

PRELIMINARY PALAEOMAGNETIC RESULTS FROM THE FEN CARBONATITE COMPLEX, S. NORWAY

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Received 22 June 1972

Revised version received 1 October 1972

Samples from a hematite carbonate rock of the Eocambrian–Lower Cambrian Fen carbonatite–alkaline rock complex in southern Norway, yield a stable NRM with a direction after magnetic cleaning of $D = 205^\circ$, $I = -56^\circ$ ($N = 19$, $k = 138$, $\alpha_{95} = 3^\circ$). This corresponds with a palaeomagnetic pole position at 63°N , 142°E . The NRM is likely to be of primary origin and probably reflects a Lower Cambrian pole, although a Triassic age might be suggested because of the position of the palaeomagnetic pole. The observed discrepancy between Lower Palaeozoic poles of Great Britain and Norway may be explainable by assuming that these areas belonged to different crustal plates during the Lower Palaeozoic.

1. Introduction

The natural remanent magnetization (NRM) of samples from the rødberg (a hematite-bearing carbonate rock) of the Fen carbonatite–alkaline rock complex was investigated in order to obtain rather more information about the geomagnetic field direction relative to stable Europe during the Lower Cambrian. A well-defined Lower Cambrian palaeomagnetic pole is of great importance for the study of continental drift and polar wandering during Late Precambrian and Early Palaeozoic time; the more so as Lower Palaeozoic palaeomagnetic data from Europe are relatively scarce.

For this study the samples were collected from the rødberg (=red rock) because this hematite-bearing rock promised to be usable for palaeomagnetic research. Moreover the age of the Fen carbonatite rock complex is well defined. The Fen area is situated at $59^\circ 17'–19'\text{N}$, $9^\circ 15'–20'\text{E}$, immediately east of Ulefoss in Telemarken, S. Norway.

2. Geological setting and mineralogy

The carbonatite and alkaline rocks at Fen form a circular complex over an area of about 5 km^2 , 12 km west

of the Oslo graben, and are surrounded by the gneisses and gneissic granites of the Telemark Precambrian.

The Fen complex has been investigated and described by Brøgger [1], Saether [2], Bergstøl and Svinndal [3] and Barth and Ramberg [4].

The main rock types of the Fen complex are: (1) alkali syenite (fenite) in the peripheral parts; (2) feldspar-free, ultra-basic rocks in the central parts; (3) kimberlite and kimberlite breccia, occurring in dike-like bodies or volcanic plugs respectively; and (4) carbonatite rocks (sövite, rauhaugite, rødberg) in the central and eastern parts.

Brøgger [1] proposed the rocks of the Fen complex to have been derived from a carbonate-rich magma, an opinion which is nowadays generally accepted. He also proposed an Eocambrian age for the Fen complex. Later K–Ar and Rb–Sr determinations revealed ages ranging from 600×10^6 to 530×10^6 yrs [5,6], implying Eocambrian to Lower Cambrian age after the Geological Society of London Time Scale [7]. Barth and Ramberg [4] suggested the Fen volcanism to be related to faults, which predated the subsidence of the Oslo graben. The last movements in the Oslo graben are of Permian age.

The rødberg differs from the other Fen carbonatite rocks because of its hematite content, which may locally attain up to 50%, forming vein- and lens-shaped iron

ore bodies. This rock type is only known from the Fen area. In the samples collected for this study the hematite content is considerably lower. The crystals occur as minute tablets, 0.001–0.01 mm in diameter, within the calcite crystals, or as irregular aggregates, often along the calcite grain boundaries.

According to Saether [2], the rødberg is a product of hydrothermal–metasomatic alteration of mainly damtjernite (one of the ultra-basic magmatic rocks) by solutions derived from the deeper-situated parts of the damtjernite magma, which remained partly liquid after the consolidation of those parts of the same magma which had reached nearer the Earth's surface. These solutions must have carried large amounts of iron that precipitated as hematite.

Saether disagrees with Brøgger's view that the hematite was formed by oxidation of siderite due to atmospheric action, because siderite is missing in the whole Fen area. Further he reports: (p. 124) "Microscopic studies of the contact between rødberg and older rocks show that the finely dispersed hematite invades the older rocks from the beginning of their metasomatic transformation into rødberg, without any structural features, which might indicate that it should have replaced an earlier formed iron carbonate". Therefore this opinion is that the hematite has been primarily deposited in the rødberg. This deposition must have taken place either by escape of CO₂ from the iron-bearing carbonate solution or by atmospheric oxidation of the iron in solution. Beside hematite, some magnetite may occur as sharp-edged crystals, which are considered to be relics from the early stage of the rødberg genesis. This magnetite sometimes shows alteration into hematite. Qualitative X-ray analysis of a number of our samples showed hematite to be the most important iron oxide. Magnetite occurred only in a few samples in small quantities.

