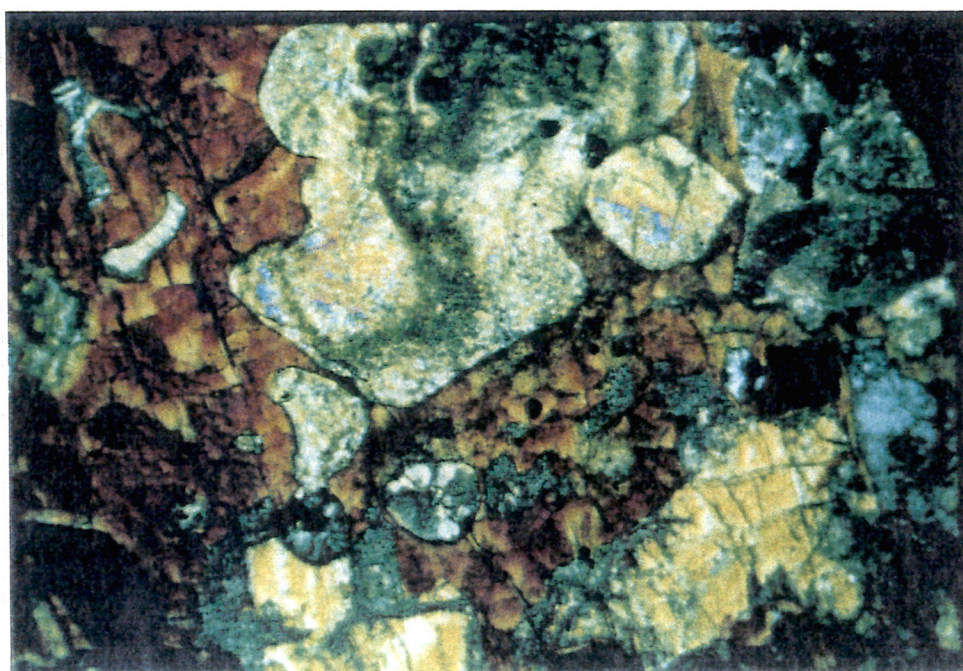


Plate 24

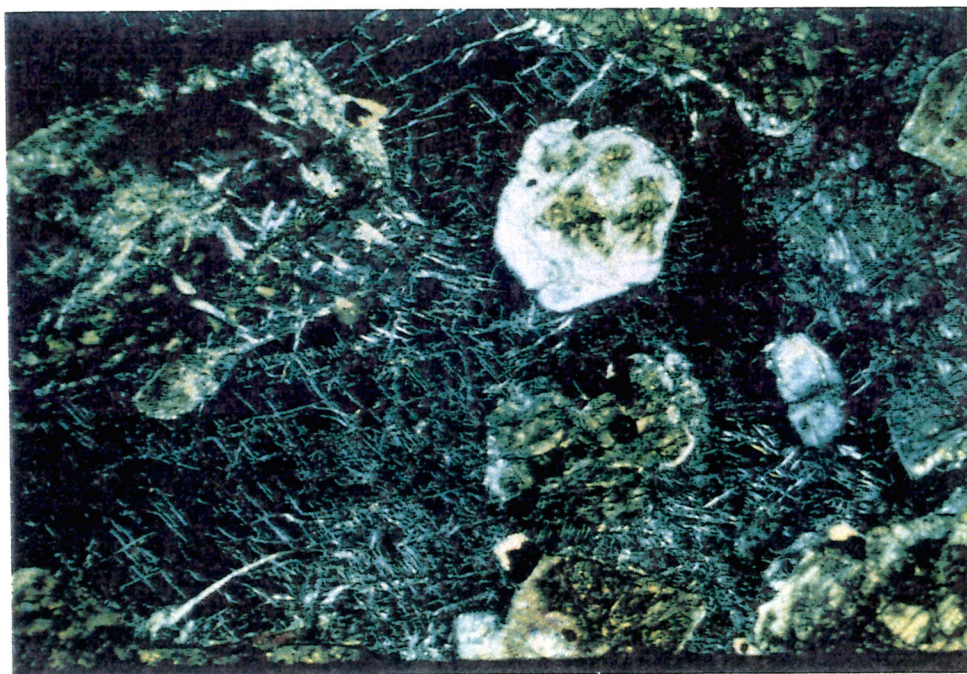


Plate 25. Photomicrograph (2.66 mm across the top edge of the photo; crossed polars) of hydrothermally altered gabbro. The primary alteration product is chlorite (deep blue and gray).

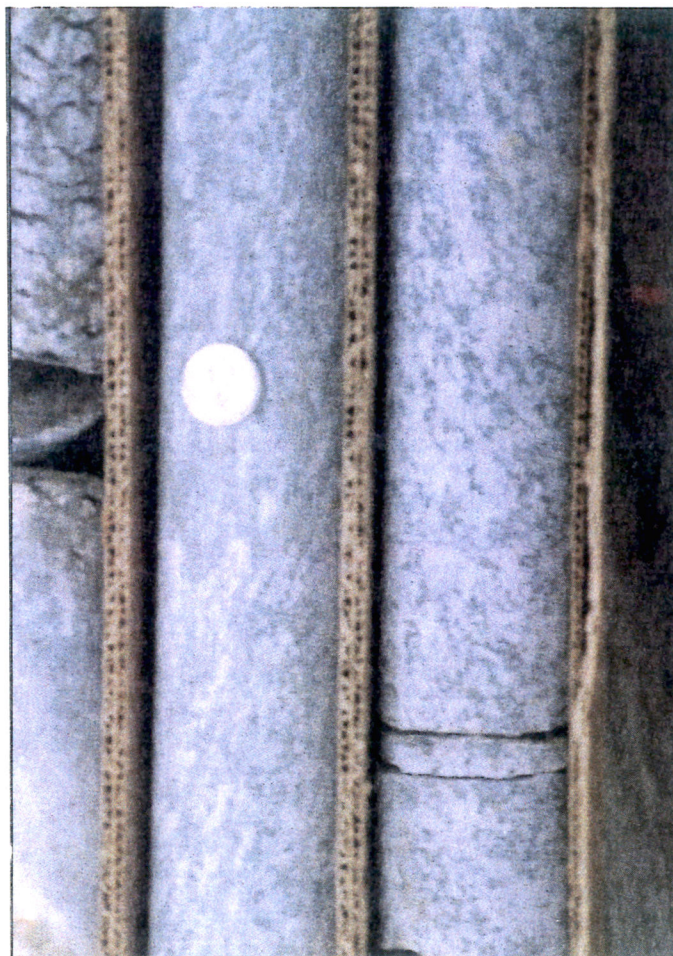


Plate 26. Photograph of the alignment of light and dark minerals in core F-8. The open fractures (top, left core) were filled with calcite. They have since been reopened and oxidized.

VEINS AND FRACTURES IN THE GABBRO

The veins and fracture coatings in the gabbro generally have similar mineralogy, although there are some differences. The gabbro is frequently cut by veins of quartz and calcite. Calcite veins are more common than quartz veins and are found throughout the gabbro (see Appendix C).

The quartz veins range from a hairline to 1 foot in thickness (see Table 2) and contain biotite, plagioclase, opaques, and sphene (see Plates 27, 28, and 29). Dip angles vary from horizontal to 60 degrees.

Table 2. Quartz veins in the gabbro

<u>Core</u>	<u>Quartz vein thickness (in)</u>	<u>Depth below the surface (ft)</u>	<u>Angle of dip</u>
F-3	6	101.0	5 degrees
F-6C	4	78.0	20 degrees
F-6C	12	179.0	60 degrees
F-8	6	59.5	0 degrees
F-8	4	76.5	45 degrees

The cores with thicker quartz veins (Table 2) are within 600 feet of each other and are approximately 300 to 800 feet away from the 1/4-inch thick quartz veins in the syenite core F-7. This implies that the quartz veins were emplaced locally and that they post-date solidification of the gabbro and the syenite. Hematite, limonite, calcite and chlorite are commonly found in association with fractures in the quartz veins.

Calcite veins, generally less than 1/4 inch thick, occur throughout the gabbro cores. They are often rehealed suggesting multiple episodes of fluid circulation. Chlorite occurs in both veinlets and as

fracture coatings (see Plate 31). It is black (in hand specimen) and very soft, making it conducive to slipping and fracturing; slickensides are common. In core F-6C, a 1/4 inch thick black chlorite vein at 158 feet has a dip angle of 50 degrees (see Plate 30).

In addition to chlorite, fractures in the gabbro are generally coated with calcite, sulfides, and hematite and limonite if oxidized.

Calcite occurs in all the cores; in a few veinlets, green chlorite (in hand specimen) occurs as a fine-grained "dusting" on black chlorite and calcite. Sulfides, mainly pyrite, are common below the maximum depth of oxidation (see Plate 32). Sulfides occur as patches on calcite and black chlorite.

Sheet fractures, noted by Nelson and Stewart (1992), were not observed in the cores.

Explanation of Plate 27 and Plate 28

Plate 27. Photo of a one foot wide quartz vein dipping 60 degrees at 179 feet in gabbro core F6C.

Plate 28. Photomicrograph (2.66 mm across the top edge of the photo; polarized light) of a quartz vein in gabbro. The quartz grains decrease in size at the edge of the vein.

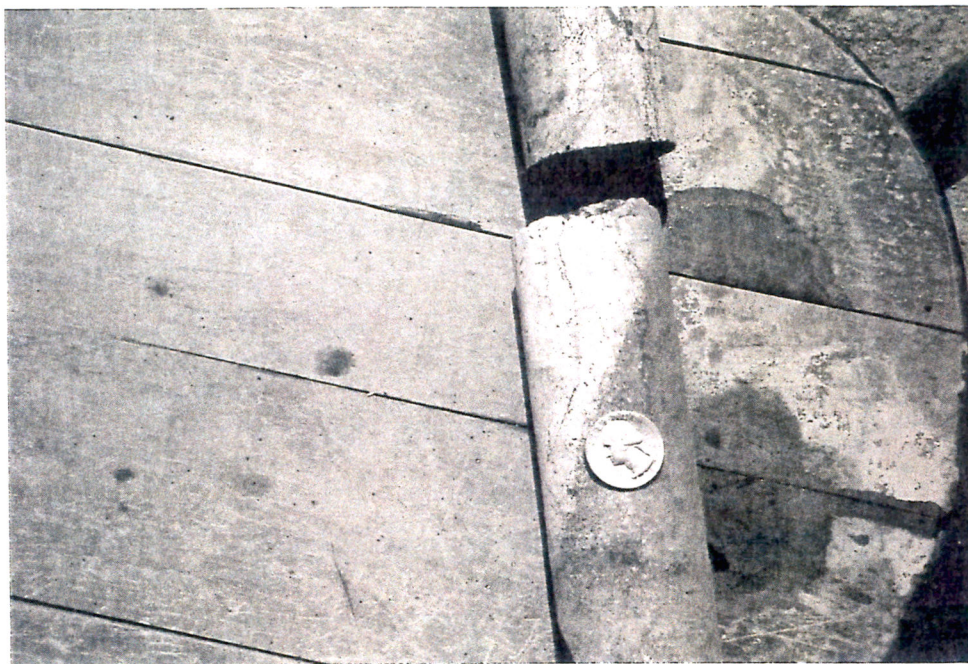


Plate 27

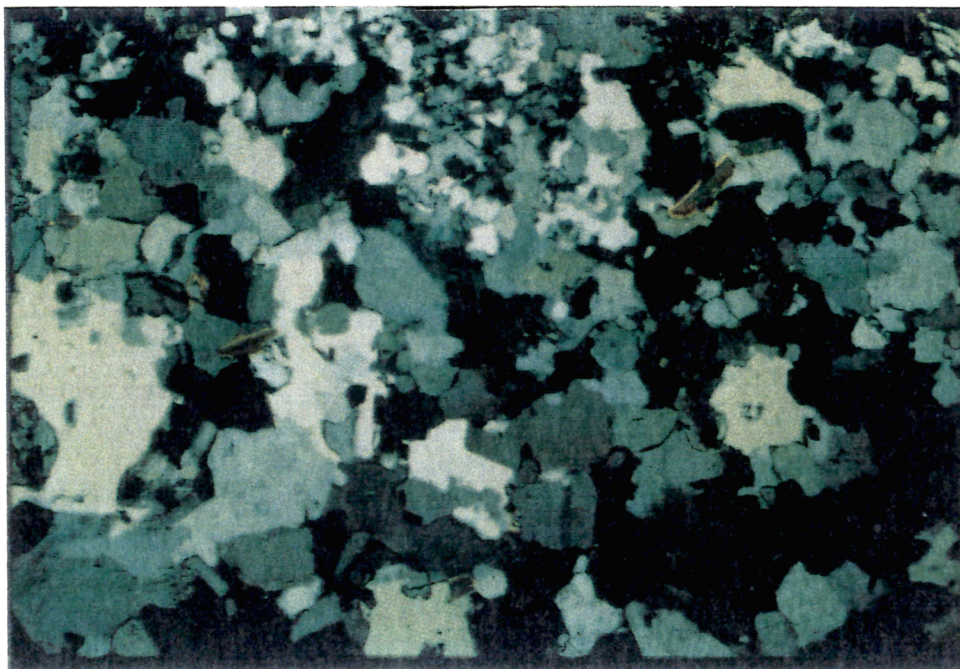


Plate 28

Explanation of Plate 29 and Plate 30

Plate 29. Photomicrograph (2.66 mm across the top edge of the photo; polarized light) of sphene in a quartz vein in the gabbro.

