THE ARCHEAN - PROTEROZOIC BOUNDARY IN NORTHERN LABRADOR, REPORT 2

by

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Abstract

The Nain and Churchill structural provinces and the boundary between them have been investigated in the Hebron Fiord area of northern Labrador. The Nain Province comprises migmatized early Archean orthogneiss and interleaved supracrustal gneiss belts intruded by several generations of late Archean tonalite to granite. Diabase dikes intrude all lithologies. Metamorphism of the gneisses and some of the granites reflects granulite facies conditions. The Churchill Province comprises predominantly garnetiferous tonalitic gneisses with lesser mafic and ultramafic granulites, and hypersthene-bearing quartzofeldspathic gneisses, the latter in part derived from Proterozoic reworking of the adjacent Archean complex. Ramah Group supracrustals in the eastern Churchill Province are metamorphosed to amphibolite facies and are structurally interleaved with Hudsonian-refoliated Archean basement. The Archean-Proterozoic boundary is defined by a 2 to 5 km zone in which rocks of the Nain Province are progressively modified by Hudsonian thermotectonism upon approaching a sharply faulted boundary with high grade gneisses of the Churchill Province. No minerals of economic importance were detected in the area.

INTRODUCTION

The 1983 season was the second of a two-year program to investigate the nature of the boundary between the Archean Nain Province and the Proterozoic Churchill Province, and to assess the mineral potential of northern Labrador between Saglek and Hebron Fiords. The 1982 season concentrated on the Saglek Fiord section of the zone (Ryan et al., 1983); during the 1983 season most of the field work was carried out in the Hebron Fiord area. Heavy Arctic pack-ice along the Northern Labrador coast delayed positioning of helicopter fuel and prevented small-boat work on the coast; hence mapping did not commence until July 28, 1983. Two 1:50,000 map sheets (14L/2,3; Figure 1) were mapped during the field season which ended on September 1. Ryan, Martineau and Lee were responsible for regional mapping of the Archean terrane covered by 14L/2; Korstgaard concentrated on the Churchill Province and its boundary with the Archean complex on 14L/3. Much of the area included in Figure 2 was ground-traversed, but helicopter reconnaissance was also employed, especially to complete coverage of the northwest corner and the southern one-third of 14L/3.

Studies complementary to the regional mapping program were also conducted during the 1983 season. Some of these are a continuation of investigations begun last year, but new programs were also initiated. D. Bridgwater and L. Schiotte (Geologisk Museum, Copenhagen, Denmark) have been concentrating on geochronological studies of the early Archean Uivak gneisses and their migmatization in the northern coastal stretch. A. Nutman (Grønlands Geologiske Undersøgelse, Copenhagen, Denmark) conducted detailed studies of the various lithologies that make up the Nulliak assemblage, a series of pre- 3.6 Ga supracrustal rocks occurring as rafts in the Uivak gneisses. F. Mengel (Memorial University, St. John's, Newfoundland) has begun a comprehensive mapping and stratigraphic/metamorphic/structural analysis of the southern extension of the Ramah Group, an Aphebian supracrustal belt in the eastern part of the Churchill Orogen. K.