3. Sampling, measurement procedures and results

From the rødberg, outcropping at the shore of Lake Nordsjø, 19 samples were collected over a span of about 100 m. The orientation was made by sun compass and clinometer. Cores drilled from these samples were measured with an astatic magnetometer and their NRM was analyzed by means of alternating field (a.f.) and thermal demagnetization.

The intensity of the NRM ranged in general from 10⁻⁵ to 10⁻⁴ gauss and the Q_n values from 1 to 10. The direction of the NRM appeared to be rather consistent. Some specimens had very low Q_n values (less than 1), presumably on account of their high susceptibility, and were rejected because of their inferred magnetic instability. The direction of the stable magnetization was determined after a.f. demagnetization at 500 Oe peak value. Stepwise demagnetization of some pilot samples proved this value to be sufficient to eliminate viscous magnetization components. Thermal demagnetization supported the results obtained by the a.f. demagnetization. The intensity of the remaining stable magnetization after treatment at 3200 Oe peak value was 10–40% of the initial value. Heating at 600°C decreased the intensity to 1–5%.

In fig. 1 the direction of the magnetization of the rødberg samples have been plotted after a.f. demagnetization at 500 Oe peak value. The mean direction is: $D = 205^\circ$, $I = -56^\circ$, with Fisher's precision $k = 138$ and $\alpha_{95} = 3^\circ$. Before demagnetization, these values were: $D = 203^\circ$, $I = -53^\circ$, $k = 94$ and $\alpha_{95} = 3.5^\circ$. Unit weight was given to specimens, each representing one sample ($N = 19$). The corresponding palaeomagnetic pole position appears to be at 142°E, 63°N ($dp = 3^\circ$, $dm = 4^\circ$). Because there are no indications for tilt of the Fen complex, no tectonic correction was made.

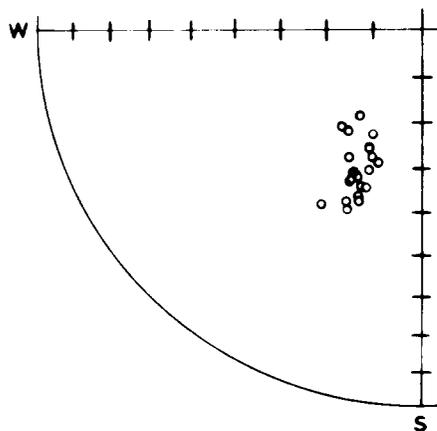


Fig. 1. Equal area projection of the magnetization directions of the Fen rødberg after a.f. demagnetization at 500 Oe peak value. All directions point upward. Mean direction is indicated by an asterisk.

4. Origin of the NRM

The palaeomagnetic significance of the Fen palaeomagnetic pole position depends on the question whether the magnetization is primary and reflects the Lower Cambrian geomagnetic field direction or whether it is secondary. Therefore the possibility of thermal as well as chemical remagnetization has to be considered.

A thermal event of any importance after the emplacement of the Fen rock complex would likely reset the K–Ar biotite ages of the Fen rocks. However, according to Priem et al. [6], such rejuvenations of the K–Ar ages are conspicuously absent. It is therefore implausible that the magnetization of the rødberg is secondary as a consequence of thermal remagnetization.

Essential to the question of whether the NRM is primary or has been acquired by chemical remagnetization, is the origin of the hematite in the rødberg. As has been discussed already, the bulk of the hematite is considered to have been primarily deposited. Although some magnetite is present in the rødberg, showing alteration into hematite, the textural features of the hematite do not indicate that this process took place on an important scale. Considering the hematite as a primary mineral, the NRM of the rødberg may be considered to be primary as well and not to be due to chemical remagnetization.

From a geological point of view there are no indications for remagnetization of the rødberg. Hence, we may consider the NRM as having been acquired during the origin of the rødberg. Taking into account that the rødberg represents a late phase in the Fen magmatic sequence, the palaeomagnetic pole observed is of Lower Cambrian age (Geological Society of London Time Scale [7]).

5. Palaeomagnetic speculations

The palaeomagnetic pole of the Fen rødberg at 144° E 63° N lies in the vicinity of the mean Triassic pole position of stable Europe at 142° E 53° N and the Triassic pole position of Eurasia obtained by triangulation at 142° E 64° N [8, 9]. Creer [10] argued that extensive chemical remagnetization of Lower Palaeozoic rocks occurred during the Permo-Carboniferous, when the European (and North American) landmasses occupied equatorial latitudes. According to Creer, the atmospheric

