K-Ar ages of Basaltic rocks collected during a traverse of the Frans Josef Land Archipelago (1895–1896)

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Age determinations for rock samples collected by Fridtjof Nansen during his trans-Arctic expedition from 1893–1896 have yielded additional information on the tectonic chronology of the Arctic Basin. The data suggest pulses of volcanic activity in the Frans Josef Land Archipelago with approximate averages of 120 ma and 135 ma. These ages are consistent with postulated opening dates for the western Arctic and thus suggest that initial volcanism affected the entire Arctic margin.

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In light of the upcoming centennial for the unique Fram trans-Arctic Ocean expedition (1893–1896) it was thought appropriate to present results of analyses of material gathered during this epic scientific endeavor (Nansen 1900). These data cast new light on the timing of major geologic events during the creation of the Arctic Basin.

The Frans Josef Land Archipelago is situated in the north-eastern part of the Barents Sea (Fig. 1) (Dibner 1970). The archipelago was discovered in 1872 by two young members of the Austrian-Hungarian expedition, Navy Lieutenant Karl Weyprecht and Army Lieutenant Julius Payer, who sailed into the Barents Sea. Their objective was to investigate the famous German geographer Petermann's claim of a relatively ice free approach to the North Pole in this part of the Arctic Ocean. Petermann's theories were not substantiated, but the two Austrians discovered the archipelago of Frans Josef Land, part of which they mapped (Weber & Roots 1988). From 1894 to 1897 the English expedition of F. Jackson studied the archipelago (Vakor 1970). Fridtjof Nansen and Hjalmar Johansen too in this time frame collected rock samples during their return from attempting to reach the North Pole. It is their rock samples which form the basis for this report.

The islands of Frans Josef Land are composed of mainly Mesozoic sedimentary and volcanogenic deposits. They are represented by marine sediments of Carnian age and by an essentially continental coal-bearing succession assigned to the Norian of the upper Triassic, middle to upper Jurassic deposits of silty-argillaceous, partly calcareous, flint and quartzite sands and marine sandstone deposits. In Frans Josef Land the Cretaceous is represented by a sedimentary-effusive succession consisting mainly of basalts, tuffs, and partly of sediments of continental origin. The younger strata of near shore marine origin belong to the Cenomanian of the lowermost Upper Cretaceous. The Cretaceous as well as the older Mesozoic formations of the archipelago contain sills and cross-cutting intrusions of dolerites and gabbro-dolerites (Table 1). The Mesozoic sequences are thought to overlie middle Carboniferous limestones and dolomites (Dibner 1970). Traces of development of assumedly lower Carboniferous coal-bearing strata are known in the archipelago (for recent review see Bailey & Brooks 1988).

Soviet scientists (Tarachovskij et al. 1983) recently have reported the results of a drill hole in the western part of the archipelago (Fig. 1). The drill hole penetrated a succession of early Cretaceous basalts overlying older sedimentary rocks of Mesozoic to Paleozoic age which in turn overlie an upper Proterozoic folded metamorphic sequence. The early Cretaceous basalts were found to a depth of 283 m and were dated by K-Ar methods at 120 ± 8 ma. The Mesozoic-Paleozoic

