1972, *Phys. Earth Planet. Interiors* 5, 167–176. North-Holland Publishing Company, Amsterdam

PALAEOMAGNETISM OF THE ROGALAND PRECAMBRIAN (SOUTHWESTERN NORWAY)

R. P. E. POORTER

Palaeomagnetisch Laboratorium, Fort Hoofddijk, Rijksuniversiteit, Utrecht, The Netherlands

Received 3 July 1971

Palaeomagnetic investigations were made on Precambrian rocks from Rogaland (southwestern Norway). Samples from anorthosite masses, a noritic layered intrusion and high grade metamorphic migmatites, together called the basement, revealed a similar "reversed" magnetization. This is explained by a simultaneous magnetization during uplift after the Sveco–Norwegian regeneration. The pole position calculated for the basement rocks is located at 36° S and 133° W. The age that can be assignated to this pole is $850–950 \times 10^6$ y. This is concluded from U/Pb determinations on zircons, K/Ar determinations on biotite and Rb/Sr determinations on biotite, microline and total rock. Dolerite dikes belonging to the Hunnedalen system revealed a "reversed" magnetization and a pole position at 34° S and 152° W, while dolerite dikes belonging to the Egersund system revealed a "normal" magnetization and a pole position at 22° S and 129° W. A correlation is made with other Precambrian poles from the Baltic Shield and Great Britain.

1. Introduction

The Rogaland Precambrian consists of high grade metamorphic migmatites enveloping anorthosite masses and a lopolith-shaped noritic intrusion. The whole complex is dissected by dolerite dikes. The determination of the pole-positions belonging to this complex seemed to be useful in establishing a palaeomagnetic stratigraphy for this part of the Baltic Shield, which might in turn enable us to correlate rock formations within this Shield.

The Rogaland Precambrian in SW Norway has been the subject of geological and petrographical research of the department of petrography of the Utrecht State University since 1964. This research is directed by TOBI (1965). Previous geological investigations in this area were made by BARTH (1945), MICHOT (1957, 1960), ANTUN (1956), HEIER (1956), and BARTH and DONS (1960). Previous palaeomagnetic research in the Rogaland area has been carried out by STORETVEDT (1965) and STORETVEDT and GIDSKEHAUG (1968) on the Egersund dolerite dikes.

2. Geological setting

The Precambrian complex of Rogaland is the western extension of the Telemark Precambrian, which constitutes the southern tip of Norway. This western extremity consists of high-grade metamorphic migmatites and intrusive masses, dissected by younger dolerite dikes. The Rogaland Precambrian is bordered in the west and the north by the Caledonides. Fig. 1 is a keymap and geological outline of SW-Scandinavia.

The migmatites consist of layers of granitic, noritic and amphibolitic rocks, and more massive granite and augengneiss bodies. Going from west to east, the rocks grade from the granulite facies into the amphibolite facies. Because of three phases of folding, according to MICHOT (1957, 1960), the migmatite complex reveals an intricate tectonical structure.

Fig. 2 shows the anorthositic intrusive masses along the coast and the lopolith-shaped intrusion of Bjerkreim–Sokndal. This lopolith has been folded: the fold-axis plunges SE, and the east wing is somewhat overthrown to the SW. The lopolith itself reveals a rhythmic layering of anorthosite, leuconorite and norite, while the upper part consists of quartz-bearing mangeritic rocks. A monzonoritic rock type of the lopolith, intruded after the noritic sequence and before the mangerite, penetrated the anorthosite masses in a discordant way. A more detailed description of the lopolith and the anorthosite masses and their genesis is given by MICHOT (1960, 1961).

The dolerite dikes can be classified in two systems: the Egersund system in the southwest strikes ESE–

