STRONTIUM AND NEODYMIUM ISOTOPIC VARIATIONS IN EARLY ARCHEAN GNEISSES AFFECTED BY MIDDLE TO LATE ARCHEAN HIGH-GRADE METAMORPHIC PROCESSES: WEST GREENLAND AND LABRADOR. K.D.Collerson[1,5], M.T.McCulloch[1], D.Bridgwater[2], V.R.McGregor[3] and A.P.Nutman[4]
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Introduction. Relicts of continental crust formed more than 3400 Ma ago are preserved fortuitously in most cratons. They provide the most direct information about crust and mantle evolutionary processes during the first billion years of Earth history. In view of their polymetamorphic character, these terranes are commonly affected by subsequent tectonothermal events. Hence, their isotope systematics may be severely disturbed as a result of bulk chemical change or local isotopic homogenization. This leads to equivocal age and source information for different components within these terranes (see for example, [1-3]). In this paper we present Sr and Nd isotopic data for early Archean gneisses from the North Atlantic Craton in west Greenland and northern Labrador which have been affected by younger metamorphic events.

Regional Geological Setting.
(1) West Greenland. The early Archean Amitsoq gneisses of southern West Greenland were first identified around the mouth of Ameralik Fjord, ca. 15 km south of Nuuk (Godthaab). In this area, both field and isotopic data document the existence of an ancient high-grade gneiss complex [4 -6]. It is important to note that late Archean tectonothermal events (3100 to 2600 Ma) in this area were characterized by amphibolite facies rather than granulite facies metamorphic conditions, and that little migmatization occurred during this time interval. To the south and east, late Archean metamorphic grade reached granulite facies at 2900 - 2800 Ma, and mid-Archean tonalitic gneisses (correlated with 3050-2900 Ma Nuk gneisses in Godthaabsfjord) as well as later Archean granitoid gneisses, are volumetrically important. However, field studies suggest that an early component (Amitsoq gneiss) is present within these polyphase gneisses [7]. Relevant aspects of the regional geology are discussed in detail by McGregor et al., [7] and Nutman et al., [8]. Isotopic data for the gneisses are discussed in the context of three regional geologic field divisions:
(i) Amitsoq gneisses from type area (northwestern Buksefjorden and outer Ameralik). In this area there is evidence of ca. 3600 Ma granulite facies metamorphism [9].
ii) Amitsoq gneisses (from Nordafar) which are continuous with those in the type area but are strongly affected by late Archean granitoid injection and variable metasomatic alteration. The late granites probably formed as a result of granulite facies metamorphism at depth.
iii) Gneisses further to the south and east (at Kangimut sangmissoq, Tinissaq and Ikerasakisup akornga) which preserve field characteristics of Amitsoq gneisses but were metamorphosed under granulite facies conditions at ca. 2900 to 2800 Ma and subsequently experienced patchy retrogression under amphibolite facies conditions. These units are not structurally continuous with the type Amitsoq gneisses to the northwest.

