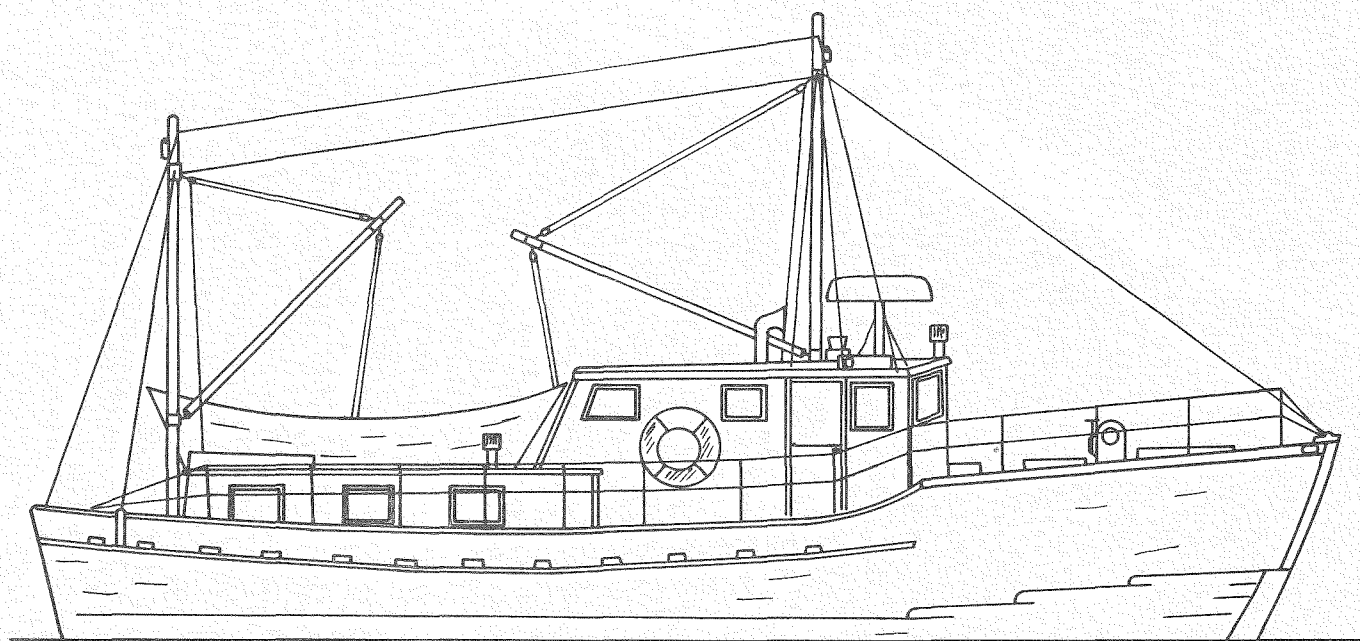


THE NAIN ANORTHOSITE PROJECT, LABRADOR: FIELD REPORT 1975

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THE NAIN ANORTHOSITE PROJECT, LABRADOR:

FIELD REPORT 1975

S. A. Morse, Editor

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"Evolution of anorthosite and related
crustal rocks in coastal Labrador."

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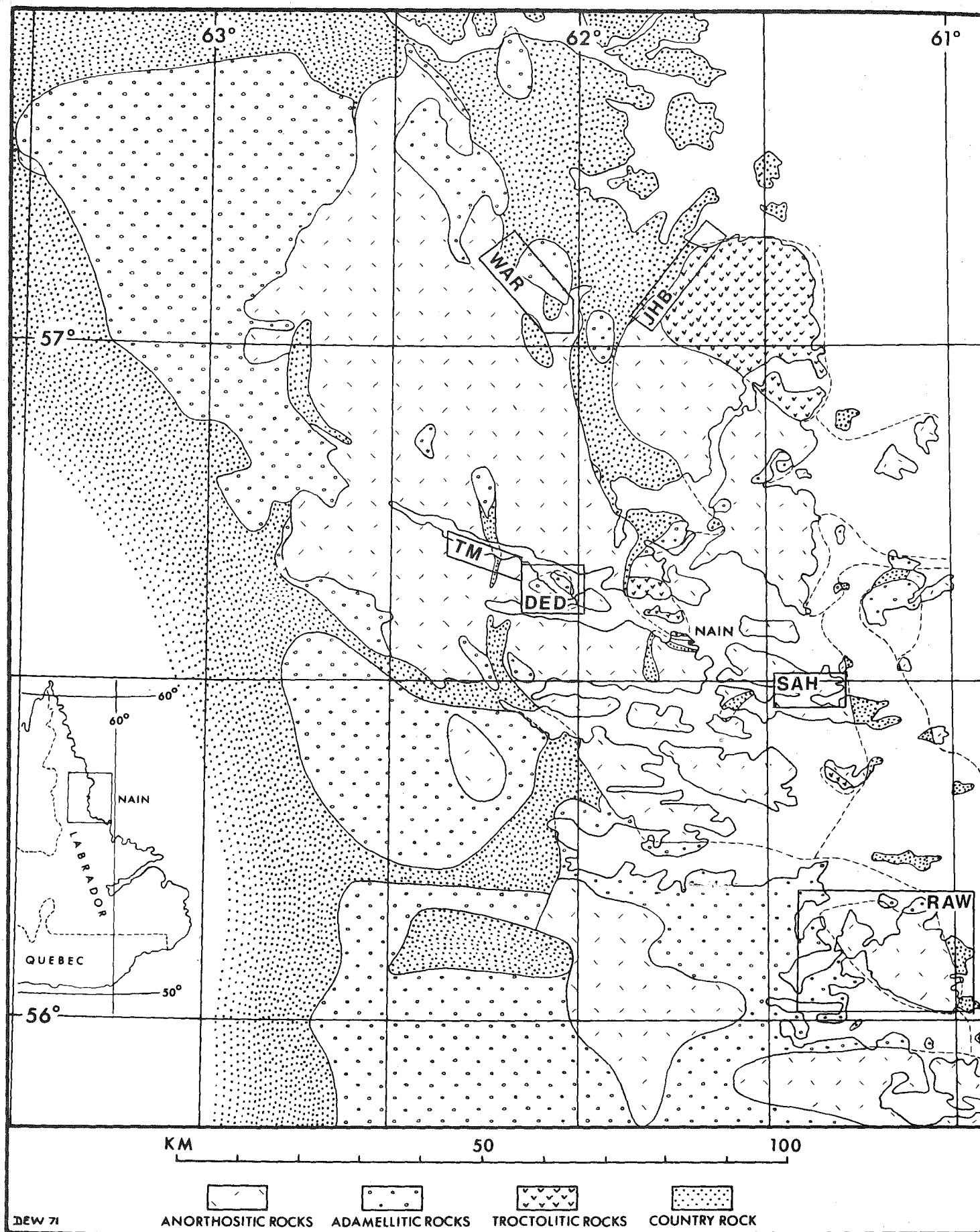


Fig. 1. Regional geology of the Nain area, after Wheeler (1968), showing locations of 1975 field areas. Key, north to south: JHB, Berg (Snyder Group); WAR, Ranson (Ighlokhsokhtalik-soakh Lake); TM, Morse (Tikkoatokhakh Bay); DED, Deuring (Akpaume Island); SAH, Hancock (Paul Island); RAW, Wiebe (Tunungayualuk Island).

THE NAIN ANORTHOSITE PROJECT, LABRADOR: FIELD REPORT 1975

INTRODUCTION AND REVIEW

The anorthosite problem is many things to many people. There is an unabated rash of current literature which purports to find solutions to the problem based on conventional mythology or novel insight. Within the mythology are to be found the concepts of great depth of anorthosite emplacement, hydrous parent magmas, and the dualism of andesine-type versus labradorite-type anorthosite. For comic relief, one of the truly novel insights includes the derivation of associated granites by partial melting of syenite.

The Nain Anorthosite Project, as we have often remarked, is dedicated to the proposition that it is not the lack of imaginative hypotheses so much as the lack of accurate data which limits our progress. We are of course not alone in this view, and among the more helpful of recent contributions are the concise review by Emslie (1975) and the multi-pronged attack on the age of the Laramie complex by Hills and Armstrong (1974) and Subbarayudu, Hills, and Zartman (1975). Recent work by our own group tends to dispel the myth of the hydrous parent magma and especially the myth of deep, granulite facies emplacement (Berg, 1975; Berg and Wheeler, 1976; Speer, FR 1974). A comment on the andesine/labradorite dualism is offered by Morse in this report.

All such advances depend first upon the careful perception of field relations, which are exposed to view in the Nain area as in few if any others. They also depend upon the variety of rock types exposed, which again is unusually great in the Nain area. And finally, they depend upon the scope and precision of analyses. In this regard, we are now fortunate in having at UMass one of the most modern and stable automated electron microprobes in existence. The centrally important analytical work of Berg, cited above, was begun on the instrument at M.I.T., and concluded with great success on our own instrument. A control program for very rapid grain-mount analyses of major mineral groups is now being brought on line, and this will match or exceed the speed of the dispersion method, with the added advantage of eliminating operator bias due to subjectivity, the chief cause of fatigue and uncertainty in the dispersion method. The new analytical

RAW

facility, obtained with the support of NSF, promises to increase greatly the scope and power of our efforts to define and eventually resolve the anorthosite problem.

Progress along other analytical lines continues to be moderately paced but important. The earlier isotopic and XRF work by J.M. Barton and R.W. Hurst has now culminated in simultaneous and independent reports of a 3.6 Gyr terrane in northern Labrador (see "Abstracts and Bibliography"). This terrane is apparently exceeded in antiquity only by the Godthaabsfjord region of Greenland and the Minnesota River Valley, U.S.A., among known ancient rocks. Isotope dilution studies of anorthosites and related rocks by Simmons (1976) furnish our first survey of Rare Earth Elements in the Nain complex. These studies provide important and as yet incompletely understood constraints on the parent magmas of the complex, but they offer no quick and easy solution to the anorthosite problem. Indeed, this group of elements offers a fertile field for detailed research in the Nain complex, and one that will require improved knowledge of plutonic partition coefficients as well as the careful kind of sampling and analytical control practiced by Simmons. A study long in progress by Haskin and Morse (e.g. 1969) should help in the choice of partition coefficients.

The regional geologic setting of the Nain complex continues to receive close attention. In this report, Berg describes with the help of large scale maps the new stratigraphy first reported by him in FR 1974* and now called the Upper Snyder Group. For the first time, an attempt is made to suggest a stratigraphic correlation with other known sequences of Aphebian age. The Piling Group of the Baffin Geosyncline is a possible correlative, and the limited thickness of the Snyder Group suggests that it is a distal edge of such a sequence, unmetamorphosed by the Hudsonian orogeny. Some unknown younger sequence (Croteau Group?) presumably covered the Snyder Group and effected its burial to about 13 km by the time the Kiglapait intrusion was emplaced. On the whole, the tectonic history of the northern Labrador coast prior to anorthosite emplacement is characterized by remarkable stability. Not only are the anorthosite rocks anorogenic, but they also occupy a terrane with a long history as a stable cratonic shield.

*"FR" refers to previous field reports of this series.

One of the distinctive features of anorthosites themselves is the widespread occurrence of "block structure", in which xenoliths, generally poor in mafic minerals, are contained in a matrix typically of leuconorite composition. Considerable attention has been paid to this feature in past reports of this series, chiefly by Runkle and Saunders (FR 1973) and Davies (FR 1974). Rarely, however, has it been possible to observe on a regional scale the relationship between the matrix rock and the source rock of the blocks. Wiebe has now been able to map such a relationship on Tunungayualuk Island. An older anorthosite unit occupies a central, elongate core of the map area, and has been engulfed by a leuconorite. These two units are everywhere separated by a large, mappable unit of megabreccia, which is composed of variable proportions of anorthosite blocks in a leuconorite matrix. The anorthosite unit is considerably deformed on a large scale, whereas the invading leuconorite shows much less deformation. Several lines of evidence suggest a close relation in age between the anorthosite and leuconorite, so that minor amounts of magma were still present in anorthosite during deformation. The occurrence of megabreccia in bands which are hundreds of meters wide may be helpful in visualizing the third dimension in areas of more restricted block structure. Wiebe also reports several large xenoliths of Archean country rocks in anorthosite, cut by anorthositic veins and dikes.

The age relations of dioritic rocks and adamellite were elucidated in last year's report by Wiebe, who found convincing evidence for the simultaneous presence of both magmas, with diorite commonly invading and chilling against adamellite. Further examples of this plutonic variety of pillow structure are described by him in this report. A thin zone of pillow diorite (diorite pillows in adamellite) occurs over a strike length of about 20 km where adamellite liquid was formerly in contact with anorthosite. The emplacement sequence is clearly: anorthosite, leuconorite, adamellite, diorite. Wiebe concludes that the diorite could represent the residual liquid of the anorthosite suite, expelled into marginal zones during the deformation produced by the emplacement of adamellite. Field evidence does not suggest a genetic relation of adamellite to any of the other rocks, and liquid immiscibility appears ruled out by the chilling of diorite against

adamellite. In this sequence, we have perhaps the most persuasive evidence yet known from the Nain area of the close temporal relation of adamellite and anorthosite. The apparent age difference suggested by the Rb-Sr isochron age of 1.42 Gyr for a granophyric segregation in anorthosite (Barton, FR 1973) and the zircon age of 1.29 Gyr for adamellite at Dog Island (Krogh and Davis, 1973) points up sharply the need for systematic isotope and age studies using the Tunungayualuk-Zoar area as a baseline. Wiebe's assignment of the adamellite in this area to crustal melting consequent upon the emplacement of anorthosite offers an attractive solution to the adamellite problem.

The megabreccia described by Wiebe is the ordinary kind of block structure encountered in the Nain complex, with leuconorite being the matrix. Ranson, however, reports local occurrence of the inverse relationship in the new Ighlokhsokhtaliksoakh Lake map area, where angular blocks of well layered leuconorite occur in anorthosite. Such relations serve once again to remind us of the multiple intrusive events displayed by the Nain complex, and demonstrate the dangers of becoming too enamored of generalizations. Ranson's work has also revealed what appears to be a major mylonite zone along a prominent linear, and an extensive region of pyroxene granulite in the Archean basement complex. The extent and age of this granulite is as yet unknown, but at the moment it appears too widespread to be explained as part of the contact aureole.

Iron-enriched monzonitic rocks are characteristic fractionation products of basaltic liquids such as the parent of the Kiglapait intrusion; they are also common as small, younger plutons cutting anorthosite, both in the Nain complex and elsewhere. Where these are found near country rock contacts, they can be difficult to interpret. Deuring describes in this report the Akpaume layered intrusion, which is a small stock completely enclosed by anorthosite, and presumably devoid of important contamination from the walls. A coarse, younger facies of this rock contains abundant zircon, as well as assemblages involving the minerals ferrohypersthene, fayalitic olivine, quartz, magnetite, K feldspar, and biotite. In addition, the presence of subcalcic ferroaugite (hypersolvus pyroxene) suggests high temperatures of crystallization. The opportunity for estimating T, P, f_{O_2} , and f_{H_2O} for this body appears excellent.

A troctolitic layered intrusion within the anorthosite of Paul Island emerges from new mapping by Hancock.

A summary of plagioclase compositions determined to date aboard ship is presented by Morse. The range encountered in anorthosites is now An_{83} to An_{38} , and a cumulative frequency diagram, when compared to the curve for the Kiglapait intrusion, indicates that a wide variety of magma batches were involved in the production of anorthosite in the Nain complex. The inferred plagioclase composition of these magmas ranges from at least An_{74} to An_{42} . It is concluded that the proposed distinction between andesine-type and labradorite-type anorthosites is not a fruitful one, and that basaltic and andesitic parents cannot be distinguished on the basis of plagioclase composition.

-- S.A. Morse

REGIONAL GEOLOGY

APHEBIAN METASEDIMENTARY AND RELATED ROCKS
IN THE SNYDER BAY - AVAKUTAKH RIVER AREA, LABRADOR

J. H. Berg

University of Massachusetts¹Introduction

Last year a newly discovered stratigraphic sequence of rocks overlying the known Snyder Group rocks was described (Berg, FR 1974). This description and the stratigraphic column (Fig. 8, FR 1974) were based primarily on detailed mapping in the immediate vicinity of Snyder Bay. This year detailed mapping was extended to the southernmost extent of these rocks near the Avakutakh River (see Fig. 2).

The mapping of these rocks is made difficult by the abundance of basic granulites in the area. Many of these basic granulites are obviously of igneous origin (FR 1974), but some of them can be traced along strike into cordierite-bearing pyroxene granulites. Thus it is often impossible to determine whether an outcrop is igneous or meta-sedimentary; if judged igneous, it is normally impossible to determine whether the basic granulite is metavolcanic and therefore part of the stratigraphy or a sill and therefore not part of the original stratigraphy. Certainly some of the basic granulites appear to be sills (Berg, FR 1974), and this creates yet another obstacle. Not only do these sills spread apart the original stratigraphy, but locally they also stope parts of it.

¹ Authors' full addresses are given at the back of this volume.

Snyder Group

While mapping near the Avakutakh River, all five formations of the known Snyder Group (Speer, in preparation) were located in a well-exposed area. All of these units have been traced northward, where outcrop permits, to the point where Speer (in preparation) shows all but the lower quartzite disappearing to the south. The upper quartzite appears to be missing locally, and either was not deposited or has been removed by erosion or stoping. Outcrops of the graphite-sulfide hornfels unit and especially of the quartzite-marble are sparse, but it can be demonstrated in the field that these formations typically occupy topographic lows which are devoid of outcrops and which are parallel to the strike of exposed Snyder Group rocks. Locally, all of the units above the lower quartzite become so heavily intruded with sills of basic granulite that the Snyder Group rocks appear almost as xenoliths. Nevertheless, the stratigraphic order seems always maintained, and therefore only thickening or dilation of the stratigraphy has occurred.

General Description of Stratigraphy Near The Avakutakh River

Continuous exposure, such as along Falls Brook near the coast, cannot be found in the southern areas, and a stratigraphic column is more difficult to construct. A qualitative stratigraphic column is presented for the southern areas (Fig. 3) which is less rigorous than the one described for the Snyder Bay area (FR 1974). Within the lower quartzite a large sill, previously mapped by Speer (FR 1972), consists of a gabbro porphyry. Although some pyroxene is present, the rock consists mainly of a fine- to medium-grained amphibole and plagioclase groundmass which is choked with large black megacrysts or phenocrysts of plagioclase, many of which appear fragmented.

Although small sills of basic granulite occur locally throughout the Snyder Group, several large sills are very extensive. These sills occur between the lower quartzite and silicate iron formation, between the quartzite-marble and graphite-sulfide hornfels, and between the graphite-sulfide hornfels and the upper quartzite. The sill between the

MAP LEGEND

META-SEDIMENTARY UNITS

PYROXENE PARAGRANULITE



CALC-SILICATE UNIT



BANDED IRONSTONE



UPPER QUARTZITE



GRAPHITE-SULFIDE HORNFELS



QUARTZITE-MARBLE



SILICATE IRON FORMATION



LOWER QUARTZITE



IGNEOUS UNITS

KOGHUKULLUK DIABASE DIKE



AGMATITE



KIGLAPAIT INTRUSION



LEUCOTROCTOLITE



ANORTHOSITE-LEUCONORITE



MELATROCTOLITE



GABBRO PORPHYRY



BASIC ORTHOGRANULITE



ARCHEAN GNEISSES



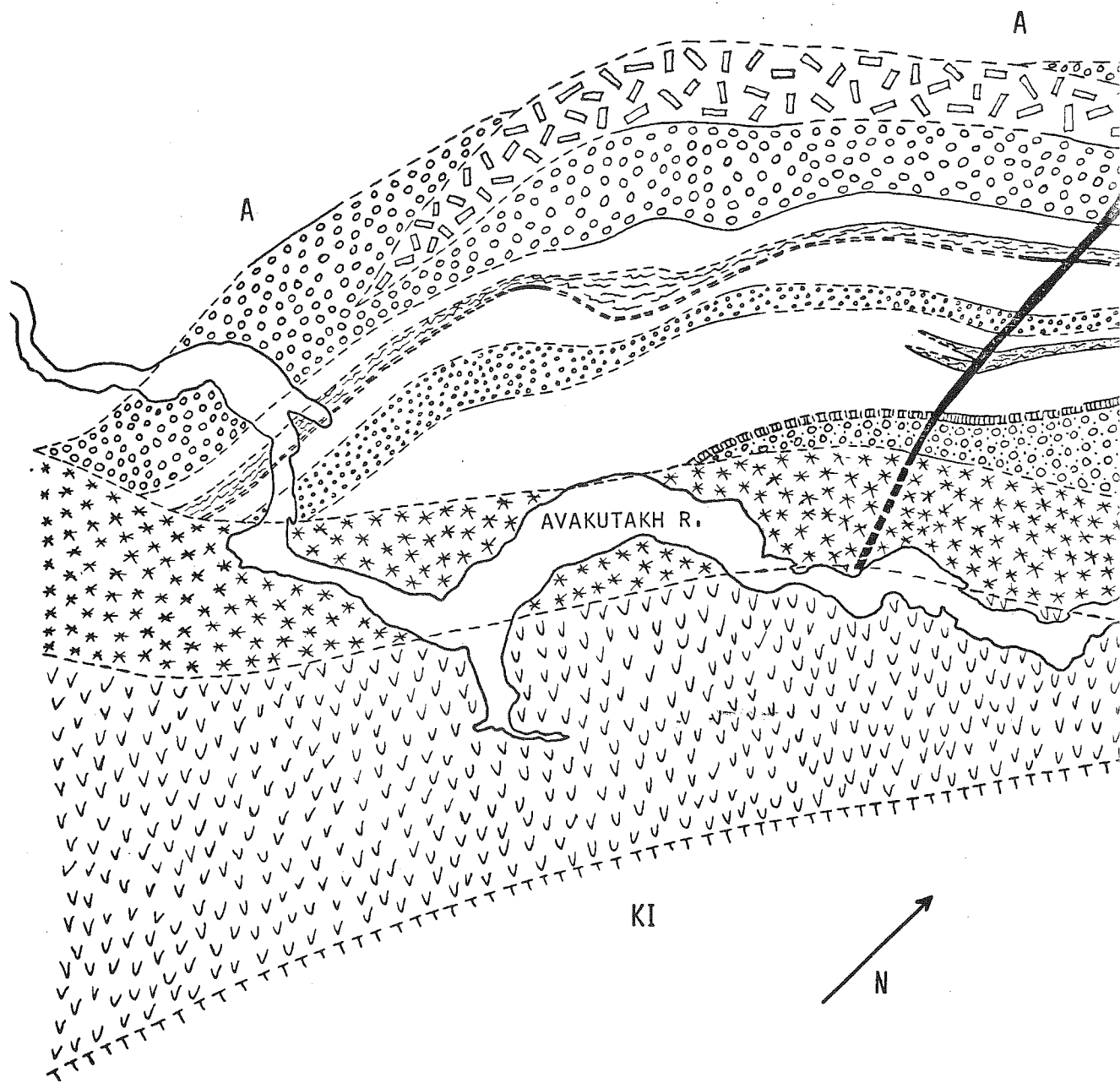
FAULT



Fig. 2. Geologic map of the Snyder Bay - Avakutakh River area. Sheets A through F progress from southwest to northeast. The bases used for A-C and D-F were enlargements of air photos LAB-43-180 and LAB-59-048, respectively. Index map on page 13 shows approximate distribution of Lower Snyder Group (SG) and Upper Snyder Group (stippled).

