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# COMMENTARY ON THE LOCATION OF THE NAIN–CHURCHILL BOUNDARY IN THE NAIN AREA

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## ABSTRACT

*This paper addresses the position of the Nain – Churchill collisional suture in northern Labrador, and is a response to queries from explorationists in Labrador. The principal attributes of the boundary from Nachvak Fiord southward to Harp Lake are discussed. The boundary between Archean and Proterozoic rocks can be reliably constrained and determined from Nachvak Fiord to Okak Bay on the basis of continuous stratigraphic markers and structures. The point stressed is that from Nain Bay to Harp Lake, including the Voisey's Bay sector, the location of this major geological junction is less certain; the presently defined boundary has been established on the basis of a knowledge of relationships in the north, coupled with precise age-dating of rocks on each side of the extrapolated contact.*

## INTRODUCTION

The Nain area has long been of interest to those studying anorogenic plutonic rock suites because a classic Mesoproterozoic batholithic example of such a suite is magnificently exposed in the rugged terrain of this part of Labrador. The anorogenic batholith here comprises four "families" of rocks – anorthosite, granite, diorite, and troctolite – that together constitute the Nain Plutonic Suite (NPS). The NPS covers an area of approximately 20 000 km$^2$, straddles the Paleoproterozoic collisional boundary between Archean rocks of the Nain Province to the east and Paleoproterozoic and Archean rocks of the Churchill Province to the west, and was emplaced between 1350 and 1290 Ma (Figure 1).

The Archean, Paleoproterozoic and Mesoproterozoic rocks between Harp Lake and Okak Bay have, over the past year, been scrutinised from new perspectives. They have become the focus of frenzied exploration as a result of the discovery in 1993 by Archean Resources Limited and Diamond Fields Resources Incorporated of a major magmatic nickel – copper – cobalt sulphide deposit at Voisey's Bay, hosted by a troctolitic intrusion of the Nain Plutonic Suite. The flurry of exploration activity in the Nain area during the summer of 1995 immersed a new group of geoscientists into grappling with some of the outstanding geological problems of the region. The author spent the summer in Goose Bay serving as a government "consultant" to those who were new to the area and who were perplexed by some of the rock types and relationships encountered. This contribution to the geology of the Nain area is an extended and informal discussion that deals with one of the most frequently posed queries from explorationists during the summer in Goose Bay, namely, the degree of reliability in establishing the location of the Paleoproterozoic collisional boundary in the Nain area.

The interest among explorationists in defining the location of the Nain–Churchill boundary has apparently been prompted by a hypothesis expounded in a recent paper by Ryan *et al.* (1995). The hypothesis stated that the Voisey's Bay sulphide deposit may be the result of sulphide liquid segregation within a primitive, metal-laden NPS magma, rapidly emplaced from the mantle via a conveniently located trans-crustal fault, that fault being correlated with the junction between the Nain and Churchill provinces; en route from mantle to crust the magma became saturated in sulphide through assimilation of sulphide-bearing paragneisses along the boundary. Queries about the location of this collisional junction proximal to, and outside the Voisey's Bay area, were framed around the designation of units on the 1:500 000-scale colour regional compilation map prepared several years ago (Ryan, 1990a). The question concerning the position of the Nain–Churchill boundary on that map can be broken down into two parts and summarized thus: how reliable is the allocation of gneisses between the Nain and Churchill provinces in areas such as south of Nain Bay and at Voisey's Bay, and how were the lineages of the small gneissic septa within the Nain Plutonic Suite determined? It is perhaps appropriate at this point to elaborate on the answer to a wider audience. This contribution can be viewed as a companion to the Ryan *et al.* (1995) paper, the latter being a general discussion and model for the Voisey's Bay deposit in which the authors chose to examine the large-scale regional tectonic

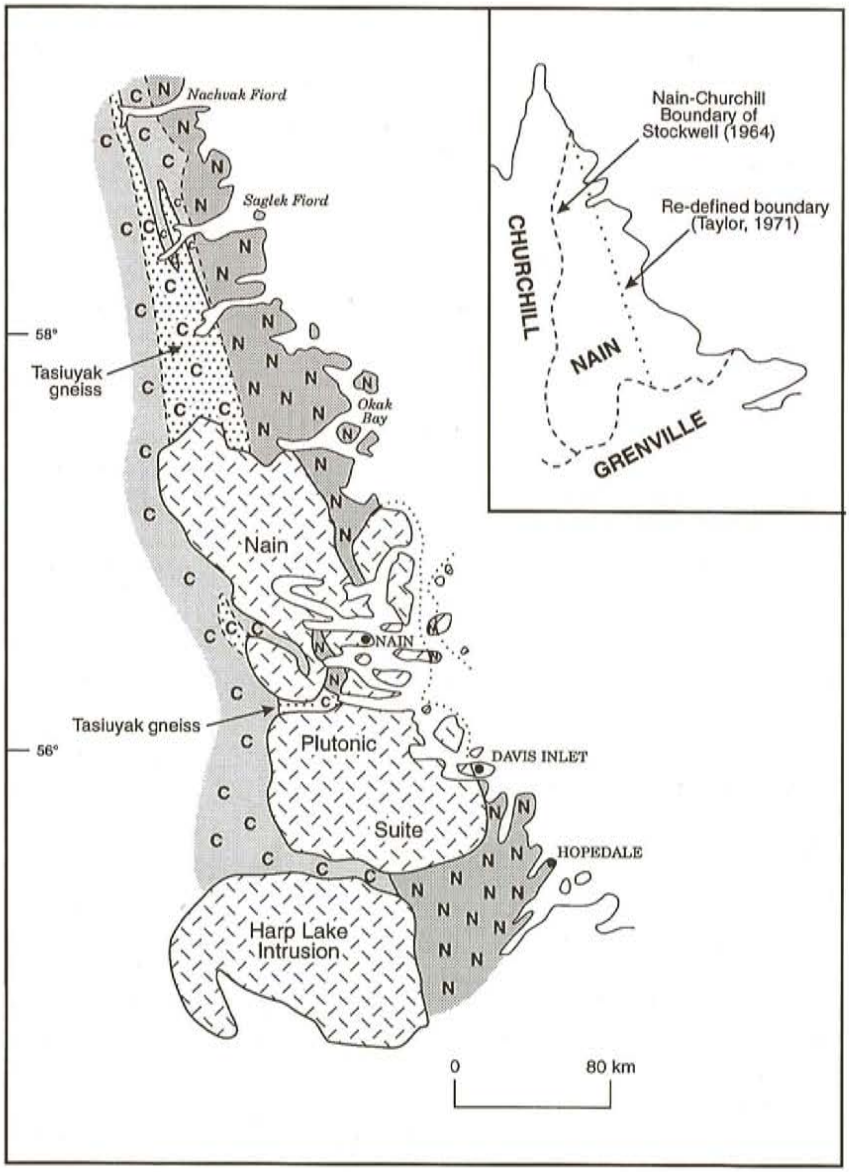


**Figure 1.** *General tectonic framework of northern Labrador, as far north as Nachvak Fiord, showing the major structural divisions and the Mesoproterozoic plutonic rocks. The location of the Nain–Churchill boundary between Hopedale and Nachvak Fiord is that given by Taylor (1971, 1972). N = Nain Province, C = Churchill Province. Distribution of Tasiuyak gneiss is based on Taylor (1979). Inset shows Taylor's Nain – Churchill structural junction relative to the isotopic boundary defined earlier by Stockwell (1964).*

picture, without resorting to long discussions of the nuances and complexities that are actually a part of the geology of the Nain region. Many of the readers will now be sufficiently familiar with the regional geology to appreciate the assumptions that were made in producing both the compilation map and an earlier map of the Voisey's Bay area by Ryan and Lee (1989a). As a preamble to the discussion of the location of the boundary in the Nain region, some of the history of regional mapping in northern Labrador that enabled the location, nature and significance of the boundary to be initially defined there, and subsequently extrapolated southward, is presented.

## THE NAIN–CHURCHILL BOUNDARY IN NORTHERN LABRADOR

### INITIAL RECOGNITION OF THE BOUNDARY

The contrast between gneisses now known to be of Archean age and those now known to be of Paleoproterozoic age had been noted by many of the pioneering geologists to venture along the northern coast (cf. Daly, 1902; Coleman, 1921). However, it was the monumental mapping effort by F. C. Taylor (of the Geological Survey of Canada during Operation Torngat, Taylor, 1979) that was the first to come to grips with the probable real significance of the difference. Taylor (1971, 1972) used the contrast to successfully argue that these rocks represented the products of two distinct orogenic events in the Canadian Shield, namely the 2.5 Ga Kenoran Orogeny and the 1.8 Ga Hudsonian Orogeny. Thus, for the first time he fairly accurately defined a roughly north-northwest-trending linear boundary (Figure 1) between two previously established, but poorly known, structural provinces of the eastern Shield – the Nain (Kenoran) and Churchill (Hudsonian); published traces of this boundary up to that time had been somewhat nebulous and sinuous (cf. Stockwell, 1964). Taylor (1979) was able to show, on the basis of his mapping, that the contact between the Nain and Churchill rocks was largely a tectonic junction, and he was able to clearly delineate a distinctive and broad belt of mylonitically foliated and subhorizontally lineated paragneiss, having abundant lilac-purple garnet and subsequently named Tasiuyak gneiss (Wardle, 1983), as the easternmost unit of the Churchill Province from Nachvak Fiord southward to Nain (Figure 1).

Taylor (1971, Figure 5) demonstrated that, on the grand scale of Precambrian structural provinces, it is possible to

portray the contact between the Nain and Churchill provinces as a sharply defined boundary. However, several focused mapping programs in northern Labrador have indicated that, like the Grenville Front in southern Labrador (cf. Gower *et al.*, 1980), this boundary is, in reality, far from being sharp. Whereas there is little doubt that both Nain and Churchill province rocks can be fairly accurately delineated, the passage between the two, in many places, is, in fact, a broad diffuse transitional zone within which increasing effects of Hudsonian tectonism on older rocks can be demonstrated. Some characteristics and the tectonic significance of the boundary zone from Nachvak Fiord southward to Harp Lake are given below, but a focused look at the boundary within the Nain region is given later.