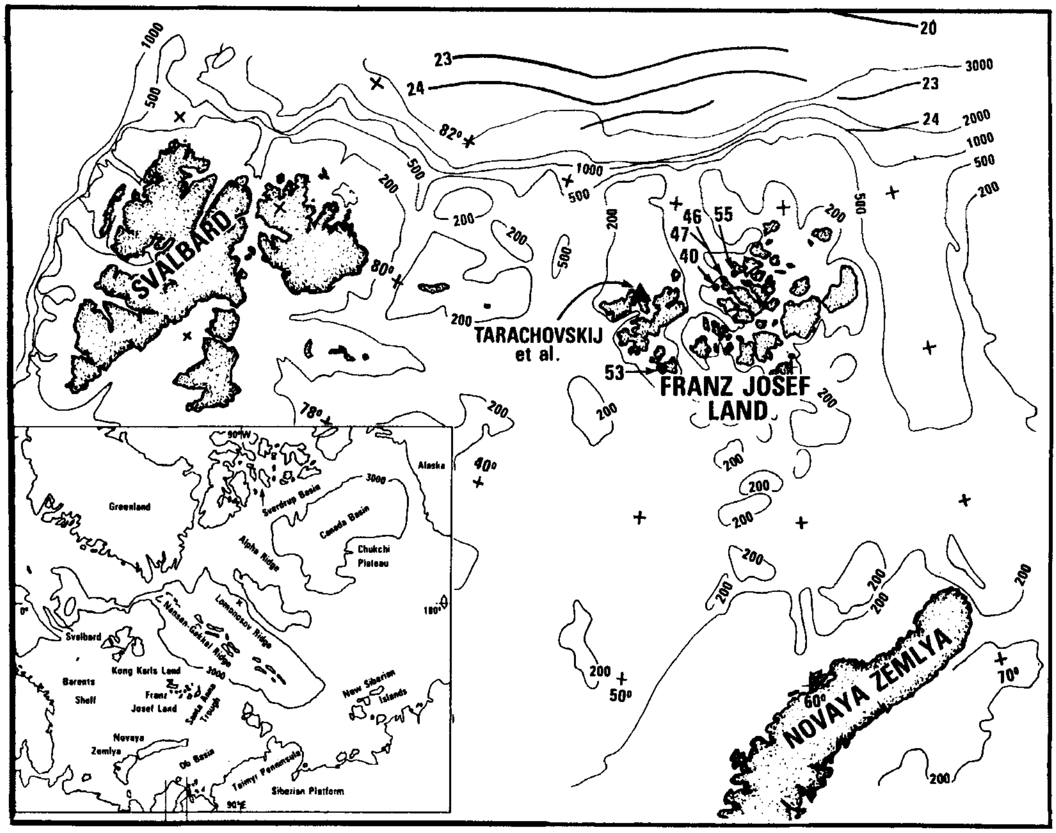

Fig. 1. Location chart. Magnetic anomalies from Vogt et al. (1979b), anomaly 24 is dated 56 MYBP, 23 at 54 MYBP and 20 at 45.5 MYBP (Kent & Gradstein 1986). Soviet drill site (Tarachovskij et al. 1983) is indicated by a triangle. Nansen samples are denoted by filled in circles. Insert map shows other features mentioned in the text.

sequences contained a series of dykes ranging from quartzose gabbro-dolerites with ages ranging from 94 ± 7 to 203 ± 14 ma (Table 1).

Magnetic lineations identified as sea floor spreading anomalies are shown on Fig. 1 and these data yield crustal isochrons. The oldest positive lineation that can be identified with certainty in the Eurasian Basin as in the Norwegian-Greenland Sea is anomaly 24. Possibly, spreading began during the reversed period before anomaly 24. Another lineation, both at the base of the Lomonosov Ridge and just north of the Barents continental margin, has been reported by Vogt et al. (1979a, b). This suggests that spreading may have begun as early as the Cretaceous-Tertiary boundary (Fig. 1). However, there is growing evidence from the Ob Basin area which suggests much earlier phases of spreading, traceable back to early Triassic (Fig. 1) (Khain 1987; Aplonov 1987).

Data

The ages from the Soviet study can be grouped into several units (Table 1, Fig. 1). Five of the samples including the uppermost palagonitic basalt can be averaged to about 120 ma. Four samples center around 140 ma. This latter grouping is chronologically close to a 135 ma Arctic volcanic pulse described by Progrebitsky et al. (1984) and a cluster of 140 ma dates from eastern Svalbard described by Burov et al. (1977).