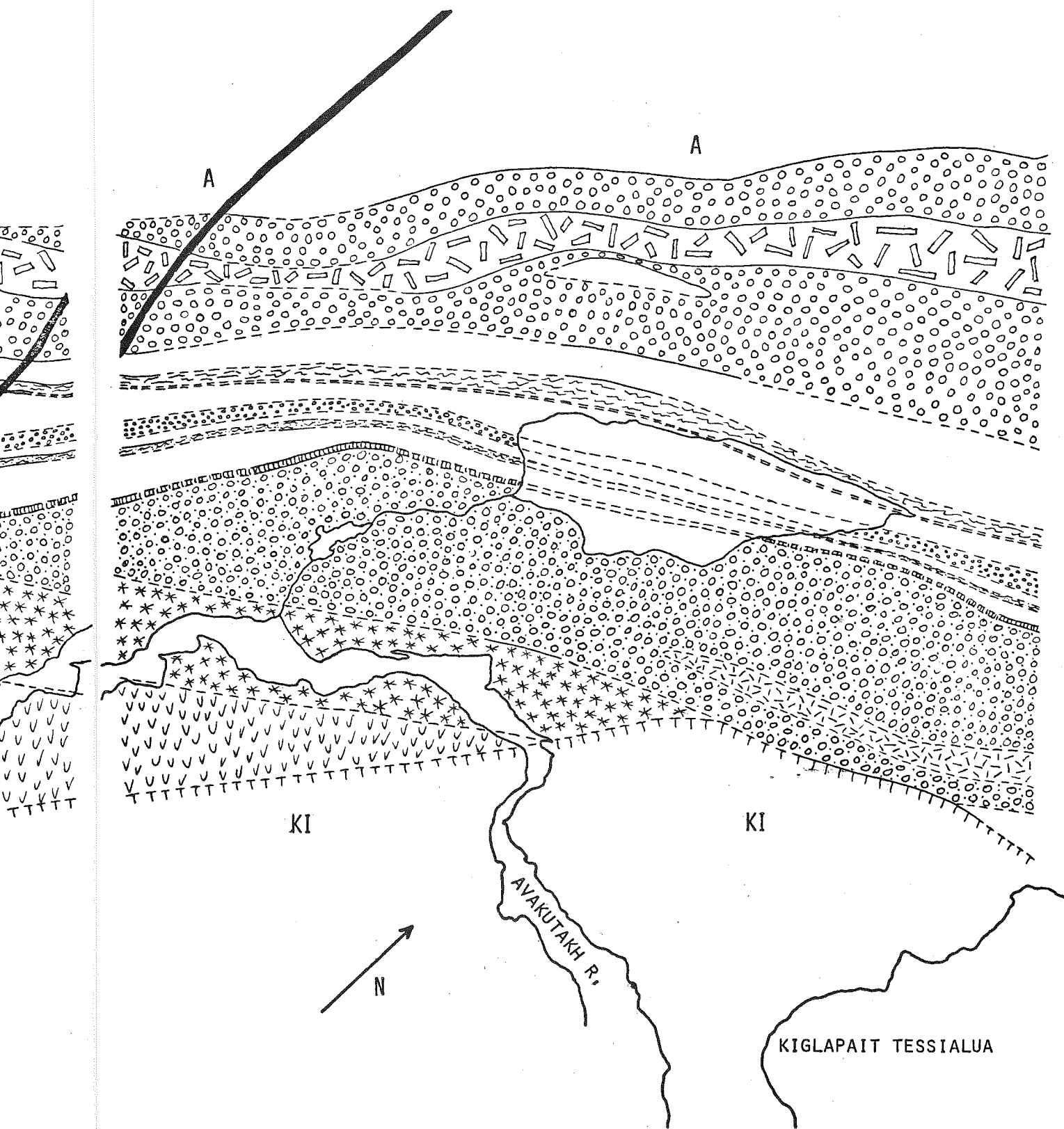
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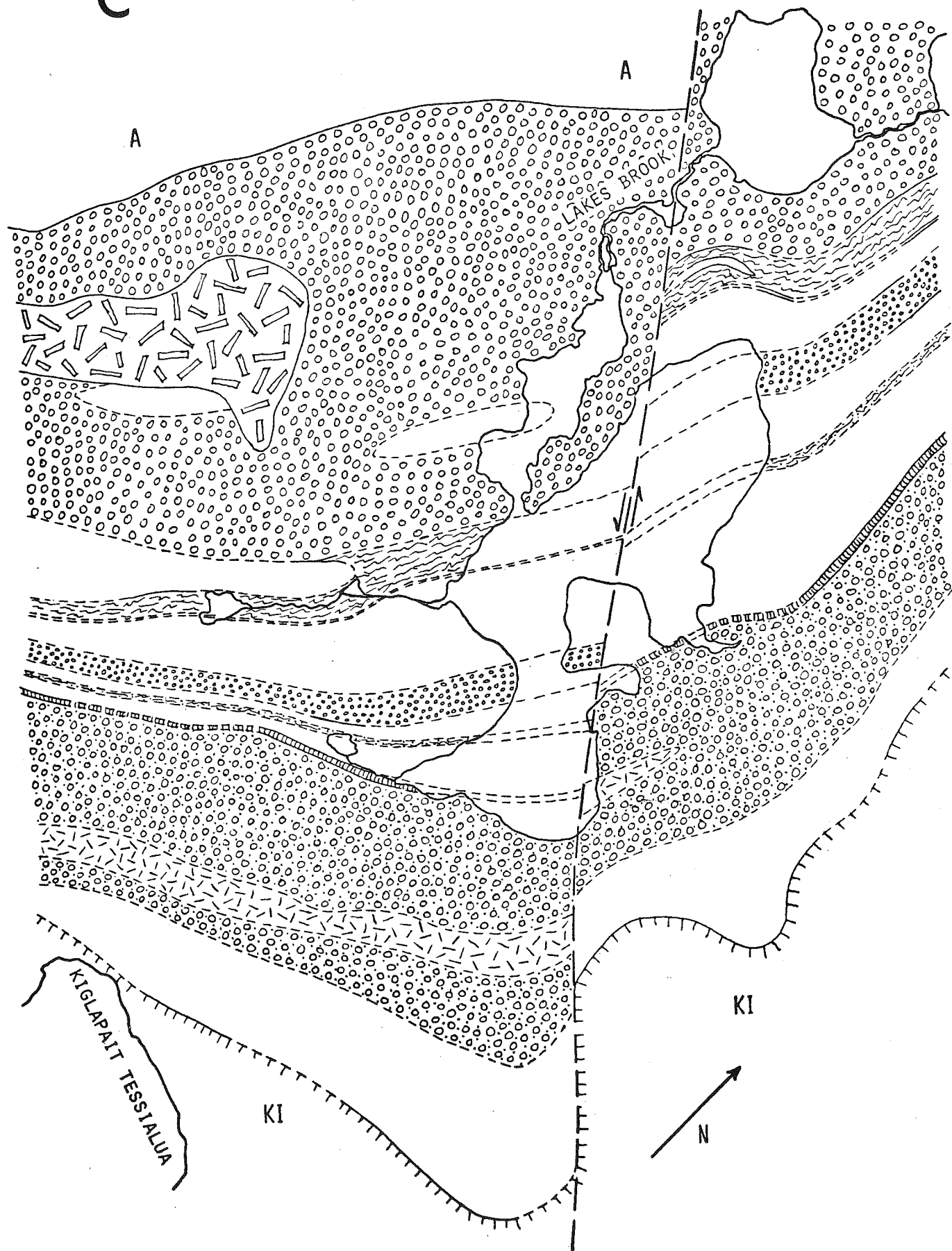
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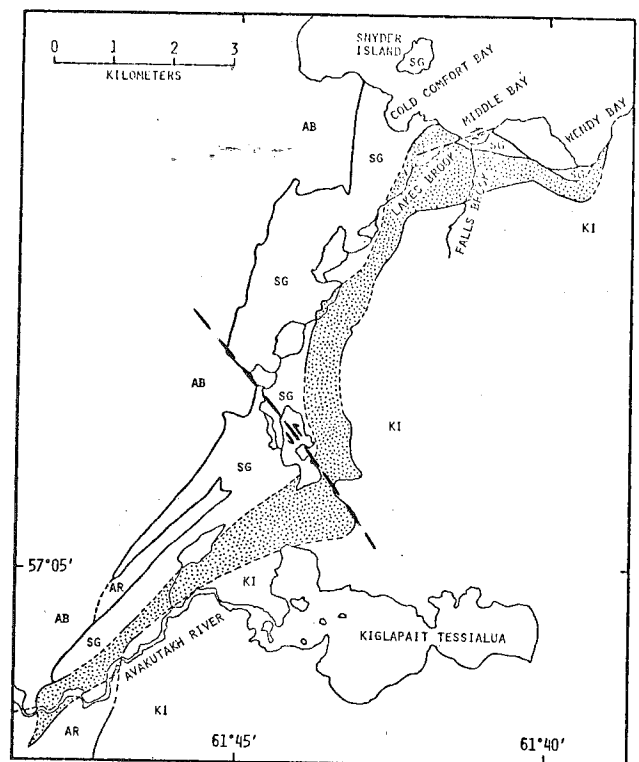
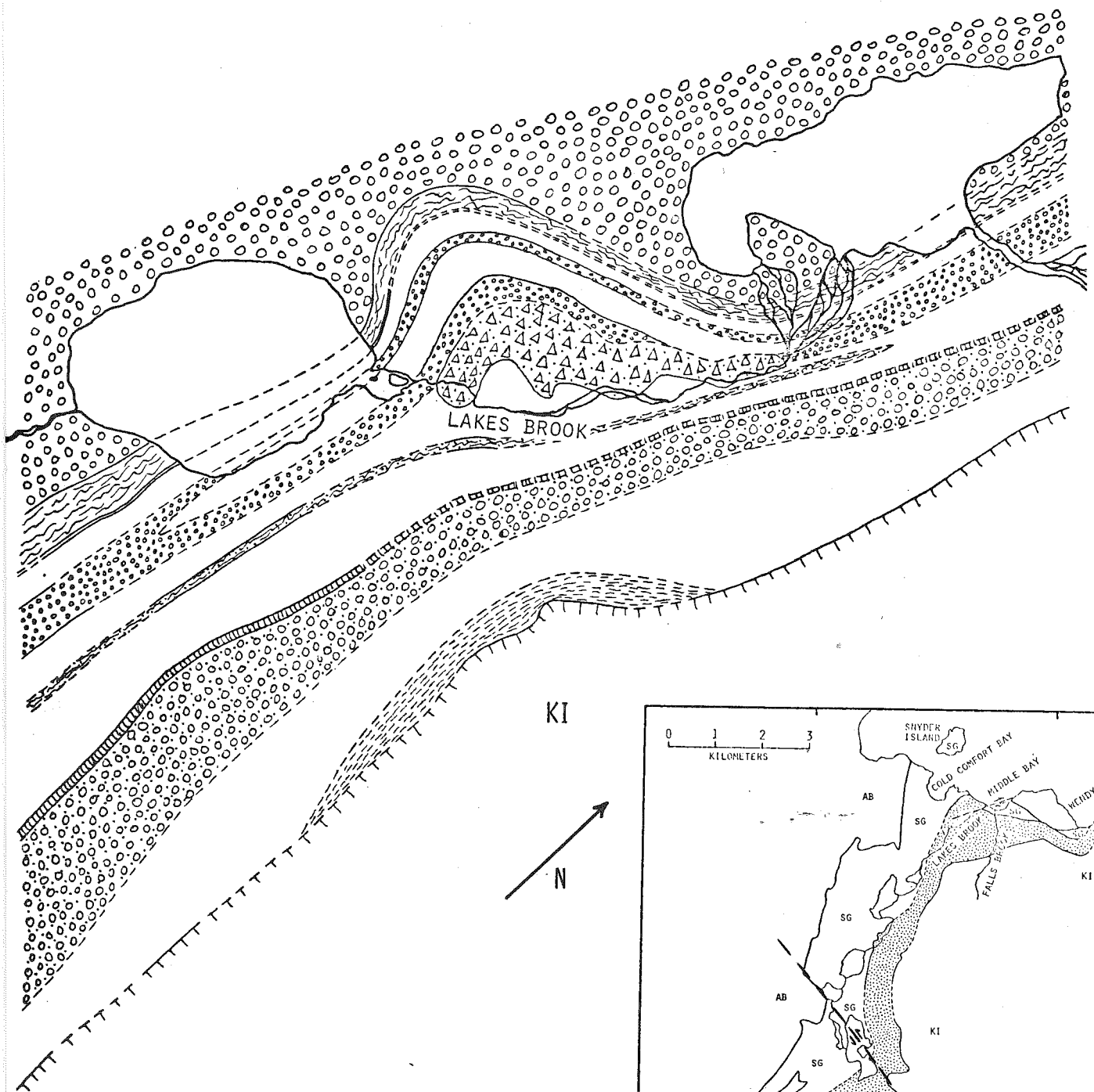


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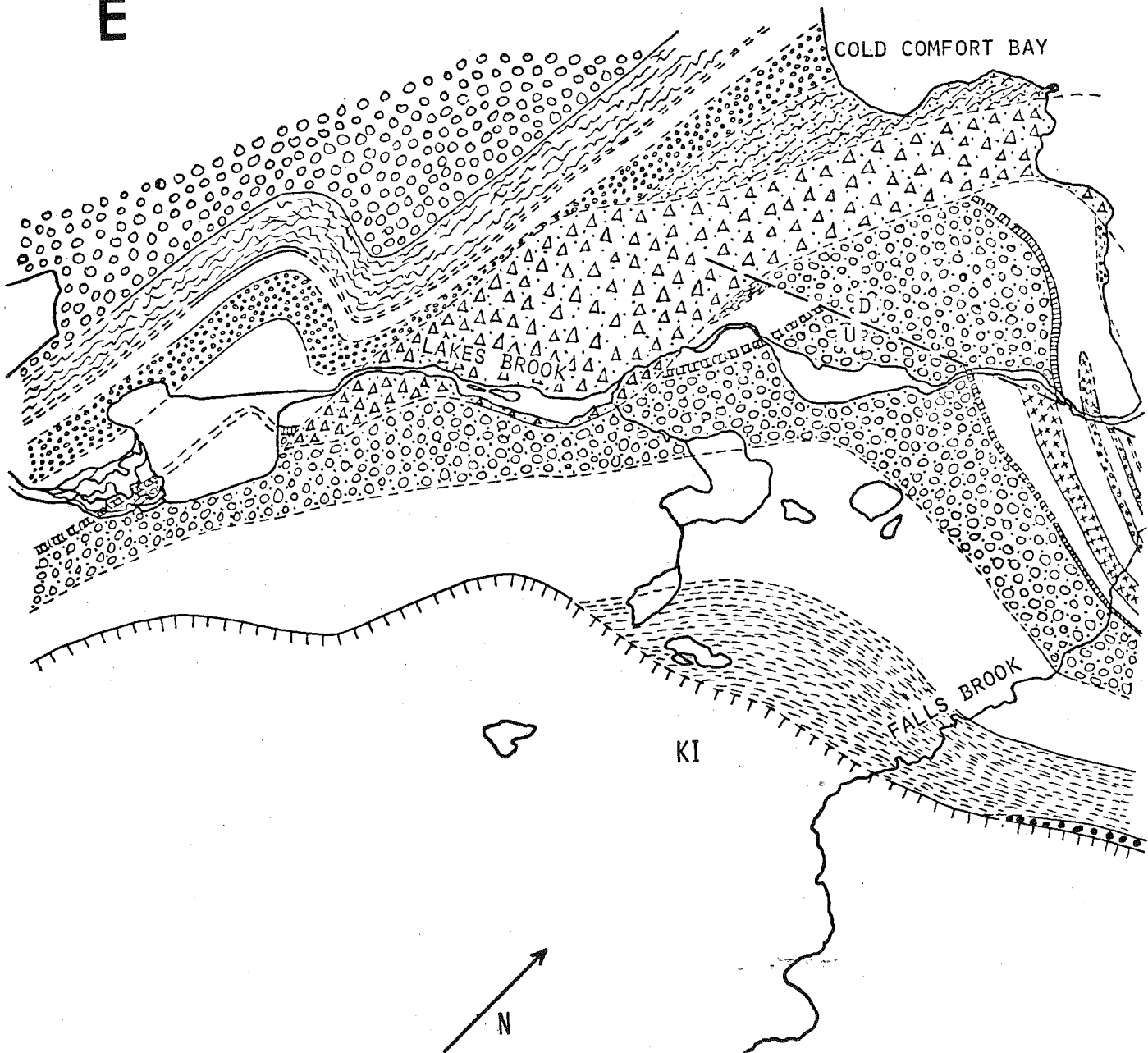


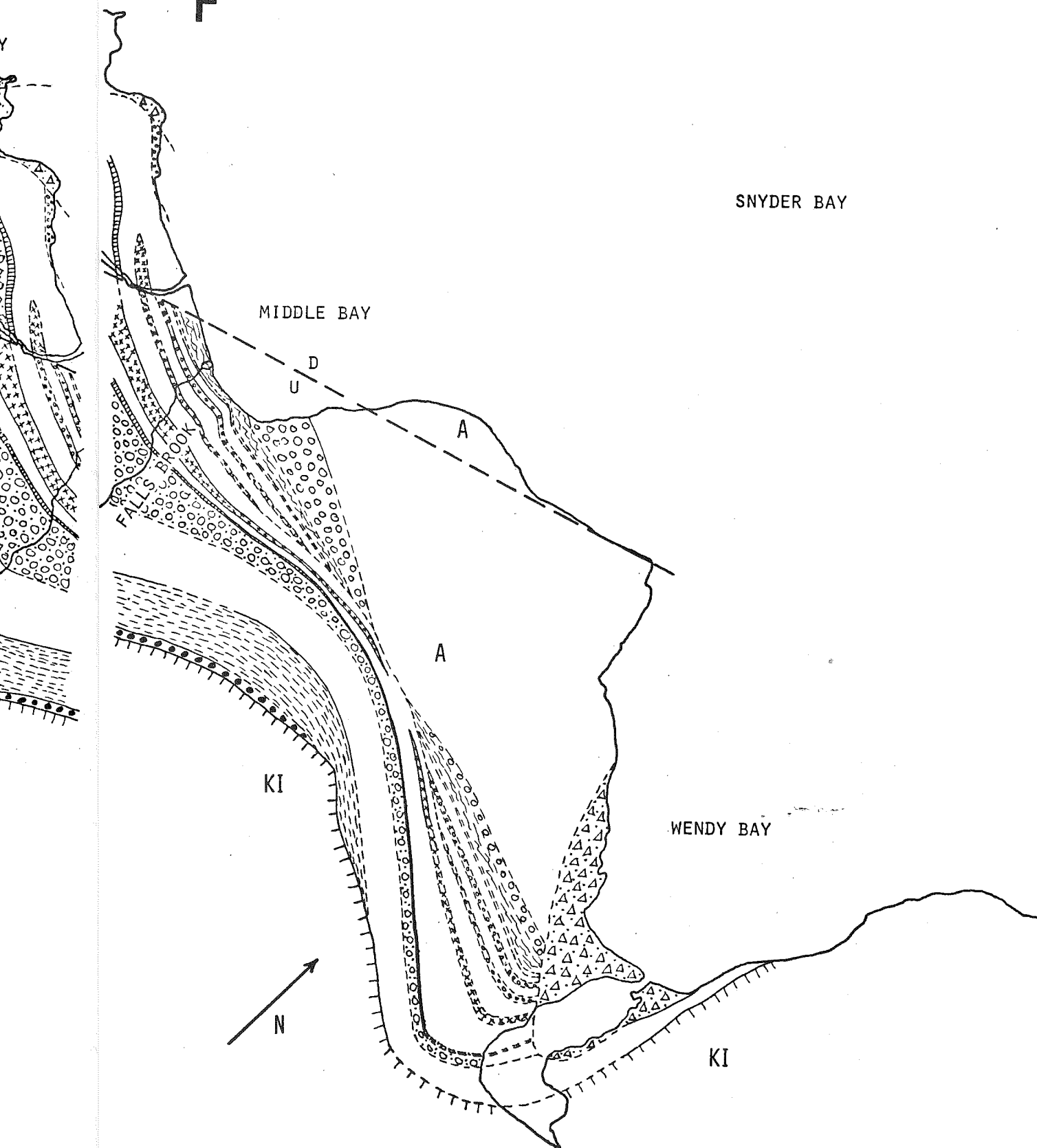
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Index Map

E





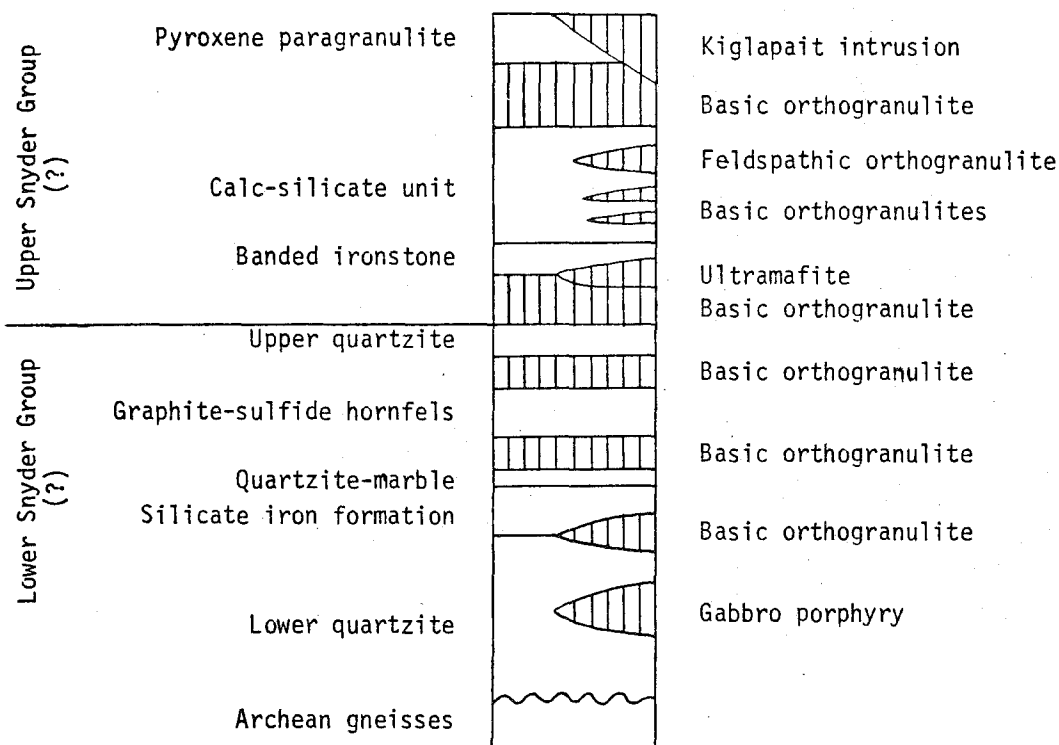


Fig. 3. Stratigraphic column for rocks in the Snyder Bay - Avakutakh River area.