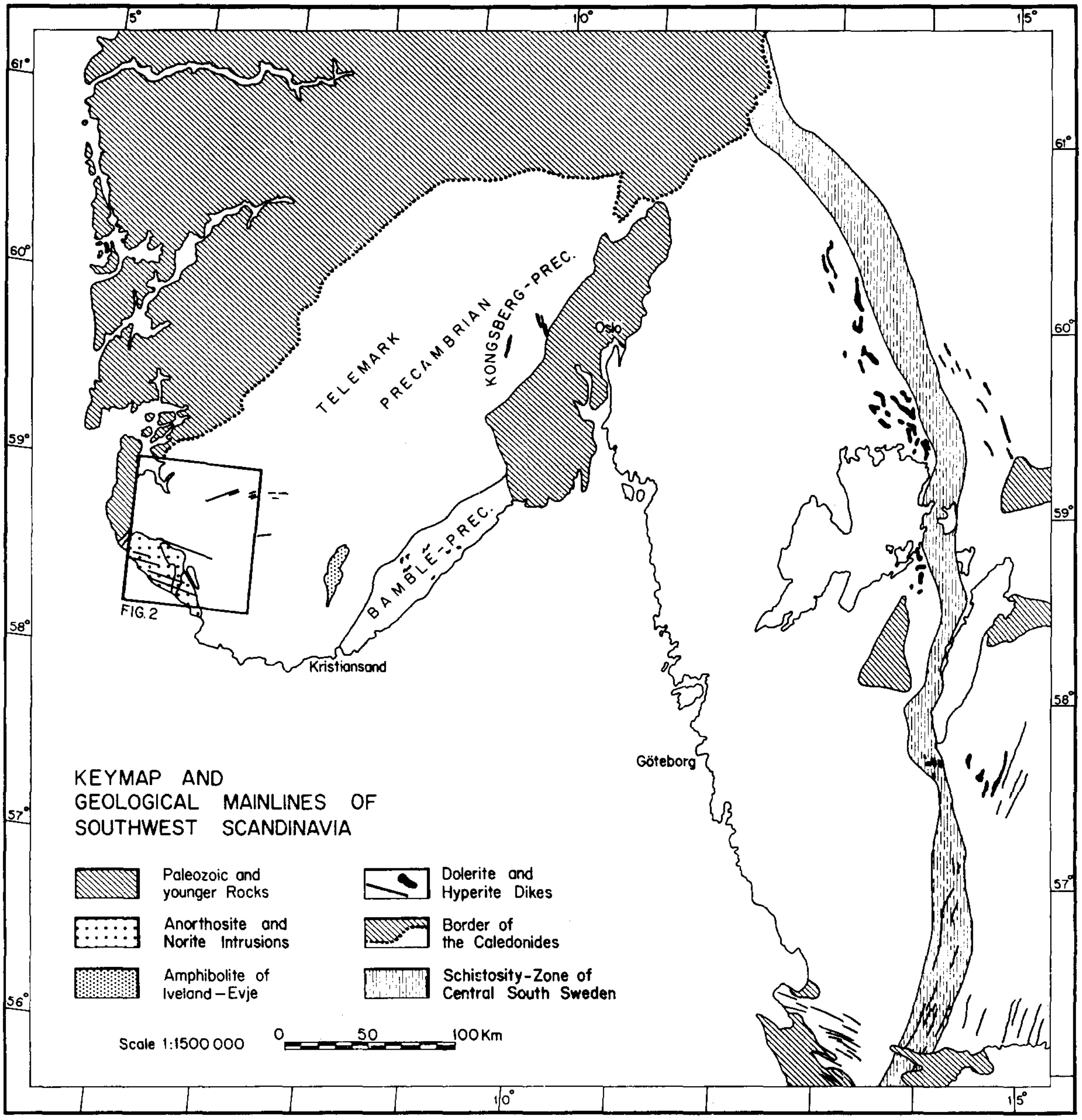

Fig. 1. The Precambrian of southwestern Scandinavia with the location of the sampling area.

WNW, whereas the Hunnedalen system in the north strikes ENE–WSW. The Egersund dolerite dikes have been studied by ANTUN (1956). This author classified them in a porphyritic olivine dolerite type, an ordinary dolerite type and an olivine trachydolerite type. The Hunnedalen dikes were mapped by TOBI (personal communication). These dikes are hypersthene dolerites, sometimes with biotite. Comparing Egersund dikes and Hunnedalen dikes of about the same thickness, the latter are coarser-grained, in the middle as well as at the margin. The chilled margins of the Egersund dikes may contain glass (ANTUN, 1956), which is not detected in the Hunnedalen dikes.

3. Geochronology

Several geochronological studies in the Precambrian area of southern Norway have been carried out. Compilations of the radiometric data by NEUMANN