Plate 30. Photo of a 1/4 inch black chlorite vein in gabbro core F6C at 158 feet below the land surface.

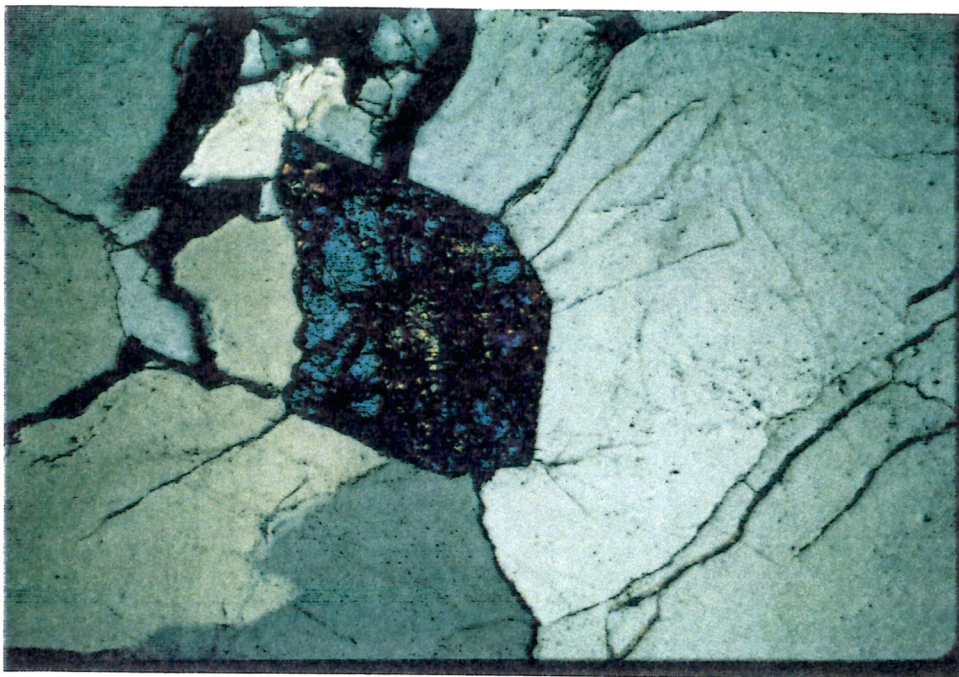


Plate 29

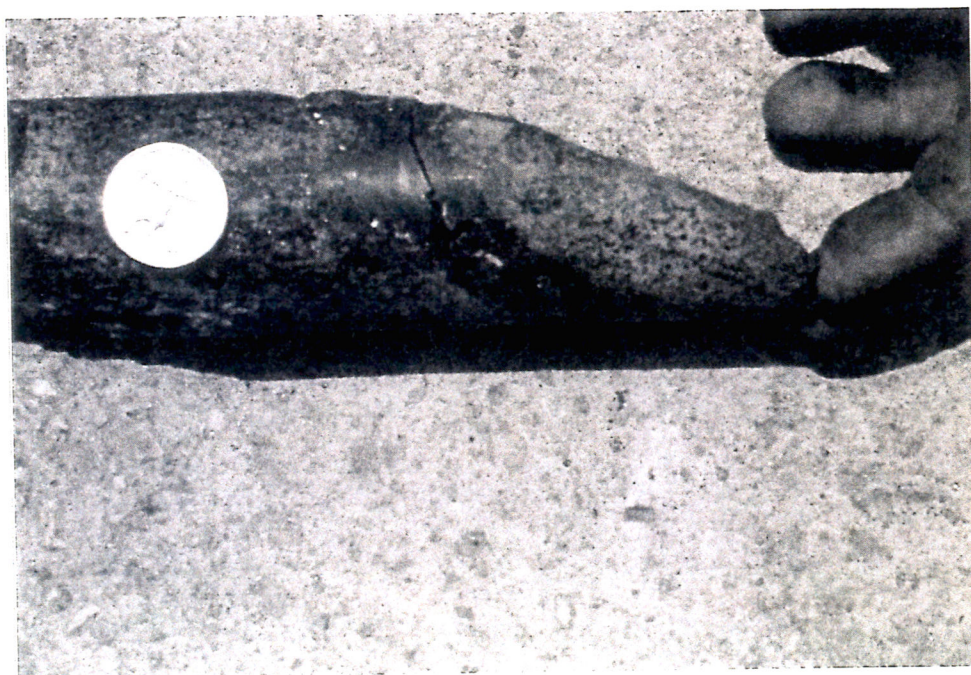


Plate 30

Explanation of Plate 31 and Plate 32

Plate 31. Photomicrograph (2.66 mm across the top edge of the photo; polarized light) of a vein in the gabbro showing at least 5 episodes of vein opening and chlorite mineralization. The minerals within this fracture are calcite and varieties of chlorite. The bubbles are in epoxy.

Plate 32. Photomicrograph (0.62 mm across the top edge of the photo; reflected light) of a pyrite veinlet in the gabbro.

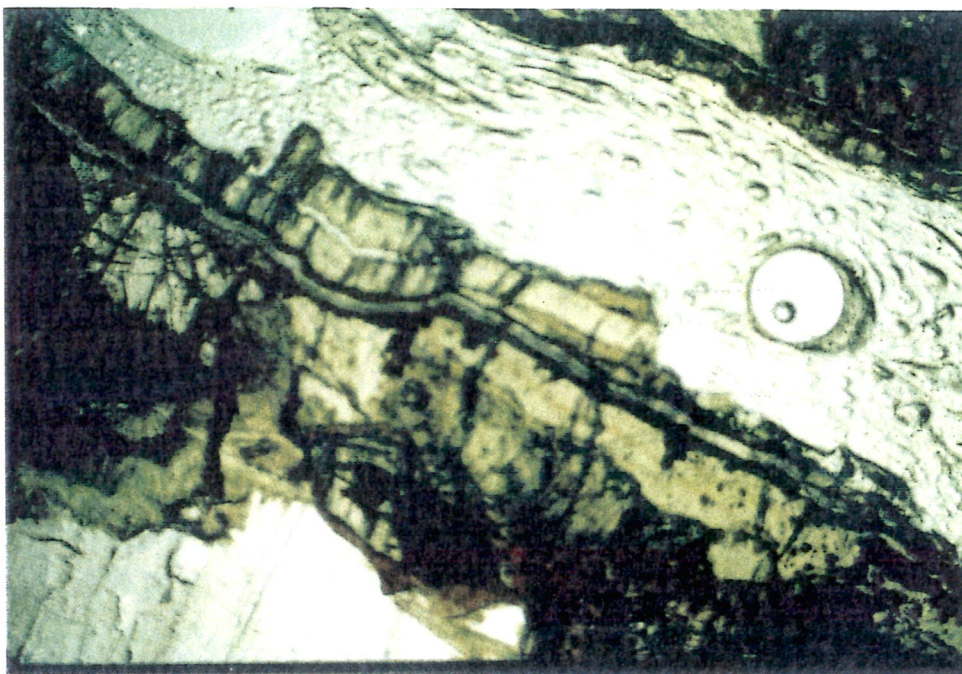


Plate 31

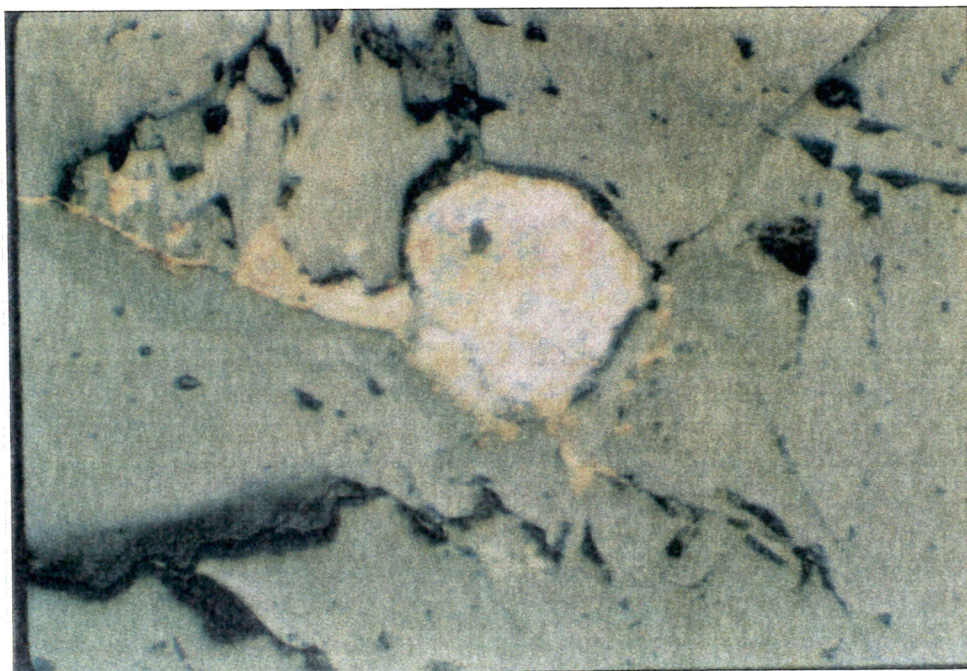


Plate 32

GRANITIC DIKES

Previously graphic granite dikes have been described from the complex, but no specific localities were given (Morgan, 1963). Graphic granite occurs in the center of the gabbro near the Rocky River bridge (Spruill, personal communication) and Nelson (in press) found it in the MRC site.

Fifteen graphic granite dikes were found in gabbro cores F-1, F-3, F-5, F-6C, and F-8. The dikes range from a half inch to 4 feet in thickness and dips range from 0 to 50 degrees; the majority of the dikes dip about 50 degrees. They are moderately fractured and contain minor hairline cracks lined with calcite. Modal analysis (Morgan, 1963) indicates a composition of 41% quartz, 57% feldspar, 0.6% muscovite, and 0.6% opaque. Thin sections of graphic granite were found to consist of quartz (with some crystal terminations), K-feldspar (see Plate 35), opaques and very minor monazite (see Plate 34). Some wall rocks have light colored alteration above and below graphic granite dikes, with the larger alteration areas occurring below (see Plate 33). No graphic granite dikes were found cutting the syenite.

Table 3. Graphic granite dikes in the gabbro cores

<u>Cores</u>	<u>Granitic dike thickness (in)</u>	<u>Depth below the surface</u>	<u>Angle of dip</u>
F-1	5	29	30 degrees
F-1	2	61	50 degrees
F-1	12	151	50 degrees
F-3	36	30	0 degrees
F-3	12	104	50 degrees
F-3	48	109	45 degrees
F-3	1	125	55 degrees
F-3	8	176	30 degrees
F-5	12	31	5 degrees
F-5	5	88	20 degrees
F-6C	48	115	10 degrees
F-8	24	86	25 degrees
F-8	12	90	indeterminate
F-8	1	108	50 degrees
F-8	1	121	50 degrees

Explanation of Plate 33 and Plate 34

Plate 33. Photograph of an 8 inch thick graphic granite dike (pink) dipping at 30 degrees in gabbro core F-3, 176 feet below the land surface. Note the lighter alteration areas along the contact to the right of the coin.

Plate 34. Photomicrograph (0.31 mm across the top edge of the photo; crossed polars) of a tiny monazite crystal in the graphic granite.