Table 1. Stratigraphy of the Piling Group, Baffin Island, and approximate correlation with the Snyder Group.

| Piling Group | |
|-------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (Jackson, 1969; Jackson and Taylor, 1972) | |
| Upper Snyder Group(?) | Metagraywacke, meta-siltstone, meta-shale; quartzite, marble in upper part; meta-basalt, serpentine, marble, iron formation, rusty paragneiss in lower part. |
| Lower Snyder Group(?) | Rusty graphitic sulfide-bearing meta-chert, and quartz-mica paragneiss, iron formation. Marble, calc-silicates. Quartzite, meta-arkose. |

lower quartzite and silicate iron formation is absent north of the drainage divide between Snyder Bay and the Avakutakh River, whereas the other two sills appear to be present everywhere except in the immediate vicinity of Snyder Bay.

Multiple sills of basic granulite occur between the upper quartzite and the banded ironstone described last year (Berg, FR 1974). Locally, below the banded ironstone and intervening basic granulite, there occurs an ultramafic body (sill?) similar to the spinel peridotite described last year (Berg, FR 1974). Above the main part of the banded ironstone, numerous thin lenses and layers of ironstone occur in feldspathic and pyroxene granulite, much of which may be paragrulite.

These rocks grade upward into a unit which is of mixed sedimentary origin and includes: pyroxene paragrulites, black amphibolites, metapelites, calc-silicate rocks, marbles, and local sills(?) of basic granulite. The unit is dominated by the calc-silicate rocks and amphibolites. The amphibolites, for the most part, appear to be intimately associated with and related to carbonates or calc-silicates, and may have originated by some decarbonation mechanism. Occurring in the top part of this unit and the base of the next are numerous sills(?), some of which are mappable, of a leucocratic granitoid granulite. This rock type intrudes the basic granulite sills, but bears the same metamorphic mineral foliation as the other granulites.

The succeeding unit consists predominantly of basic granulites. These basic granulites typically contain brown hornblende, clinopyroxene, orthopyroxene, plagioclase, olivine, Fe-Ti oxides, and apatite. Locally, amphibolites similar to those associated with calc-silicate rocks occur. The uppermost unit, which is only locally preserved adjacent to the Kiglapait intrusion, is a pyroxene paragrulite. Cordierite is present in varying amounts in this unit.

Faulting

Further evidence for the left-lateral fault shown by Speer (FR 1974) has resulted from this summer's mapping. Fig. 2c shows that the silicate iron formation and quartzite-marble units of the Snyder Group terminate

abruptly, with the next outcrops along strike consisting of lower quartzite. The continuous outcropping of banded ironstone to the north sets a northern limit for the extension of the fault. Also, Fig. 2C shows that the contact of the Kiglapait intrusion makes a sharp change in trend along a line parallel to the fault. Shearing and granulation of the marginal rocks of the intrusion are locally abundant along this part of the contact and give the rocks a gneissic appearance. While faulting in plutonic rocks is inherently difficult to demonstrate, it appears conceivable that this fault could have postdated or been contemporaneous with the emplacement of the Kiglapait intrusion.

Nomenclature

Because of the possibility of local stoping by the ubiquitous sills of basic granulite and because the silicate iron formation, quartzite-marble, graphite-sulfide hornfels, and upper quartzite are much more extensive than previously thought (Speer, FR 1972), the existence of an unconformity above the upper quartzite (Berg, FR 1974) becomes very difficult to prove. If it does exist, it cannot be nearly as extensive as previously postulated (Berg, FR 1974). Present mapping indicates that if any stratigraphy has actually been removed by erosion, only the upper quartzite could have been so removed.

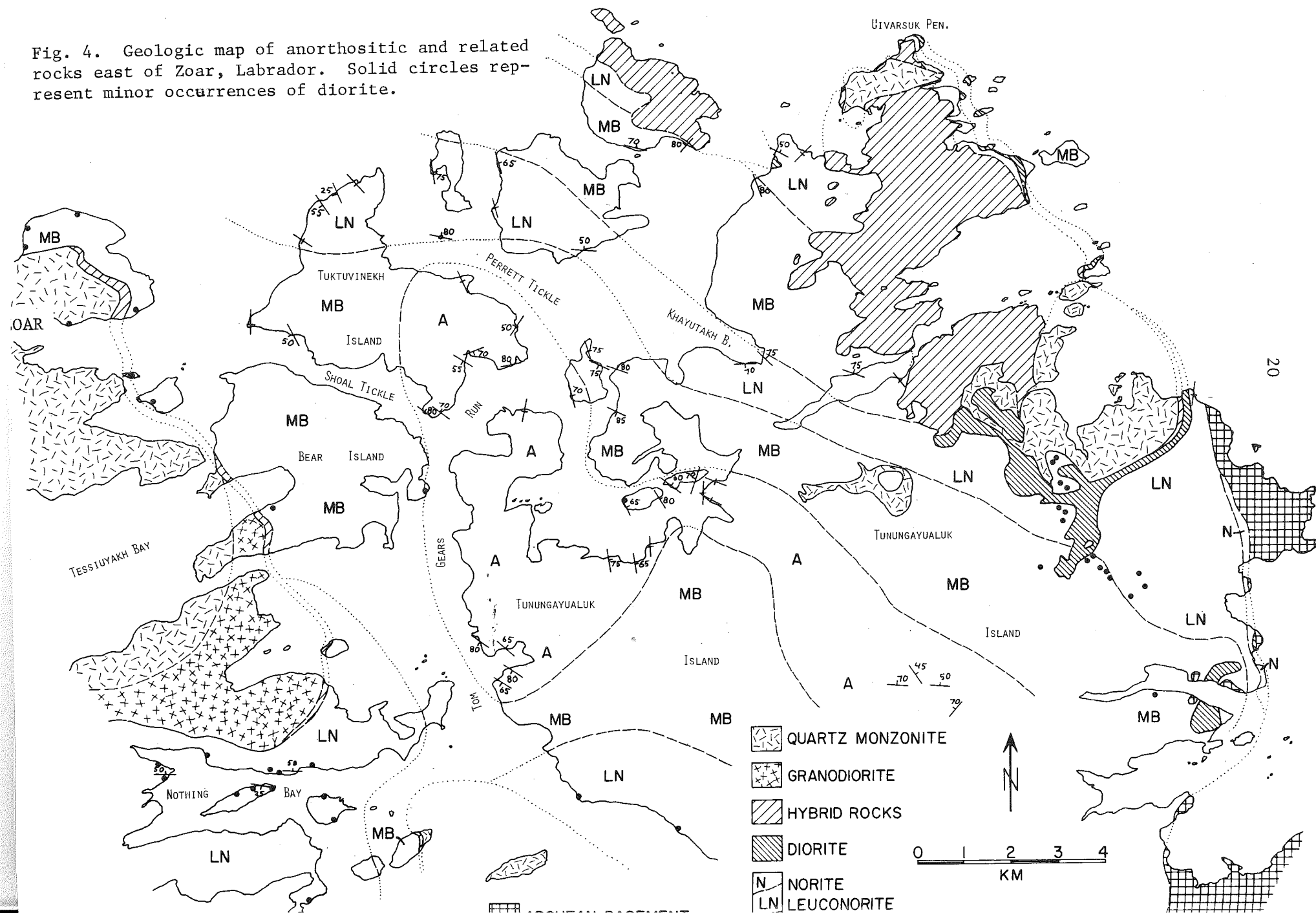
The diminution of this possible unconformity raises the question of the status of the metasedimentary sequence above the presently defined Snyder Group. Does it deserve separate status as a group, or should it be included as part of an expanded Snyder Group stratigraphy? The limited occurrence and intimate association of these two rock sequences argue strongly for a single group name. Thus it is proposed that the five previously defined units (Speer, FR 1972) be known as the Lower Snyder Group and that everything above the upper quartzite (or graphite-sulfide hornfels, if the upper quartzite is missing) be known as the Upper Snyder Group. The essential units of the Upper Snyder Group, while less easily defined or mapped than those of the proposed Lower Snyder Group, would inclu

(1) banded ironstone, (2) calc-silicate unit (including amphibolites, calc-silicate rocks and marbles, pyroxene paragonulites, metapelites, and biotite schists), (3) basic orthogranulite, and (4) pyroxene paragonulite.

Correlation

The stratigraphic sequence of this expanded Snyder Group is remarkably similar to other middle to late Aphebian sequences associated with the Labrador and Baffin geosynclines, especially the miogeosynclinal Piling Group (Jackson, 1969; Jackson and Taylor, 1972). Table 1 lists the stratigraphy of the Piling Group for comparison with the Snyder Group. This comparison suggests that if the correlation is valid the Snyder Group must represent the distal portion of a miogeosynclinal sedimentary wedge. This is because the thickness of the Snyder Group is about an order of magnitude less than that of the Piling Group. This would also suggest that the Labrador and Baffin geosynclines were associated with extensive seas which may well have covered all of present-day Labrador. Because the limits of Hudsonian metamorphism do not extend as far east as Snyder Bay, it would appear that the Snyder Group is the only preserved late Aphebian sequence which was unaffected by Hudsonian deformation and metamorphism. It is also interesting to note that if the Snyder Group represents a thinner but complete Aphebian sequence, then post-Aphebian strata amounting to ~12 km in thickness are needed to account for burial of the Snyder Group to a depth of about 12-13 km before emplacement of the Kiglapait intrusion (Speer, FR 1974). The closest known strata of this age and thickness are those of the Croteau Group (and Seal Lake Group?) of central Labrador (e.g., Baragar, 1974). For tectonic models of Labrador, it is at least worth considering that correlatives of the Croteau (and Seal Lake?) rocks may have extended as far north as the Snyder Bay region of Labrador, prior to or during emplacement of the Elsonian plutons (anorthosite-adamellite).

Fig. 4. Geologic map of anorthositic and related rocks east of Zoar, Labrador. Solid circles represent minor occurrences of diorite.



NAIN COMPLEX

ANORTHOSITIC INTRUSION ON AND NEAR TUNUNGAYUALUK ISLAND, LABRADOR

Robert A. Wiebe

Franklin and Marshall College¹

Introduction

A body of anorthositic rocks, approximately 300 square kilometers in area, is located on and in the vicinity of Tunungayualuk Island. Mapping was begun in 1974 (Wiebe, FR 1974) and continued during the past summer.

Although the anorthositic rocks are extremely variable in texture, it has been possible to map three main units. These units are internally heterogeneous but bear consistent structural relations to each other.

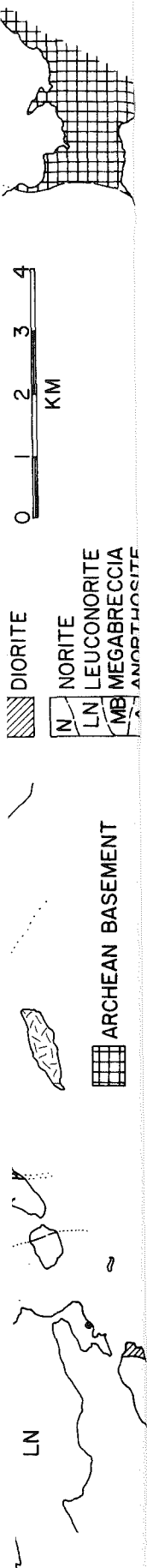
External contacts of this anorthositic intrusion were observed on the west, north, and east sides. The eastern margin is bounded by Archean basement. The intrusive relations of anorthosite are well displayed in many outcrops along the eastern side of Tunungayualuk Island. Elsewhere, the anorthositic rocks are bounded by large bodies of younger adamellite.

Units

The anorthositic rocks have been divided into three major units: anorthosite, megabreccia, and leuconorite (Fig. 4). In addition, small bodies of diorite occur widely in the anorthositic terrane - particularly near the eastern margin. Where adamellite has invaded this diorite, significant areas of hybrid rocks have formed (Wiebe, FR 1974).

The distribution of the three main units is complex. A central area of anorthosite trends roughly NW-SE and is surrounded by megabreccia. Megabreccia and leuconorite alternate in relatively thin bands which have roughly NW-SE trends. Diorite occurs mostly within areas of leuconorite. Adamellite dikes occur sparsely in all units of the anorthosite terrane.

¹Authors' full addresses are given at the back of this volume.



Anorthosite

Most rocks within this unit have $CI < 15$ and lack any trace of quartz or K-feldspar. Rocks consist essentially of plagioclase, inverted pigeonite and minor oxides. Most outcrops lack visible layering, and textural variation appears to be irregular and gradational. Common varieties include: 1) massive 2-cm anorthosite with $CI < 5$, 2) similar 2-cm anorthosite with varying proportions and sizes of oval patches of poikilitic pyroxene, 3) seriate anorthosite with plagioclase ranging from 2 to 20 cm in length. Adcumulus crystallization appears to have been important judging from lack of zoning and low content of mafics. Some areas display well developed steeply dipping layering defined by textural and modal variation. A strong lamination is generally present parallel to the layering.

This unit is cut by dikes of leuconorite, norite and pegmatitic norite with granophyric patches. Uncommonly, anorthositic rocks also contain blocks of older anorthosite.

Field and petrographic data suggest that this unit has undergone considerable deformation - probably while in a plastic state. In thin section, plagioclase is variably bent and recrystallized. Interstitial pyroxene is generally much less affected. The attitudes of layering suggest large scale deformation. The strike of layering and lamination in this unit is consistent for distances of only about 1 km. Dip is generally greater than 60° and is variable in direction.

No stratigraphic section was established for this unit. No layers were traced for distances greater than a few hundred meters. Evidence for top determinations is extremely scarce and ambiguous. The apparent deformation of this unit makes any stratigraphic determination even more difficult.

Leuconorite

The area mapped as leuconorite consists of anorthositic rocks with color index mostly between 15 and 25. After plagioclase, poikilitic orthopyroxene (inverted pigeonite) is the most important phase. Plagioclase

exhibits prominent iridescence in many areas of the leuconorite. Poikilitic ilmenite and magnetite are common, and interstitial to poikilitic quartz occurs widely. Interstitial K-feldspar is scarce. Apatite is a prominent accessory phase. These rocks are quite varied texturally; a common type has plagioclase ranging in size from 2 to 20 cm with subophitic pyroxene. Layering and lamination occur locally. Within this unit, some dikes and gradational zones of pegmatitic norite have prominent granophyre, quartz, K-feldspar, magnetite and hornblende. Elongate zircons are a prominent accessory phase in some dikes. In thin section, leuconorite shows considerably less evidence of deformation than does anorthosite.

Megabreccia

This unit is essentially a transition zone between the anorthosite and leuconorite units. It contains rocks typical of both units in roughly equal amounts. Contacts of this unit are approximate and are intended to delimit the area in which both anorthosite blocks and leuconorite matrix represent 1/3 or more of the area. Anorthosite occurs mainly as angular blocks in a matrix of leuconorite, though in some zones blocks are rounded. Blocks in this unit are unsorted and range in diameter from a few centimeters to several tens of meters. This unit appears to be similar to areas of block structure described by Davies (FR 1975, 1974) and Runkle and Saunders (FR 1973) except for its generally higher content of blocks.

There is some evidence that the anorthositic blocks are closely related to the leuconorite matrix. In several localities scattered plagioclase megacrysts within the matrix have sizes and habits essentially identical to those of closely packed plagioclase within the anorthosite inclusions. In one locality leuconorite cross-cuts layering in a large anorthosite inclusion and appears to grade continuously to one of the more mafic layers in the inclusion.

Diorite

Dark weathering Fe-rich diorites with color index between 20 and 50 occur in scattered locations, generally within the leuconorite unit. Most of the diorite occurs in the Goodnews intrusive complex (Wiebe, FR 1974).

Typical homogeneous diorite consists of plagioclase, Fe-rich pyroxenes, oxides and apatite. A few percent interstitial quartz and K-feldspar are usually present. Where these rocks are associated with granitic rocks, hornblende and biotite are abundant and pyroxenes reduced in amount.

Both sharp and gradational contacts with leuconorite exist. Some diorite occurs in the form of sharply cross-cutting, gently dipping dikes with prominent gravitative layering. Graded bedding and channel scours are common features. "Dropstones" of anorthosite disturb the layering.

A small body near the southeast contact of the anorthositic rocks with the Archean basement has prominent layering and lamination which define a gently dipping trough. The basal layers texturally resemble leuconorite and grade upward to typical medium-grained diorite. Abundant rounded inclusions of leuconorite occur near the base of this small diorite body. Prominent and numerous irregular veins of diorite define an anastomosing network in the adjacent and underlying leuconorite.

Hybrid Rocks and Adamellites

Adamellite and a hybrid mixture of diorite and adamellite are the major constituents in the Goodnews complex, which is located in the north-eastern portion of the anorthositic body. These rocks have been previously described (Wiebe, FR 1974). Hybrid rocks also occur in a narrow zone along the western contacts of anorthositic rocks with adamellite. Homogeneous adamellite occurs as sharply cross-cutting, gently-dipping dikes throughout the anorthosite terrane.

Archean Basement

Archean basement occurs along the north and east sides of the intrusion. The northern outcrops have been briefly described (Wiebe, FR 1974). The eastern area of Archean basement was mapped during the last summer. These rocks are dominantly monotonous quartzo-feldspathic gneisses with subordinate layers of mafic granulite. No pelitic layers were recognized.

Intrusive Contact of Anorthosite

The eastern margin of the anorthosite displays intrusive relations with the adjacent Archean basement. Based on topographic expression and exposures in several sea cliffs, the contact appears to be essentially vertical.

Homogeneous norite and leuconorite are dominant along the contact. Anorthositic rocks along the northernmost exposed contact are homogeneous seriate leuconorite. Steep rough alignment of plagioclase approximately parallels the mapped contact. Layering appears to be absent.

Along the southern half of the contact, norite and leuconorite are still dominant rock types within 100 meters of the contact but some areas are notably heterogeneous. One exposure contains leuconorite with minor areas of oxide-rich norite, pegmatitic norite, norite with prominent randomly oriented tabular plagioclase, and dikes of diorite.

In general, inclusions of Archean basement are very scarce within the anorthosites. Striking exceptions are the two or three large inclusions which occur within 1 km of the contact about midway down the mapped contact (Fig. 4), near the diorite intrusion. These consist dominantly of mafic granulite. They appear to have influenced the position and shape of the layered diorite body that occurs between them. These mafic granulite inclusions are clearly cut by anorthositic veins and dikes ranging in width from nearly one meter to a few cm. The veins are dominantly medium-grained leuconorite with a color index of about 15. In some veins interstitial quartz is apparent and in the thinner veins average grain size decreases to as little as 1 mm. Plagioclase is strongly zoned.

