NIEDERSÄCHSISCHE STAATS- UND
UNIVERSITÄTSBIBLIOTHEK GÖTTINGEN

Werk

Jahr: 1982
Kollektion: fid.geo
Signatur: 8 Z NAT 2148:51
Digitalisiert: Niedersächsische Staats- und Universitätsbibliothek Göttingen
Werk Id: PPN1015067948_0051
PURL: http://resolver.sub.uni-goettingen.de/purl?PPN1015067948_0051

LOG Id: LOG_0013
LOG Titel: Palaeomagnetic results from lower Paleozoic diabases and pillow lavas from the Frankenwald Area (northwestern edge of the Bohemian Massif)
LOG Typ: article

Übergeordnetes Werk

Werk Id: PPN1015067948
PURL: http://resolver.sub.uni-goettingen.de/purl?PPN1015067948
OPAC: http://opac.sub.uni-goettingen.de/DB=1/PPN?PPN=1015067948

Terms and Conditions

The Goettingen State and University Library provides access to digitized documents strictly for noncommercial educational, research and private purposes and makes no warranty with regard to their use for other purposes. Some of our collections are protected by copyright. Publication and/or broadcast in any form (including electronic) requires prior written permission from the Goettingen State- and University Library.
Each copy of any part of this document must contain there Terms and Conditions. With the usage of the library's online system to access or download a digitized document you accept the Terms and Conditions.
Reproductions of material on the web site may not be made for or donated to other repositories, nor may be further reproduced without written permission from the Goettingen State- and University Library.

For reproduction requests and permissions, please contact us. If citing materials, please give proper attribution of the source.

Contact

Niedersächsische Staats- und Universitätsbibliothek Göttingen
Georg-August-Universität Göttingen
Platz der Göttinger Sieben 1
37073 Göttingen
Germany
Email: gdz@sub.uni-goettingen.de

J Geophys (1982) 51:24–28

Journal of Geophysics

Palaeomagnetic Results from Lower Paleozoic Diabases and Pillow Lavas from the Frankenwald Area (Northwestern Edge of the Bohemian Massif)

In-Soo Kim* and H.C. Soffel

Institut für Allgemeine und Angewandte Geophysik, Universität München, Theresienstrasse 41, D-8000 München 2,
Federal Republic of Germany

Abstract. In the Frankenwald area (northwestern part of the Bohemian Massif, mean geographic coordinates: 11.72° E, 50.33° N), 15 sites of mostly Upper Devonian and partly older (Late Ordovician) diabases and pillow lavas have been sampled. The entire region has been affected by the Variscan Orogeny (Sudetian Phase) causing folding, uplifting and a low grade regional metamorphism. For 11 of the 15 sites, consistent mean characteristic remanence directions (ChRM) could be determined after AF demagnetization and application of various techniques for vector separation. Thermal demagnetization, though partly confirming the alternating field demagnetization results, was in general not successful. The characteristic remanent magnetization of 8 sites, all of reversed polarity, cluster together with a mean direction at $D=198.9°$, $I=-17.2°$ ($N=8$, $R=7.877$, $k=57.0$, $\alpha_{95}=6.6°$) before tectonic correction. They become dispersed ($k=7.6$) after tectonic correction indicating that the characteristic remanent magnetization is syngenetic or younger than folding.

Compared with the European APWP of Irving (1977), the mean pole position obtained from the 8 sites ($\lambda'=164.4°$ E, $\varphi'=45.7°$ N, $K=82.3$, $A_{95}=5.5°$) gives a Permian age to the remanence (270-240 m.y.). The magnetic overprint was probably caused by the Variscan Orogeny of the region or possibly in connection with the intrusion of the granites of the nearby Fichtelgebirge, for which youngest cooling ages of 280 m.y. have been determined. The reversed characteristic remanence may be explained by the reversed Kiaman interval (290-230 m.y.).