## NACHVAK FIORD TO SAGLEK FIORD

Morgan (1975) was the first to highlight the problems associated with defining the Nain–Churchill boundary on a local scale in northern Labrador. He was able to demonstrate that a well-preserved, north–south-trending Paleoproterozoic belt of dominantly quartzitic, pelitic and calcareous sedimentary rocks, named the Ramah Group, which on its eastern margin sits unconformably on Nain Province Archean gneisses and a swarm of Paleoproterozoic basic dykes between Saglek Fiord and Nachvak Fiord (Figure 2), had been affected by Hudsonian deformation. He also noted that the western margin of Ramah Group was in both thrust and steep reverse fault contact with amphibolite- to granulite-facies reworked gneisses cut by deformed basic dykes; he interpreted these gneisses and dykes to be a structural repetition of the pre-Ramah Archean basement of the Nain Province. The author believes that some of Morgan's westernmost granulite-facies rocks on the north shore of Saglek Fiord are equivalent to granulites of probable Paleoproterozoic age that occur west of Ramah Group on the south side of the Fiord (Ryan and Martineau, 1992). Consequently on Figure 2 these are portrayed by Pg, and indicated to be in reverse fault contact with dyke-bearing Archean Nain Province gneisses. A large deformed anorthositic and gabbroic body (Taylor, 1979; Wardle, 1983) is also relegated to this overriding block. Morgan's maps (Morgan, 1975, 1981) portray the contact between the granulite-facies gneisses and the blastomylonitic, shallowly lineated, Tasiuyak paragneiss to the west simply as a "normal" tectonic, or an interleaved gradational one (see also Wardle, 1983; Calon and Jamieson, 1994), rather than a fault as later indicated by Mengel (1988), Mengel and Rivers (1990) and Rivers and Mengel (1994). This non-faulted contact is also adopted in Figure 2 because ductile interleaving zones, which are locally mylonitic, have been observed between the two, rather than the discrete fault zones that mark the contact between other units here. Morgan (*op. cit.*) also demonstrated that the Ramah Group occupied a doubly plunging asymmetric synclinorium, locally overturned on its western limb, and that metamorphism increased from greenschist- to amphibolite-facies east to west and north to south within the group. He was not able to draw a sharp line of demarcation between the Nain and Churchill provinces in the Saglek – Nachvak sector, and proposed that the boundary be chosen to coincide with the eastern margin of the Ramah Group against Archean basement because that contact (Figure 2) conveniently marked a well-defined "eastern limit of deformation and metamorphism caused by the Hudsonian Orogeny". He thus assigned the "Ramah Group fold belt" to the Churchill Province, and introduced the term "foreland zone" to refer to the Nain Province east of the Ramah Group where Hudsonian orogenic effects were minor (Morgan, 1979, 1981). Morgan (1975) also made an important observation on the extent of the Ramah Group: from reconnaissance work he recognized that "very highly deformed .... intensely folded, sheared, and mylonitized" Ramah Group rocks could be identified as a narrow linear belt for at least 20 km south of Saglek Fiord, thus extending the Group much farther than previously known.

Wardle (1983) conducted a detailed examination of the Nain–Churchill border zone along Nachvak Fiord. He substantiated Morgan's observations on the degree of deformation in the Ramah Group, but also showed Archean rocks were recognizable at least 10 km west of the Ramah Group and that Hudsonian deformation and metamorphism had affected the basement east of the group. Wardle (*op cit.*) concluded that a foliated anorthositic and leucogabbroic gneiss unit within the gneisses west of Ramah Group was probably Archean in age, but in Figure 2 the author has included this metaplutonic unit within gneisses of probably Paleoproterozoic age. Wardle (*op cit.*) included the Ramah Group, some of the overthrust western basement rocks, and part of the Nain gneisses to the east of the Ramah Group in a "Churchill Border Zone", and introduced the term Tasiuyak gneiss for the garnet-rich gneiss that constitutes a distinctive unit in the eastern Churchill Province west of the Ramah Group.

## SAGLEK FIORD TO HEBRON FIORD

Building onto the above framework, Ryan *et al.* (1983, 1984) and Ryan and Martineau (1992) undertook a survey of the Nain and Churchill boundary from Saglek Fiord south to Hebron Fiord. The delineation of the boundary between the Nain and Churchill provinces within this region is less rigidly demarcated than to the north. The Ramah Group supracrustal rocks have been largely stripped off, thus eliminating the stratigraphic marker used by Morgan in defining the eastern limit of Hudsonian overprint to the north of Sagkek. Erosion has likewise exposed a deeper structural level and a differing structural regime along the western margin of a Hudsonian-

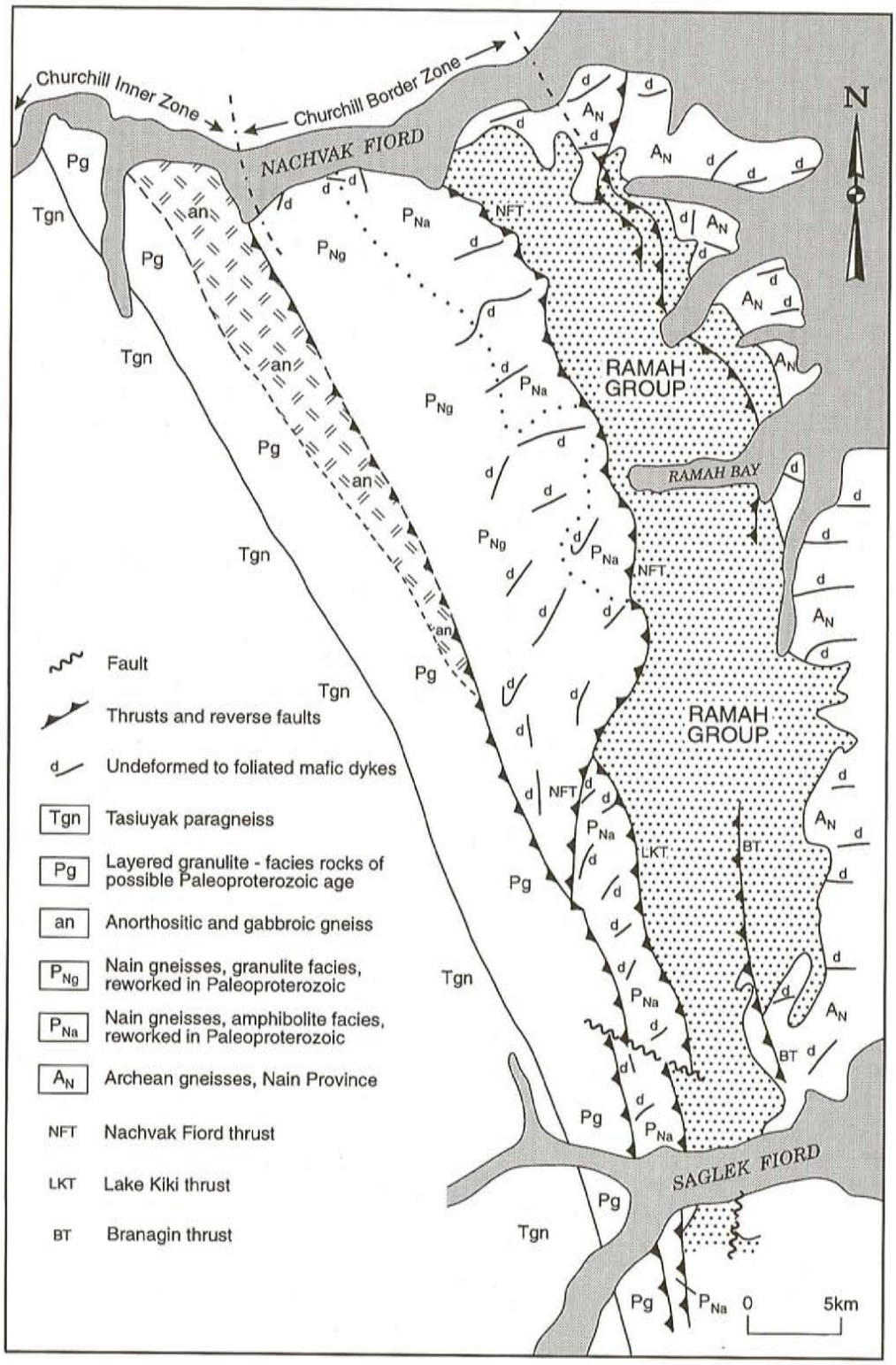


**Figure 2.** *The Nain–Churchill boundary between Nachvak Fiord and Saglek Fiord; based on Morgan (1975), Wardle (1983), and re-interpretation of some structures by Calon and Jamieson (1994), Rivers and Mengel (1994) and the author. Morgan* (op. cit.) *proposed that the eastern extent of Ramah Group be used as the eastern edge of the Churchill Province; Nain Province gneisses were considered a foreland zone. Subdivisions shown at Nachvak Fiord reflect Wardle's* (op. cit.) *proposed zonation resulting from an examination of the shoreline of the fiord.*