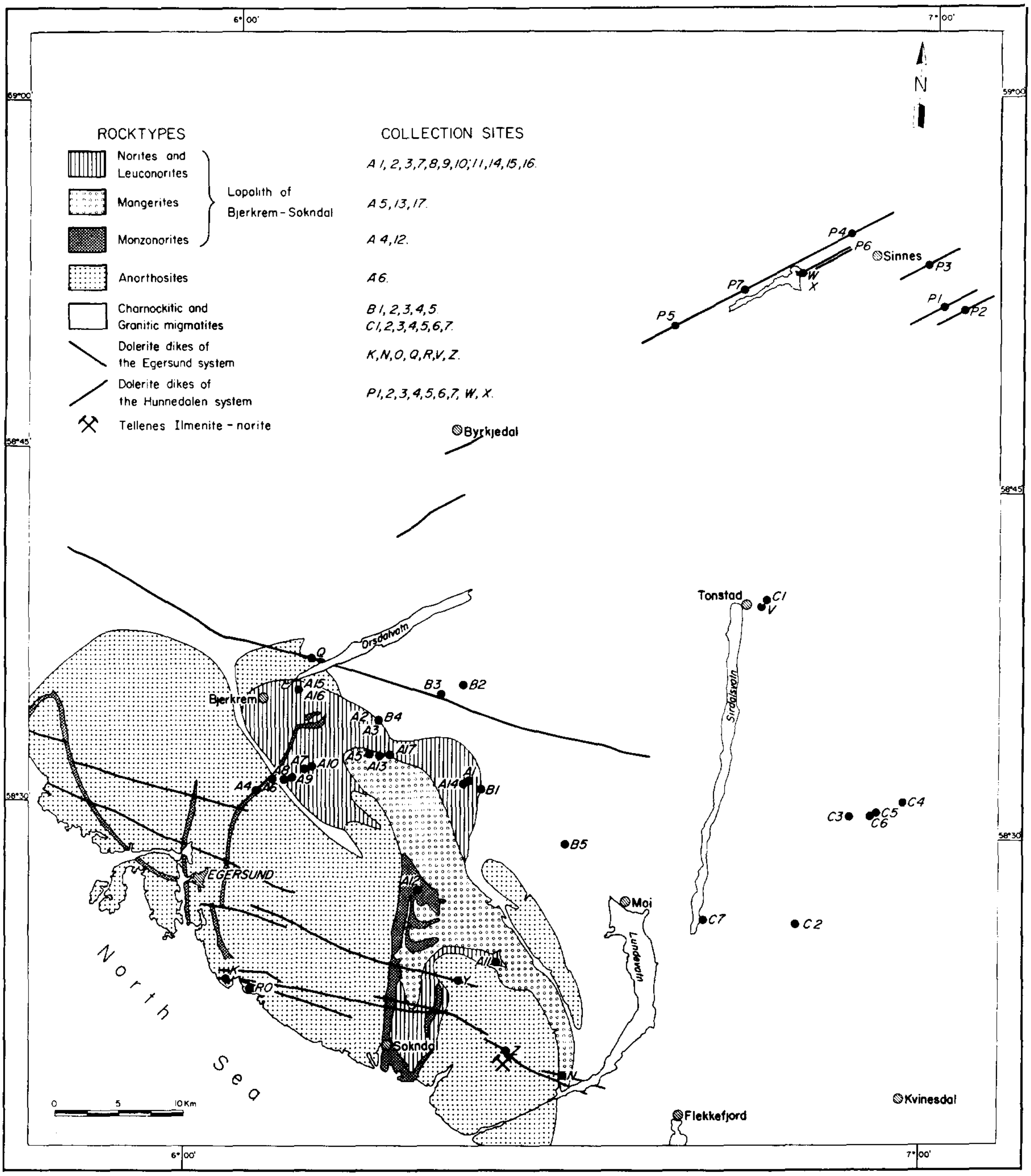

Fig. 2. Collection sites within the Rogaland Precambrian area with the corresponding rock types. Geological data after MICHOT (1960), ANTUN (1956) and TOBI (personal communication).

(1960) and BROCH (1964) revealed apparent ages iu southern Norway ranging from 750×10^6 to 1050×10^6 y. The only data concerning the Rogaland Precambrian in these studies are the K/Ar age values determined by Polkanov and Gerling (see BROCH, 1964) on biotites from the lopolith of Bjerkreim–Sokndal, which are 815×10^6 and 864×10^6 y. MICHOT and PASTEELS (1968) made U/Pb determinations on the zircons from the mangerite rock of the lopolith and obtained values of $(950 \pm 50) \times 10^6$ y. Determinations made by the same method on zircons of the enveloping migmatites yielded an age of $(1030 \pm 50) \times 10^6$ y. The same authors made Rb/Sr determinations on biotite, microcline and total-rock of the migmatites. The biotite and microcline revealed ages around 850×10^6 y; the total rock gave 1050×10^6 and 1152×10^6 y, depending on the assumed initial Sr isotope ratio. They concluded that the orogeny ended about 1050×10^6 y ago, reflected by the zircon and total-rock age values of the migmatites. The solidification of the lopolith is dated at 950×10^6 y ago. The apparent ages of the biotite and microcline of about 850×10^6 y are supposed by MICHOT and PASTEELS (1968) to reflect the postorogenic uplift, which caused the closing of the radiogenic Sr system. After JÄGER (1969) and other authors, the closing of the radiogenic Sr system of biotite takes place at about 300 °C. Biotite retains its argon below 150 to 200 °C (O'NIONS *et al.*, 1969). Therefore it can be stated that the apparent ages of about 850×10^6 y revealed by the K/Ar and Rb/Sr determinations, reflect the postorogenic stage of uplifting, which caused the cooling below a few hundred °C.

4. Sampling

Samples were taken from the migmatites, the lopolith, the anorthosite masses and the Egersund and Hunnedalen dolerite dikes. From the migmatites only the dark components were sampled because preliminary measurements indicated that these rocks were more suitable for palaeomagnetic research than the light components. At most sites, five or six samples were collected. The Egersund dikes were sampled together with the adjacent country rock. The location of the collection sites are shown in fig. 2.

Both oriented cores and hand specimen were collected. From the hand specimen, cores were drilled in the laboratory. The design of the portable drilling outfit is of DOELL and COX (1967). The strike of the orientation was determined both with a suncompass and a magnetic compass. This was desirable because magnetic deviations may occur due to local magnetic anomalies of up to 10°.

5. Measuring techniques

The magnetic measurements were carried out with an astatic magnetometer. Its design and the measuring technique are described by AS (1960). The various magnetic parameters were calculated according the computing programs by KLOOTWIJK (1967).

Demagnetization techniques were applied to eliminate viscous magnetization and to reveal the more stable components of the natural remanent magnetization (N.R.M.). After complete stepwise demagnetization of pilot samples, applying alternating fields, the remaining samples of each group were treated in fields with peak values sufficient for the elimination of the viscous magnetization. With the apparatus described by AS (1967), peak values up to 3000 Oe could be produced. Thermal demagnetization was used to support the results of the alternating field method and for the determination of the range of blocking temperatures. The oven that was used was built by MULDER (1971).

The analysis of the demagnetization results is facilitated by the orthogonal projection of the curve described by the end-point of the resultant vector of the N.R.M. in space during the progressive demagnetization, after ZIJDERVELD (1967). From these demagnetization diagrams, the components of the remanent magnetization are easy to distinguish. The component that is most stable is supposed to represent the "characteristic magnetization". This term has been introduced by ZIJDERVELD (1967) for "the magnetization that is characteristic for a distinct rock series in a distinct region, and which is not a viscous or similar secondary magnetization". The direction of this characteristic magnetization is used in this study to calculate the palaeomagnetic pole positions.

