Early Proterozoic events

The Early Proterozoic geological events in the Fiskefjord area may be cratonic expressions of the contemporary Nagssugtoqidian, Ammassalikian and Ketilidian orogenic events at the northern and southern margins of the Archaean block (e.g. Watterson, 1978; Kalsbeek *et al.*, 1987, 1990; Chadwick & Garde, 1996). These events are peripheral to the general topic of the present paper and only an outline is presented.

Proterozoic igneous, structural and metamorphic modification of the Archaean crust at the exposed level was very limited. As elsewhere in the Archaean block of southern West Greenland several generations of mafic dykes were emplaced in the Fiskefjord area, and a contemporaneous system of wrench faults was developed. A weak regional thermal event caused resetting of epidote and biotite Rb-Sr and biotite K-Ar ages in this and other parts of the Archaean craton (Garde *et al.*, 1986 and references therein). Besides, intrusion of a few metres thick granitic dykes of continental crustal origin at Qugssuk and Isukasia north-east of the Fiskefjord area (Kalsbeek *et al.*, 1980; Kalsbeek & Taylor. 1983) indicate that stronger localised heating also occurred.

Faults

The Fiskefjord area contains a number of prominent dextral, NE- to ENE-trending faults and a few conjugate sinistral, WNW-trending faults which are best developed in the eastern part of the area (Fig. 82). The faults are Early Proterozoic in age; they are younger than the earliest, *c.* 2200 Ma old, N–S trending high-Mg and related dykes (Bridgwater *et al.*, 1995; Nutman *et al.*, 1995) which they offset, approximately contemporaneous with NE-trending MD dykes, and apparently older than the *c.* 2085 Ma old granitic dyke at Qugssuk (see p. 87).

The largest fault is the NE-trending Fiskefjord fault with a dextral displacement of *c.* 5 km in the outer part of Fiskefjord. The displacement diminishes towards north-east, and at the head of the fjord the fault dissolves into a conjugate system of smaller NE- and WNW-trending dextral and sinistral faults (Garde, 1987); their senses of displacement indicate that the maximum stress vector had an approximately E–W orientation. Towards Taserssuaq a new dextral fault reappears along the line of the Fiskefjord fault and probably continues under the lake and the glacier Sermeq north-east of the Fiskefjord area (Garde, 1987). At outer Fiskefjord the Fiskefjord fault is accompanied by several smaller faults north of the fjord with maximum displacements of about 1–2 km (Berthelsen & Bridgwater, 1960; Garde, 1989b). Along these faults and a similar fault south of the fjord ductile deformation has locally taken place with the development of a few metres thick zones of flaggy, variably chloritised rocks. Other NE-trending faults occur, e.g. north of Tovqussap nunâ and east of Qugssuk; also in these areas lateral displacement of mafic marker horizons in the country rocks suggest dextral fault movement in the order of 1 km.

Most of the Proterozoic faults are bounded by narrow zones up to a few tens of metres wide, where movement of hydrous fluids has caused low-temperature retrogression with growth of chlorite and muscovite, oxidation of iron sulphides and reddening of feldspar.

Mafic dykes

Berthelsen & Bridgwater (1960), Bridgwater *et al.* (1985, 1995), Hall *et al.* (1985) and Hall & Hughes (1986, 1987) have published detailed field and geochemical accounts of mafic dykes in the southern Sukkertoppen, Isukasia and Fiskefjord areas. The dykes comprise several groups. An older N–S trending group of high-Mg and related dykes (Appendix 12) predates the main period of faulting (this group apparently also includes some NE-trending dykes listed in Appendix 13; Hall & Hughes, 1987). Two younger tholeiitic groups trending *c.* 050° and 085° (Appendix 13) are contemporary with, or postdate faulting and belong to the tholeiitic 'MD' dykes of southern West Greenland ('MD' for metadolerite, Rivalenti, 1975; Bridgwater *et al.*, 1976). One of the earliest dykes, the N–S trending Påkitsoq dyke through Tovqussap nunâ (Berthelsen & Bridgwater, 1960), has been dated at 2110 ± 85 Ma by the whole-rock Rb-Sr method (Bridgwater *et al.*, 1995), and an early, likewise N–S trending high-Mg dyke from the adjacent Isukasia area has yielded a SHRIMP zircon U-Pb age of 2214 ± 10 Ma (Nutman *et al.*, 1995).

