A PALEOMAGNETIC STUDY OF SOME BASALTOIDS AND ORES FROM THE PONTIC RANGES, NORTHERN TURKEY

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ABSTRACT. — The paleomagnetism of basic rocks and sulfide ores has been studied in the Küre area, Pontic Ranges, Turkey. Progressive alternating-field demagnetization revealed a characteristic remanent magnetization in all investigated rock types except a dacite. The following virtual geomagnetic poles were obtained:

Basalt and quartz diabase (oldest): $D=59°$, $I=+66°$, $\alpha_{95}=4.8$, pole 49°N, 93°E

Diabase: $D=210°$, $I=-15°$, $\alpha_{95}=15.0$, pole 47°N, 167°E

Massive sulfide ores: $D=107°$, $I=+63°$, $\alpha_{95}=8.7$, pole 18°N, 80°E

Peridotite: $D=131°$, $I=+54°$, $\alpha_{95}=10.9$, pole 2°S, 72°E

Amphibolitized diabase (youngest): $D=293°$, $I=+59°$, $\alpha_{95}=12.6$, pole 40°S, 145°E

The longitudinal difference in pole positions between the oldest and the youngest rocks is interpreted as being due to a post-Permian counter-clockwise rotation of the studied region in relation to the African continent. In addition, there are indications of local rotational movements within the Küre area.

INTRODUCTION

This paper presents a paleomagnetic investigation of rocks and ores from the Küre area, Pontic Ranges, northern Turkey. The studied units comprise basalts (massive flows and pillows), massive sulfide ores, and various dikes consisting of quartz diabase, diabase, peridotite, and amphibolitized diabase. Altogether 113 specimens from 42 localities have been measured. The paleomagnetic work was carried out at the Paleomagnetic Laboratory of the Geological Institute, Lund.

The object of the present investigation is to compare Permian-Jurassic results from the Küre area with those from other parts of Turkey, Armenia (Southwest USSR), Minor Caucasus, Africa, the Arabian Shield, and Europe. It is also of interest to see whether the paleomagnetic data for the various units can shed light on their relative movements within the faulted Alpine orogenic belt of this area, and to study the possibility of arranging the events in chronological order.

GEOLOGY

Küre is situated at 41.81°N/33.72°E, 30 km from the Black Sea coast, on the western flank of the Pontic Ranges (Fig. 1), which extend along the coast from Zonguldak to Rize. The investigated area lies about 70 km to the north of the great zone of dextral strike-slip faults, the North Anatolian fault zone, which goes from west to east straight across northern Turkey from the Dardanelles to Van Gölü (Fig. 1). Moreover, according to Pavoni (1961), one of the many tectonic lineaments belonging to this large transcurrent fault forks in Ladik-Kavak and passes east of Küre to İnebolu and into the Black Sea (Fig. 1).

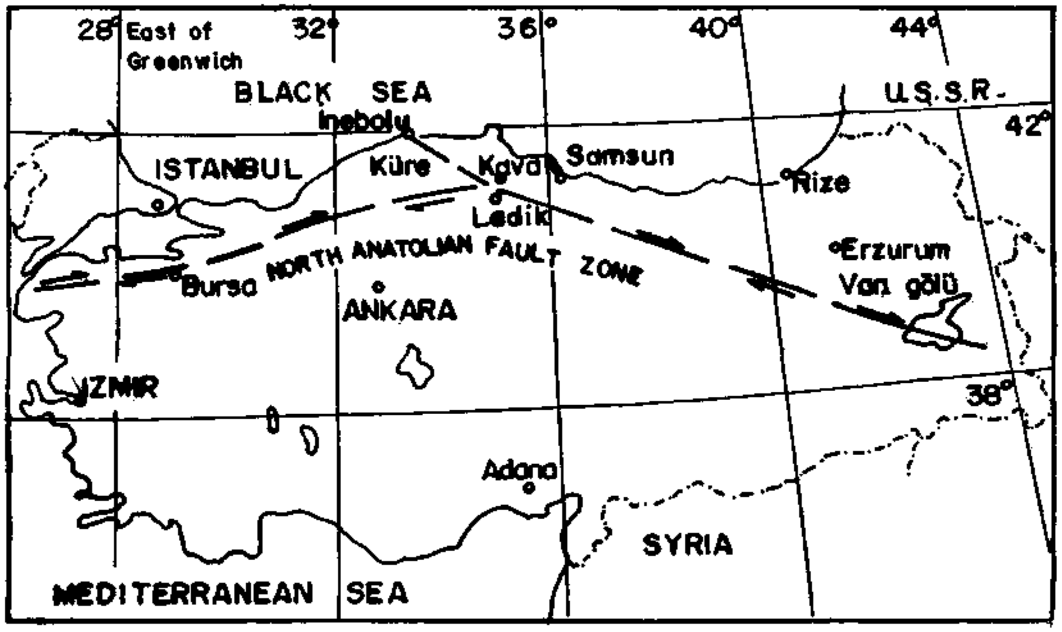

Fig. 1 - Sketch-map of Turkey showing the North Anatolian fault zone.

The geology of the area and the massive sulfide deposits at Küre have been described elsewhere (Güner, in press). A large succession of submarine basalts, generally massive flows at the base, that is upwards gradually followed by pillows, pillow breccias, and tuffaceous chloritic masses, has intruded into the eugeosynclinal accumulations of subgraywacke and black shale. The latter is estimated to be Permian (Güner, in press). The basalt complex, in turn, has been intruded by numerous dikes of diabases, dacite, and peridotite. The massive sulfide ores occur as hydrothermally deposited emplacements along weak zones in the basalt succession. The dikes and the sulfide ores are well distributed both in time and in type of rock and give information on the tectonic development of this mobile belt. Presumably, the Alpine movements of Early Kimmerian, Triassic age, had generated a series of N-S trending faults, which then acted as main channelways for the ore solutions. Ketin (1962) stated that the orogenic movements in northern Anatolia during Permian-Jurassic phases had been violent. It is most probable that, at the end of the Jurassic, the Küre area was raised above sea level as an "island, whereas its surroundings were still under water, which is indicated by the Cretaceous formation. According to Brinkmann (1976), the Pontic Ranges were formed in two phases. The older mountains are represented by the inner zones of the range and are largely incorporated into the outer Pontides. The youngest formation in the investigated area, a massive limestone, has been dated by finds of Late Jurassic fossils (Sarıcan, 1968; Kovenko, 1944).