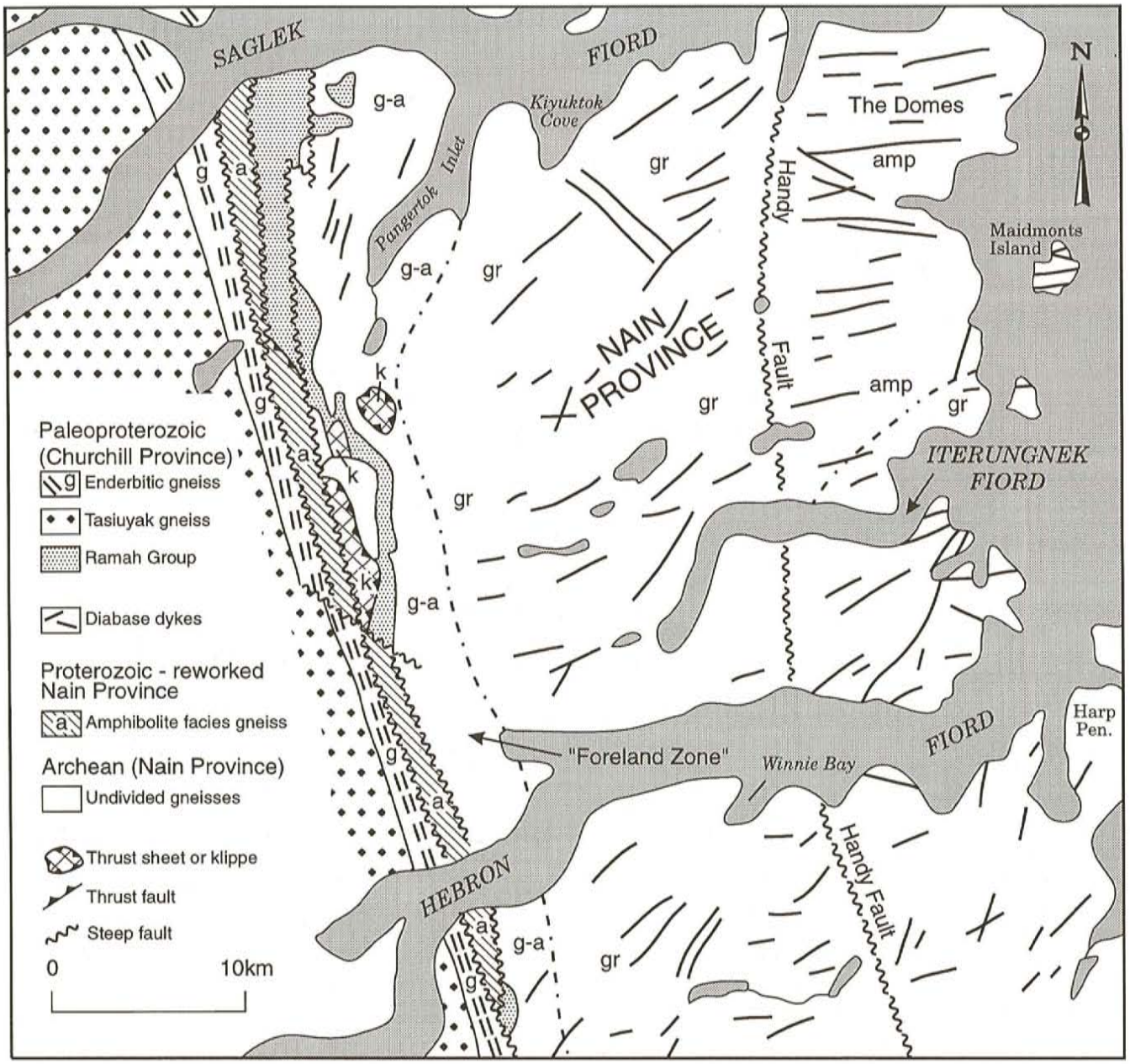


**Figure 3.** *Nain–Churchill boundary zone between Saglek Fiord and Hebron Fiord, based on Ryan (1990b) and Ryan and Martineau (1992). The eastern margin of Churchill Province was defined so as to coincide with the eastern limit of the "Foreland Zone" (see text). Amp/gr = boundary east of the Handy Fault is an Archean retrograde feature; gr/g-a = the "Foreland Zone" boundary, a line west of which granulite-facies assemblages in Nain Archean rocks are pervasively replaced by Paleoproterozoic retrograde greenschist- to amphibolite-facies assemblages, amphibolite-facies shear zones are present, and Paleoproterozoic basic dykes are foliated and/or converted to amphibolites.*

overprinted Nain Province than that seen to the north of Saglek Fiord.

It is clear that even on the south side of Saglek Fiord the Hudsonian deformation and metamorphism transgress the Ramah Group rocks and extend eastward across the pre-Ramah "foreland zone" basement. The Archean granulite-facies gneisses are severely retrogressed and the swarm of Paleoproterozoic basic dykes that was emplaced prior to Ramah deposition are foliated and have had their igneous mineralogy replaced by secondary greenschist- to amphibolite-facies assemblages (cf. Ryan, 1990b; Figure 3). The thermotectonic overprint on the basic dykes and the retrogression of granulite-facies assemblages in the Archean gneisses were used as criteria to restrict the term "foreland zone" to only that part of Nain Province that showed a

pervasive influence of the Hudsonian overprint, thus separating it from the Nain Province and including it in the Churchill Province (cf. Wardle, 1983). This designation reflected the use of structural and metamorphic criteria to define a province's limits, regardless of the age of the oldest rock involved.

The inclusion of the Hudsonian-overprinted Archean foreland zone in the Churchill Province extended the eastern boundary about 6 km east of that which would be drawn using Morgan's criterion, i.e., the eastern margin of the Ramah Group (Ryan *et al.*, 1984; Ryan, 1990b; Ryan and Martineau, 1992). The Churchill Province in the Saglek to Hebron sector was thus defined as encompassing the foreland zone, the deformed Ramah Group, and all those rocks that exhibited ductile deformation and shallow lineations west of the Ramah Group (Figure 3). (It is perhaps advisable to abandon this assignment of the Nain foreland zone to the Churchill Province in areas where it can be demonstrated that, for all intents and purposes, the rocks still bear the main attributes of their Nain parentage.) Among the gneisses west of the Ramah Group is a narrow swath of grey gneisses directly abutting the group that resemble those of the Nain Province. These grey gneisses are unlike the rocks described by Morgan (1975) and Wardle (1983) in a similar structural setting north of Saglek Fiord in that they lack clearly recognizable dykes, either because this was originally a dyke-free area or because the dykes now comprise some of the mafic layers in these refoliated rocks. Tasiuyak gneiss constitutes a broad unit west of these grey gneisses between Saglek and Hebron fiords, and has within it and along its eastern side several units of granulite-facies (enderbitic to gabbronoritic) gneiss (Ryan and Martineau, 1992).

The main contrast in structural style of the boundary zone between this area and that immediately to the north examined by Morgan (1975) can be best seen by comparing the attributes of the Ramah Group between Saglek and Hebron. Ramah Group quartzite, slate, and tremolite-bearing dolomite, disposed within several north-plunging open to tight folds, are well preserved unconformably atop Archean gneisses on the south wall of Saglek Fiord, a feature comparable to that documented by Morgan (*op. cit.*) to the north of the fiord. In contrast, deeper and more structurally complex levels of the basement-cover contact are exposed southward, such that in the linear belt of the Ramah Group from Pangertok Inlet to south of Hebron Fiord (cf. Morgan, 1975) the supracrustals are preserved only as tightly folded, largely steeply to vertically dipping, tectonic slivers of quartzite, tremolite marble and biotite–muscovite±garnet±kyanite±sillimanite± staurolite schists (Figure 3). These belts are bounded by mylonitically refoliated Archean gneisses. The interpretation placed on these mylonitic contacts (Ryan, 1990b) is that they represent décollement surfaces, or slides, along which there was subhorizontal tectonic translation between basement and overlying cover during the earliest compressional phase of Hudsonian deformation in the area; these slides were folded by later deformation.

For about 15 km north of Hebron Fiord, and continuing south across the fiord, there is a spectacular, black, locally pseudotachylite-veined ultramylonite up to 200 m wide, separating Ramah Group and refoliated Archean grey amphibolite-facies gneiss of Nain parentage from Churchill granulite-facies (enderbitic) gneiss of unknown age (Ryan and Martineau, 1992). This prominent ultramylonite apparently passes northward into a narrower, and locally pseudo-tachylite-veined, cataclasite zone that continues across Saglek Fiord to separate reworked Archean gneisses, which are overthrust Ramah Group, from gneisses to the west as earlier noted by Morgan (1975). This ultramylonite and cataclasite zone was interpreted by Ryan (1990b) to represent a major uplift fault along the Nain–Churchill boundary, a fault that postdated the more ductile tectonic regime represented by the interslicing of the Archean gneisses and the Ramah Group in this region.

## HEBRON FIORD TO OKAK BAY

An examination of the boundary zone from Hebron Fiord south to Okak Bay was included in a regional mapping program between the Labrador Sea and the eastern part of Quebec carried out by I. Ermanovics and colleagues between 1987 and 1989 (cf. Ermanovics *et al.*, 1988, 1989; Van Kranendonk, 1992; Ermanovics and Van Kranendonk, 1990, 1995). One of the important contributions to Nain Province geology from this survey was the discovery of several deformed, layered, Archean peridotite–gabbro–anorthosite bodies southwest of Napaktok Bay, indicating the farther extent of these intrusions beyond the known occurrences at Okak Harbour (Hurst *et al.* 1974) and at Tasiuyak Bay (Wiener, 1981).

Ermanovics and his co-workers demonstrated that the Nain–Churchill junction in the Hebron Fiord–Okak Bay area (Figure 4) displays several identical characteristics to that north of Hebron Fiord. Among the common features are: (i) tectonized quartzite and pelitic schists of the Ramah Group, which Ermanovics *et al.* (1989) included within a boundary zone subdivision of their "Churchill Foreland Zone", can be traced in a fairly continuous strip from Hebron to Okak, a setting analogous to that of the slices north of Hebron Fiord, (ii) basic dykes in Archean gneisses of the Nain Province are deformed and metamorphosed about 5 km east of Ramah Group; the development of Proterozoic foliations and the hornblende-in isograd in these dykes were used by Van Kranendonk and Ermanovics (1990) to define the eastern extent of the "foreland zone", (iii) a strip of Hudsonian-