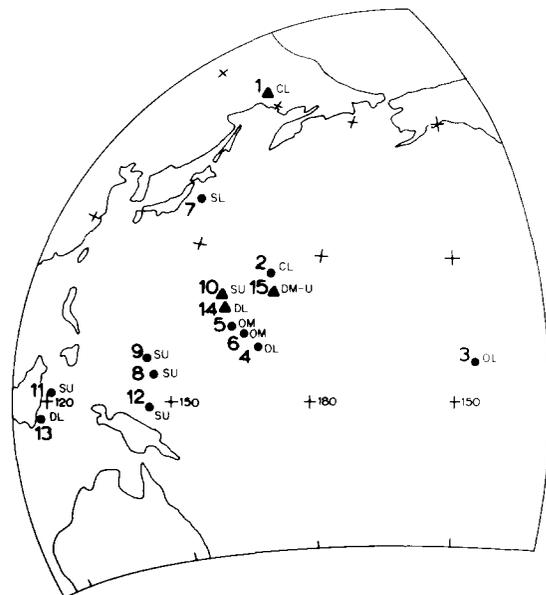


Fig. 2. Lower Palaeozoic and Devonian pole positions of Western Europe in approximate order of age (Norwegian poles indicated by triangles): 1. Fen complex, Norway (this study). 2. Caerfai series, Wales [11]. 3. Ignimbrites, Killary Harbour, Eire [12]. 4. Girvan lavas, Scotland [13]. 5. Builth volcanics, Wales [13]. 6. Borrowdale volcanics, England [13]. 7. Skomer volcanic group, Wales [11]. 8. Garaval Hill–Glen Fyne complex, Scotland [14]. 9. Arrochar complex, Scotland [14]. 10. Ringerike sandstone, Norway [15]. 11. O.R.S. lavas, Scotland [16]. 12. O.R.S. lavas, Scotland [17]. 13. Lower O.R.S. sediments, Wales [18]. 14. Røragen red sandstone, Norway [19]. 15. Kvamhesten O.R.S., Norway [20].

conditions at these low latitudes favoured chemical reactions which involved dehydration and oxidation of iron hydroxides and oxihydroxides. If chemical remagnetization of the Fen rødberg actually proceeded in this way, the magnetization of the rødberg should be expected to reveal a Permo-Carboniferous palaeomagnetic pole instead of a Triassic pole position, since during the Triassic, Europe occupied higher latitudes than during the Permo-Carboniferous. Moreover, hematite is the most probable primary iron compound of the rødberg instead of iron-hydroxides and oxihydroxides, which are not stable under the hydrothermal conditions of the rødberg genesis. For these reasons the Fen palaeomagnetic pole may be considered as a real Lower Cambrian pole, which means that its position in the vicinity of the Triassic poles is merely a coincidence.

The palaeomagnetic pole positions of Lower Palaeozoic and Devonian rocks of stable western Europe have been plotted in fig. 2. The same poles are used as given by McElhinny and Briden [21]. The palaeomagnetic pole from the Hartshill quartzite, England [22] was omitted, for only low field demagnetization (100 Oe) had been carried out and the precision is low. The scatter of the Lower Palaeozoic and Devonian poles over the northeastern Pacific area is evident from fig. 2. The pattern becomes even more intricate if one considers the geological ages assigned to these poles. McElhinny and Briden [21], reviewing the Lower Palaeozoic and Devonian palaeomagnetic data of Europe, arrived at the conclusion that the palaeomagnetic pole remained essentially at the same place throughout Lower Palaeozoic and Devonian time, except for a westerly excursion during the Upper Silurian. They considered the magnetization of the Ringerike sandstone (pole 10) as younger than this excursion. The result from the Skomer volcanic group (pole 7) is regarded by Briden et al. [11] as a record of the Permo-Carboniferous geomagnetic field due to remagnetization, rather than being a real Lower Silurian magnetization. The Lower Ordovician pole of the Killary Harbour ignimbrite (pole 3) is completely aberrant.

A real discrepancy exists between the Upper Silurian and Devonian poles of Norway (poles 10, 14 and 15) and Great Britain (poles 8, 9, 11, 12 and 13) respectively. The Lower Cambrian poles of the Fen complex and the Caerfai series are also widely apart. Hence, the disagreement between the Lower Palaeozoic and Devonian data of Norway and Great Britain already existed during the Lower Cambrian. An even greater discrepancy exists with respect to the Siberian Lower Palaeozoic poles (in the vicinity of Australia), used by Creer [10] in his modified polar wandering curve for Europe.

Unless: (a) the magnetization ages of the Fen røddberg or of the Caerfai series are much younger than the rock ages, or (b) the magnetization direction of the Fen røddberg is not typical of the local Cambrian field and only represents a "spot-reading" (e.g., during a polarity transition or unusually large secular variation), the present work supports the suggestion of Briden [14] and McElhinny and Briden [21] that Great Britain, Norway and Siberia belonged to separate crustal plates during Lower Palaeozoic time.

Acknowledgements

The author is indebted to Dr. J.D.A. Zijdeveld, Prof. J. Veldkamp, Prof R.D. Schuiling and Mr. P. van der Kruk for their helpful criticism of the manuscript.

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