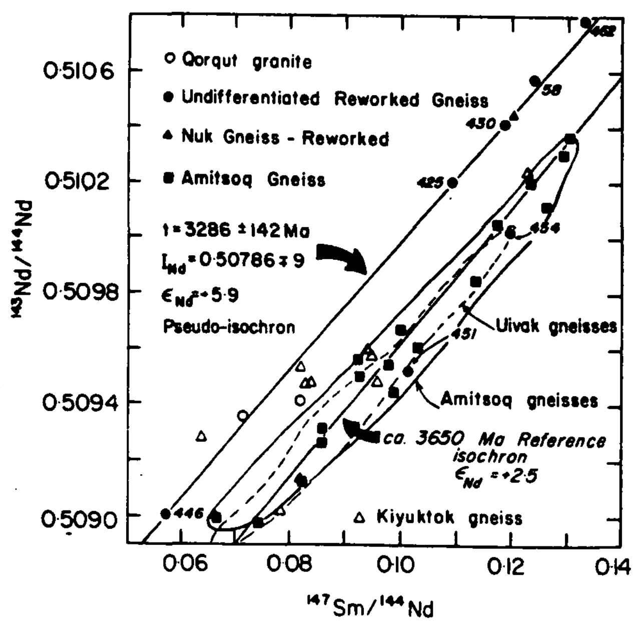
(2) Northern Labrador

The Uivak 1 gneisses and the interleaved Nulliak (supracrustal) assemblage in northern Labrador are of similar age and character to rocks described above from west Greenland [10-13]. Large areas of northern Labrador show variable effects of late Archean (ca. 2800 to 2900 Ma) granulite facies metamorphism. Early Archean relationships are best preserved on Big Island, Cape Uivak and the area immediately to the west and southwest, where late Archean metamorphic grade did not exceed amphibolite facies conditions. This is shown by Sr and U-Pb isotopic data presented in [14 & 15] . A striking feature of the early Archean Uivak 1 gneisses affected by the late Archean granulite facies event is the obliteration of early Archean fabrics by garnet and orthopyroxene porphyroblasts. This results in the development of a characteristic "blebby texture" [11] in the quartzofeldspathic gneisses. Development of this texture is associated with pervasive migmatization by granitic material. The resulting nebulitic assemblage constitutes the Kiyuktok gneisses [11]. Rocks similar to the Kiyuktok gneisses (albeit, generally strongly deformed) were recognized in west Greenland in 1984 [7]. The Kiyuktok gneisses, together with the Amitsoq gneisses discussed above, are interpreted to represent different evolutionary stages (and perhaps crustal levels) in the chemical and metamorphic differentiation of the gneiss complex in the North Atlantic Craton ca. 2800 to 2900 Ma ago.

Isotopic Data Nd and Sr isotopic data are presented in Figures 1 to 5. The following data presentation for each area is arranged in order of increasing severity of late Archean "reworking".

(1) Type Amitsoq gneisses. Sr isotopic data presented by Moorbath et al., [5] for mixed populations of Amitsoq gneisses yielded ages ranging between 3670 and 3612 Ma (recalculated using $1.42 \times 10^{-11}\ a^{-1}$ as the ^{87}Rb decay constant). Initial $^{87}Sr/^{86}Sr$ ratios (I_{Sr}) for these populations ranged between 0.7001 and 0.7015. Nd isotopic data for samples from the same area are shown in Figure 1. The data show a significant degree of scatter about the reference 3650 Ma isochron (calculated assuming that the I_{Nd} had a positive ε_{Nd}). The

Figure 1.



range in $\varepsilon_{Nd}(0)$ for the samples (ca. -28.5 to -56.4) reflects extreme fractionation in $^{147}Sm/^{144}Nd$ ratios and demonstrates their primitive character. $T_{CHUR}{}^{Nd}$ model ages range from ca. 3300 to 3680 Ma. Similar Sr and Nd isotopic variations are observed in the best preserved Uivak I gneisses [14,16-19].

(2) Uivak gneisses. Nd isotopic data for the Uivak I gneisses exhibit a range of $^{147}Sm/^{144}Nd$ values between 0.0612 and 0.1197, corresponding to $\epsilon_{Nd}(0)$ of -63.1 to -35.4. $T_{CHUR}{}^{Nd}$ model ages range from ca. 3300 to 3620 Ma. When regressed together with data for the early Archean Nulliak assemblage the total population yields an isochron with a slope equivalent to an age of 3665+/-104 Ma and an I_{Nd} of ϵ_{Nd} +2.5-/+1 [14 & 19]. U-Pb ion probe results for Uivak 1 zircon cores yield Concordia intercept and $^{207}Pb/^{206}Pb$ ages ranging from ca. 3600 to 3900 Ma [2].

(3) Nordafar. Sr isotopic data for a varied suite of 8 samples of Amitsoq gneiss from this area yield a poorly correlated isochron (Fig. 2) equivalent to an age of 3001 +193/-153 Ma with an I_{Sr} of 0.7021 -20/+17 (regressed using