MEASUREMENT AND DEMAGNETIZATION

113 specimens were drilled from 46 oriented samples and sawn into cylinders 25.0 mm in diameter and 25.0 mm in length. The directions and intensity of remanent magnetization of each specimen was measured with a Digico Balanced Fluxgate Rock Magnetometer. The lower range of sensitivity of this instrument is 10^{-8} *emu/cc.*

Systematic alternating-field demagnetization was carried out in an attempt to isolate the primary component of magnetization. For each specimen, the demagnetizations were done stepwise with measurements after each step. In Fig. 2, the variations of the ratio M/M_0 versus the demagnetizing field demonstrate that all the curves, with the exception of that for the dacite, have uniform relative decay patterns, which indicates the presence of minerals with moderate obercivity. A rapid decrease of the ratio M/M_0 versus the demagnetizing field shows the presence of minerals with low coercivity arid is, as a rule, accompanied by unstable remanence. On the other hand, minerals with high coercivity give curves with slow decrease. It is seen from the intensity curves, that all the specimens of the various units retain a marked fraction of their initial moment up to 800 Oe peak fields. During demagnetization, a stable consistent direction of the magnetic vector was generally obtained in fields as low as 50 Oe. The data obtained by the measurements are listed in Table 1. The magnetic directions before and after demagnetization are plotted in stereograms (Figs. 3-5).

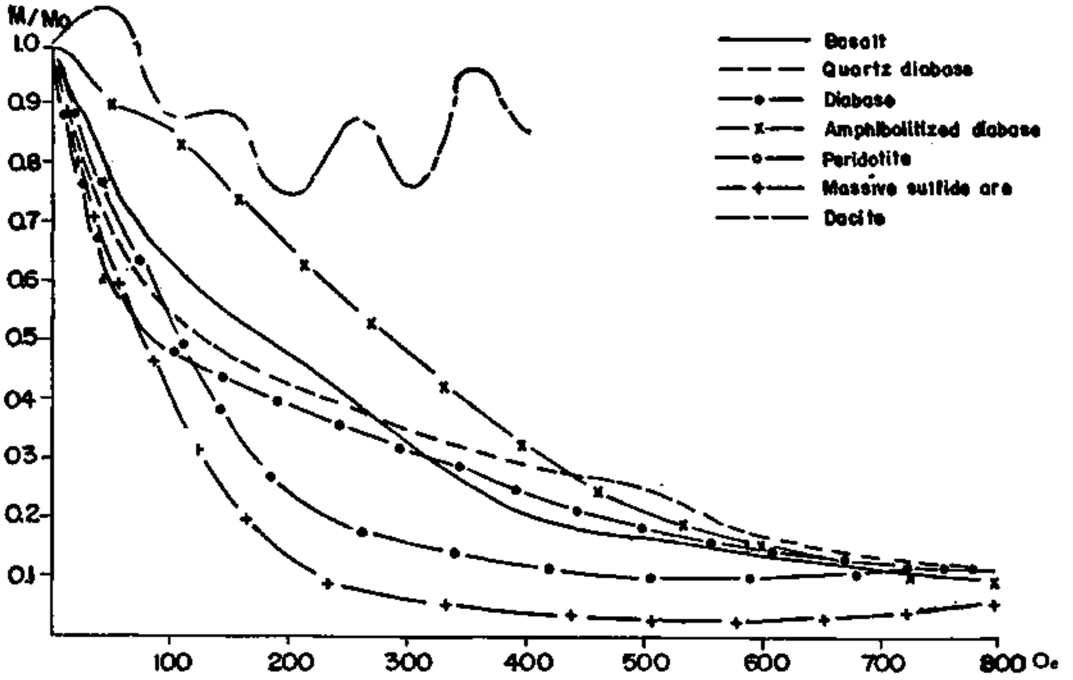

Fig. 2 - Plot of M/M_0 versus the demagnetizing field. M_0=intensity of the initial remanence, M=intensity measured demagnetization in field.

Basalt

The 34 specimens of massive flows and pillows were collected from 14 localities. The intensity of the NRM varies from about 2x 10^{-6} to 2x 10^{-3} emu/cc. Some of the measured specimens displayed a remaining stable remanence after demagnetization in alternating fields between 50 and 100 Oe, indicating that a small secondary component has been eliminated during the first step (Fig. 7). In alternating fields from 400 Oe, they generally became unstable. Those of high initial intensity displayed a rapid decay in intensity during demagnetization, which suggests that the minerals that carry the NRM have a low coercivity. A sample from a locality within a fault system adjacent to the sulfide ore was strongly chloritized, that means affected by hydrothermal ore solutions. Specimens from that sample displayed different magnetic directions during successive demagne-

Table 1 - Paleomagnetic data of measured rock types/sulfide ores from Küre area

			N. R. M.					*After demagnetization*				*Pole position*	
Rock type/ore	*n*	*N*	*D*	*I*	α_{95}	*S*	*D*	*I*	*R*	*k*	α_{95}	*Lat.*	*Long.*
Basalt	14	34	33.4°	+72.4°	10.2	32-5562	64.0°	+65.4°	32.2	18.6	5.8	45.4°N	93.5°E
Quartz diabase	3	9	21.4°	+75.8°	18.1	1153-3649	51.2°	+69.3°	8.6	19.5	11.9	54.4°N	87.4°E
Diabase dike	6	15	216.9°	+33.7°	47.4	27-2110	210.2°	—15.2°	13.1	7.3	15.0	46.7°N	166.9°E
Massive sulfide ore	7	20	53.8°	+70.0°	9.6	11-70	107.0°	+63.0°	18.7	15.0	8.7	18.1°N	79.5°E
Dacite dike	4	12	309.3	+41.0°	53.7	4-12	266.4°	+ 5.1°	9.6	4.4	23.1	0.9°N	127.9°E
Peridotite dike	4	13	76.3°	+64.3°	21.8	228-2868	130.9°	+53.6°	12.2	15.2	10.9	1.6°S	72.3°E
Amphibolitized diabase	4	10	290.3°	+70.8°	19.6	44-296	292.8°	+58.7°	9.4	15.4	12.6	40.3°S	144.8°E

Note: N.R.M.- Normal Remanent Magnetization; n - Number of sample localities; N - Number of specimens measured; D - Declination of remanent magnetization; I - Inclination of remanent magnetization; α_{95} - Semi angle of cone of 95% confidence for mean direction; S - Susceptibility × 10^{-6} G/Oe; R - Length of the resultant of the N unit vectors; k - (N-1) / (N-R)= estimate of Fisher's K parameter (Fisher, 1953).