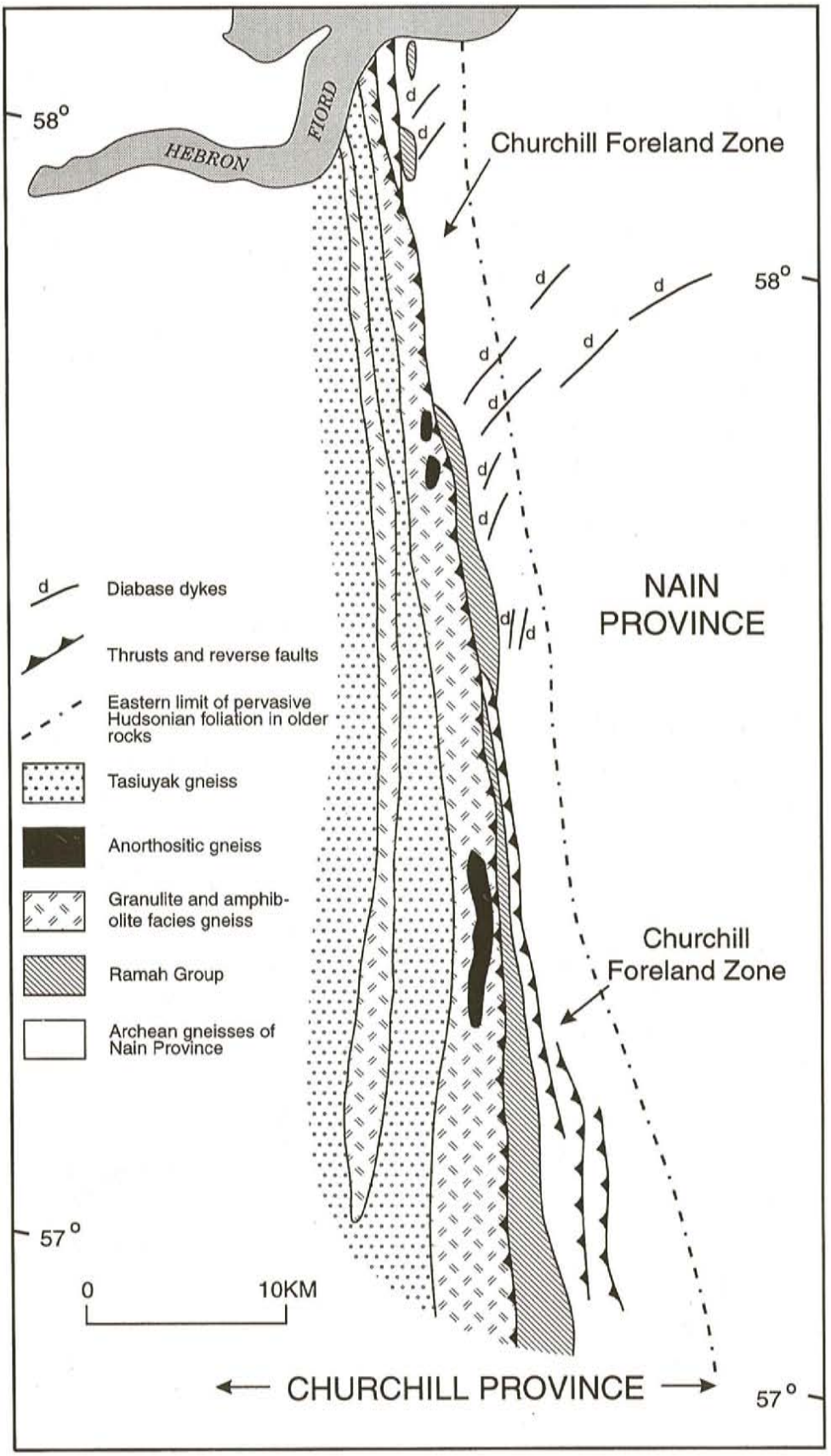


**Figure 4.** *Nain–Churchill boundary zone between Hebron Fiord and Okak Bay, based on Ermanovics and Van Kranendonk (1995) and Van Kranendonk and Ermanovics (1990), with some re-interpretation and modification by the author.*

deformed, dyke-free, granulite- and amphibolite-facies gneiss occurs west of the Ramah Group; this gneissic zone is characterized by podiform bodies of tectonized gabbroic anorthosite, an assemblage analagous to that found by Wardle (1983) at Nachvak Fiord, (iv) prominent black ultramylonite zones, like that north of Hebron, define the contact of the Ramah Group slivers and the gneisses to the west, and (v) mylonitic and shallowly lineated Tasiuyak gneiss contains numerous enderbitic gneiss units along its eastern side, but the mylonite fabric dies out westward. Tasiuyak gneiss at its western extent in the Okak region is internally characterized by large areas of diffusely layered diatexite and fairly massive megacrystic garnetiferous granite.

In addition to the above similarities, Ermanovics and co-workers also documented steeply plunging Hudsonian lineations in the eastern part of the foreland, replaced by more shallowly plunging linetions westward toward the deformed Ramah Group rocks. They also noted that the shallowly plunging lineations, which are characteristic of the gneisses of the Churchill Provnce west of Ramah

Group, are present in the Ramah Group itself here, a feature not recognized in the Saglek area (cf. Calon and Jamieson, 1995, page 107). This observation provided the first evidence to link a high-level deformation with a similar deep-crustal deformational event, the latter exemplified by the lineated granulite-facies gneisses.

## NORTHEAST OF HARP LAKE

The southernmost area where the Nain–Churchill boundary has not been eradicated by younger intrusions is northeast of Harp Lake, where 12 km of the boundary zone is sandwiched between the Harp Lake intrusion to the south and the NPS to the north (Figure 5; Ermanovics and Korstgård, 1981; Ermanovics and Ryan, 1990; Ermanovics, 1993; Thomas and Morrison, 1991). There, for several reasons, the distinction between rocks that are definitely Paleoproterozoic and those that are definitely Archean is difficult to make, and consequently the Nain–Churchill boundary is less rigidly defined. Typical leucocratic, purple-garnet-rich and mylonitic-textured Tasiuyak gneiss, a reliable Churchill Province indicator, is apparently missing. In its place there appears to be a biotite-rich, grey to white garnetiferous paragneiss, invaded by extensive linear plutons of foliated and gneissic, leucocratic, garnetiferous tonalite to granite (cf. Hill, 1982; Thomas and Morrison, 1991). This series of gneisses and deformed intrusions seems to be equivalent to Churchill Province rocks that were mapped by Ryan and Lee (1989b) directly on strike with Tasiuyak gneiss south of Cabot Lake–Kogaluk River, a relationship used to suggest that south of the Cabot Lake area the Tasiuyak gneiss was completely excised along east–west sinistral transcurrent faults prior to emplacement of the NPS (Ryan and Lee, 1986, page 82). Alternatively, the absence of Tasiuyak gneiss in the Harp Lake area could reflect the oblique excision of the paragneiss unit against the western margin of Nain Province along the roughly north–south late faults that characterize the boundary in the north. Another possible explanation could be that the Tasiuyak gneiss changes character along strike from north to south, and that the garnetiferous granitoids reflect a greater manifestation of the foliated granites found in the western part of the Tasiuyak gneiss in the Okak area (Ermanovics and Van Kranendonk, 1995). East of this paragneiss-granite terrane is a broad belt of well-layered tonalitic gneiss and a series of low-grade supracrustal rocks known as the Ingrid Group (Figure 5).

The Ingrid Group is unique to the area north of Harp Lake and comprises a deformed (foliated, folded and thrust-faulted), greenschist-facies sequence of mafic and intermediate lavas and coarse clastic rocks. Ermanovics and Korstgård (1981), Ermanovics and Ryan (1990) and Ermanovics (1993) have drawn attention to the fact that the Ingrid Group rocks show a strong imprint from Hudsonian deformation, and that the contact with adjacent gneisses is everywhere tectonic, although perhaps in some cases representing a modified unconformity. Ermanovics (1993) indicated that the gneisses east of the Ingrid Group are Archean in age and are part of the Nain Province; he interpreted the gneisses south and west of the Group to be Paleoproterozoic and therefore part of the Churchill Province (although his Figure 26 acknowledges a possible Archean protolith). Thomas and Morrison (1991), on the other hand, interpreted the gneisses both east and west of the Ingrid Group to be Archean, and, by inference to be continuous with the Nain Province. Ermanovics (1993) considered the whole of the Ingrid Group to be allochthonous, and transported eastward upon the underlying Churchill Province gneisses during early Hudsonian deformation, whereas Thomas and Morrison (*op. cit.*) imply that the Group is floored entirely by Nain crust. Recent geochronological studies of gneisses on both sides of the Ingrid Group substantiate the Thomas and Morrison (*op. cit.*) view, in that the ages indicate all the gneisses are derived from an Archean protolith (Wasteneys *et al.*, 1995), but the data also indicate a Paleoproterozoic overprint on the western terrane. The gneisses to the west of the Ingrid Group are locally characterized by mylonitic fabrics, and discrete mylonitic shear zones can be recognized as significant components within these gneisses (Ermanovics, 1993; Thomas and Morrison, 1991).

One of the problems associated with defining a major crustal break between the Nain and Churchill gneisses in the Harp Lake area is obvious from the foregoing discussion regarding those gneissic rocks abutting the Ingrid Group – they could all be of Nain parentage, or they may be Nain on the eastern side and Churchill on the western one. As noted in the foregoing, Ermanovics (1993) used the latter interpretation and defined the Nain–Churchill boundary northeast of Harp Lake as a faulted contact, marked in part by the eastern extent of the Ingrid Group and in part by juxtaposition of dyke-free mylonitic orthogneisses to the west against dyke-bearing Archean Nain Province gneiss to the east (Figure 5); the geochronological data referenced above indicate that the western gneisses are likewise Archean, but perhaps allied to the Churchill rather than the Nain. The faulted trace suggested by Ermanovics (*op. cit.*) is the one adopted by Wardle (1993) on a recent compilation map of the Harp Lake intrusion and surrounding region. Ermanovics (1993) also demonstrated that the extent of the Hudsonian metamorphic overprint on the Archean terrane east of the Ingrid Group can be well delineated in the same manner as in the Saglek–Hebron area, by the increasing secondary alteration in the Paleoproterozoic dykes of Nain Province as the Ingrid Group is approached.

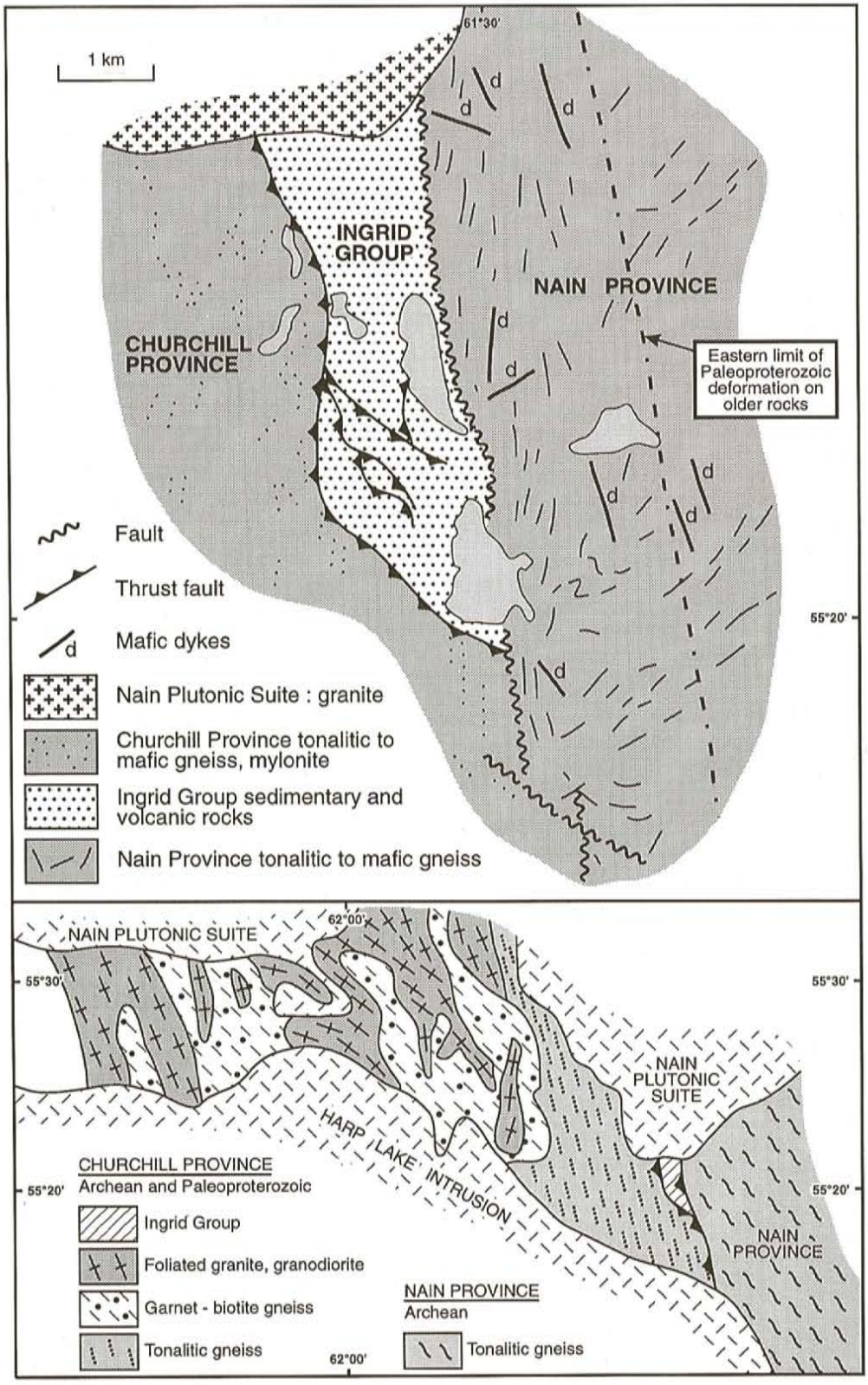


**Figure 5.** *Nain–Churchill boundary zone northeast of the Harp Lake intrusion, based on Ermanovics (1993), Thomas and Morrison (1991) and Wardle (1993). Upper panel shows the general disposition of the Ingrid Group and surrounding gneiss; lower panel is regional view of the Nain – Churchill boundary.*

