PALAEOMAGNETISM AND THE ORIGIN OF THE EGERSUND DOLERITES, S. NORWAY

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In a previous palaeomagnetic investigation of the Egersund dolerites it was suggested that the total time span recorded was short compared with the time scale of geomagnetic secular variation. The within-dike scatter was ascribed to other causes than field changes. Because of the presence of glass and since the overall mean remanence direction was fairly close to that of the present dipole field (within the range of secular variation), a Tertiary age of this dike system was suggested. However, this conclusion is probably no longer valid as further palaeomagnetic measurements have shown that :

a) the genuine mean direction is too far from any expected Tertiary dipole field to be reasonably attributed to secular variation at that time, and
b) there is every reason to suggest that the within-dike dispersion is largely affected by palaeosecular variation.

Following the last assumption, the attitude of the ancient axis of rotation can be estimated. The calculation of a north pole (in present co-ordinates) at 28°N, 52°E or alternatively a south pole at 28°S, 128°W suggests that the considered dolerites are of late Precambrian origin.

The dolerite dike swarm which cuts through the Precambrian of the Egersund area, S. Norway, was subjected to a palaeomagnetic study in 1964 (Storetvedt 1965, 1966a, b). The purpose of the investigation was to obtain some information about the age of these intrusions.

Petrogical observations (Antun 1956) indicate an intrusive act of short duration, and the presence of chilled contacts with glassy stringers provide evidence of rapid solidification. Therefore, it appeared adequate to consider the whole magmatic emplacement as a short event compared with the time scale of geomagnetic secular variation (10,000—100,000 y.).

The remanence directions as cleaned for low stability components showed fairly steep downward (positive) inclinations with most dike mean directions closely grouped and directed about due east. In order to estimate a reliable pole from such steeply inclined directions a fairly complete representation of the ancient field is required. On geological reasoning it was suggested, therefore, that a palaeomagnetic dating based on an estimated pole location was not a realistic approach to the age problem. However, this argument supposes that the primary magnetization, a t.r.m. acquired when these igneous rocks first cooled below their Curie points, was not subsequently destroyed or modified.

It appears to be a well accepted view among geologists that natural glass very easily undergoes diffusion and develops a crystalline texture. Because of the occurrence of fairly well preserved glass in the considered rocks (Christie 1959) there were reasions to suggest, therefore, that they were not of too ancient origin. When post-Precambrian palaeomagnetic fields were considered, the sense of the measured remanence could only be ascribed to a fairly recent field. Consequently a Tertiary age of these dolerite injections was suggested. The divergence (about 20°) between the overall mean direction and an expected Tertiary dipole field was not larger than accounted for by palaeosecular variation.

The first study tended to show that the within-dike scatter could be fairly large. Therefore, it was decided to extend the palaeomagnetic investigation of these rocks. This communication reports the experimental results obtained on altogether 33 news samples; 21 from two sites in dike No. 6, and 12 from three other dikes. In particular it was necessary to investigate the reliability of the mean direction of dike No. 6 because this had originally been found to be very close to that of an expected Tertiary dipole field in this area. The experimental procedure in the new investigation has been roughly identical to that applied in the first study, but the experimental conditions have been considerably better. Hence, it became possible to study the remanence vector