Plate 33

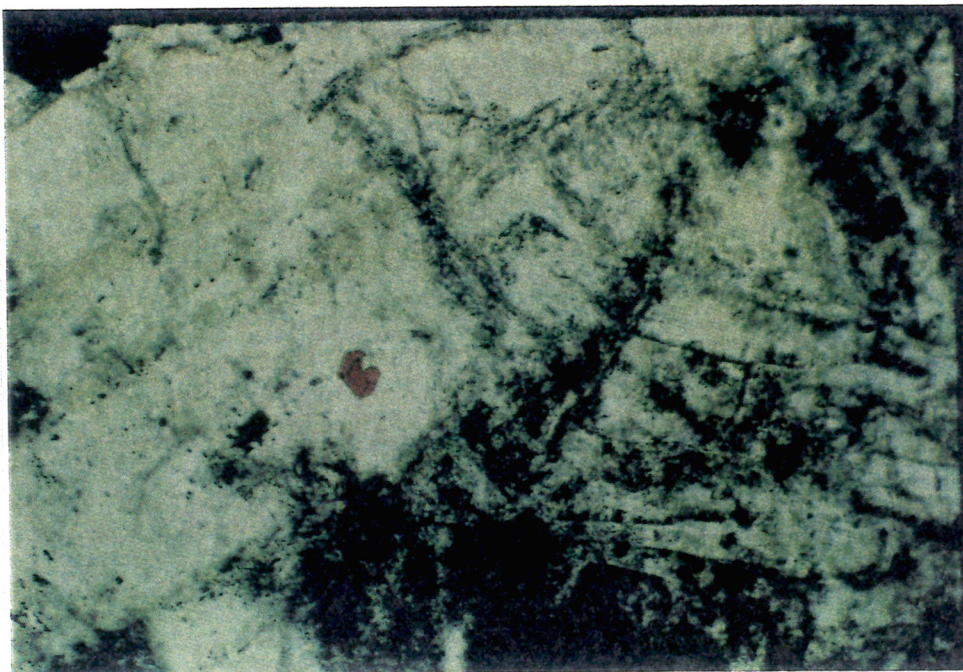


Plate 34

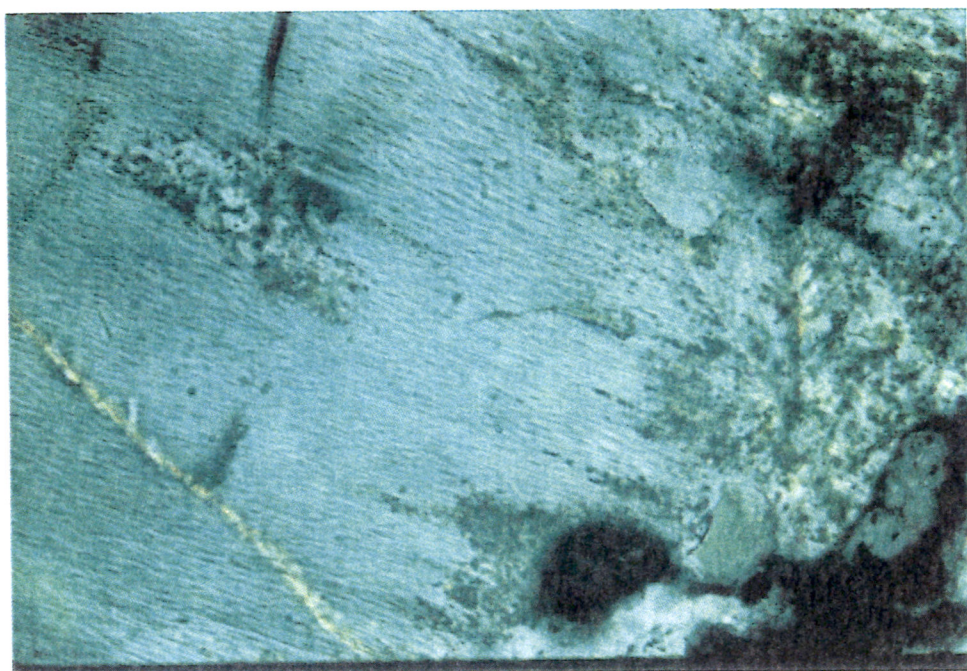


Plate 35. Photomicrograph (0.31 mm across the top edge of the photo; crossed polars) of a perthitic feldspar grain in the graphic granite.

COARSE-GRAINED DIKES

Only 3 coarse-grained mafic dikes were found in the gabbro cores (see Plate 36). Mineral grains are up to 2 cm in diameter. The dikes range from 1/2 foot to 1 foot in thickness and are all found below 185 feet (see Table 4). The average dip angle for the coarse-grained dikes is about 60 degrees. Core F-3 was intruded by two parallel, coarse-grained dikes dipping 45 and 55 degrees, and core F-8 was cut by one coarse-grained dike dipping 75 degrees. The dikes consist of plagioclase (An 55), biotite, bronzite, clinopyroxene, tremolite, hornblende, apatite, white mica, and opaques (see Plate 37). They have been weakly fractured. The minerals in the fractures include calcite, black chlorite, and pyrite (see Plate 38), similar to minerals in the seams and veinlets noted in the gabbro.

Multi-element analysis shows the coarse-grained dike (CP1) to be rich in trace elements, particularly the lanthanides (see Appendix A), suggesting the dikes represent crystallized residual liquid from the gabbro pluton.

The F-3 and F-8 cores are only 600 feet apart and dip angles of the coarse-grained dikes are similar to those of the quartz veins found in these cores, however there is no way to tell if the coarse-grained dikes and quartz veins are continuous between cores.

Table 4. Coarse-grained dikes in the gabbro cores

<u>Core</u>	Coarse-grained dike <u>thickness</u> (in)	Depth below <u>the surface</u> (ft)	<u>Angle of dip</u>
F-3	9	186	45 degrees
F-3	5+	195	55 degrees
F-8	12	200	75 degrees

Explanation of Plate 36 and Plate 37

Plate 36. Photograph of a coarse-grained dike in gabbro core F-3 at a depth of 186 feet.

Plate 37. Photomicrograph (0.62 mm across the top edge of the photo; reflected light) of ilmenite grains in a coarse-grained dike. Note that the hematite lamellae do not cross grain boundaries.



Plate 36

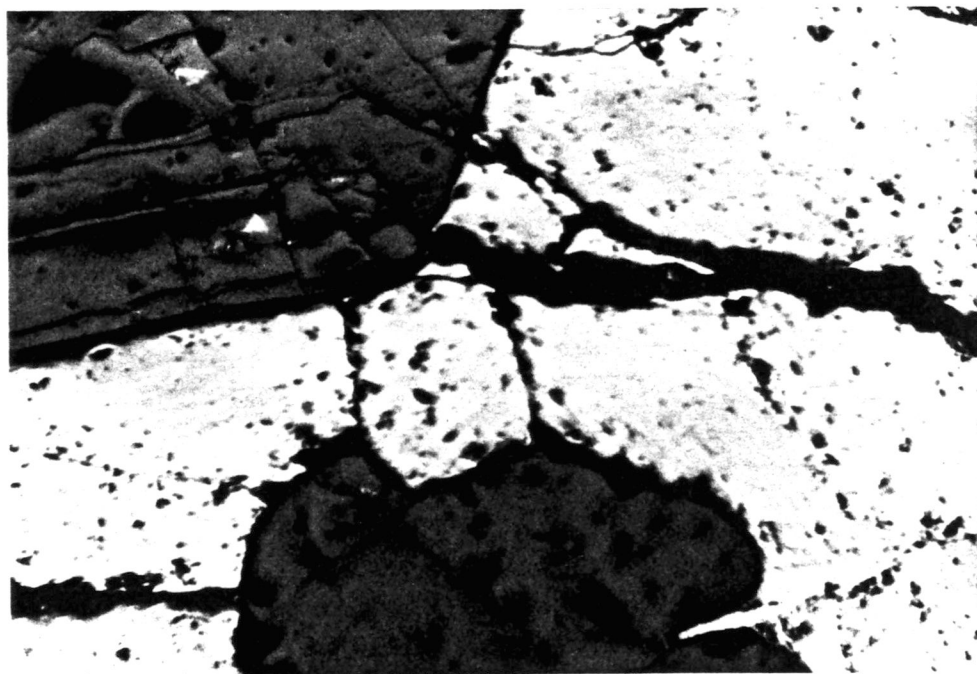


Plate 37



Plate 38. Photomicrograph (0.62 mm across the top edge of the photo; reflected light) of a chalcopyrite veinlet in a coarse-grained dike.

DIABASE DIKES

Fine-grained gabbroic dikes (23) cut the coarser-grained gabbro in cores F-2, F-3, F-5, F-6C, F-6D, and F-8. Widths range from 1 to 36 inches (see Table 5), but the majority of the dikes are only a few inches wide (see Plate 39). The larger diabase dikes can be difficult to recognize, because they can be mistaken for finer-grained masses of gabbro. Most dip angles are 45-55 degrees; a few are steeper and a few dikes have flat dips.

Table 5. Diabase dikes in the gabbro

<u>Core</u>	<u>Diabase dike thickness (in)</u>	<u>Depth below the surface</u>	<u>Angle of dip</u>
F-2	2	34	75 degrees
F-2	6	38	50 degrees
F-2	6	41	50 degrees
F-2	5	42	30 degrees
F-2	2	48	45 degrees
F-2	36	55	70 degrees
F-2	1	60	70 degrees
F-2	6	68	45 degrees
F-2	1	124	45 degrees
F-3	5	59	50 degrees
F-5	8	151	40 degrees
F-5	36	179	45 degrees
F-5	2	185	45 degrees
F-5	9	192	55 degrees
F-5	1	197	55 degrees
F-5	1	199	45 degrees
F-5	1	200	45 degrees
F-5	1	202	45 degrees
F-6C	24	119	10 degrees
F-6C	4	156	0 degrees
F-6C	1	157	65 degrees
F-6D	36	29	0 degrees
F-8	1	164	60 degrees

Plagioclase feldspar (An 72), hornblende, orthopyroxene, clinopyroxene, apatite (see Plate 40), and opaques make up the

fine grained dikes. The dikes are similar mineralogically to the gabbro and were probably derived from gabbroic magma squeezed upward into fractures in cooled, solidified gabbro.

Explanation of Plate 39 and Plate 40

- Plate 39. Photograph of a fine-grained dike dipping 45 degrees in gabbro core F-5, 202 feet below the land surface.
- Plate 40. Photomicrograph (1.07 mm across the top edge of the photo; crossed polars) of euhedral apatite crystals in plagioclase in a fine-grained dike.