Key words: Palaeomagnetism – Bohemian Massif – Paleozoic palaeopoles

Geology and Sampling

The "Frankenwald" in north-eastern Bavaria is a section of the Saxothuringian Zone of the western part of the Bohemian Massif. The geology of the area has been described by v. Horstig (1964), and Wurm (1961, 1962). It consists of Paleozoic sedimentary rocks (slates, limestones, greywackes and conglomerates) ranging in age from the Middle Cambrian to Early Carboniferous time and volcanic rocks (diabases, diabase tuffs, keratophyrs) with ages between the Ordovician and Early Carboniferous.

The entire region has been affected by the Variscan orogeny, which caused folding and uplifting, mainly during the Late Carboniferous (Sudetian Phase). The intrusion of the granites in

Table 1. Sample locality name, geographic coordinates, age, rock-type, strike and dip of the strata

Site	Locality	Geographic coordinates (° E/° N)	Age	Rock type	Strike/Dip
BL	Blechschmiedhammer	11.690/50.397	Ordov.?	diabase	240/25 NW
BS	Bad Steben	11.656/50.366	Late Devon.	diabase	55/30 SE
D	Dürrenwaid	11.571/50.347	Late Devon.	diabase	160/35 SW
ER	Erbsbühl	11.677/50.316	Ordov.?	diabase	0/60 E
F	Feilitzsch	11.934/50.357	Ordov.?	diabase	10/20 E
H	Hof	11.880/50.330	Ordov.?	pillow lava	320/25 NE
HB	Hof-Bad	11.930/50.312	Ordov.?	diabase	50/50 SE
HD	Haidt	11.944/50.339	Ordov.?	diabase	120/50 SW
HO	Hofeck	11.881/50.330	Ordov.?	diabase	50/40 SE
K	Köditz	11.839/50.321	Ordov.?	diabase	270/30 N
L	Langenbach	11.592/50.374	Late Devon.	diabase	140/20 SW
NA	Naila	11.698/50.321	Ordov.?	diabase	110/45 SW
NT	Neutauperlitz	11.958/50.299	Paleozoic	pillow lava	330/30 NE
RO	Rothenbürg	11.768/50.312	Ordov.?	diabase	180/15 W
W	Weidesgrün	11.747/50.298	Ordov.?	pillow lava	uncertain (horizontal?)

---

* *Present address:* Department of Geology, Busan National University, Busan 607, Republic of Korea

0340-062X/82/0051/0024/$01.00

Table 2. Palaeomagnetic results

NRM natural remanent magnetization; ChRM. characteristic remanent magnetization, before and after bedding correction; N: number of samples; R: resultant vector; D: declination; I· inclination; k· precision parameter; α_{95}, A_{95}: semiangle of cone of 95% confidence; AF· optimum alternating field in mT; λ', φ' geographic coordinates of palaeomagnetic pole position; $D_{corr.}$, I_{corr} : declination and inclination, respectively, after bedding correction

