PALEOMAGNETISM AND THE ALPINE TECTONICS OF EURASIA I

THE MAGNETISM OF SOME PERMIAN RED SANDSTONES FROM NORTH-WESTERN TURKEY

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SUMMARY

A series of eighteen oriented samples collected from the Permian of the Amasra region (Black Sea coast) revealed after progressive demagnetization a characteristic remanent magnetization vector with a declination of 290° and an inclination of $-14\frac{3}{4}^{\circ}$, as opposed to the declination of 210° and inclination of $-15\frac{1}{2}^{\circ}$ calculated for the same region on the basis of the mean Permian pole position as determined from samples obtained from stable parts of the European continent. Such deviations are a common feature of material collected from the neighbourhood of the alpine orogenic belt; in this instance the discrepancy is tentatively explained in terms of regional strike-slip faulting.

INTRODUCTION

The Permian rocks of some south European regions which have been affected by alpine tectonics (especially northern Italy and the Pyrenees) are found to have characteristic remanent magnetizations whose directions deviate considerably from those calculated from the mean European Permian pole position (Dietzel, 1960; Van Hilten, 1960, 1962); Van der Lingen, 1960; Schwarz, 1962, 1963; De Boer, 1963; Guicherit, 1964). These anomalous results have been explained by assuming movement of the regions concerned relative to the northwestern European shield in post-Permian times (Van Hilten, 1960, 1962; De Boer, 1963). In order to determine whether these anomalies can be followed farther through the folded Alpine Tethys belt and to establish the movement pattern of the different tectonic units, various studies of the Permotriassic rocks of this zone have been set up. Professor Th. Raven of the American University of Beirut has undertaken to promote the study of the rocks in and around the Tethys zone in eastern Europe and southwest Asia. The magnetic measurements are carried out at the Paleomagnetic Laboratory of the State University of Utrecht, under the supervision of Professor J. Veldkamp. The present paper gives the results obtained from a series of Permian red bed samples from three closely-spaced sites near Amasra in northern Turkey. The samples were collected during September 1962, their orientation being determined with the aid of a Bézard clinometer compass.

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GEOLOGY OF THE AMASRA REGION

Amasra lies on the Black Sea coast at about 41°48'N, 32°27'E, on the northern side of the Pontide chain and some 75 km to the north of the great zone of dextral strike-slip faults which runs from west to east across northern Turkey from the Sea of Marmara to Lake Van (Fig.1). The geology of the Amasra region has been described by Tokay (1955, 1962). In the area sampled, the series attributed to the Permian lies in apparent conformity on well-dated Upper Carboniferous (Stephanian) red sandstones and is covered unconformably by the Cretaceous, beginning with a compact limestone of Barremian age, some 100 m thick, that forms a prominent escarpment wherever it outcrops.

The Permian here consists of an alternation of predominantly red medium to fine grained quartz sandstones and shales, with some grey-green beds otherwise similar in character. At Çakraz and Aritdere it has a thickness of some 100–150 m, but appears to thin out to the west, being only about half as thick at Tarlaağzi. Conclusive evidence as to the precise age of these

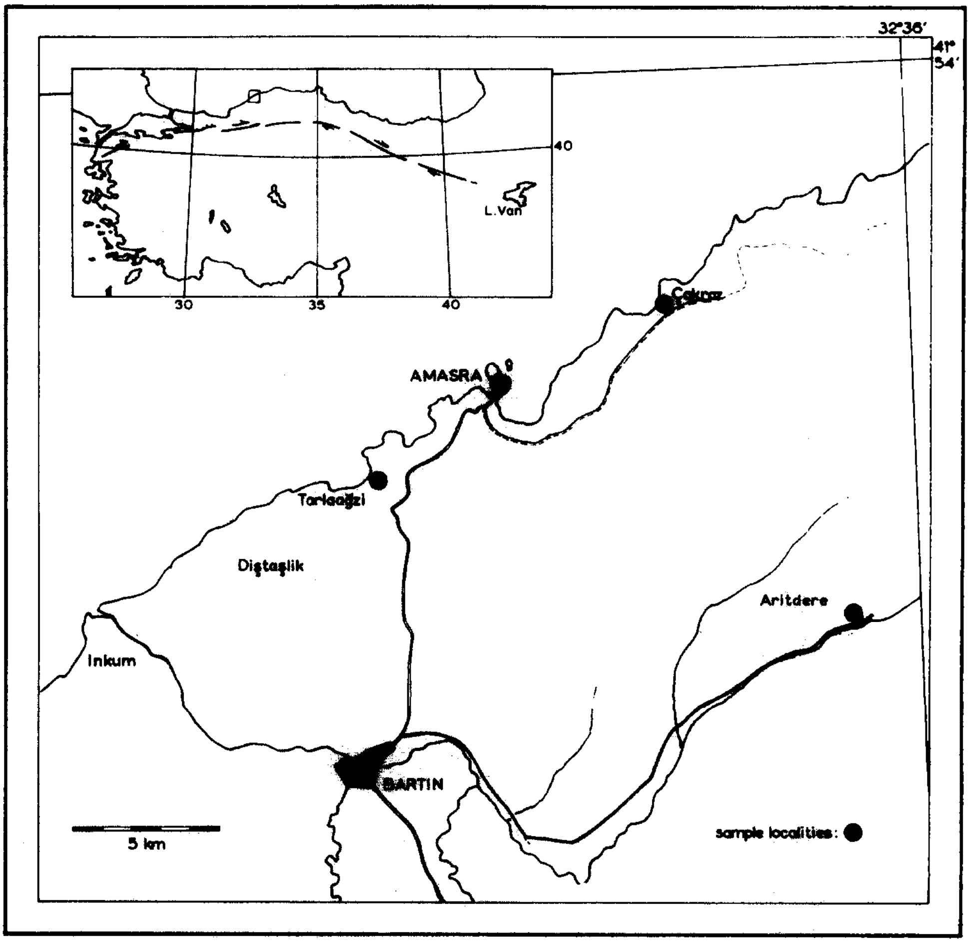


Fig.1. Location map of the Amasra area.

beds is lacking. Yaşar Bay Ergönül (personal communication, 1962) of the Mineral Research and Exploration Institute of Turkey, who is an authority on the stratigraphy of this area, believes that they belong to the Saxonian.

