THE NAIN ANORTHOSITE PROJECT, LABRADOR: FIELD REPORT 1976

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Mineral Variation in Anorthositic, Troctolitic, and Adamellitic Rocks of the Barth Island Layered Structure in the Nain Anorthosite Complex, Labrador

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The 1976 Field Report of the Nain Anorthosite Project is dedicated with respect (and no little awe) to Dirk de Waard on the occasion of his retirement.

The 1976 Report on the Nain Anorthosite Project is dedicated to Dirk de Waard on the occasion of his retirement.

DARK AND PALE FACIES ANORTHOSITE IN THE KAUK BLUFF AREA OF THE NAIN COMPLEX, LABRADOR

by

D. de Waard

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INTRODUCTION AND REVIEW

The first phase of the Nain Anorthosite Project draws to a close with this sixth in our series of Field Reports. The pause scheduled for the next two years will permit analysis and synthesis to catch up with field work, and permit some time for writing on other topics. Current plans are to seek support for a second phase beginning with the 1979 field season. There will be a special emphasis on geochemistry and geophysics, in addition to mapping and petrography. Those of our readers who would like to join in such an enterprise should contemplate submitting brief proposals at the appropriate time. High analytical precision will be stressed in reviews of geochemistry proposals.

After six years of intensive research, it is appropriate to take stock of our progress toward an understanding of anorthosite genesis. A variety of assessments have been offered over the past years, and readers wishing details of these are referred to past reports of this series, and to the growing literature cited in the bibliography. Some of the preliminary conclusions stated below reflect the writer's conviction that many magmas were involved rather than a single one for the whole complex. In this they differ from de Waard (see bibliography and abstracts). The conclusions are stated for massif anorthosites as a class, using the Nain complex as a source of boundary conditions. The conclusions need not exclude other interpretations in other areas, but they do preclude making these other interpretations necessary conditions for anorthosite genesis where they conflict with evidence from the Nain area.

The following statements about massif anorthosite appear reasonable:

1. No great pressure of emplacement is required. The indicated conditions at Nain are depths of 13-22 km, with country rocks at ambient temperatures for their depths (200-300°C; Berg, Speer).

2. Hydrous magma is contraindicated. The contact aureole is conspicuously dry (Berg). Late residual liquids (in strata, or trapped in orthocumulates) tend to be devoid of major hydrous minerals; the existence of rare hornblende-bearing rocks proves that the few wet liquids which did arrive remained wet.
3. An astatic environment of emplacement is indicated. Such deformation as has been seen can be ascribed to magma tectonics, including foundering of large slabs. Undeformed subophitic textures are common.

4. Multiple intrusions of basic to intermediate magma produced anorthositic, noritic, and troctolitic rocks. No fewer than 20 identifiable layered bodies occur, and each of these probably represents a separate magma batch. Plagioclase compositions suggest an even larger number of emplacement events. (This theme of multiple plutons was announced clearly in FR 1971 (p. 6) and developed with orchestration in every subsequent report. Despite this, a 1977 abstract proposes multiple intrusions as speculation or hypothesis!)

5. Multiple magma types (as distinct from batches) are required to explain the range of plagioclase compositions (An$_{34}$ to An$_{90}$) observed at Nain (Morse, FR 1975). At least four chemically distinct magma types are indicated.

6. Useful distinctions between labradorite and andesine "types" of anorthosite cannot be made. There is a continuum of compositions.

7. One well defined magma type (Hettasch, Kiglapait) is high-FeO, high-alumina, low-K basalt. More plagioclase-rich magmas undoubtedly are represented.

8. The distribution coefficients deduced from strongly fractionated layered intrusions are closer to 1.0 than equivalent ones determined from phenocryst-matrix pairs.

9. Such distribution coefficients can be used to infer the chemistry of parent magmas of anorthosites.

10. In particular, the high K/Rb characteristic of anorthosites derives directly from high K/Rb in the parent magma.

11. The source region of such high K/Rb magmas may have contained fluor amphibole. It must have been iron rich compared to the modern mantle, and yet depleted in large ion lithophile elements.

12. Iron enriched (ferrodiorite, ferromonzonite) differentiates are logical and defensible daughter products of anorthosite-producing magmas (Wiebe).

13. Adamellite magmas coexisted in many places with FeO-rich intermediate magmas. The latter are quenched against the former. If the latter are daughters of anorthosite, the former cannot be, because of the temperature difference and distinct chemical differences (Wiebe).
14. An origin of the adamellite series by melting of crustal rocks appears consistent with the data and with the presence of anorthosite-producing magma as heat sources (Wiebe).


I conclude that massif anorthosites are the products of aborted cratonic rifts, that they are restricted in space to such rift zones, and that they need be restricted in time only by the style of global tectonics over time. The limiting age ~1.5 Gyr may be a cutoff time for rifting tectonics on this scale (of continental thickness, for example), and ages younger than 1 Gyr should not be precluded, though they may be rare.

During the current report year, Wiebe has extended his detailed mapping of anorthosite contact relations north of Zoar. Basement rocks are found as septa between different plutons, and their contacts with leuconorite are loci of later injections of both dioritic and granitic magma. In places, distinct septa give way to zones of scattered basement inclusions, and then to leuconorite types characteristic of basement contacts but without visible basement fragments. The prior existence of basement is the logical explanation of anorthositic rocks which seem to "know" that a later quartz monzonite will come along; the contact effects remain, but the contact itself is obliterated by the combined effects of anorthositic intrusion and later invasion by quartz monzonite. The new evidence for such an explanation removes the need for a close genetic relation between anorthositic rocks and younger quartz monzonites, which on most other grounds appear unrelated. Wiebe also finds chills and fine-grained dikes of leuconorite (CI = 15) that provide strong evidence for the existence of plagioclase-rich liquids. A parent magma of noritic anorthosite is indicated.

A new layered intrusion, or at least a new part of the known Newark Island intrusion, was found by Wiebe in the Tigalak Inlet Area. This remarkable body has a gabbroic to ferrodioritic composition in the north, but is hybrid with large amounts of quartz monzonite in the south. The compositional variation is strongly discordant to the internal structural form of the intrusion. Chilled margins of pillows demonstrate that the basic material was still molten when granitic material arrived.
Once again, therefore, we find evidence for quartz monzonitic liquid chasing after and invading a more basic liquid. The field evidence suggests that a large amount of granitic magma entered the basic magma chamber during crystallization. A pronounced regional fault may have localized the conduit for both types of magma.

Ranson has completed a 65-km traverse across anorthosite and monzonite in the northwest part of the Nain complex. Hybrid rocks appear to be absent here; instead, anorthosite and leuconorite grade into monzonitic rocks which in turn grade into quartz monzonites. Again unlike the eastern contact zone, residual patches of quartz and K feldspar are absent from anorthositic rocks. Anorthosite and leuconorite carry plagioclase compositions from An$_{38}$ to An$_{64}$, with a concentration in the range An$_{44}$ to An$_{58}$. The composition distribution is geographically haphazard. A region of anorthosite, relatively rich in Fe-Ti oxide minerals, has plagioclase compositions in the upper part of the range (An$_{31}$ to An$_{60}$), and hence is not a logical fractionation product of nearby anorthosite. This rock unit appears to be unique among Nain complex rocks in its abnormally high oxide mineral content, presumably due to high TiO$_2$. It evidently signifies yet another type of basic magma parental to anorthosite.

Deuring has continued a study of the Akpaume layered intrusion and he reports modes and chemistries of monzodiorites and monzonites strikingly similar to the iron-enriched upper layers of the Kiglapait intrusion. The Akpaume body may be the top of just such another intrusion. Detailed comparison of the mineral chemistry of the two intrusions will be interesting, particularly in respect to key minor element ratios.

Plagioclase compositions in the Nain complex have been mapped for the first time at small scale, making heavy use of E.P. Wheeler's manuscript maps. A large "sodic region" appears to occur in the west central part of the complex, with values mainly less than An$_{45}$. This region includes the Susie Brook slab, discussed in earlier reports, which contains aluminous hypersthene megacrysts with exsolved plagioclase lamellae. The sodic region suggests that large volumes of leucodiorite magma with bulk plagioclase composition near An$_{40}$ or less existed. This may constitute a genuine region of andesine "type" anorthosite,
but it must be emphasized that many of the more calcic bodies elsewhere show local gradation well into this composition region, so the distinction between types is not clear-cut but gradational.

A new histogram of Nain plagioclase compositions is based on 631 observations, and retains the major features seen in past versions based on half as many points. The extreme range is An$_{34}$ to An$_{90}$, and major peaks occur in the mid 40's, low 50's, and high 50's. As concluded last year, at least 4 distinctive magma compositions are required to explain this distribution. None of these is likely to qualify as andesite, because even the sodic anorthosites are conspicuously poor or lacking in quartz - K feldspar residua and hydrous mafic minerals.

A new catalog and map of layered intrusions has been compiled; the known number is now at least 20. As a final miscellaneous topic, X-ray and optical determinative equations for augite are given for the benefit of readers who might have occasion to use them.

---S. A. Morse
Fig. 2. Geology of the peninsula and islands north of Zoar, Labrador. Units: leuconorite (ln), diorite (d), hybrid diorite and granitic rocks (hd), granitic rocks (gr), basement (b).
EASTERN CONTACT ZONE

GEOLOGY OF THE PENINSULA AND ISLANDS NORTH OF ZOAR, LABRADOR

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Introduction

This area lies west of Tunungayualok Island (Wiebe, FR 1975). The area was chosen in expectation of a well exposed contact zone between adamellite and anorthosite. The area was also assumed to include a zone at the junction between extensive terranes of adamellite, anorthosite and basement. Uivakh peninsula (Figs. 2, 3) clearly displays the intricate interfingering of adamellite, diorite, anorthosite and basement of such a zone.

Basement Rocks

Major exposures of basement rocks occur on Uivakh peninsula, on the Inuksuktokh Islands and on Kheovik Island (Fig. 2). On the peninsula, the basement rocks occur in irregular masses cut by anorthosite, diorite and granite (Fig. 3). Basement rocks on Kheovik Island occur as a septum between leuconorite and diorite bodies and are intensely veined by diorite.

The basement consists dominantly of banded quartzo-feldspathic gneiss. Possibly pelitic lenses a few cm thick were noted in two locations on the peninsula. Some granitoid gneiss shows little or no banding and may have originated as intrusive granite. Basic granulite occurs in segmented layers from one to several meters thick. Basic rocks appear to be particularly prominent near the contact with leuconorite on the Inuksuktokh Islands.

The quartzo-feldspathic gneisses are strongly folded and highly migmatized. Orientations of fold axes and foliation are highly irregular even on a local scale. Small bodies of leucocratic granite occur in the basement and leuconorite near the leuconorite contact on the Inuksuktokh Islands.

1 Authors' full addresses are given at the back of this volume.
Fig. 3. Detailed map of Uivakh Peninsula. Unit symbols and patterns as in Fig. 2.
Anorthositic Rocks

Most of the anorthositic rocks are leuconorite with an average color index of approximately 15. On the islands, except near the contact zones, the leuconorite is relatively homogeneous, coarse grained, and seriate, with plagioclase crystals up to 20 cm in length. On Uivakh peninsula, leuconorite is finer grained with highly variable textures. Particularly distinctive are varieties with highly tabular, radiating to aligned plagioclase and with spots of ophitic pyroxene. Leucotroctolite occurs locally on the island SSW of Sungilik Island. Its relation to leuconorite is uncertain. A small body of norite occurs near the western end of Kheovik Island.

Preliminary dispersion determinations indicate that plagioclase composition on the peninsula ranges between An$_{49}$ and An$_{40}$; on the islands to the north and west it ranges between An$_{61}$ and An$_{53}$. Textural and compositional differences indicate that the two areas may represent separate plutons.

All of the contacts with basement appear to be steep. East of Sungilik Island leuconorite appears to become more mafic toward the contact. Within 100 meters or so of the contact, the rock is finer grained norite (CI > 35). Preliminary dispersion results suggest that plagioclase is more calcic (An$_{61}$) and orthopyroxene more magnesian (En$_{73}$) in this zone. Scarce poikilitic perpendicular pyroxene occurs in a few layers near the contact and along one margin of a basement inclusion on Sungilik Island (Fig. 2).

The anorthositic rocks along the contact on southern Kheovik Island show textural variation only within 5 to 10 meters of the contact. Fine-grained leuconorite with blocky plagioclase averaging 2 to 5 mm occurs within 1 to 2 meters of the basement and as dikes extending a few meters into the basement. For several meters inward from the finer grained margin, the leuconorite is marked by dense concentrations of coarse (4-20 cm) blocky plagioclase; further away from the contact leuconorite acquires its typical seriate texture.

Away from the contact zones, leuconorite generally appears massive and unlayered. The main exceptions occur along the north and east coastline of Kheovik Island. Here rare, steeply-dipping layers from one to several meters in thickness are defined faintly by variation in the percentage of plagioclase phenocrysts and rarely by a variation in color index. In some layers there appears to be weak variation in the
size of phenocrysts suggestive of grading. If these layers are gravitational in origin and are reliable way-up indicators, they suggest the possibility of folding and even local overturning of the layers. Until the origin of such layering is understood, no such conclusions seem warranted.

Several dikes of coarse-grained oxide-rich norites cut leuconorite on Kheovik Island. These dikes are generally about 10 cm thick, and are linear for at least several tens of meters. They do not cut individual crystals in the leuconorite and could have been mistaken for layers except for the fact that they truncate at a large angle the layers described above. Similar rock occurs as pegmatitic pods of irregular form several meters in average dimension. These dikes and pods may represent residual liquid.

On the peninsula, a zone in the leuconorite consists of intermingled norite (CI~40) and leuconorite (CI~15). In some locations, the two phases are in equant and globular masses; elsewhere they occur as interconnected thin lenses of great length. There is no evidence of chilling, though both phases are relatively fine grained with thin tabular plagioclase.