From the samples suitable for palaeomagnetic use from each site, the directions of the characteristic magnetization were averaged, with unit weight given to each sample. Next, the site mean directions were averaged, with unit weight given to each site, to yield the overall mean directions of each rock formation. Within site dispersion and dispersion between the site means are expressed by the k-values and a_{95}-values of FISHER (1953). Finally, for each rock formation the palaeomagnetic pole position was calculated from the overall mean direction.

6. Description of results

6.1. *The lopolith of Bjerkreim–Sokndal*

Within the lopolith and in the adjacent anorthosite, 97 samples were collected at 18 sites. The samples from

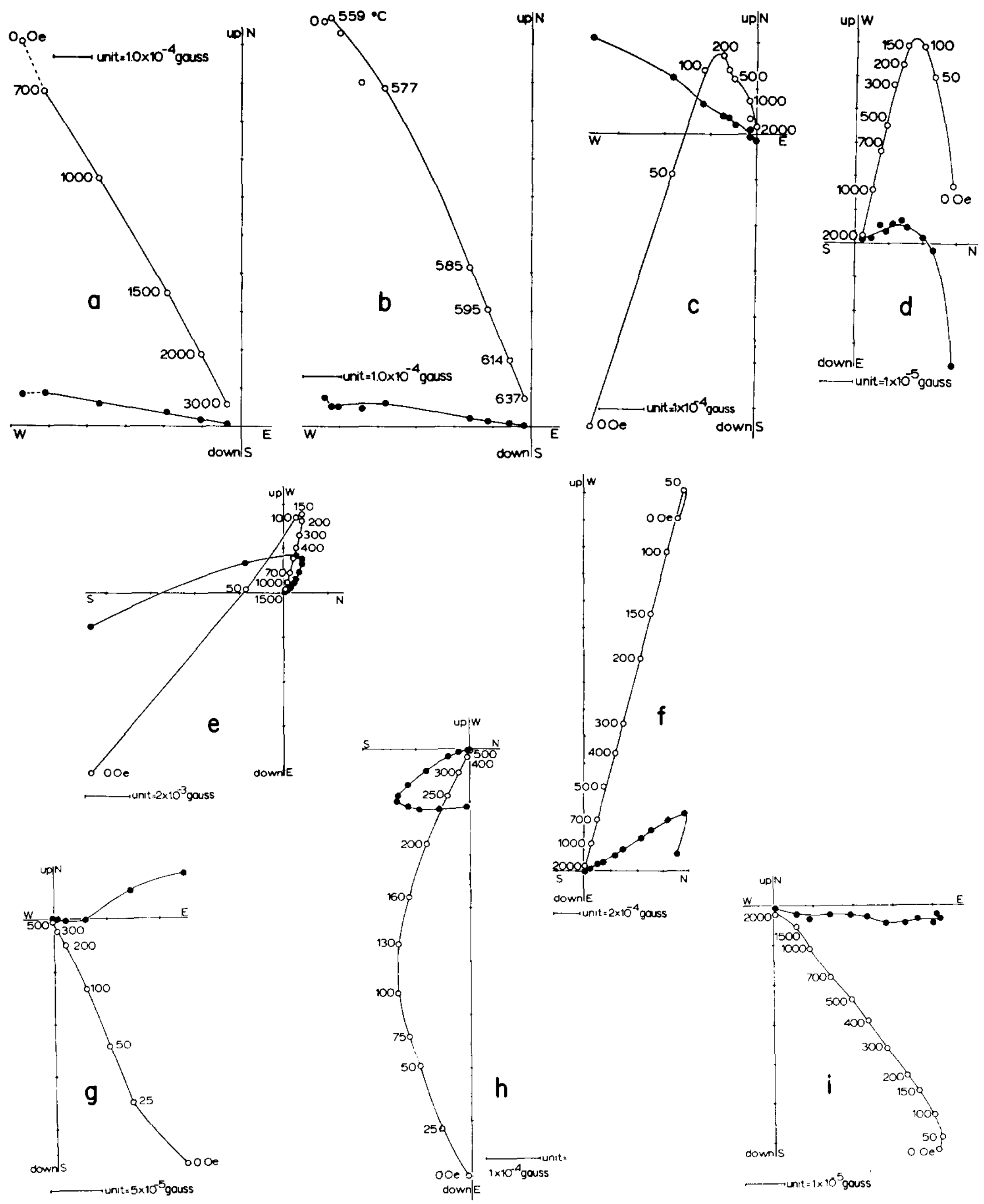

Fig. 3. Typical demagnetization diagrams of samples from (a, b) the lopolith, (c, d) the migmatites, (e, f) the Hunnedalen dikes (g, h) the Egersund dikes and (i) its remagnetized country rock. The projection of the end-point vector of the NRM is indicated by dots in the horizontal plane and by circles in the vertical plane.

9 sites were rejected for this study because of their instability or because the characteristic component was too small for an accurate determination of its direction. The NRM of the samples of the remaining 9 sites which were suitable for palaeomagnetic research appeared to be rather hard in most cases. Two examples of this type of magnetization, as revealed by stepwise magnetic and thermal demagnetization are shown in fig. 3a, b.