Structure

Attitudes of layering and lamination are plotted on Fig. 4. These structures are most apparent in the anorthosite unit. With the exception of steep structures along the eastern margin, they appear to have a normal gravitative cumulus origin. Strike and dip are locally consistent for

over a distance of 1 km, and in these areas it appears possible to establish a stratigraphic section. However, such coherent areas are isolated from each other by distances of at least a few km. In most areas strike and dip present no consistent pattern, and, here, determination of a stratigraphic section would be difficult. The zone of megabreccia commonly truncates trends of layering and lamination in the anorthositic unit. Since the matrix of the megabreccia grades to leuconorite, it is apparent that layering within the leuconorite unit formed after partial deformation and brecciation of the anorthosite unit.

Discussion

Consistent relations between the three major units are displayed throughout this anorthositic intrusion. Older anorthosite has been invaded by younger leuconorite, producing an extensive and widely occurring zone of megabreccia and extensive areas of homogeneous leuconorite adjacent to the megabreccia. The occurrence of leuconorite throughout the intrusion suggests that it is not simply a younger unrelated injection of magma. The anorthosite unit may have been an adcumulus portion of a large layered intrusion; the leuconorites may represent coexisting liquid and orthocumulus portions.

The anorthosite unit shows more evidence of deformation than does the leuconorite unit. The irregular pattern of layering indicates that deformation was not related to a homogeneous penetrative tectonic event. The major cause of deformation was most probably due to relative movement of adcumulates, orthocumulates and liquids within the developing anorthositic intrusion. The original spatial relations of such adcumulus, orthocumulus and liquid portions is not clear. Emplacement of younger adamellite plutons may have effected some local deformation - particularly deformation of the leuconorites.

CONTACT ZONE BETWEEN ADAMELLITE AND ANORTHOSITE AND THE
OCCURRENCE OF DIORITIC ROCKS NEAR ZOAR, LABRADOR

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Franklin and Marshall College¹

Introduction

A major goal of the past summer's field work was to establish the contact relations between anorthosite and adamellite and to clarify the importance and role of rocks of intermediate compositions (here termed diorites) along the contact zones. A contact between adamellite and anorthosite was mapped for a distance of approximately 20 km. in the vicinity of Zoar (Fig. 5). Superb coastal exposures allowed detailed study of several sections of the contact zone. A zone of heterogeneous intermediate rocks occurs along most of the contact and is approximately 100 to 200 meters wide.

Adamellite

Adamellitic rocks occur in two separate plutons which extend beyond the map area (Fig. 5). The total area of adamellite mapped is about 80 km². The small southeastern pluton of adamellite and the main core of the large adamellite pluton consist of medium-grained biotite quartz monzonite with a color index less than 10. K-feldspar appears consistently more abundant than plagioclase, and prominent equant quartz (up to 5 mm in diameter) makes up about 30-40% of most rocks. This facies of the adamellite is exceptionally homogeneous and massive.

Portions of the larger pluton are mapped as granodiorite. These rocks are somewhat poorer in quartz and K-feldspar and have hornblende in addition to biotite. They generally weather to a buff color. Color index rarely exceeds 10 percent. Coarse equant quartz is still present, but most quartz is interstitial. The granodioritic rocks also appear to lack any layering

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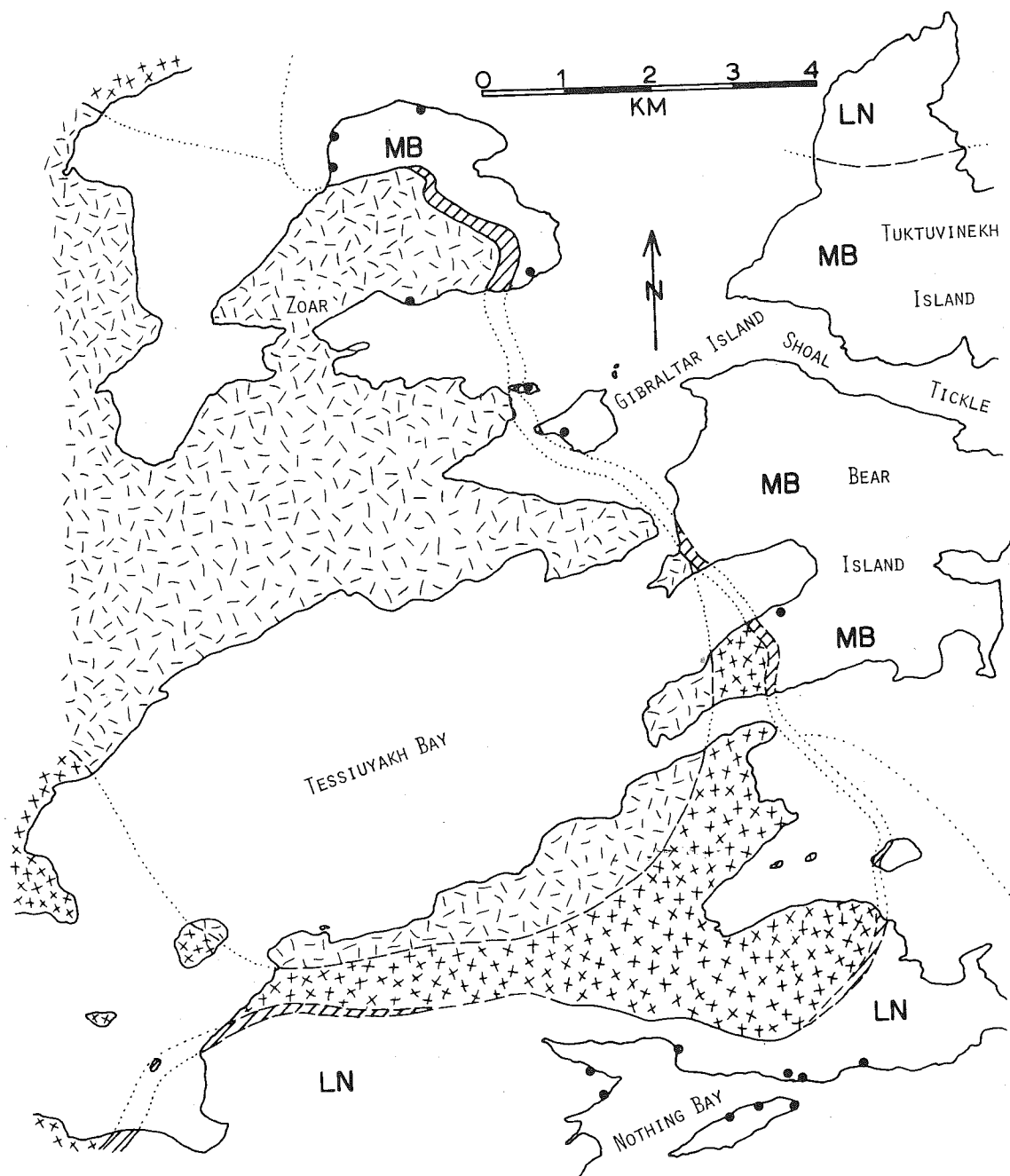


Fig. 5. Geologic map of the contact zone between anorthositic and granitic rocks. The contact zone consists of a mixture of granitic and ferrodioritic rocks. Diorite pillows are prominent within a hybrid matrix. See Fig. 4 for explanation of symbols.

or preferred orientation of minerals. In at least one location there is a sharp contact between the two facies of the adamellite. The granodiorite facies appears to lie near the contact of adamellite and anorthosite, but it is not always present along the contact. Regardless which facies is in contact with the anorthosite, there does not appear to be any significant compositional gradation within a facies toward the contact zone. Both adamellite and granodiorite occur as minor components in the heterogeneous contact zone.

Anorthositic Rocks

Following Streckeisen's (1973) classification, major rock types within the anorthosite complex range in composition from anorthosite through leuconorite to norite. Probably over 90 percent of the rocks have a color index less than 25. Three units having gradational contacts with each other have been mapped: anorthosite, megabreccia, and leuconorite. In terms of cross cutting relations, the anorthosite unit contains the oldest rocks. These rocks are dominantly anorthosite (CI<15) with highly variable texture and locally well developed steep layering and lamination. Some compositional layers are leuconorites. Strike of layering is locally consistent, but dip direction and steepness of dip are generally variable, suggesting the possibility of folds in layers. Tops of layers were not noted and no folds were observed. Minor leuconorite and pegmatitic norite veins cut these rocks.

The anorthosite unit grades to a broad zone of block-structure (megabreccia) in which the older anorthosite occurs as rotated angular blocks, representing between about 1/3 and 2/3 of the volume, in a matrix of leuconorite. This unit of megabreccia in turn grades to a unit of homogeneous leuconorites with a color index generally between 15 and 25. Blocks of older anorthosite occur sparsely throughout most of the leuconorite unit. Layering and lamination are locally developed; subordinate rocks with color index less than 10 occur in this unit and grade to the dominant leuconorite.

Diorite

Diorite and related intermediate rocks are volumetrically very minor constituents of the Zoar region. Medium-grained diorite and monzodiorite occur as small bodies within the anorthositic terrane (dominantly within the leuconorite unit) and locally appear to be gradational to leuconorite. Several small bodies are located in Fig. 5. The main occurrence of diorite is in the contact zone between adamellitic and anorthositic rocks. Here it is texturally and compositionally heterogeneous. Fine-grained chilled pillows of diorite are characteristically present in a matrix of heterogeneous medium-grained intermediate rock grading from diorite to granodiorite.

The Contact Zone

The contact zone has an average width of about 150 meters and has been mapped for a distance of about 20 km. The dip of the contact zone varies along its length. On the basis of topographic expression and one approximate measurement, the long NNW-trending segment of contact along the large adamellite body appears to dip about 30° to 50° to the southwest. On the basis of topographic expression the east-west segment of contact along the south side of the same pluton appears to be nearly vertical. The contact zone of intermediate rocks is relatively wide along the NNW segment and apparently absent along part of the E-W segment.

The contact zone is dominated by rocks of dioritic composition, some of which resemble the diorite which occurs as small bodies deep within the anorthositic terrane. All segments of the contact zone which have been directly observed contain prominent fine-grained chilled pillows of diorite in a heterogeneous matrix. In some areas most pillows are less than 1 meter in diameter while in others similar diorite with chilled margins occurs in bodies over 20 meters in diameter. Some of these bodies carry abundant tabular phenocrysts of dark plagioclase up to 2 cm in length. Some zones have widely scattered pillows ranging in size from a few cm to a few meters and having a wide range in textures suggestive of variable

amounts of assimilation. Within different pillows, coarse poikilitic hornblende can be seen in all stages of development. Fine-grained chilled pillows lacking any poikilitic hornblende may occur next to hornblende-rich pillows.

In zones where pillows are closely packed, they are generally texturally identical (save for internal core-rim variation), and many of these pillows have shapes which suggest they were molded against adjacent pillows while in a fluid state.

Within some of the heterogeneous medium-grained matrix of the pillows, coarse equant quartz like that in adamellite is very sparsely scattered and generally is surrounded by a rind of mafic silicates. Color index of the matrix ranges from about 15 to 40. Dark color in plagioclase is uncommon but locally prominent.

Anorthosite inclusions are abundant and range in diameter from a few centimeters to several meters. Most have sharp angular contacts, but several larger anorthosite inclusions have rounded and crenulate contacts suggestive of a plastic condition.

Although inclusions of basement rock are very scarce within the adamellite and anorthosite terranes, such inclusions are generally present within the contact zone. Most are between 2 cm and 1 meter in diameter. Quartzofeldspathic inclusions are the largest and most obvious; small pelitic inclusions are abundant in some areas.

In two locations, equant bodies (about 5 meters in diameter) of quartz-rich quartz monzonite (identical to the main phase of the adamellite bodies) occur within the heterogeneous dioritic matrix. These inclusions demonstrate that at least part of the contact zone was still liquid after some adamellite had solidified. Further verification of this age relationship is found in two dioritic dikes which cut adamellite within 200 meters of the contact zone.

Emplacement of Adamellite

The shapes of the adamellite plutons are smoothly curved and mostly convex outward. They do not appear to have been significantly controlled by fractures or faults within the anorthosite. Dikes of similar adamellite do occur within the anorthosite, but are very scarce and were never seen to cut through the contact zone. Inclusions of anorthosite appear to be absent in the adamellite bodies. Their absence could mean that stopping was

not an important mechanism or possibly that anorthosite inclusions have sunk below the present level of exposure.

Field relations provide some evidence that the adamellite plutons may have been emplaced by shouldering aside partly unconsolidated anorthosite. The strike trends of layering within the anorthosite and leuconorite conform very broadly to the external shape of the larger adamellite pluton. This configuration may reflect the shouldering aside of weakly layered anorthositic rocks. The irregularity of dips may have been enhanced during the emplacement of the adamellite.

Discussion

Within the leuconorite, local gradations from leuconorite to diorite are common. By way of contrast, diorite and adamellite lack gradations to each other except in the contact zone where gradations are clearly hybrid in origin. Field evidence strongly suggests that these diorites cannot be related to adamellite by fractional crystallization. The strongly chilled contacts of diorite pillows against adamellite appear to rule out a relation of liquid immiscibility. If the diorite is not genetically related to the adamellite suite then it must either be related to the anorthositic rocks or have an origin independent of either suite. The pattern of occurrence and relative volume of diorite strongly suggest that the diorite is a residual liquid from the anorthositic suite.

Field relations in and near the contact zone indicate unequivocally that adamellite and diorite coexisted as separate liquids and that at least some of the diorite solidified after the adamellite. If diorite represents a residual liquid from the anorthositic terrane, it is then clear that adamellite was emplaced into anorthositic rocks which were incompletely crystallized.

This timing of the adamellite emplacement provides a ready explanation for the occurrence of the thin dioritic contact zone and the complex relations displayed within it. I believe that the following sequence most completely explains all of the features observed.

1) Adamellite magma rises upward into anorthositic rocks containing at least a few percent residual liquid.

2) As it rises upward through the somewhat plastic anorthosite, it causes deformation, disturbs original layering and effects some filter pressing of residual liquid. (Most of the anorthositic rocks show petrographic evidence of such a high-temperature deformation).

3) The residual liquid (diorite) migrates into the contact zone where it is initially chilled and forms pillows.

4) Some mutual contamination of adamellite and diorite occurs, resulting in a heterogeneous matrix. The somewhat more hydrous adamellite magma provides water for the development of poikilitic hornblende in the diorite pillows and hybrid matrix. The amount of amphibole in different pillows reflects the variable timing and conditions of hybrid diorite.

In summary, the field relations strongly suggest that anorthositic and dioritic rocks are related by fractional crystallization. Adamellitic rocks appear to represent a separate and relatively low temperature melt, probably of crustal origin. A likely source of heat for the production of this granitic magma is the voluminous anorthosite with which it is associated.

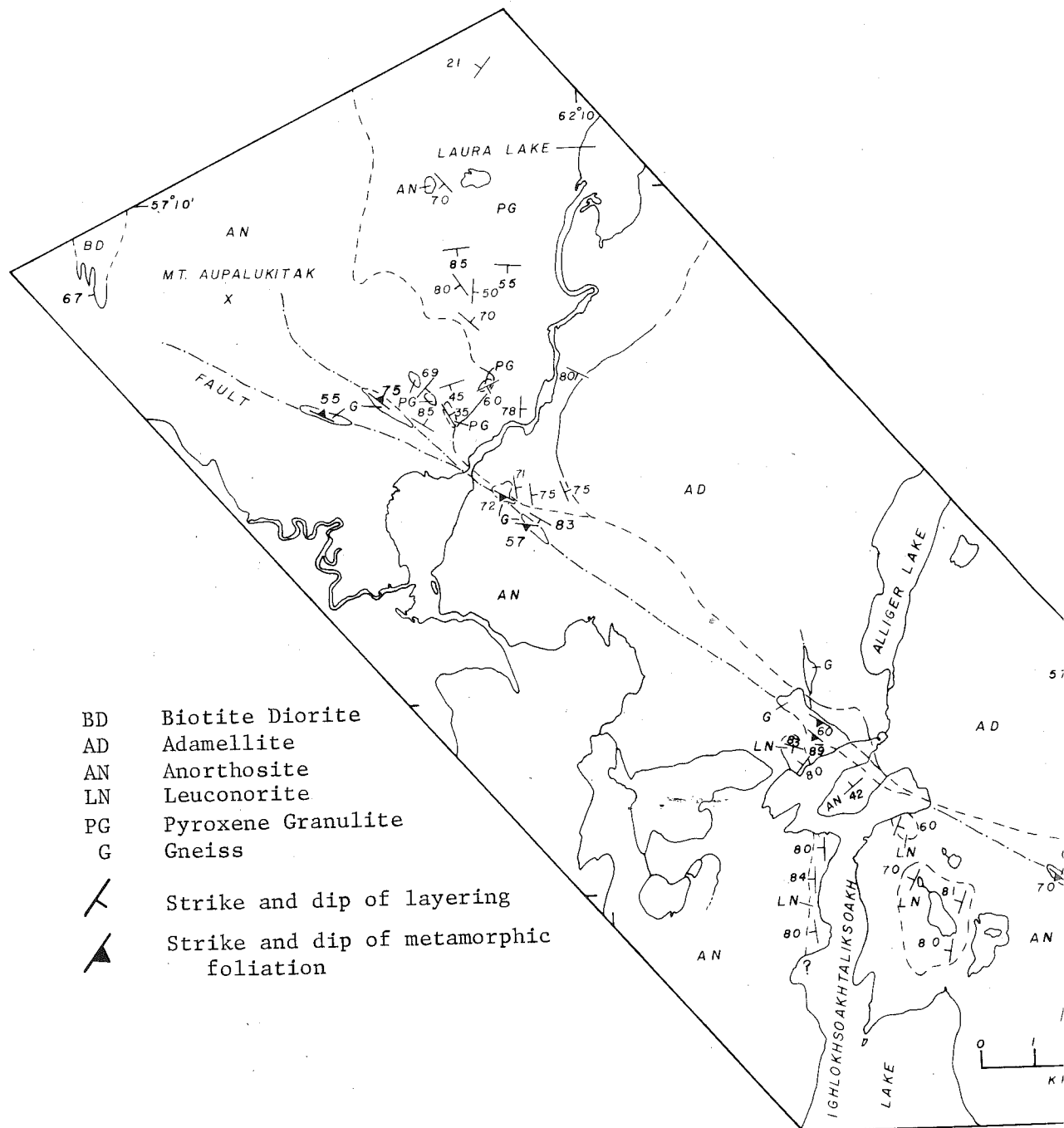


Fig. 6. Geologic map of the Ighlokhsokhtaliksoakh Lake area.

Geology of the Ighlokhsokhtaliksoakh Lake Area

William A. Ranson

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The area of study is located approximately 30 km west of the Kiglapait Mountains and 70 km north northwest of Nain in the Nain Complex, Labrador (Fig. 1). The region is underlain by anorthositic rocks, adamellite, and basement complex which consists chiefly of Archean pyroxene granulite. In addition two unexpected rock types were discovered. The first is a blue-gray gneiss which occurs along a major zone of faulting and shearing. The gneiss, which locally has poorly developed augen structures, is believed to be a wedge of basement rock and is closely associated with mylonite. The second is a body of medium-grained pyroxene-biotite diorite which was encountered at the close of the field season. The body unquestionably intrudes the anorthosite, but its extent is not yet known.

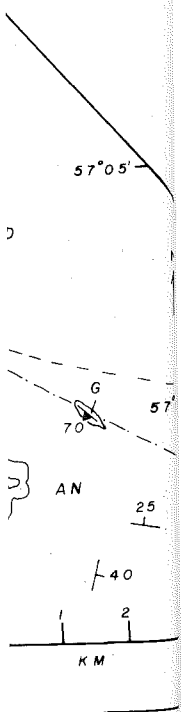
The contact relations of the above rocks are of great interest but on the whole are rather poorly exposed. The geologic map presented in Fig. 6 shows the known extent of the rock units.

Basement Rocks

The predominant rock type of the Archean basement is a relatively little-deformed pyroxene granulite. This dark-gray to brownish granulite is best exposed in the northern part of the area along the banks of the large river which flows into Laura Lake (Fig. 6). The most striking characteristic of the rock is its layering. Dark and light layers result from concentration of pyroxene and plagioclase, respectively. Although generally well developed, the layering may be very subtle or even non-existent at some outcrops. The strike of the layering is predominantly N-S with steep easterly dips, but variations in strike as large as 90°

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were noted. Broad, gentle warping of the layers was observed commonly.

The pyroxene granulites contain mainly fine-grained (0.5-1 mm), equigranular plagioclase (An_{45-55}) and pyroxene with minor biotite and quartz. Quartz accompanies plagioclase in the leucocratic layers and locally it is a major constituent of the rock. Green hornblende is also present in minor amounts and the predominant pyroxene is hypersthene, although some augite was noted in preliminary oil immersion studies.

Near the central part of the area on the northern shore of Ighlokhsoakhtaliksoakh (Iglusuataliksuak) Lake the exposed Archean basement consists of a well-foliated, blue-gray augen gneiss, which is associated with a fine-grained gray mylonite. This patch of basement, which is mapped in greater detail in Fig. 7, occurs along a zone of faulting and shearing. The major constituents of the gneiss are fine-grained (0.5-1 mm) plagioclase, quartz, biotite, and hornblende. Quartzofeldspathic layers containing poorly developed augen structures alternate with mafic layers which consist primarily of hornblende. The well-developed foliation strikes consistently to the NW with moderate to steep SW dips. The gneiss is associated with a fine-grained, dark-gray mylonite, which contains narrow (<0.5 mm) bands of light colored minerals. The fine grain size precludes accurate identification of the mineralogy, but it is presumed to be similar to that of the gneiss.