In one location on the peninsula, leuconorite shows strong textural changes within 50 to 100 meters of a contact with basement. Within a few meters of the contact the leuconorite is distinctive for its extremely thin tabular plagioclase which commonly occurs in irregular to radiating sprays. Less commonly, these plagioclase crystals have a preferred orientation which might be due to flow. In cross section, a single plagioclase crystal is commonly about 1 mm thick and 12-20 mm long. The size of plagioclase clearly increases away from the basement and the length/thickness ratio decreases. Within 20 meters of the contact interstitial pyroxene is homogeneously distributed throughout the leuconorite. At greater distances the pyroxene begins to occur in closely spaced equant ophitic spots which increase in size and spacing at greater distances. The average color index appears to be about 15 through all of this textural variation. These textural changes may reflect strong super-cooling of leuconoritic magma. The nucleation rates of both plagioclase and pyroxene appear to have decreased strongly away from the contact.
Dioritic Rocks

Dioritic rocks mapped on Kheovik Island are relatively homogenous fine-grained pyroxene diorite or gabbro. Color index varies from 30 to 50. Oxide minerals and/or hornblende are locally prominent. Felsic lenses layers occur rarely. Similar rocks occur on the island SSW of Sungilik Island. One small area of homogeneous diorite occurs on the peninsula, but most dioritic rocks there occur as the main component of a heterogeneous complex - apparently a hybrid mixture of diorite and granite which resembles the hybrid portion of the Goodnews Complex (Wiebe, FR 1974). Within the area mapped as heterogeneous diorite, the degree of assimilation, mutual contamination and veining is variable. Locally up to 40% granitic material is present. In granite-rich areas, poikilitic hornblende is the dominant mafic phase in both diorite and granite.

On the island east of Uivakh peninsula, the contact between heterogeneous hybrid diorite and homogeneous granite is gradational through a zone of well-defined dioritic pillows in a matrix of granite. Chilled pillows are unsorted and range in diameter from less than 10 cm to more than 10 meters.

Hybrid dioritic rocks separate granite from leuconorite on the northern side of the peninsula. Angular blocks of gneissic basement, leuconorite and coarse-grained quartz-rich granite occur as inclusions in this diorite. The granite blocks texturally resemble much of the granite terrane to the south. Anastamosing dioritic veins occur in the leuconorite north of this zone and locally appear to grade imperceptibly into the matrix of the seriate leuconorite.

One fine-grained diorite (?) dike in leuconorite varies along its length to a pinch and swell structure and finally to a linear zone of pillows.

Granitic Rocks

The main body of granitic rocks occurs on the mainland peninsula. It is probably an extension of the granitic rocks on Akpiktok Island (Wiebe, FR 1974). Within the map area similar granitic rocks occur on islands south of Kheovik Island.

Granitic rocks are homogeneous, medium-grained, biotite hornblende quartz monzonite. Color index is generally less than 10 and coarse equant quartz is common.
Granitic dikes and veins occur abundantly throughout the leuconorite of Kheovik and Sungilik Islands. Extensive networks of abundant granitic veins ranging in thickness from several cm down to a few mm occur in many zones and demonstrate the brittle condition of the leuconorite. In some of these zones, the leuconorite appears intensely shattered on a fine scale as if granitic injection had been explosive.

**Basaltic Dikes**

Several basaltic dikes with roughly north-south vertical attitudes were encountered. They range in thickness from about 1 to 5 meters. Most contain blocky plagioclase phenocrysts 2-4 cm in length and a few also contain augite phenocrysts of similar size. One dike contains cumulate nodules up to 10 cm in diameter consisting of laminated tabular plagioclase with interstitial augite. Plagioclase in the nodules is less than 1 cm in length.

**Discussion**

Within this area basement rocks occur as septa between different plutons in a pattern reminiscent of areas within the Sierra Nevada batholith. Contact zones between leuconorite and basement appear in several places to be loci of later injections of dioritic and granitic magma. Basement septa thin out laterally to the point where only basement inclusions remain scattered within the contact zone between two plutons.

These relations can help explain two apparently anomalous features of contacts between different plutons (e.g., leuconorite and quartz monzonite) where no mappable basement septa are present. The first anomaly is the presence of scattered inclusions of basement restricted to a zone only a few tens of meters wide along contacts between different plutons. These inclusions can be viewed most reasonably as last remnants of a pre-existing basement septum. Such an interpretation implies that textural and compositional variation in the marginal zone of the older pluton developed in response to cooling in contact with pre-existing basement. A second and long-recognized anomaly in the Nain Province has been the commonly developed textural and compositional variation of anorthositic rocks where they come into contact with apparently younger quartz monzonite. Such variations have been used to suggest a close genetic relation between anorthosite
and quartz monzonite or an uncanny ability of anorthosite to "know" where the granite was going to be injected. It now seems more likely that where such a variation exists in the anorthositic rocks, it developed in response to cooling against basement and that granitic and dioritic magma were injected at a later time along this major structural discontinuity.

Chill zones have been noted at two separate contacts of leuconorite against the basement. At one of these, color index of the chilled rock is about 15 and is therefore comparable to the average rock within the plutons. In addition, fine-grained leuconorite occurs as scarce dikes cutting the basement and even penetrates included basement blocks along foliation planes in veins as thin as a few centimeters. These rocks show no evidence of plagioclase accumulation (e.g., plagioclase phenocrysts) and provide significant evidence for the existence of anorthositic liquids comparable in composition to the average composition of the plutons.
Fig. 4. Geology of the Tidalak Inlet area, South Aulatsivik Island, Labrador. Units: leuconorite (ln), norite (n), pillow diorite (pd), quartz monzonite (qm), Tidalak intrusion (TI).
Introduction

The main purpose of studying this area was to investigate the adamellitic pluton shown by Wheeler (FR 1972, p. 33) and its relations with the surrounding anorthositic terrane. The pluton (Tigalak layered intrusion) was found to be much larger than his maps indicated and to consist dominantly of layered, fine-grained gabbroic to dioritic rocks in the north and major areas of hybrid diorite and quartz monzonite in the south. These compositional variations are strongly discordant to the external and internal structural form which consists of an irregular trough or inverted cone.

To the north, older leuconorite and leucotroctolite bodies may be correlative with units sampled and mapped by Morse (FR 1972, p. 104) and Berg (FR 1973, p. 110). The southern end of Tigalak layered intrusion may join with the northern end of the Newark Island intrusion (Woodward, FR 1972, p. 44).

Leucotroctolite

A small area of layered leucotroctolite was mapped (Fig. 4) along the northwestern margin of the Tigalak intrusion. The eastern contact with leuconorite is a steep fault marked by a zone of intensely sheared anorthosite rocks at least several meters wide. This fault does not appear to affect the Tigalak intrusion. There is a fair likelihood that this fault passes northwestward through Second Rattle and joins a fault mapped by Berg (FR 1973, p. 110).

Age relations between leucotroctolite and leuconorite lying to the west are uncertain. Leucotroctolite is clearly older than the Tigalak intrusion and occurs as blocks (generally rounded) in the base of that intrusion.

Rocks in this unit range from anorthosite (CI<5) to leucotroctolite (CI=15 to 20). Layering and lamination are variably developed. Layers

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marked by differences in color index occur locally. Near the contact with the Tigalak intrusion some layers, which have been strongly folded and broken up, occur in a matrix of massive leucotroctolite. A central area of this body consists of coarser leucotroctolite with lensoid patches (usually 5 x 15 cm in cross section) of poikilitic olivine. Mineralogical and textural features appear to resemble the lower zone of the Hettasch intrusion (Berg, FR 1973, p. 112-114). The mineralogy and structural trends of this unit also appear to correlate with rocks sampled and mapped by Morse along Port Manvers Run from Second Rattle southward to sample 1041 (Morse FR 1972, p. 104).

Leuconorite

Most of the rock surrounding the Tigalak intrusion is massive seriate leuconorite. Weak, steeply dipping lamination occurs in a few outcrops. Plagioclase phenocrysts are commonly dark and iridescent. In many areas they range up to a maximum of 50 cm in length. No olivine was noted and only rarely was interstitial quartz or alkali feldspar observed.

No internal contacts were observed within the leuconorite, and it seems possible that all rocks mapped as leuconorite belong to a single intrusion. Block structure occurs only as a minor feature of the leuconorite on and near Quest Island.

The younger Tigalak intrusion cuts leuconorite sharply except in a few locations along the eastern contact. On Quest Island, medium-grained norite occurs as a mappable unit along the contact zone. Contacts between the three units here appear to be gradational locally. Southeast of Bakeapple Bay, portions of the contact appear gradational through a zone where dark plagioclase phenocrysts up to 7 cm occur in a finer grained granular matrix similar to fine-grained gabbroic or dioritic rocks of the Tigalak intrusion. At one location along this contact, a rounded block of fine-grained Tigalak-type gabbroic rock (about 3 meters in diameter) occurs within coarse seriate leuconorite and is cut sharply by a 15 cm-thick dike of the leuconorite.

Quartz monzonite

Two steeply dipping east-west trending dikes of leucocratic medium-grained quartz monzonite occur east of the Tigalak intrusion. Mafic minerals are hornblende and biotite. Quartz monzonite also occurs
widely in the southern part of that intrusion. One sharply bounded body is shown on the map (Fig 4); other distinct mappable bodies undoubtedly exist. Similar quartz monzonite has gradational contacts and occurs intimately mixed with dioritic and gabbroic rocks in the Tidalak intrusion, particularly in the southern half.

**Tidalak Intrusion**

The Tidalak intrusion is composed of fine-grained rocks ranging in composition from gabbroic to granitic. Internal structures such as layering and lamination appear to define a relatively simple pattern of an irregular inverted cone. Compositional variation is less systematic: the northern portion largely consists of a layered sequence ranging from olivine leucogabbro at the base to ferrodiorite or ferrogabbro at the highest exposed levels; the southern portion lacks any coherent stratigraphy and is marked by abundant intermingling of the gabbroic and dioritic rocks with granite.

In gross aspect the external form of the intrusion appears to resemble a trough or elongated inverted cone. In detail, the shape is quite irregular, particularly along the northwest margin. On the basis of topographic expression, the inward dip of the contact varies between 0° and 50°. Topographic irregularities have resulted in a "window" of leucogabbro and an outlier of the intrusion resting with a low dip on leucogabbro.

The fault between leucogabbro and leucotroctolite, discussed above, lies roughly on and trends parallel to the axis of the intrusion. There has been no measurable effect on the layered sequence in the northern part of the Tidalak intrusion. It is possible that the Tidalak magmas were injected along the fault zone.

Contacts with leucogabbro and leucotroctolite have been described above. In addition, minor lenses of basic granulite(?) occur along the contact on the coast east of Bakeapple Bay. Sulfide-rich and carbonate lenses and veins occur sparsely. These rocks appear to represent a septum of basement.

The best exposures of the northern part of the body occur along the shores and islands of Tidalak Inlet and the north side of Kolotulik Bay. The lower part of the intrusion shows little evidence of layering or lamination. The rocks are leucocratic (CI=25) fine-grained gabbros or olivine gabbros. These grade upward to more mafic fine-grained rocks.
Layering becomes well developed on the peninsula between Tigalak Inlet and Kolotulik Bay. Gravity-stratified layers a few cm thick are common, as are unimodal leucocratic layers 2 to 5 cm thick. Further upward, oxide minerals become prominent and are strongly concentrated in some well developed trough bands. The westward projecting lobe of the intrusion displays little layering and no clearly systematic compositional variation.

Granitic rocks occur within the layered sequence. In the eastern exposures, granite occurs as sharply bounded dikes. To the west such dikes are less common but similar granite occurs as lenses and layers within the layered gabbroic rocks. Fine-grained mafic pillows with chilled margins occur within these granitic lenses and layers. The granitic rocks consist mainly of quartz monzonite with red-stained equant quartz (4-8 mm in diameter). Locally a mafic rind surrounds the quartz grains. Fayalitic olivine occurs as a prominent interstitial to poikilitic phase in some related hybrid rocks.

The southern part of the Tigalak intrusion (south of Kolotulik Bay) is very different in character in spite of the fact that it clearly is structurally continuous with the northern part. Most exposures appear to represent a hybrid mixture of fine-grained gabbroic to dioritic rocks and quartz monzonite. Layering is only rarely well developed, and no systematic composition variation could be discerned within the mafic rocks. Flattened pillows produce a planar structure which is parallel to layering where the two have been observed together. One zone with prominent black plagioclase phenocrysts was mapped inland (Fig. 4). Similar rocks were not located on the coast, and it appears likely that this porphyritic rock has little lateral extent.

Granitic rocks occur in some areas as dikes which sharply cut the fine-grained gabbroic rocks. In other areas the dikes are absent, but similar granite is intimately mixed with layers, lenses and pillows of gabbroic rocks. Gradational contacts are common in some areas while in others strongly chilled gabbroic pillows occur in a distinct leucocratic granitic matrix. The matrix commonly grades to diorite where the abundance and definition of pillows decrease. A hybrid origin for this matrix seems most likely.

Prominent inclusions of strongly layered troctolite ranging in size from a few cm to more than 100 m occur at the mouth of Tigalak Inlet. Most of the small islets at the mouth represent single
troctolite inclusions with host Tigalak rocks visible at sea level. The area of prominent inclusions is shown on the map (Fig. 4). Attitudes of layering within the inclusions indicate overturning and suggest no coherent pattern. The largest inclusion occurs in the center of this inclusion zone, is right side up, and has a gentle dip. Layers range in composition from anorthosite to dunite with leucotroctolite being most common. Abrupt textural variations from strongly laminated layers to snowflake textures are typical. Channel scours and cross bedding are well developed in several inclusions. These troctolitic rocks are unique in this area and in texture and internal structure do not resemble the leucotroctolite unit to the northwest or any other rocks seen outside the Tigalak intrusion. The mapped inclusion does, however, have an attitude consistent with the leucotroctolite unit. Possibly the inclusions represent a structurally higher level portion of the same troctolitic intrusion. The large mapped inclusion may in fact be a roof pendant.

Inclusions of leuconorite and basement rocks occur very sparsely but widely throughout most of the Tigalak intrusion. None were found in the area of troctolite inclusions.