Site	NRM						ChRM												
	N	R	D(°E)	I(°)	k	α_{95}(°)	N	R	D(°E)	I(°)	k	α_{95}(°)	AF	λ'(°E)	φ'(°N)	$D_{corr.}$(°E)	I_{corr} (°)
BL	21	12.1	215.3	−3.9	2.2	20.4	14	13.575	200.7	−19.3	30.6	6.8	30–40 mT	161.6	46.1	197.0	− 2.7
BS[a]	12	11.8	294.7	79.5	65.1	5.0	not possible to isolate ChRM							–	–	–	–
D	26	14.4	179.5	72.7	2.2	18.7	11	10.296	195.8	−14.4	14.2	11.2	30–40 mT	169.1	45.1	182.1	−31.9
ER[a]	14	12.1	21.2	74.8	6.9	14.2	not possible to isolate ChRM							–	–	–	–
F	30	25.0	220.6	84.6	5.8	10.6	9	8.833	196.9	−19.4	47.9	6.7	30–45 mT	167.0	47.3	203.2	−15.9
H[a]	22	21.0	241.1	83.3	20.5	6.6	not possible to isolate ChRM							–	–	–	–
HB	14	12.6	43.1	80.8	9.0	12.5	12	11.760	200.9	−30.6	45.8	6.0	45–50 mT	158.0	52.2	239.1	−40.4
HD[a]	17	13.8	288.7	87.6	5.0	15.2	not possible to isolate ChRM							–	–	–	–
HO	28	23.6	231.6	79.8	6.1	10.7	5	4.962	184.4	−12.2	104.1	6.1	30 mT	185.7	45.7	203.3	−40.0
K	23	19.6	188.6	54.1	6.4	11.5	9	8.776	195.4	− 4.2	35.7	7.8	30–60 mT	171.5	40.0	196.9	+24.7
L[b]	25	24.0	39.9	85.3	23.8	5.7	19	18.619	97.2	+84.4	47.2	4.7	30 mT	28.1	47.8	215.6	+73.3
NA	14	10.6	214.0	13.1	3.8	19.3	11	10.504	209.6	−16.8	20.2	9.4	30 mT	150.9	41.6	219.0	−60.7
NT[b]	20	19.2	351.7	78.6	24.5	6.3	15	13.949	304.8	+71.8	13.3	9.9	50 mT	314.9	57.7	21.9	+62.8
RO	17	16.2	220.5	65.1	19.4	7.7	8	7.415	208.4	−19.7	12.0	14.3	30–40 mT	151.6	43.5	202.6	−26.2
W[c]	6	5.5	164.4	57.8	9.7	18.3	14	13.835	170.8	+ 1.6	78.8	4.2	40 mT	203.5	38.3	170.8	+ 1.6
							8	7.877	198.9	−17.2	57.0	6.6		λ' = 164.4°E φ' = 45.7°N K = 82.3 A_{95} = 5.5° Mean pole position		$N=8$; $R=7.085$ $D=203.7°$ $I=-25.4°$ $k=7.6$; $\alpha_{95}=17.9°$ Mean direction of ChRM after bedding correction	
							Mean ChRM direction before bedding correction										

[a] Sites where no ChRM could be determined

[b] Discarded because of too steep an inclination

[c] Discarded because of uncertain tectonic position

the Fichtelgebirge (about 25 km SE of the investigated area) occurred at that time and is believed to be responsible for a anchi- to epizonal metamorphism of the Paleozoic rocks in the Frankenwald area.

As mentioned above, the diabase volcanism occurred from the Ordovician until Early Carboniferous times with strongest activity during the Late Devonian. The ages of the volcanic rocks (see Table 1) have been determined from the stratigraphic relations with the fossiliferous sedimentary rocks. However, the Ordovician ages are not certain and there are good arguments (v. Horstig, 1964) that they are in fact mostly of Late Devonian age.

A simplified geological map of the area is shown in Fig. 1 (modified after Wurm, 1961). The 15 sampling localities are shown as dots. More details about the sampled sites (geographic coordinates, age, rock type, strike and dip) can be taken from Table 1.

From each site, a large number (see Table 2) of oriented cores and hand samples have been taken. The very low magnetization of the rocks allowed the use of a magnetic compass for orientation.

Palaeomagnetic Measurements

Natural Remanent Magnetization, Q-Ratio

The measurement of the remanent magnetization has been carried out with a Digico spinner magnetometer. All specimens with a magnetization less than 0.5×10^{-3} A/m have been discarded (89 specimens = 6.8%) in consideration of lack of precision of the magnetometer in our laboratory. Most specimens had NRM intensities between $1–100 \times 10^{-3}$ A/m.

The Koenigsberger ratios Q determined from an inducing field of 0.474 Oe = 47.4 μT have a maximum at $Q = 0.1$, which is about two orders of magnitude smaller than Q of Tertiary volcanic rocks (e.g. Becker, 1978) and indicates that the primary thermoremanent magnetization (TRM) of the diabases and pillow lavas may have decayed considerably or has been replaced by a secondary magnetization.