Anorthositic Rocks

The two types of anorthositic rocks encountered, anorthosite and leuconorite, can be distinguished on the basis of mafic mineral content, grain size, and less importantly by the presence or absence of layering. The anorthosite is equivalent to Wheeler's pale anorthosite. Wheeler (1960) describes the pale anorthosite as containing pale-gray plagioclase, and hypersthene rather than olivine as the mafic phase. In the area of study the proportion of orthopyroxene ranges from zero to approximately 10 percent. Also characteristic of the anorthosite is the coarse grain size of

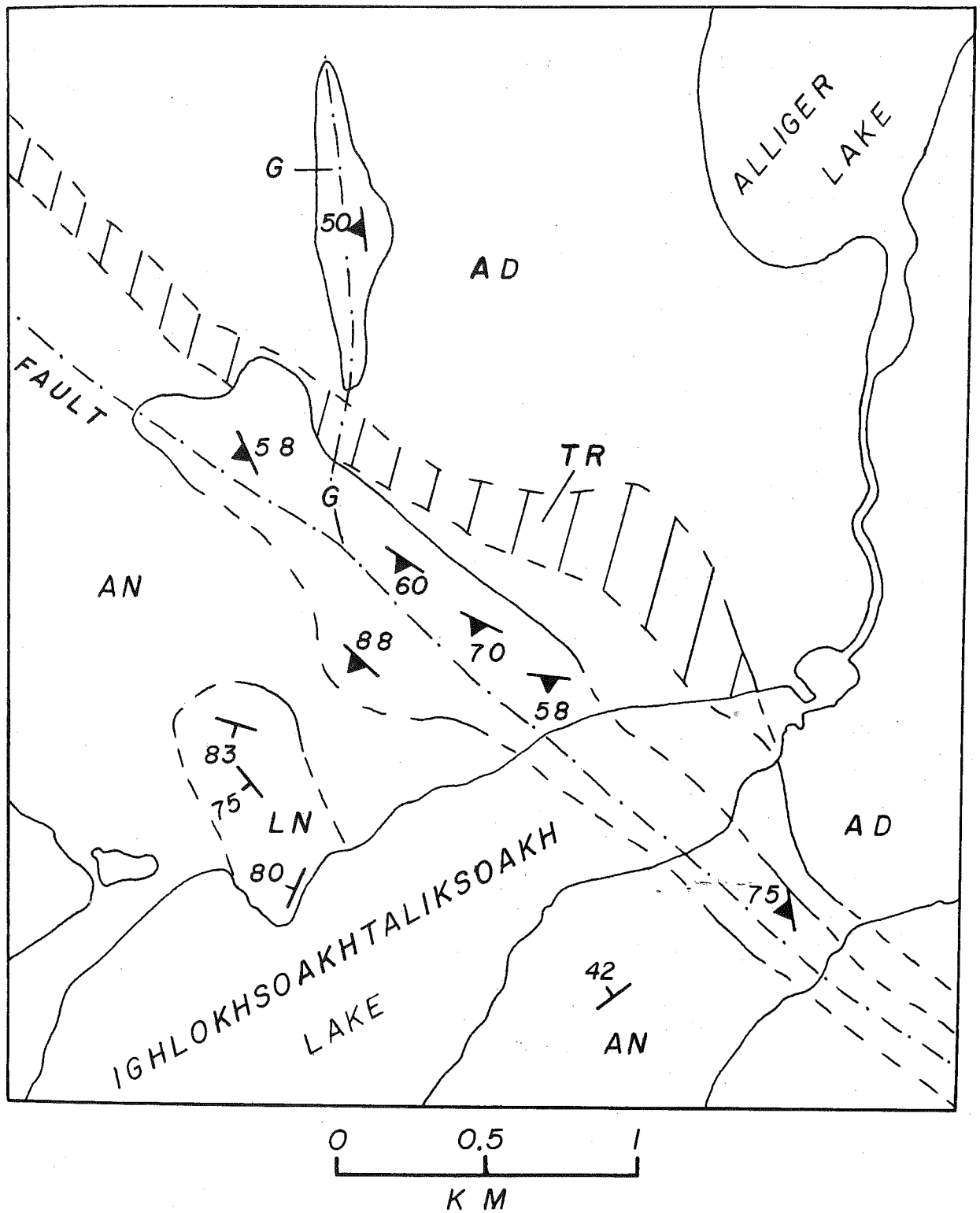


Fig. 7. Detailed geologic map of northern portion of Ighlokhsokhtaliksoakh Lake showing occurrence of basement gneiss in fault zone. TR: transitional rock; all other symbols as in Fig. 6.

the plagioclase (2-6 cm) and orthopyroxene (1-6 cm), which occurs as clotty aggregates among the plagioclase crystals. Preliminary oil immersion studies made aboard R/V *Pitsiulak* indicate that the plagioclase has a composition ranging from An_{44} to An_{48} ; the orthopyroxene in one sample of anorthosite has a composition of En_{79} .

Most commonly the anorthosite is massive and unlayered, but where layering is observed the grain size of the rock is reduced and accumulations 5 to 10 cm thick of orthopyroxene crystals occur.

The leuconorite (0.5-2 cm) is not as coarse grained as the anorthosite and contains more orthopyroxene. Orthopyroxene, rather than occurring in aggregates or clots occurs as individual crystals fairly evenly dispersed throughout the rock. Preliminary study of the leuconorite mineralogy reveals that the plagioclase has a composition of approximately An_{45} and that orthopyroxene ranges in composition from $En_{82.5}$ to En_{100} . In light of studies made by Wheeler (FR 1971 and 1972), these En values are anomalously high for the corresponding An values of the plagioclase. It is still too early to conclude whether these values are typical of the orthopyroxene in the leuconorite, but in any event they support Wheeler's contention that orthopyroxene was a primary cotectic phase in many anorthosites.

Layering, where present, consists of alternating pyroxene-rich and plagioclase-rich bands that range in thickness from 8 to 15 cm. In the extreme form of layering, melanocratic layers become pyroxenites and leucocratic layers become nearly devoid of mafics. Pyroxene lamination is present generally, and locally troughs of cumulus pyroxene occur in the layering. Another characteristic of the leuconorite is the presence of norite pegmatite dikes containing coarse-grained (up to 8 cm in length) plagioclase and orthopyroxene which transect the layering.

Adamellite

Adamellite in the Ighlokhsokhtaliksoakh Lake area is quite uniform in hand sample appearance and mineralogy. The rock is medium to coarse grained (3-7 cm) and light to dark gray in color on a freshly broken

surface. Weathered outcrops are typically lichen-covered, and extensively weathered adamellite has a rusty red color. Plagioclase ($An_{25}-An_{35}$) is the most abundant mineral (40-50%), with K-feldspar (20-25%) and quartz (10-15%) being the next most abundant phases. Green hornblende (8-10%) is the dominant mafic, but biotite (2-4%) and magnetite (1-2%) are nearly everywhere present in varying proportions. The most distinctive mineral is quartz, which forms bluish or milky white phenocrysts ranging in size from 3 to 6 mm in diameter. The quartz is subhedral to euhedral and commonly exhibits hexagonal cross sections.

The adamellite is uniformly massive except adjacent to contacts with Archean basement, where a foliation is developed. Wiebe (FR 1974) makes a similar observation concerning the contact zones of adamellite bodies in the vicinity of Tunungayualuk Island. The foliation consists of quartz and K-feldspar-rich layers alternating with plagioclase and hornblende-rich layers and results in a finer grain size for the overall rock.

Intermediate Rocks

In the northwestern corner of the field area an intrusion of pyroxene-biotite diorite of uncertain extent invades the pale anorthosite. The intrusion was discovered late in the field season and is at present inadequately sampled and mapped. Field evidence suggests that the intrusion reaches its greatest extent to the north. The southernmost limit of the intrusion invades the anorthosite in finger-like bodies which project outward from the main mass of biotite diorite. Blocks of anorthosite up to 1 m in length occur in the biotite diorite near the margins of the intrusive body. Layering is absent in the intrusion, but subtle pyroxene lamination is prevalent.

The rock is fine grained (1-2 mm) in comparison with the anorthosite, and is brownish gray on a freshly broken surface. Weathering changes the coloration to pale reddish brown. Plagioclase, pyroxene, and biotite are the major phases with Fe-sulfide being a common opaque phase.

Dike Rocks

Numerous dikes transect the rock units described above and deserve brief mention. Fine-grained dikes of basaltic composition commonly intrude the adamellite and more rarely the anorthositic rock. Most basaltic dikes range in width from 0.5 to 1 m and may be continuous over a distance of up to 1 km. Aplite dikes of granitic composition are restricted mainly to the adamellite but also occur in anorthositic rocks and pyroxene granulite. There is a suggestion that the aplite dikes may be a late stage magmatic effect of the adamellite intrusion because they are more prevalent in the anorthosite and basement rocks adjacent to the contacts with the adamellite. Aplite dikes are 5 to 15 cm in width and rarely continue for more than 50 m. The orientation of most of the dikes conforms to the regional fracture patterns in the rock.

Linears

The major linears which crisscross this region can be adequately mapped from aerial photographs. The most prominent linear is a zone of faulting and shearing trending NW-SE, which is usually distinctive in the field because of the associated mylonite. This linear is a portion of a longer linear mapped by Wheeler, which continues with much the same trend to the SE. Anorthosite occurring along the fault zone is sheared increasingly as the center of the zone is approached. Pyroxene is segregated into flattened lenses, or layers, and both plagioclase and pyroxene are reduced in grain size.

Characteristically associated with the fault zone are patches or narrow bands of Archean basement, which consist mainly of gneiss. It is not known whether the basement slices are uplifted or dropped down. In many places the fault has provided an avenue along which basaltic dikes have intruded the sheared anorthosite and basement rock.

Contact and Age Relations

Contact and age relations in the region are complicated by the shear zone, which is coincident with part of the adamellite-anorthosite contact,

and by the scarcity of exposure in lowland areas. The oldest rocks, the pyroxene granulites of the Archean basement, are intruded by both adamellite and anorthosite. On its western margin, pyroxene granulite is intruded by coarse-grained anorthosite with variable mafic content. In the zone of contact, small exposures of pyroxene granulite, presumably roof pendants, occur within the anorthosite. In much the same manner small plugs of anorthosite lie isolated within the basement rock not far from the main anorthosite massif. Limited data suggest that the anorthosite dips at moderately steep angles beneath the pyroxene granulite.

On its southwestern boundary the basement rock is intruded by adamellite. Only three or four outcrops display sharp intrusive contacts, in which the layering of the pyroxene granulite is abruptly truncated by the adamellite. The orientations of these contacts indicate that the pyroxene granulite dips beneath the adamellite. As the contact is approached, the adamellite is no longer massive but rather becomes increasingly foliated. Apophyses of adamellite penetrate the granulite and the gneiss, and inclusions of gneiss occur within the adamellite near the contact. In some places adamellite has intruded the pyroxene granulite conformably along layers and an interlayered rock is produced.

As discussed in the previous section, the contact between the patches of gneiss and the adamellite and anorthosite appears to be faulted.

The contact relations between the anorthosite and leuconorite are not consistent. Generally, the contact is gradational with the leuconorite becoming less mafic and less prominently layered toward anorthosite. Where intrusive contacts do occur, the anorthosite generally intrudes the leuconorite, although the opposite case, in which leuconorite intrudes anorthosite, was noted. The clearest example of anorthosite intruding leuconorite occurs spectacularly in a single large outcrop in the south-central part of the field area. Well-layered angular blocks of leuconorite 0.5 to 1 m in length are surrounded by invading anorthosite, which is coarser grained and contains clots of orthopyroxene. These blocks have been disoriented only slightly with respect to one another because

the relict layering in them is subparallel (see Fig. 8). Commonly associated with leuconorite-anorthosite contacts are basic pegmatite dikes composed of coarse-grained plagioclase and orthopyroxene.

Relations between the adamellite and anorthosite are ambiguous. The zone of contact is poorly exposed, and just north of Ighlokhsoakhtaliksoakh Lake wedges of basement gneiss intervene between the adamellite and anorthosite. No intrusive contacts between the adamellite and anorthosite exist here or further to the north where the contact zone is not obscured by intervening basement. There is a suggestion in this region, however, that the contact may be transitional. A progression of rock types was noted from anorthosite to leuconorite, to a quartz and plagioclase-bearing rock, to reddish-colored adamellite. Characteristically, the rocks are weathered and difficult to classify. Further insight into the contact relations of these rocks is supplied by large plagioclase xenocrysts, which occur only rarely within the adamellite near adamellite-anorthosite contacts. If these xenocrysts are of anorthositic origin, they suggest that the anorthosite slightly preceded the adamellite. More detailed mapping and sampling in this and adjacent areas is needed before the adamellite-anorthosite contact can be adequately described.

Summary and Discussion

The basement rocks described herein can be classified into two types, the more widespread pyroxene granulite and the fault-related gneiss. The layered pyroxene granulite is the dominant country rock into which the adamellite and anorthositic rock were intruded. Gneiss and augen gneiss occur exclusively along a zone of faulting and shearing. One explanation for the patches of gneiss is that faulting has juxtaposed these islands of metamorphic basement with the intrusive rocks. Fine-grained mylonite of composition similar to that of the gneiss is nearly always found with the gneiss and favors this theory.

A discussion of the igneous history of this region underscores the critical gaps in field data, especially with regard to anorthosite-

adamellite relations. First of all, however, it is beneficial to summarize relationships that are known with reasonable assurance. Concerning the anorthositic rock, field evidence bears out the hypothesis that the leuconorite and anorthosite represent compositionally slightly different batches of the same magma, which were intruded into the country rock penecontemporaneously. Leuconorite layering dips primarily to the west at moderate to steep angles ($>55^\circ$) that are generally steeper than expected for layering produced by crystal accumulation. One explanation is that after an interval of accumulation the leuconorite was tilted and moved into a new orientation when the more voluminous anorthosite was intruded.

The genetic and temporal relations between the anorthosite and adamellite are not easily deciphered. A clear-cut intrusive relation between the two rock types does not exist, but neither is there convincing evidence for a gradational contact between them, for intermediate rocks are lacking. Another possibility is that the contact is transitional, resulting from the limited physical mixing of the two magmas which produced the ambiguous zone of contact. The origin and significance of plagioclase xenocrysts in the adamellite are not yet known, but may be a clue in favor of the limited mixing of magmas. In view of the sparse data, it is too early to choose one of the above alternatives, but field evidence seems to suggest a transitional contact involving partial physical mixing of two contemporaneous magmas.

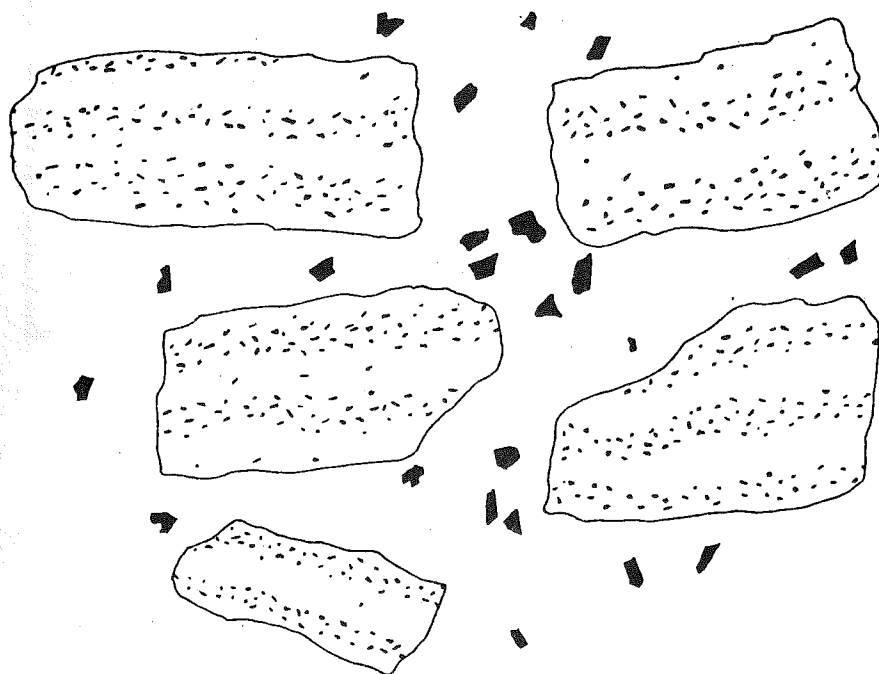


Fig. 8. Angular blocks of layered leuconorite occurring in coarser grained anorthosite. Black patches represent clots of hypersthene crystals.

0.5 m

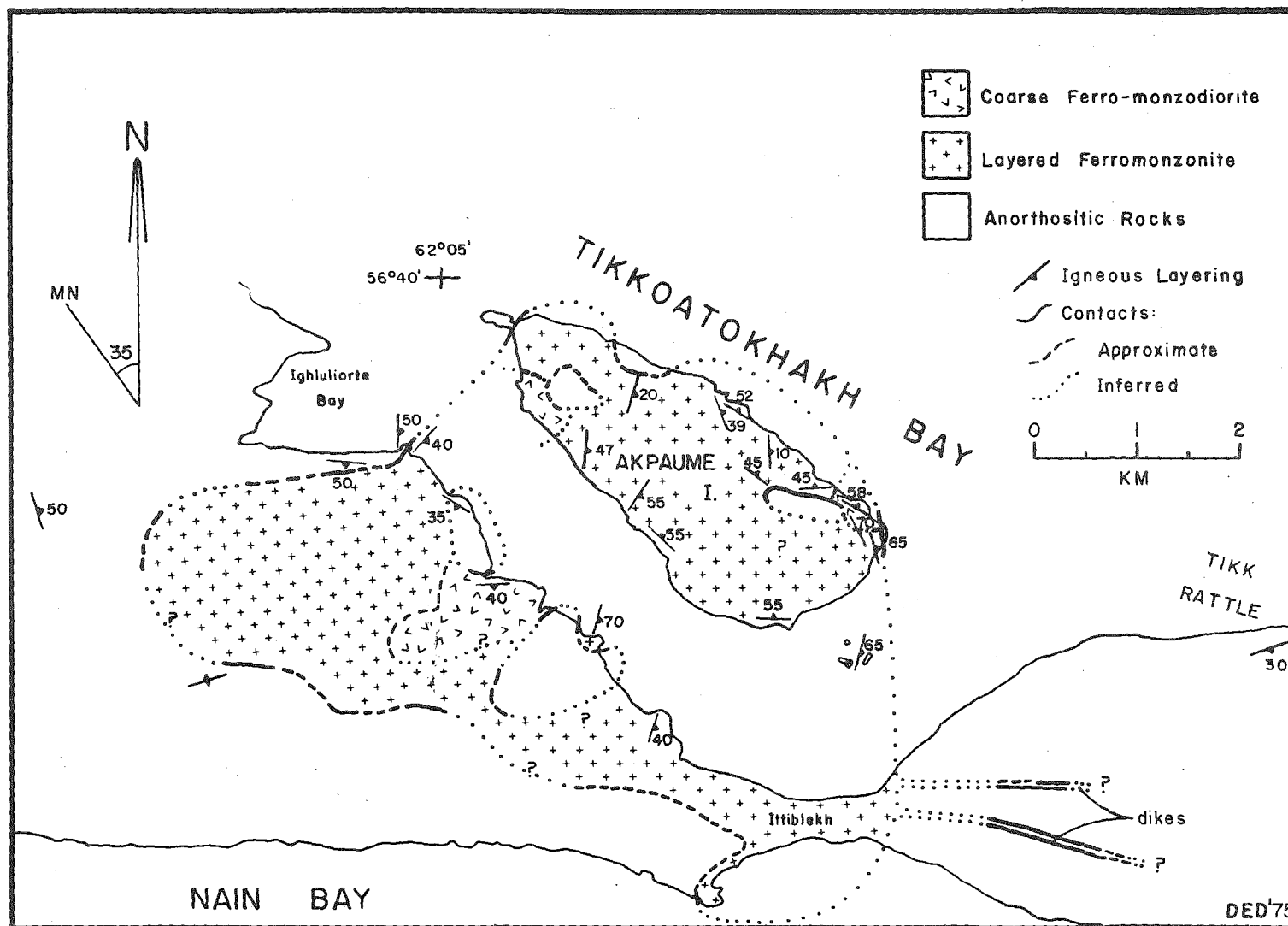


Fig. 9. Geologic sketch map of the Akpaume layered intrusion. "?" indicates areas not examined directly.

AKPAUME LAYERED INTRUSION: FIELD ASPECTS

Dwight E. Deuring

Dartmouth College¹Introduction

E.P. Wheeler has reported a layered adamellite intrusion occupying Akpaume Island (in Tikkoatokhakh Bay, 62°03'W., 56°39'N.) and portions of the mainland to the south (see Fig. 1). Reconnaissance mapping and sampling were carried out to determine internal relations and variations within the intrusion. Excellent shoreline exposures were examined in detail and sampled, and four inland traverses made. Provisional topographic sheet 14 D/9 (1:50,000) was used as the base map in the absence of air photo coverage. Mineral modes reported here are estimations from immersion mounts, and compositions are shipboard optical determinations by dispersion methods (FR 1971, p. 69; FR 1972, p. 121). Rock names are from the I.U.G.S. classification (Streckeisen, 1973).

Three mappable rock units are recognized: (i) anorthositic rocks are the country rocks for the Akpaume intrusion, (ii) layered ferromonzonite forms the bulk of the exposed intrusion, and (iii) coarse ferro-monzodiorite is a later stage intrusive rock. General areal relations are presented in Fig. 9.

