Geophys. J. R. astr. Soc. (1979) 59, 437–444

Palaeomagnetism of dykes and tuffs from the Mesudiye region and rotation of Turkey

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Received 1979 April 18; in original form 1978 June 1

Summary. The pole positions obtained from Upper Cretaceous and Eocene tuffs and dykes of the Mesudiye region, which is located between the north of the North Anatolian Fault Zone and eastern Black Sea coast, are at 75.3° N, 275.4° E and 41.7° N, 138.6° E respectively. These results, taken together with the results of previous studies of Turkish rocks, suggest that rotational movements of Turkey have been 45–50° counterclockwise to Europe since the Upper Cretaceous.

Introduction

The number of palaeomagnetic studies, for the purpose of determining past movements of Turkey, has been few. The first palaeomagnetic study was carried out on Permian red sandstones from the Black Sea region (Amasra) by Gregor & Zijderveld (1964). They found an average inclination of – 14.8° in accordance with the European Permian isoclines. But the determined declination of 292° implies counterclockwise rotation through 80° of the Amasra region with respect to stable Europe since the Permian.

Van der Voo (1968) has determined Cretaceous and Eocene pole positions for formations north and south of the North Anatolian Fault Zone and compared them with pole positions for stable regions of Arabia, Africa and Europe. The pole positions from the stable regions of Euro-Asia and the results from Turkey are different. However, the pole positions for Turkey are very close to the pole positions of the same geologic periods for Syria and Lebanon. Van der Voo (1968) concluded that the Turkish plate has been rotated 50° counterclockwise with respect to Europe since the Cretaceous.

More recently Orbay (1978) investigated Cretaceous and Eocene volcanic rocks in three regions of the North Anatolian Fault Zone, and he concluded that the Turkish plate has rotated 50° counterclockwise with respect to Europe since the Cretaceous.

The purpose of this study is to bring more clarity to our knowledge about the movements of the Turkish plate since the Cretaceous. For this reason the Mesudiye region has been selected. This is between the North Anatolian Fault Zone and the eastern Black Sea coast. In this region the oldest geologic unit is the Mesudiye formation. It consists of the

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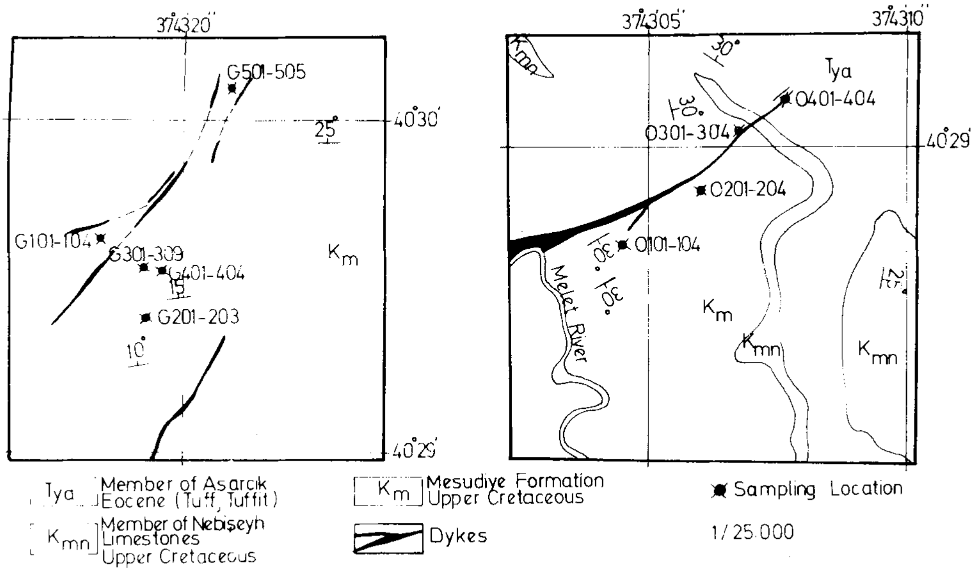

Figure 1. Geological map of the sampling area.

volcanic Upper Cretaceous deposits series, containing agglomerates, tuffs and tuffites interlayered with sandstone deposits. In this undifferentiated unit a limestone level (member of Nebiseyh limestone) is noticeable (Fig. 1). In some places Eocene (Lutesian) agglomera called 'member of Abarcık' having conglomeratic characteristics and tuff–tuffite recursions sit on top of the Mesudiye formation. There are also many basaltic dykes of Eocene or younger age in the studied region (Tütüncü 1977).