Table 2 gives the mean directions of NRM of all sites. With few exceptions, the precision parameter k was less than 10 indicating a large scatter. Figure 2 shows the means of all sites together with the cones of confidence. The present geomagnetic field in the sampling area (asterisk) has no major influence on the NRM directions. In only one case it is situated within a cone of confidence (site ER). The means have a trend towards a great circle distribution between a very steep direction with positive inclination and a shallow direction with negative inclination in the third quadrant (site BL). This distribution of the directions indicates that the NRM is composed of at least two remanence components.

Demagnetization Experiments

Alternating Field (AF) Demagnetization. AF demagnetization was made with a Highmoor AF demagnetizer (maximum field 1,000 Oe = 100 mT). The occasional application of higher fields

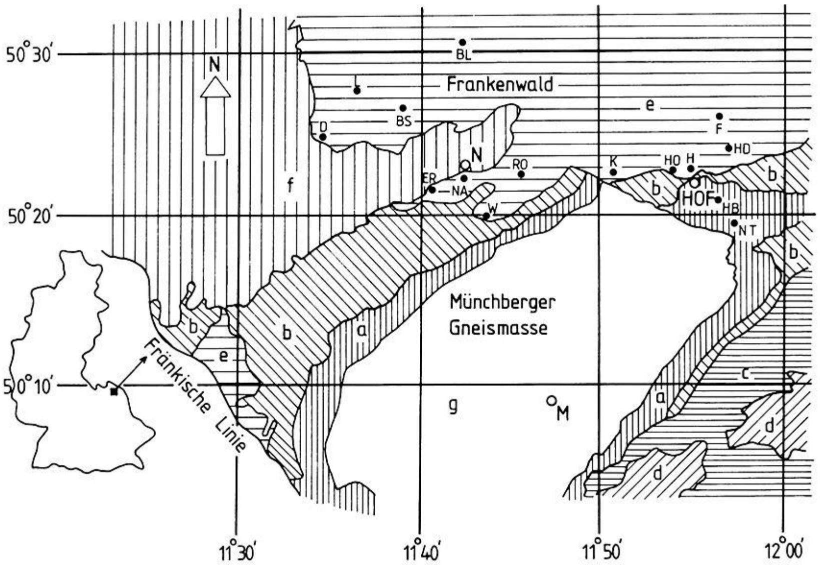

Fig. 1. Geological map of the sampling area (simplified, after Wurm (1961)) showing sampling sites (*closed circles*). *Open circles*: localities HOF, Naila (*N*), Münchberg (*M*).
a: Amphibolites and green schists; *b:* Lower Carboniferous – Upper Devonian, mainly greywackes and schists; *c:* Ordovician, mainly schists; *d:* granites of the Fichtelgebirge, cooling ages from 280–310 m.y.; *e:* Devonian sediments, diabases and keratophyrs; *f:* Lower Carboniferous; *g:* Gneisses of the Münchberger Gneismasse

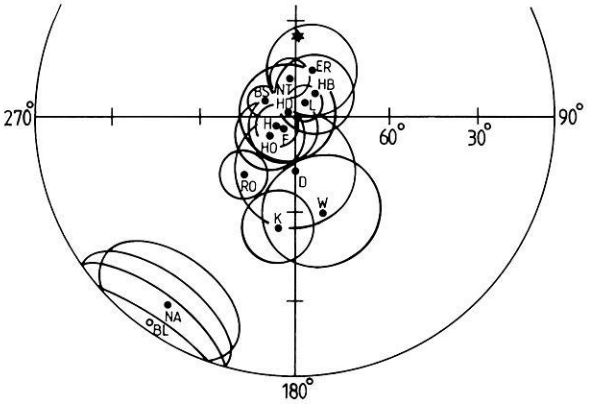

Fig. 2. Equal area projection of the site mean NRM directions together with their α_{95} cones of confidence. All sites except site BL have a positive inclination. Note the great circle distribution. *Asterisk:* direction of the present geomagnetic field in the sampling area