Discussion

The Tigalak intrusion is clearly composite in nature. The northern part is dominated by fine-grained mafic (gabbroic to dioritic) rocks which display a mappable layered sequence. The southern part consists of roughly equal amounts of gabbroic and granitic materials which are variably mixed. Several features in both parts of the intrusion suggest that granitic magma was injected while gabbroic magma was undergoing differentiation by crystal settling.

The quartz monzonite dikes which lie west of the intrusion trend into the Tigalak intrusion. The dikes either do not continue into the intrusion or are greatly reduced in thickness. East of these dikes, however, similar quartz-rich quartz monzonite occurs as irregular veins with gradational contacts and as a matrix to zones with chilled mafic pillows and as intercalated lenses and layers within the Tigalak gabbroic rocks.

In the southern part of the Tigalak intrusion some areas of homogeneous gabbroic rocks are clearly cut by granitic dikes. In other areas the dikes are absent but similar granite occurs abundantly
as a matrix to chilled pillows. South of Kolotulik Bay such mixed and hybrid material (with variable proportions of granite) is more abundant than homogeneous mafic rocks. The great abundance of this material and the range of relations between mafic and granitic rocks may be explained in the following way.

Assume first, a floored chamber of fractionating gabbroic magma. If cooler granitic magma were injected into the chamber, it would rise and significantly cool and stir the gabbroic magma through which it passes. The cooled and locally chilled gabbroic magma would sink, dragging some granitic magma with it. As the granitic magma heats up, greater hybridization with gabbro would be possible. By its difference in density, granitic magma could gain access to large volumes of gabbroic magma and produce significant chilling and mixing. The southern part of this intrusion appears to have been injected by large volumes of granitic magma in the manner just described. The end result would be the large volume of hybrid rocks.

If the fault at the northern end of the intrusion is the structural feature causing localization of magmatic activity, it could help explain why diverse magma types have been injected into this intrusion.
Anorthositic and Monzonitic Rocks Near Puttualuk Lake, Labrador

William A. Ranson
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Introduction

Geologic mapping initiated near Ighlokhsokhtaliksoakh Lake in 1975 (FR 1975) was resumed in 1976. Fig. 1 gives the location of the field area and shows that during the past field season mapping proceeded in a westerly direction across the large body of anorthosite shown by Wheeler (1968).

Anorthositic, monzonitic, and dioritic rocks are present in the area of study, and of these the anorthositic rocks are the most abundant. Differences in kind and proportion of mafic minerals have made it possible to separate the anorthositic rocks into three mappable units.

Although fairly homogeneous in texture, the monzonitic rocks encompass a range of rock compositions. Mapping has established that the monzonitic rocks become enriched in quartz and slightly depleted in mafic minerals in a westward direction away from the main mass of anorthositic rocks (Fig. 5). On the basis of this petrographic variation, the monzonitic rocks have been divided tentatively into three gradational units.

Diorite dikes and several small intrusions of diorite cut the anorthositic rocks and are distinguished from them in the field by their finer grain size and by the greater abundance and variety of mafic minerals in the diorite. Two small layered intrusions of mafic composition were discovered intruding the anorthositic rocks, but they are volumetrically less significant than the diorite.

Anorthositic Rocks

Three units of anorthositic rocks have been mapped. These units are anorthosite, leuconorite, and oxide-rich anorthosite (Fig. 5). Intrusive contacts between these three units were noted, but generally occur on a mesoscopic or outcrop scale only. Most of the contacts shown on the

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Fig. 5. Geologic map of the Puttualuk Lake area.
accompanying geologic map (Fig. 5) are gradational.

Anorthosite

The rocks of this unit are similar to those described in FR 1975 as pale anorthosite (Wheeler, 1960). The anorthosite has a color index of less than 10 and is composed chiefly of coarse-grained (1-4 cm), gray to purplish-gray plagioclase. Preliminary oil immersion (R/V Pitsiulak) and microprobe studies show the plagioclase to vary from An$_{38}$ to An$_{64}$ in composition. Small amounts of K-feldspar and quartz may be present in the interstices between plagioclase crystals. Mafic minerals are primarily orthopyroxene with minor amounts of clinopyroxene and the oxide minerals magnetite and ilmenite. Orthopyroxene crystals (0.5-2 cm) fill the interstices between plagioclase crystals. This subophitic to ophitic texture suggests that orthopyroxene crystallized late from intercumulus liquid trapped between plagioclase crystals.

The distribution of orthopyroxene in the anorthosite can be puzzling. Two textures are distinct. The first shows orthopyroxene evenly distributed among plagioclase crystals in a subophitic to ophitic manner. The second texture shows 20-to 50-cm-wide patches of anorthosite containing concentrations of subophitic orthopyroxene crystals surrounded by anorthosite nearly devoid of mafics. The cause of this patchy texture is unclear but it presumably reflects small scale differences in the amount of trapped liquid.

A noteworthy departure from the normally coarse-grained, equigranular texture of the anorthosite is the occurrence of porphyritic anorthosite. This rock consists of 2-to 4-cm-long, purple plagioclase megacrysts in a matrix of gray plagioclase crystals 0.5 to 1 cm in length. The large, dark plagioclase crystals may actually be xenocrysts rather than phenocrysts. Pegmatitic zones and veins are another common feature of anorthosite texture. They are of limited extent and consist of very coarse-grained (5 to 10 cm) plagioclase and pyroxene.

Layering within the anorthosite is uncommon. Igneous lamination resulting from the subparallel alignment of plagioclase crystals is present locally but does not acquire any regional significance.

The anorthosite is intruded by diorite and granophyre dikes and by small diorite intrusions and mafic layered intrusions.
The relationship between anorthosite and leuconorite is ambiguous. Examples occur of anorthosite intruding leuconorite and of leuconorite intruding anorthosite. Generally the relationship of the anorthosite to both the leuconorite and the oxide-rich anorthosite is a gradational one. Anorthosite dominates the feldspathic rocks in the eastern portion of the area in the vicinity of Puttualuk Lake and Mt. Aupalukitak.

Oxide-Rich Anorthosite

The anorthosite of this unit is distinctive enough to map as a separate division of the anorthositic rocks because of its higher proportion of magnetite and ilmenite relative to the anorthosite just described. From field estimates, magnetite appears to predominate over ilmenite, and together they comprise from 4 to 8 percent of the rock. In other respects such as grain size and color the oxide-rich anorthosite is identical to the anorthosite. Mafic silicates, primarily orthopyroxene, may vary in amount from 2 to 10 percent. Generally when the oxide minerals are abundant the mafic silicates are reduced in amount.

Textural features described in the anorthosite persist in the oxide-rich anorthosite. Subophitic to ophitic texture occurs in which oxide minerals nearly enclose larger plagioclase crystals. Oxide minerals are closely associated with orthopyroxene and together they fill narrow interstices between plagioclase crystals.

The distribution of the oxide-rich anorthosite is much more limited than that of anorthosite and leuconorite (Fig. 5). It occupies a zone between anorthosite on the east and leuconorite on the west. No mappable layering was detected in the oxide-rich anorthosite.

Discussion of Oxide-Rich Anorthosite

Preliminary data for this unit suggest a range in plagioclase composition from An$_{51}$ to An$_{60}$. Assuming that oxide minerals represent more advanced fractionation, it would be expected that oxide-rich anorthosite would have a more sodic composition than the adjacent oxide-poor anorthosite and leuconorite, which apparently is not the case. Anderson and Morin (1968) have attempted to distinguish between "labradorite-type" and "andesine-type" anorthosites on the basis of An content and the nature of the iron-titanium oxide minerals. They state that "labradorite-type" anorthosites (An$_{45-63}$, Or$_{2-3}$) are characterized by titaniferous magnetite, whereas hemoilmenite is the predominant oxide mineral in "andesine-type"
anorthosites (An$_{23-48}$, Or$_{6-25}$). In the Puttualuk Lake field area the distinction between "andesine type" and "labradorite-type" anorthosites fails in that here single complexes show a wide range in An content and proportion of oxide minerals. The oxide minerals require further study in order to test whether or not the oxide-rich anorthosites (An$_{51}$ to An$_{60}$) are characterized by titaniferous magnetite, as Anderson and Morin suggest. Preliminary work indicates that both ilmenite and magnetite are present.

**Leuconorite**

The higher color index of the leuconorite makes it possible to map it separately from the anorthosite. The average color index for the leuconorite is about 20, but there is a fairly wide range from 15 to 30. Orthopyroxene is the chief mafic mineral, but clinopyroxene, magnetite, and ilmenite may also be present. Preliminary oil immersion and microprobe studies give plagioclase compositions ranging from An$_{42}$ to An$_{48}$.

The leuconorite is commonly not as coarse grained as the anorthosite, but does display the same subophitic to ophitic texture. Significant changes in grain size over distances of tens of centimeters are characteristic of the leuconorite near its contact with the monzonite. Layering in this unit is perhaps more prominent than in the anorthosite, but it is still not mappable on a regional scale. Anorthositic and granitic pegmatite veins intrude the leuconorite, as do diorite and granophyre dikes.

The leuconorite is found in small patches throughout the anorthositic rocks, but reaches its greatest extent at the western edge of these rocks where it lies in contact with monzodiorite. The leuconorite-monzodiorite contact has been carefully examined and will be discussed below.

**Layered Bodies Within the Anorthositic Rocks**

Layering within the anorthositic rocks is uncommon and occurs only on a local, not a regional, scale. There are within the area, however, two localities where layered sequences occur at the base of much larger volumes of generally massive anorthosite and leuconorite. The two sequences occur in the vicinity of Puttualuk Lake and are probably related. The best exposed layered sequence is located on the projection of land sandwiched between Puttualuk Brook and the western margin of Puttualuk Lake.
The northern end of this projection is a 260-m-high hill composed of anorthositic rocks. On the southwestern side of this hill a layered sequence was discovered.

The lowermost member of the sequence is a 1.0-1.5-m-thick layer of coarse-grained pyroxenite. Unfortunately this layer is the lowermost exposure of rock on the hillside so the true thickness of the layer is uncertain. Furthermore, it is impossible to determine if this sequence is complete or if other such sequences occur at depth. The pyroxenite appears to be mainly orthopyroxene with minor amounts of magnetite and ilmenite. No plagioclase is present. Above the pyroxenite is an approximately 1-m-thick layer of coarse-grained, plagioclase-bearing pyroxenite. Interstitial plagioclase comprises from 10 to 25 percent of the rock, which is still dominantly orthopyroxene. This layer becomes slightly more plagioclase-rich towards the top, and then in an interval of approximately 10 cm becomes quite fine grained and almost basaltic or diabasic in texture. This 30-cm-thick, fine-grained plagioclase-bearing pyroxenite is the third layer in the sequence, and it gives the impression of a chilled margin. Above this chilled margin is coarse-grained leuconorite of normal appearance. There is some local gradation to anorthosite, but as the geologic map shows (Fig. 5), the entire southwestern portion of the hill is leuconorite. The leuconorite-anorthosite contact here is intrusive. A relatively fine-grained, chilled zone of anorthosite at the anorthosite-leuconorite boundary indicates that the anorthosite intruded the leuconorite.

A thorough understanding of this sequence must await laboratory studies, but it is possible to postulate an origin for the observed relationships. Probably the key to understanding the chronology of events is the chilled zone in the plagioclase-bearing pyroxenite. This chilled margin indicates that the layered pyroxenite and plagioclase-bearing pyroxenite were intruded into a relatively cool body of anorthositic rock. The source of this ultramafic material (liquid or crystal mush) is open to speculation. It could be a ultramafic cumulate (plus liquid) residuum from the process which segregated plagioclase from the parent of the anorthosite, if that parent was basaltic in nature. The mechanism responsible for the layering could be crystal settling in situ or perhaps even multiple injection of successively slightly less mafic liquids. The former explanation seems to be more consistent with field observations and the size of the intrusion. In any event, the existence of this layered
zone proves the existence of pyroxene-saturated liquid at some stages of the magmatic activity related to anorthosite.

Diorite

The 1975 field season ended with the discovery of a body of biotite-pyroxene diorite of unknown extent (FR 1975). Field study during the 1976 field season has led to a better understanding of the size and nature of this body, which is located on a small lake due south of Puttualuk Lake (Fig. 5). In addition, diorite dikes and small diorite intrusions of similar mineralogy and general appearance were noted elsewhere in the region.

The nature of the diorite intruding anorthosite south of Puttualuk Lake is complex. The rock itself contains fine-grained (2–4 mm) plagioclase (An$_{25}$–An$_{35}$), pyroxene (orthopyroxene ± clinopyroxene), varying amounts of biotite, and an Fe-sulfide mineral. Complications arise from the fact that swarms of diorite dikes of varying size intrude the anorthosite over an area of nearly horizontal exposure. The discovery of some nearly vertical exposures led to the clarification of the diorite-anorthosite relationship. The main body of diorite lies beneath the anorthosite and generally has the form of a saucer-shaped intrusion. Radiating out from this central body are numerous diorite dikes which penetrate the anorthosite and are exposed at the surface. Layering in the intrusion consists of laminated plagioclase and pyroxene crystals and has a shallow dip southwest of the lake, which steepens progressively in a north-easterly direction. A schematic cross section (Fig. 6) shows that the intrusion is exposed in the cliff northeast of the lake where the layering is steeper. Anorthosite lies above the diorite, but the contact is not well exposed. The general impression obtained is that of a small, saucer-shaped intrusion that is exposed at the surface in only a few places but otherwise lies beneath the anorthosite, except where dikes have penetrated to the present erosion surface. The southwestern half of the intrusion presumably lies beneath the anorthositic rocks on the mountain slope facing the lake.

The diorite body just described is the largest mapped, but dikes and smaller intrusions are common. Where extensive enough, these diorite intrusions have been mapped. Texturally and mineralogically the diorite throughout the area is quite similar. From field observations alone,
Fig. 6. Schematic cross section of small, saucer-shaped diorite body intruding anorthosite.
however, it is difficult to determine whether all of the diorite mapped
is genetically related.