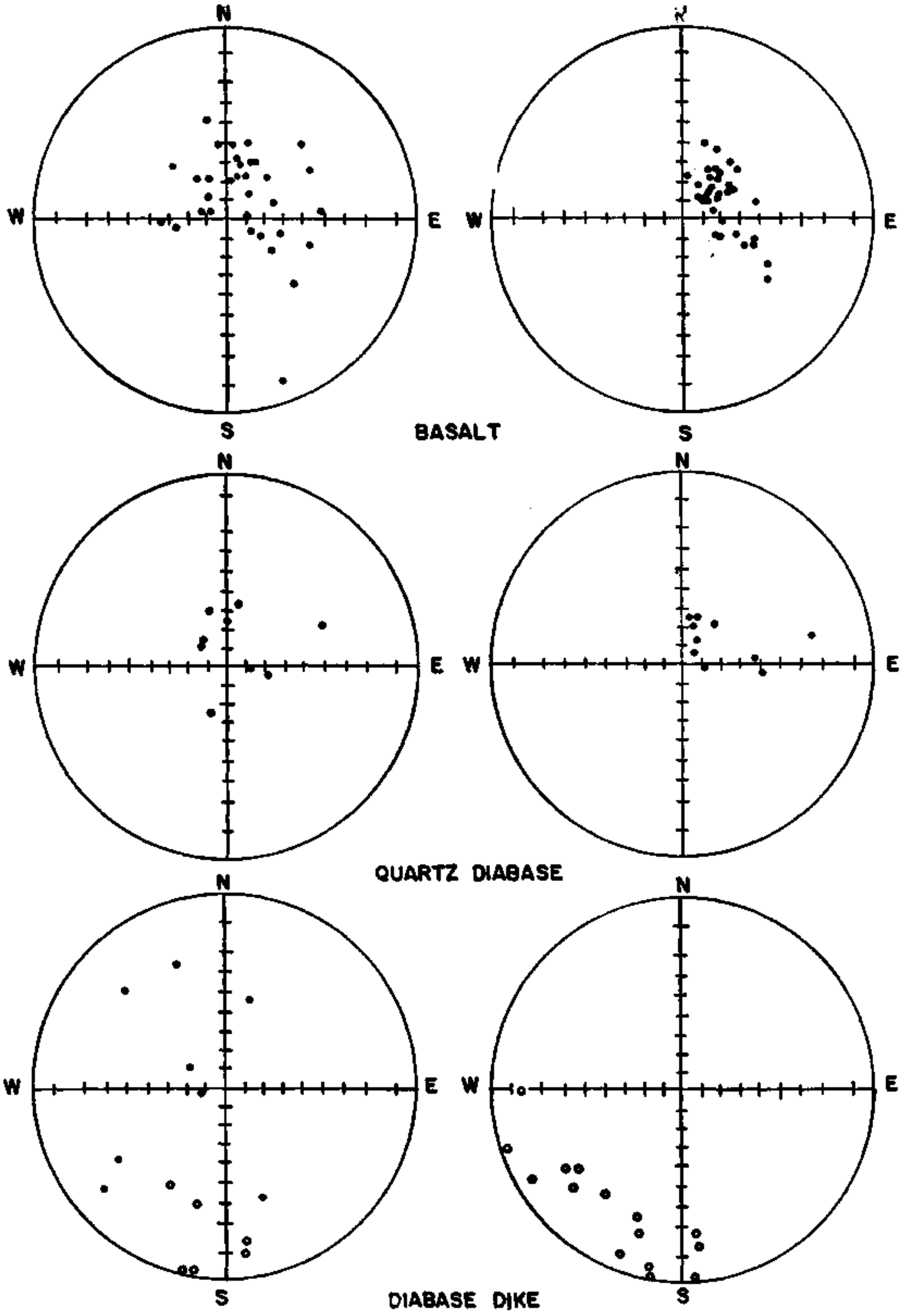

Fig. 3 - Directions of remanent magnetization before (left) and after demagnetization (right).

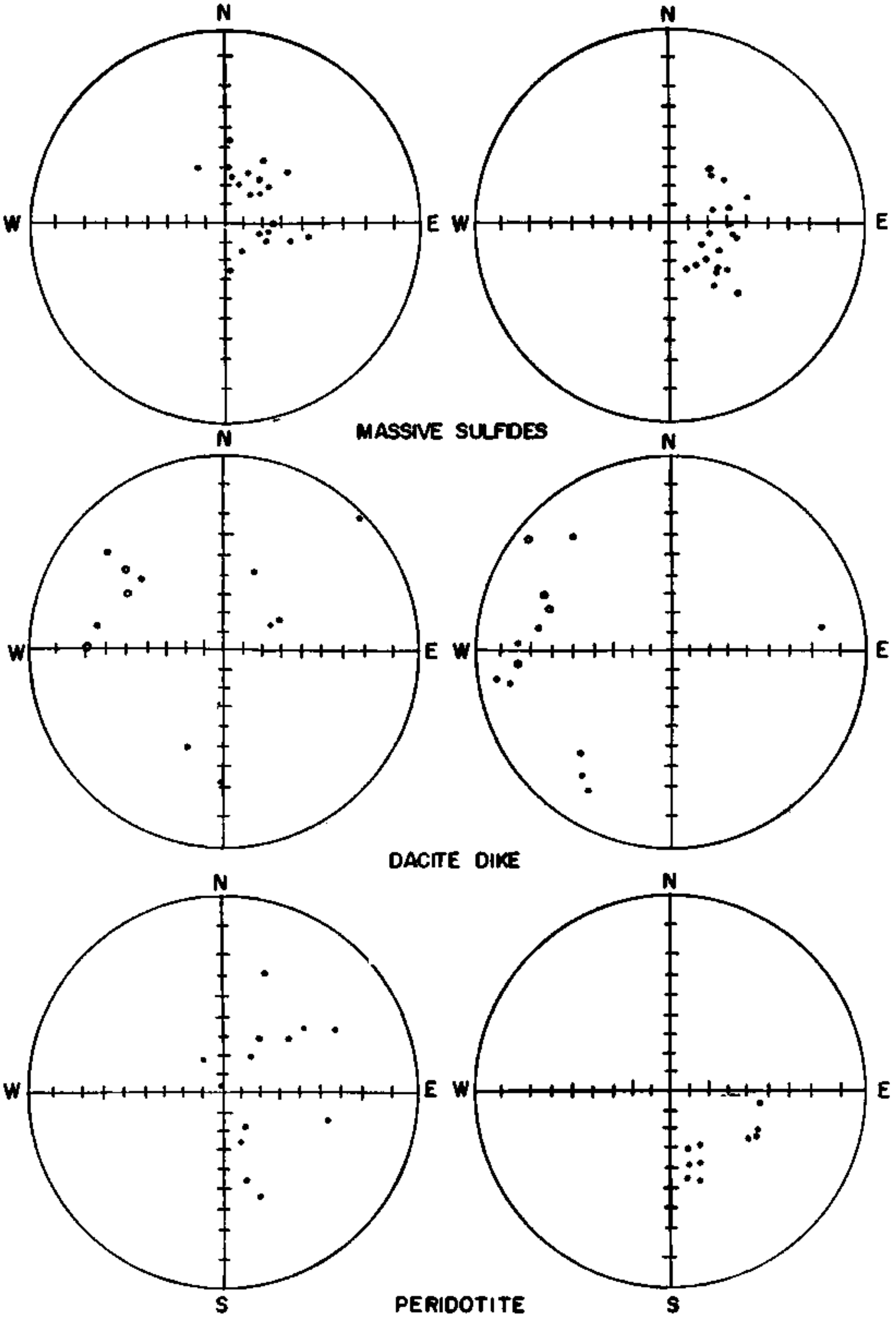

Fig. 4 - Directions of remanent magnetization before (left) and after demagnetization (right).