The region has been affected by both the Hercynian and Alpine orogenies. In the former, the uplift of the Inkum–Diştaşlik area to the west of the Tarlaağzi–Amasra trough has resulted in some local gravity sliding into the latter of slabs of the later Paleozoic sediments (Tokay, 1962). These movements may have persisted, intermittently, up to the end of the Permian. The Alpine movements (mainly of Eocene and Oligocene age) have thrown the area into a series of southwest–northeast trending folds whose axes contrast with those of the Variscan structures (which are oriented roughly west-northwest–east-northeast).Normal and reverse faults are quite common, the former especially so in the Tarlaağzi–Amasra area. The three sampling sites were selected at the corners of a triangle of 10–15 km side in order to minimize the risk of incorporating in the results errors due to the local disturbances in the Tarlaağzi neighbourhood. As the laboratory measurements have since shown good agreement between the Tarlaağzi samples and those from the other two sites, we may conclude that the gravity sliding has left the orientation of the Tarlaağzi site unaltered with respect to the other two localities.

PETROGRAPHY

The rocks sampled were all haematite-bearing siltstones with angular to subangular quartz and a variable amount of calcite. The haematite, which does not as a rule exceed 5% by volume, occurs as discrete grains and granular aggregates as well as around grain boundaries in interstitial cement. Accessory minerals include green biotite, muscovite, sericite, chlorite and partly altered feldspar (mainly andesine).

The samples from Çakraz and Tarlaağzi (T013–T026) are characterised by the presence of abundant interstitial calcite and some calcite veins, no doubt partly derived by infiltration from the Barremian limestone above. The Tarlaağzi samples contain in addition some detrital calcite and fragments of what appear to be organic structures. The haematite grains of T013–T015 are larger and less numerous than those of T016-T018; it is possible that the difference in magnetic properties between these two groups of samples (of which more below) is related to this observation. In the Aritdere samples (T027-T031), calcite is not nearly so abundant as in those from the other two localities. The Aritdere location lies some kilometers from the nearest outcrop of the Barremian; having presumably been longer exposed, the sandstones here have perhaps lost again much of their calcite to infiltrating rain water.

MEASUREMENT AND DEMAGNETIZATION

The samples varied in volume from 100 to 300 cm^3. For measurement they were embedded in their correct orientations in paraffin cubes with 10 cm edges, after sawing to approximately cubic shape in order to minimize mag-

TABLE I

Summary of measurements

Locality	Geographical coordinates	Sample number	Strike and of dip bedding[2]	Natural remanent magnetization			
				direction[1]		intensity	
				a[2]	b	(e.m.u./cm^3)	Q-value
Çakraz	41°50'N; 32°30'E	T013	72-43S	323.5	+39.0	$0.6\cdot10^{-6}$	0.16
		T014	64-37S	333.5	-18.5	$0.8\cdot10^{-6}$	0.42
		T015	62-55S	286.5	-41.0	$4.6\cdot10^{-6}$	0.85
		T016	120-35S	286.5	-11.5	$17.9\cdot10^{-6}$	2.79
		T017	120-35S	288.0	- 7.5	$17.0\cdot10^{-6}$	2.80
		T018	120-35S	290.0	-12.0	$20.6\cdot10^{-6}$	2.85
Tarlaağzi	41°46'N; 32°24'E	T019	24-24E	292.5	+28.5	$1.6\cdot10^{-6}$	0.44
		T020	18-22E	287.5	+ 3.0	$1.7\cdot10^{-6}$	0.50
		T021	24-20E	275.0	+ 5.0	$2.2\cdot10^{-6}$	0.82
		T023	18-29E	287.0	+13.0	$1.1\cdot10^{-6}$	0.31
		T024	24-20E	293.5	-19.0	$3.1\cdot10^{-6}$	0.79
		T025	24-20E	279.5	-17.5	$4.4\cdot10^{-6}$	0.97
		T026	24-20E	286.0	- 7.0	$3.2\cdot10^{-6}$	1.05
Aritdere	41°44'N; 32°34'E	T027	188-58W	277.0	+46.5	$6.1\cdot10^{-6}$	0.99
		T028	188-58W	283.0	+49.5	$6.3\cdot10^{-6}$	0.76
		T029	188-58W	271.0	+54.5	$4.4\cdot10^{-6}$	0.88
		T030	160-22W	281.0	+20.5	$3.1\cdot10^{-6}$	0.86
		T031	176-20W	282.5	+ 9.0	$4.0\cdot10^{-6}$	0.99

[1] a = declination (in degrees); b = inclination (in degrees)
[2] Azimuths uncorrected for local present-day geomagnetic declination (3°21'E)

netic shape effects. Directions and intensities of magnetization were then measured on the Dutch astatic magnetometer by procedures described previously (see e.g., As, 1960; Van Everdingen, 1960). The data obtained by these measurements are summarized in Table I and plotted in the stereograms (Fig.2–4).

The first measurements yielded the initial magnetizations, i.e., the directions and intensities of the natural "resultant" remanent magnetizations of the samples after transportation, storage and preparation for measurement but before any other treatment. This natural remanent magnetization had in most of the samples directions with west-northwest declinations and negative as well as positive inclinations. (In the figures these initial directions are shown without correction for dip and strike of the bedding.) The intensities of these initial magnetizations ranged from $0.6\cdot10^{-6}$ to $20.6\cdot10^{-6}$ e.m.u./cm^3.