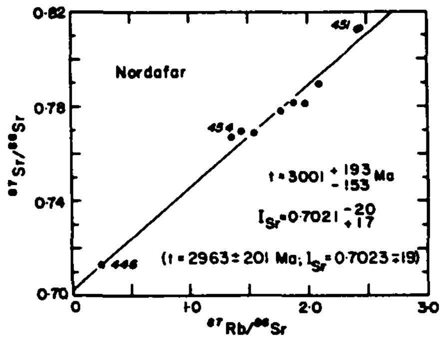


Figure 2

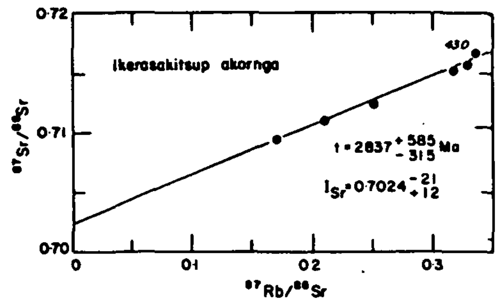


Figure 3

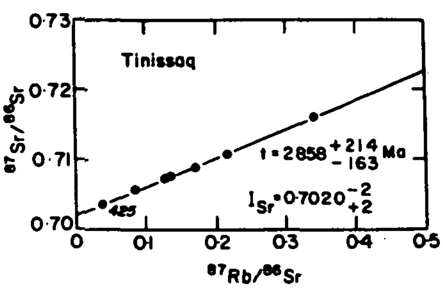


Figure 4

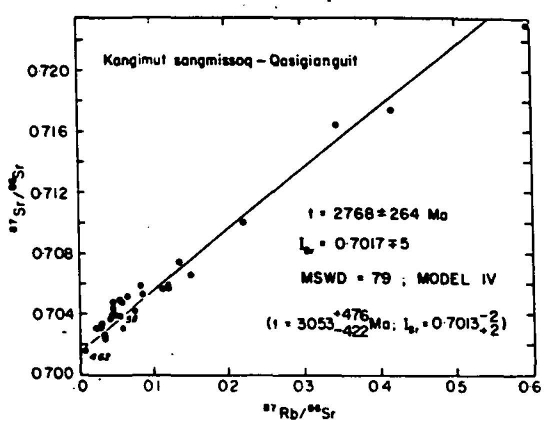


Figure 5

the method of Cameron et al., [17] and assuming partial isotopic homogenization at 1800 Ma). Nd isotopic data for three Nordafar gneisses (Fig. 1) lie within the scatter for the type Amitsoq gneisses. These samples yield $T_{Ur}{}^{Sr}$ model ages between ca. 3400 and 3200 Ma.

(4) Kiyuktok gneisses. Sr and Nd isotopic data for these rocks are discussed in [11, 14, 19-21]. The nebulitic reworked components of the Kiyuktok gneisses comprise varying proportions of old and new components. They have high I_{Sr}'s (ca. 0.7055 to 0.7081) and relatively unradiogenic Pb isotopic compositions which reflect involvement of pre-existing crust in their formation. Nd isotopic data for the Kiyuktok gneisses (Fig. 1) plot either within the Uivak 1 -

Amitsoq gneiss field or above this field, with more enriched radiogenic ^{143}Nd compositions.

(5) Ikerasakitsup akornga. Sr isotopic data for felsic gneisses from this area are shown in Figure 3. They are moderately well correlated and define an isochron with slope equivalent to an age 2837+585/-315 Ma and an I_{Sr} of 0.7024-21/+12. The large uncertainty in age results from limited dispersion in $^{87}Rb/^{86}Sr$ within the suite. Nd isotopic data for specimen (430), the gneiss from this area which gives the oldest T_{UR}^{Sr} model age (3284 Ma), is plotted in Figure 1. The T_{CHUR}^{Nd} model age of this gneiss is 2755 Ma.

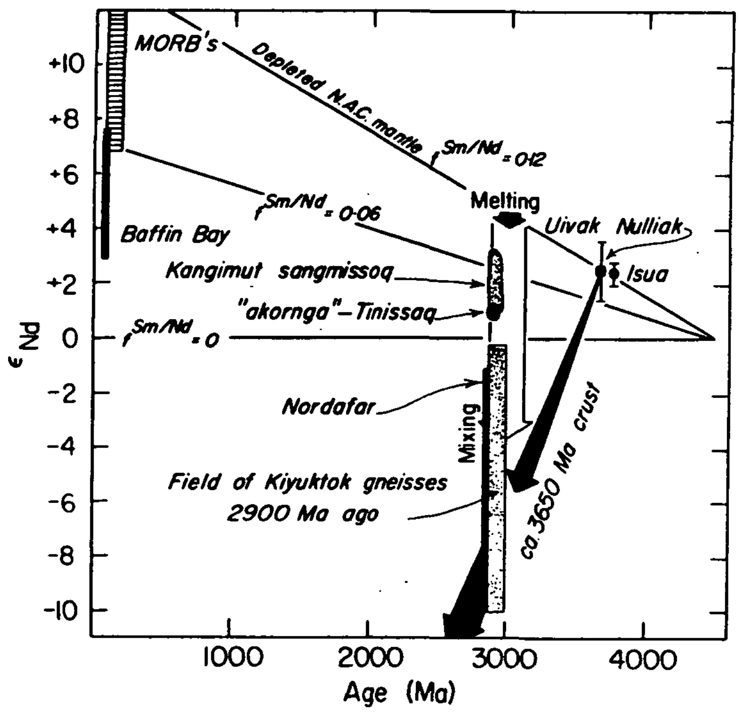
(6) Tinissaq . Gneisses from Tinissaq show greater dispersion in their $^{87}Rb/^{86}Sr$ ratios than those from Ikerasakitsup akornga and define an isochron with slope equivalent to an age of 2858+214/-163 Ma and an I_{Sr} of 0.7020-2/+2 (Fig. 4). When Rb-Sr isotopic data for the Tinissaq and Ikerasakitsup akornga populations are regressed as a regional population using the McIntyre et al., [22] method they define a Model 2 isochron equivalent to an age of 2906+/-136 Ma with an I_{Sr} of 0.7020-/+3 (MSWD = 10). Using the Cameron et al., [17] method the age is 2903+115/-103 Ma and the I_{Sr} is 0.7020-/+2. Nd isotopic data for a single specimen of felsic gneiss from Tinissaq (425) are shown in Figure 1. This specimen has a slightly more fractionated REE pattern ($\varepsilon_{Nd}(0)$ = -31.9) than the specimen from Ikerasakitsup akornga and yields a T_{CHUR}^{Nd} model age of 2821 Ma.