Monzonitic Rocks

This term refers to those rocks in which K-feldspar is a major
constituent, and in the area of study the name encompasses the following
rock types, using the classification of Streckeisen (1973): monzodiorite,
monzonite, and quartz monzonite. There are two principal occurrences of
these rocks in the field area. The most extensive is in the western
portion of the area in the vicinity of Bear Lake (Fig. 5). Here monzo­
diorite occurs adjacent to the leuconorite just east of the lake, and
proceeding westward grades into monzonite and eventually into quartz
monzonite. In the monzonite and quartz monzonite, K-feldspar is consis­
tently more abundant than plagioclase, whereas in the monzodiorite
plagioclase is more abundant. The color index decreases as the monzo­
diorite grades into monzonite and finally into quartz monzonite. Horn­
blende and small amounts of biotite comprise the mafic minerals in the
monzonite and quartz monzonite. Pyroxene in addition to these phases is
present in the monzodiorite. Bluish-gray quartz makes up about 10 to 20
percent of the quartz monzonite.

All three rock types are similar in texture and grain size. The grain
size ranges from 4 to 10 mm with the monzodiorite being the most coarse
grained. No layering or lamination was detected in the monzonitic rocks,
either near their contact with the leuconorite or in the core of the
intrusion.

The other major occurrence of monzonitic rocks is southwest of
Puttualuk Lake. The principal rock type here is best classified as monzo­
diorite, which is generally depleted in mafic minerals and somewhat
coarser grained than the monzodiorite in the western part of the area.
Plagioclase is more abundant than K-feldspar, and mafic phases, primarily
pyroxene, make up less than 20 percent of the rock. Minor interstitial
quartz may be present. The low color index, the poor exposure and the
abundance of diorite dikes make it difficult to distinguish the monzo­
diorite from the neighboring anorthosite and to delimit the size of this
body.
Contact Relations Between Anorthositic and Monzonitic Rocks

Sharp contacts between monzonitic and anorthositic rocks have not been observed. In areas where exposure is sufficient to permit scrutiny of the contact zone, the contact appears gradational. The best place for studying the contact relations is east of Bear Lake. Observations made on five traverses across the contact zone have led to the conclusion that from east to west the leuconorite becomes enriched in K-feldspar, depleted in pyroxene, and the additional phases hornblende and biotite appear. Thus from field data it appears that there is a continuous gradation in the contact zone from leuconorite to monzodiorite and eventually to monzonite and quartz monzonite. Monzodiorite-anorthosite contact relations west of Puttualuk Lake are not well enough exposed to warrant discussion.

The conclusions outlined above for contact relations between anorthositic and monzonitic rocks differ from those made for the region around Ighlokhsoakhtaliksoakh Lake (FR 1975). For that area it was stated that the contact was transitional, resulting from the limited mixing of two penecontemporaneous magmas. In general the rocks are better exposed to the west of Puttualuk Lake than around Ighlokhsoakhtaliksoakh Lake, but weathered outcrop and lack of outcrop in certain areas still leaves in some doubt the gradational contact interpretation. The petrogenetic implication of a gradational contact is that the anorthositic and monzonitic rocks are derived from a single parent magma. Objections to this theory in the past have stemmed from the absence of rocks intermediate in composition between quartz monzonite and anorthosite, and also from the fact that the monzonitic rocks seem too voluminous, relative to the anorthositic rocks, to be the end product of fractional crystallization of a basic magma. Clearly in this area intermediate rocks do exist. Volume estimates for the various rock types would be necessary in order to ascertain whether the monzonitic rocks have the proportions expected for differentiates of a basic magma.

Summary and Discussion

The three subdivisions of anorthositic rocks, anorthosite, leuconorite, and oxide-rich anorthosite, have mutually gradational relationships, with the exception of a few local examples of intrusive contacts. The differences in proportion and kind of mafic minerals in these rocks may reflect:
(1) changes in the composition of the magma as anorthosite production proceeded; (2) several injections of different magmas, (3) contamination of the magma from some outside source resulting in a shift of the path of crystallization; or (4) some combination of the above possibilities. The mechanisms responsible for the variation observed in the anorthositic rocks remain speculative.

Intruding the anorthositic rocks are dikes and small intrusions of diorite as well as small mafic layered bodies. The mode of occurrence and composition of the mafic layered bodies suggest that they are mafic residua segregated during the anorthosite-forming process and later intruded into the anorthositic rocks. The chilled margin reported in the uppermost layer of the described sequence indicates that the anorthosite had cooled sufficiently to produce this chilling effect. The diorite may also be related to the anorthosite, perhaps by means of fractional crystallization of one or more parent magmas of the anorthositic rocks.

After a second field season in Labrador, I continue to grapple with contact relations between anorthositic and monzonitic rocks (Ranson, FR 1975). Somewhat improved exposure in 1976 has added important observations which support a gradational contact. Nevertheless, the limited mixing of two penecontemporaneous magmas, one anorthositic and the other monzonitic, should not be ruled out as a plausible alternative to explain the observed relations.
Fig. 7. Composite map of the Ighlokhoakhtaliksoakh
and Puttualuk Lake areas showing plagioclase compositions.
PRELIMINARY REPORT ON PLAGIOCLASE COMPOSITIONS FROM ANORTHOSITIC ROCKS
William A. Ranson
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Forty-seven plagioclase compositions have been determined for anorthositic rocks by the dispersion method aboard the R/V *Pitsiulak* and by electron microprobe. Fig. 7, a composite map of the Ighlokhoakhtaliksoak and Puttualuk Lake areas (Ranson, FR 1975 and this report), shows the distribution and range of plagioclase compositions. The determinations are for anorthositic rocks only, including leuconorite and oxide-rich anorthosite in addition to anorthosite. Regionally, there appears to be a slight increase in An content going from east to west, but this trend is disrupted in several localities. Interestingly, the oxide-rich anorthosite has plagioclase of relatively high An content, not greatly different from the nearby oxide-poor anorthosite, both being in the labradorite range. This fact may prove significant in light of forthcoming studies of oxide mineralogy.

Fig. 8, is a plot of frequency versus mole percent An in plagioclase for 47 samples. Although there is a wide range in An content from An₃₈ to An₆₄, most plagioclases have a composition in the interval from An₄₄ to An₅₈. This graph represents only a preliminary report of plagioclase compositions, although an attempt was made to select samples from dispersed parts of the field area. Thus it is somewhat premature at this stage to draw any conclusions concerning magma types from these data.

Morse (FR 1975) summarized plagioclase compositions in anorthositic rocks from various parts of the Nain complex in a histogram like that of Fig. 8. This range of plagioclase compositions is from An₃₈ to An₈₃, and includes some very calcic rocks from basic layered intrusions and pure anorthosite xenoliths in leuconorite block structures. It is noteworthy that the major concentration of plagioclase compositions reported by Morse lies in the interval from An₃₈ to An₆₄, which corresponds exactly to the range determined in this area. Thus these data are in good agreement with plagioclase compositions from other parts of the Nain complex.

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1Authors' full addresses are given at the back of this volume.
Furthermore, they support the conclusion drawn by Morse that the Nain complex anorthosites are not strictly of the "labradorite-type" as proposed by Anderson and Morin (1968).

![Plagioclase compositions of anorthositic rocks from the Ighlokhoakhtaliksoakh and Puttualuk Lake field areas.](image-url)

Fig. 8. Plagioclase compositions of anorthositic rocks from the Ighlokhoakhtaliksoakh and Puttualuk Lake field areas.
THE AKPAUME LAYERED INTRUSION:
FURTHER INVESTIGATIONS

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The Akpaume layered intrusion was mapped and sampled during the 1975 field season (FR 1975, p. 45). Several day-trips were made inland this year to resolve contact relations. Preliminary data are also available from laboratory work. Figure 9 is the revised map.

Anorthositic Rocks

These are largely leucodiorites in this area, dominated by the simple "noritic" mineralogy of andesine and orthopyroxene. Ortho­cumulate layers carry compositions near An_{36}, En_{40}. The sketch map of Tikkoatokhakh Bay by Morse and Wheeler in FR 1973 suggests that this anorthosite is part of the "Lister Massif." Wheeler's manuscript map (Wheeler Collection, U. Mass.) gives An 34, 37, 38, 40, 41, and 45 for plagioclase compositions which might safely be assigned to the Lister Massif, so the present value of An_{36} is not abnormal. The low anorthite content of plagioclase is similar to that of other anorthosite massifs along Tikkoatokhakh Bay; evidently this is a large area of andesine anorthosite (see Morse, this Report).

Layered Group

The bulk of the Akpaume intrusion is a layered group ranging in composition from ferrodiorite to ferrosyenite. The differential settling of mafic phases and plagioclase, presumably in a convecting magma chamber, produced rhythmic layering on 1-to 10-cm scales. Color indices observed in thin section range from 20 to 70. Representative modal analyses are presented in Table 1. Quartz is notably absent from the layered group, suggesting that the magma was critically saturated with respect to silica. Table 2 contains several chemical analyses of layered group rocks.

Electron microprobe analyses show that iron enrichment in the mafic

\footnote{Authors' full addresses are given at the back of this volume.}
Late-stage hybrid
Layered ferromonzonite
ag=agmatite
Anorthositic rocks

Igneous layering
Contacts:
approximate
inferred

Fig. 9. Geologic sketch map of the Akpaume layered intrusion. Cross sections are shown in Fig. 10.
phases is strong. For example, ferroaugites from sample 37A have an average composition of $\text{En}_{20}, \text{Fs}_{26}, \text{Wo}_{44}$. Olivine in the same rock has the composition $\text{Fo}_{13}$.

Other minerals are subhedral plagioclase, interstitial mesoperthite, and abundant apatite and zircon. Mesoperthite becomes a cumulus phase in the syenites.

**Late-stage Hybrid Intrusive**

This rock unit was previously mapped as coarse ferromonzodiorite. It is found cutting both anorthosite and the layered group. It is possible that this rock represents the mixing of late differentiates of the Akpaume magma with crystals of plagioclase and orthopyroxene from the anorthosite. This would explain the presence of partially resorbed $\text{An}_{36}$ plagioclase and $\text{En}_{42}$ orthopyroxene xenocrysts in monzonite host rock with $\text{An}_{30}$ plagioclase, $\text{Fo}_{13}$ olivine and $\text{En/En+Fs}$ 0.20 ferroaugite. The xenocryst compositions match those of orthocumulus leuconorite layers ($\text{An}_{36}, \text{En}_{40}$) in the anorthosite suite. Ferroaugite grows to 10 cm or larger in much of the hybrid rock. In several places there are clusters of deformed blocks of anorthosite, whose corners and edges trail out into the surrounding monzonite. Beginning about 5 meters from one such cluster of blocks, the grain size and mode of pyroxene in the monzonite increase steadily from 1 cm and 10% to over 8 cm and 20% respectively. The largest pyroxene crystals are found in the monzonite separating the deformed blocks. Numerical experiments are under way to determine the extent of mixing possible, given the compositions of various Akpaume rocks.

**Structure**

Unfortunately, much of the external contact between the layered intrusion and the anorthosite is covered by water or glacial drift. However, it was possible this summer to trace most of the contact from the south shore of Ighluliorite Bay, southwest to "Offset Pond." It seems to dip away from the center of the intrusion, cutting across the layering in the adjacent anorthosite. This unconformable contact and the preponderance of angular blocks of anorthosite suggest that the intrusion was emplaced into the anorthosite by stoping. The large area of anorthosite under cross section line B-B' is probably a roof pendant (Figure 10), as is the block on the eastern summit of Akpaume.
Fig. 10. Diagrammatic cross sections of the Akpaume layered intrusion as located in Fig. 9. Horizontal scale is twice that of Fig. 9. The cone sheet shown in section A-A' as projected onto the plane of the section.
**Table 1.** Modal analyses of Akpaume layered group rocks.

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<th>Monzodiorites</th>
<th>Monzonites</th>
<th>Syenites</th>
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<td></td>
<td>14A</td>
<td>18A</td>
<td>29</td>
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<tr>
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<tr>
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<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td># pts</td>
<td>2017</td>
<td>2012</td>
<td>2018</td>
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</tbody>
</table>

An plag 34 36 33 34 33 30 29 31 29 29 33 n.d.

Note: mesoperthite resolved into Plag and Kfs components.

**Table 2.**

Major element analyses of Akpaume layered group rocks.

<table>
<thead>
<tr>
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<th>Monzodiorites</th>
<th>Monzonites</th>
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<tr>
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<td>SiO₂</td>
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<td>TiO₂</td>
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<tr>
<td>Al₂O₃</td>
<td>14.12</td>
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</tr>
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<td>FeO*</td>
<td>21.18</td>
<td>13.74</td>
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<tr>
<td>MnO</td>
<td>0.33</td>
<td>0.18</td>
</tr>
<tr>
<td>MgO</td>
<td>2.09</td>
<td>1.70</td>
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<td>CaO</td>
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<td>Na₂O</td>
<td>3.32</td>
<td>4.75</td>
</tr>
<tr>
<td>K₂O</td>
<td>1.42</td>
<td>1.87</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>1.55</td>
<td>1.31</td>
</tr>
<tr>
<td>H₂O⁺</td>
<td>0.87</td>
<td>0.84</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100.96</td>
<td>100.21</td>
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Island. The interpretation is that the exposed portion of the Akpaume intrusion is the top of an irregular cylindrical pluton.

Two new ferrosyenite dikes were discovered, one at the bottom of Ighluliorde Bay and the other to the south of the main intrusion, both of which dip toward the center of the pluton. These new dikes, and the two mapped previously east of Ittiblekh, may be fragments of cone sheets associated with the main intrusion.

The left-lateral offsets of the western contact are tentative interpretations because of the limited outcrop in that area. The offsets are consistent with the left-lateral motion demonstrated for the Tikkoatokhakh Bay and Nain Bay lineaments (de Waard and Mulhern, FR 1972, p. 71). Only two of the several dozen linear features which cross the intrusion are shown on the sketch map in Fig. 9.

**Discussion**

The petrographic similarities between Akpaume layered group rocks and ferrosyenites above the 98% solidified level of the Kiglapait layered intrusion are striking. Features such as graded bedding, channel scours and slump breccias are also similar to Kiglapait structures.