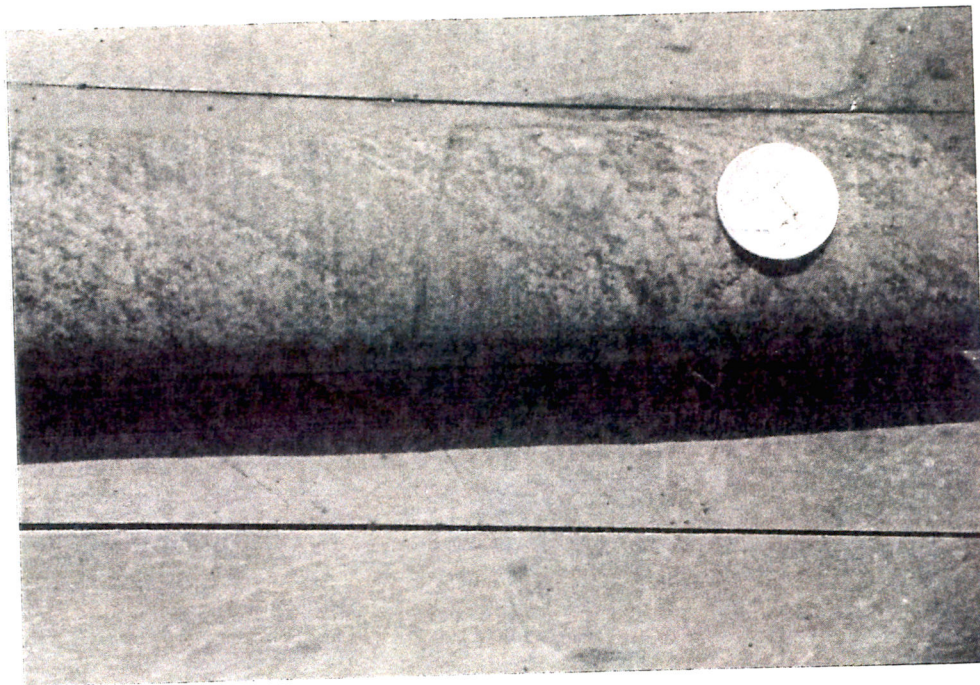


Plate 39

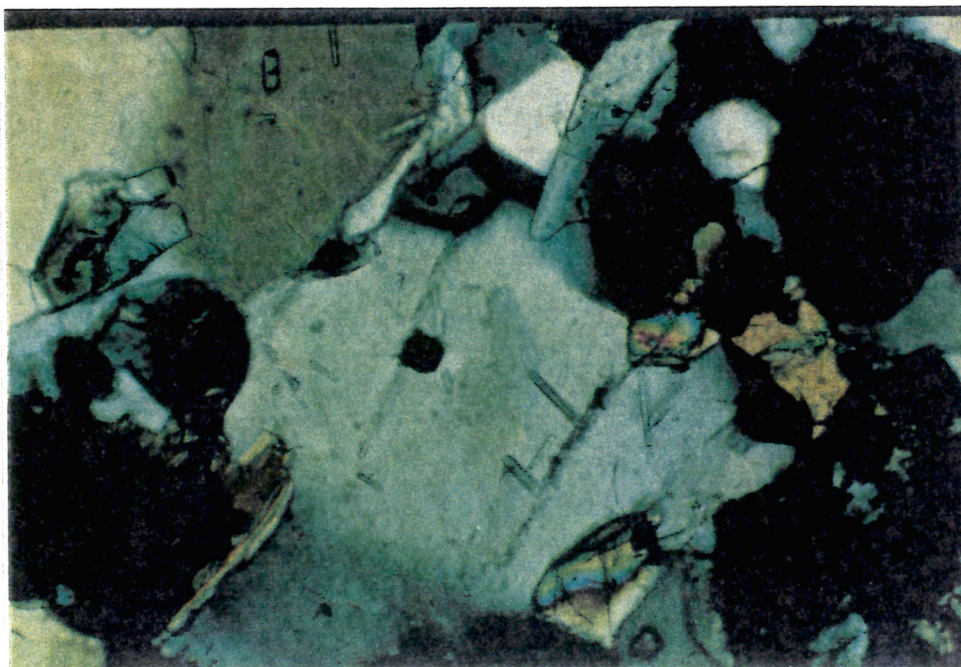


Plate 40

AGE OF THE VEINLETS AND FLUID HISTORY

The ages of the gabbro and syenite have been determined to be 401 Ma $\pm$ 30 (Rb-Sr) and 407 Ma $\pm$ 36 (Sm-Nd) old respectively (Fullager, 1971; Olsen and others, 1983). Mauger (1988) verified the date of the syenite (K-Ar) at 430 Ma $\pm$ 10. Minette dikes, age-dated between 330 and 347 Ma (K-Ar), exist 3 miles to the northeast and southwest of the MRC plant site (Mauger, 1988). Since biotite loses argon above 300 degrees C, this area was fairly cool and high in the crust, probably since early to middle Devonian time. The plutonic rocks of the Concord gabbro\syenite complex do not show any signs of deformation caused by the Late Paleozoic orogenies in the Piedmont-Blue Ridge region. This is another indication that the rocks were solidified by the early to early middle Devonian. It is likely that as the rocks crystallized and cooled, veinlets and fissures opened. At this time the main fluid components were CO₂, H₂O, and a sulfur species. Thin calcite veins and veinlets are found extensively in gabbro, syenite, and all of the dike types in the complex. The abundance of chlorite indicates that there was extensive H₂O in the system. Hydrothermal alteration of the gabbro has produced fibrous actinolite and tremolite in the bluish-gray zone of Core F-6C. The local "hydration" of olivine and the occasional presence of sericite in the gabbro thin sections also support the

existence of a hydrous fluid phase after the crystallization of gabbro. Minor occurrences of pyrite, pyrrhotite, and chalcopyrite veinlets mostly are found in the gabbro.

The absolute ages of the quartz veins, graphic granite dikes, coarse-grained mafic dikes, and diabase dikes are not known. None of the coarse-grained mafic dikes, diabase dikes, or granitic dikes show chilled margins. Even the very thin diabase dikes do not show chilled margins. The lack of chilled margins in these dikes implies that they were emplaced into "warm" wall rocks. It is common for Mesozoic dikes in North Carolina to show chilled margins. Mauger's minette (330 Ma) from a nearby locality shows evidence of "chilling." Enriched K-feldspar zones adjacent to some granite dikes in core F-3 (See Plate 33) suggest that the wall rocks were still warm when these dikes were emplaced. The coarse-grained gabbro dikes were probably late stage derivations of the gabbro source magma, because they are rich in trace elements. Quartz veins (see Plate 27 and 28) show finer grain sizes along margins. The quartz veins probably represent very late-stage hydrothermal activity.

DEPTH OF OXIDATION IN THE SYENITE AND GABBRO

The maximum depth of oxygen penetration was determined in the gabbro cores by finding where limonite and hematite cease to exist in the fractures. A more heavily fractured gabbro core almost always has a deeper depth of oxidation than a less thoroughly fractured one, because of enhanced circulation of groundwater (see Figure 2). A similar relationship should be expected in the syenite. However, syenite core F-7 was not drilled deeply enough to reach below the maximum depth of oxidation. The fractures in the syenite core were found to be oxidized to at least a depth of 116.5 feet.

LeGrand (1984) found that groundwater generally occurs down to depths of 150 feet and rarely is found below 300 feet in the North Carolina Piedmont and Mountain Region. In the gabbro cores the maximum depth of oxidation ranges from 84 to 192.5 feet (refer to the contour map) and falls within LeGrand's groundwater ranges. Cores F-4 and F-6D were only drilled to 105.5 and 75 feet respectively, and therefore, the maximum depth of oxygen penetration was not reached. By referring to the contour map (see Figure 3) the maximum depth of oxidation in cores F-4 and F-6D would be about 180 and 120 feet respectively.

Table 6. Depth of Oxidation in the Concord Area Cores

<u>Core</u>	<u>Lithology</u>	<u>Length of core (ft)</u>	<u>Depth of maximum oxygen penetration (ft)</u>
F-1	gabbro	200.0	192.0
F-2	gabbro	200.0	84.0
F-3	gabbro	195.5	110.0
F-4	gabbro	105.5	105.5 +
F-5	gabbro	203.5	135.0
F-6C	gabbro	200.0	119.0
F-6D	gabbro	75.0	75.0 +
F-7	syenite	120.5	116.5 +
F-8	gabbro	<u>200.5</u>	192.5

total core length - 1500.5 feet

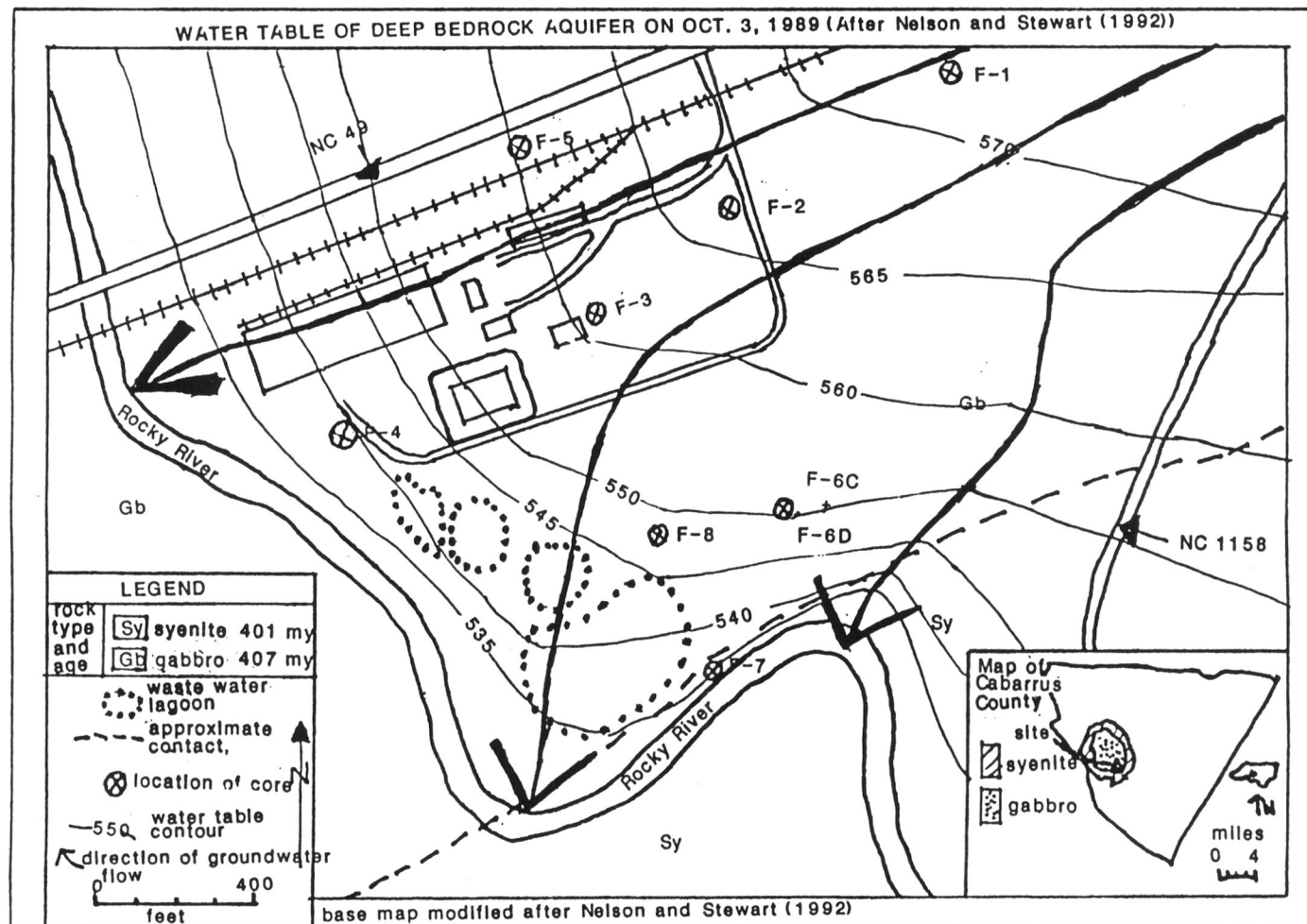


Figure 2. Map depicting groundwater flow in the deep bedrock aquifer on the MRC site (Nelson and Stewart, 1992).

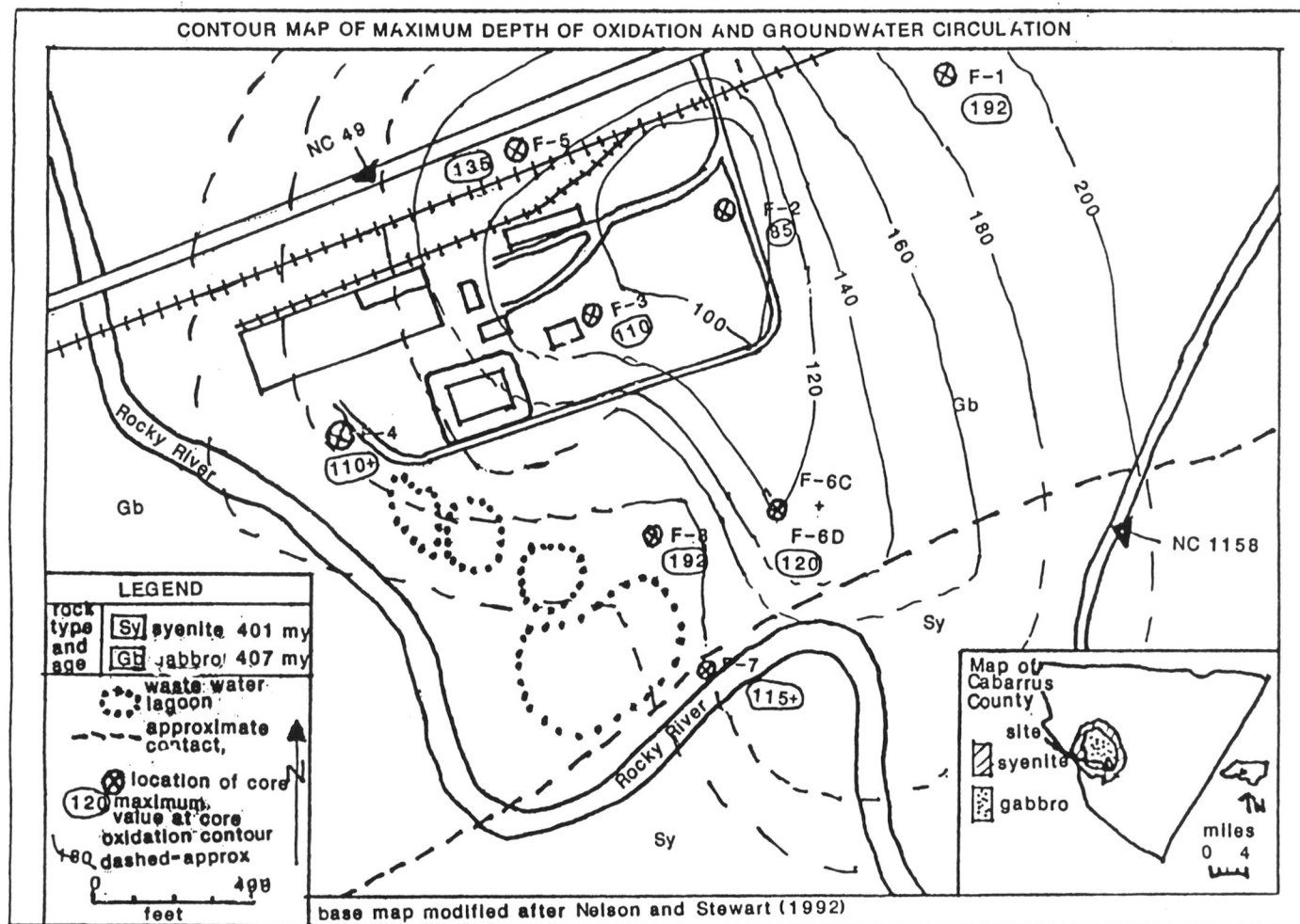


Figure 3. Map showing the maximum depth of oxidation and groundwater circulation.