It is well known that the natural remanent magnetization of most rocks consists of several components (Creer, 1957; As and Zijderveld, 1958). In order to obtain an analysis of their magnetizations, all the samples were subjected to progressive partial demagnetization by alternating magnetic fields. The demagnetizations were carried out stepwise, the samples being remeasured after each step. The behaviour under this treatment of some

TABLE I
(continued)

Components eliminated by higher AC-fields					Components remaining after 950 Oe			
AC-field range (Oe)	Before tectonic correction[1]		after tectonic correction[1]		before tectonic correction[1]		after tectonic correction[1]	
	a[2]	b	a[2]	b	a[2]	b	a[1]	b
					305.0	+10.0	289.5	+41.5
650-950	308.5	-33.5	313.0	+ 1.5	311.0	-48.0	318.5	-13.0
500-950	292.0	-20.0	291.0	+24.0	291.0	-46.0	305.0	+ 2.0
650-950	290.0	-15.5	301.0	-18.0	285.0	-14.5	296.0	-20.5
650-950	289.0	- 7.5	295.0	-12.5	287.5	-10.5	296.0	-16.0
650-950	289.5	-13.0	298.0	-17.0	289.5	-14.5	299.0	-18.5
400-950	285.5	+ 8.0	284.0	+32.0	289.0	-36.0	290.0	-12.0
500-950	298.5	- 8.0	299.0	+14.0	293.5	-26.0	293.0	- 4.0
500-950	294.5	- 9.5	294.0	+11.0	284.5	-20.0	285.0	- 0.5
800-950	293.0	-33.5	292.5	- 4.5	285.5	-33.0	286.0	- 4.0
650-950	314.0	-17.0	313.0	+ 2.5	288.5	-29.5	289.5	- 9.5
950 only					284.0	-34.0	285.5	-14.0
500-950	295.5	- 7.0	295.5	+13.5	291.5	-23.5	292.0	- 3.5
650-950	288.5	+50.0	285.0	- 8.0	279.0	+37.5	278.5	-21.0
650-950	279.0	+40.0	279.0	-18.0	280.0	+38.5	280.0	-20.0
500-950	267.5	+49.5	270.5	-13.0	283.0	+44.5	282.0	-13.5
650-950	281.5	+40.5	275.0	+21.0	283.0	+ 4.0	284.5	-14.5
650-950	284.0	+27.0	282.0	+ 8.0	278.5	- 6.0	279.5	-25.0

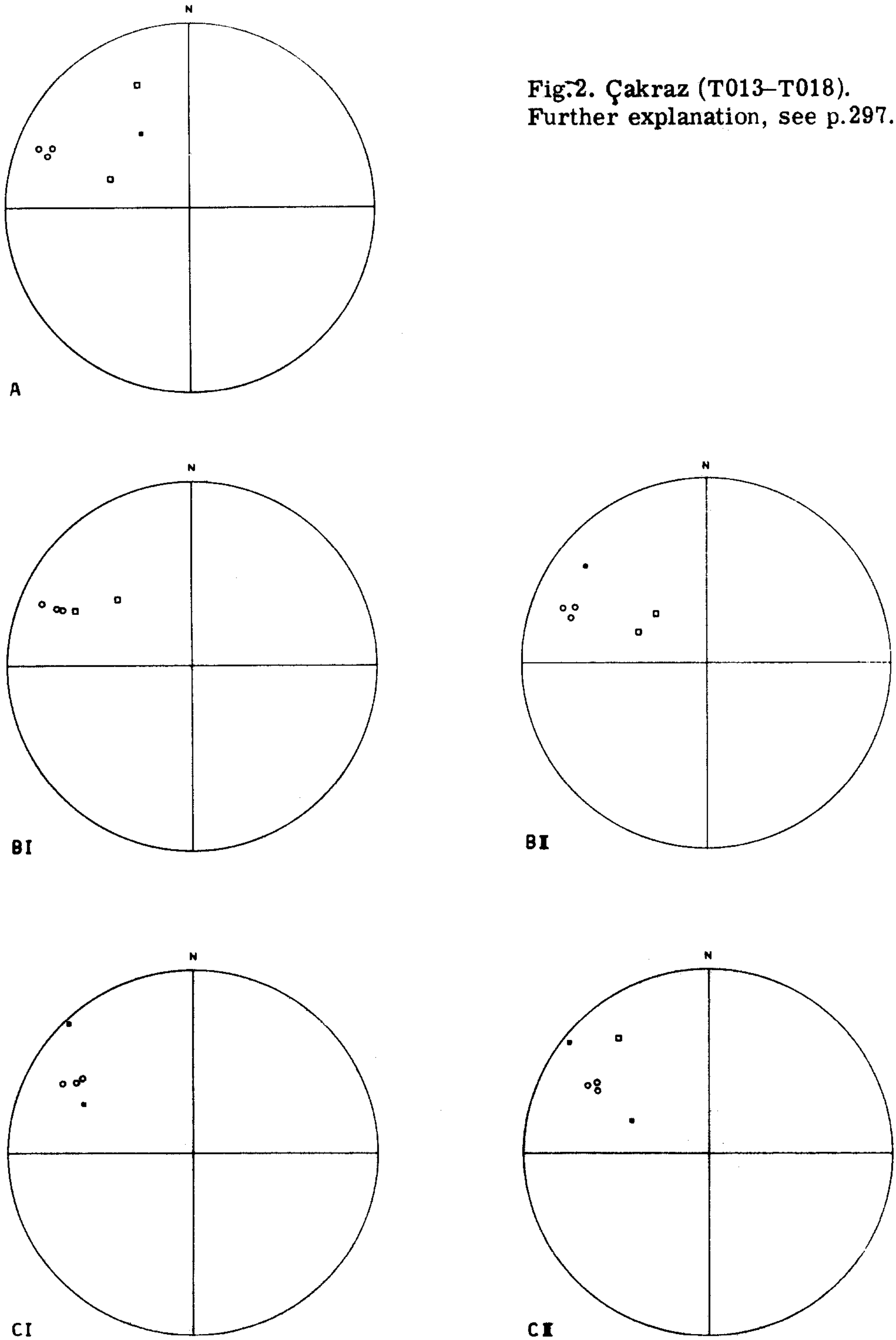
typical examples is illustrated in Fig.5–8, in which are plotted the successive positions of the end of the magnetic vector after each demagnetization treatment.