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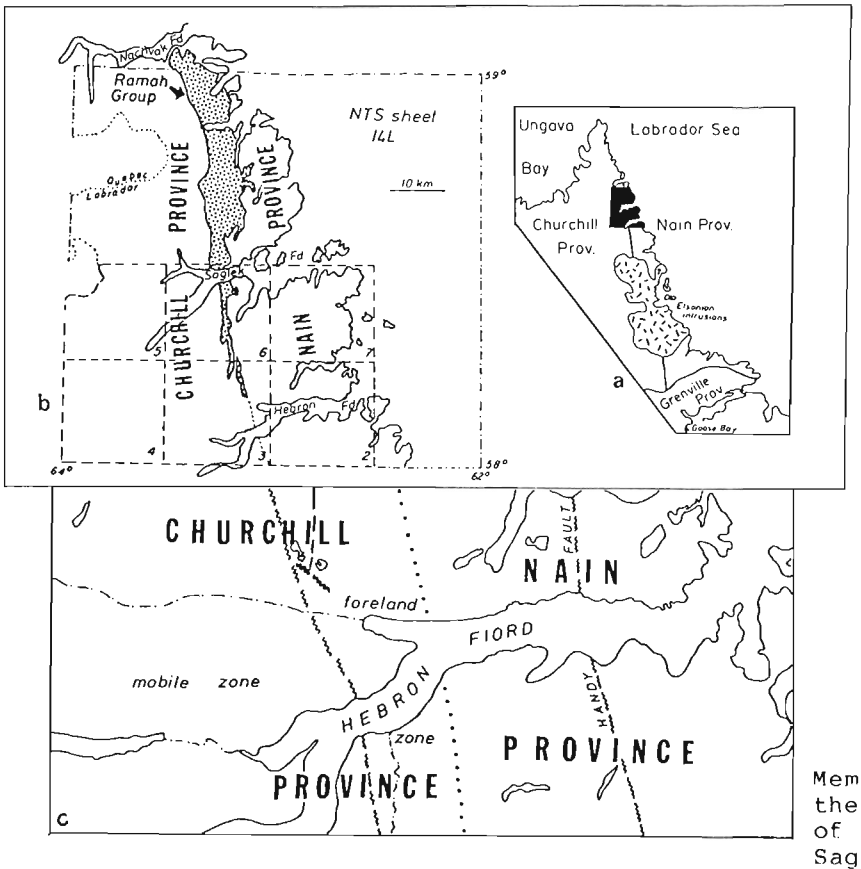


Figure 1. *Index maps to study area. (a) Shaded area is part of northern Labrador covered by NTS grid 14/L. Major lithotectonic elements of Labrador are after Greene (1972). (b) Outline of 1:50,000 sheet areas at southwest corner of 14L. Sheets 14L/2, 3 were mapped in 1983. (c) Structural subdivisions of the study area. Dotted line represents easternmost limit of Hudsonian deformed diabase dykes in the Archean terrane, and thus defines the eastern boundary of the Churchill Province foreland zone. See text for details.*

Collerson (Australian National University, Canberra) collected material for isotopic investigations of both the Archean and Proterozoic crustal blocks.

Geological Setting and Previous Work

The study area presents a cross-section of the junction between the Archean Nain Province (Taylor, 1971) and the early Proterozoic Churchill Province (Figure 1). The Nain Province is the western portion of the fragmented North Atlantic Craton (Bridgwater et al., 1973) and contains gneisses older than 3.6 Ga (Hurst et al., 1975; Collerson, 1983); the latest major deformation probably occurred circa 2.7 Ga. The Churchill Province in the study area is part of the southeast projection of an extensive, irregularly shaped Proterozoic orogen which stretches westward and northward into central and Arctic Canada (Davidson, 1972). The Churchill Province comprises rocks which exhibit a strong structural and metamorphic imprint from the Hudsonian Orogeny circa 1.8 Ga, but the majority of the rocks of this younger mobile belt in the study area are probably derived from Archean protoliths.

The major geological elements in northern Labrador were outlined and discussed by Taylor (1969, 1970, 1971, 1979). Joint work by the G.S.C. and Memorial University in 1974 and 1975 led to the unravelling of the geological history of the Archean complex in the eastern Saglek fiord area and the coastal segment directly north of the present study area, *cf.* Bridgwater et al. (1975), Bridgwater and Collerson (1976), Collerson et al. (1976), and Collerson and Bridgwater (1979). As part of the 1975 Memorial University program, the senior author conducted a study of the eastern half of the peninsula bounded by Iterungnek and Hebron Fiords (Ryan, 1977). In addition Barton (1975) and Collerson, Brooks et al. (1982) presented discussions of some aspects of the geochronology of the Archean gneisses from the Hebron area. The Churchill Province in this area, however, has received little attention, and apart from Taylor's regional reconnaissance studies, no information is available.