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APPENDIX A
WHOLE ROCK AND MULTI-ELEMENT ANALYSES

**Whole Rock Analyses for Rocks Found in the Concord
Gabbro/Syenite Complex**, present study (in percent)

<u>Sample</u>	<u>SiO₂</u>	<u>Al₂O₃</u>	<u>CaO</u>	<u>MgO</u>	<u>Na₂O</u>	<u>K₂O</u>	<u>Fe₂O₃</u>	<u>MnO</u>	<u>TiO₂</u>	<u>P₂O₅</u>	<u>LOI</u>	<u>SUM</u>
Cp1	43.8	12.3	8.45	7.91	2.83	0.58	16	0.3	4.52	2.48	0.2	99.4
Cs2	59.6	17.5	3.02	1.54	6.37	3.64	5.04	0.19	1.2	0.45	1.1	100
Cgr3	74.8	12.9	0.18	0.11	2.75	6.62	0.15	0.01	0.08	0.03	0.45	98.1
Cd4	46.7	14.1	10.4	6.45	3.05	0.37	15.2	0.32	2.55	0.44	0.5	100
Cm5	50.9	16.2	7.43	3.8	4.92	1.14	10.8	0.31	2.4	1.25	0.65	99.9
Cgb6	37.6	11	13.6	6.56	1.82	0.19	21.9	0.28	3.82	2.73	0.1	99.6

<u>Sample</u>	<u>Rock Type</u>
Cp1	Coarse-grained dike
Cs2	Syenite
Cgr3	Granite
Cd4	Fine-grained dike
Cm5	Gabbro
Cgb6	Gabbro

**Comparison of Multi-element Analyses For Syenite Rocks From
the Concord Gabbro/Syenite Complex, after Price (1969) (in parts per million (PPM))**

<u>Rock Type</u>	<u>Sample</u>	<u>Cu</u>	<u>Pb</u>	<u>Zn</u>	<u>Li</u>	<u>V</u>	<u>Cr</u>	<u>Co</u>	<u>Ni</u>	<u>Sr</u>	<u>Zr</u>	<u>Rb</u>
Syenite	NC28A	13	7	78	6	55	23	360	8	369	275	27
Syenite	NC140	10	7	86	6	69	15	7	4	384	895	31
Syenite	NC141	10	9	82	8	69	8	20	6	297	794	22
Syenite	NC142	6	7	54	2	29	8	11	4	124	882	37
Syenite	CRD18	7	7	61	5	31	4	6	4	155	440	38
Syenite	CRD20	6	7	45	7	20	9	7	4	34	458	52
Syenite	CRD22	8	7	73	4	59	1	10	6	77	193	13
	average	9	7	68	5	47	10	60	5	206	562	31

**Multi-element Analysis of a Syenite Sample From the Concord
Gabbro/Syenite Complex, present study (in PPM)**

<u>Rock Type</u>	<u>Sample</u>	<u>Cu</u>	<u>Pb</u>	<u>Zn</u>	<u>Li</u>	<u>V</u>	<u>Cr</u>	<u>Co</u>	<u>Ni</u>	<u>Sr</u>	<u>Zr</u>	<u>Rb</u>
Syenite	CS2	2.1	<2	104	5	50	10	<1	<1	473	206	15

**Comparison of Multi-element Analyses For Gabbro Rocks From the
Concord Gabbro/Syncnite Complex, after Price (1969) (in PPM)**

<u>Rock Type</u>	<u>Sample</u>	<u>Cu</u>	<u>Pb</u>	<u>Zn</u>	<u>Li</u>	<u>V</u>	<u>Cr</u>	<u>Co</u>	<u>Ni</u>	<u>Sr</u>	<u>Zr</u>	<u>Rb</u>
Gabbro	NC3	115	10	65	3	94	325	96	970	664	118	8
Gabbro	NC4	58	9	62	2	96	295	32	680	935	216	5
Gabbro	NC16	74	11	62	3	108	365	120	1180	756	155	9
Gabbro	NC17	106	17	100	3	104	273	130	620	630	129	7
Gabbro	CRD24	76	12	88	7	181	144	29	240	690	189	12
Gabbro	CRD29	64	11	97	6	110	195	110	780	586	157	8
	average	82	12	79	4	116	266	86	745	710	161	8

**Multi-element Analyses of Gabbro Samples From the Concord
Gabbro/Syncnite Complex, present study (in PPM)**

<u>Rock Type</u>	<u>Sample</u>	<u>Cu</u>	<u>Pb</u>	<u>Zn</u>	<u>Li</u>	<u>V</u>	<u>Cr</u>	<u>Co</u>	<u>Ni</u>	<u>Sr</u>	<u>Zr</u>	<u>Rb</u>
Gabbro	CGB6	105	<2	206	3	380	5	35	<1	713	86	4
Gabbro	CM5	12.9	<2	170	9	144	5	4	<1	847	139	8

**Comparison of Multi-element Analyses of Rocks Found in the Concord
Gabbro/Syenite Complex, present study (in PPM)**

<u>Rock Type</u>	<u>Sample</u>	<u>Cu</u>	<u>Pb</u>	<u>Zn</u>	<u>Li</u>	<u>V</u>	<u>Cr</u>	<u>Co</u>	<u>Ni</u>	<u>Sr</u>	<u>Zr</u>	<u>Rb</u>
Syenite	CS2	2.1	<2	104	5	50	10	<1	<1	473	206	15
Gabbro	OGB6	105	<2	206	3	380	5	35	<1	713	86	4
Gabbro	CM5	12.9	<2	170	9	144	5	4	<1	847	139	8
Coarse-grn dike	CP1	25.8	<2	160	10	271	22	23	39	562	238	6
Granite	OGR3	565	61	326	1	9	10	<1	<1	21	79	154
Fine-grain dike	CD4	67.7	<2	183	3	205	88	25	54	763	59	5

<u>Rock Type</u>	<u>Sample</u>	<u>Ba</u>	<u>B</u>	<u>Cl</u>	<u>Sc</u>	<u>Ga</u>	<u>Ge</u>	<u>As</u>	<u>Se</u>	<u>Br</u>	<u>Y</u>	<u>Nb</u>
Syenite	CS2	3	26	153	15.6	21	14	0.9	<.5	3	33	19
Gabbro	OGB6	6	49	375	52.6	19	13	<.1	<.5	3	47	14
Gabbro	CM5	2	15	277	27.6	21	<10	<.1	<.5	2	60	20
Coarse-grn dike	CP1	4	<10	943	27.7	17	<10	<.1	<.5	3	74	37
Granite	OGR3	2	38	176	1.44	13	<10	1.2	<.5	2	14	36
Fine-grain dike	CD4	4	44	140	49.5	20	<10	<.1	<.5	3	34	10

(Continued)

<u>Rock Type</u>	<u>Sample</u>	<u>Mo</u>	<u>Ag</u>	<u>Cd</u>	<u>In</u>	<u>Sn</u>	<u>Sb</u>	<u>Cu</u>	<u>Ba</u>	<u>La</u>	<u>Ce</u>	<u>Pr</u>
Syenite	CS2	<1	<1	<2	<5	5	0.1	<1	2820	93.3	178	24.1
Gabbro	OGB6	<1	1	<2	<5	5	<1	<1	104	43.2	111	17.4
Gabbro	CM5	<1	0.3	<2	<5	5	0.1	<1	914	107	240	32.1
Coarse-grn dike	CP1	<1	<1	<2	<5	19	0.2	<1	285	168	373	45.1
Granite	OGR3	<1	0.2	<2	<5	6	0.4	1	54	10	22	2.9
Fine-grain dike	CD4	<1	0.3	<2	<5	10	0.2	<1	294	28.7	70.5	11

<u>Rock Type</u>	<u>Sample</u>	<u>Nd</u>	<u>Sm</u>	<u>Eu</u>	<u>Gd</u>	<u>Tb</u>	<u>Dy</u>	<u>Ho</u>	<u>Er</u>	<u>Tm</u>	<u>Yb</u>	<u>Lu</u>
Syenite	CS2	102	16.7	7.37	13.4	1.7	8.7	1.53	4.4	0.5	2.9	0.43
Gabbro	OGB6	84.6	17.3	4.05	14.9	2.1	11.5	2	5.3	0.7	3.4	0.49
Gabbro	CM5	146	26.9	7.11	21.3	2.9	15.3	2.85	7.5	0.9	5	0.71
Coarse-grn dike	CP1	198	31.9	5.69	22.2	3.2	16.5	3	7.8	0.9	5.8	0.81
Granite	OGR3	11.6	2.9	0.19	2.9	0.6	3.4	0.69	2.6	0.4	2.7	0.39
Fine-grain dike	CD4	50.8	11.7	3.55	10.5	1.5	8	1.53	4	0.5	2.9	0.44

(Continued)

<u>Rock Type</u>	<u>Sample</u>	<u>Hf</u>	<u>Ta</u>	<u>W</u>	<u>Tl</u>	<u>Bi</u>	<u>Th</u>	<u>U</u>
Syenite	CS2	3.6	<1	<1	<.1	<1	0.9	0.4
Gabbro	CGB6	2.6	<1	<1	<.1	<1	0.5	<.1
Gabbro	CM5	3.1	1	<1	<.1	<1	1	<.1
Coarse-grn dike	CP1	5.2	2	<1	<.1	<1	2.3	0.8
Granite	CGR3	3.9	3	<1	1.1	<1	23	29.3
Fine-grain dike	CD4	1.5	<1	<1	<.1	<1	<.5	0.2

**Comparison of Multi-element Analyses of Rocks Found in the Concord
Gabbro/Syenite Complex**, present study (in parts per billion (PPB))

<u>Rock Type</u>	<u>Sample</u>	<u>Au</u>	<u>Pd</u>	<u>Pt</u>	<u>Hg</u>
Syenite	CS2	18	<1	<10	<5
Gabbro	CGB6	3	<2	<10	<5
Gabbro	CM5	4	3	<10	<5
Coarse-grn dike	CP1	2	<1	<10	<5
Granite	CGR3	3	<1	<10	<5
Fine-grain dike	CD4	3	2	<10	<5



X-RAY ASSAY LABORATORIES 10-JUL-92

KEVIN HEADD (REF# 12447)

CHONDRITE NORMALIZED VALUES

SAMPLE	LA	CE	PR	ND	SM	EU	GD	TB	DY	HO	ER	TM	YB	LU
CP 1	533.3	458.8	451.0	331.7	166.1	78.8	85.7	65.3	50.8	41.7	36.6	28.1	27.8	25.1
CS 2	296.2	218.9	241.0	170.9	87.0	102.1	51.7	34.7	26.8	21.3	20.2	15.6	13.9	13.3
CGR 3	31.7	27.1	29.0	19.4	15.1	2.6	11.2	12.2	10.5	9.6	12.2	12.5	12.9	12.1
CD 4	91.1	86.7	110.0	85.1	60.9	49.2	40.5	30.6	24.6	21.3	18.8	15.6	13.9	13.6
CM 5	339.7	295.2	321.0	244.6	140.1	98.5	82.2	59.2	47.1	39.6	35.2	28.1	23.9	22.0
CGB 6	137.1	136.5	174.0	141.7	90.1	56.1	57.5	42.9	35.4	27.8	24.9	21.9	16.3	15.2

CHONDRITE RARE EARTH ELEMENT FACTORS USED TO NORMALIZE THE SAMPLE DATA :