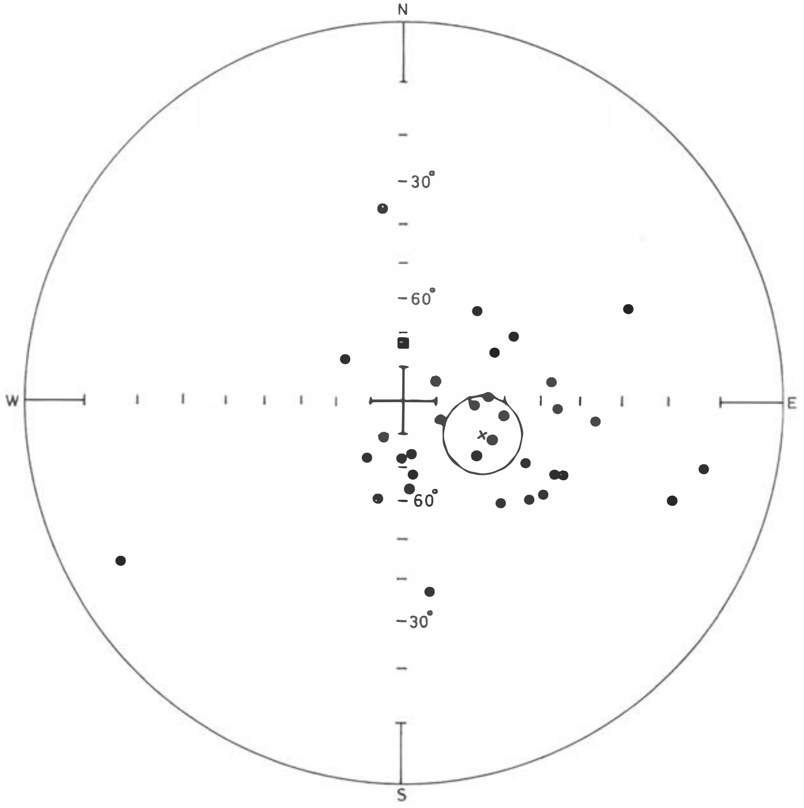

Fig. 1. Stereographic plot of all tested sample directions (all positive) together with their 95% confidence circle for the mean. The square is the direction of present dipole field.

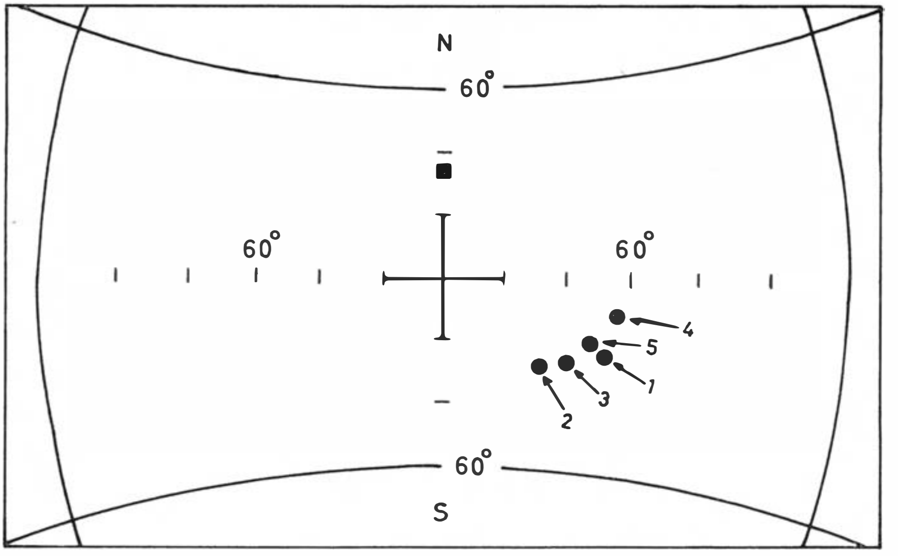

Fig. 2. Stereogram showing mean magnetization directions of the various sample groupings of Table 1.

down to a much lower intensity level than previously obtained. Unfortunately, these rocks become very unstable after heat treatment around 550° C, implying in this case that the last 10 per cent of remanence intensity escaped the thermal analysis. This is very unfortunate because the low intensity ranges may be the clue to many palaeomagnetic problems (Storetvedt 1968a). The remanence directions accepted as most reliable are those obtained after demagnetization to about 520° C. At about this temperature each group of specimens heated simultaneously showed a minimum scatter. Similar directions are also obtained after a.c. field treatment in 150 oersteds (peak). It is a general feature that samples from central parts of the dikes showed high magnetic stability against both a.c. and thermal treatment, while those of the fine-grained contacts exhibited a considerable portion of unstable magnetization resulting in an excessive scatter of the natural remanence. Nevertheless the demagnetization trends of the latter moved consistently into the area of stable directions.