## INTERPRETATION OF THE EVOLUTION AND SIGNIFICANCE OF THE NAIN–CHURCHILL BOUNDARY ZONE IN LABRADOR

Bridgwater *et al.* (1973) and Watterson (1978) were the first to propose that the Nain–Churchill boundary represented a major Paleoproterozoic strike-slip crustal suture between two cratons. Korstgård *et al.* (1987) elaborated on this proposition by defining some of the structural elements that justified this tectonic model. The most critical element of the boundary in the Korstgård *et al.* (*op cit.*) study area between northernmost Labrador and Hebron Fiord is what they termed the Abloviak transcurrent shear zone, a structural appellation applied to the zone of mylonitic rocks exhibiting shallowly plunging lineations, largely confined to the Tasiuyak gneiss between Hebron Fiord and Ungava Bay. Korstgård *et al.* (*op cit.*) noted that the thrusting and intercalation of the Ramah Group and its basement between Saglek and Hebron could not be temporarily linked to the development of the Abloviak shear, but that the overall tectonic regime suggested by the structural data was one of oblique convergence between the Nain craton and another Archean craton to the west, the latter largely reworked within the interior Churchill province. The conclusions of Korstgård *et al.* (*op cit.*) were used by Hoffman (1988, 1990) to propose that the western crustal block was probably a southeast arm or promontory of the Y-shaped Rae Province, a remnant of an Archean craton that is more widely developed in western Arctic Canada.

The geochronological data base derived from age-dating studies of the interior part of the Churchill Province (Ryan *et al.*, 1991a) verified earlier suggestions of an Archean component to the Churchill, which, along with the work of Ermanovics *et al.* (1988, 1989) and Ermanovics and Van Kranendonk (1990), provided much new data that later allowed others (see below) to provide an elaboration on the Korstgård *et al.* (1987) model for the evolution of the Nain–Churchill boundary zone. Among the important conclusions from the data referred to above are that (i) the effects of Abloviak transcurrent shearing diminish westward, (ii) the interior of the Churchill Province includes much better preserved Archean crust of probable Rae Province lineage than hitherto known, and (iii) the Tasiuyak gneiss probably developed as a clastic wedge or turbidite succession on the eastern leading edge of the Rae Province prior to its collision with the Nain Province, or it may have been accreted to the Rae Province by the convergence process (cf. Van Kranendonk and Wardle, 1994).

The whole deformational and metamorphic zone that arose from the oblique collision and subsequent uplift along the Nain–Rae (Churchill) boundary has been termed the Torngat Orogen (Hoffman, 1988). Several recent papers (e.g., Hoffman, 1988; Wardle *et al.*, 1990; Van Kranendonk *et al.*, 1993; Van Kranendonk and Wardle, 1994) have provided elegant models of the convergence and collision of the two Archean continents. The reader is referred to these papers for the detailed tectonic analyses and modelling, but the salient characteristics are summarized as follows. Prior to 1.86 Ga, the Nain and Rae continents, the former carrying the Ramah Group supracrustal rocks and the latter carrying a similar supracrustal sequence (the Lake Harbour Group), were converging across a subducting oceanic plate, with the protolith sediments to the Tasiuyak gneiss as a clastic wedge or accretionary prism on the eastern margin of the Rae Province. Collision, with its attendant metamorphism and deformation occurred at 1.86 Ga. The tectonic regime that prevailed during this collision led to a double thickening of crust on the Rae side (Rivers and Mengel, 1994). The crustal response to the doubling was varied. On the Rae side, the collision caused extensive reworking of the Rae block and the intercalation of the Rae Archean basement with its supracrustal veneer. The overriding Nain Province was subjected to frontal contraction that initiated east-directed thrusting in the Ramah Group. Sinistral translation along the collisional suture gave rise to the Abloviak shear zone between 1.84 and 1.82 Ga, the imprint of which remains as the mylonitic and subhorizontally lineated rocks along the boundary. Late contraction and uplift of the Rae crust orogenic core against Nain crust persisted until 1.74 Ga, the manifestation of this being the brittle faults and ultramylonite zones that locally mark the junction between the Nain and Churchill provinces.

## WHERE IS THE NAIN– CHURCHILL BOUNDARY IN THE NAIN–VOISEY'S BAY AREA?

Now that the varying attributes, positions and significance of the unobstructed boundary between the Nain and Churchill provinces have been addressed, it is appropriate to examine the problems encountered in positioning the boundary between Okak Bay and the Harp Lake area where the junction between the two provinces is punctured by the NPS. The rationale for the allocation between the Nain and Churchill provinces of the small septa of gneisses that occur within the NPS will be discussed. The largest such remnant of pre-NPS gneiss occurs between Voisey's Bay and Nain Bay, and is the country-rock to the Voisey's Bay sulphide-mineralized intrusion, a dyke that is postulated to have fed part of the adjacent Reid Brook intrusion (Ryan *et al.*, 1995). Also, the problems encountered with demarcating the Nain–Churchill boundary in this region will be discussed.

### VOISEY'S BAY–ANAKTALIK BROOK

The results of a geological transect from Voisey's Bay on the coast of Labrador westward to the Quebec border have

been reported by Ryan and Lee (1986) and Ryan *et al.* (1987, 1988). This is the only systematic study of the Churchill Province, among those reviewed here, to penetrate to any degree the interior part of the Churchill Province west of Tasiuyak gneiss. Some of the results of that mapping (Ryan and Lee, 1986; Ryan *et al.*, 1987, 1988; Ryan and Lee, 1989a and b; Ryan and Corriveau, 1989, Ryan *et al.*, 1991b) are particularly significant to any discussion of the establishment of the Nain–Churchill boundary in the Nain–Voisey's Bay area. Of particular interest are the following points: (i) the easternmost gneisses between Voisey's Bay and Anaktalak Bay are grey migmatites of Archean age (ca. 2843 Ma; G.M. Oliver, written communication, 1990) that are cut by mafic dykes, (ii) these eastern grey gneisses and dykes are overprinted by a Paleoproterozoic (ca. 1805 Ma) amphibolite- to granulite-facies metamorphism and deformation – including a strong, moderately to steeply plunging mineral lineation – that resulted in a laminar-style mylonitic banding locally; this general deformational style can be equated with relationships observed along the western periphery of the Nain Province in northern Labrador, and would equate with the foreland zone of Churchill Province as defined by Ryan *et al.* (1984) and Van Kranendonk and Ermanovics (1990), (iii) there are meta-anorthositic gneiss units within the eastern Archean gneisses that are comparable to those observed in the Archean gneisses of the Nain Province north of Okak, (iv) Tasiuyak gneiss, containing enderbitic gneiss units, forms a 30-km-wide belt in the area; it is severely contact metamorphosed adjacent to the NPS intrusions, and (v) it was recognized in 1986 and 1987, as mapping progressed west across Churchill Province, that many of the assumed Proterozoic gneisses of the Churchill Province west of Tasiuyak gneiss are superficially similar to the Nain Province rocks, in that they contain metamorphosed gabbroic anorthosite layers and are cut by metamorphosed mafic dykes (Ryan *et al.*, 1988; Ryan, 1990c). Subsequent geochronological data confirmed suspicions that these were Archean rocks, yielding U–Pb ages in the range of 2800 to 2600 Ma (cf. Ryan *et al.*, 1991a); these interior gneisses were considered remnants of Archean crust – the Rae Province of Hoffman (1988) – that had escaped significant Hudsonian isotopic and deformational modification.

In light of the foregoing points, how was the position of the Nain–Churchill boundary in the Voisey's Bay–Anaktalik Brook area originally delineated? Although it seemed likely from the 1985 mapping (Ryan and Lee, 1986, page 81) that Archean and Paleoproterozoic gneisses were present in the Voisey's Bay–Anaktalak Bay sector, the position of the Nain–Churchill boundary was not readily apparent. Several factors contributed to this, one of these being that the most reliable indicator of the west margin of the Archean craton, the Ramah Group, was not recognized as extending this far south. In addition, the black ultramylonite or any other indications of major faults that are locally diagnostic of the boundary in the north were not obvious in this area. Therefore, other criteria were applied to define the boundary.

Ryan and Lee (1986) recognized that there was an obvious break north of Voisey's Bay between shallowly lineated Tasiuyak gneiss and enderbitic gneiss of the Churchill Province to the west of the bay and the grey migmatite, marble- and quartzite-bearing semipelitic and metavolcanic supracrustal rocks, and gabbroic to anorthositic gneiss to the east. Therefore, it was proposed (Ryan and Lee, 1986, page 81) that the Archean–Proterozoic contact followed, in part, the sand-filled Reid Brook valley between Voisey's Bay and Anaktalak Bay (Figure 6; see also Taylor, 1977a). A visit to shoreline exposures at Anaktalak Bay by the author in 1986, to collect geochronological specimens, indicated that the rocks at the sampling locality were intruded by several mafic dykes, but the whole was subsequently mylonitically deformed and metamorphosed and had a strong, moderately plunging mineral lineation imposed upon it. The mylonitic overprint on the eastern gneisses, the deformation and metamorphism of the dykes, coupled with the well-developed mineral lineation, reinforced the earlier conclusion that this complex was Nain Province crust that had suffered a Proterozoic overprint, a situation identical to the Hudsonian "foreland zone" between Saglek Fiord and Okak Bay. Subsequent geochronological work on the gneiss and one of the metadiabase dykes from the eastern block further corroborated, as noted above, the conclusion based on field work that the southern Reid Brook valley marked a fundamental break between Archean and Proterozoic rocks.