The site mean directions are shown in fig. 4a. The range of the a_{95}-values is 4°–9°. The average direction

(a)

(b)

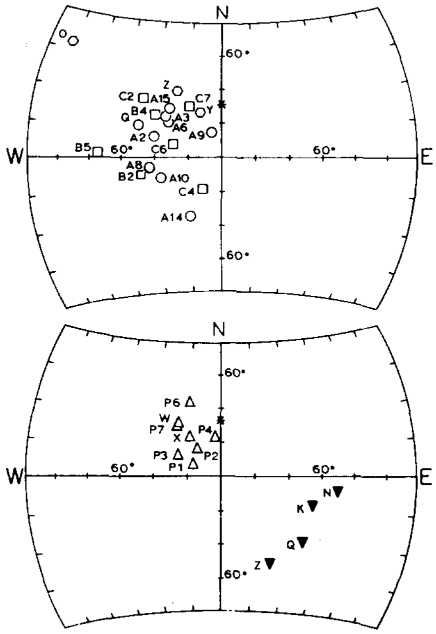

Fig. 4. Equal area projection of the site mean directions of the different Rogaland rock types. Open symbols represent directions pointing upward; closed symbols represent directions pointing downward. (a). Circles: Lopolith of Bjerkreim–Sokndal; hexagons: anorthosite masses; squares: migmatite complex. (b). Triangles pointing upward: Hunnedalen dikes; triangles pointing downward: Egersund dikes or its country rock. The asterisks indicate the direction of the present field.

TABLE 1

Characteristic overall directions of the Rogaland rock formations, number of sites N, FISHER's (1953) best estimate k and a_{95}-values. The numbers in parentheses are the total numbers of samples

Rock formation	N	D (°)	I (°)	k	a_{95}
Lopolith (45)	9	283	−73	45	8
Anorthosites (22)	3	318	−58	12	38
Migmatites (27)	7	286	−70	29	11
Hunnedalen dikes (37)	8	322	−75	134	5
Egersund dikes (35)	4	119	+61	44	14

of these 9 sites, which is the overall direction of the lopolith, is $D = 283°$ and $I = -73°$ (table 1).

6.2. *The anorthosite masses*

The samples of the anorthosite masses were collected near the Egersund dikes. Here, the results are given of the samples which are not affected by the dolerite dikes. The magnetization of these samples is rather hard and is comparable with that of lopolith samples. The direction of the stable magnetization is characteristic for that of the lopolith. The equal area projection of the site mean directions are shown in fig. 4a. The range of the a_{95}-values is 5°–8°. The overall direction is given in table 1.

6.3. *The migmatite complex*

From the migmatites, 72 samples were collected at 12 sites. Considering the stability of the magnetization, the samples of 7 sites were selected for this study. Demagnetization diagrams, representing the type of magnetization encountered, are given in fig. 3c, d. There are some obvious differences with the magnetization type of the samples from the lopolith and the anorthosites. The characteristic magnetization of those samples is generally harder than that of the migmatite samples: the first could not be eliminated completely in alternating fields with 3000 Oe peak value, while the latter could be almost completely decayed by treatment in alternating fields of 2000 Oe peak value. By thermal treatment also a difference in hardness was established: the magnetization of the lopolith and anorthosite samples could in most cases be eliminated completely at temperatures of 640 °C, while 600 °C appeared to be sufficient to eliminate the magnetization of the migmatite samples. An other difference is constituted by the secondary magnetization, which is larger in the migmatite samples than in those of the lopolith and the anorthosite masses.

The overall direction of the migmatite complex is $D = 286°$, $I = -70°$. This direction is almost parallel with that of the lopolith (table 1). Fig. 4a shows the projection of the site mean directions of the migmatite complex. The a_{95}-values of these site mean directions are greater than those of the lopolith, ranging from 6° to 31°.

6.4. *The Hunnedalen dikes*

From the Hunnedalen dikes, 40 samples were collected at 9 sites. Sites X and W are situated in two dikes separated by only 25 m country rock. Sites P4–P7 are in the same dike; P4 and P6 are as close as 20 m from each other and are presented separately because of the systematic different directions of the NRM. The samples of site P5 could not be used because of their instability.

The demagnetization diagram in fig. 3e offers a good example of the magnetization type of the samples from site W, which revealed a rather great but soft secondary magnetization. The demagnetization diagram in fig.

3f is representative for the other samples of the Hunnedalen dikes, which have a very small secondary component. Alternating fields of 2000 Oe peak value were sufficient to eliminate the characteristic magnetization, like heating up to about 580 °C.

The overall magnetic direction of the Hunnedalen dikes is $D = 322°$, $I = -75°$ (table 1). The site mean directions are shown in fig. 4b. The range of the a_{95}-values of the site mean directions is 4°–7°, except for site P1 for which the value of a_{95} is 21°.

6.5. *The Egersund dikes and the adjacent country rock*

Only three sites in the Egersund dikes yielded samples with a suitable magnetization. Moreover, at one site (N), the adjacent country rock appeared to be usable for the determination of the characteristic direction of the Egersund dikes, because the samples became completely remagnetized by the intruding dike and acquired a stable magnetization, which is characteristic for the Egersund dikes.

Samples from the dolerite dikes possess a characteristic magnetization, which could be eliminated by treatment with alternating fields of 500 Oe peak value (fig. 3g, h). The samples from the dolerite dike at site Z, situated in the Tellenes open pit mine, revealed a rather large secondary component, obviously induced by the present field, as is shown by the demagnetization diagram of a sample from site Z (fig. 3h). The remagnetized samples of site N have a rather hard magnetization, which could be eliminated with alternating fields of 2000 Oe peak value (fig. 3i).