Fig. 1 is a stereonet of all tested sample directions. Mean magnetization directions of various groupings and statistics thereof (Fisher 1953) are listed in Table 1. Mean directions are also shown in Fig. 2.

The renewed investigation showed that the original mean direction of dike No. 6 (D=024, I=+66) was not genuine. The reason for this obviously that too few observations (3 samples only) were drawn from a fairly scattered population. The new mean direction, based on 21 samples, deviates towards south-east at an angular distance of about 35°. Furthermore, by comparing the results of Table 1 there is every reason to suggest that arbitrary sampling schemes, if of sufficient size, would exhibit identical mean directions and equal

Table 1

No.	Palaeomagnetic unit	Number of samples	R	k	α_{95}	Mean directions	Remarks
1	Site A, dike No. 6	8	6.9	6.6	23.5	115, +61	Unit weight to samples
2	Site B, dike No. 6	13	10.2	4.2	23	131.5,+69	,, ,, ,, ,,
3	Dike No. 6	21	17	5	16	123.5,+66	,, ,, ,, ,,
4	Dike Nos. 1, 3, 7, 8, 10	12	10.6	7.9	16.5	101.5,+61	,, ,, ,, ,,
5	All dikes	33	27.5	5.8	11.5	114, +64.5	,, ,, ,, ,,

scatter. In all probability one is here faced with the validity of a generally accept hypothesis in palaeomagnetism, i.e. that a narrow dike (the considered ones range between 1 and 30 metres in thickness) records approximately a spot reading of the external field during intrusion. This hypothesis seems now entirely at question (Storetvedt 1968b) and it appears more likely to assume that dikes in general record the ambient field in a sufficient time span to be affected by secular variation. As the t.r.m. is a metastable state, the time effect may have appreciable importance on the geological time scale especially if somewhat elevated temperatures are involved. Hence it seems reasonable to ascribe the within-dike scatter observed in the Egersund dolerites as being largely caused by palaeosecular variation either at about the time of emplacement or in some time subsequent to formation. Following this argument, mean directions of abitrary sampling groups should be expected to agree. This is also in accord with the actual observations.

The overall mean direction of the Egersund dolerites does therefore most likely reflect a dipole field direction. Nevertheless, the important question is the age of this field relative to the age of the rocks. As one was unable to provide a thermal analysis of the full stability range of the remanence, the extent of possible remagnetization by a later deviating field is not fully assessed. However, because the apparent polar wandering seems to constitute episodic events with long time intervals of a stable rotation axis (or dipole axis) in between, and in addition the considered dolerites represent the last magmatic activity visible in the area, there are reasons for suggesting that the mean direction in question represents a reliable estimate of the average magnetic field at about the time the rocks originated.

This suggestion renders a Tertiary age of the dolerites impossible because the mean direction differs too much from that of an expected Tertiary dipole field. Also the relatively large angular deviation between these two directions (about 35°) makes it highly unlikely that the mean direction should represent a spot reading of a Tertiary field.

By adopting the dipole field assumption for the mean magnetization direction, the geographic poles relative to the sampling region can be estimated. This calculation gives a north pole location, in present grids, at 28° N, 52° E or alternatively the south pole at 28° S, 128° W. Relative to Europa, this axis falls into the 'Precambrian palaeomagnetic region'. Because the Precambrian is palaeomagnetically highly unexplored and the few results aviable (mostly untested) are not related to a sufficiently secure time basis, further age limitation must be mainly based on pure guesses. However, the estimated axis does not deviate by more than 20° from that calculated from the Upper Torridonian Sandstone of N. Scotland (Irving & Runcorn 1957), a formation which is overlaid unconformably by Lower Cambrian strata. It is possible therefore that the Egersund dolerites date back to the uppermost Precambrian. This suggestion is supported by the fact that the anorthosite complex of this area, which the dolerites intersect, give radiometric ages around 850 m.y. (results from the Laboratory of pre-Cambrian Geology, Leningrad, quoted in Brock 1964).

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