Definition of Archean and Proterozoic Tectonic Elements

The definition of Archean vs. Proterozoic structural elements is relatively straight forward in general terms in the Nain and Churchill Provinces of Northern Labrador as outlined by Taylor (1971, 1979). However, as Morgan (1975a) correctly pointed out, Hudsonian effects extend beyond the Churchill Province mobile zone into the terrane immediately to the east. This is dramatically illustrated by the thermotectonism which affected the Aphebian Ramah Group, and Morgan therefore assigned the Ramah Group to the Churchill Province.

Although he did not define its extent, he recognized that the Hudsonian imprint was also evident in the Archean gneisses east of the Ramah Group and assigned them to the "Hudsonian foreland" zone (Morgan, 1975b, 1978). This designation was also used by Ryan et al. (1983) who noted that where Ramah Group was not present, the late Archean diabase dike swarm could be used to indicate the eastward extent of Hudsonian deformation into the Nain Province. The delineation of Hudsonian effects on the Archean terrane becomes more problematical when these two critical markers are absent. Such is the case for parts of the boundary zone in the Hebron Fiord area. However we have been able to show that the Hudsonian overprint extends up to 6 km into the Nain Province east of the Churchill Province mobile zone (see below) and we include this area in the foreland zone of the Churchill Orogen (Figure 1c).

Nain Province

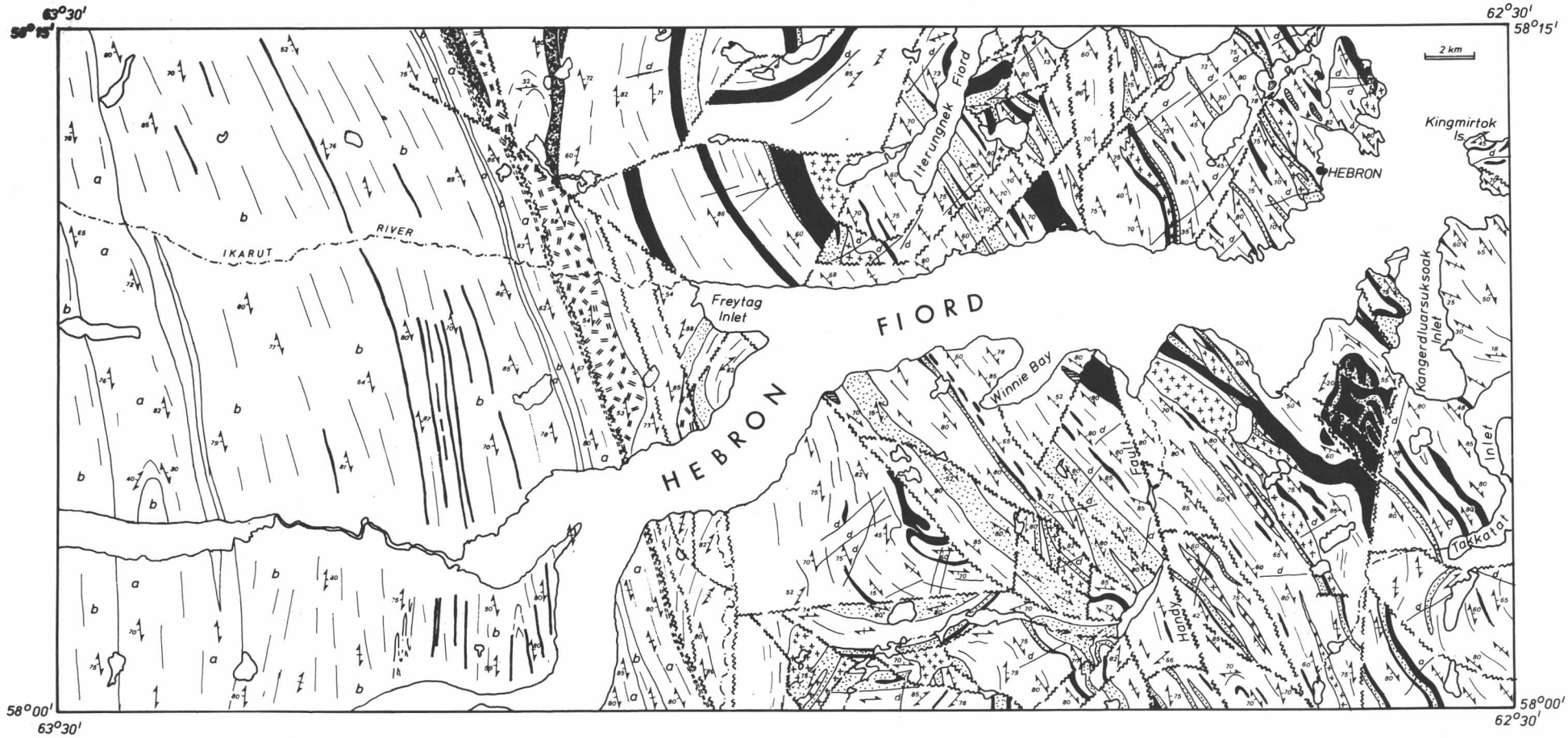
The Archean complex of the Nain Province of northern Labrador has been subdivided into several stratigraphic units of orthogneiss and paragneiss as a result of work in the Saglek area in the mid-1970's (*cf.* Bridgwater et al.,1975; Collerson et al., 1976; Bridgwater and Collerson, 1976; Bridgwater et al., 1978; Collerson et al., 1981). These lithologic and chronologic studies have shown that the geological history of the Nain Province (Table 1) entails a complex sequence of deposition, igneous activity, metamorphism and deformation. The major aspects of the geology of the Saglek area follow, summarized briefly.