Çakraz (samples T013–T018)

The six samples from this locality can be divided into two groups. Three of them (T016, T017 and T018) had relatively intense natural remanent magnetizations (greater than 10^{-5} e.m.u./cm^3), Q-values (Königsberger, 1938)[1] in excess of 2.5, and consistent directions. The other three samples had natural remanent magnetizations of considerably lower intensity, Q-values lower than 0.9, and widely scattered directions even after tectonic correction. Progressive demagnetization revealed that the samples of the first group all had identical magnetic compositions. A small component, clearly secondary, appears to have been eliminated by the 300 Oe (= Oersted) de-

[1] Q denotes the ratio of the intensities of remanent and induced magnetization. For the vertical magnetometer, $Q = \frac{J_R}{k \cdot H_Z}$, where J_R = intensity of remanent magnetization, k = susceptibility, and H_Z = vertical component of the ambient field.

Fig. 2. Çakraz (T013–T018). Further explanation, see p.297.



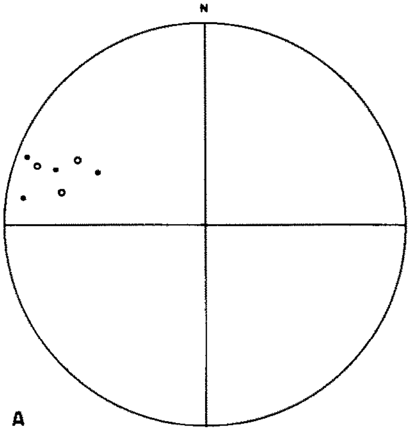
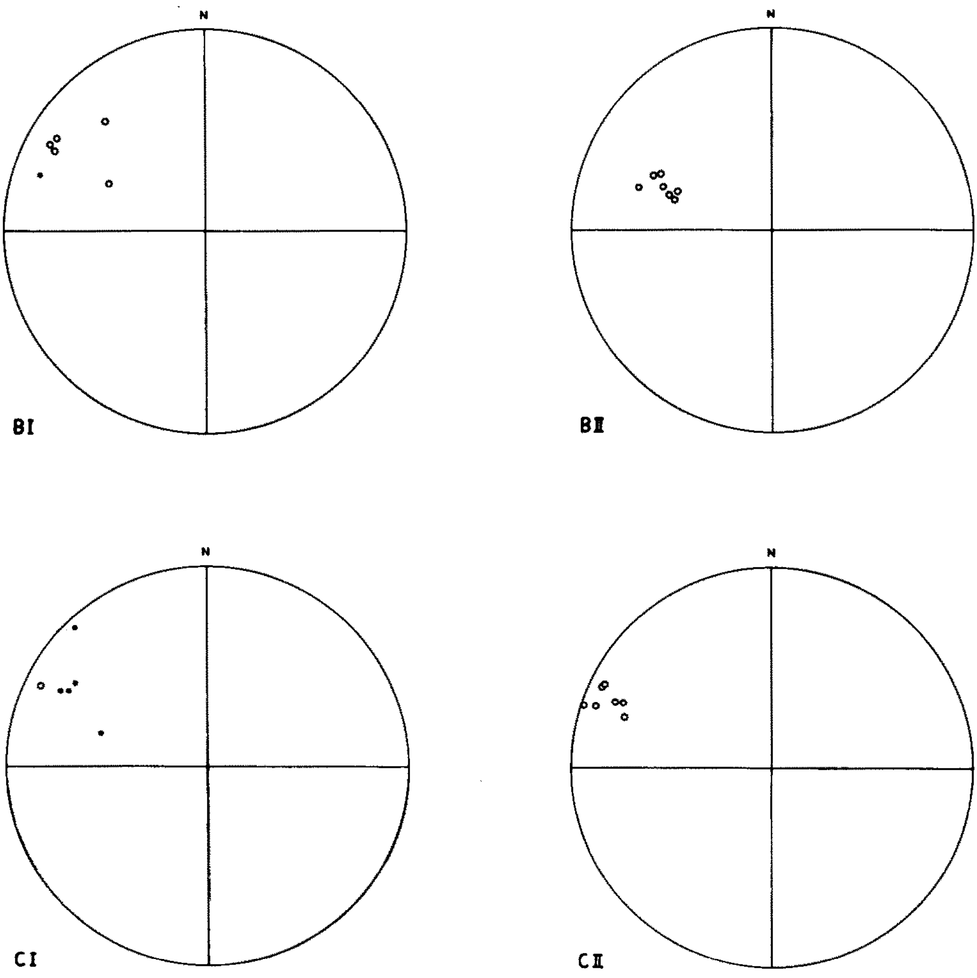