with a home made AF demagnetization apparatus (maximum field: 2,500 Oe = 250 mT) yielded no general improvement. As it was very difficult to isolate a stable and consistent direction of characteristic remanence (ChRM), different methods of analysis (stable endpoint method (Irving, 1964), reversal test (Cox and Doell, 1960), minimum scatter (Dagley and Ade-Hall, 1970), vector differences (Roy and Park, 1974; Hoffman and Day, 1978) and Zijderveld diagrams (Zijderveld, 1967; Dunlop, 1979) had to be applied simultaneously. Only sample means with an internal precision parameter larger than 15 have been used for the computation of a site mean direction. Furthermore the results of specimens with a magnetization less than 0.5×10^{-3} A/m have been omitted (see above). Figure 3 shows some typical examples of demagnetization experiments plotted in Zijderveld (1967) orthogonal vector diagrams (see also legend of Fig. 3). An example of the presence of two almost antiparallel components of different stability is given in Fig. 3a (Na 30/2/3).

Thermal Demagnetization. Thermal demagnetization was carried out using a nonmagnetic furnace described by Schweitzer (1975). The laboratory field was compensated by double μ-metal shielding and Helmholtz-coils. This demagnetization method was applied in order to test the results obtained by AF demagnetization and to investigate all those sites where AF demagnetization failed to yield a consistent direction. However, thermal demagnetization was unsuccessful in many cases, as shown in Figure 3b (specimen from site ER). This was mainly due to the instability of maghemite (see below) at elevated temperatures.

Characteristic Remanent Magnetization (ChRM)

The final results together with their statistical parameters are listed in Table 2. The optimum peak alternating field in mT is also given. For sites marked with a, no consistent remanence direction could be obtained with any of the techniques mentioned above. The sites L and NT have a mean remanence direction very close to the NRM direction with a steep positive inclination (even after tectonic correction, see below). They have been discarded. The direction of site W is also apart from those of the others and has therefore not been included in the computation of a mean ChRM direction. The remanence directions of the other 8 sites are well grouped (see Fig. 4) and give a mean of: $D = 198.9°$, $I = -17.2°$, $k = 57.0$ and $\alpha_{95} = 6.6°$. It is noticeble that all ChRM directions are of reversed polarity. We will refer to this point later.

Application of Bedding Corrections

The diabases which have been sampled are located within complicated geological structures. Strike and dip at each site is listed in Table 1. The ChRM directions corrected for the bedding are listed in Table 2. The 8 directions, well clustered, before bedding correction become more dispersed by the correction, while the mean value does not change very much. The exact figures can be taken from Table 2. The precision parameter drops from $k = 57.0$ before to $k = 7.6$ after bedding correction indicating that the ChRM direction is of the same age or younger than folding (Graham, 1949). We will discuss this again below.

Rock Magnetism and Polished Section Studies

The induced magnetization in a 300 mT field was measured as a function of temperature (*J*/*T*-curves) in order to identify the carrier of magnetization. The Curie temperatures were in general between 500° and 560° C. Most curves show a sharp drop of J at around 350° C in the heating cycle, but not in the cooling