As an allied side-discussion, it is perhaps relevant to comment on the apparent contradiction between the "provincial" designation of one of the several prominent hills in the Reid Brook valley on the original Ryan and Lee (1989a) 1:50 000-scale map versus its designation on an interim update that was issued in 1994. This difference has been questioned in several inquiries to the author. The hill in question is underlain by foliated and lineated rocks that are intruded by the sulphide-bearing dyke that hosts part of the Voisey's Bay deposit. On the original map that arose from the 1985 field work (Ryan and Lee, 1986, 1989a) the hill was interpreted as being possibly underlain by Churchill Province gneisses because a shallowly plunging lineation was noted to be present, a field criterion used at that time to separate Churchill Province from Nain Province. Subsequent petrographic work indicated considerable retrogression in the granulite-facies assemblage in this gneiss, a feature more common in the Archean rocks than in the Paleoproterozoic rocks of this area. Therefore, the gneisses were reassigned a questioned Archean age on the 1994 update. The true parentage of these rocks must await further work.

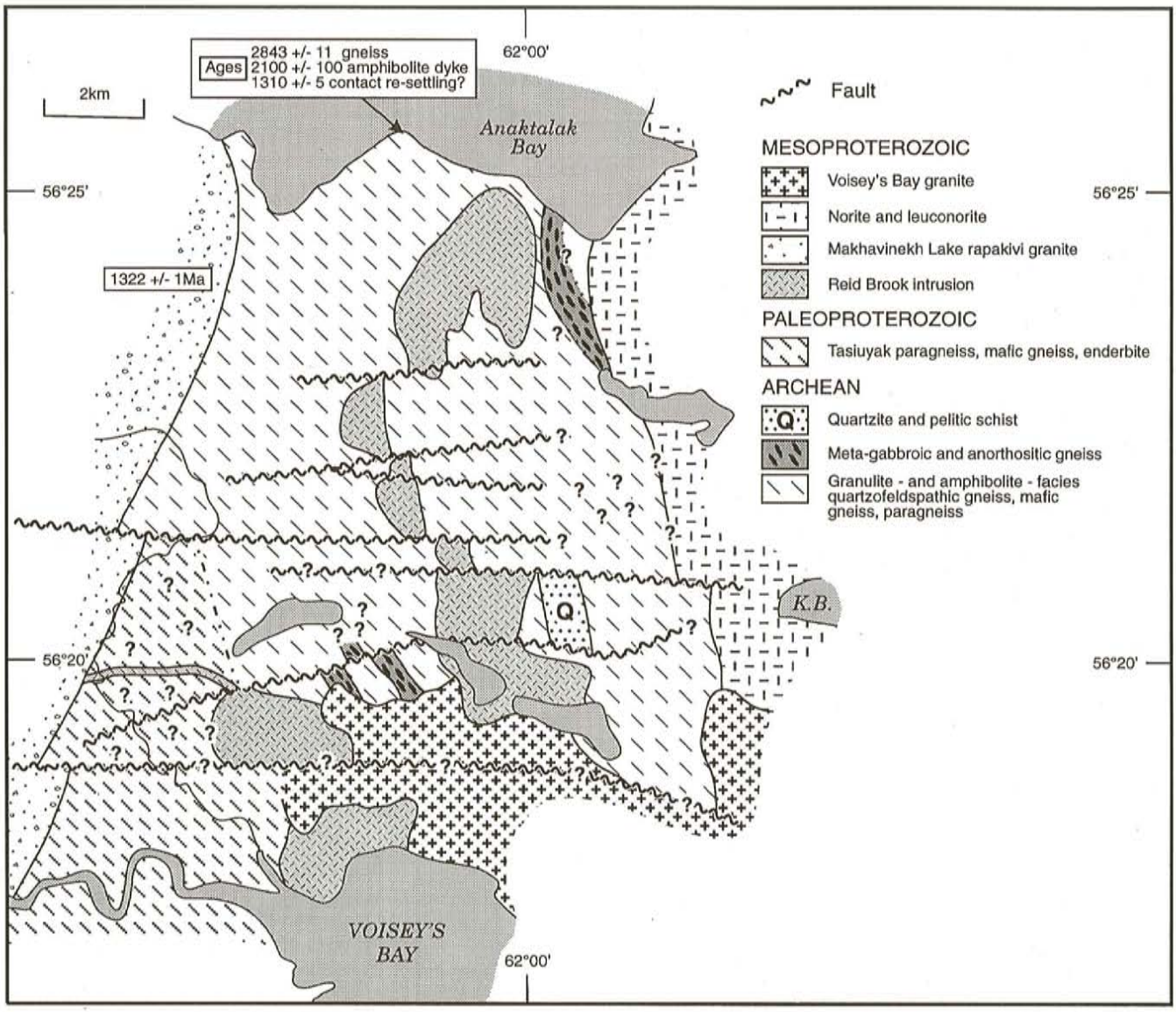


**Figure 6.** *Contact zone between Archean and Paleoproterozoic rocks in the Voisey's Bay–Anaktalak Bay sector, based on Ryan and Lee (1989a, 1995) and unpublished data of E.P. Wheeler and the author. Dot-dash heavy line is the location of the Nain – Churchill boundary proposed by Ryan and Lee (1986). K.B. = Kangeklualuk Bay. Question marks indicate uncertainty in extent and designation of a unit or feature.*

An additional contribution to the designation of Nain versus Churchill Province in the Voisey's Bay area is advanced through the following few comments. In 1990, the author conducted one short traverse from Kangeklualuk Bay west to the Reid Brook intrusion. At the westernmost extent of this traverse, a substantial outcrop area of white quartzite and mylonitic garnetiferous sillimanite-bearing biotite schists, at least 600 m wide, was mapped (Figure 6). The overall character of these rocks, like those on the Akuliakutak Peninsula north of Anaktalak Bay (see below), is reminescent of the Ramah Group. Thus, a case could be made for advocating that this Archean terrane east of the Reid Brook intrusion may retain remnants of a Hudsonian deformed Paleoproterozoic cover. On the other hand, quartzites and sillimanite schists of this type are also found as an integral part of the Nain Province Archean gneisses on several islands east of Nain (Ryan, 1991, 1992).

North of Anaktalak Bay (Figure 7) the position of the boundary was proposed by Ryan and Lee (1986, page 81; 1989) to correspond with a break in topography and a small valley across which the metamorphic grade and general character of the rocks changed. West of the valley, the rocks are predominantly granulite-facies enderbitic gneisses having a weak foliation, west of which is cordierite-bearing contact metamorphosed Tasiuyak gneisses; this distribution of rocks is akin to that of the eastern Churchill Province between Okak and Saglek. To the east of the smal l valley, the rocks are

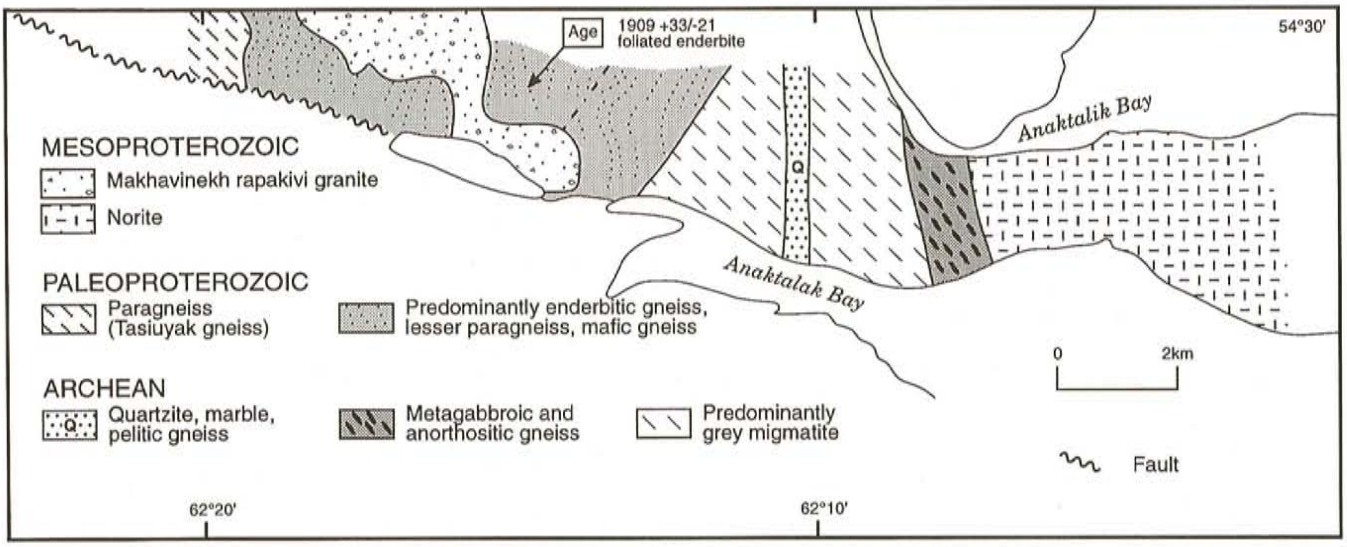


**Figure 7.** *Possible location of the junction between Paleoproterozoic and Archean rocks north of Anaktalik Bay. The thin double-dot-dash line is the location of the Nain – Churchill boundary originally suggested by Ryan and Lee (1986); the wide dot-dash line is the location suggested by Ryan and Lee (1995).*

predominantly retrogressed granulite- and amphibolite-facies grey migmatite, marble-bearing quartzitic supracrustal rocks and anorthositic–gabbroic gneiss, locally displaying a moderately to steeply plunging lineation. This latter suite of gneisses corresponds with that of the Archean rocks of the Nain Province north of Okak Bay and to the south of Anaktalak Bay as noted above. However, in spite of the presence of two apparently contrasting groups of rocks, it was obvious to Ryan and Lee (*op cit.*) that here, too, the most reliable markers for the boundary were missing, and other means were necessary to define the Archean–Proterozoic contact. Geochronological studies of the enderbitic gneiss indicated a Paleoproterozoic age, namely 1909 $^{+33}_{-21}$ Ma (Krogh and Schärer, 1987), so it is plain that the western granulite-facies gneisses are part of the Churchill Province. The case for an Archean complex in the east is less rigid; the only indicator of a probable Archean age for the eastern gneisses is the unit of (Archean?) anorthosite and metagabbroic gneiss on the Akuliakatak Peninsula. The quartzitic metasedimentary rocks that occur in the gneisses here are superficially similar to the Ramah Group of northern Labrador, but exposure precludes a firm assignment; they were considered by Ryan and Lee (1986, 1989a) to be Archean and equivalent to smaller belts of supracrustal rocks east of Reid Brook.