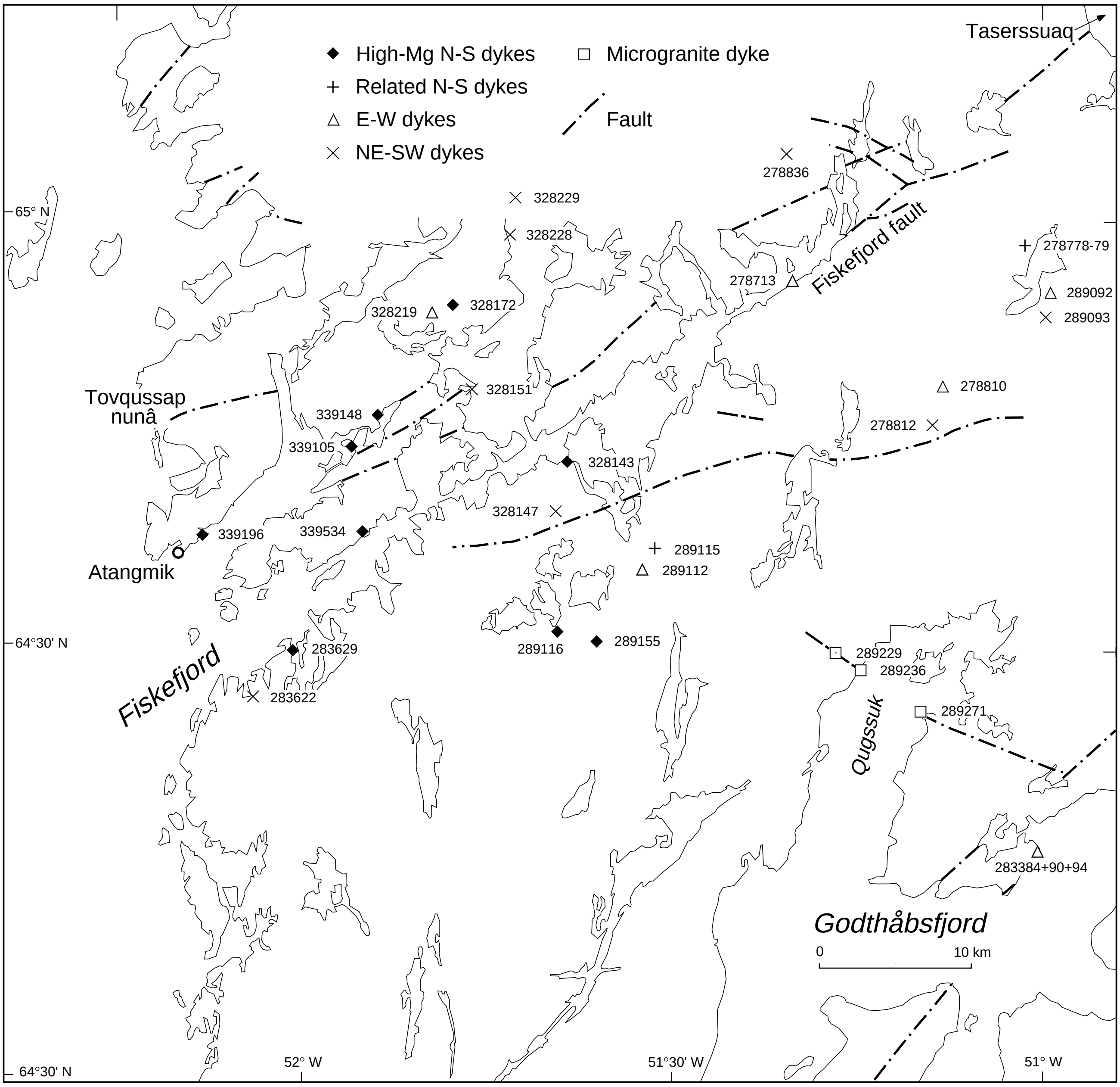

Fig. 82. Proterozoic faults in the Fiskefjord area, and locations of analysed samples of Proterozoic dykes.

The high-Mg dykes were first described by Berthelsen & Bridgwater (1960). Geochemical, mineral-chemical and isotopic data from these dykes have been published by Bridgwater *et al.* (1985, 1995), Hall *et al.* (1985) and Hall & Hughes (1986, 1987). Additional, previously unpublished major and trace element analyses of high-Mg and tholeiitic dykes in the Fiskefjord area are listed in Appendix 12 with accompanying sample localities in Fig. 82; the dykes themselves are shown on the Isukasia and Fiskefjord 1:100 000 scale maps (Garde, 1987, 1989b). Several of the new analyses come from new sample localities of dykes described in previous contributions, or they were collected from presumed continuations *en echelon* of previously described dykes.