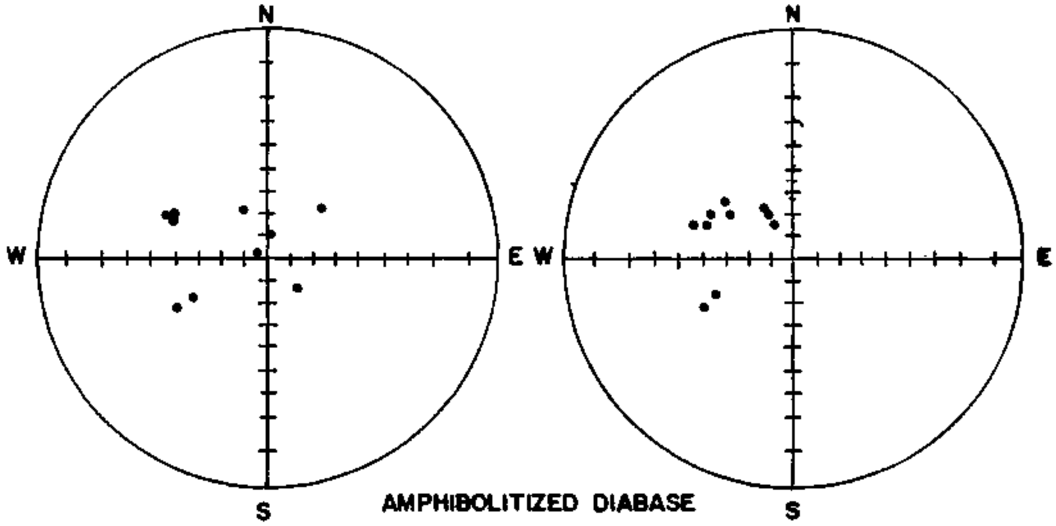

Fig. 5 - Directions of remanent magnetization before (left) and after demagnetization (right).

tization treatment. This is probably due to their content of large amounts of secondary magnetite dust (Fig. 8C). Also samples from three other localities, collected at intrusive rock contacts, contained a stable remanence up to 500 Oe peak field, but presented a large scatter in directions between the individual samples. Sample B in Fig. 7, collected within the Bakibaba mine area at the contact with a peridotite dike, was presumably first affected by ore solutions and later by the *peridotite.* The opaque minerals in the basalt are predominantly titaniferous magnetite and ilmenite represented by a reticulated network of leucoxene lamellae. Other opaques are chrome spinel, pyrite with martite rims, chalcopyrite, and hematite. The magnetic directions are shown in Fig. 3.

Quartz diabase

One dike of quartz diabase was sampled. It has the same magnetic directions and demagnetizing characteristics as the basalt. The specimens have intensities varying between 5×10^{-4} and 2×10^{-3} emu/cc. A relative decline of the demagnetization curve indicates the presence of minerals with moderate coercivity. No marked secondary components have been observed and the measured specimens seem to retain a stable remanence during demagnetization up to 800 Oe (Fig. 3). A demagnetization by treatment in successively higher fields up to 2200 Oe revealed still stable end-points in the same direction. The opaques consist of magnetite grains forming skeletally reticulated crystals with a network of altered lamellae of leucoxene and occurring also as intergrowths with ilmenite plates. Some martite grains form pseudomorphs after pyrite.

Diabase

Most of the diabase specimens revealed a systematic change in direction during demagnetization. Specimens which originally gave directions with moderate to high positive inclinations moved systematically to stable end-points with low negative inclinations (Fig. 3). The specimens with positive inclinations of initial NRM had commonly high intensities, which in most cases decayed rapidly in fields between 50 and 100 Oe (Fig. 9A and B). This suggests that the NRM consisted of two components. One very viscous component due to the present geomagnetic field was eliminated early in the alternating-field treatment between 100 and 200 Oe, while another stable component was retained (Fig. 9). In other cases, specimens with negative initial inclinations retained a larger fraction of their initial intensities of NRM to about 500 Oe. The initial NRM intensities of the specimens varied between 6 X 10^{-6} and 5 X10^{-4} emu/cc. The opaque minerals are magnetite, pyrite, chalcopyrite, ilmenite, and hematite. The iron oxides occur as discrete grains in the matrix and in diallage clinopyroxene but are also associated with uralitization. The ilmenite contains some minute inclusions of hematite.

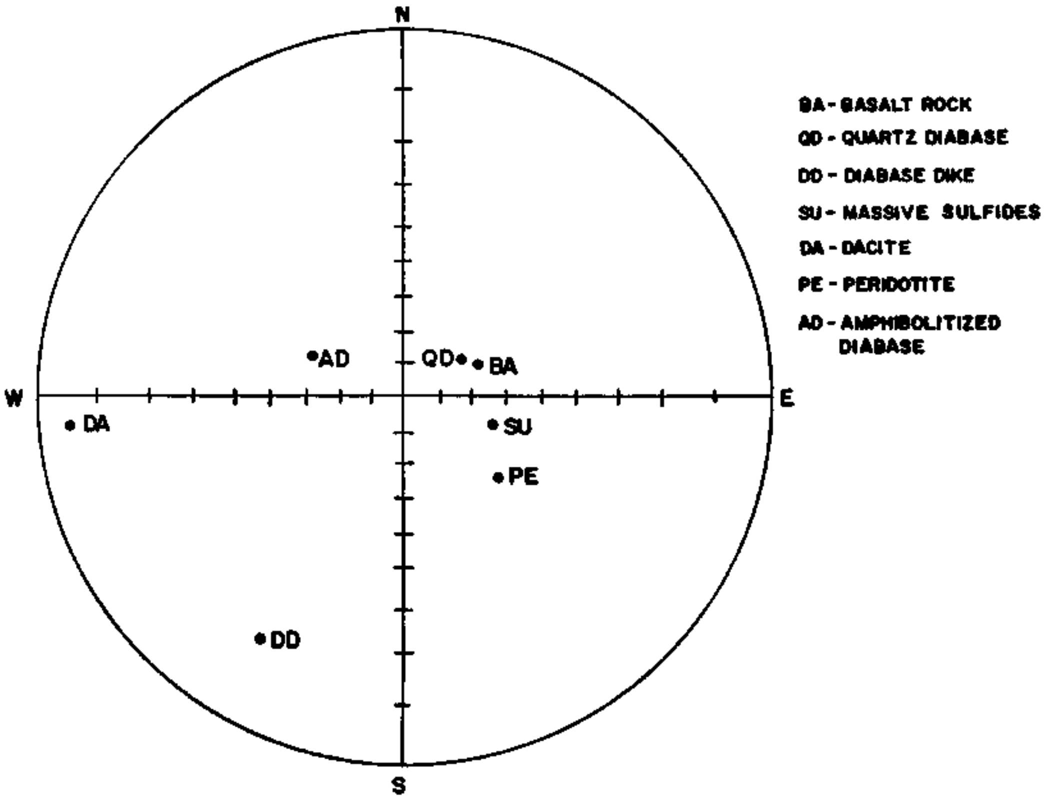

Fig. 6 - Stereographic projection of mean directions after demagnetization. Dots=normal polarity, circles=reversed polarity.