Fig.3. Tarlaağzi (T019–T021 and T023–T026).
Further explanation, see p.297



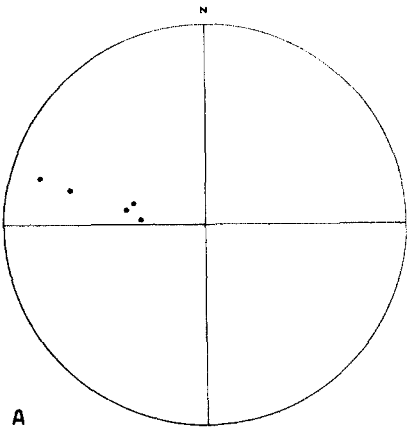
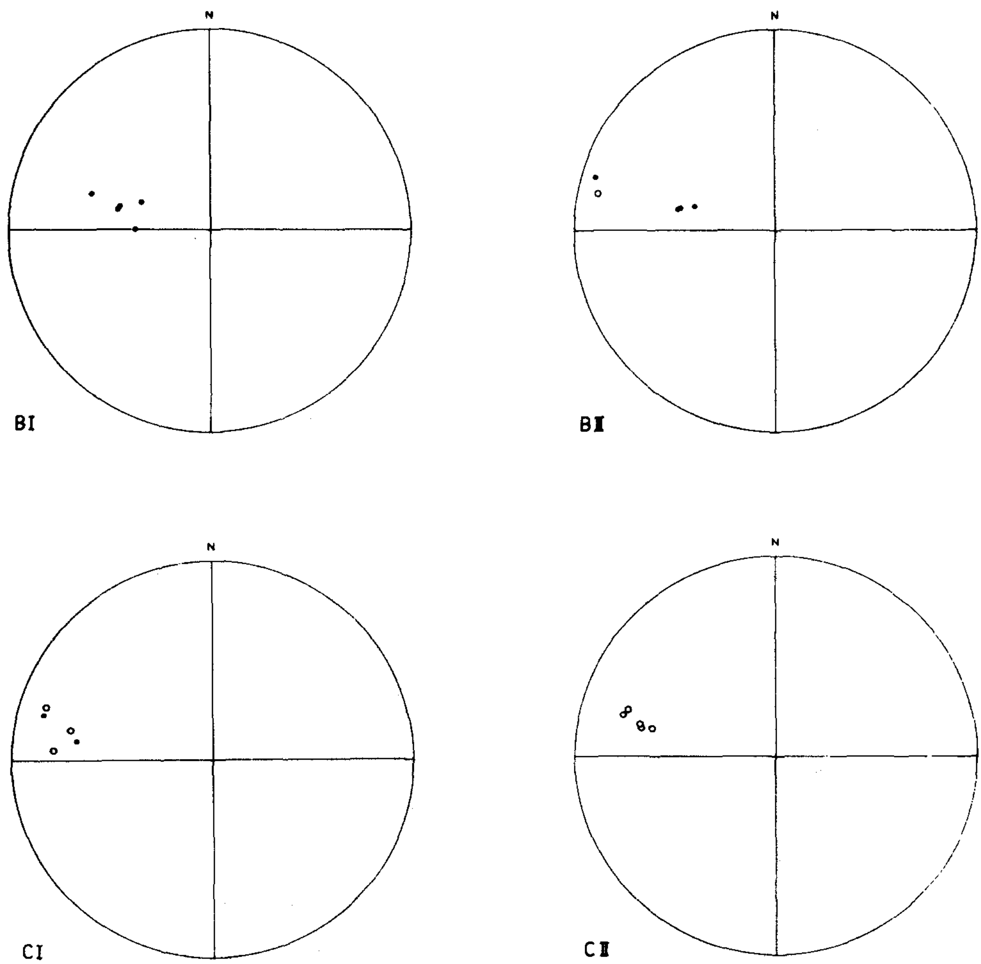


Fig.4. Aritdere (T027–T031). Further explanation, see p.297.



magnetizing field (see Fig.5; all *AC*-field values given in this paper are peak values). The elimination of this secondary component increased the inclination of the remanent magnetization vector by 3° only. The remaining bulk magnetization had a direction common to the samples from the other two sites, being thus characteristic of these Permian red beds in this region.

Close examination of Fig.5 reveals that the decrease of the magnetization vector between 300 Oe and 950 Oe takes place in a direction which does not quite pass through the origin, the direction of the component eliminated having a slightly smaller inclination than that of the component remaining after treatment with 950 Oe (the highest field attainable in our laboratory at the present time). It is not yet possible to say whether in such cases we are dealing with the separate magnetizations of two or more different magnetic fractions, or with a single magnetic fraction with a single magnetization vector which decreases during alternating field treatment in a direction deviating slightly from the origin in consequence of limitations in our measuring

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Fig.2. Çakraz (T013–T018). Stereograms showing directions of magnetic vectors.
A. Natural remanent magnetization, without tectonic correction.
BI. Components removed between 650 and 950 Oe, without tectonic correction.
BII. Components remaining after 950 Oe, without tectonic correction.
CI. Same as BI, corrected for dip and strike of bedding.
CII. Same as BII, corrected for dip and strike of bedding.
Full symbols denote north-seeking poles pointing down; open symbols denote north-seeking poles pointing up: squares denote T013–T015; circles denote T016–T018.

Fig.3. Tarlaağzi (T019–T021 and T023–T026). Stereograms showing directions of magnetic vectors.
A. Natural remanent magnetization, without tectonic correction.
BI. Components removed between 500 and 950 Oe, without tectonic correction.
BII. Components remaining after 950 Oe, without tectonic correction.
CI. Same as BI, corrected for dip and strike of bedding.
CII. Same as BII, corrected for dip and strike of bedding.
Full symbols denote north-seeking poles pointing down; open symbols denote north-seeking poles pointing up.

Fig.4. Aritdere (T027–T031). Stereograms showing directions of magnetic vectors.
A. Natural remanent magnetization, without tectonic correction.
BI. Components removed between 650 and 950 Oe, without tectonic correction.
BII. Components remaining after 950 Oe, without tectonic correction.
CI. Same as BI, corrected for dip and strike of bedding.
CII. Same as BII, corrected for dip and strike of bedding.
Full symbols denote north-seeking poles pointing down; open symbols denote north-seeking poles pointing up.