The overall direction of the Egersund dikes is $D = 119°$, $I = +61°$. The equal area projection of the site mean directions is given in fig. 4b. The value of a_{95} is 6° for sites N, P and Q, and 11° for site K.

6.6. *The Iveland–Evje amphibolite*

From the Iveland–Evje amphibolite, situated about 100 km east from the Rogaland area, 7 samples were collected from a site near Evje. Most samples revealed an unstable magnetization. Only one sample showed a magnetization that was stable up to 1000 Oe peak value. Its direction is characteristic for that encountered in the Rogaland basement rocks.

7. Discussion of the results

The similar overall magnetic directions of the lopolith, the migmatite complex and the anorthosite masses, suggest a simultaneous magnetization. Hence, if the remanence is thermal in origin, a simultaneous cooling of these rock formations has to be assumed. The range of blocking temperatures, determined for the characteristic magnetizations, points to a temperature range of 550 to 650°C. This temperature range fits the temperatures involved in the amphibolite and granulite facies metamorphism of the migmatites. It is presumed that the characteristic magnetization originated during the cooling after this metamorphic event. The simultaneous cooling of the lopolith and the anorthosite masses together with the migmatites can be explained by a regional uplift. This can also explain the similar magnetization direction found in the Iveland–Evje amphibolite.

Starting from the fact that the lopolith, the anorthosite masses and the migmatite complex reveal similar magnetization directions, the site mean directions of these rock formations can be taken together and averaged to yield an overall magnetic direction of the basement, which is $D = 292°$, $I = -71°$.

Since the overall magnetization direction of the Hunnedalen dikes differs from that of the basement, it is presumed that these dikes intruded after the magnetization of the basement.

The overall direction of the Egersund dikes places the intrusion of these dikes after the supposed uplift of the basement and the intrusion of the Hunnedalen dikes, because of its opposite direction. However, the parallelism of the magnetization suggests that no long time elapsed between the uplift and the intrusion of the Egersund dikes. The overall magnetization direction of the Egersund dikes agrees with the direction determined by STORETVEDT and GIDSKEHAUG (1968), as is shown in table 2.

As the site mean directions within the basement are similar, it is obvious that no great deformation took place after acquisition of the characteristic magnetization. There is no relation between the direction of the bedding planes neither in the migmatites nor in the lopolith and the direction of the stable magnetization. For that reason no tectonical corrections were made.

Attention has to be given to the possibility of a selfreversal mechanism, responsable for the reversed magnetization of the anorthosite masses and the lopolith, because in similar rocks from the Allard Lake

TABLE 2

Palaeomagnetic pole positions observed from the Precambrian of the Baltic Shield and of Great Britain (see fig. 5)

Locality	Age	Pole position (°)	d*p*	d*m*	References
1. Tärendö (Sweden)	2000×10^6 y	45 N 132 W	–	–	1
2. Föglö (Finland)	Sub-Jotnian	31.3 N 186.5 E	5.8	11.5	2
3. Kumlinge (Finland	Sub-Jotnian	13 N 159 W	11	19	3
4. Åva (Finland)	Sub-Jotnian	41 N 169 E	9	17	3
5. Märket (Finland)	Jotnian?	5.9 S 145.5 E	7	11	2
6. Vaasa (Finland)	Jotnian	7 N 164 E	–	–	4
7. Satakunta (Finland)	Jotnian	2 N 158 E	2.8	4.8	5
8. Southern Sweden	$781–1573 \times 10^6$ y	12 S 134 W	17	23	6
9. Scotland (Upper Torridonian)	Late Precambrian	6 S 137 W	4	6	7,8
10. Scotland (Lower Torridonian)	Late Precambrian	35 N 118 W	5	8	7,8
11. England (Longmyndian)	Late Precambrian	2 N 120 W	7	13	9
12. Rogaland (Norway) (basement)	$850–950 \times 10^6$ y	36 S 133 W	10	12	10
13. Rogaland (Norway) (Hunnedalen dikes)	Late Precambrian	34 S 152 W	9	10	10
14. Rogaland (Norway) (Egersund dikes)	Late Precambrian	22 S 129 W	14	16	10
15. Rogaland (Norway) (Egersund dikes)	Late Precambrian	28 S 128 W	–	–	11

References: (1) CORNWELL (1968); (2) NEUVONEN and GRUNDSTRÖM (1969); (3) NEUVONEN (1970); (4) NEUVONEN (1966); (5) NEUVONEN (1965); (6) MULDER (1971); (7) IRVING and RUNCORN (1957); (8) IRVING (1957); (9) CREER (1957); (10) Present study; (11) STORETVEDT and GIDSKEHAUG (1968).

district in Quebec a selfreversal mechanism has been reported by CARMICHAEL (1959, 1961) and HARGRAVES and BURT (1967). In the case of the Rogaland rocks however, such a selfreversal mechanism is improbable, because the reversed magnetization is found in rocks of different composition, like the migmatites and the dolerite dikes of the Hunnedalen system. The haemo-ilmenite minerals which are supposed to be responsible for the selfreversal in the Allard Lake anorthosites and ilmenite norites, are absent in most migmatite rocks and in the dolerite dikes. In the migmatite rocks, the main magnetic minerals are ilmenite–magnetite lamellae, just as in some parts of the lopolith. Moreover, the remagnetized country rock adjacent to the Egersund dikes is remagnetized according to the magnetization of these dikes, which has a normal polarity.