Massive sulfide ore

The specimens are from three orebodies in the Bakibaba and Aşıköy mines. They had rather low intensities of initial NRM, that varied from 5x 10^{-6} to 15x10^{-6} emu/cc. The sulfides show insignificant changes in the mean direction during demagnetization up to 2200 Oe (Fig. 4). The measured specimens contain 95-100 % sulfide minerals, the remainder being a gangue of quartz. These sulfides consisted of pyrite, chalcopyrite, bornite, covellite, sphalerite, digenite, marcasite, tennantite, carrollite, idaite, and galena. Iron oxides or pyrrhotite could not be detected in any of the more than 100 studied polished sections. Thus, the carriers of NRM are not positively identified, but the demagnetization curves suggest fine-grained magnetite.

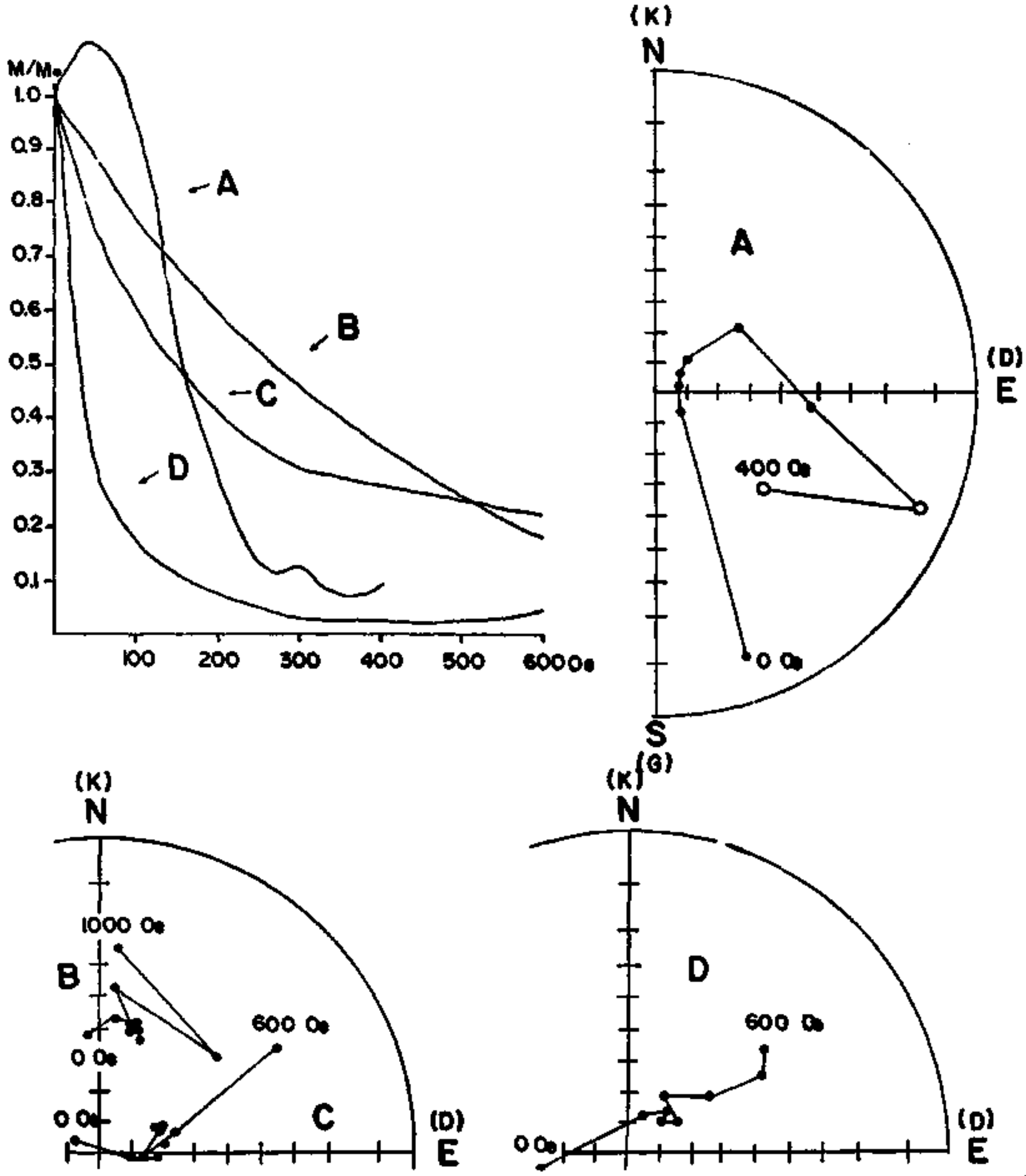

Fig. 7 - Demagnetization diagrams of four typical basalt specimens containing a small secondary component which is eliminated by the first-step treatment (50 Oe). Dots=positive inclinations, circles=negative inclinations.