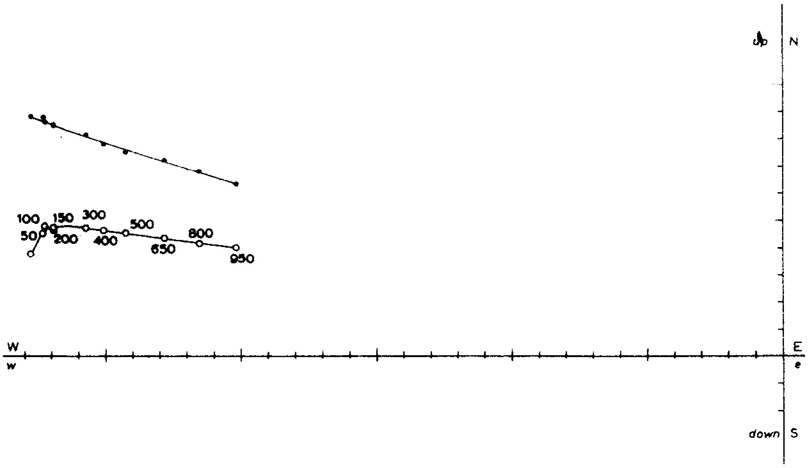

Fig.5. T017 (Çakraz): demagnetization diagram. Plotted points represent successive positions - in orthogonal projection - of end of magnetic vector during progressive demagnetization. Full symbols represent projections on the horizontal plane, open symbols projections on the east–west vertical plane. Each unit on either axis represents $5.8 \cdot 10^{-7}$ e.m.u. /cm^3. Numbers denote AC-field intensities in the Oersteds.

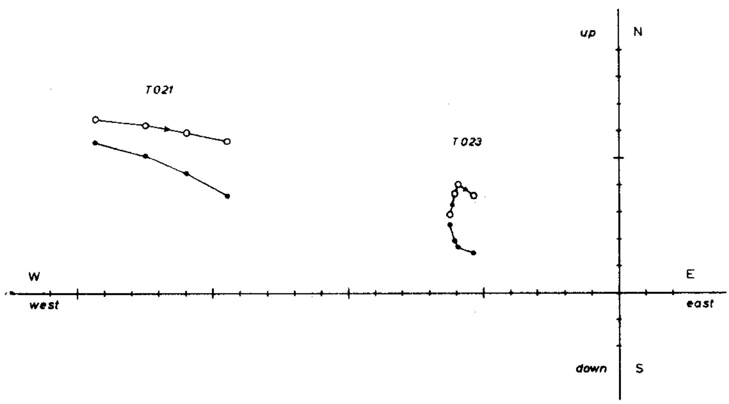

Fig.6. T021, T023 (Tarlaağzi): demagnetization diagram. Plotted points represent successive positions - in orthogonal projection - of end of magnetic vector during progressive demagnetization. Full symbols represent projections on the horizontal plane, open symbols projections on the east–west vertical plane. Each unit on either axis represents $0.86 \cdot 10^{-7}$ e.m.u./cm^3. Fields of 500, 650, 800 and 950 Oe.

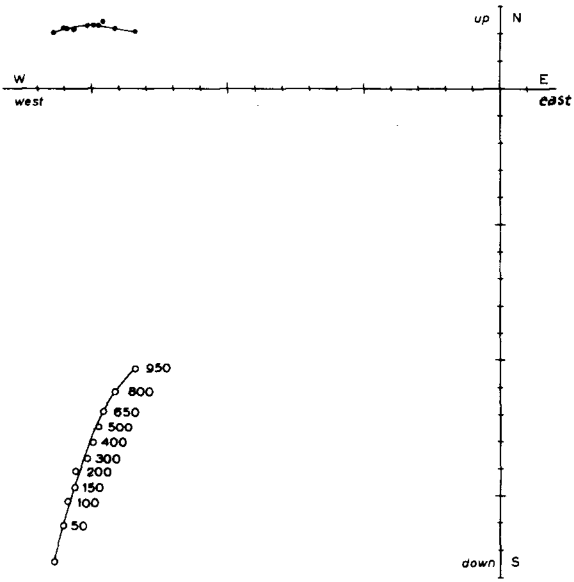

Fig.7. T027 (Aritdere): demagnetization diagram. Plotted points represent successive positions - in orthogonal projection - of end of magnetic vector during progressive demagnetization. Full symbols represent projections on the horizontal plane; open symbols projections on the east–west vertical plane. Each unit on either axis represents $2.5 \cdot 10^{-7}$ e.m.u./cm^3. Numbers denote AC-field intensities in Oersteds.

technique (excentric dipoles, etc.). The difference between the two directions is in any case very small, and does not materially affect the results.

The remaining three samples (T013, T014 and T015) showed a considerable change in the direction of their remanent magnetization under alternating field treatment, indicating that they had an important secondary component. But in the range 500–950 Oe, where the characteristic magnetization might have been expected to reveal itself, the decrease in total magnetization was very small, making it impossible to determine reliably the directions of the components removed by these higher fields. The components remaining after treatment with 900 Oe are consistent neither with one another nor with those of the other three samples from this locality. As mentioned earlier (p. 291), there is a noticeable difference in the size of the haematite grains between these two groups of samples. In T013–T015 some eighteen grains, with a mean diameter of about 40μ, were counted to the square millimetre in thin sections; T016-T018 showed about 60 grains per square millimetre, with a mean grain diameter of 17μ. If, as seems possible, these rocks owe their magnetic properties largely to the granular haematite in them (as opposed to that occurring in the cement), the explanation may well lie in the greatly superior potential for effective orientation (in the sedimentary environment) of the smaller, more numerous haematite grains of T016–T018.

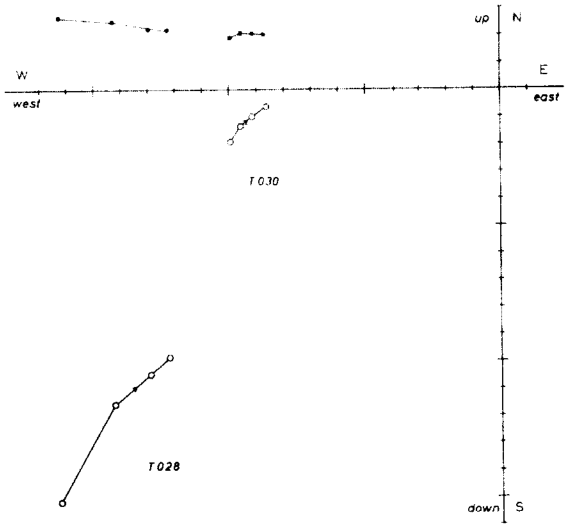

Fig.8. T028, T030 (Aritdere): demagnetization diagram. Plotted points represent successive positions - in orthogonal projection - of end of magnetic vector during progressive demagnetization. Full symbols represent projections on the horizontal plane, open symbols projections on the east–west vertical plane. Each unit on either axis represent $2.6 \cdot 10^{-7}$ e.m.u./cm^3. Fields of 500, 650, 800 and 950 Oe.

