REMANENT MAGNETIZATION OF TWO INTRUSIVE BODIES IN SOUTHEASTERN FINLAND

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Direction of natural remanent magnetization (NRM) was measured for a diabase from the intrusive contact of rapakivi granite (1650 Ma) and for a granodiorite intrusion (1810 Ma). The results, although statistically poor, suggest that the apparent polar wandering curve drawn earlier for the Middle Precambrian of Fennoscandia from about 2000 to 1200 Ma is correct and not caused by differences in uplift rates.

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Introduction

The direction of natural remanent magnetization of several Middle Precambrian dike systems (Neuvonen 1965, 1966, Neuvonen and Grundström 1969) and intrusive bodies (Cornwell 1968, Priem *et al* 1968, Neuvonen 1970, Pesonen and Stigzelius 1972) was determined. In accordance with these measurements a paleomagnetic apparent polar wandering curve for the Fennoscandian shield was constructed from about 2 000 Ma to 1 200 Ma (Neuvonen 1973). Later studies (Poorter 1975, Abrahamsen 1977, Magnusson and Larson 1977) have confirmed the curve to be essentially correct.

There are two questions, however, which are not adequately answered in drawing the curve. First, the direction of the natural remanent magnetization of rapakivi granites (1630—1670 Ma old according to Vaasjoki 1978), so dominant in the evolution of Precambrian Fennoscandia, has still to be established. Several attemps have been made to measure the magnetization directions of different rapakivi varieties, but without success. Dikes assosiated with rapakivi or contact zones with stable magnetization have not been encountered. The magnetization measured is always either too weak or too soft to yield reliable results.

Secondly, the younger (1 200 Ma) end of the polar curve is based on magnetic measurements of rocks occurring on or close to the coastal line of Baltic Sea; here the rate of crustal uplift is greater than inland, which refers to the older end of the curve (Kääriäinen 1963). Consequently, the present author (see Neuvonen 1973) suspected that the curve might be due to the difference in uplift rate and not to the wandering of the paleomagnetic pole.

Recent measurements of magnetic orientation for two intrusive bodies of quite different types and different ages give, I feel, every reason to believe that one of these was magnetized during the cooling period of rapakivi granite and that the polar curve constructed really does represent polar wandering during the appropriate Precambrian time span.

Remanent magnetization of quartz diabase, Kuisaari, Jaala

In the northwestern corner of the large Wiborg rapakivi massif there is a small separate rapakivi body surrounded in the east by an anorthosite-gabbro (Frosterus 1902). This so-called Ahvenisto massif has been described in detail by Savolahti (1956). The basic rock types of the massif were sampled by the present author in 1966, but the magnetization was found to be soft and unstable. About 5 km southeast of the Ahvenisto massif there is a quartz diabase dike surrounded by microcline granite. This diabase is cut by the rapakivi granite, as shown in the contact at the southeastern end of Kuisaari, an island on Lake Vuohijärvi (Fig. 1). The diabase dike in the contact zone was sampled and measured to establish the magnetic orientation of the rapakivi granite. A hard magnetization was found in the diabase of the contact zone but not in the same rock a few kilometers away from the contact. Another diabase dike occurs near the rapakivi granite in the Lake Lovesjärvi area, not far from