The location of the sampled sites with the sample numbers are shown in Fig. 1. Samples were collected from seven sites in the Upper Cretaceous Mesudiye formation and from two sites (O301-304 and O401-404) in Eocene dykes. Although there are plateau basalts in the northern part of this region, they are of Ologocene–Miocene age.

Measurements and results

Forty-one hand samples were used in this study. The natural remanent magnetization of all samples was measured and then pilot samples were subjected to progressive alternating field (af) demagnetization up to 750 Oe peak values (see Fig. 2). According to these results the remaining samples were all demagnetized in peak fields of 200–250 Oe (10^4 Oe $\hat{=}$ 1T).

The results of all measurements are given in Table 1, and the directions of natural and characteristic remanent magnetizations of the hand samples are shown in Figs 4 and 5 for the Cretaceous and Eocene formations respectively. It can be seen that the within-site scatter as well as the between-site scatter was reduced by the af treatment. Tectonic corrections have been added to the directions except for those samples collected from the Eocene dyke formations (sites O3 and O4), because their positions are not known with certainty.

Table 2 gives the results of X-ray and electron microprobe analyses of the oxide minerals of these samples. These results show that the samples generally contain members of the titanomagnetite series with a composition near magnetite. When the thermomagnetic curves of those samples which belong to the same hand sample are examined (Fig. 3), it can be seen that the Curie point of the samples G10222 and O40222, which are expected to be similar

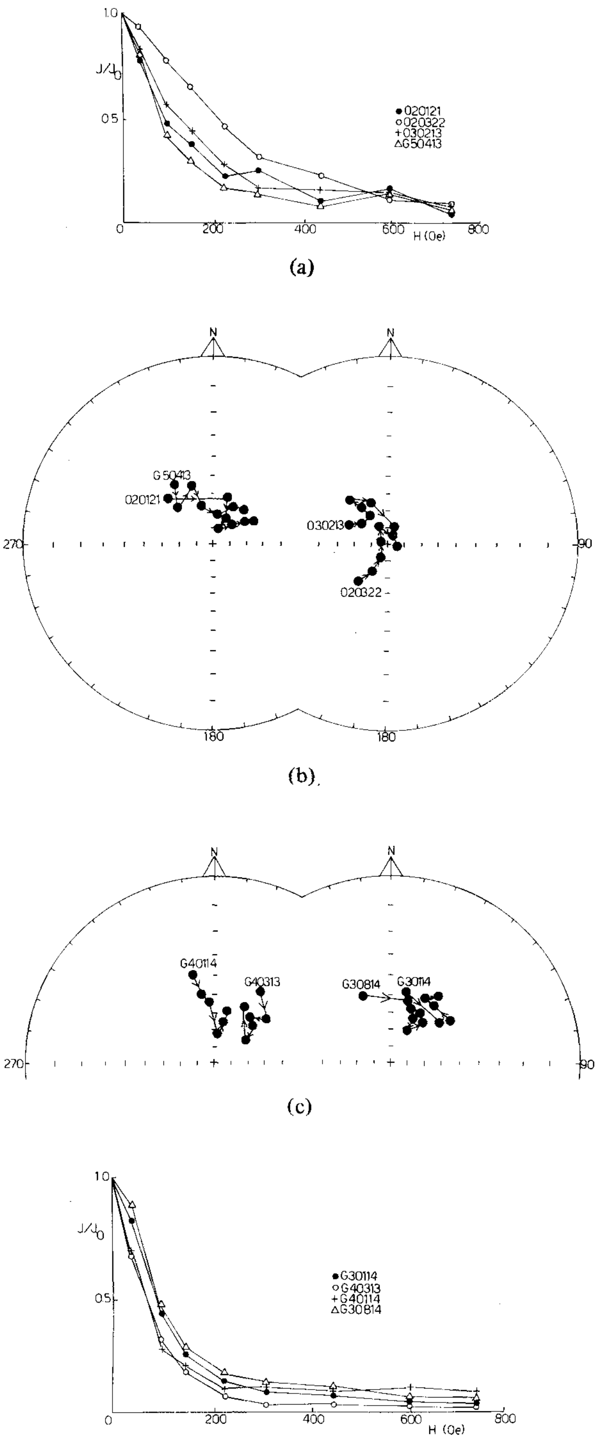

Figure 2. Magnetization intensity curves and equal area projection of the magnetization direction as a function of the peak value of alternating field for pilot samples. Full circles indicate (positive) downward inclinations.