Most of the dykes consist of variably altered pyroxene and plagioclase and have doleritic textures and tholeiitic compositions, but several of the N–S trending ones are olivine- or orthopyroxene-bearing or both and boninitic to noritic in composition, with up to 21% MgO, high Cr and Ni, high Mg/Fe ratios, and also relatively high silica contents (Appendix 12; Hall & Hughes, 1987; Bridgwater *et al.*, 1995). In addition to several high-Mg N–S trending dykes Appendix 12 also contains analyses of two N–S dykes from the central and eastern parts of the Fiskefjord area with SiO_2 contents of *c.* 56.5 % and MgO contents of only *c.* 5–6 %. In spite of their low MgO contents both of these dykes probably belong to the high-Mg series. The dyke sampled north-west of Usuk, which probably represents a southern continuation of the Aornit dyke (Berthelsen & Bridgwater, 1960; Hall & Hughes, 1987) has 1–2 mm grains of composite pigeonite-augite primocrysts (like those previously described from the high-Mg group of dykes) and strongly zoned plagioclase laths with albitic overgrowths, from which microcline has been exsolved. The other sample is very fine grained but likewise mainly consists of primary pigeonite-augite and plagioclase. Compared with the tholeiitic E–W dykes both dykes have higher K_2O, Na_2O, Ba, Sr and Rb contents, and lower TiO_2 and FeO* contents, like the high-Mg dykes themselves.

The high-Mg dykes only rarely show evidence of interaction with their local wall rock, and for this and other reasons Hall & Hughes (1987) argued that they represent a distinct boninitic magma type and were derived from depleted harzburgitic mantle which had been metasomatised in the Late Archaean prior to melt extraction. Contrary to this interpretation Bridgwater *et al.* (1985, 1995) suggested that the high-Mg dykes were derived from a primitive high-magnesium magma, which was contaminated shortly before dyke emplacement with components selectively extracted from the lower crust. In this context it is interesting to note that post-kinematic Archaean diorites south of outer Fiskefjord have most likely obtained their apparent boninitic character by strong contamination with wall rock orthogneiss (see previous section and Garde, 1991), which may lend support to the second of the above interpretations of the origin of the high-Mg dykes by Bridgwater *et al.* (1985, 1995).

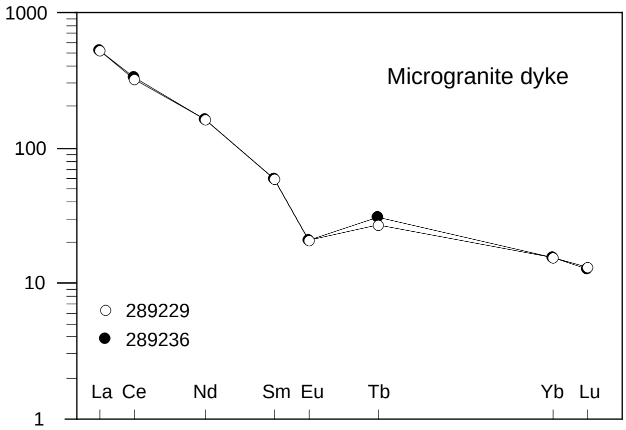

Fig. 83. Chondrite-normalised REE diagram (using normalisation constants by Nakamura, 1974) of microgranite dyke north-west of Qugssuk. The LREE enrichment is interpreted as inherited from a source of Archaean grey gneiss; note the negative Eu anomaly, which suggests retention of plagioclase in the source.

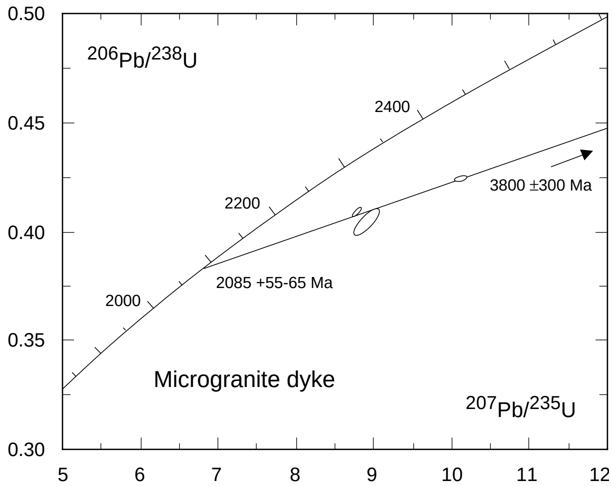

Fig. 84. U-Pb concordia diagram, microgranite dyke north-west of Qugssuk. Analyst: B. T. Hansen. See discussion in the main text.