The Fram expedition collected numerous rock samples from the Arctic, including Frans Josef Land, and one from the Taimyr Peninsula (Table 2, Fig. 1) which have been dated. Sample 9 (Table 2) is from a dyke striking 070°, collected on the Taimyr Peninsula. It comes from a region of riftogenic troughs and grabens filled by sediment related to Late Permian to Mesozoic extension of the crust marking the inception of the West

Table 1. Absolute age of traps of Frans Josef Land.

Number of sample (depth of sampling)	Interval of location of intrusion (m)	Rocks	Absolute age (mill. years)
49.2	0–283	Palagonitic basalts	120 ± 8
1249.3	1244–1256	Glassy dolerite	103 ± 7
1359.4	1355–1376	Quartzose gabbro-dolerite	151 ± 11
1840.0	1824–1862	Quartzose gabbro-dolerite	138 ± 10
1985.7	1895–2035	Quartzose gabbro-dolerite	132 ± 9
2060.3	2052–2070	Quartzose dolerite	139 ± 10
2198.6	2129–2247	Quartzose gabbro-dolerite	112 ± 8
2416.3	2409–2440	Quartzose gabbro-dolerite	192 ± 13
2607.7	2554–2662	Quartzose gabbro-dolerite	115 ± 8
2683.4	2662–2746	Taxitic gabbro-dolerite	125 ± 7
2085.8	2746–2860	Leucogabbro-dolerite	94 ± 7
2864.8	2860–2910	Quartzose dolerite	112 ± 8
2930.6	2915–2848	Quartzose gabbro-dolerite	170 ± 12
3200.4	3160–3202	Quartzose gabbro-dolerite	203 ± 14

After Tarachovskij et al. 1983.

Siberian Basin (Green et al. 1984) and, if Khain (1987) and Aplonov (1987) are correct, from a region displaying effects of early Triassic spreading. The date of 256 ± 9 ma is consistent with both these possibilities and with the extensive Upper Permian to Middle Triassic Siberian trap province (Gusev 1979).

Samples 40, 46, 47, 53 and 55 are from various localities throughout the Frans Josef Land Archipelago (Table 2, Fig. 1). Samples 47, 53 and 55 lie close to the 135 ma group noted in the Soviet data (Progrebitsky et al. 1984), and samples 40 and 46 can be interpreted to belong to the 120 ma group from Table 1.

Table 2. K-Ar ages of basaltic rocks from the Frans Josef Land Archipelago and Taimyr Peninsula, collected by Fridtjof Nansen on his first Fram expedition 1893–1896.

Sample no.	Location	Rock description	% K	Average 40Ar, ppm	40Ar/40K	Age
9	On Eastern Taimyr Peninsula, Soberoa 77° 2′N, 103°50′E	biotite bearing microlitic basaltic glass	3.456	.06586	.01598	256 ± 9 ma
40	Goose Island, facing Cape M'Clintock	olivine bearing alkaline basalt	0.908	.007532	.006955	116 ± 6 ma
46	Jackson's Cape M'Clintock Solsberi Island	tholeiitic dolerite	0.073	.000568	.006529	109 ± 11 ma
47	Jackson's Cape M'Clintock Solsberi Island	quartz bearing tholeiitic dolerite	0.134	.001402	.008818	145 ± 9 ma
53	Cape Flora, south-western Peninsula of Northbrook Island	tholeiitic basalt	0.091	.000835	.007661	128 ± 10 ma
55	Winter Hut, Frederick Jackson's Island	microlitic glassy basalt	0.783	.007603	.008144	135 ± 6 ma

Data partially from Mineralogisk-Geologisk Museum, Oslo, pers. comm. Inge Bryhni 1978. Samples presented here were selected on the basis of chemical and petrographic criteria for freshness. Values for K and ^{40}Argon are the averages for 2 to 3 measurements.
Constants used:

$\lambda_\beta = 4.962 \times 10^{-10}$/year

$(\lambda_e + \lambda'_e) = 0.581 \times 10^{-10}$/year

$^{40}K/K = 1.193 \times 10^{-4}$ g/g

Discussion

Oceanic basins are created by tensional forces often with concomitant volcanism and rifting of which the Arctic Ocean is a typical example (Green et al. 1984).