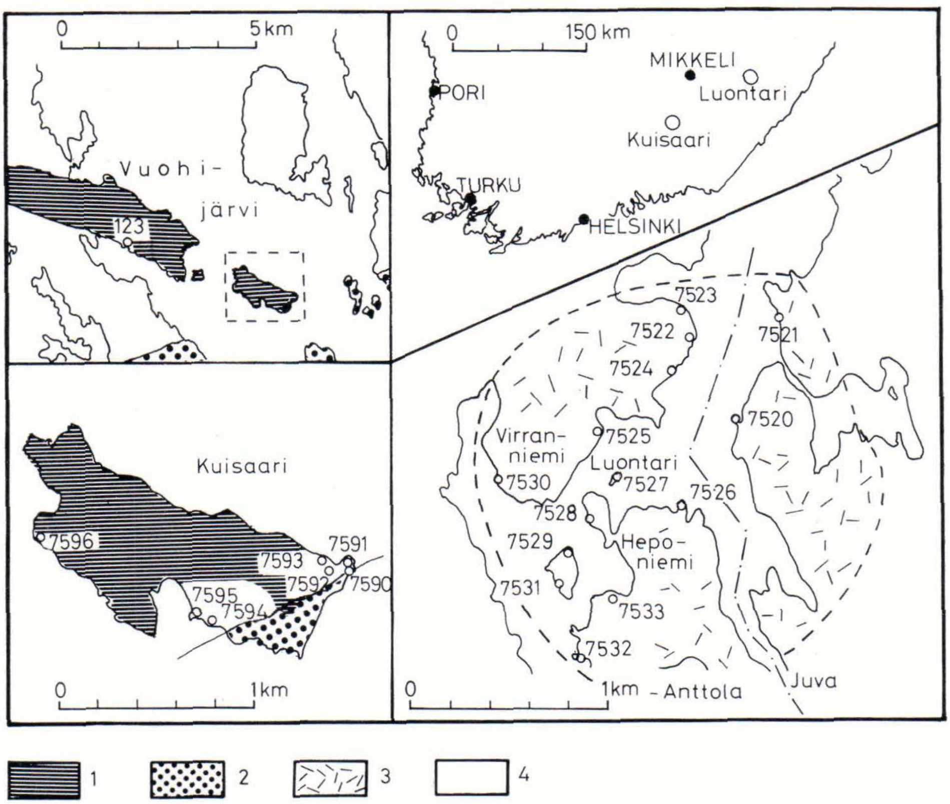

Fig. 1. Location of the sampling sites. 1 = quartz diabase, 2 = rapakivi granite, 3 = granodiorite, 4 = granites and gneisses.

Table 1. Paleomagnetic stability of specimens from Kuisaari, Jaala (Giddings and McElhinny 1976).

Specimen	Stable Range	C_s	C_p	CI	MBI	PSI
7590.111	—					0
7591.22	40—10	.750	.500	.375	.454	.170
7592.16	—					0
7592.19	60—15	.750	.750	.563	.493	.277
7583.16	60— 5	.917	.750	.688	.486	.334
7594.112	60—15	.583	.750	.437	.495	.216
7595.14	60—10	.833	.750	.625	.682	.426

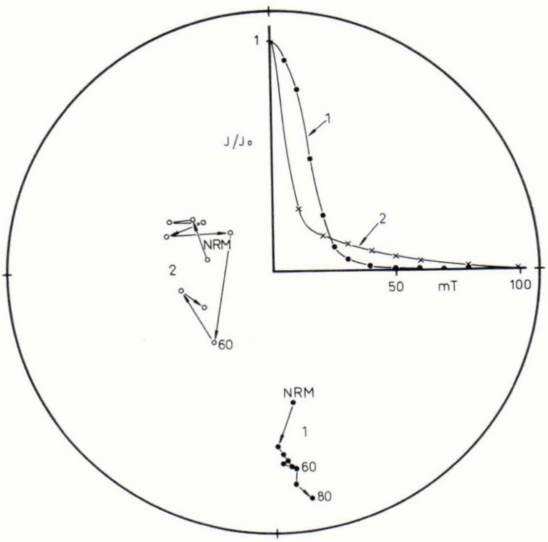

Fig. 2. AF-demagnetization of two pilot specimens. (1) Kuisaari diabase No. 7592.19, (2) Luontarivesi granodiorite No. 7527.21.

Kuisaari; no hard magnetic component was found in this rock, however.

The magnetization in the contact zone diabase was quite strong but mostly rather soft. The hard remanence component isolated after af-cleaning, although not very coherent, was still fairly reliable (Fig. 2 and Table 1). This hard NRM component was not revealed by thermal treatment, evidently because of the difficulty of nullifying the geomagnetic field inside the furnace. The large portion (up to 99 %) of magnetization that had to be removed (randomized) is very sensitive to the remnant of the field in the furnace and causes irregular components which cover the small primary magnetization of the specimens.

Stability tests performed on pilot specimens according to the method of Gidding and McElhinny (1976) showed that some of the specimens were very stable (Table 1). The stable magnetization was due to large magnetite grains which were partially oxidized, presumably because of contact effects by the rapakivi granite. The paleomagnetic pole (Lat = 22°N, Long = 190°E) is reversed and not very reliable as shown by the individual values of 95 % circles of confidences (Table 2). It is worth noting that the Kumlinge dikes in the Åland archipelago also have a reversed pole and that the two poles come quite close to each other (see Fig. 3). The two poles evidently represent the same ages, i.e. the age of the rapakivi granite, 1650 Ma.

