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NEW PALEOMAGNETIC DATA FROM OLIGOCENE FORMATIONS OF NORTHERN AEGEA

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Abstract. New paleomagnetic data obtained from volcanic and plutonic formations in Thrace (Northern Aegea) show that this region has not undergone any significant rotation since the Lower Oligocene. The mean value of the inclination is shallower than expected on the basis of a geocentered dipole field implying a large northward drift of about 1000 km. Although a comparison with published data from Bulgaria leads to a puzzling large shortening between these two regions, the measured shallow inclinations are coherent with most of other paleomagnetic studies from Oligocene formations throughout the entire Mediterranean area. Together with published results from Chalkidiki Peninsula, our data suggest that the 'Circum Rhodopean Belt' was almost rectilinear and trending E-W in Lower Oligocene time.

Introduction

Thrace is situated in the northern part of mainland Greece, close to the southern margin of the Rhodope Massif. Together with the adjacent Serbo-Macedonian zone, the Rhodope Massif is traditionally thought to represent a pre-Mesozoic crystalline basement (Mercier, 1966; Kockel et al., 1971; Aubouin, 1973). Basement units are unconformably overlain by thick sequences of sediments. Kaufman et al., (1976) have defined an arcuate Jurassic facies belt which they called the 'Circum Rhodopean Belt', running from the Serbo-Macedonian zone and the Chalkidiki peninsula to the Alexandroupolis region in Thrace (Figure 1).

Southern Thrace was the site of extensive Tertiary magmatism. Igneous rocks comprising both plutonic and calcalkaline extrusives are characteristic of the type of activity that affected the entire central and northern Aegean area during a large part of the Cenozoic. Since the Lower Miocene, there has been a general southward migration of this volcanic activity. Bellon et al. (1979) suggested that the magmatism is related to major southwest directed thrusting of continental-type lithosphere. On the other hand, Fytikas et al. (1984) assume that the Oligo-Miocene magmatism provide evidence of a northwardly subducting African slab. The southward migration is then tentatively attributed to an increase in the dip of this subducting slab during the continental collision.

Paleomagnetic studies may contribute to a better understanding of this region by providing a geodynamical framework within which the original plate configuration can be investigated. Indeed, paleomagnetic data obtained in Chalkidiki have been interpreted as providing evidence of a large clockwise rotation since the Lower Oligocene (Kondopoulou and Westphal, 1986). Other studies, in Bulgaria (Nozharov and Petkov, 1976, 1977; Nozharov et al., 1977a, b), north of the Rhodope massif, do not show any significant rotation of this region since the Upper Cretaceous.

The purpose of this study was to obtain additional data from Thrace in order to extend this pattern of rotational

deformation into northern Aegea. Thus, we have studied the widespread igneous rocks which crop out in the Alexandroupolis region of southern Thrace (Figure 1).

Geological setting and sampling

In Thrace, the products of Cenozoic volcanic activity are distributed over three large basins: the Maronia, Kirki-Essimi, Feres-Soufli-Dadia basins (Figure 1). These basins developed over the Cretaceous detritic series within post-Alpine extensional grabens. The oldest volcanic products are intercalated with Priabonian sediments which consist mainly of tuffs and pyroclastic deposits. Volcanism was important during Oligocene time. These igneous rocks have K/Ar ages ranging between 33 and 23 Ma (Innocenti et al., 1984). The lavas show a clear calcalkaline affinity with a predominance of intermediate products (dacites, andesites) of variable enrichment in K_2O and P_2O_5 (Innocenti et al., 1984). Finally, during the Lower Miocene, calcalkaline volcanic activity migrated southward and no younger products can be found in Thrace.

Plutonites of monzonite-granodioritic type are found in many places coexisting with the volcanics. Economou et al. (1980) have obtained a K/Ar age of 36.6 Ma for the Leptokaria granite and of 45.2 Ma for the Maronia granodiorite. Recently, Rb/Sr dating yielded an age of 33.1 Ma for the Maronia granodiorite (Innocenti, personal communication).

The location of the sampled sites is shown in Figure 1. The sites were selected in the field essentially on the basis of tectonic criteria. Indeed, for the correct interpretation of the paleomagnetic data, it is necessary to restore the formations to their original palaeohorizontal position. This has been sometimes difficult for volcanic formations which are often devoid of 'bedding plane' criteria.

Five sites (TH 283 to 287) were located within the rhyolitic Feres Massif. These lavas are intercalated with a well bedded fine-grained marly succession with which one can apply a precise paleohorizontal correction. In other cases a local structural study gave a reasonable estimate of the palaeohorizontal. Seven sites have been sampled in granodiorites near Leptokaria and Maronia. We have assumed in these cases on the basis of the morphological aspect of the plutons that they have not been significantly tilted.