A preliminary Bouguer Gravity map of the Nain complex (Stephenson, 1974) places a +30 mgal anomaly on the Akpaume intrusion. While this is less than the +90 mgal anomaly on the Kiglapait, it is possible that the Akpaume body is the top of a smaller but similar differentiated troctolitic body. The density contrast involved, 2.72 ± .07 (N=9) for the anorthosite country rock versus 3.00 ± .16 (N=36) for the ferromonzonite, should allow a first-order model of the size of the intrusion to be made when more gravity data are available.
Introduction

A regional map of plagioclase composition has been compiled for the first time at small scale, and newly compiled data have more than doubled the entries in our histogram of plagioclase composition. The map shows an extensive "sodic region" roughly straddling Berg's (1977) high pressure axis, and the histogram retains most features of the old ones, with a strong mode near An$_{52}$ but an enlarged population in the andesine range. The cumulative frequency shifts somewhat toward Ab.

Sodic Region

Figure 11 shows the summarized regional distribution of plagioclase An content. The data were compiled from E. P. Wheeler's (1973) manuscript map at 1 mile to the inch, with additions from Field Reports and the literature, and some unpublished data. Such a map is a mixed blessing. Some of the local variations (for example, The Bridges layered group) are well understood in terms of layering and stratigraphy; that is, they represent single fractionated plutons. Other variations (for example in Ranson's area; see this Report) are not related to known structures and are difficult to interpret. I have heretofore resisted plotting the data on such a grand scale, because the best understanding comes from seeing the data in their appropriate field context. Nevertheless, there are times for looking at truly gross relationships and for entertaining simplistic ideas. Perhaps this is such a time, since the data are surprisingly abundant and at a temporary plateau as far as these Reports are concerned.

The gross regional variation is bimodal. Most of the Nain anorthosite is characterized by varying compositions in the An 50's. A large "sodic region" centered near Susie Brook is dominated by values less than An$_{45}$. This region may approach 2000 km$^2$ in area, or 20% of the area of Nain.

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1 Authors' full addresses are given at the back of this volume.
Fig. 11. Map of plagioclase compositions in anorthositic rocks of the Nain complex.
anorthositic rocks. A subsidiary sodic band may lie slightly to the north. The density of data is not great, but this is offset by two facts: the areal distribution is fairly good, and the known variation in the three massifs along Tikkoatokhakh Bay (see Morse and Wheeler, FR 1973) is systematic. Where sampling has been intensive, numbers below An_{45} do indeed predominate, and variation above this value is local. The sodic region may perhaps consist of the three large massifs (Bird, Susie, Lister) alone.

A pressure arch has been postulated by Berg (FR 1974; 1977) to lie over the Nain complex. He proposes a simple model involving incipient rifting, emplacement of masses of anorthosite, and subsequent uplift to expose a 6-kbar axis flanked by gradients down to about 4 kbar. One hardly knows what to expect of the character of anorthosite in the central part of such a mass. Our view has been that so many plutons were emplaced, probably at random levels, that no gross differences would emerge from axis to flanks. On the other hand, one can imagine a family of models in which large-scale processes might have produced a more sodic region of anorthosite deeper in the section; such models include but are not limited to roof accumulation of plagioclase, and upward differentiation in a floored chamber beneath an older roof of more calcic anorthosite. At the very least, one can say that the occurrence of a sodic region near the proposed high pressure axis does no violence to the uplift hypothesis, and may ultimately strengthen it.

The Susie Brook slab dips 70° E between the gently dipping Bird Lake and Lister massifs. It also shows cumulus layers of hypersthene, and a plastic stretching implying deformation before complete solidification. The tectonic and structural history of these relationships is poorly understood, but it can at least be said that in order to rotate an 8- km-thick slab, one needs a bit of room to do so. A large volume of magma appears required, and this suggests a further reason for considering the "sodic region" to represent a large-scale pond of magma. Clearly much more work needs to be done on field relationships and chemistry before the history of this region can be intelligently deciphered.

This is meant to be a clarion call to future field workers.

**Plagioclase Histogram**

The data plotted in Fig. 12 represent more than 600 determinations by the dispersion method (Pitsiulak, Wheeler, and many other sources) and
Fig. 12 (above). Histogram of plagioclase compositions in anorthositic rocks of the Nain complex.

Fig. 13 (left). Cumulative frequency of plagioclase compositions in anorthositic rocks of the Nain complex, compared with plagioclase in the Kiglapait intrusion (KI).
rapid electron probe analysis (mainly Ranson). All of these carry a precision near 1 mole % An, and represent at least 5 to 10 grains in grain mounts. A few of the plotted values are the extremes of variable samples reported by Wheeler, but in most cases they are mean values. Comparisons with the histograms given in FR 1972 and 1975 show surprisingly little change in the fundamental picture. There are distinct valleys near An$_{46}$ and An$_{57}$, and peaks near An$_{43}$ and An$_{52}$. The extreme range is An$_{34}$ to An$_{90}$. Some of the most calcic values belong to "ribbon rocks" or other mafic-free rocks, and these could be residua from local melting events as well as early crystallization products. Some, however, belong to known stratiform intrusions and are clearly cumulus compositions. The sodic extremes appear to be genuine anorthosites and leucodiorites.

The conclusions of last year's discussion (Morse, FR 1975, p. 51) remain substantially unchanged, and I will not dwell upon these. A new cumulative frequency diagram is offered in Fig. 13; again it is sigmoidal (roughly gaussian), distinctly unlike the single curve of a single fractionation event, represented by the Kiglapait intrusion. The fictive bulk composition of the Nain anorthosite (taken at the same frequency level as the Kiglapait) is An$_{47}$, but this is by itself of little genetic significance. As declared last year, such a distribution probably represents at least four different magma types and the field evidence suggests many more actual batches.

In view of the "sodic region" discussed above and the An$_{43}$ peak in the histogram, it might be supposed that the distinction between "labradorite-type" and "andesine-type" anorthosites had re-emerged in all its glory. The distinction is still dubious, however, in view of the large number of transitional compositions, some of them to be found within single plutons. The histogram for Ranson's area (this Report) illustrates the problem nicely. And yet one must concede, in view of the apparent integrity of the "sodic region" and of what has been said above about multiple magma types, that at least one major class of these must have had a bulk modal composition in the low or middle An 40's. The possibility that these compositions are merely fractionation products seems remote. The important distinction, however, is not between andesine and labradorite but between a large range of magma types, for which evidence mounts, and one or two restricted types, which seem inadequate to explain the Nain complex as a whole or in detail.
Fig. 14. Layered intrusions in the Nain complex. Inset shows Adirondack anorthosite, New York, for scale comparison.
Catalog of layered intrusions in the Nain complex (Morse).

The alphabetical list below brings up to date a list given in FR 1972. Figure 14 shows the locations of the layered bodies described here. The list now contains 20 entries, as compared to 10 in FR 1972. I have included all occurrences where substantial exposures of layering have been reported in basic, anorthositic, and intermediate rocks. These range in size from a fragment less than 1 km\(^2\) in area on The Castle (island) to several anorthositic bodies conjecturally greater than 400 km\(^2\) in area, and of course the Kiglapait intrusion, which at 560 km\(^2\) still holds the size record in the Nain area.

With respect to the large anorthositic occurrences, it cannot always be said that each layered massif represents a different pluton. Within some bodies, the layering attitude is quite variable (as at Tunungayualok I.), and yet may simply represent foundered or rotated objects belonging to a single pluton. By the same token, the very large and seemingly independent massifs along Tikkoatkokh Bay may conceivably be rotated parts of a single batholith. Field evidence such as chilled or mafic margins or cross-cutting relations, which could tell us whether such bodies represent one or more intrusions, is so far unknown.

The status of the Newark Island intrusion (Woodward, 1976) is uncertain; Wiebe (personal communication, 1976) has suggested that it may be coextensive with the Tigalak intrusion. For the moment I have grouped them both under the latter name, although this may turn out to be unjustified. They are lithologically similar (troctolites to ferrodiorites), and interpretation may be complicated by a prominent E-W fault. The name "Newark Island" has mystified some; this is an older name for the large island called "South Aulatsivik" on most maps. Wheeler preferred "Newark" for the southern part of this island, since the word Aulatsivik has reference only to the high land at the northern end of the island, and does not comprehend the whole island in the original Inuit meaning. Further confusion arises because "North Aulatsivik Island" occurs in far northern Labrador, far out of context with the presently considered island.

Akpaume layered intrusion (Deuring, FR 1975, 1976). About 20 km\(^2\).

Monzonitic, wholly enclosed in anorthosite. Iron enrichment pronounced; similar to top layers of Kiglapait intrusion.

Brid Lake massif (Morse & Wheeler, FR 1973). Possibly 400 km², but limits are unknown north and south. Leucocratic andesite anorthosite.

Bridges intrusion (Planansky FR 1971, FR 1972; 1974; 1977). Area indefinite, but probably greater than 30 km². Basal layered gabbro, olivine gabbro, troctolite, anorthosite, the latter of indefinite extent eastward on Paul I. Basal parts very basic (An 80's etc.)

Castle layered body (Wheeler, FR 1972). Less than 1 km² exposed. Leucodioritic, with large xenoliths of anorthosite.

Dike (de Waard and Hancock, FR 1973; de Waard, 1974). Near 10 km², 20 km long by 1/2 km wide. Extends from Newark I. west to Barth I. in an arc. Composition gabbroic to granodioritic, average jotunite. Layering local only.


Goodnews complex (Wiebe, FR 1974, 1975). About 40 km². Diorite, locally layered, for the most part in a hybrid association with adamellite.

Hettasch intrusion (Berg, FR 1972, 1973). About 180 km². Leucotroctolite, anorthosite, and leucogabbronorite. Remarkable for several features, including its synclinal structure, snowflake troctolite zone, chilled margin, and contact aureole. Bulk composition of chilled margin is high-alumina basalt.

Kiglapait intrusion (Morse, 1969; FR 1972; in preparation). 560 km². Troctolite to ferrosyenite, bulk composition high-alumina, low-K olivine tholeiite. Low volatile content (Davies, 1974).

Lister massif (Morse & Wheeler, FR 1973). Possibly 400 km², limits unknown to north and south. Leucocratic andesine anorthosite.


Newark -- see Tigalak.

North Ridge gabbro (Berg, FR 1972). 15 km². A basic, east-dipping gabbroic sheet along the margin of the Hettasch intrusion. An₈₃ to An₅₅.

Nukasorsuktokh troctolite (Speer & Morse, FR 1971; Davies, FR 1973). About 5 km². Troctolitic, An₅₂, range not yet reported.

Susie Brook slab (Morse & Wheeler, FR 1973; Morse, 1975). Possibly 200 km² or more. Steeply dipping (70°E) slab of andesine anorthosite between Bird Lake and Lister massifs. Layering locally well-developed throughout 8-km section. Distinguished by cumulus and subophitic aluminous orthopyroxenes with plagioclase lamellae.


Tunungayualok anorthosite (Wiebe, FR 1975). Perhaps 40 km². Locally layered anorthosite with diverse attitudes.


Wyatt Harbour complex (Davies, FR 1973). About 5 km². Diorite to monzonite and quartz monzonite. Hypersolvus clinopyroxenes and calcic mesoperthites prove very high temperatures (~1000°C?). Simmons (thesis, 1976) reports a K/Rb of 11,000!

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X-ray and optical determinative curves for augite (Morse).

A suite of augites from the Kiglapait intrusion has been analyzed by K. Aoki, and their (150) X-ray powder diffraction peaks have been measured against silicon by T. M. Usselman. I have measured beta refractive indices by the dispersion method. The data will be published in a more comprehensive report on the Kiglapait augite series. Meanwhile, it may be helpful to report the resulting determinative equations for En = molar Mg/(Mg + Fe²⁺ + Mn).

Small amounts of Fe and Ti are present in these pyroxenes as exsolved titanomagnetite and ilmenite lamellae which no longer contribute to the X-ray spacings or the refractive index. The host pyroxene is therefore slightly more magnesian than the bulk analysis indicates. No attempt has been made to correct for this effect, which is probably small. That this is so for the refractive index can be inferred by the close correspondence of refractive indices for magnesian compositions between Kiglapait and Skaergaard augites, which have very similar minor element chemistry.
but differ in the vanishingly small amount of visible Fe-Ti oxide lamellae present in Skaergaard augites. When the Skaergaard (and other) analyses are recalculated in the same way, they plot very close to the present refractive index determinative curve. (This is not true of the Fe-rich Skaergaard data, in which there is circumstantial evidence for large errors in the refractive index.) Kiglapait augites span the range from about En_{73} to En_{0}.

The (150) X-ray peak was chosen as the best signal for monitoring variation in the b dimension which varies most strongly with Mg, Fe substitution. The determinative equation based on 22 points is

\[
\text{En} = 1.1584 \left( \frac{150}{200} - 0.17261 \right),
\]

where \(150 = \Delta 2\theta \left( 150_{px} - 220_{Si} \right) \cdot 4\), in degrees CuK\(\alpha\). All but three of the points lie within one standard deviation of the curve, which amounts to a determinative error of about 2 mole % En.

The beta refractive index, determined by the dispersion method on 1202 grains in 20 samples, is given by the regression

\[
\beta = 1.7447 - (0.0686 \text{ En}),
\]

and the determinative equation is

\[
\text{En} = 14.577 \left( 1.7447 - \beta \right).
\]

One standard deviation corresponds to 0.0005 in refractive index or 0.7 mole % En. This high precision refers only to the pooled standard deviations in determining about 10 grains in each of four different oils. The operative one standard deviation precision for a more normal determination of 10 grains in a single oil is 0.0014 in R.I. or about 2 mole % En.

The two determinative methods therefore have about the same precision for ordinary applications. The optical method is inherently faster and has the advantage of giving data on sample variability. It is apparently more precise if many grains are measured in several oils.
RECENT ABSTRACTS

GEOLOGY, PETROLOGY AND GEOCHEMISTRY OF THE LOWER KINGURUTIK RIVER AREA, LABRADOR, CANADA

Stephen Richard Brand

The lower Kingurutik River area, at the western margin of the Nain anorthosite massif, consists of a series of intrusive units that are gradational from anorthosite to a "granite" suite. The unit originally mapped as, and termed, buff-weathering anorthosite includes three separate intrusions: diorite, monzodiorite and meladiorite. The buff color of the outcrop surfaces is the result of oxidation of iron leached from the iron-rich pyroxenes.