(7) Kangimut sangmissoq. Sr isotopic data for felsic gneisses from this locality (Fig. 5) are poorly correlated and define a McInytre et al., [22] Model 4 isochron equivalent to an age of 2768+/-264 Ma with an I_{Sr} of 0.7017-/+5 (MSWD=79). The Cameron et al., [17] treatment for the same data is also shown in Figure 5. The large uncertainty in the age reflects the influence of the large population with $^{87}Rb/^{86}Sr$ ratios less than 0.1. This depletion in Rb relative to Sr is a characteristic feature of gneisses from this locality. Nd isotopic data for two felsic gneisses are shown in Figure 1. They are less fractionated than the gneisses from the other localities and have $\varepsilon_{Nd}(0)$ values of -24.6 and -20.5 respectively. T_{CHUR}^{Nd} model ages for these samples (viz., 2625 and 2508 Ma respectively) are significantly lower than model ages displayed by the other felsic gneisses. Also presented in Figure 1 are Sm-Nd isotopic data for a ca. 2900 to 3000 Ma Nuk gneiss from Kangimut sangmissoq, which has an T_{CHUR}^{Nd} model age of 2773 Ma.

Discussion The different groups of felsic gneisses described above are considered to represent different stages in evolution of late Archean crust in the North Atlantic Craton. Sr and Nd isotopic data for most of the gneisses yield equivocal information regarding the crustal prehistory of the gneiss complex. This is particularly true when different groups are studied in isolation. Only the type Amitsoq and Uivak 1 gneisses preserve unequivocal Sr and Nd isotopic evidence of the antiquity of their protoliths. The Kiyuktok gneisses and some of the Nordafar gneisses preserve information about their crustal history in their Sm-Nd isotope systematics (see Fig. 1). However, the Rb-Sr isotopic evolution of the Nordafar gneisses differs from that of the Kiyuktok gneisses and yields no information concerning a possible crustal pre-history (cf. data for the Kiyuktok gneisses, [11 & 21]. This contrasting pattern is interpreted to reflect either variation in metamorphic grade of the early Archean protoliths of these rocks or variable enrichment in Rb during the ca. 2900 Ma metamorphic events (see Nutman et al., [8]. Gneisses at Ikerasakitsup akornga and Tinissaq have similar I_{Sr}'s to those at Nordafar (cf. Figs 2 to 4). However, unlike the Nordafar gneisses, their Nd isotope systematics show no evidence that they contain an older crustal component. Most of the Kangimut sangmissoq gneisses are significantly more depleted in Rb relative to Sr than felsic gneisses from the other areas and are characterized by less highly fractionated REE patterns. Nd isotopic data for these gneisses also show no evidence of an older crustal component.

When combined, the Nd isotopic data for Ikerasakitsup akornga, Tinissaq and Kangimut sangmissoq define a remarkably well correlated array (Fig. 1) with a slope equivalent to an age of ca. 3300 Ma and an extremely depleted ε_{Nd} (+5.9). On face value this might be interpreted as having "real age significance". However, one of the samples from Kangimut sangmissoq which plots on this line is a ca. 3000 Ma Nuk gneiss also affected by the granulite facies event. This array is therefore interpreted as a pseudoisochron; probably a mixing line without any geochronological significance. The Sm-Nd isotopic systematics of samples which fall on this array, together with the Nordafar and Kiyuktok gneisses, are interpreted to have developed during the ca. 2800 to 2900 Ma tectonothermal event. The data appear to reflect mixing between isotopically evolved Uivak and Amitsoq crust (ε_{Nd} -8 to -12 at ca. 2900 Ma) and a juvenile-like component, possibly derived from a depleted mantle source with ε_{Nd} of +4 to +6 at ca. 2900 Ma. The nature of this juvenile component or the mechanism by which the interaction occurs has not yet been established. The model is depicted graphically in Figure 6. Nd isotopic data for Tertiary

Figure 6



basalts flanking, and formed during the opening of Davis Strait, when Labrador was separated from west Greenland clearly have been derived from depleted mantle source regions. The Baffin Bay data, combined with the postulated evolutionary vector for the mantle source region of the early Archean suites, demonstrates that the mantle beneath the North Atlantic Craton would have had the appropriate depleted character at ca. 2900 Ma required by the postulated mixing process. A similar model was suggested by Collerson and McCulloch [14] for the Kiyuktok gneiss and is strengthened by the data presented for the west Greenland gneisses.

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