Tarlaağzi (T019–T021 and T023–T026)

All the samples from this locality had comparable natural remanent magnetizations and Q-values (see Table I). The tectonic correction does not differ much from one sample to another, and it can be seen (Fig.3A) that the directions of the natural remanent magnetizations lie approximately on a great circle passing through the direction of the present-day dipole field. This distribution, often found in paleomagnetic collections, results from the presence in the various samples of different amounts of a secondary magnetization directed according to the present field.

These samples were treated only with alternating fields of 500, 650, 800 and 950 Oe, and measured after each treatment. Three of them (T020, T021 and T026) readily yielded their secondary components (as in the case of T016–T018), but the others retained theirs until after treatment with 800 Oe.

Aritdere (samples T027–T031)

The Aritdere samples were all very much alike in intensity and Q-value (see Table I). Differences in their directions of magnetization were mainly eliminated on applying the tectonic correction. All showed identical behaviour under alternating field treatment. The demagnetization diagram of one of these samples (Fig.7, T027) shows that even at 950 Oe the magnetization vector is still changing direction, from which it must be concluded that the secondary magnetizations were not entirely eliminated at that intensity. Fig. 8, T028, shows this even more clearly. It may nevertheless fairly be assumed that the remaining effect of the secondary components is less than the normal scatter of the group as a whole (see, e.g., Fig.8, T028).

THE CHARACTERISTIC REMANENT MAGNETIZATION

Table I and the stereograms (Fig.2–4) show for each sample the directions of the magnetizations eliminated by the higher alternating fields, as well as the direction of the component remaining after exposure to the highest available field of 950 Oe. For the Aritdere group, it is clear that the component remaining after 950 Oe comes nearest to representing the characteristic magnetization, though it is possible that the inclination thus obtained may be slightly too low. In the majority of samples from the other localities, the decrease of magnetization in the higher alternating fields was so slight that precise determination of the components eliminated is not possible. However, the three magnetically stronger samples (T016–T018) from Çakraz, in which both directions (of eliminated and residual components) can be well determined, show that in their case at least the difference is rather small. Here, taking the residual direction after 950 Oe as characteristic results in an inclination which may be slightly too high. In short, we believe that we obtain the best approximation of the characteristic direction by using in all cases the component remaining after treatment with 950 Oe. This is supported by the fact that these directions provide - after tectonic correction - the most internally consistent groups for the two localities at Tarlaağzi and Aritdere; furthermore, the best agreement between the directions of the different sites is obtained in this way: in other words, these are the directions which best satisfy the so-called "unfolding test" (Graham, 1949). They are shown, together with the pole positions corresponding to them, in Table II.

DISCUSSION OF RESULTS

These results will eventually be re-examined in their relation with data from work now in progress in other parts of the Alpine orogenic belt. For the present we can say that, whilst the mean pole position indicated by these Permian rocks from northern Turkey falls in the zone covered by the Permian poles thus far determined for the African continent (Nairn, 1959, 1964; Opdyke, 1964; see Table III), the rather marked disagreement between the latter makes the comparison inconclusive. The mean inclination of $14^{\circ}45'$ fits well into the pattern of Permian European latitudes derived from the most reliable northwest European data (see Fig.9), but the mean declination lies about 80° clockwise from the direction to be expected locally for the mean European Permian pole. Granted a geocentric axial dipole field, and failing evidence of extensive polar wandering in the Permian, this observation can only be explained by assuming post-Permian movements of the Amasra area

TABLE II

Characteristic magnetization and ancient pole position

Locality	Characteristic magnetization[1]		Ancient pole position		α_{95}	Number of samples
	declination	inclination				
Çakraz	304.5°	- 5.0°	23.0S	95.5E	22.0°	6
Çakraz (omitting T013–T015)	300.5°	-18.3°	15.0S	94.0E	4.0°	(3)
Tarlaağzi	292.0°	- 7.0°	13.5S	105.0E	4.5°	7
Aritdere	284.5°	-19.0°	3.0S	106.5E	5.0°	5
Mean of all samples	293.8°	-10.3°	13.8S	102.3E	22.0°	3 sites
Mean (omitting T013-T015)	292.0°	-14.8°	11.0S	101.5E	18.0°	3 sites
Direction (calculated for Amasra area) of mean Permian pole position for stable Europe	210°	-15.5°	46.5N	165.5E	see Table III	

[1] Azimuths corrected for local present-day geomagnetic declination (3°21'E)

TABLE III

Ancient pole positions derived from Permian Rocks in stable parts of Europe and Africa