Most of the rocks forming the major intrusive units have particularly high Fe/Mg ratios and are characterized by the absence of hydrous minerals. The composition and texture of the anorthosite suggests a cumulate origin. In most of the rock types plagioclase is predominant over alkali feldspar; pyroxene is the common mafic mineral. Apatite and ilmenite are common accessory minerals in all units except the anorthosite. The pyroxene is commonly orthopyroxene that has inverted from pigeonite. In the "granite" suite, fayalite (to Fa95), the product of subsolidus reequilibration of pyroxene, is commonly intergrown with quartz.

The enrichment of Si, Fe/Mg, K, Rb, Rb/Sr, K/Rb, Ba and the REE; and the depletion of Ca/Na, Al, Fe, Mg, Sr with relative age from the anorthosite to the "granite" suite indicates that the intrusions (excluding the meladiorite) formed from the differentiation of a single magma, possibly of quartz diorite composition. The Rb-Sr data suggest that the magma was derived from the lower crust or upper mantle and that later differentiates may have been contaminated by crustal material. The chemical data for the meladiorite precludes a comagmatic relationship with other intrusive units. However, a cogenetic relationship is not precluded. The RE and alkaline earth element data suggest that plagioclase accumulation played a role during formation of the intrusive units. Anhydrous conditions existed during formation as is indicated by the water-deficient nature of the constituent minerals. Initial crystallization of the intrusions occurred at a depth of approximately 16 to 20 kilometers.

The approximate age of emplacement for the "granite" suite (adamellite) of the Nain complex is 1.45 ± 0.3 b.y. This massif is part of a widespread late Precambrian (1.1 - 1.5 b.y.) magmatic event, elsewhere represented by separate cratonic intrusions extending along curvilinear belts in both the Northern and Southern Hemispheres.

--Ph.D. Thesis, Purdue Univ., 1976
The Nettasch intrusion is a layered anorthositic (orthopyroxene-troctolite) intrusion that is part of the main complex. It has a distinctive chilled margin which has a uniform chemical composition of high-alumina olivine basalt. Locally, just inside the chilled margin, the olivine-troctolite rocks contain large (3 cm) blebs of sulfide, consisting of pyrrhotite, chalcoprite, and pentlandite. Because the blebs occur only locally, they are believed to have resulted from localized sulfur contamination from the country rocks. The sulfide blebs are roughly spherical but are penetrated by plagioclase laths. Within a radius of about 2-3 cm around the blebs many of the olivine crystals of the troctolite have been partially or completely converted to symplectites of orthopyroxene + magnetite + pyrrhotite. Further away from the sulfide blebs, olivine crystals are unaffected. The breakdown of the olivine can be described in terms of the following partial reactions: 

1. $\text{Fe}_2\text{SiO}_4 + 2\text{S}_2 + 2\text{FeS} + \text{SiO}_2 + 1/2\text{O}_2$ (fa) (Po) 
2. $3\text{Fe}_2\text{SiO}_4 + 3\text{O}_2 + 2\text{Fe}_2\text{S}_3 + 3\text{SiO}_2$ (RN) 
3. $2\text{Fe}_2\text{SiO}_4 + 2\text{SiO}_2 + 2\text{FeS}_2\text{O}_6$ (fa) (Ps) 
4. $2\text{Mg}_2\text{SiO}_4 + 2\text{SiO}_2 + 2\text{MgS}_2\text{O}_4$ (Ps) (in) 

Thus the summary reaction is olivine + $2\text{S}_2$ + pyrrhotite + magnetite + orthopyroxene. Apparently the cooling and crystallization of the immiscible sulfide liquid evolved sulfur, raising the $a_2$ around the sulfide bleb and driving the above reaction to the right.

**Abstracts with Programs, 1977**

**Northeastern Section, Binghamton, N.Y.**

**Transition from Layered Gabbro to Anorthosite, Paul Island, Nain, Labrador**

**Planasnyk, George A., Department of Geological Sciences, Harvard University, Cambridge, Massachusetts 02138**

The Bridges intrusion in the Nain massif is a layered sequence consisting of a 1.5 km thick layered gabbro stratigraphically overlain by several km of anorthosite. Between these is a 100 to 500 m transition zone of olivine gabbros and troctolites. The three are considered to be a single crystallization sequence. An analogous gabbro -- troctolite -- anorthosite sequence occurs in the Michikamau intrusion.

The transition zone is locally heterogeneous but overall trends are clear. Grain sizes coarsen upwards from 1-5 mm to 1-10 cm or more. Olivine and pyroxene change from cumulus to subophitic minerals; textures then become functions of plagioclase accumulation. Layering becomes weak and irregular and igneous lamination in the lower troctolites disappears upwards. Local block structures and limited protoclastic textures develop. Non-cumulus crystallization in veins and zoned pockets grows more common. Olivine-plagioclase and olivine-pyroxene intergrowths with harristic textures occur in the upper part of the zone.

The changes in layering and textural styles suggest that plagioclase began to accumulate in suspension instead of sinking. This might result from an iron enrichment trend. The switch from cumulus to subophitic mafic minerals requires changing the magma from a three or four phase saturated liquidus boundary into the two phase melt-plagioclase field. Magma mixing, perhaps of successive inflows of new magma with somewhat differentiated old magma, might do this.
THREE-DIMENSIONAL GRAVITY ANALYSIS OF THE KIGLAPAIT LAYERED INTRUSION, LABRADOR

Stephenson, R.A., Department of Geology, Carleton University, Ottawa, Ontario; Thomas, H.D., Gravity and Geodynamics Division, Earth Physics Branch, Department of Energy, Mines and Resources, Observatory Crescent, Ottawa, Ontario KIA 0E4.

The Kiglapait intrusion on the northern Labrador coast is a large pear-shaped (32 km long, maximum width 27 km) basic layered body forming part of the Nain anorthosite massif. It is emplaced between anorthositic rocks of the massif and Archean basement rocks of the Nain structural province. Layering is well developed throughout the intrusion and is characteristically inward-dipping. The control afforded by the surface dips has been used previously to interpret a lopolithic body with a maximum thickness of about 8.7 km. The intrusion is associated with a large (50 mgal) positive gravity anomaly. This observed anomaly correlates closely with the theoretical anomaly computed for the lopolith over much of the intrusion, supporting the geological work. However, over the southeastern region of the intrusion the observed anomaly is considerably less than the theoretical anomaly. Interpretation of the gravity data indicates a circular negative gravity anomaly, 25 mgal in amplitude, in this area. This anomaly coincides areally with numerous dykes and stocks of granite (Manvers granite), which invade the Kiglapait intrusion. Two alternative granitic models extending from near-surface to depths of 6 km (located within Kiglapait intrusion), and 8 km (vertical pluton intruding Kiglapait intrusion and underlying rocks) can each explain the anomaly.


GEOLOGY

PAUL ISLAND CONTACT OF THE NAIN ANORTHOSITE COMPLEX, LABRADOR

BY

D. DE WAARD AND S. A. HANCOCK

(Communicated at the meeting of April 24, 1976)

ABSTRACT

On eastern Paul Island, the anorthosite complex is in contact with the Ford Harbour Formation, which presumably represents a eugeosynclinal pile of clastic sediments, volcanics, and ultramafic rocks recrystallized under high-grade metamorphic conditions. Fine to medium to coarse-grained noritic to leuconoritic rocks suggest a chill zone, about 100 to 200 m wide, in which rapid crystallization from basaltic parental magma took place. Early fractionation is suggested by a zone of leucotroctolite with relatively high An and En percentages. Further fractionation produced the large mass of anorthosite, which has lower An and En percentages, and commonly contains a little interstitial quartz.

At gradually lower temperatures, intercumulus liquid in anorthositic cumulates crystallized in vaguely defined pegmatoid bodies; cumulus plagioclase intruded as a crystal mush to form equigranular, almost monomeric anorthosite dikes, and residual liquid from the magma chamber crystallized to jotunitic dikes.
GEOLOGY

DARK AND PALE FACIES ANORTHOSITE IN THE KAUK BLUFF AREA OF THE NAIN COMPLEX, LABRADOR

BY

D. DE WAARD

(Communicated at the meeting of April 24, 1976)

ABSTRACT

In the Nain complex a distinction is made between dark-gray, commonly olivine-bearing anorthosite, and light-gray anorthosite containing a more sodic plagioclase and locally some interstitial quartz and feldspar.

In the investigated area the two types adjoin each other without intrusive or deformational features. In the boundary zone dark plagioclase occurs in and around patches of poikilitic pyroxene which are embedded in a pale, pure plagioclase matrix. The composition of plagioclase and orthopyroxene varies little and unsystematically across the boundary. Some olivine occurs in one sample of dark-facies anorthosite. Interstitial quartz is common in the pale facies, but it occurs also in the dark facies near the boundary.

The conclusion is that here dark and pale-facies anorthosite grade into each other, suggesting a comagmatic origin.

Anorthosite-adamellite-troctolite layering in the Barth Island structure of the Nain complex, Labrador

D. DE WAARD

LITHOS


The Barth Island structure is an oval, 9 by 6 km body of layered igneous rocks. The central part contains a rhythmically layered troctolite-adamellite sequence. The sequence is repeated outward, but appears overturned, strongly sheared and reduced in thickness. Outward follows an adamellite-anorthosite sequence in which the effects of shearing gradually diminish. In both sequences cryptic layering is evidenced by gradual change in mineral compositions. Isopleth maps based on the compositions of plagioclase, orthopyroxene and olivine show a circular high of An, En and Fo percentages in troctolite, gradually decreasing inward to a low in adamellite rock. Between the highs in troctolite and the surrounding anorthosite occurs a low-temperature trough where both sequences grade into adamellite rock. The structure may represent a deformed portion of pre-existing igneous layering. An alternative explanation would involve mixing of successive magma batches of gradually more sodic and ferrous composition.

D. de Waard, Department of Geology, Syracuse University, Syracuse, N.Y. 13210, U.S.A.
Mineral Variation in Anorthositic, Troctolitic, and Adamellitic Rocks of the Barth Island Layered Structure in the Nain Anorthosite Complex, Labrador

D. de Waard, K. Mulhern, and D. F. Merriam

The Barth Island layered structure is an oval, 6 by 9 km body, consisting of rhythmically layered adamellitic rock in the center which grades outward through jotunite into troctolite. Farther outward the sequence repeats itself in reversed order, strongly reduced in magnitude and finer grained; the adamellitic zone is followed by jotunite which grades into coarse-grained leuconorite and into anorthosite of the Nain complex. The Barth Island structure, having an inverted conical base topped by a hemispherical depression, seems to represent a distorted sequence of rock layers with troctolite at the bottom, grading upward into adamellitic rocks which grade into anorthosite at the top. Trend-surface analysis demonstrates the regional variation of plagioclase and orthopyroxene compositions in the troctolite-adamellite sequence of the central part of the structure. The fits for the second- and third-degree surfaces are good and significant at the 99 percent level. The regression line for compositional variation in coexisting plagioclase and orthopyroxene in all analyzed rocks has a correlation coefficient of \( r^2 = 0.78 \). The difference between the trends in the troctolite-adamellite sequence and the anorthosite-adamellite sequence is insignificant. The regression curve for compositional variation in coexisting orthopyroxene and olivine has a correlation coefficient of \( r^2 = 0.98 \). The curve shows good correlation with the experimentally established partitioning curve of Medaris, which indicates that equilibrium conditions prevailed during formation of the olivine-orthopyroxene pairs. The results suggest that the troctolite-adamellite sequence and the anorthosite-adamellite sequence are products of fractional crystallization, possibly from the same parental magma. KEY WORDS: regression analysis, trend analysis, geochemistry, petrology.
THE NEWARK ISLAND LAYERED INTRUSION

Charles W.D. Woodward

Newark Island, near the town of Nain, Labrador, lies in the eastern part of the Nain Anorthosite Complex. Several layered igneous intrusions are associated with the complex. Newark Island is underlain by anorthosite on the west and a layered intrusion on the east. Rock types ranging from troctolite to jotunite occur in the intrusion.

Structural and mineralogical data indicate that the intrusion is asymmetrical and basin shaped, with a steeply dipping contact on the east. Layering in the western portion of the intrusion is shallowly dipping. The intrusion plunges below the Ford Harbour Formation on the south.

The layered igneous rocks show both local transgressive and transitional relationships with the anorthosite to the west, whereas the intrusion is clearly transgressive with the metamorphosed country rock, the Ford Harbour Formation, to the east. No chill zones are obvious at transgressive igneous contacts with the older rocks. Contacts usually are conformable to the layering in the Ford Harbour Formation or parallel to the leuconoritic margin of the anorthosite.

The intrusion can be described in terms of an eastern limb containing steeply dipping conspicuously layered rocks, and a western limb, containing shallowly dipping cryptically layered rocks. The rocks of the intrusion can be divided into four zones. The Border Zone consists of conspicuously layered troctolite, norite, gabbro and wehrlite, and forms the steep eastern margin of the intrusion. The shallow western limb contains the Lower Zone, which consists of massive troctolites, and the Middle Zone which consists of gabbro, olivine gabbro and local occurrences of troctolite. Layering within the Border Zone becomes diffuse at high levels within the stratigraphy. The Border Zone and the Middle Zone merge gradually at the level of the upper Middle Zone. Upper Zone rocks, which are diorites and jotunites, overlie the Middle Zone.

The troctolites crystallized first, followed by the gabbros and lastly the jotunites. Plagioclase composition ranges from An$_{64}$ in the troctolites to An$_{28}$ in the jotunites. Olivine composition ranges from Fo$_{52}$ in the troctolite to Fo$_{40}$ in the jotunites. Augite appears as an abundant cumulus phase in the Middle Zone. K feldspar appears in the Upper Zone as anti- to mesoperthite. Layering in the troctolitic, noritic, and gabbroic rocks seems to be due to variable currents in the magma chamber, coupled with progressive fractionation of the magma.