Table 1. Directions of remanent magnetization, intensities and statistical parameters before and after af cleaning, and pole positions of the sites.

				NRM					After af cleaning					Pole positions			
Site	Age	*S*	*N*	Magnetization A/m	Dec.	Inc.	*k*	α_{95}	Magnetization A/m	Dec.	Inc.	*k*	α_{95}	Palaeolat.	Palaeolong.	*k*	α_{95}
G1	Upper Cretaceous	4	32	13.74	341.2	62.9	14.3	25.1	5.68	339.2	57.1	23.8	17.6	73.6 N	304.5 E	16.2	21.3
G2		3	30	2.13	347.3	57.7	11.7	37.8	0.45	340.0	49.0	40.0	19.0	70.5 N	280.8 E	40.0	19.0
G3		9	54	9.26	341.4	56.5	44.5	7.8	2.07	8.2	41.5	92.9	5.4	71.9 N	192.7 E	60.4	6.7
G4		4	34	6.46	321.9	34.1	11.2	28.8	2.17	4.6	32.8	27.0	2.0	67.0 N	206.4 E	44.0	14.0
G5		5	38	5.17	300.1	50.3	37.6	12.6	1.00	326.7	65.3	84.7	8.3	65.2 N	335.0 E	81.7	11.4
O1		4	30	11.50	12.6	70.8	23.4	19.4	4.04	337.2	47.0	608.5	3.8	67.6 N	281.4 E	188.1	6.7
O2		4	23	9.67	329.4	85.7	6.9	26.5	2.20	334.9	50.2	1000.0	1.0	67.6 N	290.4 E	890.2	3.1
Mean		7	–	8.28	332.7	61.3	17.5	14.8	2.52	346.8	49.9	30.6	9.6	75.3 N	275.4 E	24.2	10.7
O3	Eocene	4	26	2.88	359.5	73.8	8.6	33.2	0.58	62.1	38.4	56.1	12.7	34.7 N	127.8 E	90.4	9.3
O4		4	26	3.34	25.3	61.6	98.3	10.2	1.39	39.9	29.3	106.1	8.9	47.4 N	151.5 E	128.8	8.3
Mean		2	–	3.11	15.9	68.2	55.7	34.1	0.99	50.3	34.4	31.4	17.7	41.7 N	138.6 E	27.6	18.8

S: number of samples; *N*: number of specimen.

Table 2. Results of electron microprobe analysis in wt per cent.

SAMPLE	%Fe	%Ti	%Mn	%Mg	%Al	%Si	lattice constant of spinel-phase (A^{o})
G20112	50.812	8.284	0.578	1.301	2.816	0.512	8.488 (x)
G20316	51.555	7.580	0.631	1.106	2.321	0.821	8.356
G10214	55.264	3.664	0.675	1.053	1.685	0.886	8.386
G10414	59.109	3.719	0.307	0.934	1.407	0.645	8.424
040112	53.190	6.524	0.539	0	1.565	0.677	8.392
040214	59.064	2.369	0.251	0.418	0.867	1.170	8.413

(x) This lattice constant is not consistent with the microprobe analysis and the Curie temperature for unknown reasons.

to samples G10214 and 040112, is 580°C, and the Curie point of the sample G20216 which is expected to be similar to sample G20112 is 540°C consistent with its higher titanium content than that of the samples G10214 and 040112. These values support the results of X-ray analyses.

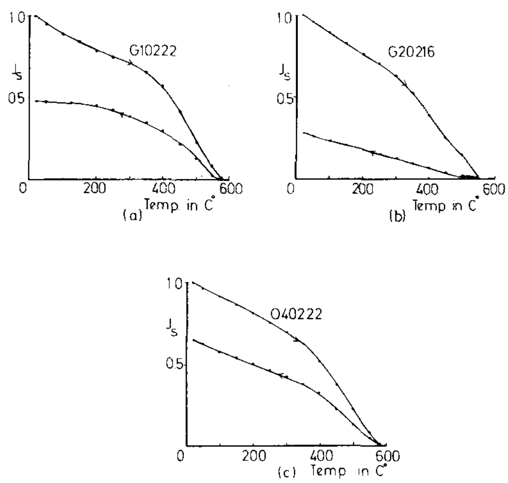

Figure 3. (a), (b), (c). Thermomagnetic curves for tuff samples (G10222 and G20216) and a dyke sample (040222).