The apparent absence of a strong indicator of the Nain–Churchill boundary north of Anaktalak Bay prompted the author to revisit the "contact valley", in 1991, in order to re-examine the area for any diagnostic feature comparable to that seen in the north. The re-examination revealed that no major structural break could be demonstrated to be present here, and the break in topography corresponded to a retrogression of the enderbitic and noritic gneisses to amphibolite-facies assemblages, rather than a fundamental change in rock type. Consequently, the revised version (Ryan and Lee, 1995) of the original map (Ryan and Lee, 1986) depicts the Archean–Proterozoic contact as corresponding to a more prominent valley 2 km east of where the boundary had been depicted earlier (Figure 7). Even this location, however, is open to question, as is the validity of invoking the presence of a boundary at all.

Given the above observations and the comments on the Nain–Churchill boundary relationships presented in the foregoing text, it is clear that in light of later mapping some of the criteria originally used in 1985 for the field identification of Nain Province gneisses in the Voisey's Bay area were ambiguous. This is because there are Archean gneisses that are an integral part of both the eastern Churchill Province and the western part of Churchill Province that are not easily distinguished from those of the Nain Province. However, in the absence of evidence to the contrary, it is for the present, reasonable to interpret those Archean gneisses in the vicinity of the Reid Brook intrusion between Voisey's Bay and Anaktalak Bay as being of Nain Province parentage.

## NAIN BAY AREA

The positioning of the Nain–Churchill boundary from Nain Bay south to Anaktalik Brook as shown on the 1:500 000-scale colour regional map of the NPS (Ryan, 1990a) is based on a series of unpublished manuscript geological maps by the late E. P. Wheeler (see also Wheeler *et al.*, 1984) and on earlier interpretations of the geology

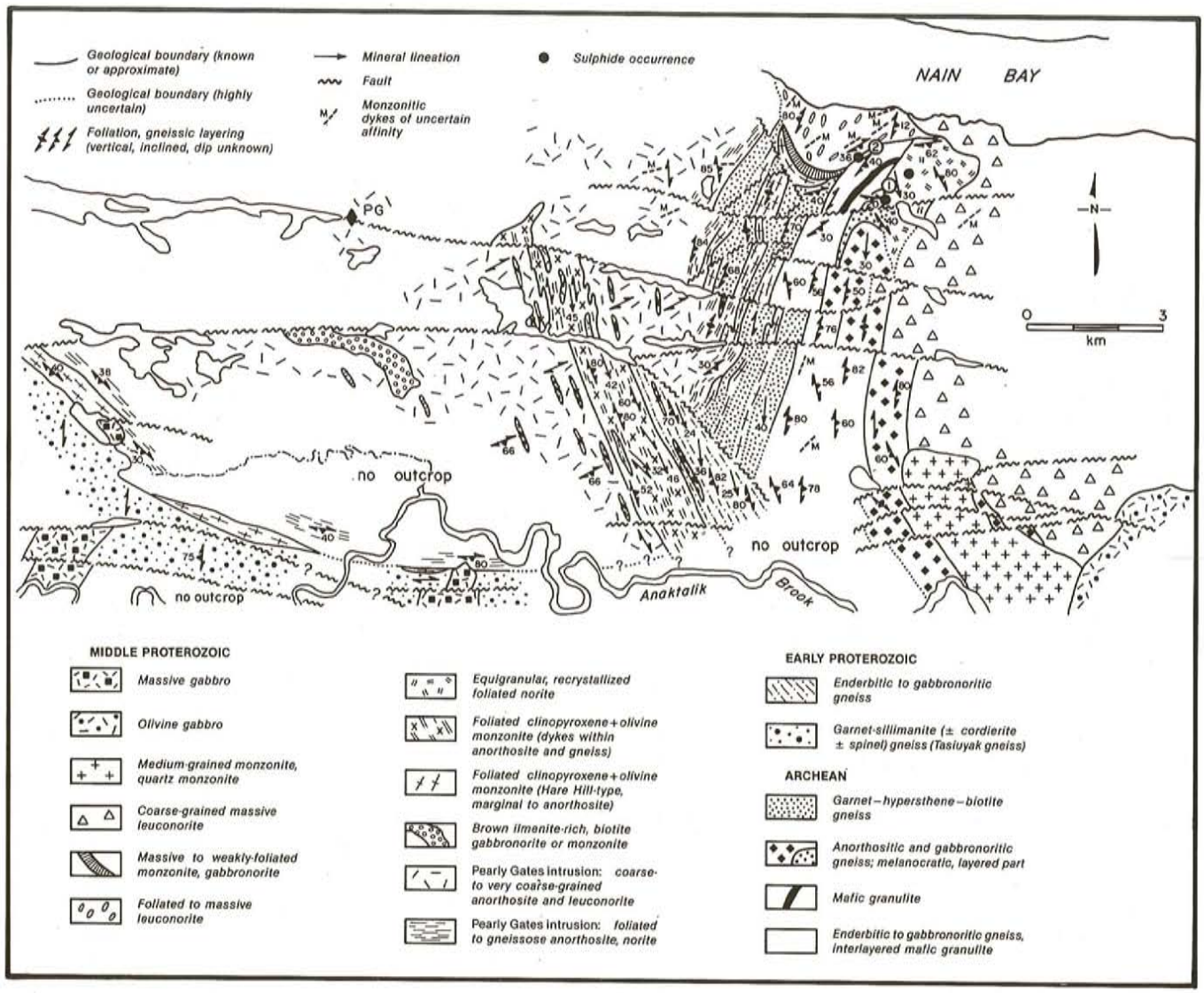


**Figure 8.** *Geology of the area south of Nain Bay, showing assumed northwest-trending fault north of Anaktalik Brook that may mark the Nain–Churchill contact (from Ryan, 1993).*

south of Anaktalik Brook by the author as outlined above. However, after an initial reconnaissance field study in the area in 1990, it became obvious that the assumptions made on the basis of Wheeler's maps were inaccurate. Hence, no firm conclusions were drawn from that field program about the boundary between the Nain Province and Churchill Province in this area (Ryan, 1991, page 263).

The Nain Bay–Anaktalik Brook sector was briefly visited again in 1991 (Ryan, 1992) and in 1992 (Ryan, 1993), during which a series of ground traverses was conducted. The preliminary map that evolved from this work (Ryan, 1993, Figure 2) showed the main lithological subdivisions in the area, but the additional field work corroborated the earlier conclusion that it is difficult to make a Nain–Churchill distinction directly south of Nain Bay because of the absence of any strong indications that such a separation between the gneissic units could, in fact, be made (Ryan, 1992, page 392). The most appropriate location for the boundary, based on the 1991 and 1992 work, would be a northwest-trending linear, interpreted to be a fault, that separates an enderbitic to gabbroic gneiss – a good candidate for a Proterozoic rock – to the southwest (Ryan, 1992, page 388), from granulite-facies migmatite, paragneiss and gabbroic–anorthositic gneiss to the northeast that may be Archean in age (Ryan, 1991, 1993, page 65). This separation (Figure 8) would correspond to the tectonic classification of gneisses south of Anaktalik Brook.

## ASSIGNMENT OF SMALL GNEISSIC SEPTA ENCLOSED BY THE NPS, AND DEFINITION OF EXTERNAL CONTACTS OF THE NPS

The designation of the "provincialism" of several small gneissic septa within the NPS between Nain and Kingurutik

Lake on the regional compilation map was, like the Nain–Churchill boundary south of Nain Bay, based mainly on Wheeler's manuscript maps. Exceptions are the belts of gneisses just west of Nain, the distribution of which is derived from the results of a thesis project carried out during the Nain Anorthosite Project (Rubins, 1973). In light of reconnaissance work that has been conducted by the author since the compilation was published, the status of some of these septa is certainly open to change.

Wheeler's maps depict a unit he referred to as "granulites of uncertain origin" (see, for example, Wheeler *et al.*, 1984). During the compilation of the Nain map in 1989, assumptions were made about these "granulites" in order to portray them with respect to adjacent rocks. It is now apparent that, in some cases, the assignment of these rocks to a pre-NPS niche was an error because subsequent examination of some of these units in the field indicates that they are simply the foliated margins of deformed NPS intrusions (cf. Ryan, 1991, page 242). This has turned out to be the case, for instance, for the north–south unit on the south shore of Kingurutik Lake. On the other hand, "Churchill Province" quartzofeldspathic granulite-facies gneisses north of Tikkoatokak Bay and contact-metamorphosed garnetiferous paragneiss south of the bay resemble units of probable Archean (Nain Province) age south of Nain Bay.

The contact between anorthosite and gneiss portrayed on the compilation map is locally in need of revision. For example, northward from Webb Bay it can be shifted 1 km eastward because the "granulites" that had been assigned to the Nain Province there, are, in fact, the eastern foliated margin of the Mount Lister intrusion. Similarly, anorthositic rocks extend farther west in the region of Kingurutik Brook; here some "granulite of uncertain origin" was assigned to Tasiuyak gneiss. Other examples of deformed NPS plutonic rocks incorrectly included with country-rock gneisses may also exist.

Thus, the portrayal of the intra-NPS gneisses on the map and the external contacts of the NPS may not reflect the true picture. However, in interpreting the NPS-marginal belts and the isolated septa of "granulites" (and gneisses) in the manner in which it was done, put them in the Nain Province or Churchill Province rather than leaving them in an "uncertain" category. Most were assigned to the Churchill Province because of their "granulite" status, a metamorphic aspect more typical of Paleoproterozoic than the Archean rocks. The exceptions are the granulitic zones within anorthosite mapped by Rubins (1973) near Nain; these were interpreted to be extensions of the Archean terrane exposed north of Webb Bay (Taylor, 1977b).

## DISCUSSION

All the above comments on the nature of the Nain–Churchill boundary northward from Harp Lake make it clear that the boundary is not strikingly apparent in the Nain–Voisey's Bay–Harp Lake sector, and, if it does coincide with any of the locations suggested, then its character is different from that seen in the Okak to Nachvak sector. It is also clear that in the absence of critical stratigraphic criteria, such as Ramah Group and the Paleoproterozoic diabase dykes, the assignment of a particular or isolated region of gneisses to the Nain or Churchill provinces is, to some degree, a "judgement call". To reiterate, even if gneisses containing metamorphosed dykes are recognized within a particular area east of Tasiuyak gneiss, it cannot be emphatically maintained that these are Nain Province rocks because the interior Churchill Province has identical characteristics where Rae Province Archean crust has not been structurally reworked. Therefore, expanses of Archean dyke-bearing and dyke-free gneissic rocks east of Tasiuyak gneiss could represent structural repetition of the Rae crust (basement to the Tasiuyak gneiss?), not juxtaposed Nain crust. A comparable dilemma arises with respect to the provincial assignment based on the presence of meta-anorthositic gneiss – these occur both in the Nain Province and the Churchill (Rae) Province. Similarly, confirmation of gneisses as being Archean on the basis of geochronological data cannot be used to delineate the extent of the Nain Province – these, too, occur in both the Nain and Churchill provinces (cf. Ryan, 1990b; Ryan *et al.*, 1991a).