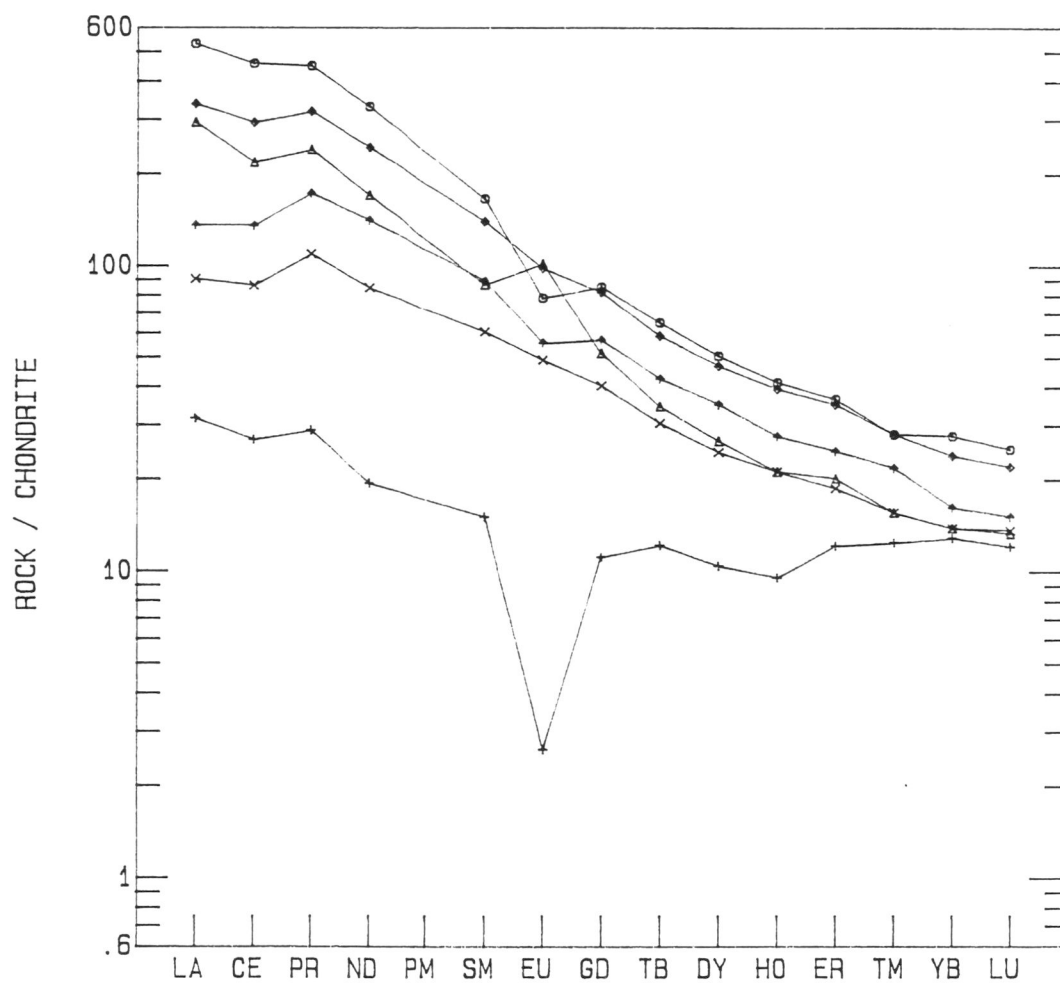
LA .3150 CE .8130 PR .1000 ND .5970 SM .1920 EU .0722 GD .2590
 TB .0490 DY .3250 HO .0720 ER .2130 TM .0320 YB .2090 LU .0323

X-RAY ASSAY LABORATORIES 10-JUL-92

RARE EARTH CHONDRITE PLOTS

KEVIN HEADD
(REF# 12447)

○ CP 1
 △ CS 2
 + CGR 3
 × CD 4
 ◆ CM 5
 * CGB 6



XRAL**X-RAY ASSAY LABORATORIES**

A DIVISION OF SGS SUPERVISION SERVICES INC.
 1885 LESLIE STREET • DON MILLS, ONTARIO M3B 3J4 • CANADA
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CERTIFICATE OF ANALYSIS
REPORT 19739

TO: KEVIN HEADD
 353 HIDDEN BRANCHES CLOSE
 WINTERVILLE, NORTH CAROLINA
 28590

CUSTOMER No. 2316

DATE SUBMITTED
 9-Jun-92

REF. FILE 12447-M4

Total Pages 8

6 ROCKS

	METHOD	DETECTION LIMIT
AU PPB	FADCP	1.
LI PPM	ICP	1.
BE PPM	DCP	1.
B PPM	DCP	10.
WRMAJ %	WR	.01
S %	LECO	.005
CL PPM	XRF	100.
SC PPM	ICP	.05
V PPM	DCP	2.
CR PPM	NA	2.
CO PPM	ICP	1.
NI PPM	ICP	1.
CU PPM	ICP	.5
ZN PPM	ICP	.5
GA PPM	ICPMS	1.
GE PPM	DCP	10.
AS PPM	NA	.1
SE PPM	GFAA	.5
BR PPM	NA	1.
RB PPM	XRF	2.
SR PPM	ICP	1.
Y PPM	ICP	1.
ZR PPM	XRF	1.
NB PPM	XRF	2.
MO PPM	ICP	1.
PD PPB	FADCP	1.
AG PPM	ICP	.1
CD PPM	AA	.2
IN PPM	AA	.5

	METHOD	DETECTION LIMIT
SN PPM	XRF	2.
SB PPM	NA	.1
CS PPM	NA	1.
WRMIN PPM	WR	10.
LA PPM	ICPMS	.1
CE PPM	ICPMS	.1
PR PPM	ICPMS	.1
ND PPM	ICPMS	.1
SM PPM	ICPMS	.1
EU PPM	ICPMS	.05
GD PPM	ICPMS	.1
TB PPM	ICPMS	.1
DY PPM	ICPMS	.1
HO PPM	ICPMS	.05
ER PPM	ICPMS	.1
TM PPM	ICPMS	.1
YB PPM	ICPMS	.1
LU PPM	ICPMS	.05
HF PPM	NA	.5
TA PPM	NA	1.
W PPM	NA	1.
PT PPB	FADCP	10.
HG PPB	WET	5.
TL PPM	ICPMS	.1
PB PPM	ICP	2.
BI PPM	ICPMS	1.
TH PPM	NA	.5
U PPM	NA	.1

DATE 23-JUL-92

CERTIFIED BY

Jean H.L. Odebeek, General Manager

Member of the SGS Group (Société Générale de Surveillance)

XRAL**MULTIELEMENT RESEARCH PACKAGE - INAA**

	<u>NBS-1632A</u>	<u>SDC-1</u>	<u>RGH-1</u>	<u>STM-1</u>	<u>BHYO-1</u>
AG PPM	<2 (-)	<2 (-)	<2 (-)	<2 (-)	<2 (-)
AS PPM	9 (9.1)	<1 (-)	3 (-)	4 (-)	1 (-)
AU PPM	- (<5)	- (-)	- (-)	- (-)	- (-)
BA PPM	130 (130)	680 (650)	880 (800)	630 (560)	200 (135)
BR PPM	43 (43)	9.2 (-)	10 (-)	7.9 (-)	8.8 (-)
CA %	0.2 (24)	1.2 (99)	0.8 (0.82)	0.6 (78)	9.9 (8.09)
CO PPM	6.9 (6.6)	16 (17)	2.0 (2.37)	0.8 (17)	45 (45)
CR PPM	35 (34.4)	86 (667)	6.7 (47)	4.1 (47)	310 (300)
CS PPM	2.6 (2.5)	3.7 (3.97)	9.6 (-)	1.3 (1.57)	0.3 (1.57)
FE %	1.14 (1.11)	4.84 (4.81)	1.35 (1.31)	3.52 (3.65)	9.43 (8.56)
HF PPM	1.3 (1.6)	7.8 (8.1)	5.9 (6.07)	26 (277)	4.5 (4.3)
MO PPM	<2 (<4)	<2 (-)	<2 (2.3)	5 (5.2)	<2 (-)
NA PPM	960 (840)	15500 (15570)	32200 (30560)	63000 (66400)	16800 (17000)
NI PPM	<50 (19)	<50 (36)	<50 (67)	<50 (37)	80 (120)
RB PPM	20 (29)	120 (1207)	140 (1557)	100 (1207)	10 (10)
SB PPM	0.7 (0.7)	0.59 (0.547)	1.36 (1.37)	1.7 (1.77)	0.2 (0.177)
SC PPM	6.16 (6.3)	15.1 (157)	4.65 (4.7)	0.50 (0.77)	33.9 (31)
SE PPM	2.5 (2.7)	<0.5 (-)	<0.5 (-)	<0.9 (-)	<0.6 (-)
SR PPM	<100 (90)	200 (180)	100 (100)	700 (700)	400 (420)
TA PPM	<0.5 (0.40)	1.2 (1.37)	0.9 (1.07)	18 (187)	<1.2 (1.17)
TH PPM	4.4 (4.5)	11 (127)	15 (157)	29 (317)	1.2 (1.0)
U PPM	1.2 (1.29)	2.8 (3.07)	5.2 (5.87)	10.2 (9.17)	0.4 (0.47)
W PPM	1 (0.8)	1 (0.8)	1 (1.67)	4 (3.8)	<1 (-)
ZN PPM	27 (28)	100 (105)	35 (36)	170 (240)	120 (105)
LA PPM	14.9 (15)	42.0 (42)	24.1 (237)	159 (150)	14.9 (177)
CE PPM	30 (30)	95 (92)	49 (487)	257 (260)	42 (39)
ND PPM	10 (12)	39 (38)	17 (197)	74 (78)	26 (24)
SM PPM	2.28 (2.2)	7.42 (8.37)	4.16 (4.37)	11.4 (13)	5.90 (6.1)
EU PPM	0.45 (0.54)	1.78 (1.77)	0.67 (0.77)	3.67 (3.7)	2.30 (2.0)
TB PPM	0.4 (0.3)	1.0 (1.27)	0.7 (-)	1.7 (1.6)	1.0 (1.0)
YB PPM	1.24 (1.10)	4.88 (4.2)	2.70 (2.5)	4.37 (4.3)	2.33 (-)
LU PPM	0.20 (0.19)	0.77 (-)	0.50 (-)	0.74 (-)	0.34 (-)

Note: () are useable values as per Sydney Abbey, 1983 (G.S.C. paper 83-15) or Gladney, et al., 1984. (-) indicates no values available. This represents part of a group of reference materials used for calibration purposes. These standards represent a single analysis of each.

INSTRUMENT STABILITY

(10 REPLICATE ANALYSES NBS 1632a)

<u>Element</u>	<u>Mean (ppm)</u>	<u>S.D. (ppm)</u>
Ba	123	8
Br	42.2	1.0
Ca	0.26	0.15
Co	6.2	0.2
Cr	34.3	0.5
Cs	2.3	0.1
Fe	1.11 %	0.01 %
Hf	1.35	0.05
Mo	1.5	0.9
Ni	<50	0
Rb	23	5
Sc	6.05	0.04
Se	2.7	0.4
Sr	100	-
Ta	<0.5	0
Th	4.39	0.08
Zn	32	2
La	15.5	0.4
Ce	29.4	0.7
Nd	11.5	0.8
Sm	2.25	0.03
Eu	0.53	0.04
Tb	0.31	0.03
Yb	1.10	0.08
Lu	0.186	0.007

Member of the SGS Group (Société Générale de Surveillance)

X-Ray Assay Laboratories
 Summary of Precision Statistics Based on In-House Duplicates
 Method: X-Ray Fluorescence on a Glass Disk
 XRAL Method Code: 100-1

Element	Lower Limit of Detect'n	Number of Dupl. Pairs	Relative Standard Deviation by Class					Average
			1	2	3	4	5	
SiO ₂	0.01%	10638	112.62	20.78	8.05	2.70	0.56	0.90
Al ₂ O ₃	0.01%	10451	38.04	7.70	3.39	0.85	0.47	0.80
CaO	0.01%	10082	37.30	10.29	2.07	0.75	0.66	1.40
HgO	0.01%	10331	49.80	16.90	2.85	0.78	0.68	1.60
Na ₂ O	0.01%	9866	40.24	23.56	6.79	1.30	0.60	4.80
K ₂ O	0.01%	9671	34.71	2.01	2.71	1.10	0.59	1.70
Fe ₂ O ₃	0.01%	10412	51.41	24.10	8.65	1.39	0.76	2.70
MnO	0.01%	9418	24.97	1.04	0.74	0.89	0.40	0.90
Cr ₂ O ₃	0.01%	3166	2.30	2.69	1.35	0.30	2.31	2.50
P ₂ O ₅	0.01%	9009	90.44	1.48	0.05	0.77	0.86	0.80
TiO ₂	0.01%	11316	40.26	0.20	6.04	1.18	0.82	1.50
LOI	0.01%	9978	51.31	8.79	17.16	4.12	0.69	5.30
Ba	10ppm	8980	42.14	19.23	4.79	1.65	1.38	6.30
Nb	10ppm	5614	52.04	22.32	6.16	0.92	ND	21.70
Rb	10ppm	7386	52.15	15.16	4.23	2.79	ND	13.00
Sr	10ppm	8108	31.46	14.27	3.38	0.80	0.89	6.70
Y	10ppm	5123	39.06	22.47	4.61	0.37	ND	21.10
Zr	10ppm	8469	30.84	12.96	4.23	1.49	1.43	7.10

Notes: Between 8 to 15% of samples are analyzed in duplicate. The average relative standard deviation is calculated for each pair of data points. The data are divided into 5 classes based on lower limits of detection (LLD):

- 1 - At least one of the data points is below the LLD. For the purposes of this calculation, data below the LLD is assigned a value of half the detection limit.
 - 2 - Mean of the 2 data points falls between 1 and 10 times the LLD.
 - 3 - Mean of the 2 data points falls between 10 and 100 times the LLD.
 - 4 - Mean of the 2 data points falls between 100 and 1,000 times the LLD.
 - 5 - Mean of the 2 data points falls between 1,000 and 10,000 times the LLD.
- ND (No data) - Insufficient data for the calculation.