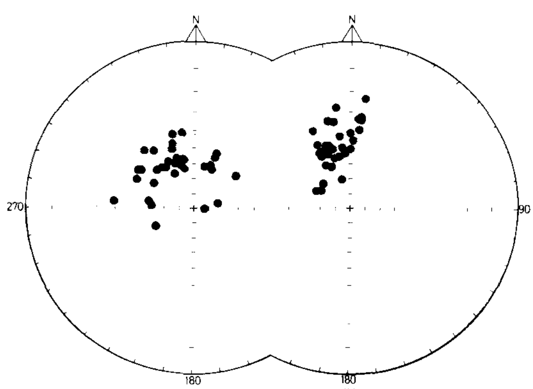

Figure 4. Distribution of NRM (a) and magnetic directions after af cleaning (b) of Upper Cretaceous hand sample means.

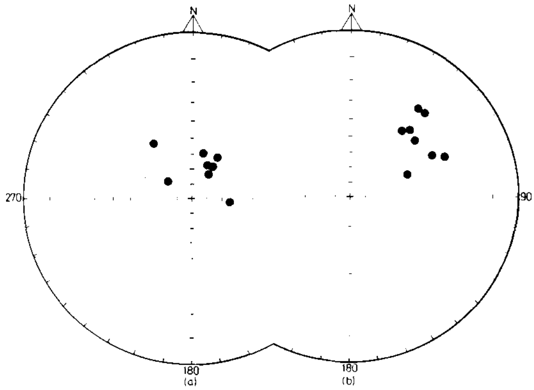

Figure 5. Magnetic directions of NRM (a) and magnetic directions after af cleaning (b) of Eocene hand sample means.

Interpretation

A compilation of Cretaceous (and Eocene) poles for Turkey, Near East, Africa, and Europe is given in Table 3 and Fig. 6. There is a good agreement between the pole position for Turkey belonging to the Upper Cretaceous obtained in this study and those of Van der Voo (1968) and Orbay (1978). The Upper Cretaceous data for Turkey are closer to the pole positions obtained for Africa, Israel and Lebanon than those from Europe.

The palaeo-isoclines have been reconstructed using the mean Cretaceous virtual pole positions from Africa and Eurasia and are shown in Fig. 7. The relationship between the data for Turkey and the results from Africa, Eurasia and Near East are also shown in Fig. 7. The azimuthal directions of magnetization of Turkey, Lebanon and Israel approximately perpendicular to the palaeo-isoclines for Africa and their inclinations come very close to the isoclines belonging to Africa. It can also be seen that the declinations deviate largely from the directions expected locally for the mean European Cretaceous poles. This difference

Table 3. Palaeomagnetic data of Turkey and neighbouring regions.

LOCATION	AGE	DEC	INC	PALEOLAT.	PALEOLONG.	A_{95}	REFERENCE
Europe	Ku	--	--	78.6 N	172.3 E	--	Lowrie and Alvarez, 1975.
Europe	Ku	357.6	43.1	72.0 N	200.4 E	--	Lowrie and Alvarez, 1975.
Europe	Kl	--	--	72.6 N	221.0 E	--	Van der Voo and French, 1974.
Africa	Ku	342.2	35.1	62.0 N	230.4 E	--	Lowrie and Alvarez, 1975.
Africa	Kl	--	--	53.9 N	253.4 E	--	Van der Voo and French,1974.
Africa	K	336.0	-54.0	62.0 N	259.0 E	3	Gough and Opdyke, 1963.
Lebanon	Kl	313.5	9.5	38.0 N	282.0 E	5.5	Van Dongen, 1967
Israel	Kl	332.5	8.5	53.0 N	265.0 E	--	Helsley and Nur, 1970.
Israel	Ku	--	--	42.0 N	264.0 E	--	Nur and Helsley, 1967.
Israel	Ku	--	--	60.0 N	254.0 E	--	Nur and Helsley, 1967.
Turkey	Kl	326.0	13.0	47.3 N	273.9 E	21.0	Orbay, 1978.
Turkey	Ku/Eo	346.1	44.6	75.3 N	279.2 E	6.0	Orbay, 1978.
Mesudiye	Ku	346.8	49.9	75.3 N	275.4 E	10.7	Present Paper.
Gümüşhane	K	153.5	-36.5	60.5 N	278.5 E	5.5	Van der Voo, 1968.
Niksar	K	140.0	-36.0	51.0 N	296.0 E	16.0	Van der Voo, 1968.
Gümüşhane	Ku/Eo	346.0	40.0	69.5 N	261.5 E	7.0	Van der Voo, 1968.
England	Eo	6.0	63.0	78.0 N	153.0 E	4.0	Irving, 1964.
Europe	Te	4.7	51.0	78.6 N	172.0 E	--	Lowrie and Alvarez, 1975.
Africa	Te	354.7	48.0	75.4 N	211.7 E	--	Lowrie and Alvarez, 1975.
Turkey	Eo	110.5	-49.4	32.8 N	328.0 E	8.9	Orbay, 1978.
Tunceli	Eo	152.5	-48.0	65.0 N	294.0 E	16.0	Van der Voo, 1968.
Mesudiye	Eo	50.3	34.4	41.7 N	138.6 E	18.8	Present Paper.