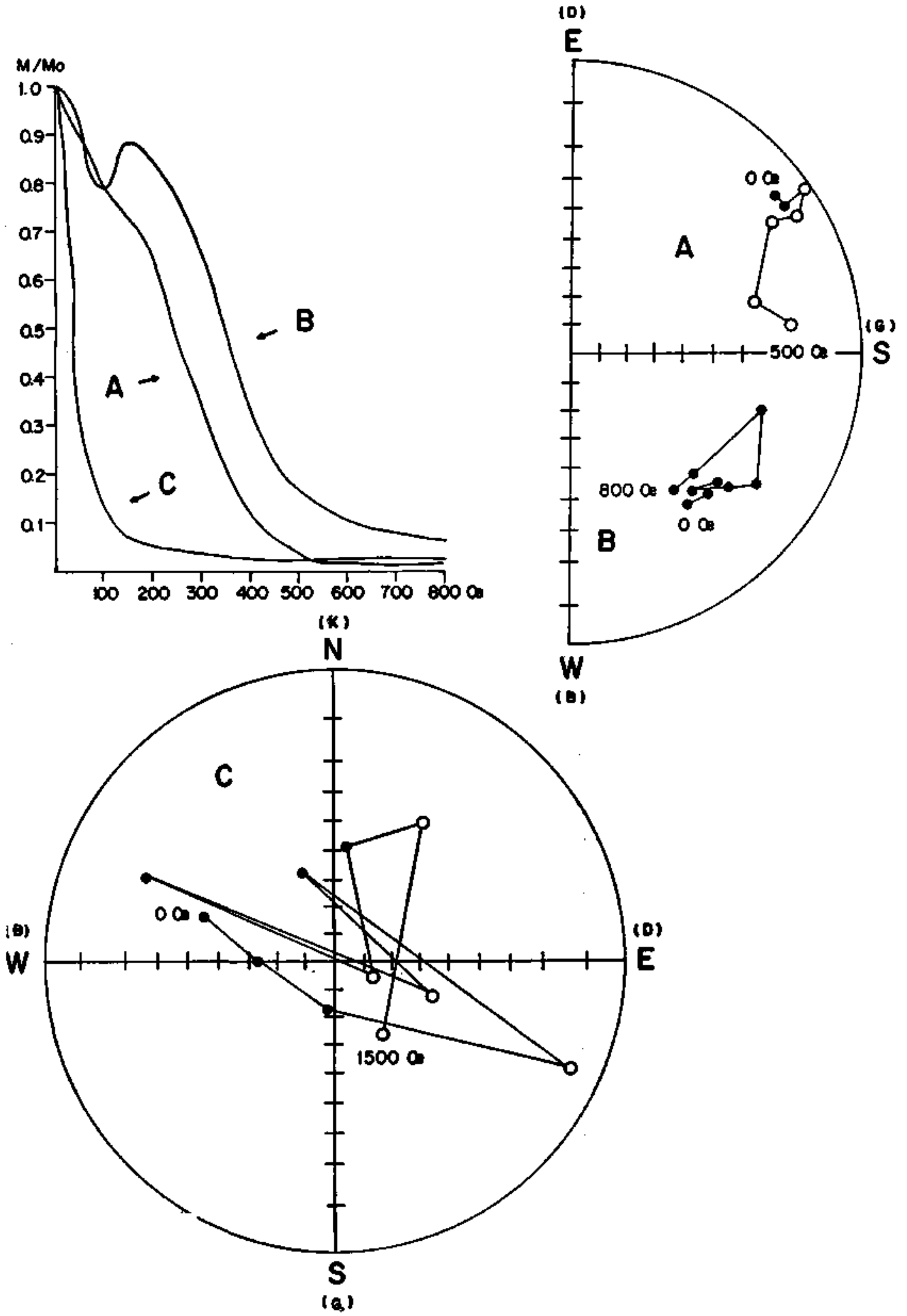

Fig. 8 - Demagnetization diagrams of three basalt specimens displaying different magnetic directions. Specimens A and B are from contacts with diabase and peridotite, C is affected by ore solutions.

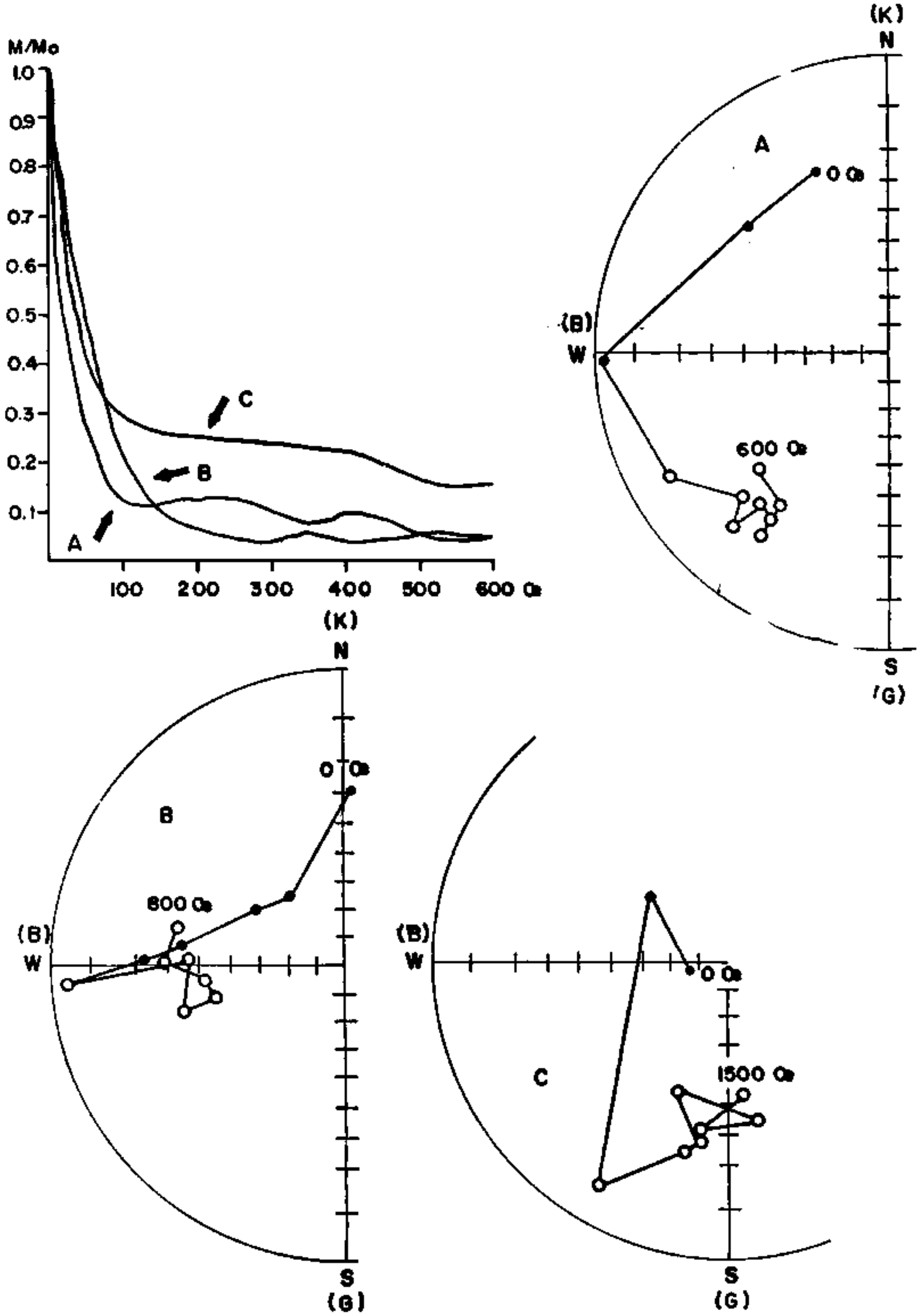

Fig. 9 - Demagnetization diagrams of three typical diabase specimens comprising positive inclinations of initial NRM.

Dacite

The 12 specimens from the three dikes in Aşıköy had very low NRM values, from 3x 10^{-8} to 3x 10^{-7} emu/cc. This means that most of these specimens were not measurable as the noise level of the instrument was about $15x10^{-9}$ emu/cc. In the instrument manual (Digico Computers, 1975) it is recommended that for reliable measurements the prepared specimen should have an intensity of at least 10 times the noise level. As is evident from Fig. 2, there is no systematic correlation between the M/M_0 ratio and increased demagnetization level. Also, the results from the various specimens have widely scattered directions (Fig. 4), with large a_{95} and low k values (Table 1). On account of these circumstances they are considered less reliable and put between brackets in Table 2. In the polished sections, no opaque minerals have been observed. However, the surface exposures are strongly oxidized and contain masses of limonite.