The early Archean (pre-3.4 Ga) Uivak gneisses are the oldest regionally distributed gneisses. These comprise a tonalitic to granodioritic suite (Uivak I) which is intruded by and structurally interleaved with a more potassic, Fe-rich augen gneiss (Uivak II). Both subgroups contain rafts of older supracrustal rocks (banded iron formation, quartzite, calcareous metasediment, and mafic to ultramafic compositions) termed the Nulliak assemblage, and it can be demonstrated that both the Nulliak assemblage and the Uivak I gneisses had suffered polyphase deformation prior to emplacement of the Uivak II protolith. All the above lithologies were intruded by a suite of massive to feldspar megacrystic basic dikes (Saglek dikes) circa 3.2 to 3.4 Ga ago. Interleaved with the early Archean orthogneisses is a varied group of rocks termed the Upernavik supracrustals comprising pelitic, psammitic and calcareous metasedimentary rocks and basic rocks which are interpreted to be of both extrusive and intrusive origin. No Saglek dikes have been observed in the Upernavik supracrustals, and they are interpreted as either an original cover sequence developed on the Uivak gneisses or else an exotic assemblage tectonically juxtaposed against the Uivak gneisses. The intercalation of Uivak gneisses and Upernavik supracrustals probably occurred in the period between 3.2 and 2.8 Ga. Contacts between the two groups are usually marked by podiform ultramafic bodies.

Table 1: *Simplified geological history of the Nain Province in northern Labrador. Includes data from Collerson (1983).*

Emplacement of diabase dike swarm	(2.3-2.4 Ga)
Emplacement of Igukshuak granite	(2.5 Ga)
Emplacement of late syn-kinematic to post kinematic Saglek sheets and Ikarut tonalite	(2.7-2.8 Ga)
Emplacement of synkinematic granites	(2.8 Ga)
Reworking of Uivak gneisses to give Kiyuktok gneisses and Iterungnek gneisses, granulite facies metamorphism	(2.8 Ga)
Intercalation of Upernavik supracrustals and Uivak gneisses	
Deposition of Upernavik supracrustals	
Intrusion of Saglek dykes	(3.2-3.4 Ga)
Deformation and metamorphism	
Intrusion of protoliths for Uivak II gneisses	(circa 3.4 Ga?)
Deformation and metamorphism	
Intrusion of protoliths of Uivak I gneisses	(circa 3.8 Ga)
Deposition of Nulliak assemblage	(pre-3.8 Ga)