Continent	Locality	Sedimentary or igneous	Characteristic magnetization declination	inclination	Pole position		α_{95}	Number of samples	Author
Europe	Oslo region	igneous	204°	-36°30'	47°N	157°E	2.75°	484	Van Everdingen (1960)
Europe	Nahe region (a) (Germany)	igneous	201°	- 9°	42°N	163°E	4.25°	28	Nijenhuis (1961)
	Nahe region (b) (Germany)	igneous	196°	-18°	48°N	168°E	7.75°	34	Nijenhuis (1961)
Europe	Nideck region (France)	igneous	192°30'	-12°30'	47°N	169°E	4.5°	37	Roche et al. (1962)
Europe	Lodève region (France) (Autunian)	sedimentary	189°30'	+ 4°	44°30'N	178°E	-	14	Kruseman (1962)
	ditto (Saxonian)	sedimentary	198°30'	- 6°30'	48°N	164°E	-	30	Kruseman (1962)
Europe (mean)[1]	-	-	-	-	46°30'N	165°30'E	-	-	-
Africa	Maji Ya Chumvi (Kenya)	sedimentary	267°	+38°	4°	150°E	11°	5	Nairn (1959)
Africa	Taru Grit (Kenya)	sedimentary	87°	+61°	0°	87°E	16.4°	8	Nairn (1959)
Africa	Ecca Sandstone (Tanganyika)	sedimentary	156°	+52°	58°S	74°E	7.1°	11	Nairn (1964)
Africa	Ecca Sandstone (Tanganyika)	sedimentary	-	-	38°S	70°E	16°	9	Opdyke (1964)

[1] The European Permian pole positions given here are those so far determined from samples subjected to progressive demagnetization. In calculating the mean position (by direction cosines), the individual determinations have been weighted as follows:

Oslo (Van Everdingen, 1960) 2
Nahe (Nijenhuis, 1961) (a) 1
Nahe (Nijenhuis, 1961) (b) 1
Nideck (Roche et al., 1962) 2
Lodève (Kruseman, 1962) (Autunian) . . . 1
Lodève (Kruseman, 1962) (Saxonian) . . . 1

relative to the European shield[1]. A sinistral rotation of western Turkey through 80° around the Gulf of Iskenderun offers an interesting, if somewhat heroic, reconstruction; but difficulties arise in tying up the loose ends of the

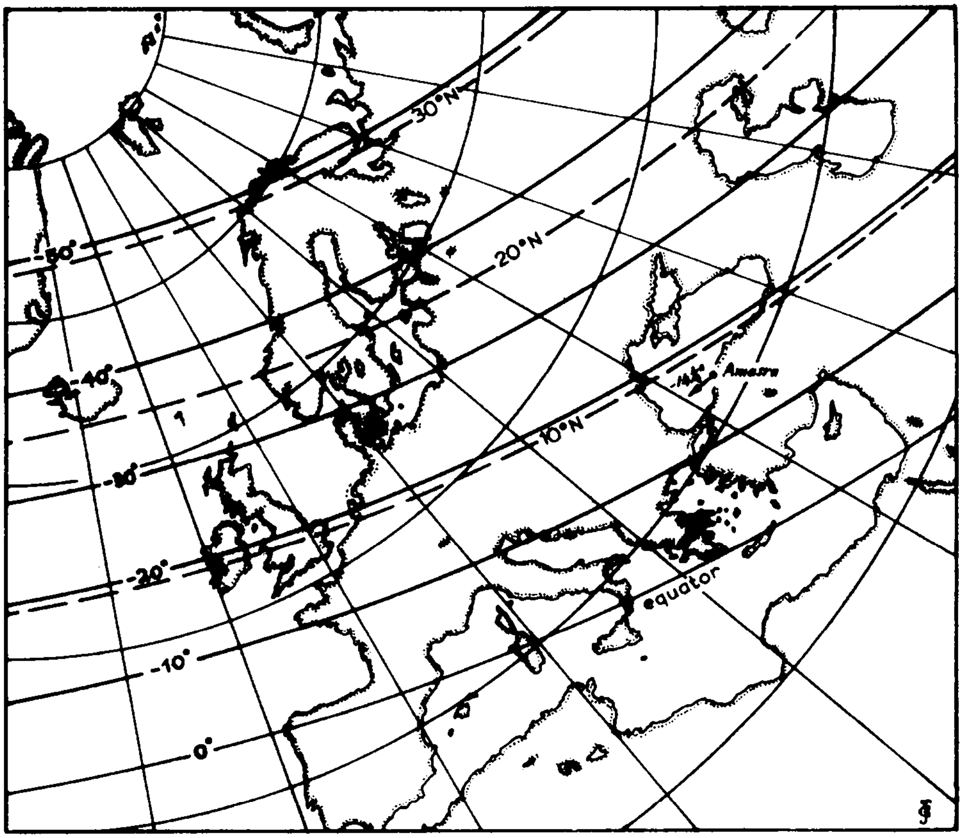

Fig.9. Map of Europe showing Permian isoclines (full lines) and paleolatitudes (broken lines) derived from measurements on rocks collected from stable parts of the European continent, with declination and inclination of the Permian of Amasra for comparison. (Stereographic projection.)

Hercynian structures. It is hoped that further work on the Permian of Turkey may shed more light on the anomalous declination of the Amasra area; for

[1] As we have pointed out earlier (p. 291), the late Paleozoic gravity sliding phenomena at Tarlaağzi have left the orientation of this site unchanged relative to Çakraz and Aritdere. There is no evidence of similar disturbance at either of these other two localities; that gravity sliding could cause extensive, exactly equal rotations at three localities separated from each other by more than 10 km, is scarcely within the realm of possibility in any case. The whole area must have rotated as a unit, and the cause of this rotation must have been of a higher (geotectonic) order.

the present, we are inclined to assume a post-Permian rotation of local character.

The region sampled lies only 75 km to the north of the great north Anatolian fracture zone, even now an active earthquake belt, in which nearly all reported movements involve an eastward displacement of the northern (European) landmass relative to the southern one (Omote and Ipek, 1959). Pavoni (1961) considers this zone as a main dividing line between Eurasia and Gondwanaland, and the observed dextral displacements along it are in agreement with the idea that Europe has been moving eastward relative to Africa. It is in the line of expectation to find clockwise-rotated, dragged regions on either side of a zone of dextral strike-slip faulting on such a scale as here envisaged; and it is our tentative conclusion that the Amasra area is a part of such a region lying on the southern margin of the European shield. Should this supposition prove correct, it may point to paleomagnetism as a possible means of discovering large strike-slip faults and investigating their ancient movement patterns.

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