Several small transgressive adamellite bodies occur in the field area. The layered intrusion also is cut by pink granitic dikes and by diabase dikes. These later intrusions produce only a local alteration of the original igneous rocks.

It has been suggested that the Nain Complex developed from a magma crystallizing at depth, which produced an overlying layer of plagioclase by flotation. Because of fractionation, the underlying magma residuum would become less dense with time than the overlying anorthosite, and rise around it, as indicated at the margin of the anorthosite against the Ford Harbour Formation. The shape and structure of the body seem to support this working hypothesis.  

BIBLIOGRAPHY OF THE NAIN ANORTHOSITE PROJECT

Note: This continues the bibliography contained in FR's 1974 and 1975.

1976


1977


Fig. 15. Location of new tracks on sheet 14 C, north.

Fig. 16. Location of track 91.
INTRODUCTION

The 1975 and 1976 seasons saw the addition of 181 miles of new sounding track, bringing the total for six years to 762 nautical miles sounded by R/V Pitsiulak. The new tracks are listed in Table 3, and located on the index maps, Figs. 15 to 19. Edited field sheets and fathometer records are being submitted concurrently with this report to the Dominion Hydrographer. Much of the mileage was surveyed this season by Mr. D.E. Deuring, whose competent efforts are gratefully acknowledged. Several steersmen participated in the work, but the unerring eye, steady hand, and iron nerve of Anne Morse deserve special mention.

The 1976 season brought several quests to a satisfactory conclusion. Among these are the complete circumnavigation with soundings of Tunungayualok Island, surveys of two Shoal Tickles (Tom Gears and Cape Harrigan), and at long last, a reasonably comprehensive understanding of the hazards along Tom Gears Run, the main inside passage from Davis Inlet to the Nain area. Among new projects of long-standing interest are the intensive survey of the Kikkertavak-Tabor I. route to Nain (a major thoroughfare), a survey of Igiak Bay on Kikkertavak Island, and in the area south of Hope-dale, a track across the Bay of Islands from Cape Point in Kaipokok Bay to Tickle Arichat near Winsor Harbour Island. The aid of Dr. William Fitzhugh and R/V Tunuyak on this track (Track 91) is gratefully acknowledged.

DANGERS TO NAVIGATION

Shoal, Sheet 14 C/6, 4.5 cables off the south shore of Nochalik Island. This appears to be the same as the "Little Gull Island" shoal of Forbes (1938, Navigational Notes, p. 12, 14), although the location of that island is unclear. The shoal can be identified on airphoto LAB 43-67 or 66. It was encountered in 1975, very close to our Track 2 of 25 August, 1972.

1Authors' full addresses are given at the back of this volume.
Table 3. 1975 and 1976 Sounding Tracks, Listed in Chronological Order

Note: Spellings are those of published hydrographic charts, except as noted. Sheets designated 14 -- are Canada Topographic Series 1:50,000. LAB refers to an airphoto. "Hydro" refers to preliminary plotting sheets furnished by the Canadian Hydrographic Service. 5153 is a manuscript hydrographic chart. For tracks 1-82, see 1972, 1973, and 1974 reports.

<table>
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<tr>
<th>Track Description</th>
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<td>14 C/11, C/14</td>
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<td>- 1976 -</td>
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<td>Hydro 15</td>
<td>1-76</td>
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<td>25 Jun</td>
<td>14 C/3</td>
<td>1-76</td>
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¹"Iglosiatik" of published maps; see 1974 note, p. 91
²Uivaq (Uivakh of Wheeler, 1953) is taken from E.P. Wheeler's unpublished place name map as applying to the peninsula as well as to the Cape on the mainland west of Akpiktok I.
Fathoms and meters intermixed, Manuscript Chart 5153. New soundings and lead-line calibration in Windy Tickle (see Track 90) indicate that depths are given in meters on this part of the sheet. However, a recent transcription of Pitsiulak soundings in Lat. 55°-58' to 56°, west of Kasungatak I., is in fathoms. Other scattered soundings in this area may also be in fathoms (see Track 93, below). New tracks 89, 92, and 93 on this sheet are in fathoms, and should be converted.

All soundings of R/V Pitsiulak to date have been reported in fathoms. A metric scale is on hand, and metric depths can be furnished in the future if that is desired.

Shoal north of Pigeon I., Tom Gears Run. See directions below. Shoal and rocks, NW of (Tom Gears) Shoal Tickle; see directions below.

NOTES ON THE TRACKS

Track
83
See Tom Gears Run description below under "Descriptions and Directions."
84, 88
Tracks skirt eastern side of Tunungayualok Island in apparently good water.
85, 90, 92
This is the Shoal Tickle west of Windy Tickle, near Cape Harrigan. It is used by coastal freighters when they draw less than two fathoms, and provides a welcome shortcut for vessels proceeding to Davis Inlet or the inside runs to Nain. As well known to coastal ship masters, the Tickle has a smooth bottom at 2 fathoms all along its narrow part. The Tickle is entered from Windy Tickle by steering a westerly course after the mainland point is cleared, crossing the mouth of a deep bay situated just west of Windy Tickle. From there on, a vessel should steer by the land, favoring the southern half of the narrow part of Shoal Tickle. Two alternatives then present themselves in respect to an inner island and an outer islet aligned NW in the wider part of Shoal Tickle. Both islands and islet can be left close to port, with least depths 3 and 2.5 fathoms off each, respectively. Deeper water (4-8 fm) is obtained by leaving both about 4 cables
Fig. 17. Airphoto overlay of track into Tickle Arichat.
to starboard and emerging along the outer part of track 92.

Track 90 was run from Shoal Tickle to Windy Tickle as a calibration track to verify the fathoms/meters confusion mentioned above under "Dangers."

Tom Gears Shoal Tickle; see Tom Gears Run description below.

A short track with no apparent dangers; depths 22 to 51 fm.

See 84.

Track begins at entrance to "Fox Inlet" and runs past the SW corner of Kasungatak I., off which there is an 8-fm patch, and thence to the mainland point 3.4 mi NWW of Davis Inlet.

See 85.

Cape Point (Cape Roy of older charts) is the outermost of two conspicuous points on the west side of outer Kaipokok Bay. The track runs from about 1 mile NW of this point to Tickle Arichat (see directions below). Sandbars and shallows occur well off the mainland shore and the offlying islands; these are avoided by keeping about 7 cables offshore west of C. Point, after which a vessel may swing to the SW to enter a narrow passage between the mainland and an island group, about 1.6 miles west of C. Point itself. This passage gave a depth of 3 fm. Track 91 then leads northerly along the aforementioned island group, avoiding shoals noted on Sheet 6, to enter another passage between mainland and offlying island, which gave a least depth of 5 fm hard against the northern side. The track then cuts westerly across the mouth of Bay of Islands, finally approaching a long, narrow passage leading northerly along the mainland shore at the NW outer limit of Bay of Islands. This passage carries deep water except for a 2.5 fm spot in the "S-turn" toward the northern end. From this passage, Tickle Arichat is approached after crossing a small inlet reaching to the SW.

See 85.
Fig. 18. Locations of new tracks on Sheet 13 N.
Track begins 4.6 mi NWW of Davis Inlet (town), runs northwesterly and then northeasterly along the west side of the passage between Kasungatak I. and the island to the west. Scattered depths "26" "35" "22" on manuscript 5153 in this general area appear consistent with fathoms, not meters, and should be converted. Track 93 continues on Sheet 14 C/2 to the islets off the mouth of "Fox Inlet."

Track runs north to south across mouth of "Fox Inlet." Track "94a" is examination of the 6-fm shoal off mouth of "Fox Inlet."

Track runs north to south from aforementioned shoal, past islets, to island off SE peninsula of Tunungayualok I.

Track starts on 20-fm sounding of Track 89 and runs west along south shore of Tunungayualok I. A bar with 7 fm appears to extend off the first point of land cleared on the track, and another off the first point cleared on Sheet 14 C/3, again 7 fm. Track continues, to join with Track 82.

Inshore track across Pigeon I. shoal bar, run because this route was taken by the local pilot of a CNR coastal freighter on her maiden trip to Nain. The pilot, the late David Edmunds, did very well to avoid the shoal which lies close inshore. We had to stop at 1 fm, shear off toward the shore to the SE, and re-lay the rest of the track hard by the shore. Even here, a least depth of 2 fm was encountered on the bar, which then drops sharply off to 14 fm. This inner track is not recommended; see directions for Tom Gears Run, below, for the preferred track.

Short track, Boat Hr. (see Place Names, below) to Shoal Tickle.

See descriptions and directions under "Kiuvik I. to Tabor I.", "Igiak Bay", and "Kamarsuk", below. These tracks collectively constitute a survey of the Tabor I. route to Nain. Track 98 begins at Tabor I. and runs southward. Track 99 begins at the mouth of Igiak B., Track 100 begins at Kiuvik I. and runs westerly. Track
Fig. 19. Locations of new tracks on Sheet 14 C, south.
Tickle Arichat: Directions (Track 91)

This is the passage between Marykulluk Island and the mainland SW of Winsor Harbour Island (Chart 4752, bottom edge). A vessel may approach along the mainland shore from the south, emerging from the narrow passage between the mainland and a group of islands. There is a conspicuous islet off the south end of Tickle Arichat. A vessel should steer toward this islet aligned with the right tangent of the mainland (western) shore of the tickle. There is a monument and a small cabin on this head of land. When about 1/2 mile from the rock, a vessel should steer for the mainland shore and make a partial circuit around the rock, leaving it about 2-3 cables to starboard, until the tickle is once again well open. From this point a course directly away from the rock should lead toward the left tangent of Marykulluk Island. This course should be maintained so as to favor the eastern side of the tickle until about 1 cable off the Marykulluk Island shore, at which point a vessel may clear away to the NW on soundings. A least depth of 3 fm was found opposite the southern tip of Marykulluk Island, but the center and western part of the tickle near the monumented headland is foul with shoals.

Tom Gears Run. This is the main inside track from Davis Inlet to the Nain region. It skirts the southern and western shores of Tunungayualuk Island and then passes through either Perrett Tickle on Shoal Tickle to Akpiktok Island. Data are now sufficient to permit an adequate description for running under favorable conditions. Reference is made to Figs. 20 to 23, which show summary data from Porcupine Rattle to Perrett Tickle and detailed data in the difficult area near Pigeon Island. The inset to Fig. 23, included for historical interest, is Alexander Forbes' original sketch describing the run (see Forbes, 1938, Fig. 7), to be compared with our new map.
Fig. 20. Southern part of Tom Gears Run.

1:100,000

1976; S.A. Morse
Directions. Porcupine Rattle may be negotiated along the indicated track (Fig. 20) with a least depth of 3 fm. Reference is also made to Chart 5153 (in manuscript).

From the site of the town of Davis Inlet, situated just north of Porcupine Rattle near the eastern end of Iluikoyak Island, a vessel should steer northward toward Kasungatak Island, then about 305°T to pass between Kasungatak Island and the northeastern extremity of Iluikoyak Island, and thence through the passage between Uyagaksuak Island and Ivinaq Island. Depths in the range 10-35 fm occur along this general route. A group of islets lies about 3 cables off the eastern end of Uyagaksuak Island. From these islets, a course of about 308°T will lead close along the SW shore of Ivinaq Island, where depths in the range 10-35 fm occur within 2 cables of the shore. This course should be maintained to within 2.5 or 3 cables of the south shore of Tunungayualok Island (15 fm). A course of 290°T will then lead along this shore, toward the middle of the passage between Pigeon Island and Tunungayualok Island (see Fig. 22).

This course leads directly away from a conspicuous, house-sized boulder on the north end of Ivinaq Island, a landmark which is generally more useful on the southward run as a steering mark. A mile-long group of inconspicuous low islets and shoals lies 3 to 5 cables south of the recommended track, and extensive shoals reach outward from each of the two wooded indentations along the Tunungayualok shore. A least depth of 3 fm occurs on the inner part of the first shoal, 3 cables off the mouth of the brook in the first such indentation, and shallower water lies farther offshore. This is the most critical part of Tom Gears Run. The second shoal indentation, about 1 mile east of Pigeon Island, deepens abruptly offshore to 22 fm, and appears not to constitute a difficult hazard. Depths along the track range from 42 fm just after the cited 3 fm shoal to 8 fm, northeast of Pigeon Island.

An extensive shoal bar lies 6-10 cables due north of Pigeon Island. The course 290°T should be maintained for about 4 cables beyond the east end of Pigeon Island, at which point a vessel should steer 338°T to pass along the narrower parts of Tom Gears Run, and thence by the land into Perrett Tickle. Depths of 3-4 fm can be expected on the bar 8-10 cables north of Pigeon Island, at which point the shore of Tunungayualuk Island should lie no closer than 5 cables, as a dangerous shoal lies 3 cables from that shore at the northern edge of the bar. See Fig. 22 for details.

1See comment on names at the end of this report.
Fig. 21. Northern part of Tom Gears Run.
Depths of 3 fm are to be expected west of the recommended track.

The remainder of Tom Gears Run is deep and straightforward. Shores are bold on both hands.

**Perrett Tickle: Directions** (Fig. 21). After passing by the entrance to Shoal Tickle a vessel should swing sharply to the east toward the entrance to Nuverdluktok Bay, thence north, favoring the eastern shore, and thence northwesterly through Perrett Tickle. A vessel may pass to either side of the small island about two-thirds of the way through Perrett Tickle, but greater depths (20 fm) are found on the north side.

**Akpiktok Island** lies two miles north of the western entrance of Perrett Tickle. The southwest corner of the island can be skirted at a distance of 5 cables to avoid inshore shoals of 3-4 fm, and thereafter a vessel should seek the eastern half of the passage between Akpiktok Island and the island 1 mile to the west, to avoid a 6-7 fm patch which extends eastward across the western half of the passage. Smooth bottom with depths of 40-50 fm occurs off the NW corner of Akpiktok Island.