All drilled cores were oriented with both magnetic and sun compass, and the attitude of the palaeohorizontal was assessed by conventional methods.

A total of 300 cores were obtained from 24 sites.

Results

The different lithologies have shown considerable variations in values of the NRM intensity. The mean value for the dacites, granites and andesites is about 1 A/m while the rhyolitic formations of Feres were systematically rather more weakly magnetized (about $5 \cdot 10^{-2}$ A/m). Within-site differences up to a factor of 10 were recorded.

Thermal demagnetization of all the samples, involving at least 12 steps from room temperature to about 550-590°C has been used for this study. Measurements were made using either

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Fig. 1. Schematic map of Thrace showing (A) the location of the Circum Rhodopean Belt according to Kauffman et al. (1976) and (B) the distribution of the sampling sites. 1: Pre-Mesozoic basement; 2: Mesozoic formations; 3: Tertiary sediments; 4: Quaternary alluvions; 5: granites; 6: andesites, dacites; 7: rhyolites.

a Spinner magnetometer or a LETI 3-axes cryogenic magnetometer for weakly magnetized lavas. Bulk susceptibility was measured at each demagnetization step using a susceptibility bridge. No significant changes of the susceptibility of samples were observed up to temperatures as high as 550°C indicating that the magnetic minerals are not significantly affected by the thermal treatment up to this temperature. Moreover, IRM acquisition curves show that in all the cases magnetite is almost certainly the main magnetic carrier.

Typical demagnetization diagrams for samples retaining a stable remanence are shown in Figure 2. It can be seen that apart from a small viscous component removed at temperature below 300°C, a single stable component is almost invariably present, the intensity of which decreases progressively up to 550°C. Its direction was precisely obtained by drawing a straight line through the last 5-6 points.

Paleomagnetic results

The results from nineteen out of the 24 sampled sites are recorded in Table 1. For the remaining five sites, no stable component could be effectively isolated. Furthermore, some of the sites reported in Table 1 were rejected when, in spite of very convenient demagnetization diagram of single samples, the overall site scatter was too large ($K < 5$).

North of the Feres massif, andesitic flows overlie a sedimentary series whose bedding attitude can be precisely measured. Coherent results from the three sites drilled in this formation can be obtained only when two of the three (TH 288, 289) are corrected for tilt, while for the last one no correction is applied. This would imply that this last flow (site TH 290) was erupted later than the other two flows and subsequent to tectonic tilting. Although no detailed K/Ar or Rb/Sr dates are available, this interpretation is not

inconsistent with the fact that this flow has a more dacitic composition than the two others (Papadopoulos, 1980).

All the obtained results are reported in Table 1. Figure 3 shows clearly that both normal and reversed polarities are present. The almost perfect antiparallelism of the normal and reverse directions is a strong indication that the magnetization is stable and primary in origin. However, it has not been possible to apply a standard fold test. Indeed,

Fig. 2. Typical thermal demagnetization plots of various samples from sites of different lithologies. The number of steps depends on the samples and the maximum temperature is indicated. M_0 is given in 10^{-3} A/m. Open circles: projection on E-W or N-S vertical plane; full circles: horizontal projection.

Table 1. Paleomagnetic Results from Thrace

Sites	n	Da	Ia	Db	Ib	K	α_{95}
TH 288	5	195.0	-12.0	201.0	-40.0	84	6.8
TH 289	10	191.2	-18.0	197.8	-47.4	117	4.0
TH 290	6	.....	....	200.0	-48.6	107	6.0
TH 291	10	.....	....	22.0	43.2	50	6.2
TH 292	10	.....	....	187.0	-56.8	52	6.0
TH 293	9	346.3	5.0	335.3	38.3	37	7.6
TH 294	8	.....	....	229.0	-45.5	10	15.4
TH 302*	10	.....	....	296.5	3.5	2	29.0
TH 303	11	.....	....	162.8	-24.8	73	5.0
TH 304	10	.....	....	161.5	-27.5	31	7.8
TH 297	10	.....	....	194.6	-49.0	133	3.8
TH 306	9	35.6	49.3	13.8	35.2	19	10.0
TH 295*	10	.....	....	188.0	-11.5	3	26.0
TH 296	10	.....	....	189.8	-58.7	19	10.2
TH 298*	9	.....	....	214.0	8.0	1	42.0
TH 299*	9	.....	....	8.2	29.0	2	33.7
TH 300	8	.....	....	359.0	49.0	172	3.7
TH 301	6	.....	....	2.5	51.0	52	8.0
TH 307	9	.....	....	7.0	58.0	302	2.7

*: sites rejected on the basis of too high within-site scatter (K<5). Results are reported before (Da, Ia) and after (Db, Ib) bedding correction was applied.