Microgranite dyke at Qugssuk

An up to *c.* 5 m thick and apparently *c.* 8 km long microgranite dyke occurs in the Qugssuk area with outcrops on both sides of the fjord; the dyke is homogeneous and fine grained, with a pale greenish grey colour. It was emplaced along a WNW-trending Proterozoic fault which has a maximum sinistral displacement of *c.* 800 m (Garde, 1989b) and is probably related to the above mentioned conjugate fault system. The dyke itself is not visibly affected by faulting and is probably younger, having exploited the weak zone of the fault during its emplacement. It consists of microporphyritic biotite, plagioclase, microcline and pseudo-hexagonal quartz set in a very fine-grained matrix of the same minerals and abundant accessory sphene and epidote, besides apatite, zircon and iron oxide. The *c.* 0.5 mm large pseudo-hexagonal quartz crystals commonly contain euhedral plagioclase and apatite inclusions; microcline forms subhedral, partially resorbed laths 0.5–3 mm long with inclusions of small euhedral quartz and plagioclase grains.

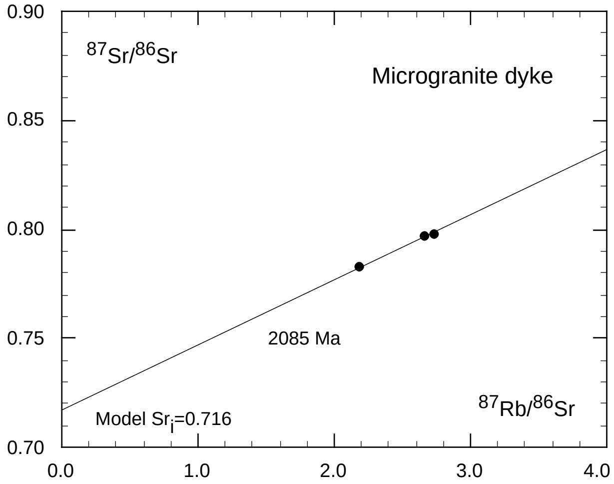

Fig. 85. Rb-Sr isochron diagram, microgranite dyke north-west of Qugssuk. The three samples, which all have high $^{87}Sr/^{86}Sr$ and $^{87}Rb/^{86}Sr$ ratios, plot along a reference line of 2085 Ma (zircon age, Fig. 84); the model initial $^{87}Sr/^{86}Sr$ ratio of *c.* 0.716 indicates an Archaean continental crustal source (the grey gneiss).

Table 9. Rb-Sr whole rock data, microgranite dyke at Qugssuk

	Rb ppm	Sr ppm	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
Microgranite dyke				
289231	256	275	2.7367	0.7979
289237	255	280	2.6633	0.7968
289271	217	291	2.1822	0.7833

See also Fig. 85. Analytical methods as described by Garde *et al.* (1986); the precision of Rb/Sr measurements is within *c.* 1% (2σ), and of $^{87}Sr/^{86}Sr$ measurements better than 0.0002 (2σ).

Chemical compositions of three samples collected on either side of Qugssuk (Appendix 12) are very similar. The samples are true granites strongly enriched in both LIL trace elements and REE; compared to the nearby Archaean Qugssuk granite (Appendix 10) their concentrations of several of these elements are much higher. A REE spectrum from the dyke (Fig. 83) shows that the REE are strongly fractionated; in this respect the microgranite resembles the Archaean country rock grey gneiss and adjacent granitoid rocks (Figs 62, 75), but it has a strong negative Eu anomaly (see below).

A conventional U-Pb zircon discordia age with a lower intercept of 2085 $^{+55}_{-65}$ Ma (B. T. Hansen, personal communication, 1990; Fig. 84) was obtained from euhedral, less than 100 μm long zircon crystals, which were extracted from several small samples collected at two adjacent outcrops of the dyke north-west of Qugssuk. The age is not very precise and the upper intercept of the discordia line at 3800 ± 300 Ma may not have geological significance; the data points might also support a line with an upper intercept of *c.* 3000 Ma.

Three samples collected at both sides of the fjord were analysed to determine the Sr isotopic composition of the dyke (Table 9). The three samples all have high $^{87}Sr/^{86}Sr$ and $^{87}Sr/^{86}Sr$ ratios (Fig. 85), and a model initial $^{87}Sr/^{86}Sr$ isotopic composition of *c.* 0.716 at 2085 Ma was estimated using the zircon age as reference. This relatively high initial $^{87}Sr/^{86}Sr$ ratio indicates that the dyke probably originated as a partial anatectic melt from a source of Middle Archaean orthogneiss. The enrichment of LIL and REE elements, as well as the strong negative Eu anomaly, furthermore suggest that only a small degree of partial melting took place; the strong fractionation between LREE and HREE (Fig. 83) is interpreted as inherited from the Archaean source. Within error the zircon age indicates that the microgranite dyke was intruded contemporaneously with the regional episode of MD dyke emplacement. It is considered likely that the local heat source necessary to achieve the crustal melting was a mafic or picritic magma related to this episode.