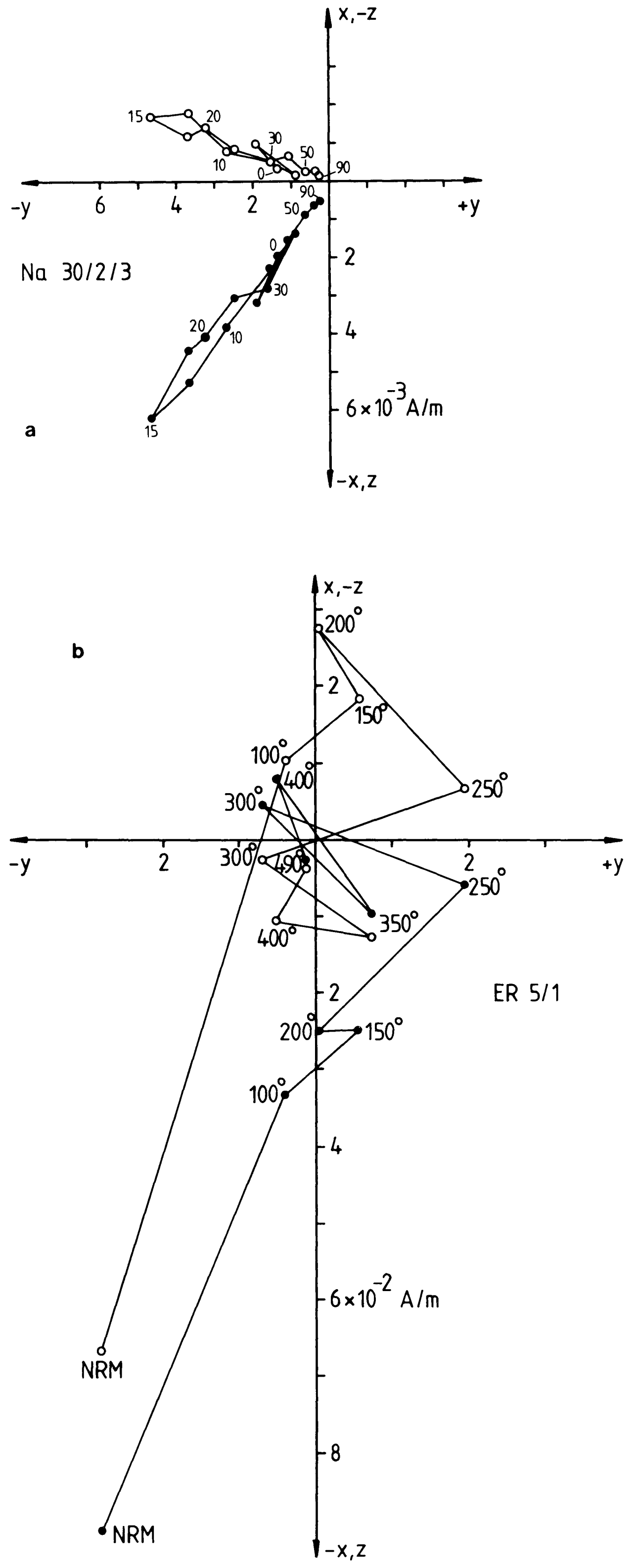

Fig. 3a, b. Remanence during stepwise demagnetization. *Closed symbols*. horizontal components. *Open symbols*. plot of the horizontal component *y* versus the vertical component *z*. The directions refer to an internal coordinate system of the specimens. Temperatures and peak alternating field values are given in ° C and mT, respectively. **a** AF demagnetization of a specimen from site NA showing antiparallel remanence components. **b** Thermal demagnetization of a specimen from site ER, where no consistent remanence could be isolated

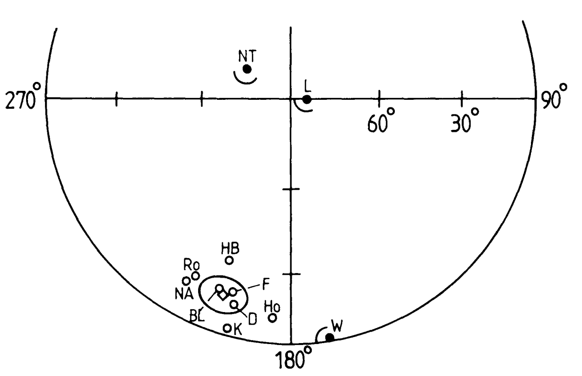

Fig. 4. Equal area projection of the site mean directions of characteristic remanent magnetization before bedding correction. *Open square*. mean direction with cone of confidence of 8 well grouped sites, omitting sites W, L and NT *Closed* and *open symbols*. positive and negative inclination, respectively

cycle. While the high Curie temperatures indicate a phase close to magnetite, the drop of *J* near 350° C is interpreted as due to the destruction of maghemite or titanomaghemite. Only a few measurements showed indications of a primary titanomagnetite. Therefore the low temperature oxidation products of titanomagnetites, namely titanomaghemite and maghemite can be regarded as the typical magnetic ore minerals of the diabases of this study. The presence of metastable maghemite also explains why thermal demagnetization was less successful than AF demagnetization.