Anorthositic Rocks

The anorthositic rocks range in composition from pure anorthosite to leucodiorite. Morse and Wheeler (FR 1973, p. 129) named the layered anorthosite in the eastern Tikkoatokhakh Bay area the Lister Massif. In the immediate vicinity of the Akpaume body, the rocks are massive, with 1 to 5 cm waxy pale-gray antiperthitic plagioclase (An 41 to 49), locally increasing in size to 15 cm. Subophitic orthopyroxene, usually less than 5% in the mode, is locally concentrated to form discontinuous layers of leucodiorite

¹Authors' full addresses are given at the back of this volume.

(leuconorite, but $An < 50$). Layering near the intrusion, however, is not ubiquitous. Ilmenite is also present in trace amounts.

The anorthositic rocks exhibit a wide range of behavior in response to the Akpaume intrusion. Contacts vary from sharp and agmatitic to diffuse. The anorthosite on the westernmost point of the island, for example, is an agmatite of anorthosite blocks floating in ferromonzonite. Some of the blocks have sharp corners and are coherent over several meters, but others are pulled apart, with clumps of plagioclase crystals and individual crystals swirled into the matrix of ferromonzonite in flow bands. Individual crystals here are not sheared or granulated. The contacts of the 1-km block of anorthosite 1 km southeast of the mouth of Ighluliorte Bay, on the other hand, are more gradational in nature. Dikes and dikelets of ferromonzonite cut "spotted" anorthositic rock, in which there are 5-to 10-cm rusty clots of K feldspar, pyroxene and biotite, in a 1-to 2-cm matrix of gray plagioclase. This altered rock gradually loses its rusty spots and dikelets over a distance of tens of meters and gives way to clean anorthosite. Anorthosite immediately west of the intrusion is granulated and sheared near the contact, suggesting that this region was more brittle prior to intrusion of the ferromonzonite. Inclusions of anorthosite on the size order of centimeters to tens of meters are found throughout the Akpaume body, ranging in outline from sharp and angular to stretched and "smeared-out". The larger blocks of anorthosite are indicated in Fig. 9. No reaction rims were observed on any blocks of anorthosite.

Layered Ferromonzonite

The bulk of the Akpaume intrusion is a layered rock of 2-to 10-mm grain size, varying in composition from monzonite to monzodiorite. The prefix "ferro-" indicates Fe:Mg greater than 1:1 in mafic phases. Feldspars are generally mesoperthitic, with green plagioclase (An_{25-35}) constituting 50-80% of total feldspar. Mafics average 10 to 35% and are dominated by ferropargasite (En_{25-50}). Also present are up to 6% olivine (Fo_{15-20}) and traces of orthopyroxene ($En_{33,7}$). Accessories are 1-2% ilmenite (+ magnetite), apatite, and up to 2% zircon in places. Local discontinuous stringers of ilmenite, magnetite and pyroxene are found within layering. This rock weathers deeply to a rusty grus, and generally may not be sampled away from

the shoreline exposures. Fresh rock surfaces are a dark gray-green.

The layering in the ferromonzonite is due to igneous sedimentation and consists of darker layers with cumulus pyroxene, 2 to 20 cm thick, alternating with more leucocratic layers in which the pyroxene is fine grained and apparently anhedral. Some localities with larger pyroxene crystals exhibit a planar foliation suggesting lamellar flow. Blocks of included anorthosite locally disturb the layering, as in Fig. 10. Unambiguous graded layering is rare, but indicates, along with other evidence, that the layering is right-side up and dipping generally to the east. Along the

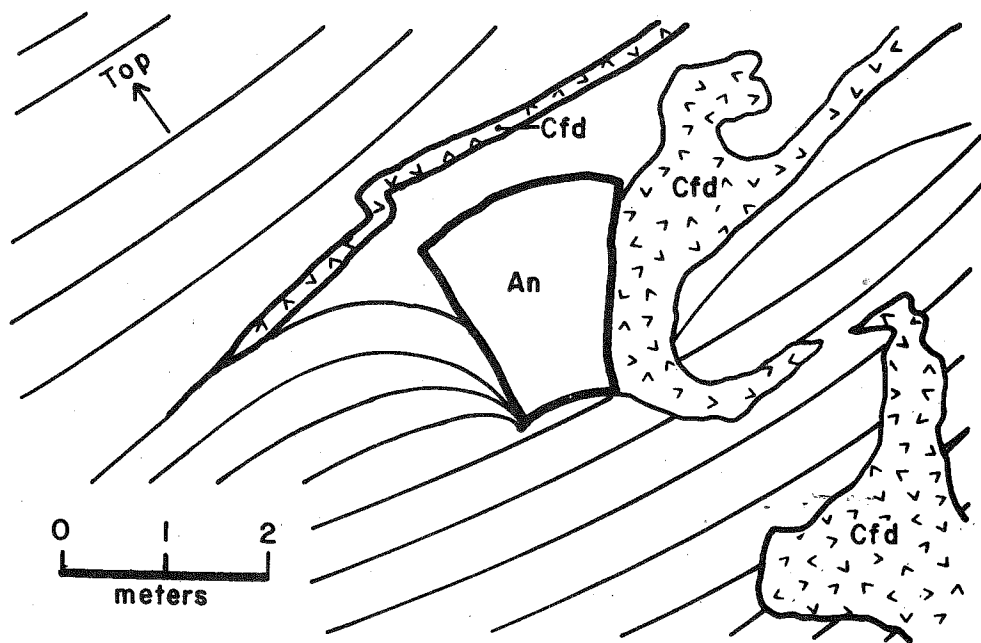


Fig. 10. Sketch of settled block of anorthosite (An) in layered ferromonzonite (layering schematic). Coarse ferro-monozodiorite (Cfd) penetrated layered rock but not anorthosite. Near-vertical shoreline exposure 1.8 km WNW of Ittiblekh.

southern shoreline of Akpaume Island the orderly sedimentation is interrupted by channel scours several meters wide, similar to structures seen in the lower zone of the Kiglapait intrusion (Morse, 1969). Along the middle of the southwest shore of the island is a zone of igneous slump breccia. Layering here is continuous on the order of 1 to 10 meters, but layers and groups of layers are displaced with respect to one another. Some zones of mixing are not layered at all. In areas with high percentages of included blocks of anorthosite, and near contacts, the foliation in the ferromonzonite is largely a flowage foliation between blocks rather than a sedimentation feature. Fine-grained ferromonzonite also occurs as dikes in anorthosite. In addition to the small dikes associated with the agmatitic contacts, two major dikes were found east of Ittiblekh. They are 10-15 meters wide, nearly vertical and are foliated parallel to the contacts. They may extend farther than indicated on the map.

Coarse Ferro-Monzodiorite

This rock unit is mineralogically similar to the fine-grained layered rocks, but has a distinctive texture and occurrence. It is a 1-to 5-cm equigranular rock, with mafic phases increasing to 10 cm in places. Fifty to ninety-five percent of feldspar is gray-green plagioclase (An_{35-45}). The blocky crystals of K-feldspar are most often perthitic. Quartz was not observed in hand specimen but was found as 3% of one sample under the microscope. Mafic phases average out to 40% and consist mainly of ferroaugite (En_{17-20}) with prominent exsolution lamellae of ferropigeonite indicating an initial subcalcic-ferroaugite pyroxene composition. Orthopyroxene (En_{42}) is present in several samples, but iron-rich olivine (Fe_{12-15}) is more common. Accessories are ilmenite (\pm magnetite), apatite and zircon (up to 2 or 3%). This rock is also gray green in fresh surface, but weathers to a rusty gravel of angular perthitic K-feldspar crystals. The presence of iron-rich olivine, orthopyroxene and quartz in this rock, combined with a regional emplacement pressure of about 6 kb (Berg, FR 1974, p. 35), suggest crystallization temperatures on the order of 900°C (Smith, 1971).

Coarse ferro-monzoiorite is generally present as dikes in layered ferromonzonite, and also in some anorthosites, and forms several small but mappable bodies. The grain size of the coarse rock increases away from some contacts, with central patches becoming very iron-enriched (pyroxene and ilmenite modes increase to 50% or more). Contacts with fine-grained ferro-monzonite are generally sharp, but are in many places contorted. There is other evidence that the ferro-monzonite was soft during the introduction of the coarse facies. In areas where coarse-grained rock dominates there are 0.5-to 2-meter inclusions of fine-grained monzonitic rock. Boundaries of inclusions are rounded and stretched much like the hybrid magma occurrences reported by Wiebe (FR 1974) on Tunungayualuk Island. No reaction rims were observed on the inclusions or on the minerals within them, and no chilled margins were seen.

Dikes and Linears

The map area is cut by several dikes whose relationship to the Akpaume body is not understood. They are generally medium-grained granitic rocks several meters wide at the most. They cut all other rock types with sharp, straight contacts. As in most parts of the Nain region, conspicuous east-west trending linears cross the map area. Tikkoatokhakh Bay and Nain Bay occupy the largest of these, and other, less prominent topographic linears cut through the map area. The contacts of the Akpaume body were not followed far enough to confirm the left-lateral motion suggested by Wheeler's manuscript map. One linear feature examined in anorthositic rocks west of the Akpaume body contained a weathered-out, 15-meter wide diabase dike, but it was not traceable through the map area.

Remarks

The tentative history of the Akpaume intrusion begins with the injection of an iron-enriched magma into a region of hot anorthosite. A period of convection and rapid sedimentation produced the fine-grained layered ferro-monzonite. The layered rock was partly consolidated when another pulse of more iron-enriched magma (coarse ferro-monzoiorite) was introduced, cutting the layering and incorporating portions of the still-mushy monzonite. Tilting of the layering to the east and intrusion of minor granitic dikes

occurred after considerable cooling, because no secondary foliation was observed. The concordant contacts between layered ferro-monzonite and anorthosite on the northeast summit of Akpaume Island and on the northeast shoreline suggest that these blocks are pieces of the roof of the intrusion. Unfortunately, not enough of the contacts are visible to suggest the shape of the intrusion at depth.

Research work will center on determining the genetic relationships among the Akpaume magma types and their possible relationship to the anorthosite of the Lister Massif.

Acknowledgments

The writer wishes to thank Dr. S.A. Morse for help with microscopic determinations and for his valuable advice. Field work was supported entirely by the Nain Project. Thanks are also due Bruce Thompson for his tireless pursuit of fresh rock samples.

PLAGIOCLASE COMPOSITION AND ANORTHOSITE CLASSIFICATION

S.A. Morse

University of Massachusetts¹Introduction

A summary of plagioclase compositions determined aboard R/V Pitsiulak by the dispersion method was presented in FR 1972. The histogram of Fig. 11 brings this summary up to date, with a total of 282 determinations. The determinations

AN / PLAG NAIN

1971 - 75

N = 282

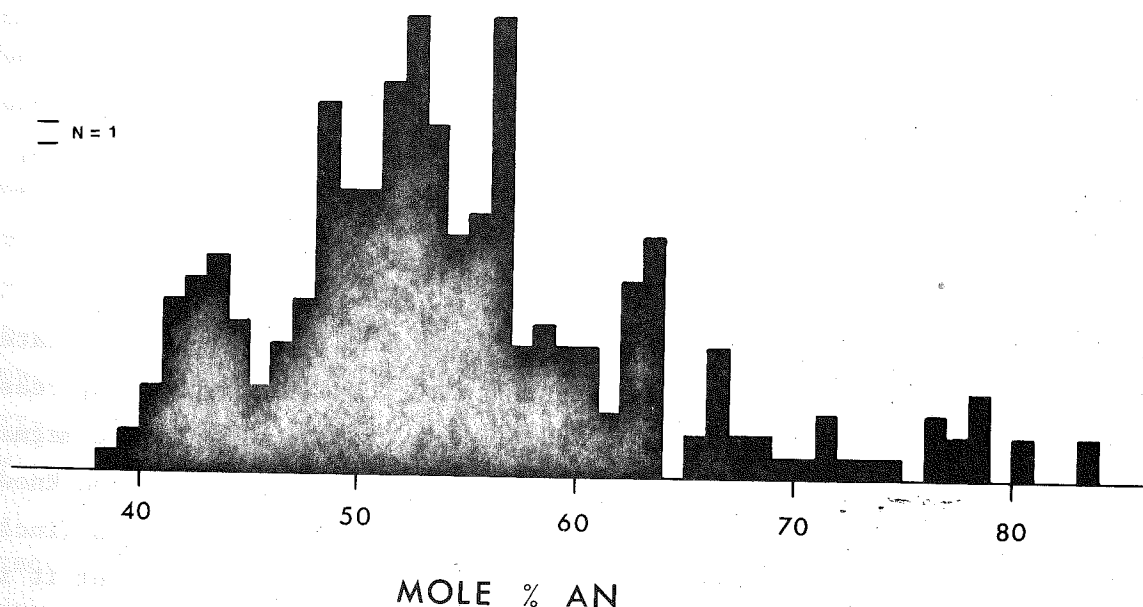


Fig. 11. Plagioclase compositions of anorthositic rocks in the Nain complex, compiled from all shipboard determinations by the dispersion method in the 1971-75 field seasons.

refer to anorthositic rocks, including leucotroctolite, leuconorite, leucogabbro, and leucodiorite, which typically contain more than 75% plagioclase, and in the majority of cases more than 85% plagioclase. Ferrodiorites and other rocks which are either fractionation products of anorthositic magmas or related to the adamellitic suite are excluded.

¹Authors' full addresses are given at the back of this volume.

The usual cautions should be stated. Fig. 11 constitutes a very select sample of the anorthositic rocks of the Nain complex. The Hettasch intrusion, for example, is not represented, nor indeed are most of the known anorthositic plutons, large and small. Furthermore, it would be absurd to suppose that any one of the major bodies is well represented by the sampling, with the possible exception of the Susie Brook Slab in Tikkoatokhakh Bay (Morse, FR 1974; 1975) which has been chip-sampled over its entire stratigraphy and which accounts for much of the distribution in the low 40's. Obviously the sampling fails to represent, except by chance, the relative volumes of anorthosite masses at all levels. On the other hand, it is fair to say that the extreme ends of the compositional range represent real anorthositic rocks, and that these limits have not changed appreciably since the earlier summary. The very calcic rocks include some layered intrusions (North Ridge Gabbro, The Bridges Layered Group) as well as calcic, pure anorthosite xenoliths in leuconorite block structures. Further, it is reasonable to predict that continued sampling will preserve the chief feature of the distribution, which is the maximum in the low to mid-50's, as well as the skewed shape away from the very calcic tail.

Interpretation

Bearing in mind these cautions and predictions, it may be appropriate to draw a few conclusions which are consistent with the data. The first reasonable conclusion is that all these rocks cannot be the product of the same magma or of very similar magmas. This conclusion was obvious already from the knowledge that the Nain complex is composed of a great many individual plutons (including at least 16 layered intrusions, many of them truly anorthositic), but it is worth pursuing this foreordained conclusion even further in terms of plagioclase composition distribution alone, because such studies can in principle be carried over to other anorthositic complexes.

A cumulative frequency curve is a convenient means of portraying and interpreting plagioclase compositional data. Such a curve has been derived from the histogram of Fig. 11, and is shown here in Fig. 12. The curve shows the elements of the characteristic sigmoidal shape of a gaussian distribution except that its lower tail is missing because we have arbitrarily rejected data from daughter rocks which undoubtedly exist but cannot always be

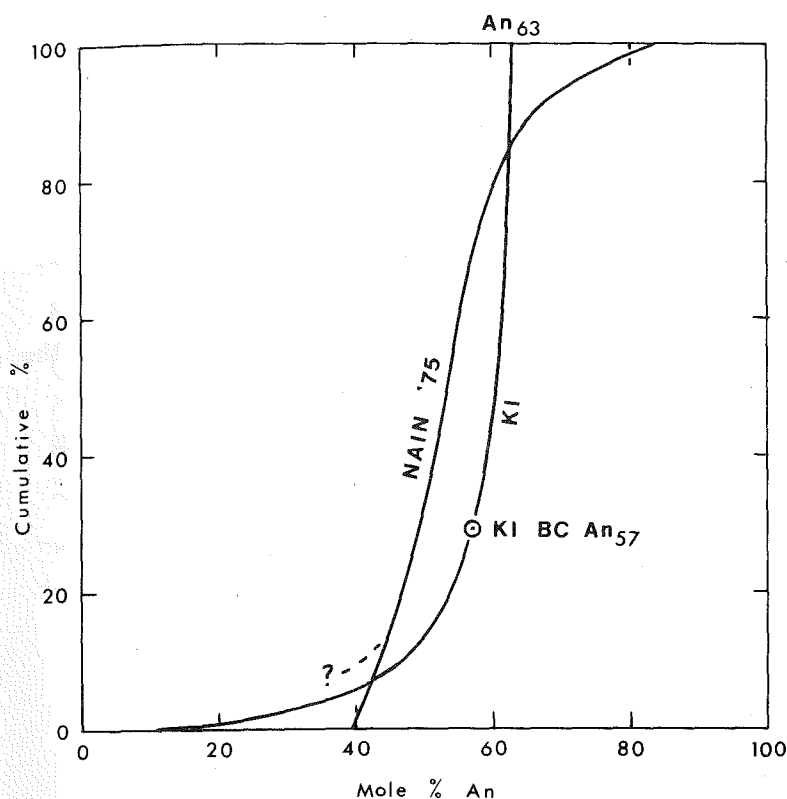


Fig. 12. Cumulative frequency of plagioclase compositions in the Nain anorthosites and in the Kiglapait layered intrusion. Data from Fig. 11 for the Nain rocks and from Morse (1969 and unpublished) for the Kiglapait.

unambiguously assigned to the anorthosite suite. The presumed existence of such a tail is shown by the query in the figure. By contrast, the cumulative curve for the Kiglapait intrusion (constructed from Morse, 1969 and unpublished data) is asymptotic to the frequency axis, and of course shows a well developed lower tail due to known daughter rocks. Lest the Kiglapait intrusion be thought irrelevant, it should be noted that most of the curve relates to leucotroctolites of the Lower Zone which carry about 78% plagioclase, on the average.

The Kiglapait curve points up certain important features of single-stage fractionation series. The very steep slope of the curve and its high angle of intersection at the top is one such feature. Another is the close relation between the bulk composition and the early plagioclase formed; here the difference is only 6 mole percent An for rocks with very little trapped liquid (13 to 3%; Morse, unpublished data). Cumulus plagioclase near the base of the Kiglapait intrusion has a composition of about An_{66} , so for strictly adcumulate anorthosites (considered to be important by Morse, 1968) a maximum difference of 9 mole percent An would apply. A third point is that the bulk composition lies near the 30% cumulative level, in the steep portion of the curve, and

presumably lies at about the same level for other fractionated, plagioclase-rich magmas.

The contrast between the singly curved Kiglapait model and the sigmoidal curve for the Nain anorthosites is marked. Obviously, the Nain distribution cannot be accounted for by one magma. Also obviously, the main portion of the Nain curve is nearly parallel to the Kiglapait curve, but is about 7 mole percent An more sodic, so a large portion of the anorthositic rocks could be accounted for by fractional crystallization of magmas with modal bulk compositions near An_{50} . The following table gives the inferred plagioclase compositions of four magma batches which would, at minimum, be required to account for the sigmoidal Nain distribution:

| <u>Bulk composition (liquid)</u> | <u>Initial cumulus composition</u> |
|----------------------------------|------------------------------------|
| An 73 (76) | An 84 |
| 63 (65) | 72 |
| 52 (55) | 60 |
| 42 (44) | 48 |

The values in parentheses would apply in the case of about 10% trapped liquid in the cumulus rock. Of course, a much larger number of magma batches is required by the field evidence, but the table gives an appropriate indication of the required range of magma types.

Magma Types

The CIPW norm of the calculated Kiglapait parent magma (Morse, 1974) gives a plagioclase composition of An_{61} , which is 4 percent higher than the observed mode of An_{57} (Fig. 12). Since most anorthosites of the Nain complex are noritic or troctolitic, it is probable that the CIPW normative plagioclase of their parents would correspond as closely in composition to their modes. The CIPW normative expression of a bulk modal composition of An_{50} would therefore be about An_{54} .

Many theorists have supposed that a plagioclase composition near An_{50} must indicate an andesitic rather than a basaltic parent for anorthosites. There is a fatal flaw in this supposition, as shown in Fig. 13: there is scarcely any basis for distinguishing andesites from basalts by means of A

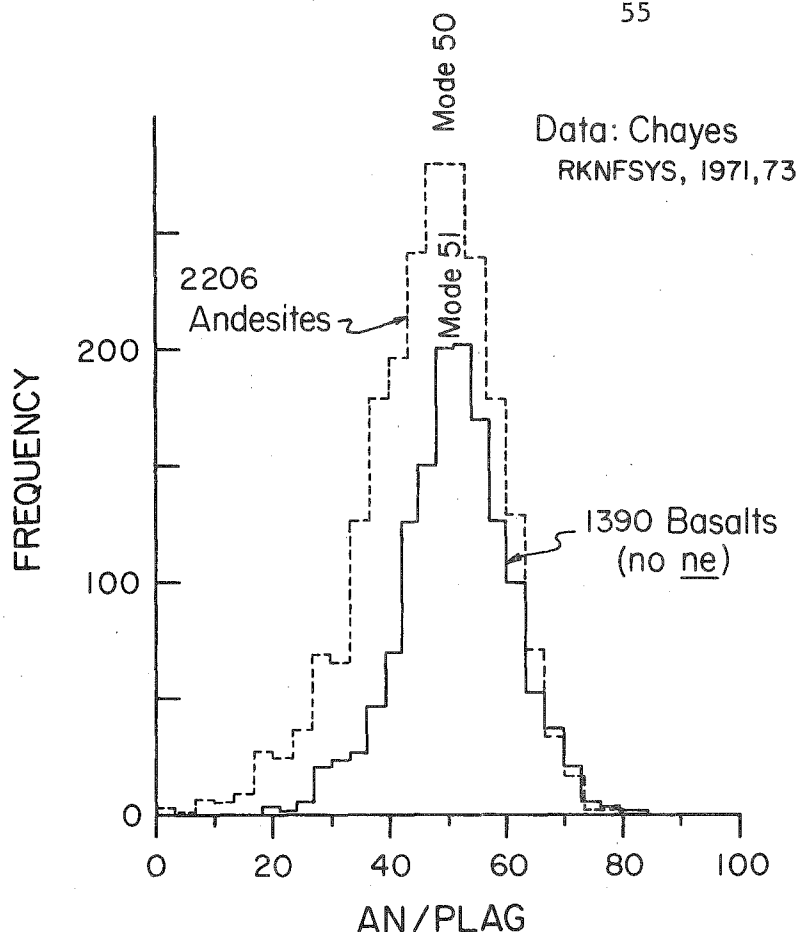


Fig. 13. CIPW normative plagioclase compositions of basalt and andesite in the rock analysis library RKNFSYS, courtesy of Felix Chayes, Carnegie Institution of Washington.

content. Bowen long ago (1928) showed that the normative plagioclase of basalts had a maximum very near An_{50} , and his conclusion remains unchanged by modern data.