Number of Duplicate Pairs: Total number of duplicate pairs; most data falls into classes 2 and 3. RSD for other classes may be overestimated.

X-Ray Assay Laboratories **Summary of Precision Statistics Based on In-House Duplicates**

Inductively Coupled Plasma Using a Nitric Aqua Regia Digestion: Method Code 70-1

Element	Det'n Limit	Number of Analyses	Relative Standard Deviation by Class					Average
			1	2	3	4	5	
Al	0.01%	1192	60.18	1.82	3.62	3.34	nd	3.4
Sb	5 ppm	233	6.51	11.13	14.00	19.26	nd	11.7
As	3 ppm	907	16.10	16.01	7.70	3.18	16.89	11.7
Ba	1 ppm	1485	5.55	6.94	4.55	4.02	2.63	4.6
Be	0.5 ppm	1004	24.24	8.49	22.10	134.34	nd	9.0
Bi	3 ppm	348	19.05	17.37	4.42	2.60	nd	16.9
Cd	1 ppm	397	3.77	9.98	2.00	1.08	nd	9.4
Ca	0.01%	1152	10.48	3.36	3.51	3.30	1.96	3.3
Cr	1 ppm	1444	49.46	11.00	6.43	4.89	3.46	6.5
Co	1 ppm	1269	27.51	13.72	5.32	24.05	nd	9.7
Cu	0.5 ppm	1567	88.56	18.99	5.52	2.80	2.90	5.7
Fe	0.01%	1324	90.91	38.44	4.45	2.82	2.22	3.7
Pb	2 ppm	1120	15.07	16.93	8.23	2.92	2.83	12.3
Li	1 ppm	1048	20.87	12.00	8.60	43.65	nd	10.6
Mg	0.01%	1131	3.42	1.36	2.76	2.38	1.87	2.4
Mn	0.01%	1106	nd	5.71	2.71	1.40	nd	4.9
Mo	1 ppm	561	13.10	12.88	6.11	3.40	nd	11.8
Ni	1 ppm	1195	20.44	16.14	9.99	3.79	1.86	11.9
P	0.01%	965	nd	4.03	4.12	nd	nd	4.0
K	0.01%	1193	5.00	4.48	4.25	3.35	nd	4.3
Sc	0.5 ppm	1234	1.49	6.82	4.14	nd	nd	5.8
Na	0.01%	1271	21.17	6.82	5.12	2.59	nd	6.5
Sr	0.5 ppm	1470	65.32	6.13	4.32	3.19	1.91	4.4
Ag	0.1 ppm	602	36.95	30.93	12.27	2.92	44.22	26.6
Sn	10 ppm	18	2.71	20.66	124.00	nd	nd	37.9
Ti	0.01%	491	nd	8.70	10.79	nd	nd	9.3
W	10 ppm	25	.99	17.77	22.74	nd	nd	19.8
V	2 ppm	1305	32.30	11.53	6.04	4.22	nd	7.7
Y	0.1 ppm	1426	14.50	7.83	4.82	3.91	50.10	5.0
Zr	0.5 ppm	1263	33.51	16.28	10.15	43.42	38.32	14.0
Zn	0.5 ppm	1600	83.25	9.76	7.17	4.13	2.55	5.5

APPENDIX B

CORE LOGS

KEY FOR CORELOGS

Depth - in feet below the land surface

Lithology - symbols:

gb - gabbro

sy - syenite

gr - granite

qz - quartz

cd - coarse-grained dike

fd - fine-grained dike

xn - xenolith

- - - - - contact between different lithologies

Lithologic Description -

regolith - refers to near surface material
consisting of soils, saprolite, and heavily
weathered rock fragments

top of the core - the uppermost part of
the collected core

thicknesses - example - 5 inch quartz vein -
refers to a 5 inch thick quartz vein

Thin Sections - refers to the specific location where a thin
section was taken. The exact thin section name is
also listed (example - c-28).

Fracturing - Dip -

fracturing - symbols:

h - heavily fractured - > 30

fractures per ten feet of core

m - moderately fractured - 15 - 30

fractures per ten feet of core

w - weakly fractured - < 15 fractures
per ten feet of core

(Continued)

KEY FOR CORE LOGS (CONTINUED)

dip - the dip angle for the fractures in
degrees, generally given as a range.

Notes - general information like: slickensides present, calcite
veins etc. symbols:

x - the fractures below here contain either hematite or
limonite (indicates the core has been oxidized)

y - the fractures below here do not contain hematite or
limonite (indicates the core has not been oxidized)

The dikes are not to scale (they are vertically
exaggerated to give an idea as to what the dip angle is).

The dike dip angle and the exact position can be found in
the appropriate table in the main text. Example:

Table 3. Graphic GraniteDikes in the Gabbro Cores

Core	Thickness	Depth	Angle of dip
F-1	5 inches	29 feet	40 degrees.

Core F-1 (ET)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
0					
5					
10	rg	regolith			
15					
20		top of the recovered core			
	gb	severely weathered gabbro		h 10-30 degrees	x
25					

Core F-1 (ET)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
25	gb	severely weathered gabbro			
30	gr	5 inches of graphic granite			
35					
40				h 10-30 degrees	x
45	gb	severely weathered gabbro			
50					

Core F-1 (ET)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
50	gb	gabbro weathering diminishes 2 inches of graphic granite		h 10-30 degrees	x
55				m 0-10 degrees	
60				w 0-50 degrees	
65	gb	gabbro			
70					
75					

Core F-1 (ET)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
75	gb	gabbro		w 40-60 degrees	x
80					
85					
90	gb	gabbro			y
95					
100					

Core F-1 (ET)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
100					
105	gb	gabbro			y
110		grains in core coarsen			
115		2 inch biotite grains are present			calcite veins
120	gb	gabbro			
				w 15-30 degrees	
125					

Core F-1 (ET)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
125	gb	gabbro			
130					
135				w 10-30 degrees	y
140	gb	gabbro			
145					
150				h 20-80 degrees	x slickensides

Core F-1 (ET)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
150	gr	1 foot of graphic granite		h 10-80 degrees	x
155					
160				w 10-80 degrees	
165	gb	gabbro			y
170				m 10-85 degrees	
175					

Core F-1 (ET)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
175	gb	gabbro	c-23	m 10-85 degrees	y
180				w 10-85 degrees	
185	c-22	m 10-80 degrees	x		
190				gb	gabbro
195	w 10-80 degrees				
200					

Core F-2 (F2D)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
0					
30	rg	regolith			
35	fd	top of the recovered core 2 inches of fine-grained dike gabbro			
	gb	8 inches of fine-grained dike gabbro			
40	fd	6 inches of fine-grained dike gabbro			
	gb	5 inches of fine-grained dike gabbro			
45	fd				
	gb				
50	fd				
	gb				

m 0-45 degrees

x

Core F-2 (F2D)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
50	gb	gabbro			
55	td	3 feet of fine-grained dike			
	gb	gabbro			
60	td	1 inch of fine-grained dike		m 0-65 degrees	
65	gb	gabbro			x
	td	8 inches of fine-grained dike			
70	gb	gabbro		m 20-90 degrees	
75					

Core F-2 (F2D)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
75	gb	gabbro			x
80					
85	gb	gabbro		m 10-70 degrees	y
90					
95					
100					

Core F-2 (F2D)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
100	gb	gabbro		m 10-70 degrees	
105				w 0-70 degrees	
110					calcite veins y
115					
120	gb	gabbro			pyrite in fractures
125			c-8		

Core F-2 (F2D)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
125	gb	gabbro			
130					
135					slickenside
140	gb	gabbro		w 5 -30 degrees	y
145					
150					

Core F-2 (F2D)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
150	gb	gabbro		w 0-40 degrees	y calcite veins
155					
160					
165	gb	gabbro			
170					
175					

Core F-2 (F2D)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
175					pyrite in fractures
180	gb	gabbro			
185			c-9	w 5-70 degrees	y
190					
195	gb	gabbro			
200					slickensides

Core F-3 (F-3)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
0					
5					
10	rg	regolith			
15					
20		top of the recovered core			
25	gb	severely weathered gabbro		n 0-30 degrees	x

Core F-3 (F-3)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
25	gb	severely weathered gabbro			
30	gr	3 feet of graphic granite		h 0-30 degrees	
35					x
40					
45	gb	severely weathered gabbro			slickensides
50					

Core F-3 (F-3)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
50	gb	severely weathered gabbro			
55					
60	fd	5 inches of fine-grained dike		h 0-30 degrees	calcite in fractures
65	gb	severely weathered gabbro			
70			m 0-60 degrees	x	
75	gb	gabbro			

Core F-3 (F-3)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
75				m 0-60 degrees	
80	gb	gabbro			
85					x
90				h 0-60 degrees	calcite veins
95					
	gb	gabbro			
100					

Core F-3 (F-3)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
100	gb	gabbro		h 0 degrees	x
	qtz	6 inches of quartz			
	gb	gabbro			
	gb	12 inches of graphic granite			
105	gr				
	gb	gabbro		w 45 degrees	y
110		4 feet of graphic granite			
	gr				
115	mz	2 foot granite + gabbro mixing zone			
	gb	gabbro			
120		1 inch of graphic granite			
	gr				
125	gb	gabbro			

Core F-3 (F-3)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
125	gb	gabbro			y
130					sulfides in fractures
135					local biotite zones in core
140	gb	gabbro		w 0 degrees	
145					
150					w 0 - 60 degrees

Core F-3 (F-3)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
150	gb	gabbro			a few thin quartz veins
					parallel calcite veins
155					
160	gb	gabbro		w 0 degrees	y
165					
170					
175					

Core F-3 (F-3)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
175	mz	1 foot granite + gabbro mixing zone	c-13		
	gr	8 inches of graphic granite			
	mz	1 foot granite + gabbro mixing zone	c-14		
180	gb			w 30 degrees	
185			c-12 c-11		
	cd	9 inches of coarse-grained dike			y
190	gb		c-29	w 10-70 degrees	
195	cd	5+ inches of coarse-grained dike	c-10		end of core
200					

Core F-4 (M2D)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
0	rg	regolith top of the recovered core			
30					
35	gb	biotite gabbro		w 5-50 degrees	x
40					
45					
50					

Core F-4 (M2D)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
50	gb	gabbro			x
55					
60	?	core missing			
65	gb	gabbro		w 45 degrees	y
70					
75					

Core F-4 (M2D)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
75	gb	gabbro		w 45 degrees	y
80					
85					
90	gb	gabbro			x
95					
100					

Core F-4 (M2D)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
100	gb	gabbro	c-30	w 45 degrees	x
			c-16		sulfides in fractures
			c-15		end of core
105					
110					
115					
120					
125					

Core F-5 (F-5)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
0					
	rg	regolith			
30	?	top of the recovered core weathered rock			
	gr	1 foot of graphic granite			
35					
40	gb	severely weathered gabbro		h 0-90 degrees	x
45					
50					

Core F-5 (F-5)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
50					
55	gb	severely weathered gabbro		h 0-90 degrees	
60					x
65	gb	weathering diminishes gabbro		m 0-80 degrees	
70					calcite veins
75					

Core F-5 (F-5)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
75	gb	gabbro			
80					
85					sulfides in fractures
	gr	5 inches of graphic granite			
90					x
				m 0-80 degrees	
95	gb	gabbro			
100					

Core F-5 (F-5)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
100	gb	gabbro		m 10-90 degrees	slickensides x
105					
110					
115	gb	gabbro			
120					
125				h 10-90 degrees	

Core F-5 (F-5)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
125	gb	gabbro		h 10-90 degrees	x
130					
135					quartz veins
140	gb	gabbro		m 0-70 degrees	y
145					
150					

Core F-5 (F-5)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
150	gb	gabbro 8 inches of fine-grained dike		m 0-70 degrees	y
	fd				
155					
160					
165					
				w 0-70 degrees	
170	gb	gabbro			
175					

Core F-5 (F-5)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
175	gb	gabbro	c-26		
	fd	3 feet of fine-grained dike			
180	gb	gabbro			
	gb	2 inches of fine-grained dike			
	fd	gabbro	c-27		
185	gb	9 inches of fine-grained dike			y
	fd			w 0-80 degrees	
190	gb	gabbro	c-24		
195	fd				calcite veins
	gb	1 inch of fine-grained dike			
	fd	1 inch of fine-grained dike			
	gb	1 inch of fine-grained dike			
	fd	1 inch of fine-grained dike			
200	gb	1 inch of fine-grained dike			
	fd				

Core F-6C (F-7A)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
0	rg	regolith			
20		top of the recovered core			
30					
35					
40	gb	gabbro		h 0-90 degrees	x
45					
50					