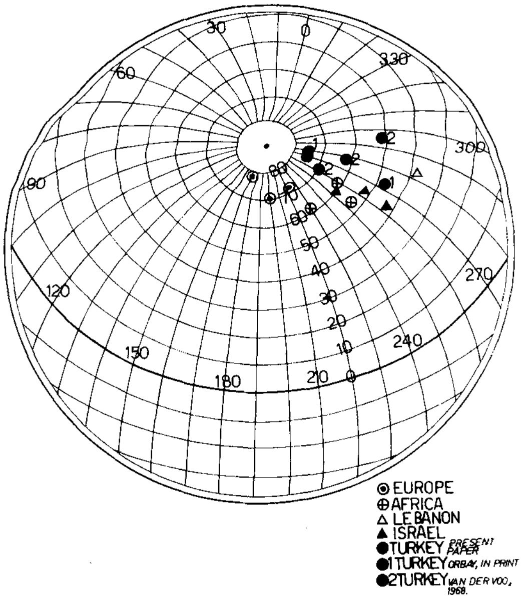

Figure 6. Cretaceous pole positions obtained for Turkey (Table 1). Africa, Europe, Lebanon and Israel (Table 3) plotted with their present day positions.

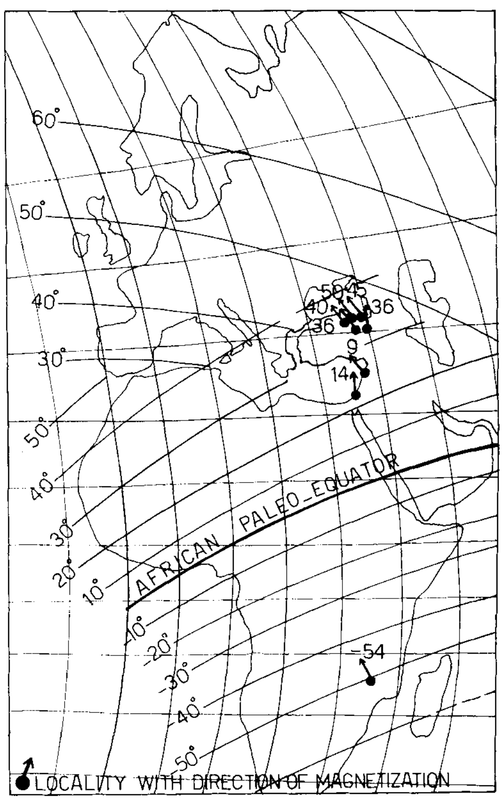

Figure 7. Palaeo-isoclines drawn for reliable virtual pole positions from Africa and Europe.

can be attributed to a counterclockwise rotation of Turkey since the Cretaceous of 45–50°. A similar counterclockwise rotation of 50° has been proposed by Van de Voo (1968).

The pole positions belonging to Eocene aged samples are given in Table 3, together with the results obtained for the same geological period by Van der Voo (1968) and Orbay (1978). The pole positions found from these earlier studies are not in agreement with the present result. As was mentioned before, the reason for this lack of agreement could be: first, the Eocene pole position was derived from two sites only; secondly, no tectonic correction could be made because of the uncertainty of the field position of the samples. Therefore, this Eocene pole position can be accepted only as a preliminary result.

Acknowledgments

The authors are very grateful to Professor Dr İ. Özdoğan for his help, the Mineral Research and Exploration Institute of Turkey which provided all kinds of aid in the field work, Mr K. Tütüncü who is a geologist at the same Institute, Dr W. O'Reilly who provided the opportunities for carrying out this work, Mr Davison who carried out the electron microprobe analysis and to the staff of the palaeomagnetism laboratory in the School of Physics, University of Newcastle-upon-Tyne.

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