**Shoal Tickle: Directions** (Fig. 21). A vessel should enter the eastern end favoring the southern shore and steer so as to favor the northern shore for the first half of the run. The northern shore may be kept close aboard midway along the Tickle, after which a vessel should swing over to favor the southern shore, at the narrowest part of the Tickle. As the passage begins to open up, a least depth of 2 fm can be expected. A vessel should once again steer toward the northern shore, holding just inside the northern entrance point, to avoid a shoal reaching out from the south. Exit from the tickle is made favoring the northern half of the passage in deep water (8-24 fm).

To proceed northward toward **Akpiktok Island**, a vessel should round the northern entrance point immediately to avoid an extensive shoal lying 3-5 cables offshore, just north of the entrance to Shoal Tickle. After this danger is passed, the track is clear of dangers.

To proceed to **Zoar**, a vessel should steer due west (true) from Shoal Tickle.
To proceed to Boat Harbour, a vessel should stand off and then steer south-southwesterly to pass east of Gibraltar Island, then skirt that island to pass westward into Boat Harbour. Anchorage may be obtained in 7-9 fm. at the head of the harbour. Note: strong currents set out of Tessiyuyak Bay Rattle on the ebb tide.

Anchorage. Kangerdlutannak Bay (Fig. 22), on the SW shore of Tunungayuaku-lok Island is well protected but deep (10 fm?).

Kamarsuk (Track 102)

The track shows an abundance of deep water (around 50 fm) from Cape Uivaq along the south shore of Kiuvik I. The settlement of Kamarsuk lies on the mainland point just west of the west end of Kiuvik I. Beyond the entrance to Headforemost Tickle (see comments on place names, below), a least depth of 12 fm is encountered in such a position as to suggest a sill running SW across the channel off the SW end of Kiuvik I. Beyond this deep water is again encountered until the passage between the settlement and a small channel islet is reached. In this passage, a least depth of 6 fm was recorded, but care should be taken to avoid the shoal point to port. Wheeler's maps indicate strong currents flowing through this passage. The track leads northerly from Kamarsuk inside of Near I. but outside of Middle I. (see place names, below), assuming that Near I. is the large island nearest Kamarsuk.

Kiuvik Island to Tabor Island (Tracks 98, 99, 100, 101, 102).

This run provides an alternate route to Nain from the area of Akpiktok Island, either via Kamarsuk or via Sungilik Island and the south side of Kikkertavak Island. The route avoids The Bridges Passage (Chart 4748, depth 4 fm) and carries a least depth of 5 fm in the narrow tickle east of Simmikutaq Island, and 4 fm east of the Pitsiulatsuit Islands (near Turn Island of Chart 4748). At the latter place, currents are probably weaker than in The Bridges. Its advantage lies in greater protection, particularly from heavy pack ice or NE storms.
Fig. 23. Tom Gears Run: comparison of 1938 sketch by Alexander Forbes (inset; collection of the author) with 1977 compilation.
The route has been investigated with some intensity and appears to be clear of dangers, particularly in mid-passage between Hare Island and Kikkertavak Island. The narrow tickle east of Simmikutaq Island is recommended over the wider but shallower passage west of that island. Anchorages have not been investigated, but the name of Umiakovikulluk Harbour implies a choice place for smaller craft, at least.

**Igiak Bay** (Track 98 and informal survey)

This is the long bay penetrating from the south side of Kikkertavak Island. It is accessible only to small vessels drawing less than 3 meters (≈ 1.6 fm). Least depths of this magnitude (referred to low water) are found at the entrance narrows and at the innermost narrows before the cove in which the bay terminates. Very strong currents set in and out of the entrance narrows. A vessel wishing to enter should favor the north side, keeping clear of visible boulders to port, and continue toward the northern shore until about 2 cables inside the starboard entrance point, and then swing to the left to seek mid-channel.

**Anchorage** (4 fm, grass and mud) is obtained in the west corner of the inner cove, off the mouth of a brook where water can be obtained.
NOTES ON PLACE NAMES

In this Hydrographic Report, as in past years, conventional names and spellings have been used which appear on published hydrographic charts on topographic maps. This year, however, several names have been used which apparently do not occur on published maps.

New Names:

**Boat Harbour**, south of Zoar and SW of Gibraltar Island, sheet 14 C/3, 56°-06.5' N, 61°-21' W. Informant (1975) was Mr. Julius Ford of Nain, who has for years maintained a seasonal home 6 miles north of here and who is widely travelled and knowledgeable. Several graves occur on the south side of the harbour; one is marked with the name of Chesley Ford.

**Porcupine Rattle**, immediately south of the new Davis Inlet, 55°-52' N, 60°-54' W. Informant (1971) was Mr. Sam Anderson of Nain, who implied that this name was universally used locally.

**Wheeler names:**

These are taken from current (manuscript) place name maps of E.P. Wheeler 2nd, which represent his compilations of local usage since 1927. In cases where the soft Inuit "k" (K of current local use and kh of Wheeler) occurs, this has been rendered "q", in case of the possible adoption of this convention by the Labrador natives and by the appropriate commission on toponymy. These names have been applied only where purposes of navigation are served, and only where published alternatives are not known. The names selected are listed alphabetically below by map sheet. Reference is made to Wheeler (1953) for further information on Inuit names.

<table>
<thead>
<tr>
<th>Sheet</th>
<th>Name</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>5153</td>
<td>Ivinaq I.</td>
<td>Ivinnakh of Wheeler, Ivênaq of Bourquin. An important landmark along Tom Gears Run.</td>
</tr>
<tr>
<td>14 C/3</td>
<td>C. Úivaq</td>
<td>Úivakh of Wheeler, elsewhere (as at Sagleq) Úivak on published charts. Origin of word &quot;Webeck&quot; near Cape Harrison.</td>
</tr>
</tbody>
</table>
Sheet Name Comments
14 C/12 Amos I. Pencilled query on Wheeler's ms. map.
Far I. Agree logically with Middle-Near-Far sequence from Kamarsuk, and equivalence of Pigeon with Pitsiulak, also suggested by Wheeler in pencil.
Hare I. -
Headforemost Tickle Name said to derive from an incident in which a person fell head first off a boat and was seized by the legs by those left aboard (Wheeler, verbal communication).
Kangerdlualuk B. -
Kangerdlukulluk B. -
Near I. See Far I. Pencilled query by Wheeler.
Middle I. - ditto -
Pitsiulak I. Pitsiulaksialuk of Wheeler.
Pitsiulatsuit Is. Local usage confirmed.
Simmikutaq I. Simmikutakh of Wheeler.
Tokauyaq I. Tokauyakh of Wheeler.
Umiakovikulluk Hr. "The little boat harbour."

Informal:
"Fox Inlet", SE Tunungayualok I. Name applied for field purposes by Dr. R.A. Wiebe, who saw a fox there in 1975. No local name known.
During the winter of 1975-76, R/V Pitsiulak was frozen in for the first time, in a small cove near the tidal limit on the Kaipokok River. This procedure worked very well, except that at breakup she took in a large amount of water which flooded the main engine and caused eventual damage to the alternator. Despite these spring problems, she was moving under her own power by 4 June, and began operational work in the Nain area on 26 June, the earliest date ever. Pack ice presented no problem this season. Geological research was begun early (27 June) and was prosecuted successfully until 24 August in one camp; another camp finished work by 10 August. The work of R/V Pitsiulak was interrupted by a destructive bearing failure at the auxiliary drive end of the main engine, and because of deficiencies in the local air express service, she was kept out of action for a full fortnight. Work was then further interrupted in August by the tragic disappearance at Ramah Bay of Anne Abraham, a much-loved member of our companion archeological research team from the Smithsonian Institution. This shattering experience, combined with construction of a new storehouse at Khaukh Harbour, left little time for research during the last three weeks of the season. Operations were concluded on 1 September after securing stores in the new building and laying the vessel up at anchor at Postville. She was hauled out for the winter in November at Postville Shipyards. Pitsiulak will be used and maintained over the next two seasons by the Smithsonian group, who will conduct a reconnaissance survey of Northern Labrador, using her in conjunction with their own R/V Tunuyak.

TOPICAL SUMMARIES

Ice

Early breakup, no troubles with pack ice.
Weather

Very much better than average; in 69 days of record, 12 were stormy or wet, for an average of one bad day in every 5.8 days. This appears to be a record during our operation; it was, by and large, a dry summer. There were good stretches of weather of 9 days each, back to back in late June—early July, and another good stretch of 13 days in early August. There was one great gale (southwest and west) on 21 July, posing a severe problem of handling the disabled vessel in the night at the wharf in Nain. There were two NE storms of 2 and 3 days' duration, and one remarkable day of wet snow on 28 June.

Vessel Maintenance

Energetic work by the entire crew, especially in early season, brought the vessel to a peak of condition hitherto unmatched in her career. A rotten spot near her starboard rail, forward, was discovered and repaired; decks, stanchions, and cabin trunks were well scraped, filled, and painted, and her engine room and electrical system were brought forward to excellent condition. The radar T/R unit was rebuilt and competently reinstalled, and at this time it was discovered that the fathometer had been subjected to overvoltage since the original installation. Deuring quickly ran a 24 volt line to it, and the problem was solved. Despite drying, the accidental immersion during the spring breakup caused the alternator, voltage regulator, and ballast resistor to fail when the engine was started. When these were replaced, it was found that the ballast resistor had been miswired during the original engine installation, so that problem was finally corrected.

The destructive bearing failure of 20 July injured all the appurtenant gears related to auxiliary drives (salt water pump, camshaft, bilge pump, alternator, and so forth), but fortunately spared the main crankshaft gear. The cause evidently had something to do with periodic lay-up of the engine, as similar engines subjected to continuous duty are not known to develop this problem, whereas it is just becoming familiar in fishing vessels. The obvious preventive cure is routine replacement of the front end bearing every 2 years. The failure found Deuring alone to solve the problem, and within a day he had torn down the entire front end of the engine, located all the damaged parts, and ordered new ones. There followed an exhaustive cleanup of metal chips,
and then a frustrating 10-day delay while new parts were mislaid in Goose Bay after having been sent promptly by the shop. The repair required difficult gear-pulling without proper tools, and was, all told, a masterpiece of careful field repair.

The reefer-freezer unit still has problems of unknown origin, and for most of the summer it was operated only while under way, to extend the life of ice used as a refrigerant. To all intents and purposes, this is now an icebox.

**Communication**

Radio conditions were generally good throughout the summer. Extensive communications with Ramah Bay and Saeglekh Bay required transferring the *Pitsulak* radio to a shore station in Nain, where it could be operated alongside the telephone to outside stations.

**Flying**

Service from the local air charter company in Goose Bay hit new lows this year. One of their aircraft was lost with several fatalities, and the entire fleet was grounded for a period. Passengers and freight were delayed more than usual during the entire season. Charter services were more difficult to obtain on time than ever. By contrast, a full day's difficult work was accomplished on schedule by a competing company out of Knob Lake, and it is probable that this source will deserve greater attention in the future.

**Laboratory**

Fifty-two mineral determinations were made aboard ship, despite the curtailed use of the laboratory caused by exigencies. Great problems were again encountered in shipping specimens from the field area. In this case, essentially all the sample drums were mislaid at one point or another, and none arrived until half the winter was over. The sample recovery process will have to be completely reviewed in the future.

**Health**

The 1976 season saw the first major loss of time from ill health in our six seasons of operation. The cause was an aberrant form of the bacterium *shigella* which produces a persistent, dysentery-like illness.
This affected Williamson and Wright for most of the early half of the summer, and required their recuperation at a stateside medical center.

Wintering

The vessel was hauled out on the new slipway (really a nascent railway) at Postville Shipyards.

SUMMARY OF OPERATIONS

The 1976 working season lasted 59 days, with interruptions which affected some parts of the operation for about three weeks. The first field camp was established on 27 June, a new record by the remarkable margin of seven days. A successful three-day field conference was held at the beginning of the season. Many new tracks were sounded, and several new runs brought for the first time onto soundings. The shipboard laboratory furnished 53 new mineral determinations and processed 21 drums (probably about a ton) of samples. The calendar below summarizes the main events.

CALENDAR

May 29  Exec. Officer and Cook to Pitsiulak at moorings. Water in engine.
June 3   Main engine started.
         Vessel to wharf. Commissioning started.
         Second crew to vessel. New engine on Tunuyak.
         New voltage regulator installed.
         Vessel to Khaukh Hr. from Postville, 19 hours.
         Geologic research started, Fox Inlet.
         Snow all day.
         Vessel return to Postville.
July 1   Sounder rewired to 24 volts. Radar repaired.
         Pitsiulak, Tunuyak leave for Nain. Ranson to field area.
         Geology resumed.
         Begin house construction, Khaukh.
         Coordinator departed field area.
         Cook returned aboard.
20 Bearing failure on main engine. Pitsiulak idled at wharf, Nain.
23 Food drop to Ranson.
24 Wiebe camp moved to Tigalak via Tunuyak.
29 Khaukh house shell erected.
30 Exec. returned with engine parts.

August 1 Main engine restarted.
3 Geology resumed, Tikkoatokhakh Bay.
6 Vessel returned Nain. Concern about Ramah party.
7-13 Search at Ramah, Pitsiulak personnel aiding in communications.
10 Coordinator returned to field via Schefferville. Ranson moved, Wiebe party out for season.
12 Resumed work on Khaukh house.
18 BRINEX visit to Snyder Group via helicopter.
19 Resumed geology, Tikk. Bay.
21-22 Field conference, September Harbour.
23 Resumed work on Khaukh house. Began transfer of stores.
24 Ranson crew out.
25 Operations ended; stores into new storehouse, vessel departed for Postville.
26 Arrived Postville.
27 All geology crews out.

Sept. 1 Vessel at anchor for fall.

Nov. - Vessel hauled out at Postville Shipyards.
PERSONNEL

Scientific Staff

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Guest Investigators:

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A.J. Morse, Pelham, Mass.  
Haynes Store, Nain  
Henry Webb, Nain  
S.A. Morse, Amherst, Mass.  

Executive Officer  
Cook  
First Mate  
Second Mate  
Agent  
Expeditor  
Master
REFERENCES