Remanent magnetization of the Luontari granodiorite

About 90 km northeast of Kuisaari and about 50 km east of the town of Mikkeli (St. Michel) there is a round circular granodiorite body about 2 km in diameter (Fig. 1). The rock has been described by Korsman and Lehijärvi (1973). They also give the rock radiometric (U/Pb) age of 1810 Ma based on zircon and sphene and determined by Dr. Olavi Kouvo. The granodiorite is undeformed and

Table 2. Paleomagnetic data for dolerite, Kuisaari, Jaala. Latitude 61.17° north, longitude 26.74° east.

Sample	N R M						N	After AC demagnetization						
	D	I	S	R	K	α_{95}		mT	D	I	S	R	K	α_{95}
7590.1	141°	5°	1345	7.124	1.89	41°	14	35	—144°	26°	54.6	12.855	11.35	12°
7591.1	—156°	—33°	464	3.579	2.07	63°	6	40	175°	21°	4.8	4.081	2.66	53°
7591.2	—151°	—51°	1005	3.058	2.060	73°	5	35	—163°	—6°	22.1	2.549	1.63	94°
7592.1	—107°	5°	3982	9.355	6.08	20°	11	35	Not stable					
7593.1	171°	—9°	3539	6.434	1.83	45°	13	60	—160°	—11°	187	8.804	2.93	30°
7594.1	146°	77°	2922	5.225	1.62	54°	12	60	172°	15°	31.5	4.564	1.48	61°
7595.1	177°	40°	623	9.013	3.68	26°	12	35	—155°	17°	28.6	10.726	8.63	16°
7595.2	—82°	79°	460	7.894	3.22	30°	11	60	—164°	20°	5.4	4.247	1.54	65°
7596.1	—120°	52°	1282	7.080	2.55	36°	11	60	—160°	—1°	11.4	9.572	7.00	19°
						Average	8		—165°	10°		7.579	16.62	14°

Paleomagnetic pole: *Reversed* 22°N, 190°E
$\delta p = 7°$, $\delta m = 14°$

α_{95} = circle of confidence with 95 % probability
K = precision parameter
R = resultant unit vector
N = number of specimens measured or samples compiled
S = intensity (10^{-3}A/m)

younger than the surrounding gneisses. Its magnetite content is high, giving rise to a distinct anomaly on the aeromagnetic map.

Twenty seven oriented samples were drilled from this intrusion (Fig. 1) for paleomagnetic measurements. The magnetization was found to be strong but rather soft (Fig. 2). The small hard component was badly camouflaged by the large soft component, which could be removed (randomized) by af-cleaning but not by thermal treatment. Table 3 and Fig. 3 show the magnetic directions obtained after af-demagnetization of the samples at 60 mT peak field. The directions have a large scatter and the pole position calculated (Lat = 67°N, Long = 198°E) is not very reliable (Fig. 3).

Discussion

The pole positions determined are plotted in Fig. 3. The pole for the Kuisaari diabase is south of the polar wandering curve and not very far from the pole position of the Kumlinge diabase dikes. According to Ehlers and Ehlers (1977), the Kumlinge diabase dikes either intruded a little earlier than or are of the same age as the rapakivi granite. Consequently, the poles of Kumlinge and Kuisaari dikes should both represent the age of the rapakivi intrusion (1650 Ma according to Vaasjoki 1978), since the latter was collected from the very contact of the rapakivi granite. Both poles are reversed in comparison with the rest of the poles used in constructing the curve.

The pole position of the Luontari granodiorite lies well above the curve (Fig. 3). This pole is, however, not very far from the pole obtained for the Åva intrusion from the SW archipelago and which has about the same radiometric age, 1810 Ma (Neuvonen 1970). When the large size of the cones of confidence are considered, these pole positions

Table 3. Remanent magnetization of Luontarivesi granodiorite after demagnetization with 60 mT AC-field.

Sample No.	Decl.	Incl.	N	α_{95}	K	R
7520.1	9°	76°	11	16°	9.0	9.890
.2	—14°	82°	8	20°	8.32	7.158
7521.1	— 9°	25°	6	v.l.[1]	2.49	2.796
7522.1	22°	48°	6	13°	25.27	5.802
.2	1°	50°	7	13°	23.23	6.742
7523.1	7°	46°	9	7°	55.58	8.856
.2	1°	47°	6	9°	54.91	5.909
7524.1	—13°	49°	6	v.l.	2.23	3.761
.2	— 2°	44°	5	21°	14.14	4.717
7525.1	33°	56°	6	v.l.	1.42	2.488
.2	26°	40°	5	v.l.	1.82	2.813
7526.1	14°	50°	6	51°	2.69	4.141
.2	34°	61°	11	37°	2.51	7.023
7527.1	58°	47°	10	39°	2.47	6.362
.2	66°	67°	9	48°	2.11	5.205
7528.1	—20°	57°	10	26°	4.27	7.893
.2	—11°	46°	10	40°	2.40	6.250
7529.1	—62°	55°	10	v.l.	1.34	3.305
.2	—70°	60°	10	v.l.	1.38	3.488
7530.1	—16°	65°	12	22°	4.73	9.676
.2	31°	55°	12	17°	6.90	10.407
7531.1	2°	60°	11	20°	6.18	9.383
.2	12°	57°	10	23°	5.46	8.350
7533.1	19°	74°	10	23°	5.21	8.271
.2	—17°	59°	6	29°	6.28	5.203
Average	5°	58°	25	7°	16.30	23.527