The presence of (titano) maghemite could also be confirmed by polished section studies. Only site F showed indications of a high temperature oxidation (exsolution lamellae). In all other diabases the primary titanomagnetites were seriously altered by low temperature oxidation (formation of titanomaghemite) along margins and cracks. In the rocks yielding no consistent remanence direction at all (BS, ER, H, HD), the primary ore content was almost completely replaced by unidentified, partly transparent, in any case nonmagnetic minerals (pseudobrookite?). The condition of the ore minerals makes the presence of a primary magnetization, such as a TRM, very unlikely. Details of the polished section studies can be found in Kim (1981).

Pole Positions and Conclusions

From the 8 consistently grouped ChRM directions the virtual geomagnetic pole positions have been computed and listed in Table 2. A mean palaeomagnetic pole postion at $\lambda' = 164.4°$ E, $\varphi' = 45.7°$ N ($K = 82.3$, $A_{95} = 5.5°$) was obtained. It's position (Fig. 5) is very distant from other European Early to Middle Paleozoic pole positions and indicates that the ChRM is in fact much younger than the ages of the rocks. A comparison with Irving's (1977) pole positions gives an age of ChRM of 250 m.y. The cone of confidence (5.5°) and the course of the APWP limits the age to between 240 and 270 m.y. This must be the time interval in the sampling area when Variscan folding took place or came to an end and when the primary ore content could have been replaced by secondary ore minerals.

It should be noted here that all well grouped sites are of reversed polarity and that the age of remanence points to the Kiaman reversed interval (290 to 230 m.y. according to McElhinny, 1973).

We conclude therefore that the Middle Devonian (or possibly even partly Ordovian) diabases in the Frankenwald area have

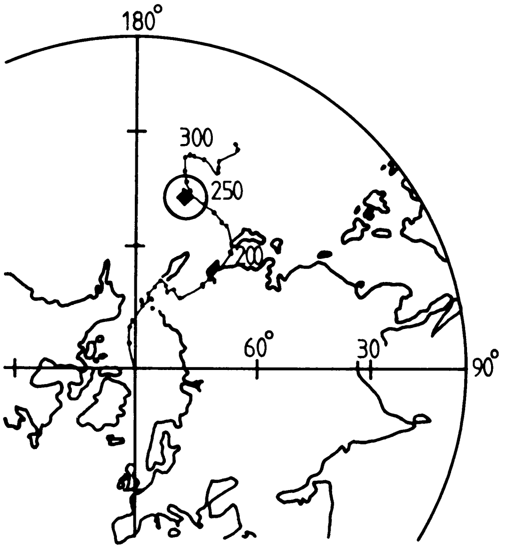

Fig. 5. Apparent polar wander path of Eurasia since the Devonian (simplified, after Irving, 1977). *Numbers* are absolute ages in m.y. *Closed square* with cone of confidence: mean pole position of this investigation, derived from the characteristic remanence directions before bedding correction, showing an Upper Carboniferous to Middle Permian age of remanence of the Middle Devonian diabases

been entirely remagnetized in Late Carboniferous to Middle Permian during the Kiaman reversed interval of the geomagnetic field. The remagnetization is probably related to the Variscan Orogeny or eventually to the granitic intrusions at the end of the Variscan Orogeny in that region (granites of the Fichtelgebirge) with a youngest cooling age of 280 m.y. according to Besang et al. (1976).

Since that time the different rock units have not been rotated or tilted separately. Vertical movements of the block cannot be excluded from the paleomagnetic data.

Our results seem to confirm the suspicion expressed by Creer (1968) that most of the Paleozoic rocks from Europe and North America have been remagnetized in Permo/Carboniferous times. We think, however, that the remagnetization of the diabases in the Frankenwald area is due to regional metamorphism during the Variscan Orogeny. Van der Voo and French (1977) found recently that the Ordovician red beds in northeastern America have been remagnetized by the Appalacian Orogeny. It therefore remains questionable whether Paleozoic rocks from Europe, taken from regions which have been affected by the Variscan Orogeny, can be used for reconstructions of the Paleozoic mobile belts within Europe.