Core F-6C (F-7A)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
50	gb	gabbro		h 0-90 degrees	x
55					
60					
65					
70	gb	biotite gabbro		m 10-90 degrees	
75					

Core F-6C (F-7A)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
75	gb	biotite gabbro			
	qtz	4 inches of quartz		m 10-90 degrees	x
80					
85					y
90				w 10-90 degrees	
95	gb	biotite gabbro			
100					

Core F-6C (F-7A)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
100	gb	gabbro		w 10-90 degrees	y
105				m 40-80 degrees	
110					
115	gr	4 feet of graphic granite			x
120	fd	2 feet of fine-grained dike			
125	gb	gabbro		h 10-80 degrees	y slickensides

Core F-6C (F-7A)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
125	gb	gabbro		h 10-80 degrees	
130					
135	gb	gabbro			y
140					
145					
150				w 45-90 degrees	

Core F-6C (F-7A)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
150	gb	gabbro		w 45-90 degrees	1 Inch black vein
				m 20-90 degrees	
155	fd	4 inches of fine-grained dike gabbro		w 20-90 degrees	
	gb	1 Inch of fine-grained dike			
	fd				
160					
165				h 0-90 degrees	y
170	gb	gabbro			
175					

Core F-6C (F-7A)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
175	gb	gabbro			
		1 foot of quartz	c-21	h 0-90 degrees	
180	qtz		c-17 c-18		
			c-19		
185	gb	amphibole gabbro	c-20		blue core
190	gb	blotite gabbro			end of blue core y
195					
200				h 25-80 degrees	

Core F-6D (F-7B)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
0	rg	regolith top of the recovered core			
20					
30					slickensides
35	gb	severely weathered gabbro			
40	?	core missing			x
45					
50	gb	severely weathered gabbro		h 0-90 degrees	

Core F-6D (F-7B)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
50	gb	severely weathered gabbro			
55					
60					
65	gb	severely weathered gabbro		h 0-90 degrees	x
70					
75					

Core F-7 (6-A)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
0	rg	regolith			
80		top of the recovered core			
85	sy	syenite		w 45-60 degrees	x
90					
95	(xn)	1 Inch xenolith			
100	sy	syenite			1/4 Inch quartz vein

Core F-7 (6-A)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
100		8 Inch xenolith	c-1 c-2		quartz veins
105	sy	syenite			
		1 Inch xenolith			
110					
				w 0-80 degrees	x
115					
120	sy	syenite			
125					

Core F-8 (F-7)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
0	rg	regolith			
20		top of the recovered core			
30	gb	severely weathered gabbro			
35					
40				h 0-90 degrees	x
45					
50					

Core F-8 (F-7)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
50	gb	severely weathered gabbro			
55					
60	qtz	6 inches of quartz		h 0-90 degrees	x
65	gb	severely weathered gabbro			
70					
75					

Core F-8 (F-7)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
75	gb	gabbro			
	qtz	4 inches of quartz			
80	gb	gabbro			
85	gr	2 feet of graphic granite			x
90	gb	gabbro		h 45-90 degrees	
	gr	1 foot of graphic granite			
95	gb	gabbro			
100					

Core F-8 (F-7)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
100	gb	gabbro			
105		1 inch of graphic granite	c-7		x
	gr		c-6	n 0-90 degrees	
110					calcite veins
115	gb	gabbro		m 45 degrees	slickenside
120		1 inch of graphic granite			
	gr				
125	gb	gabbro		w 45 degrees	y

Core F-8 (F-7)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
125					
	gb	gabbro			
130					
135					y
140					calcite veins
	gb	gabbro		w 45 degrees	
145					
150					

Core F-8 (F-7)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
150					
	gb	gabbro			
155					
160					
		1 inch of fine-grained dike			
165	fd			w 45 degrees	y
170					
	gb	gabbro			
175					

Core F-8 (F-7)

Depth	Lithology	Lithologic Description	Thin Sections	Fracturing - Dip	Notes
175					
180	gb	gabbro			
185					y
190			c-3	w 45 degrees	x
195		1 foot of coarse-grained dike	c-4		y
200	cd gb	gabbro	c-5		

APPENDIX C
FRACTURE AND VEIN DATA

Fracture and Vein Data for Selected Locations Within the Cores**Gabbro Core F-1 177-187 feet**

Fract. or vein	Depth	Color	Mineralogy	Thickness	Angle
fracture	177.5	black	chlorite	0.01	50
fracture	178	black	chlorite, calcite, hematite	0.01	50
fracture	179	red	calcite, chlorite, hematite	0.01	50
fracture	181	black	chlorite, calcite	0.01	70
vein	184	white	calcite, chlorite	0.01	25
fracture	184	green	chlorite	0.01	0
vein	185	white	calcite	0.1	30
fracture	186	green	calcite, chlorite	0.01	55

Gabbro Core F-2 115-125 feet

Fract. or vein	Depth	Color	Mineralogy	Thickness	Angle
vein	115	white	calcite	0.1	45
vein	116	white	calcite	0.1	45
vein	116	white	calcite	0.1	45
vein	117	white	calcite	0.1	45
fracture	118	green	calcite, chlorite	0.01	40
vein	120	white	calcite	0.1	45
vein	120	white	calcite	0.1	45
fracture	120	black	calcite, chlorite, pyrite	0.01	35
fracture	121	black	calcite, chlorite, pyrite	0.01	40
fracture	121	black	calcite, chlorite, pyrite	0.01	40
fracture	124	black	calcite, chlorite, pyrite	0.01	45
vein	124	brown	chlorite	0.01	50
vein (dike)	124	gray	plagioclase, opx, cpx, biotite	0.5	45
fracture	124.5	black	chlorite, calcite, pyrite	0.01	0
fracture	125	blue	chlorite, calcite, pyrite	0.01	0

Gabbro Core F-2 175-185 feet

Fract. or vein	Depth	Color	Mineralogy	Thickness	Angle
fracture	178	black	chlorite, magnetite, pyrite	0.01	30
fracture	185	black	magnetite, chlorite, pyrite	0.01	65
vein	185	brown	chlorite	0.01	30

(Continued)

Gabbro Core F-3 175.5-185.5

Fract. or vein	Depth	Color	Mineralogy	Thickness	Angle
vein	177.5	pink	graphic granite	6	30
vein	178.5	white	quartz	0.125	50
vein	178.5	white	quartz	0.125	50
vein	178.5	white	quartz	0.125	30
fracture	180.5	gray	calcite, chlorite	0.01	5
fracture	181.5	gray	calcite, chlorite	0.01	0
fracture	184.5	black	chlorite	0.01	30

Gabbro Core F-3 185.5-195.5 feet

Fract. or vein	Depth	Color	Mineralogy	Thickness	Angle
vein	190	white	quartz, biotite	0.25	10
fracture	190	black	biotite, calcite	0.01	40
vein	190	white	quartz, biotite	0.25	15
vein (pegmatite)	190	white	plagioclase, opx, biotite	9	45
fracture	191.5	blue	chlorite, calcite	0.01	75
fracture	193.5	gray	chlorite, calcite, pyrite	0.01	0
vein (pegmatite)	195	white	plagioclase, opx, biotite	6	55

Gabbro Core F-4 95.5-105.5 feet

Fract. or vein	Depth	Color	Mineralogy	Thickness	Angle
vein	98.5	white	quartz	0.1	40
vein	98.5	white	quartz	0.1	60
vein	100.5	green	weathering phenomenon	0.1	65
fracture	100.5	black	chlorite	0.01	0
vein	101.5	green	weathering phenomenon	0.1	45
fracture	102.5	white	chlorite	0.01	45
vein	105	black	opaques, hornblende	0.05	85
vein	105.5	black	opaques, hornblende	0.01	75
vein	105.5	green	weathering phenomenon	0.25	85

Gabbro Core F-5 175.5-185.5 feet

Fract. or vein	Depth	Color	Mineralogy	Thickness	Angle
vein (dike)	175.5	gray	plagioclase, cpx, biotite	0.5	55
vein	175.5	white	calcite, plagioclase, cpx	0.1	55
vein	176.5	green	opx	0.125	5
vein	177	white	calcite	0.1	55
vein (dike)	178.5	gray	plagioclase, cpx, biotite	36	45
vein	181.5	white	calcite	0.01	45
fracture	183.3	green	calcite, chlorite, pyrite	0.01	0
fracture	183.5	green	calcite, chlorite, pyrite	0.01	0
fracture	184	black	chlorite, calcite	0.01	0
fracture	184	black	chlorite, calcite	0.01	55
fracture	184.5	black	chlorite, calcite	0.01	0
fracture	185	black	chlorite, calcite	0.01	0
vein (dike)	185.5	gray	plagioclase, cpx, biotite	2	45

(Continued)

Gabbro Core F-5 195.5-203.5

Fract. or vein	Depth	Color	Mineralogy	Thickness	Angle
fracture	196.5	white	calcite	0.01	55
vein	197.5	white	calcite	0.01	60
vein (diike)	197.5	gray	plagioclase, cpx, biotite	1	55
fracture	197.5	black	chlorite, calcite	0.01	5
fracture	198.8	black	chlorite, calcite	0.01	0
vein (diike)	199	gray	plagioclase, cpx, biotite	0.5	45
fracture	199	black	chlorite, calcite	0.01	20
vein	199.5	white	calcite, chlorite	0.5	25
vein (diike)	200.5	gray	plagioclase, cpx, biotite	0.5	45
vein (diike)	202.5	gray	plagioclase, cpx, biotite	0.5	45
fracture	203	green	chlorite, calcite	0.01	45
vein	203.5	white	calcite	0.1	20

Gabbro Core F6C 164-174 feet

Fract. or vein	Depth	Color	Mineralogy	Thickness	Angle
fracture	165	black	chlorite, calcite	0.01	0
fracture	173	black	chlorite	0.01	90
vein	174	white	calcite	0.125	25

Gabbro Core F6C 174-184 feet

Fract. or vein	Depth	Color	Mineralogy	Thickness	Angle
fracture	175	gray	calcite, chlorite	0.01	0
fracture	175	gray	calcite, chlorite	0.01	75
vein	176	white	calcite	0.1	80
vein	177	white	calcite	3	65
fracture	177	gray	calcite, chlorite	0.01	65
fracture	177	gray	calcite, sulphides, chlorite	0.01	65
vein	179	pink	graphic granite	12	65
fracture	180	black	chlorite, calcite, pyrite	0.01	70
fracture	182	black	chlorite, calcite	0.01	90

Syenite Core F-7 100.5-110.5 feet

Fract. or vein	Depth	Color	Mineralogy	Thickness	Angle
vein	101	white	quartz, calcite, white mica	0.25	50
vein	103.5	white	calcite, limonite, hematite	0.1	75
vein	103.5	white	calcite, limonite, chlorite	0.1	50
unknown	104.5	brown	quartz, calcite	0.1	80
fracture	106.5	gray	calcite	0.01	60
fracture	107.5	gray	calcite	0.01	20
vein	108.5	white	quartz	0.1	40
fracture	109.5	gray	calcite	0.01	10

(Continued)

Gabbro Core F-8 105.5-115.5 feet

Fract. or vein	Depth	Color	Mineralogy	Thickness	Angle
fracture	105.5	gray	calcite, limonite	0.01	5
fracture	106.5	gray	calcite, limonite	0.01	0
fracture	107.5	gray	calcite, limonite	0.01	0
vein	108.5	pink	graphic granite	0.5	50
vein	109.5	white	calcite, limonite	0.1	0
vein	111.5	white	calcite, limonite	0.5	50
fracture	111.5	gray	calcite, limonite	0.01	0
vein	112.5	white	calcite	0.1	35
fracture	113.5	black	chlorite, calcite	0.01	35
fracture	115.5	black	chlorite, calcite	0.01	0

Gabbro Core F-8 195.5-200.0 feet

Fract. or vein	Depth	Color	Mineralogy	Thickness	Angle
vein	196.5	black	chlorite	0.1	80
vein (pegmatite)	196.5	white	perthite, K-feld., opx, biotite	12	75
fracture	198.5	black	magnetite, chlorite, pyrite	0.01	30
fracture	199.5	black	magnetite, limonite, calcite	0.01	35

Gabbro Core F-8 185.5-195.5 feet

Fract. or vein	Depth	Color	Mineralogy	Thickness	Angle
fracture	186.5	black	biotite, pyrite	0.01	40
fracture	189.5	brown	magnetite, limonite, pyrite	0.01	50
fracture	190.5	brown	magnetite, calcite, pyrite, limonite	0.01	45
fracture	192.5	black	calcite, magnetite, pyrite	0.01	75
fracture	193	black	magnetite, chalcopyrite, pyrite	0.01	20
vein	193	brown	limonite?	0.1	60
fracture	194.5	gray	calcite, pyrite	0.1	30