Peridotite

Some of the peridotite specimens had an insignificant secondary component that was easily eliminated after alternating-field treatment in a 50 Oe peak field. Besides, there was a remaining stable component (Fig. 10). In successively higher demagnetization fields, from about 400 Oe upwards, all of the specimens were unstable (Fig. 10). However, in spite of the considerable degree of serpentinization in the rock, there is no marked spreading in mean magnetic directions between the initial NRM and the stable end-points below a 400 Oe peak field (Fig. 4). The intensities of the initial NRM were $14x10^{-5}$ to $2x10^{-3}$ emu/cc. The opaques are dominated by ilmenite and chrome spinel with additional magnetite, pyrite, pyrrhotite, and chalcopyrite. Most of the magnetite occurs in the form of discrete grains or as dust in crack fillings and along the borders of the former olivine crystals.

Amphibolitized diabase

A few specimens exhibited the presence of a soft viscous magnetic component which was eliminated by treatment in a 50 Oe alternating magnetic field (Fig. 11). Most of the specimens demonstrated small changes in magnetic directions during demagnetization and thus the initial NRM was identical with the stable remanence (Fig. 5). In spite of the «amphibolitization», all specimens had very stable remanence in successively higher demagnetization fields up to 1500 Oe (Fig. 11). In the contact with metasomatite at the western end of the dike, the rock is medium-grained, medium bluish-gray. Its basaltic hornblende seems to be of deuteric or late magmatic origin, whilst in the rest of the dike the clinopyroxene has been almost completely uralitized. No differences in magnetic directions were found between the western contact rock and the main part of the dike. This indicates that the amphibilitization had been contemporaneous with the intrusion of the dike. The slow decline of the intensity curve (Fig. 2) indicates the presence of minerals with a somewhat stronger coercive force, that retain a large fraction of their initial moment up to 400 Oe. This magnetic property is largely due to the presence of hematite in the rock. The intensities of initial NRM varied between $3x10^{-5}$ and $9x10^{-5}$ emu/cc. Ilmenite, which occurs as the predominant opaque, has almost completely undergone to leucoxene, which often encloses minute relicts of ilmenite and hematite in intergrowth positions. The pyrite grains are rimmed by martite with minute inclusions of chalcopyrite.

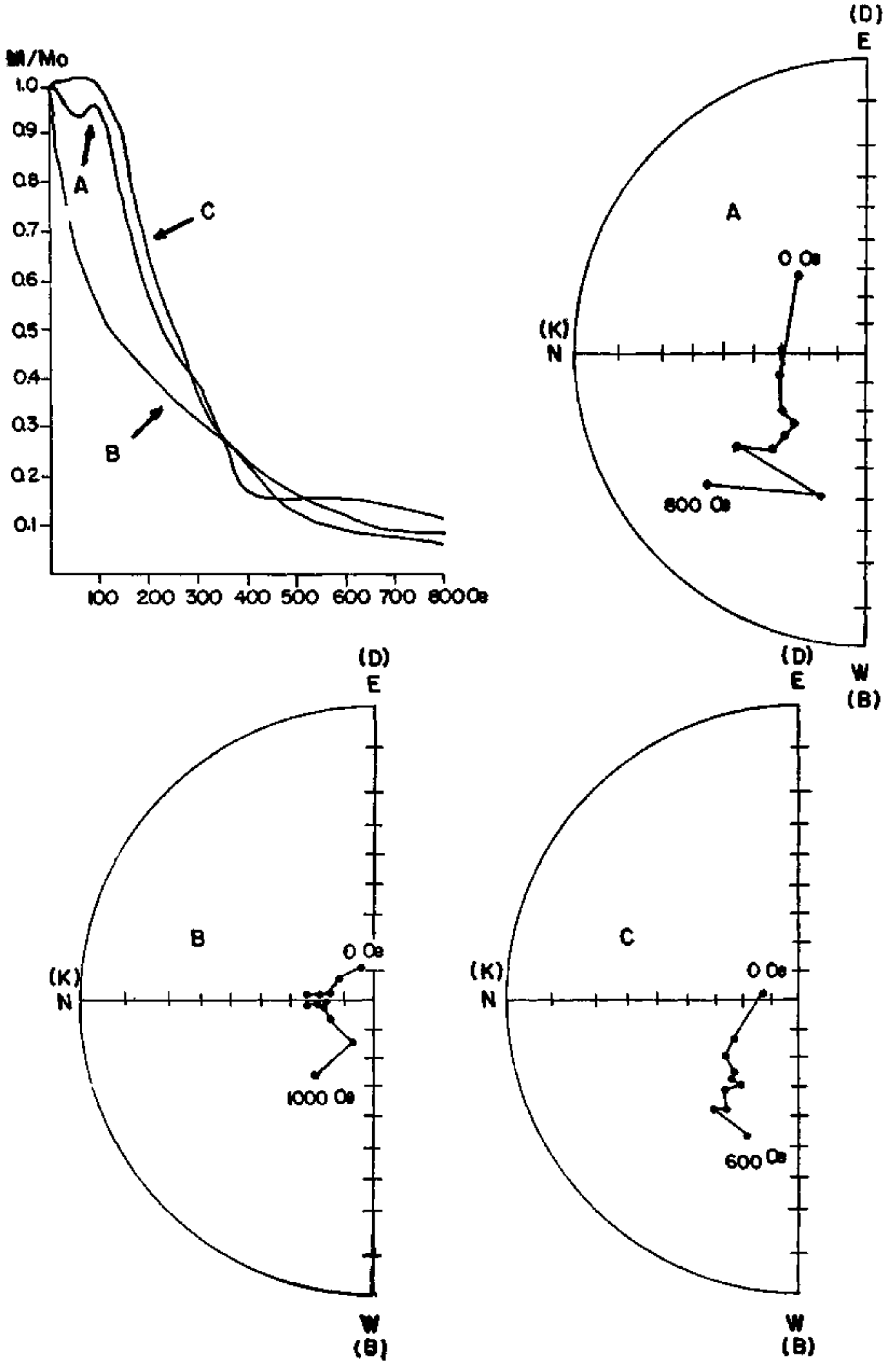

Fig. 11 - Demagnetization diagrams of three typical amphibolitized diabase specimens exhibiting an insignificant soft viscous component and stable remanence in successively higher demagnetization fields.