The whole Archean complex was subjected to a period of major crustal reconstitution circa 2.8 Ga. This is manifested in the development of granulite facies assemblages and reworking of the Uivak gneisses to produce a series of migmatites which were termed the Kiyuktok gneisses in the Saglek Fiord area west of the Handy Fault (Kerr, 1980) and the Iterungnek gneisses in the Hebron Fiord area east of the Handy Fault (Ryan, 1977). Equivalent migmatites at amphibolite facies east of



CHURCHILL PROVINCE

APHEBIAN

RAMAH GROUP: *quartzite, pelitic schist.*

ARCHEAN and/or APHEBIAN

Quartz-feldspar-garnet-graphite gneiss; mafic and ultramafic granulite (black).

Hypersthene-bearing quartzofeldspathic gneiss.

NAIN PROVINCE

ARCHEAN - APHEBIAN

Diabase dykes

ARCHEAN

Equigranular to porphyritic, foliated tonalite.

Synkinematic to postkinematic tonalite and granite.

Upernavik supracrustals: metasedimentary rocks (dots), metavolcanic and mafic/ultramafic intrusive rocks (black).

Quartzofeldspathic gneiss: Uivak gneiss and its reworked and migmatized derivatives.

Nulliak assemblage: metasedimentary and mafic/ultramafic rocks.

SYMBOLS

Geological boundary

Fault

Zone of ultramylonite

Trend of gneissic layering (from air photo)

Gneissosity (inclined, vertical, dip unknown)

Figure 2. *Geological sketch map of the Hebron Fiord area.*

the Handy Fault at Saglek were termed "undifferentiated gneisses" by Hurst et al. (1975). This 2.8 Ga event was also accompanied by the emplacement of syntectonic garnet- and orthopyroxene- bearing granites and pegmatites. Intruded late synkinematically with the reworking of the Uivak gneisses were the Ikarut gneiss protolith and the Saglek tonalite-granodiorite sheets which have yielded ages of ca. 2.7 Ga and 2.8 Ga respectively. Pegmatoidal, K-rich granite (termed the Igukshuak granite) cuts all the above units post-tectonically and was emplaced circa 2.5 Ga (Badsgaard et al., 1979). The final major event in the evolution of the Nain Province was the emplacement of a late Archean to early Proterozoic swarm of diabase dikes.

All the major lithologic units identified in the Saglek map area (Ryan et al., 1983) can be traced into the Hebron Fiord sector. However several differences from the Saglek area are noted:

1. In the Hebron Fiord sector, the gneisses east of the Handy Fault were subjected to a granulite facies event (Ryan, 1977) equated with the 2.8 Ga high grade metamorphism and reworking of earlier crustal material seen west of the Handy Fault at Saglek (Kerr, 1980; Collerson et al., 1981; Collerson, Kerr et al., 1982). Areas with relict granulite assemblages occur sporadically east of the fault just north of the present study area (Ryan et al., 1983), but the evidence for this high grade reworking is more widespread in the Hebron area indicating that deeper crustal levels are exposed in the eastern Archean block of this area. This granulite facies metamorphism is not developed to the same degree as in the block west of the Handy Fault however, so the area probably represents a zone intermediate or transitional between amphibolite and granulite facies.

2. Extensive areas of Uivak gneisses unaffected by younger events are not as common east of the Handy Fault in the Hebron area as in the Saglek area. In the Hebron area the old gneisses are preserved only as small septa on the order of a few tens of metres wide within younger migmatites. These younger migmatites, however, are derived by regional crustal reworking of the Uivak gneisses. These were termed Iterungnek gneisses by Ryan (1977), and their development is considered coeval with that of the Kiyuktok gneisses of Kerr (1980) and Collerson, Kerr et al. (1982). However, in contrast to the Kiyuktok gneisses, which are mostly a static reconstitution of the Uivak gneisses, the equivalent rocks east of the Handy Fault at Hebron appear to have developed under structurally dynamic conditions, probably reflecting their slightly higher crustal level of development.