Layered intrusions such as Stillwater, Bushveld, and Skaergaard are flagrant red herrings in the matter of plagioclase composition: they are all markedly more calcic than "average" basalts, as noted by Morse (1968, p.185). It is a mistake to think that these intrusions correctly indicate the plagioclase compositions to be expected from basaltic magma in general. On the other hand, they do appear to be good models for the calcic tail of the Nain distribution, as indeed such bodies as The Bridges Layered Group (Planansky, FR 1972) amply demonstrate in the field.

Anorthosite Classification

What are we to make of the much-quoted distinction of Anderson and Morin (1968) between "andesine-type" and "labradorite-type" anorthosites, in view of the range of Nain compositions? One point is clear at least -- the Nain complex, considered by Anderson and Morin to be an example of "labradorite-type" anorthosite, is not simply that. Thirty-two percent of the distribution falls in the strictly defined andesine range, and while that in itself does not disqualify the Nain complex as being dominantly of labradorite composition, it does remove the petrographic and genetic distinctiveness

of a solely labradorite range. Much of the andesine distribution comes from the very large Bird Lake and Susie Brook bodies in Tikkoatokhakh Bay, and while Susie Brook is distinctive among Nain bodies in having cumulus ilmenite (we don't yet know whether it is hemoilmenite, a distinctive feature of andesine-type anorthosite according to Anderson and Morin), it is (1) a layered monoclinical leuconorite, not a "domical" anorthosite, and (2) older than much or perhaps all of the labradorite anorthosite, hence not likely to be a partial melt therefrom. These features make it impossible to adhere to the distinction proposed by Anderson and Morin (1968) in the Nain complex, and cast serious doubt on the utility if not the validity of the distinction for anorthosites in general.

Another problem with the Anderson-Morin genetic model is that it assumes the labradorite-type anorthosites to be of Keewatin age, i.e., 2 Gyr or older. This is manifestly not true of Michikamau (Emslie, 1975) or Nain (Barton, FR 1973), and is almost certainly not true of the other supposed examples of the type. The undoubtedly old anorthosites are the Archean ones, which are probably older than 2.8 Gyr (e.g., Hurst et al., FR 1973), and these are less importantly anorthosites than they are layers of basic sills having olivine tholeiite bulk compositions (Myers, 1975; Wiener, FR 1974). The Anderson-Morin genetic scheme, then, properly reduces to a matter of deriving andesine anorthosite by partially melting tholeiitic basalt, a proposition beyond the scope of this discussion.

Conclusions

Anorthosites of the Nain complex contain plagioclase from An_{83} to An_{38} , with a truncated sigmoidal cumulative frequency pattern and a mode near An_{53} or An_{56} . This distribution in itself demands a variety of parent magmas, possibly ranging from An_{73} to An_{42} in bulk composition. There is nothing about these compositions that is identifiably "basaltic" or "andesitic" per se, and the overall characterization of parent magmas must be made on other grounds. Proposed distinctions between labradorite-type and andesine-type anorthosites are neither petrographically nor genetically fruitful in the Nain area, or by extension, anywhere else; they tend to oversimplify the anorthosite problem and perhaps obscure the more significant presence of a large range of compositions and inferred magma types composing at least some massif anorthosites.

Acknowledgements

Most of the composition determinations were made by R.E. Hodgson in 1973 and D.E. Deuring in 1974-75; their indispensable efforts are gratefully acknowledged.

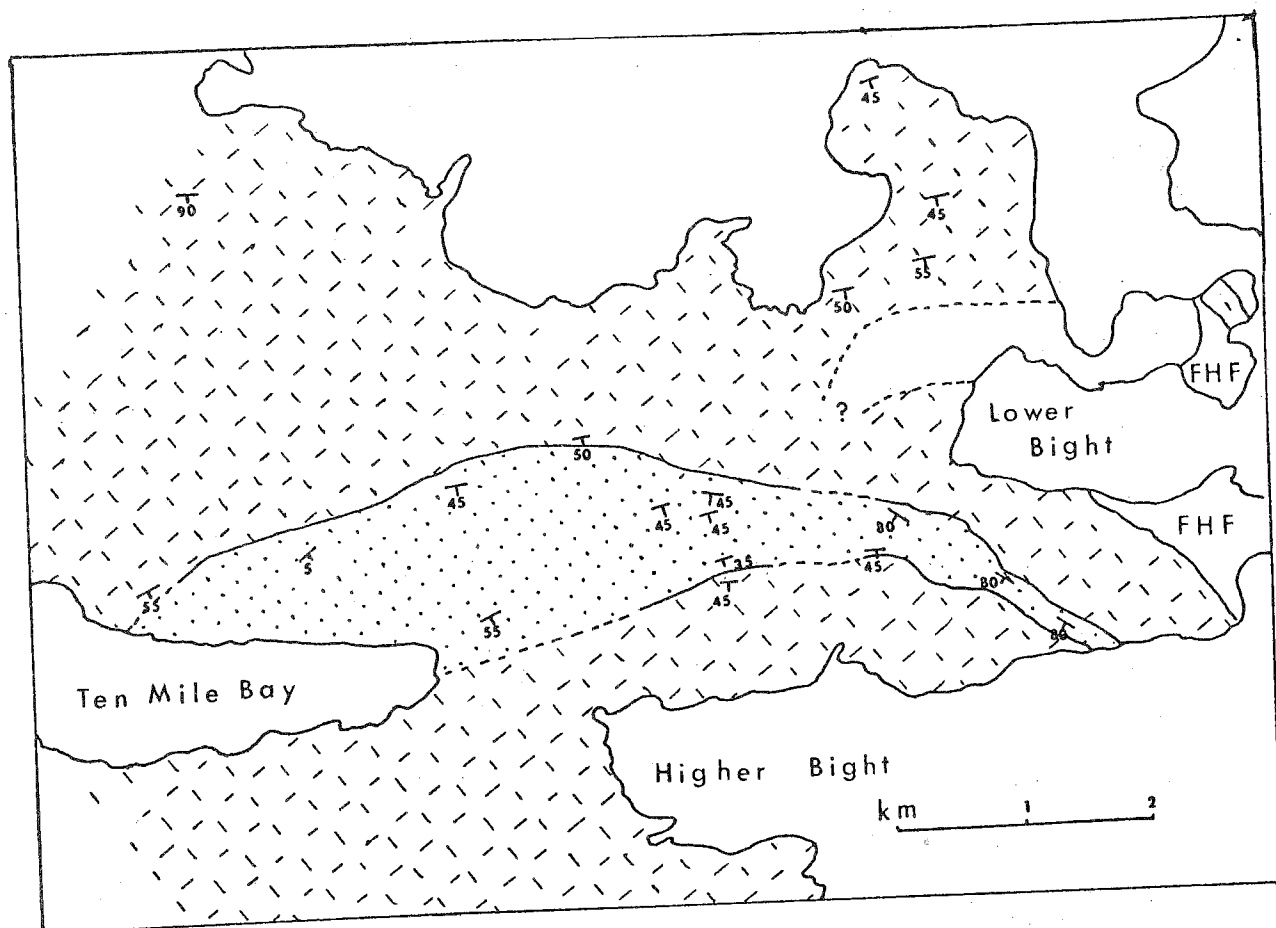


Fig. 14. Sketch map showing the extent of the layered intrusion of olivine-bearing anorthositic rock, in the less calcic anorthosite of Paul Island. FHF refers to the Ford Harbour Formation. Strike and dip symbols indicate orientation of layering in the olivine-bearing intrusion and foliation in the intruded anorthosite.

VARIATION IN THE ANORTHOSITIC ROCKS OF EASTERN
PAUL ISLAND

S.A. Hancock¹

During the field seasons of 1974 and 1975 a sampling program was carried out on Paul Island and West Red Island to try to define some systematic variation in the anorthosite westward from its contact with the country rocks of the Ford Harbour Formation. A sample grid of 1 km was set up to expand on the preliminary sampling done by de Waard in 1971 (FR 1973).

The sampling was based on the field parameters: color (pale to dark facies), mafic percentage, texture, structure, and occurrence of inclusions and pegmatoid patches. Thus far, based on field evidence and laboratory analyses of An and En percentages no systematic variation can be discerned from the contact westward.

Well developed foliation in the form of elongation of poikilitic pyroxenes was found to exist in the northeastern mapped portion of Paul Island. This seems to have no effect on the calcic content of the plagioclase found there.

The dike of anorthosite reported in 1974 (de Waard and Hancock, FR 1974) was extended farther to the west during the 1975 field mapping (see Fig. 14). It continues to widen until it goes to sea in Ten Mile Bay. No continuation of it was found on the south side of Ten Mile Bay as far as the sample grid was extended. The western extent is noticeably layered with density graded bedding of mafic-rich layers alternating with plagioclase-rich layers, dipping to the south. This layering is well exposed in a fresh rock-fall cliff at the westernmost extent of the intrusion. The red lichen cover of the olivine-rich layers described in the 1974 report persists throughout the newly mapped portion. The northern contact continues as a gradational one with the anorthositic country rock.

¹Authors' full addresses are given at the back of this volume.

Laboratory analyses done during 1974-1975 confirm the intrusion to be consistently more calcic than the intruded rock. Petrographic work aboard R/V *Pitsiulak* indicates that the intrusion may contain up to 40 percent olivine locally.

Rb-Sr ISOTOPIC CHARACTERISTICS AND CHEMISTRY OF THE 3.6-B.Y. HEBRON GNEISS, LABRADOR

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Rb-Sr isotopic analyses of the intensely deformed Hebron gneiss, Labrador, yield an isochron of approximately 3.6 b.y. with an initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of 0.7044, and chemical analyses show these rocks to be granodioritic in composition. It is believed that the isochron reflects a metamorphic event and that the Hebron gneiss was either derived from a compositionally anomalous zone in the mantle or from previously existing sialic crustal material. The Hebron gneiss is compositionally similar to some of the oldest rocks in the Archean cratons of Labrador, West Greenland, Rhodesia, South Africa and Minnesota (U.S.A.).

-- EPSL, v. 27, p. 427-435.

Of collateral interest:

3600-m.y. Rb-Sr AGES FROM VERY EARLY ARCHAEOAN GNEISSES FROM SAGLEK BAY, LABRADOR

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Field studies in the vicinity of Saglek Bay, Labrador, demonstrated that it was possible to subdivide the Archean gneiss complex into distinct lithologic units and erect a geologic chronology similar to that recognized in Godthaabsfjord, West Greenland. The Uivak gneisses are the oldest quartz-feldspathic suite in the area and are distinguished from a younger gneissic suite in the field, the undifferentiated gneisses, by the presence of porphyritic basic dykes (Saglek dykes) within the Uivak gneisses. The Uivak gneisses range in composition from tonalites to granodiorites, with the two chemically distinct suites recognized: a grey granodioritic suite and an iron-rich plutonic igneous suite which locally intrudes or grades into a grey gneiss which strongly resembles the grey Uivak gneiss. Rb-Sr isotopic studies indicate an age of 3622 ± 72 m.y. (2σ) and initial Sr isotopic composition of 0.7014 ± 0.0008 (2σ) for the Uivak gneiss suite, i.e. grey gneiss plus iron-rich suite ($\lambda_{\text{Rb}} = 1.39 \times 10^{-11} \text{ yr}^{-1}$). The grey Uivak gneiss suite, treated independently, defines a Rb-Sr isochron with an age of 3610 ± 144 m.y. (2σ) and initial Sr isotopic composition of 0.7015 ± 0.0014 (2σ) which is indistinguishable from the age and initial ratio of the total Uivak gneiss suite, grey gneisses plus iron-rich suite. The undifferentiated gneisses define a Rb-Sr isochron with an age of 3121 ± 160 m.y. (2σ), and initial Sr isotopic composition of 0.7064 ± 0.0012 (2σ). The isotopic data support field observations suggesting the undifferentiated gneisses were derived by local remobilization of the grey Uivak gneisses. The Uivak gneisses resemble the Amitsoq gneisses of Godthaabsfjord both chemically and isotopically. The interpretation of the initial Sr isotopic composition of the Uivak gneisses is interpreted as the time of regional homogenization rather than the initial ratio of the plutonic igneous parents of the Uivak gneisses as suggested for the Amitsoq gneisses. Although the undifferentiated gneisses are contemporaneous with the Nuk gneisses of West Greenland, they do not form a well-defined calc-alkaline suite and may not be associated with major crustal thickening in the Labrador Archean.

-- EPSL, v. 27, p. 393-403.

APHEBIAN SNYDER GROUP AND THE PRECAMBRIAN CHRONOLOGY OF NORTHERN LABRADOR

S.A. Morse, J.M. Barton, J.A. Speer, J.H. Berg

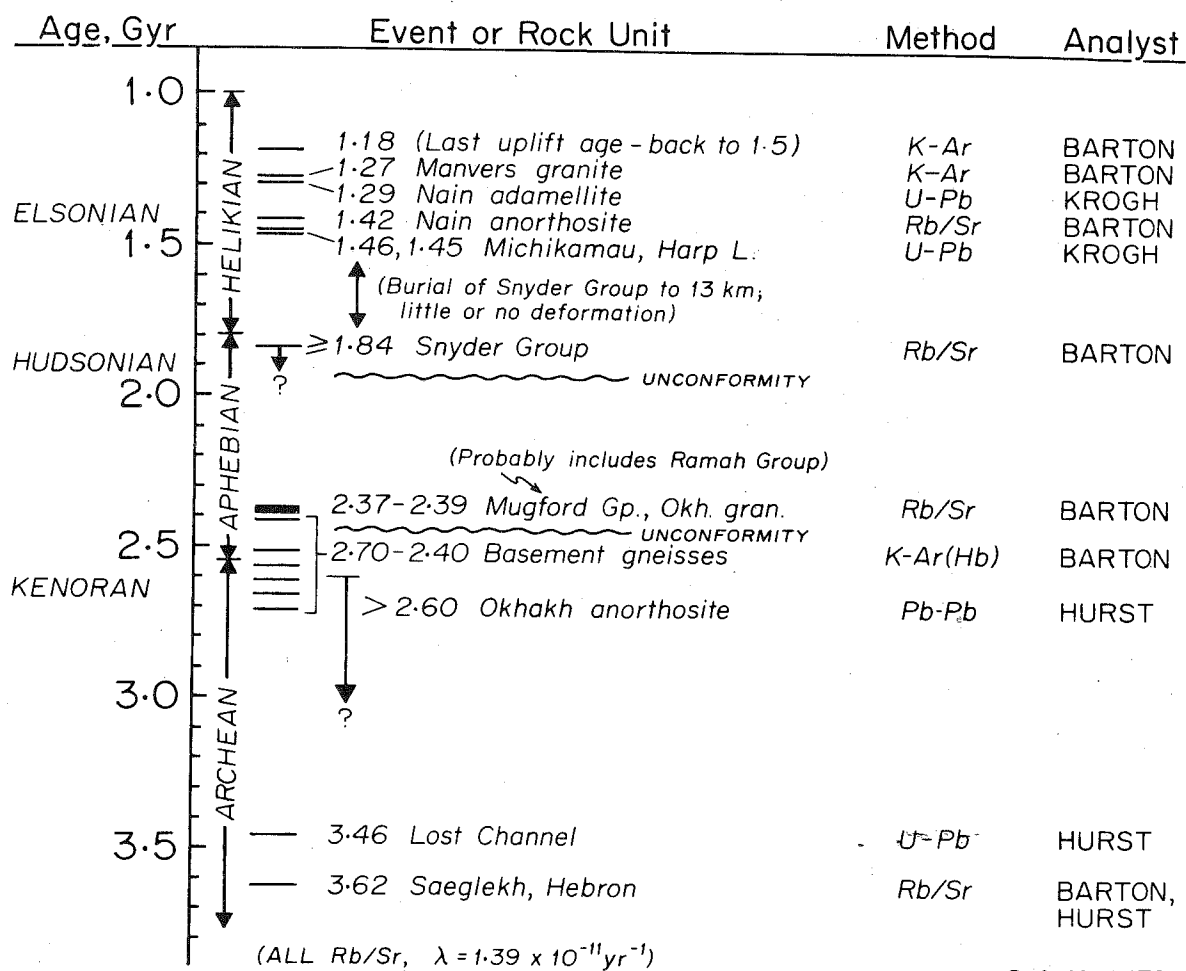
The Snyder Group has a minimum Rb-Sr isochron age of 1.842^1 Gyr, and is miraculously preserved as a small scrap against the Elsonian Kiglapait intrusion. In about 500 meters of preserved stratigraphy, it displays basal quartz pebble conglomerate, quartzite, siltstone, ironstone, marble, graphitic sulfide hornfels, ultramafite, banded ironstone, para-amphibolite, metagraywacke, metapelite, and basic granulites. The lithologies and stratigraphy invite comparison with parts of the Baffin Geosyncline, particularly the Piling group of Jackson. Deformation is mild and ascribable mainly to the emplacement of the Kiglapait intrusion. A single metamorphism is deduced, ranging from greenschist facies in the outer aureole to granulite facies (e.g. sillimanite + orthoclase) near the Kiglapait contact. The Snyder group is evidently a rare or unique example of a Hudsonian sequence which escaped Hudsonian deformation and metamorphism. Cordierite-garnet pairs, ferroproxenes, and andalusite place the metamorphic pressure very near 4 kbar, implying burial to 13 km. What covered this thin wedge-end of miogeosynclinal rocks during burial?

Pre-Hudsonian events include the 3.6 Gyr gneisses at Saeglekh and Hebron, 3.4 Gyr gneisses at Lost Channel, pre-2.6 Gyr "anorthosite" (layered basic sills, conceivably related to ophiolites) at Okhakh and Tessiuyakh, widespread Kenoran hornblende K-Ar ages, and almost simultaneous emplacement of the Mugford group volcanics and nearby massive granites at 2.4 Gyr. The Mugford age probably applies also to the Ramah group, which should not, then, be correlated with the Snyder group. The massive granites show no foliation or deformation, and record the last known event prior to the Snyder group. Was this area stable for 600 million years prior to the Hudsonian? Post-Hudsonian events include emplacement of the 1.4 Gyr Nain Complex (anorthosite and related rocks) and some adamellites to as late as 1.29 Gyr. Wheeler's fragment of red sandstone (Siamarnek fm.) is the youngest known rock unit; if that is Eocambrian, was it preceded by another long sleep for 700 million years?

$$^1\text{Rb-Sr } \lambda = 1.39 \times 10^{-11} \text{ yr}^{-1}.$$

(Presented at the Stockwell Symposium: The Hudsonian Orogeny and Plate Tectonics, Ottawa, 4 March 1976)

NORTHERN LABRADOR GEOCHRONOLOGY



S. A. M. 1/76

Fig. 15. Summary of Northern Labrador geochronology, to accompany abstract on previous page. ("Krogh" refers to Krogh and Davis, 1973.)

Of collateral interest:

PALEOMAGNETIC RESULTS OF ANORTHOSITES FROM NAIN, LABRADOR,
AND THEIR TECTONIC IMPLICATIONS

Murthy, G. S., Department of Physics, Memorial
University of Newfoundland, St. John's, Newfoundland
Paleomagnetic results are reported for 18 sites in the Nain
anorthosite massif, Labrador. Both dark and pale facies
anorthosites are included. Although the rocks are fresh,
the scatter of magnetization directions both within and
between sites is greater than that observed in other
anorthosite bodies. While AF demagnetization was not
entirely successful, thermal demagnetization yielded a
mean direction believed to be of primary origin at $D = 279$,
 $I = 42\frac{1}{2}$ ($K = 15$, $\alpha_{95} = 11\frac{1}{2}^\circ$) with the corresponding paleo-
magnetic pole at 25°N , $134\frac{1}{2}^\circ\text{W}$ ($\delta p = 9^\circ$, $\delta m = 14\frac{1}{2}^\circ$). The
result is discussed in terms of other Precambrian paleo-
magnetic evidence from the eastern Canadian Shield. The
results are compared also with paleomagnetic evidence from
other major anorthosites around the North Atlantic taking
as basis the postulation of anorthosite belts by Herz.

-- GSA Abst., v. 7, p. 827.