DISCUSSION

From the paleomagnetic investigation of the various rocks and the sulfide ores, it appears that the magnetic pole positions (Table 2) can be divided into several different groups. There is geological evidence suggesting that the different units are separated in time. All groups have significantly different magnetic directions (Fig. 6). Because the degree of alteration varies strongly from place to place, the various intensities of regional chloritization of basalts and uralitization of diabases do not seem to be the reason for the observed differences in magnetic directions. It is suggested that these alterations have been semicontemporaneous with the intrusions of the respective rocks. The diabase and the basalt and quartz diabase yield approximately the same latitude but differ about 70° in longitude. For reasons explained above, the dacite result is not included in the comparison. The position of the Permian-Jurassic poles from the Küre area differ notably from the European as well as the African data obtained from stable parts of these areas (Table 2 and Fig. 12). However, the pole positions indicated by most of the Permian-Triassic rocks and ores from the Küre area fall far from the zone covered by the Permian-Triassic poles of the African continent (Fig. 12). On the other hand, the poles of the younger rocks (Jurassic?) seem to be closer to the pole positions for Africa. A similar deviation from the African data is displayed by the Permian pole positions from the Amasra area (Gregor and Zijderveld, 1964), about 110 km west of Küre. The difference in latitude between the oldest rock (the basalt) and the estimated youngest one (the amphibolitized diabase) is about 85° (Table 1). The pole positions of basalt and quartz diabase and diabase fit fairly well into the pattern of the Permian-Jurassic data of Europe and Armenia, (Southwest USSR), whereas those of peridotite and amphibolitized diabase agree better with the Permian -Jurassic pole of the African continent (Table 2 and Fig. 12). This deviation can only be explained by the assumption that, since the Permian, the Küre area has been affected by large-scale rotational movements of more or less local character. For instance, a counter - clockwise rotation since the Permian of about 70° with respect to the African directions can be suggested. The measurements indicate that, with the exception of the diabase, there are no marked deviations in inclination (Table 1) between the different units. These range from 51° to 69° only, whereas the declinations deviate much more, i.e., from 51° to 293°. According to Ketin (1962), Kimmeridgian movements of the Alpine orogeny characterize this part of the Pontic Ranges. Along the Black Sea coastal mountains, conspicuous folding and uplift have been observed between the Liassic shales and the Malm-Cretaceous limestones. The Küre area is situated only 70 km to the north of the large Anatolian transcurrent fault, which is still an active earthquake belt. The probability that this zone was an active dextral strike-slip fault at least since the Permian, in combination with the difference in magnetic latitude between the oldest and the youngest rocks, suggests that there was rapid post-Permian counter-clockwise rotation in the considered region before the intrusion of the amphibolitized diabase. If this is so, the basalt magnetization direction requires a 70° clockwise rotation of the Küre area in the upper Permian, in order to reconcile it with the African data (Fig. 12). It is hoped that further work on the Permian will provide more details about the structural history of the Pontic Ranges in connection with the North Anatolian faults.

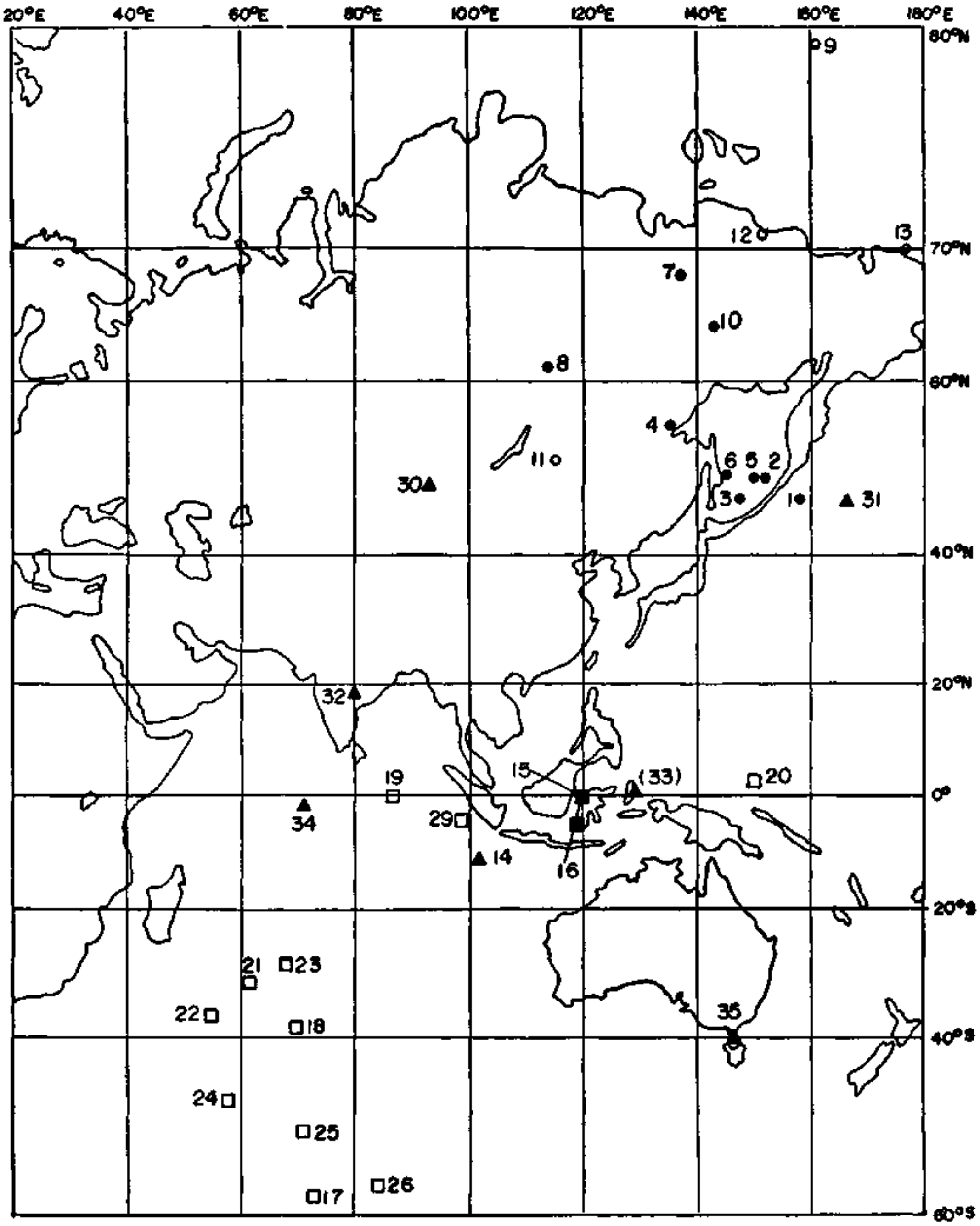

Fig. 12 - Projection of Permian-Jurassic pole positions from Europe, Armenia (Southwest USSR), Minor Caucasus, Turkey, the Arabian Shield, Africa, and the Küre area. The numbers refer to Table 2. Dots=Europe, circles=Armenia (Southwest USSR) and Minor Caucasus, triangles=Turkey, filled-squares=Arabian Shield, and open-squares=Africa.

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