3. South of Hebron Fiord, metasedimentary rocks of the Upernavik supracrustals occupy more than 30% of the granulite terrane west of the Handy Fault, and mafic metavolcanic and intrusive rocks are less abundant than at Saglek. This indicates that significant amounts of metasedimentary supracrustal material were tectonically emplaced to deep crustal levels in the Nain Province in the Archean, and may have implications regarding the origin of a distinctive garnet-rich tonalite gneiss in the adjacent Churchill Province. Granitoid melts in these Upernavik paragneisses are similar in composition to the garnetiferous tonalites, and it is conceivable that the parental tonalite for the Churchill rocks could have been derived by widespread Archean deep crustal melting of continental lithosphere which contained very large amounts of metasedimentary material (Ryan et al., 1983).

4. An extensive unit of coarse grained, undeformed to gneissic tonalite occurs along the western margin of the Nain Province (Churchill foreland zone) north of Hebron Fiord. This unit locally contains xenoliths of polydeformed quartzofeldspathic gneiss and mafic pods of diverse origin. It may be correlative with the Ikarut gneiss (Collerson, Kerr et al., 1982), an augen gneiss derived from porphyritic tonalite on the north shore of Hebron Fiord southwest of Freytag Inlet. A pre-Proterozoic age is indicated because, although tectonically interleaved with the Ramah Group, it does not intrude the group. It also forms the protolith material for the ultramylonite which defines the eastern boundary of the Churchill mobile zone.

5. Synkinematic to post-kinematic granitoid rocks appear to be areally more abundant here than at Saglek. In the northern area, younger granitoid rocks tend to occur only as isolated sheets or as parallel or crisscrossing networks, for instance the Saglek sheets and Igukshuak granite of Collerson, Kerr et al. (1982). Here however the granitoids are much more conspicuous. They vary from white, medium grained, homogeneous garnet and orthopyroxene-bearing varieties, as found north of Hebron village, to coarser porphyritic charnockites within metasediments 10 km south of Winnie Bay. An extensive unit of gray foliated tonalite to granodiorite similar to the Saglek sheets occurs subconcordant to the regional foliation east of the Handy Fault south of Hebron Fiord. Narrow lensoid units of white garnetiferous granite occur in the southern half of this eastern block.

6. The late Archean - early Proterozoic dikes are less abundant in the Hebron area than in the area to the north.

Churchill Province

The dominant rock type in the Churchill Province is a uniform leucocratic, garnet-rich quartzofeldspathic gneiss of tonalitic composition, which can be shown locally to be derived from an igneous protolith (e.g. an equigranular, medium grained tonalite, and white garnetiferous pegmatite). However, rusty garnet-graphite-rich layers appear to be relicts of metasedimentary material. These gneisses occupy a 15 km wide belt trending roughly north-northwest through the central part of 14L/3. The garnetiferous tonalitic gneiss generally appears coarse grained, but mineral subdomains are polycrystalline and highly elongated due to very strong deformation (Ryan et al., 1983). Even though in most places compositional layering and the conspicuous lenticular quartz fabric are parallel, examples are not uncommon of the quartz fabric oblique to layering, and of small folds of the layering with the quartz fabric as the axial planar foliation and lineation. Minor, but persistent and significant components in the garnetiferous gneiss belt in the present study area are garnetifeorus mafic and ultramafic granulites, some of which can be traced several kilometers along strike even though they are only 5 to 50 m thick. Their distribution is probably a function of isoclinal folding and repetition of only a few such individual units; such fold patterns can be seen most easily in the gneiss belt in the southern part of the area where macroscopic fold closures are locally preserved (Figure 2).