THE STRATIGRAPHY OF THE SNYDER GROUP, LABRADOR

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The Snyder Group is a thin sedimentary sequence that has undergone
deformation and metamorphism during the emplacement of the Kiglapait
intrusion. Lying within the contact metamorphic aureole, the Snyder
Group contains andalusite at low grades and sillimanite and ortho-
pyroxene at high grade. Unconformably overlying rocks of Kenoran
age and intruded by plutons of Elsonian age, the Snyder Group is part
of the Proterozoic succession on the coast of Labrador. Five
formations have been recognized totaling 250 m. in thickness: i) a
lower quartzitic and metaconglomeratic unit with occasional metapelites
and a discontinuous basal conglomerate ii) a manganeseiferous iron
formation containing quartz, grunerite, garnet, hedenbergite and an
orthopyroxene iii) a marble with associated calc-silicates and
quartzitic unit iv) a sphalerite and pyrrhotite-bearing graphitic
siltstone unit v) an upper quartzitic unit. The sorting of the
original sand and clay size sediments and thinness but great lateral
persistence in the lithology of the sedimentary units indicate that
the Snyder Group is a Proterozoic platform assemblage.

Porphyritic, andesite dikes and sills containing numerous subrounded
basement xenoliths have been emplaced in the sequence before
deformation and metamorphism. Later gabbroic dikes of Elsonian
age are also present.

-- GSA Abst., v. 7, p. 862.

BIBLIOGRAPHY OF THE NAIN ANORTHOSITE PROJECT

Note: This continues the bibliography contained in FR 1974. Any theses listed have been successfully defended, and in most cases will appear shortly (or have appeared) as published papers. Any omissions should be called to the editor's attention.

1975

- Barton, J.M. Jr., 1975, The Mugford Group volcanics of Labrador: age, geochemistry, and tectonic setting: *Can. Jour. Earth Sci.*, v. 12, p. 1196-1208.
- Barton, J.M. Jr., 1975, Rb-Sr isotopic characteristics and chemistry of the 3.6-b.y. Hebron Gneiss, Labrador: *Earth and Planet. Sci. Letters*, v. 27, p. 427-435.
- Barton, J.M. Jr. and Barton, E.S., 1975, Age and geochemical studies of the Snyder Breccia, coastal Labrador: *Can. Jour. Earth Sci.*, v. 12, p. 361-370.
- Berg, J.H., 1975 (abs), Osumilite of deep-seated origin in the contact aureole of the anorthositic Nain complex, Labrador: *Trans. Amer. Geophys. Union*, v. 56, p. 466.
- Berg, J.H., 1975 (abs), Quantitative regional geobarometry of the anorthositic Nain complex, Labrador: *Extended Abstracts, Internat. Conf. on Geothermometry and Geobarometry*, Penn. State Univ., Univ. Park, Pa.
- Morse, S.A., 1975, Plagioclase lamellae in hypersthene, Tikkoatokhakh Bay, Labrador: *Earth and Planet. Sci. Letters*, v. 26, p. 331-336.
- Morse, S.A. (editor), 1975, The Nain anorthosite project, Labrador: field report 1974: *U. Mass Geology Dept. Contrib. No. 17*, 108 p.
- Morse, S.A., 1975 (abs), Aluminous pyroxene in anorthosite: barometer or speedometer?: *Extended Abstracts, Internat. Conf. on Geothermometry and Geobarometry*, Penn. State Univ., Univ. Park, Pa.
- Speer, J.A., 1975 (abs), The stratigraphy of the Snyder Group, Labrador: *Geol. Soc. America, Abstracts with Programs*, v. 7, p. 862.

1976

- Berg, J.H., and Wheeler, E.P. II, 1976, Osumilite of deep-seated origin in the contact aureole of the anorthositic Nain complex, Labrador: *Am. Mineralogist*, v. 61, p. 29-37.
- Simmons, E.C., 1976 (thesis), Origins of four anorthosite suites, Unpub. Ph.D. thesis, State University of New York, Stony Brook, N.Y.

HYDROGRAPHIC REPORT

S.A. Morse

University of Massachusetts¹

There is very little to report this year because our fathometer was disabled for an extended period. Only two tracks were surveyed: Track 83 is an 8.5 mile supplement to Tom Gears Run, and Track 84 is a 10.5 mile reconnaissance track in heretofore uncharted and undescribed waters along the east side of Tunungayualok Island. Both were surveyed in early July. Submission of the plotted tracks and commentary will be made following the 1976 season, when it is hoped that operations in new areas with a repaired fathometer will increase the survey mileage more substantially. The total mileage surveyed since 1971 now stands at 599.9 nautical miles.

Attention was called in our 1972 Field Report (pp. 126, 131) to the erroneous location of the abandoned townsite of Zoar on published maps. The correct location reported by us has been confirmed once again, by conversations with Mr. Joseph Ford of Nain, to be on the north side of the bay due west of Shoal Tickle, at 56°08'N. The Labrador and Hudson Bay Pilot erroneously locates Zoar at 56°12', 2.5 miles northward of Takpanayok Bay, whereas the correct location is south of the entrance to Takpanayok Bay (see Fig. of this report). Further confusion is possible because of the presence of more obvious foundations and graves in the bay south of Zoar Bay, inside of Gilbraltar Island. These remains are at the former location of a Ford family settlement which postdates Zoar. The foundations are on the north side of this small bay, and the grave of Chesley Ford is on the south side. This is not Zoar.

Sailing directions in the Pilot, p.235, correctly state that a vessel "should proceed westward to Zoar Bay" (emphasis added) from the tickle SW of Tuktuinak (Tuktuvinekh) Island, i.e. Shoal Tickle.

¹ Authors' full addresses are given at the back of this volume.

OPERATIONS

S. A. Morse

NARRATIVE REPORT

Some say the world will end in fire,
Some say in ice....

Robert Frost

Habitual readers of these chronicles may recall that last year's activities were highlighted by fire and ice and neolithic methods for launching vessels. The 1975 season offered a welcome improvement over these afflictions, and proved once again that Labrador can be a good place to work, with a bit of luck. Despite a very late spring, breakup finally came with a rush. Preparations for launching the vessel began when an advance party led by Williamson reached Makkovike on 21 June. They found *Pitsiulak* exactly as Williamson had left her in the fall, well blocked up along her bilges. The crew now proceeded to let her down once again on her bilge, using hydraulic jacks, and to work her into line with the slipway. A self-releasing collar was then rigged, and on 24 June the vessel was moved part way into the water by a D-8 tractor pulling a cable through an offshore block. The main engine, having previously been prepared for use, was then started with no trouble, and the launching was completed on the evening tide. The vessel moved to the wharf under her own power.

Several days of refitting followed, including repair of the radar, accidentally damaged during commissioning. All this time, heavy pack ice lay along the entire coast and occasionally filled the mouth of the harbor. By the time the radar repairman left, on 29 June, it appeared that an enforced wait was in store. But by noon of the next day, more and more open water began to show, and as the last essential stores were hurriedly being brought aboard, the message came from our agent in Nain that the waters were clear there. Departure from Makkovik was taken at 1645 h. on 30 June, and after slipping comfortably around the capes in the widening shore lead, the vessel encountered only scattered ice and reached Hopedale near midnight. After a brief rest to wait for daylight, the trip was resumed on 1 July at 0400 h.,

and no serious delays were encountered. The vessel reached Nain in the late afternoon, coinciding almost perfectly with the arrival of field crews by charter aircraft. In short, vessel operations began like clockwork at the appointed time, and continued without major hindrance through the season. The same cannot be said for flying operations, which suffered severe delays on two occasions, not wholly because of weather.

Ice conditions near Nain were indeed favorable, and it proved possible to undertake a northern trip on 2 July to place a field crew in Snyder Bay and hold a field conference. On emerging from Port Manvers on 3 July, the vessel encountered slack ice in perfect weather, and it became evident that a side trip to the offlying Orphan Island was feasible. This was a long-sought opportunity to extend our mapping to its seaward limit; the trip was made with great success. The island proved to be built of a remarkably coarse-grained, massive granite, and to sustain a very busy herring gull rookery. The remainder of the field conference featured the Upper Snyder Group and the Kiglapait intrusion. By 5 July, the southernmost field camp was established in a scenic wooded inlet on the east shore of Tunungayualuk Island, and the last crews were moved inland on 8 July, only shortly after breakup in the higher lakes.

Surely no realist could expect things to continue like this, and they didn't. On 9 July your correspondent left the field to attend to other aspects of this research, and on the following day the fathometer failed. Why it failed is a complex tale related to the failure of the radar, but suffice to say that the chain of events included the explosion of a capacitor with a report "like a 12-gauge" and about the same volume of smoke as a black powder load. The unit was shipped out for repair. Resort was made thereafter, on occasion, to the hand lead for sounding. A period of intensive research and support of field parties followed, dimmed only by the occasional squall and an infestation of black bears in Ranson's camp. The vessel staff nicely fielded a navigational curve ball thrown at them while entering Wyatt Harbour late one very black night. During final approach, the radar and then the searchlight failed, and once again the old ways were resumed after the necessary interlude to recover from night blindness.

Such breakdowns are not so much dangerous as inconvenient. Flying, on the other hand, can be both dangerous and inconvenient. After a 10-day delay due to weather and administrative incompetence, Berg's crew was removed to Nain by a pilot who elected to attempt, and of necessity aborted, two downwind takeoffs, ejected half the field gear onto the beach, took off, and turned north into the mountains instead of south into the valley, with a ceiling of several hundred feet. After surviving this experience, Berg managed to negotiate, with several other geologists, a much safer but even more disagreeable overland trip through alder thickets to the world's only known plutonic occurrence of the rare mineral osumilite, where important reference collections were obtained. We are assured by all participants that this locality is not likely to be visited frequently by geologists who understand the meaning of bad bush.

The repaired fathometer was returned to Nain on 6 August in the company of your correspondent, and was reinstalled forthwith. There ensued another intensive period of geological work, mainly in Tikkoatokhakh Bay. This was followed by a joint conference ashore, at September Harbour near Dog Island, with the archeological group led by Dr. William Fitzhugh of the Smithsonian Institution. This conference was supplemented by a musicale spanning the range from flute and violin duets to penny whistles, and accompanied by a memorable feast which included a vast quantity of steamed mussels, a delicious stew, a newly baked layer cake, pies, and fresh doughnuts. Undaunted by all of this, several gluttons managed to tuck away a bedtime galley snack of scrambled eggs and chili, laced with a few pickled eggs. There is something to be said for interdisciplinary collaboration in field research.

In the closing week of operations, the vessel had occasion to be of help to the fishery collecting vessel *Oderin*, which suffered a mechanical breakdown in Cutthroat Harbour, and to Brinex Ltd., whose barge was towed to Nain from Tabor Island. In Labrador, nobody can be totally self-sufficient, and we have been fortunate to be able to exchange favors from time to time with other organizations working in our area. One favor we immediately received in return was the donation of a quantity of railroad rail from the old Brinex quarry site on Tabor Island, which we promptly donated in turn to the Postville Shipyard for construction of a marine railway. Construction of this railway has been begun, and it is our hope to share in its use in

future seasons. The installation of a good shipyard and railway at Postville should mean that all our maintenance work can be done there on a routine basis, without leaving the coast of Labrador.

Postville is located near the head of Kaipokok Bay, west-southwest of Makkovik. There are no exposed capes between Postville and Nain, which means that ice should seldom be a problem in moving to Nain once breakup occurs. When the decision was made to keep all the Government fishery vessels there for the winter, we were urged to follow suit. Among the benefits of this centralized arrangement will be the possibility of coordinating electronics and other repairs and servicing, with greatly reduced shared costs. Postville is also much closer to Goose Bay and more accessible by air than Nain, and it is close to a proposed new airfield to be designed for commercial jet flights and mining operations. Accordingly, both the Smithsonian and the UMass groups decided to move their wintering site to Postville.

The last research crews departed on 23 and 24 August, and the vessel proceeded to Postville without incident, in a 20-hour run broken by a short overnight rest at anchor in Davis Inlet. As it happened, the marine railway was not completed before freeze-up, and in early November Williamson took the vessel up through the first rattle into a small cove in the mouth of the Kaipokok River, moored her four ways, and froze her in for the winter. This is the common practice in Newfoundland, and the ice thickness in our cove is expected not to exceed three feet, so a secure wintering is anticipated. With this turn of events, we are back to our original intention of freezing in for the winter, and if all goes well this will be far preferable to hauling out and drying in terms of hull life.

TOPICAL SUMMARIES

Ice

A good season despite a moderately late breakup. There was enough ice around in early July to permit comfortable operations offshore, but never enough to get in our way.

Weather

Better than average, with no great storms. Rain occurred on one day in about 3.3 days, on the average, most of it in the middle part of August. The barometer was lower in 1975 than in 1974 for 42 out of 54 days of overlapping records, but despite this, there were several nearly unbroken stretches of good weather, of 16 days in June and early July, another week in mid-July, and 11 days in early August. A highlight of the season was the temperature of 82°F on 1 July.

Vessel Maintenance

The state of the vessel continued to improve substantially through the efforts of the entire staff. A new bow water tank was installed, with a re-routed fresh-water line through the engine room to eliminate air binds. The anchor windlass was refitted with a new wildcat and 30-fm chain and a new clutch. A new silencer was installed. Engine alignment remained stable throughout the season, thanks to the correct blocking-up of the vessel on the slipway during the winter. Improvements were made in the electrical system, and the usual scraping and painting was completed. The main engine ran like a top, and was serviced on schedule. The failure of radar and fathometer was due to an accident in hooking up the power cables, combined with an improper fuse left in the radar by the installer. The radar transmitter was exchanged for a used one which turned out to be unreliable but this is now to be replaced by a factory-reconditioned unit; the services of the original installer have been discontinued. The refrigerator/freezer is now in poor condition, and will need a thorough overhaul when opportunity permits. It is now successfully used as an icebox, with ice gathered locally or obtained from the fish plants. The shutdown of the overworked and inefficient cooling unit has resulted in an enormous improvement in the state of the ship's batteries. There are good prospects for beginning the 1976 season in excellent general condition.

Communication

Field radios were again satisfactory except during a few auroral storms. A microwave telephone system was brought to Nain in the fall of 1975, and it is now possible to communicate directly with the outside world, which will greatly improve the efficiency of operations. Television has also come to Nain, via Telsat satellite.

Flying

Service to Nain improved somewhat with increased use of the airstrip by Twin Otter during breakup and at times of heavy traffic. Local charters were obtained as available, usually with success but at times with a conspicuous lack of success, as noted above. Our operation is always at the mercy of incompetent dispatchers, and most of our successes can be credited directly to a handful of skilled and dedicated pilots.

Laboratory

Fifty-three mineral determinations were made aboard ship, the decrease from past years reflecting the reduced number of field parties and the concentration on field work by shipboard personnel. For the first time, we experienced the temporary loss of samples (six drums) in Canadian National Express. The loss was compounded by a prolonged mail strike in Canada, when effective communication with Newfoundland was very difficult. The samples finally turned up in a warehouse and were forwarded by air to Boston in March, through the kindness of Canadian National Railroads.

Subsistence

There were no major changes from previous years except in the increase of gourmet cooking by a gifted and well-prepared chef aboard ship.

Health

There were no problems except for a cut finger, which was successfully treated.

Wintering

As described above in the narrative, the new wintering site is a cove near Postville, where the vessel is frozen in.

Cooperative Investigations

Cooperation with the Memorial University group at Saeglekh and the Newfoundland Mineral Development Division in the Mugford area was limited to the relaying of messages by radio. The local fishery collecting vessel took on much of the logistic functions for northern parties which might otherwise

have fallen to us at times of need. The close proximity of the Smithsonian archeology group allowed for somewhat greater logistic cooperation, which is expected to continue in the future. There were no visiting geological investigators in 1975, for the first time.

SUMMARY OF OPERATIONS

The 1975 working season lasted 55 days, which is about normal in view of the fact that no delays were encountered due to ice. The earliest field camp was established on 4 July, which is a record for working parties in the project, although unsupported field conference camps were established earlier in 1973. A successful field conference was held on 3-4 July, and impromptu conferences were held during drilling and resupply operations at several times during the season. The shipboard laboratory furnished 53 mineral determinations and processed 16 drums of samples. The calendar below summarizes the main events.

CALENDAR

- | | | |
|------|-------|--------------------------------------------------------------------------------------------------------------|
| June | 10 | 38" ice at Hopedale. |
| | 14 | Breakup at Makkovik, flying resumed on floats. |
| | 21 | Advance personnel to Makkovik to launch vessel. |
| | 24 | Vessel launched in evening, to dock under own power. |
| | 25 | Coordinator to Makkovik; spring maintenance. |
| | 26-28 | Spring maintenance and stores. |
| | 29 | Radar repaired; heavy pack ice reported to north. |
| | 30 | Vessel departed Makkovik 1645 h. for Nain. |
| July | 1 | Arrived Nain; first vessel from south. Research crews to Nain; S. Cox crew to Okhakh. |
| | 2 | Stores aboard. Depart for north--field conference. |
| | 3-4 | Field conference: Orphan I., Snyder B., Kiglapait intrusion, returned to Khaukh. Berg crew left at Snyder B. |
| | 5 | Wiebe crew to field area (Tunungayualuk I. east shore). |
| | 6 | Operations. Spoke yawl <u>Lacerta</u> , enroute Chidley. |
| | 8 | Ranson crew to field area (Ighlokhsoakhtaliksoakh L.); Berg crew moved to Kiglapait Tessialua. |
| | 9 | Coordinator departed field area. |
| | 10 | Fathometer failed. Vessel to Tikkoatokhakh B. |

- 11-16 Geology and operations.
- 17/18 Southern resupply and drilling.
- 19-26 Geology and operations.
- 27/28 Southern resupply and drilling. Radar failed.
- 29 Northern resupply; Berg crew to Nain.
- 30-31 Sampling, osumilite locality.
- August 1-2 Operations. Lacerta returned from Chidley.
- 3 Berg crew out, Hancock crew in.
- 4 Hancock crew to Paul I. Southern pickup.
- 5/6 Wiebe crew out, coordinator returned. Repaired fathometer
re-installed.
- 7-14 Operations and geology, Tikkoatokhakh Bay.
- 15/16 Joint archeology - geology conference, Sept. Hr.
- 16/17 Fishery assistance, Cutthroat Hr.
- 18-21 Operations, towing, resupply.
- 22/23 Ranson crew to Nain, gear stowed for season.
- 23/24 Vessel to Postville, all field crews out.
- 25 Vessel crew out.
- November 3-16 Vessel moored in cove, Kaipokok River, Postville, and
frozen in for season.

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| Haynes Store, Nain | Agent |
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REFERENCES

- Anderson, A.T., Jr., and Morin, M., 1968, Two types of massif anorthosites and their implications regarding the thermal history of the crust: In Isachsen, Y.W. (ed.), New York State Mus. Sci. Serv. Mem. 18, p. 57-70.
- Berg, J.H., 1975 (abs), Quantitative regional geobarometry of the anorthositic Nain complex, Labrador: Extended Abstracts, Internat. Conf. on Geothermometry and Geobarometry, Penn. State Univ., Univ. Park, Pa.
- Berg, J.H., and Wheeler, E.P. II, 1976, Osumilite of deep-seated origin in the contact aureole of the anorthositic Nain complex, Labrador: *Am. Mineralogist*, v. 61, p. 29-37.
- Bowen, N.L., 1928, The evolution of the igneous rocks: Princeton Univ. Press, Princeton, N.J., 334 p.
- Emslie, R.F., 1975, Nature and origin of anorthositic suites: *Geoscience Canada*, v. 2, p. 99-104.
- Haskin, L.A., and Morse, S.A., 1969 (abs), Rare earths in the Kiglapait intrusion: *Trans. Am. Geoph. Union*, v. 50, p. 335.
- Hills, F.A., and Armstrong, R.L., 1974, Geochronology of Precambrian rocks in the Laramie Range and implications for the tectonic framework of Precambrian southern Wyoming: *Precambrian Research*, v. 1, p. 213-225.
- Jackson, G.D., 1969, Reconnaissance of north-central Baffin Island: *Geol. Surv. Canada*, Pap. 69-1, Part A.
- Jackson, G.D., and Taylor, F.C., 1972, Correlation of major Archean rock units in the northeastern Canadian Shield: *Can. Jour. Earth Sci.*, v. 9, p. 1650-1669.
- Krogh, T.E., and Davis, G.L., 1973, The significance of inherited zircons on the age and origin of igneous rocks - an investigation of the ages of the Labrador adamellites: *Carnegie Inst. Washington Year Book* 72, p. 610-613.
- Morse, S.A., 1968, Layered intrusions and anorthosite genesis: In Isachsen, Y.W. (ed.), New York State Mus. Sci. Serv. Mem. 18, p. 175-187.
- Morse, S.A., 1969, The Kiglapait layered intrusion, Labrador: *Geol. Soc. America Memoir* 112, 204 p.
- Morse, S.A., 1974 (abs), Kiglapait magma chemistry and application of a partition model: *Trans. Am. Geoph. Union*, v. 55, p. 476

- Morse, S.A., 1975, Plagioclase lamellae in hypersthene, Tikkoatokhakh Bay, Labrador: *Earth and Planet. Sci. Letters*, v. 26, p. 331-336.
- Myers, J.S., 1975, Igneous stratigraphy of Archaean anorthosite at Majorqap qâva, near Fiskenaesset, South-West Greenland: *Grøn. Undersølgelse*, Rpt. No. 74, 27 p.
- Simmons, E.C., 1976 (thesis), Origins of four anorthosite suites, Unpub. Ph.D. thesis, State University of New York, Stony Brook, N.Y.
- Smith, D., 1971, Stability of the assemblage iron-rich orthopyroxene-olivine-quartz: *Am. Jour. Sci.*, v. 271, p. 370-382.
- Streckeisen, A.L., 1973, Plutonic rocks-classification and nomenclature recommended by the IUGS Subcommittee on the Systematics of Igneous Rocks: *Geotimes*, v. 18, p. 26-30.
- Subbarayudu, G.V., Hills, F.A., and Zartman, R.E., 1975 (abs), Age and Sr isotopic evidence for the origin of the Laramie anorthosite-syenite complex, Laramie Range, Wyoming: *Geol. Soc. America, Abs. with Programs*, v. 7, p. 1287.