Emslie and Thériault (1991), Hamilton and Shirey (1992) and Emslie *et al.* (1994) have used the isotopic signatures of Nd, Sr and Pb within the igneous rocks of the NPS to pinpoint the "ghost" junction between the Nain and Churchill provinces south of Okak. The principle involved in using this method is that igneous rocks inherit the isotopic composition of crust through which they have passed or from which they have been derived. The isotopic studies have indicated that a fundamental difference exists between the eastern NPS and the western NPS. This difference is interpreted by Emslie *et al.* (1994) to reflect the distribution of Nain and Churchill crust, and they thereby indicate the trace of this boundary between Okak and Davis Inlet as a sinuous line located up to 20 km east of the extrapolated straight-line boundary using the geological relationships described in the foregoing sections of this commentary (Figure 9). The isotopic boundary so defined implies that all the gneisses of the country-rock "inlier" to the NPS in the Voisey's Bay–Nain Bay sector belong to the Churchill Province. Ryan *et al.* (1995), cognizant of the Archean age from the gneisses of the Anaktalak Bay area, interpreted the isotopic data to indicate

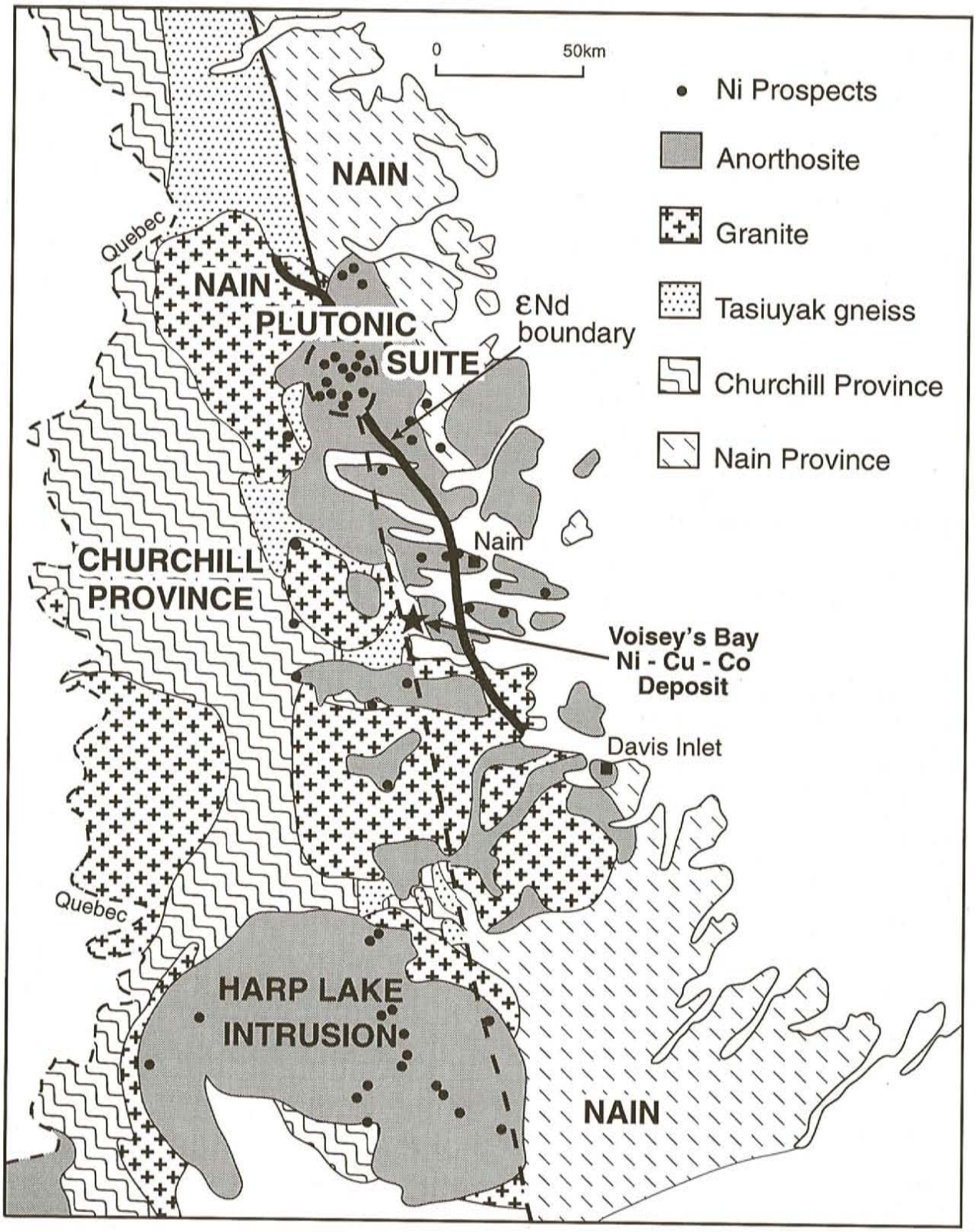


**Figure 9.** *Sinuous line through the Nain Plutonic Suite on this map indicates the Nain – Churchill boundary as determined by Emslie* et al. *(1994) based on Nd isotopic data.*

that Proterozoic crust of the Churchill Province was wedged eastward underneath the Nain Province during the collisional development of Torngat Orogen, and that the plutons were contaminated by the younger crust and acquired their Proterozoic isotopic characteristics prior to emplacement into the overlying Archean terrane. More detailed isotopic analyses, both from the tracer isotope and age-dating perspective, are needed before any further inferences can be made about the validity of either interpretation. The wedge model is attractive, however, because it can accommodate the origin of the Voisey's Bay sulphide deposit by providing Tasiuyak gneiss as a subsurface sulphur contaminant for the sulphide-hosting phase of the Reid Brook troctolite magma.

## SUMMARY

The location of the Nain–Churchill collisional boundary can be fairly well defined and positioned on structural grounds between Nachvak Fiord and Okak Bay. Southward from Okak, however, the establishment of this major tectonic feature of Labrador geology is less certain. In summarizing the response to queries regarding the reliability of assigning gneisses within the NPS as being part of the Nain or Churchill provinces, the following are pertinent.

The position of the Nain–Churchill boundary in the Voisey's Bay area, portrayed on the initial maps of Ryan and Lee (1986, 1989a), was assumed to follow, in part, a north–south-trending drift-filled valley between Anaktalak Bay and Voisey's Bay; the southern end of this valley separates Tasiuyak gneiss in the west from the Archean grey migmatites and anorthositic units (cut by deformed dykes) to the east. It was postulated that a fundamental structural break occurred here but, unlike the major ultramylonite and fault zones of the Saglek to Okak area, it was not possible to point to a particular structure that marked this junction. Another area where there appeared to be a major break in the geology is south of Anaktalik Brook. A change across a small valley from enderbitic gneisses, dated at ca. 1909 Ma, to a migmatite terrane containing a 1-km-wide meta-anorthosite unit suggested to Ryan and Lee (1986) that a break between the Nain and Churchill provinces may be present. Here again, however, there is no obvious structural feature that could be compared with the equivalent junction in northern Labrador. Regardless of the large-scale provincial designation of the rocks in the Voisey's Bay–Anaktalik Brook sector, there is no doubt that the southern Reid Brook valley marks a contact between Archean and Paleoproterozoic rocks; the outstanding problem is whether the Archean rocks have a Nain or Rae linkage.

In the Nain Bay sector, an initial distinction between Nain and Churchill rocks that was employed on the compilation map of the NPS arising from interpretation of E. P. Wheeler's maps was abandoned following a cursory examination of the area in 1991 and 1992. The position of these gneisses in the tectonic framework of Labrador is still to be resolved.

Small units of "granulite" assigned to the Nain and Churchill provinces on the 1:500 000-colour map are, in some cases, now known to be otherwise. Included among these "granulite" gneisses are rocks that are most certainly parts of foliated NPS plutons.

The isotopic data from the NPS imply that the Nain–Churchill boundary is not a sharp and generally straight junction like that mapped at the surface in northern Labrador. The isotopic signatures in the plutons imply, instead, that subsurface Paleoproterozoic rocks occur well east of the extrapolated structural contact defined on the basis of their surface distribution in the north. These data could indicate the thrust imbrication of the Archean Nain craton atop the edge of the Churchill Province, a wedging effect resulting from the collisional evolution of Torngat Orogen.

## ACKNOWLEDGMENTS

This paper is an outgrowth of the Ryan *et al.* (1995) paper on the setting of the Voisey's Bay sulphide deposit, the latter being a contribution to Nain area geology in which the authors chose not to subject the reader to a discussion of some of the regional tectonic problems that were alluded to in earlier publications. The seeds of this paper were planted at that time, and brought into bloom by the many discussions with exploration personnel during the past summer. I hope those who raised these questions in the field were sufficiently satisfied with the answers to appreciate the problems that can confront one in areas such as Nain, and will keep the comments of this paper in mind as they are examining their Labrador land holdings with respect to the tectonic framework.

I would be seriously amiss if I did not acknowledge here the personal and professional contribution that Mr. Dan Lee, my former senior mapping assistant in the Voisey's Bay area, made to my regional mapping programs in Labrador during 1982, 1983 and 1985-87. Dan initially mapped the grey gneiss complex south of Anaktalak Bay, and his observations were instrumental in determining the choice for the location of the Nain–Churchill boundary following the 1985 field season.

I thank Wayne Tuttle, Richard White and Wayne Ryder for their technical assistance, repast, and social repartee over the summer in Goose Bay. All ensured that the operations were ready to roll by the time I arrived in June, and kept the fort when I was otherwise absent.

I am particularly grateful to those explorationists in Labrador this past summer who took time from their full-speed-ahead schedule to visit me in Goose Bay or treated me to field excursions and engaged me in outcrop and evening discussions of general problems of the Nain area. Likewise, I acknowledge the interest of all those, who during the past year, phoned or contacted me otherwise about specific or alternative interpretations of the regional compilation map. I will gladly debate the options – it is dialogue that keeps us on our toes!

The final version of this commetary has benefitted greatly from the reviews and suggestions of Richard Wardle.

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