Finally, we want to draw the reader's attention to the sites which have been sampled near the town Hof (sites H, HB, HO, Fig. 1). During Roman times, the name of Hof was Curia Variscorum. From this the name of the Variscan Orogeny was taken.

References

Becker, H.: Vermessung des erdmagnetischen Feldes (ΔZ) längs Profilen in Nordost- und Ost-Island und der Versuch der Interpretation unter Berücksichtigung gesteinsmagnetischer Untersuchungen. Dissertation, Universität München 1978

Besang, C., Harre, W., Kreuzer, H., Lenz, H., Müller, P., Wendt, P. Radiometrische Datierung, geochemische und petrographische Untersuchungen der Fichtelgebirgsgranite. Geol. Jahrb. **E8**, 3–71, 1976

Cox, A., Doell, R.R. Review of palaeomagnetism. Geol. Soc. Am. Bull. **71**, 647–768, 1960

Creer, K.M.: Palaeozoic palaeomagnetism. Nature **219**, 246–250, 1968

Dagley, P., Ade-Hall, J.M. Cretaceous, Tertiary and Quaternary palaeomagnetic results from Hungary. Geophys. J. **20**, 65–87, 1970

Dunlop, D.J. On the Use of Zijderveld Vector Diagrams in Multicomponent Palaeomagnetic Studies. Phys. Earth Planet. Int. **20**, 12–24, 1979

Graham, J.W.: The stability and significance of magnetism in sedimentary rocks. J. Geophys. Res. **54**, 131–167, 1949

Hoffmann, K.A., Day, R.: Separation of multicomponent NRM: a general method. Earth Planet. Sci. Lett. **40**, 433–438, 1978

Irving, E.: Palaeomagnetism and its application to geological and geophysical problems. New York: J. Wiley, 1964

Irving, E.: Drift of the major continental blocks since the Devonian. Nature **270**, 304–309, 1977

Kim, I.S.: Paläomagnetische Untersuchungen an altpaläozoischen Diabasen und Pillow-Laven aus dem Frankenwald in Nordost-Bayern. Dissertation, Universität München 1981

McElhinny, M.W.: Palaeomagnetism and Plate Tectonics. Cambridge: Cambridge University Press 1973

Roy, J.L., Park, J.K.: The magnetization process of certain red beds: Vector analysis of chemical and thermal results. Can. J. Earth Sci. **11**, 437–471, 1974

Schweitzer, Ch.: Vergleich mehrerer Methoden zur Bestimmung der Intensität des Erdmagnetfeldes an rezenten Laven und ihre Anwendung auf mesozoische und paläozoische magmatische Gesteine. Dissertation, Universität München, 1975

Van Der Voo, R., French, R.B.: Palaeomagnetism of the Late Ordovician Juniate Formation and the remagnetization hypothesis. J. Geophys. Res. **82**, 5796–5802, 1977

von Horstig, G.: Altpaläozoikum des Frankenwaldes und im Untergrund Nordbayerns. In: Erläuterungen zur Geologischen Karte von Bayern 1:500000. 2nd Edition. Bayerisches Geologisches Landesamt, München, 1964

Wurm, A. Geologie von Bayern I. Borntraeger, Berlin, 1961

Wurm, A. Frankenwald, Fichtelgebirge und nördlicher Oberpfälzer Wald. Sammlung geologischer Führer **41**, Gebr. Borntraeger, Berlin, 1962

Zijderveld, J.D.A.: A.C. demagnetization of rocks: analysis of results. In: Methods in Palaeomagnetism, D.W. Collinson, K.M. Creer, S.K. Runcorn, eds. Amsterdam: Elsevier Publ. Comp. 1967

Received December 22, 1981; Revised version March 9, 1982
Accepted March 17, 1982