Hypersthene bearing, buff to brown weathering, quartzofeldspathic gneisses occur along the eastern and western borders of the white tonalite gneiss. These gneisses contain rare bands of mafic gneiss and garnet-bearing gneiss similar to those described above. At both margins the contact with the white garnetiferous tonalite gneiss is gradational, and in coastal exposures along inner Hebron Fiord, the tonalite is apparently intrusive into the hypersthene gneiss. In this area as well, the easternmost gneiss can be clearly demonstrated to have been derived by pervasive Proterozoic reworking of the Kiyuktok gneisses which occur in the adjacent Nain Province. The origin of the western unit is not as obvious; in fact in places it appears to have been originally a fine grained hypersthene granite which lacks compositional layering but displays the pronounced rodding lineation common to the Churchill Province rocks in this area.

Ramah Group supracrustal rocks occupy two narrow belts north-northwest of Freytag Inlet. The western band comprises strongly deformed quartzite with a single 1 m layer of amphibolite; the eastern band comprises quartzite with a central layer of pelitic (muscovite-biotite) schist. These lithologies are considered to be tectonized members of the basal part of the Ramah Group, the Rowsell Harbour Formation (Knight and Morgan, 1977; Morgan, 1975a), which have been interleaved with reworked Archean basement during the Hudsonian Orogeny. No Ramah Group rocks were found south of the northwest trending fault through Freytag Inlet.

Structure and Metamorphism

There is an obvious structural contrast between the Nain Province and Churchill Province (Figure 2). The Nain is typified by alternating orthogneiss and supracrustal gneiss units with a general northwest grain, locally displaying dome and basin fold patterns which are dissected by faults. Layering and fold axes are commonly steep, with the most obvious exception being a compositionally layered mafic gneiss (metagabbro) with metasedimentary screens which occupies a recumbent structure west of Kangerdluarsuksoak Inlet. The Churchill Province on the other hand lacks this closely alternating polylithological pattern but instead is typified by broad orthogneiss belts containing only minor amounts of other rock types with a steeply dipping north-northwest trend, and in which the intensity of Hudsonian deformation has destroyed or effectively masks any fold closures. A very prominent feature of the Churchill Province gneisses is a subhorizontal mineral rodding lineation within foliation planes, chiefly defined by gray quartz, but also by graphite smears and minute rutile needles. Ramah Group in the eastern Churchill Province is structurally interleaved with retrogressed Archean basement. Its distribution seems to be the result of refolding of basement-cover thrust slices (Ryan et al., 1983).

Metamorphic rocks exhibit amphibolite or granulite facies assemblages throughout the study area. The Archean terrane of the Nain Province east of Handy Fault is transitional between amphibolite and granulite facies; the most obvious indicator of this is coarse orthopyroxene grains in pegmatoidal sweats in mafic rocks and diffuse orthopyroxene- and garnet-bearing pegmatites emplaced syntectonically with the reworking of the Uivak gneisses (*cf.* Ryan, 1977). Retrogressed quartzofeldspathic rocks in this area have a green "blebby" aspect where orthopyroxene has been

replaced by green biotite. West of Handy Fault the granulite aspect of the Archean rocks is more obvious: mafic rocks are friable and the quartzofeldspathic rocks are brownish weathering and are greenish brown on broken surfaces. However, within this terrane there are narrow belts of retrogression to amphibolite facies which have abrupt contacts with the surrounding granulites. Sillimanite and garnet are ubiquitous in paragneisses throughout the map area; cordierite has also been locally identified.

In the Hudsonian foreland zone east of the Ramah Group (Figures 1c, 2), the Archean granulite facies gneisses exhibit an amphibolite facies overprint, and the diabase dikes are foliated and converted to amphibolites.

The part of the Churchill Province containing the Ramah Group, (Figures 1c, 2) exhibits amphibolite facies metamorphism: sillimanite and kyanite have been identified in the pelitic schists just north of the study area, the granulite facies basement is retrogressed to amphibolite facies gneisses and schists, and diabase dikes are transformed into amphibolites and rotated subparallel to an attenuated Archean layering.