8. Radiometric dating of the characteristic magnetization

It was mentioned in section 3 that the apparent age of about 850×10^6 y, determined for the lopolith and the migmatites, probably reflects the uplift of the Rogaland basement rocks. Hence, the characteristic magnetization of the Rogaland basement rocks, which was supposed to be related to a regional uplift, can be dated at about 850×10^6 y. A maximum age of the origin of the characteristic magnetization is determined by the apparent ages of the zircons from the lopolith (MICHOT and PASTEELS, 1968). It is obvious that the magnetization of the Egersund dikes, and presumably that of the Hunnedalen dikes too, is younger.

9. Palaeomagnetic correlation

In order to make possible palaeomagnetic correlation, the palaeomagnetic pole positions were calculated from the overall directions of the distinct Rogaland rock formations. These are shown in table 2 and plotted in fig. 5, together with other Precambrian poles from the Baltic Shield and Great Britain.

The pole position which is closest to those of Rogaland, has been determinated by MULDER (1971) from hyperite dikes within and along the central southern Swedish schistosity zone, which is shown in fig. 1. From the five dikes examined, two revealed a normal polarity and three a reversed polarity. The K–Ar determinations of these dikes, which has been carried out by PRIEM *et al.* (1968), resulted in apparent ages of three dikes of about $800–900 \times 10^6$ y and of two dikes of about 1550×10^6 y. However, these different ages do not correlate with the reversed and normal magnetized dikes, respectively. Although PRIEM *et al.* (1968) preferred the age of about 1550×10^6 y and

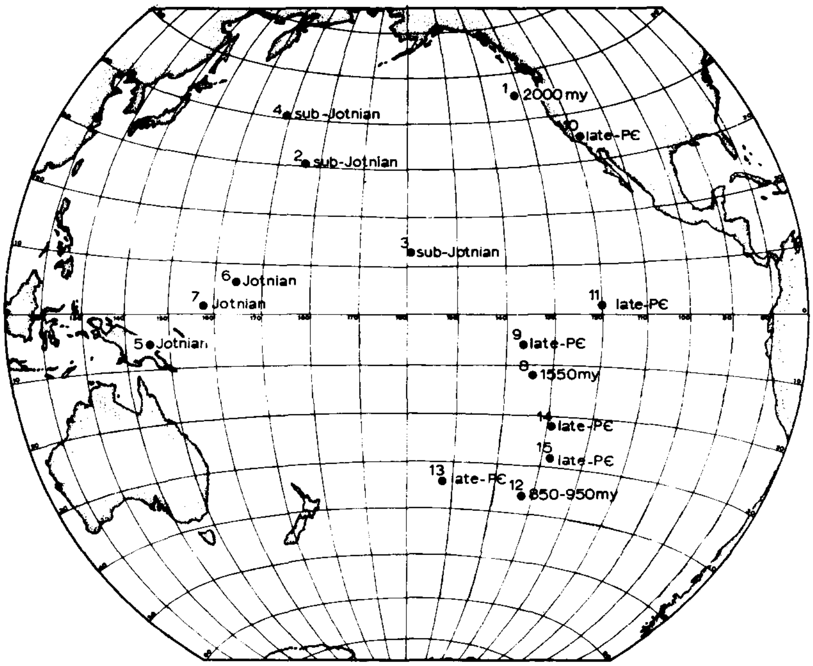

Fig. 5. Precambrian pole positions of the Baltic Shield and Great Britain. Numbers refer to table 2.

supposed the age of about $800–900 \times 10^6$ y to be due to "overprinting" during the Sveco–Norwegian regeneration period (MAGNUSSON, 1960, 1965), the agreement with the Rogaland pole positions favours the age of about $800–900 \times 10^6$ y. The ages of about 1550×10^6 y may be explained by an initial Ar content or an Ar enrichment of the dikes during the intrusion in an old alkali-rich rock. The high magnetic stability of the Swedish hyperite dikes and the existence of two polarities do not point to a remagnetization of these dikes, as has been suggested by NEUVONEN (1970).

Other Precambrian pole positions of the Baltic Shield have been reported by CORNWELL (1968) from northern Sweden, by NEUVONEN (1965, 1966, 1970) and by NEUVONEN and GRUNDSTRÖM (1969) from Finland. These poles, which are given in table 2 and plotted in fig. 5, do not correspond with the Rogaland poles.

IRVING and RUNCORN (1957), IRVING (1957), and CREER (1957) reported palaeomagnetic pole positions from the Precambrian Torridonian sandstones and Longmyndian sediments of Great Britain (table 2 and fig. 5). The pole positions for the Upper Torridonian and the Longmyndian approach those of the Rogaland rock formations.

10. Conclusions

(1). The similar magnetization directions in the lopolith, the anorthosite masses and the migmatite complex are due to a regional magnetization, caused by simultaneous cooling supposedly during a regional uplift after the Sveco–Norwegian regeneration period.

(2). Considering the difference between the overall magnetization direction of the Hunnedalen dike system and that of the basement, the magnetization of the Hunnedalen dikes is presumed to be somewhat later.

(3). After the magnetization of the basement and the Hunnedalen dikes during a reversed polarity epoch, the Egersund dikes intruded and were magnetized during a normal polarity epoch.

(4). The age of magnetization of the Rogaland basement is estimated to be $850–950 \times 10^6$ y.