$\alpha-\delta$: andesites-dacites; ρ : rhyolites; γ : granites.

although there is a slight decrease in scatter upon application of bedding correction, the number of sites where paleohorizontal can be well defined and which gave reliable paleomagnetic results, is too limited to confirm a positive fold test at 99% confidence.

When all the reverse sites are inverted through the origin, the paleomagnetic direction obtained using Fisher's statistics is:

N = 15 D = 7.0 I = 46.5 K = 23 $\alpha_{95} = 7.5$

Discussion

As shown by the results reported above, the paleomagnetic direction from Oligocene formations in Thrace is significantly different from the present day field direction at the same latitude determined on the basis of a geocentered dipole field (D = 0, I = 60°) which is also shown in Figure 3. This difference arises mainly from the value of inclination which is shallower than the one expected on the basis of a geocentered dipole field, while the declination is not significantly different from the present-day value.

The paleomagnetic direction obtained in Thrace is also significantly different from the value calculated for this region (D = 8°; I = 57°) using the well defined Lower Oligocene European pole (Westphal et al., 1986). This pole indicates that Thrace was most probably not attached to Europe at this time. The paleomagnetic data alone cannot determine whether Thrace was attached to Africa in the Oligocene as the apparent polar wander path (APWP) for the latter is poorly defined during this interval. Indeed, the results obtained by Schult and Soffel (1974), Raja (1976), Tauxe et al., (1983) and Westphal et al. (1986) yield Oligocene African poles scattered over at least 10° in latitude precluding the detection of possible movement of Thrace with respect to Africa with the necessary accuracy. No clear conclusion can thus be reached until a better African APWP is available.

The shallow inclination value provides a good indication of northward drift of about 1000 km for Thrace. This leads to considerable difficulties in the geodynamical interpretation

when results obtained in Thrace are compared with those already reported from neighbouring regions in Bulgaria (Nozharov and Petkov, 1976, 1977; Nozharov et al., 1977a, b) and the Chalkidiki peninsula (Kondopoulou and Westphal, 1986).

When combined (Kondopoulou and Westphal, 1986), the data from Bulgaria (D = 8°; I = 67°) are not inconsistent with a European appartenance. However, a comparison with the new results from Thrace shows a significant difference in inclination implying that there has been, between Thrace and Bulgaria, a large south-north shortening for which no field evidence has been reported. Indeed the Rhodope Massif is widely considered to have behaved as a coherent block for at least the last 30 Ma (Aubouin, 1973). It seems unrealistic on geological grounds to infer the existence of a major crustal discontinuity between the studied regions located on either side of the Rhodope Massif. Thus it is clear that the mean inclination from Thrace cannot be consistent with that from Bulgaria and the latter needs to be further scrutinized before an absolute interpretation can be made. Indeed the shallow inclinations measured in Thrace are not unique in this circum Mediterranean area. Similar results have been obtained not only in the surrounding regions (Kissel et al., 1986) but in most of the Mediterranean area from Iberia to Iran for the same period (Westphal et al., 1986 and references therein). In this respect the results obtained in Thrace are in good agreement with other Mediterranean data and are thus hardly questionable.

The value of inclination is even lower in the nearby region of Chalkidiki (I = 31°) where paleomagnetic results from Upper Eocene formations have been reported by Kondopoulou and Westphal (1986). These authors have suggested that this anomaly could be at least partly due to a non-visible tectonic tilt of the granodiorite pluton which could have affected mainly the inclination.

As far as the declination is concerned, a large difference of about 30° exists between Chalkidiki (D = 37°) and Thrace (D = 7°). Assuming that the curvature of the Circum-Rhodopean belt as defined by Kaufman et al. (1976) has a geological and structural significance, one can use the paleomagnetic data of Kondopoulou and Westphal (1986) to rotate Chalkidiki back to its pre-Oligocene orientation. Following this operation one finds that the belt was almost rectilinear and trending E-W from Chalkidiki to Thrace.

Unfortunately, no formations suitable for paleomagnetic investigation and younger than Lower Oligocene have been studied in Chalkidiki. Thus we have no precise idea about the age of the rotation. Moreover, because most of this belt is submerged beneath the Aegean between Sithonia and Thrace, it is very difficult to follow the structural and facies belt. It is necessary to obtain some results in the intermediate

Fig. 3. Stereographic projection of the mean paleomagnetic direction of Table 1. Full circles: normal directions, open circles: reverse directions. a: before bedding correction; b: after bedding correction; c: mean regional direction (triangle) calculated inverting the reverse directions through the origin and present-day field direction (square) in Thrace.

regions within the Rhodope massif to determine the continuous behaviour both in inclination and declination of this zone for the last 30 Ma.