Volcanism as noted by Green et al. (1984) started with the Late Permian-Mesozoic extension in the Siberian crust, of which the Siberian plateau basalts are a spectacular example. Sample 9 is from this province (Table 2). The Ob (Western Siberian) Basin (Fig. 1) is presently interpreted to have been formed as the result of seafloor spreading from the Kara Sea southwards, accompanied by very strong Triassic volcanism. It appears highly probable that a late Jurassic–early Cretaceous incipient, perhaps discontinuous, rift zone extended north of the Ob Basin (Aplonov 1987; Rudkevič 1987) to the present Sverdrup Basin (Balkwill & Fox 1982). Sverdrup Basin ages range from 152 ma to 123 ma (Balkwill & Fox 1982; Osadetz & Moore 1987) which are not dissimilar to the Frans Josef Land ages, suggesting that they may be part of the same episode reflected in western Siberia by major phases of rejuvenation of the Ob Basin, which is over 2,000 km long. Additionally, Lower Cretaceous basalt flows and doleritic dykes, of a tholeiitic type, are common on the islands of Kong Karls Land and very common on Spitsbergen, Nordaustlandet, Barentsøya, Edgeøya (Harland 1973; Burov et al. 1977; Prestvik 1978; Birkenmajer 1981) and in Frans Josef Land. In Frans Josef Land basalt flows were extruded in a similar stratigraphic setting to the Isachsen Formation of the Mesozoic Sverdrup Basin (Nalivkin 1973). Analyses of these rocks (Tyrrell & Sandford 1933) indicated that they are also iron-enriched tholeiitic basalts, quite similar to the Canadian Lake Hazen flows (Osadetz & Moore 1987). Harland (1973) and Osadetz & Moore (1987) have suggested that this igneous activity was related to initial rifting parallel with the initial spreading that created the Canada Basin. Reconstructions (Green et al. 1984) indicate that northern Ellesmere Island, northern Greenland and Svalbard formed coterminous blocks. Volcanic activity was also occurring at this time in the northern New Siberian Islands (Vol'nov 1975; Vol'nov et al. 1970; Green et al. 1984). The 135–140 ma pulse in our data and that of the Soviet scientists is consistent with the above and may well be a reflection of tectonism associated with a new phase of rifting and continental breakup. The Santa Anna shelf valley may be a reflection of this rifting (Fig. 1).

The volcanic ages would suggest another pulse at approximately 120 ma (see Green et al. 1984) with active sea floor spreading commencing in the western Arctic (Taylor et al. 1981). This increased volcanism at 120 ma is well established on a global scale (Campsie et al. 1984 and references therein). Green et al. (1984) postulated that a thinned and intruded continental fragment (Alpha Ridge) was rifted away from the Barents Platform during Middle Cretaceous (90–115 ma). As noted by Sweeney (1985) the Canada Basin appears to have formed over a 60 ma interval during the Cretaceous period. The opening process of this basin can be divided into three phases: 1) still poorly known early Triassic phase; 2) continental breakup, widespread in Hauterivian through Aptian time (about 131–113 ma ago) along what was about to become the polar margin of North America; 3) seafloor formation during the extended Cretaceous interval of normal geomagnetic polarity to marine magnetic anomaly 33 time (about 118–79 ma ago). The grouping of volcanic dates around 120 ma may support this hypothesis or be related to an early rifting associated with the present spreading center in the eastern (Eurasian) Arctic. The present Mid-Ocean (Nansen-Gakkel) Ridge formed orthogonal to this trend as it rifted Lomonosov Ridge from the present Barents Shelf about 60 ma (Vogt et al. 1979a, b).

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