(5). The Rogaland Precambrian, including the Hunnedalen and Egersund dike systems, can be correlated palaeomagnetically with hyperite dikes in central southern Sweden. Palaeomagnetic pole positions from the Upper Torridonian sandstones and Longmyndian sediments of Great Britain, approach the locations of the Rogaland pole positions. However, other sub-Jotnian and Jotnian pole positions are located far to the west and do not permit any correlation with the late Precambrian pole positions of Rogaland.

Acknowledgments

The author thanks Prof. Dr. J. Veldkamp and Drs. J. D. A. Zijderveld for their stimulating interest and for critically reading the manuscript and Dr. F. G. Mulder for his great suppoıt during the laboratory work and for the discussions. I acknowledge with great thanks Dr. A. C. Tobi's directing in the field.

The fieldwork was financially supported by the "Molengraaff fonds" and the "Norges Geologiske Undersøkelse".

References

ANTUN, P. (1956), *Géologie et petrologie des dolerites de la région d'Egersund*, Ph.D.Thesis, Univ. de Liège.
AS, J. A. (1960), Mededel. Verhandel. Koninkl. Ned. Meteorol. Inst. **78**, 56.
AS, J. A. (1967), The a.c. demagnetization technique. In: D. W. Collinson, K. M. Creer and S. K. Runcorn, eds., *Methods in palaeomagnetism* (Elsevier, Amsterdam) 221.
BARTH, T. F. W. (1945), Norsk Geol. Tidsskr. **25**, 1.
BARTH, T. F. W. and J. A. DONS (1960), Norg. Geol. Undersøkelse **207**, 208.
BROCH, O. A. (1964), Norg. Geol. Undersøkelse **228**, 84.
CARMICHAEL, C. M. (1959), Nature **183**, 1239.
CARMICHAEL, C. M. (1961), Proc. Roy. Soc. London **243**, 508.
CORNWELL, J. D. (1968), Geol. Fören. Stockholm Förh. **82**, 407.
CREER, K. M. (1957), Phil. Trans. Roy. Soc. London A **250**, 111.
DOELL, R. R. and A. COX (1967), Palaeomagnetic sampling with a portable coring drill. In: D. W. Collinson, K. M. Creer and S. K. Runcorn, eds., *Methods in palaeomagnetism* (Elsevier, Amsterdam) 21.
FISCHER, R. A. (1953), Proc. Roy. Soc. London A **217**, 295.
HARGRAVES, R. B. and D. M. BURT (1967), Canad. J. Earth Sci. **4**, 357.
HEIER, K. S. (1956), Norsk. Geol. Tidsskr. **36**, 167.
IRVING, E. (1957), Phil. Trans. Roy. Soc. London A **250**, 100.
IRVING, E. and S. K. RUNCORN (1957), Phil. Trans. Roy. Soc. London A **250**, 83.
JÄGER, E. (1969), Fortschr. Mineral. **47**, 77.
KLOOTWIJK, C. T. (1967), Internal Rept. Univ. Utrecht.
MAGNUSSON, N. H. (1960), Geol. Fören. Stockholm Förh. **82**, 407.
MAGNUSSON, N. H. (1965), Quart. Geol. Soc. London **121**, 1.
MICHOT, P. (1957), Geol. Rundschau **46**, 147.
MICHOT, P. (1960), La géologie de la catazone: le problème des anorthosites, la palingenèse basique et la tectonique catazonale dans le Rogaland méridional. In: *21st Intern. Geol. Congr., Copenhagen, 1960, Rept. Session Norden, Guide de l'excursion* A9.
MICHOT, J. (1961), Acad. Roy. Belg. Classe Sci. Facs. Mém. **1**, 95.
MICHOT, J. and P. PASTEELS (1968), Ann. Soc. Géol. Belg. Mém. **91**, 93.
MULDER, F. G. (1971), Sveriges Geol. Undersøkn. Årsbok Ser. C **653**, 56.
NEUMANN, H. (1960), Norsk Geol. Tidsskr. **40**, 173.
NEUVONEN, K. J. (1965), Compt. Rend. Soc. Géol. Finlande **37**, 153.
NEUVONEN, K. J. (1966), Compt. Rend. Soc. Géol. Finlande **38**, 275.
NEUVONEN, K. J. (1970), Bull. Geol. Soc. Finland **42**, 101.
NEUVONEN, K. J. and L. GRUNDSTRÖM (1969), Bull. Geol. Soc. Finland **41**, 57.
O'NIONS, R. K., R. D. MORTON and H. BAADSGAARD (1969), Norsk Geol. Tidsskr. **49**, 171.
PRIEM, H. N. A., F. G. MULDER, N. A. I. M. BOELRIJK, E. H. HEBEDA, R. A. VERSCHURE and E. A. TH. VERDURMEN (1968), Phys. Earth. Planet. Interiors **1**, 373.
STORETVEDT, K. M. (1965), Nature **205**, 585.
STORETVEDT, K. M. and A. GIDSKEHAUG (1968), Norsk Geol. Tidsskr. **48**, 121.
TOBI, A. C. (1965), Geol. Mijnbouw **44**, 208.
ZIJDERVELD, J. D. A. (1967), A.c. demagnetization of rocks: analysis of results. In: D. W. Collinson, K. M. Creer and S. K. Runcorn, eds., *Methods in palaeomagnetism* (Elsevier, Amsterdam) 254.