Paleomagn. pole N 67°, 198°E $\sigma m = 10°$, $\sigma p = 8°$

[1] very large

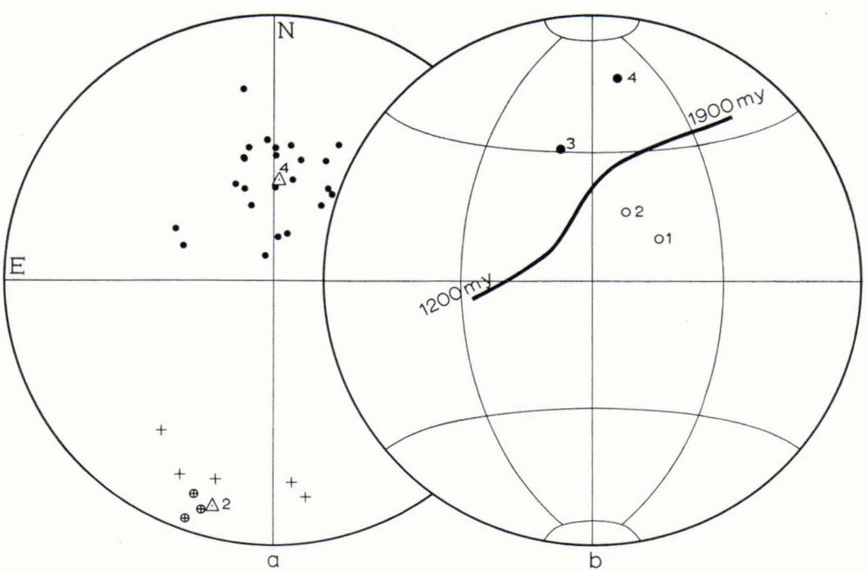

Fig. 3. Stereographic equal area projection of the demagnetized directions (a) and the paleomagnetic pole positions (b). 1 = Kumlinge, 2 = Kuisaari, 3 = Åva, and 4 = Luontarivesi. 1 and 3 from Neuvonen (1970).

may well represent one and the same position.

The two intrusions discussed in the present study gave poor results. The author thinks, however, that the findings are important and worth publishing since they show that the polar wandering curve drawn cannot be due to the difference in uplift rate.

As demonstrated by the present author (Neuvonen 1961), the apparent age pattern of the crust decreases with depth until zero-line is reached. This applies to all dating methods, including magnetic age determination. Consider now two intrusions of similar age (like Kumlinge and Kuisaari, both close to the age of rapakivi granite, 1650 Ma) but located, one in a block of high crustal uplift (Kumlinge) and the other in a block of low crustal uplift (Kuisaari). During crystallization and cooling they obtain similar remanent magnetization (TRM). Long burial at the high temperature of the lower crust might change the magnetization; hence, the rock in the block of high uplift rate shows (younger) magnetization different from that located in the block of low uplift rate. If however, these two intrusions have a similar magnetization, i.e. if they show similar pole positions, the primary magnetization probably was not changed during burial. This seems to be the case in the Kumlinge and Kuisaari diabase dikes. They have similar pole positions which refer to the time of rapakivi intrusion. The primary character of this magnetization is also demonstrated by the reversal nature of the pole. A similar reasoning applies to the magnetization and pole positions of the Åva and Luontari intrusions. They would give different pole positions if the magnetic orientation of these bodies were not primary but were caused by different uplift rates. Since the poles come roughly to the same area we can consider the magnetization to be essentially of primary character.

The polar wandering curve drawn represents the apparent wandering of the magnetic pole from about 2 000 to 1 200 Ma. The results obtained suggest that the curve is based on primary magnetization measured from different parts of the Fennoscandian shield. The curve drawn is, without any doubt, very tentative and futher studies will introduce many new details. Number of measurements are needed, however, before they can be confirmed.

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