In the Churchill Province mobile zone (Figure 1c) the consistent occurrence of orthopyroxene in tonalitic and mafic gneisses clearly demonstrates granulite facies conditions during Hudsonian deformation. It is unclear, however, whether the orthopyroxene was produced by Hudsonian metamorphism or is an Archean paragenesis which was simply modified into the Churchill Province fabric by "dry-reworking" of the Archean terrane during the Proterozoic. Directly adjacent to the western contact of the pseudotachylite ultramylonite on the eastern margin of the mobile belt (Figure 2), hornblende is abundant and orthopyroxene rare, indicating transition to amphibolite facies.

Nature of the Nain-Churchill Boundary

The definition of a discrete boundary between the Nain and Churchill Provinces entails all the problems inherent in establishing rigid demarcation lines in juxtaposed orogenic belts (*cf.* Gower et al., 1980, page 785). The following features are considered in outlining the Nain-Churchill boundary in this area.

In the easternmost Archean terrane, with the possible exception of the faults there is no mesoscopic indication of penetrative Hudsonian deformation (eg. the discordant late Archean - early Proterozoic diabase dikes are neither schistose nor metamorphosed) although the isotopic systems are disturbed (Collerson, Brooks et al., 1982). In the western part of the Archean block, however, the effects of Hudsonian deformation can be discerned in (i) the transformation of the daibase dikes to "greenstones" and schistose amphibolites, even though they retain their primary discordance with gneissic layering, (ii) the westward retrogression of granulite facies Archean gneisses to amphibolite grade, and (iii) folding and shearing of post-tectonic pegmatites in the gneisses. We also tentatively assign the regional deformation of the lenticular grey tonalite west of Freytag Inlet to the Hudsonian Orogeny. Likewise we attribute all the north to north-northwest trending faults in this sector to Hudsonian deformation. It is on the basis of these observations that we have outlined the "foreland zone" to the Churchill Orogen shown in Figure 1c.

The "Churchill Province mobile zone" (Figure 1c) corresponds to Morgan's (1975a) definition of the "Churchill Province." It comprises two domains: (i) the Ramah Group and its reworked Archean basement, confined to the area northwest of Freytag Inlet, and (ii) the high grade gneisses. The gneisses are separated from the Ramah Group in the north and from the foreland zone in the south of the study area by a major belt of ultramylonite up to 100 m wide. This ultramylonite is a dark grey to black "vitrophyric" rock characterized by large (1 cm) feldspar porphyroclasts and hornblende porphyroblasts in an aphanitic matrix. Later brittle deformation produced abundant pseudotachylite in this rock and the gneisses immediately west and east of it. On approaching the ultramylonite zone from the gneisses to the west, there is a metamorphic change in the easternmost quartzofeldspathic granulite (Figure 2) such that orthopyroxene becomes subordinate to hornblende without any change in structure. Adjacent to the mylonite, however, the subhorizontal linear fabric characteristic of the Churchill Province gneisses is abruptly replaced by steep westerly plunging lineations indicating eastward directed thrust movement.

In summary, then, the Archean-Proterozoic boundary in the Hebron area can be defined in the same terms as that of the Saglek area to the north, in being a 2 to 5 km wide zone superimposed on the Nain Province in which the Archean and early Proterozoic rocks are overprinted by Hudsonian deformation upon approaching a fault-bordered block of gneisses with pronounced Hudsonian fabrics.

Economic Geology

Hand-held scintillometer surveys and limited ultraviolet light investigation failed to reveal radioactive or scheelite mineralization. Pyritic zones are locally present in the metasediments, and graphite seams occur in granulite facies rocks in the Churchill Province, but none appear to be of economic importance.

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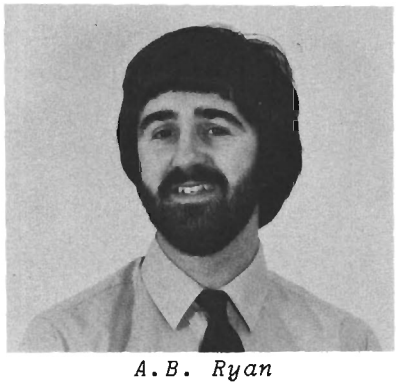

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