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References

- Aubouin, J., Des tectoniques superposées et leur signification par rapport aux modèles géophysiques: l'exemple des Dinarides; paléotectonique, tectonique, tarditectonique, néotectonique, *Bull. Soc. Géol. Fr.*, 7, XV, 426-460, 1973.
- Bellon, F., J. J. Jarrige, and D. Sorel, Les activités magnétiques éogènes de l'Oligocène à nos jours et leurs cadres géodynamiques. Données nouvelles et synthèse, *Rev. Géol. Dyn. Geogr. Phys.*, 21, 41-55, 1979.
- Economou, C., T. Makropoulos, and C. Sideris, Altération hydrothermale d'une plutonite dans la région des mines d'Aghios Philipos, Kirki, *Sci. Geol. Bull.*, 33, 2, 103-110, 1980.
- Fytikas, M., F. Innocenti, P. Manetti, R. Mazzuoli, A. Peccerillo, and L. Villari, Tertiary to Quaternary evolution of volcanism in the Aegean region, in *Tectonic evolution of the Eastern Mediterranean*, edited by A. H. F. Robertson and J. E. Dixon, *Spec. Publ. Geol. Soc. London*, 17, 687-699, 1984.
- Innocenti, F., N. Kolios, P. Manetti, and R. Mazzuoli, Evolution and Geodynamic significance of the Tertiary orogenic volcanism in Northeastern Greece, *Bull. Volcan.*, 47-1, 25-37, 1984.
- Kauffman, G., F. Kockel, and H. Mollat, Notes on the stratigraphic and paleogeographic position of the Svoula formation in the Innermost Zone of the Hellenides (Northern Greece), *Bull. Soc. Geol. Fr.*, XVIII, 2, 225-230, 1976.
- Kissel, C., C. Laj, A. Poisson, Y. Savasçin, K. Simeakis, and J. L. Mercier, Paleomagnetic evidence for Neogene rotational deformations in the Aegean domain, *Tectonics*, in press, 1986.
- Kockel, F., H. Mollat, and H. W. Walther, Geologie des Serbo-Mazedonischen Massivs und seines mesozoischen Rahmens, *Geol. Jb.*, 89, 529-551, 1971.
- Kondopoulou, D., and M. Westphal, Paleomagnetism of the Tertiary intrusives from Chalkidiki (Northern Greece), *J. Geophysics*, 59, 62-66, 1986.
- Mercier, J. L., Mouvements orogéniques, épirogéniques et magnatisme d'âge jurassique supérieur-éocène dans les zones internes des Hellénides (Macédoine, Grèce), *Rev. Géogr. Phys. Geol. Dyn.*, 8, 265-278, 1966.
- Nozharov, P., and N. Petkov, Palaeomagnetism and palaeomagnetic stability of certain magmatic rocks in the Madjavoro ore field, *Bulgarian Geophys. J.*, 11 (4), 90-104, 1976.
- Nozharov, P., and N. Petkov, Palaeomagnetism of some rocks forming the Lozen paleovolcan (East Rhodopes), *C. R. Acad. Bulg. Sc.*, 30 (3), 359-361, 1977.
- Nozharov, P., D. Veljovic, and N. Petkov, Results of paleomagnetic studies of some magmatic rocks in Srednogoriye and Standja, *C. R. Acad. Bulg. Sc.*, 30 (4), 531-533, 1977a.
- Nozharov, P., D. Veljovic, and N. Petkov, Paleomagnetism of some Upper Cretaceous and Tertiary volcanites in Sredna Gora and Eastern Rhodopes, *C. R. Acad. Bulg. Sc.*, 30 (6), 843-845, 1977b.
- Papadopoulos, P., 1980, Geological map (1/50 000) of Ferai, Peplos and Ainos region, IGME, Athens.
- Schult, A., and H. Soffel, Paleomagnetism of Tertiary basalts from Lybia, *Geophys. J. R. Astr. Soc.*, 32, 373-380, 1973.
- Raja, P. K. S., Palaeomagnetism of the Cenozoic volcanic rocks from East Africa, *Curr. Sci.*, Vol. 45, 2, 46-48, 1976.
- Tauxe, L., J. Besse, and J. L. Labrecque, Palaeolatitudes from DSDP Leg 73 sediments cores implications for the apparent polar wander path for Africa during the late Mesozoic and Cenozoic, *Geophys. J. R. Astr. Soc.*, 73, 315-324, 1983.
- Westphal, M., M. L. Bazhenov, J. P. Lauer, D. M. Pechersky, and J. C. Sibuet, Paleomagnetic implications on the evolution of the Tethys belt from the Atlantic ocean to Pamir since Trias, *Tectonophysics*, 123, 37-82, 1986.

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