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NEOTECTONIC AND PALAEOMAGNETIC RESULTS FROM NEOGENE BASINS OF MACEDONIA (N GREECE) AND THEIR GEODYNAMIC IMPLICATIONS

by

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Introduction. Geological studies of both the alpine and neotectonic history of the Hellenides and the Aegean area, as well as geophysical and geodynamical ones, provide important information about the geological evolution of this area. The Tertiary and the Recent evolution in Greece is governed by the local microcontinental collisions and also influenced by distant events related to the active collision of African and European plates.

As far as the Neogene and Quaternary stress patterns are concerned, the detailed neotectonic studies of MERCIER et al., 1979, ANGELIER 1979, LYBERIS 1984 etc, have provided enough information about the Hellenic arc, the south Aegean and occasionally the north Aegean and the mainland of northern Greece.

An important point that may require further clarification is that the neotectonic and seismotectonic peculiarities of the north Aegean and the surrounding area can not easily be explained by the up to day suggested geodynamic models. Thus, for a deeper understanding of the geodynamic evolution of this area, it is necessary to determine the stress pattern of the Neogene—Quaternary times and to distinguish among different phases of rotational deformation. Palaeomagnetism is an important tool in the attempt to clarify the details of these events giving a quantitative technique for measuring relative displacement and rotations among different geological times, because palaeomagnetic measurements are generally made on small rigid block materials which have not been deformed and which are bounded by faults.

In this work we present new data concerning the stress pattern and palaeomagnetic directions of the Neogene basins in Macedonia (N Greece), alongside with similar data already published by others. A correlation is attempted between these sets of data in order to establish a possible geodynamic pattern during the "neotectonic stage".

Methods

Methods used in the present tectonic analysis were the "right-dihedrons" and "the mean stress tensor" (ANGELIER, 1979). The chronology of fault events was established mainly by using the stratigraphical data of the sediments of the basins, as well as by taking into account criteria for successive fault motions.

Our detailed neotectonic analysis of Neogene and Quaternary fault mechanisms, as well as those published by MERCIER, 1981; LYBERIS, 1984; concerning the northern Greek mainland, enable us to characterize the direction of the regional stresses in the whole under investigation area (Fig. 1 and 2).

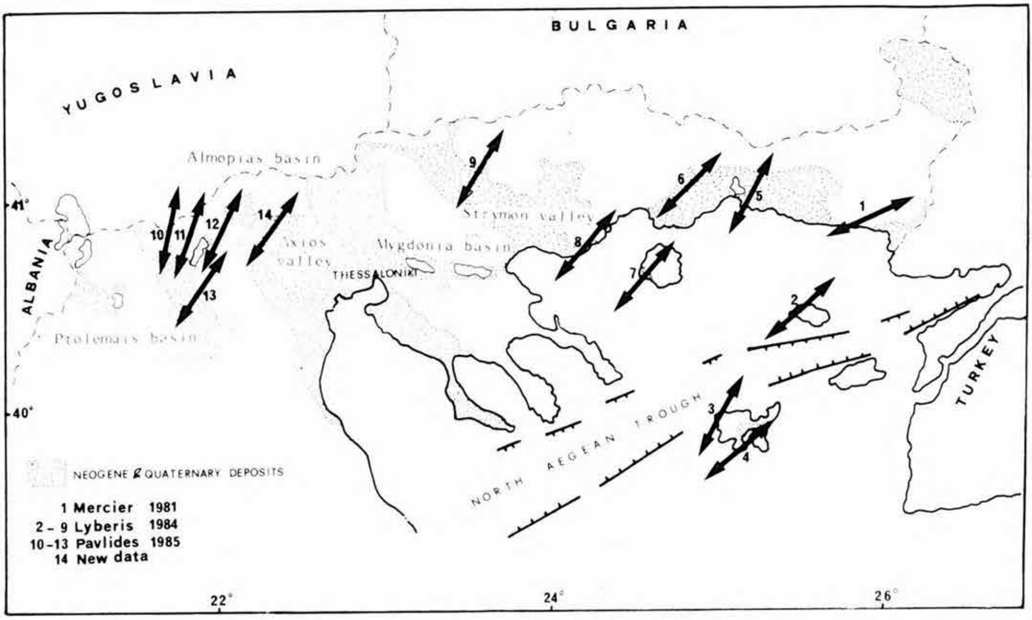

Fig. 1. A general picture of the investigated area (Macedonia and Thrace) in northern Greece with its Neogene and Quaternary deposits, which mainly fill up neotectonic basins. Arrows indicate the directions of tension for the Late Miocene—Pliocene period of extension

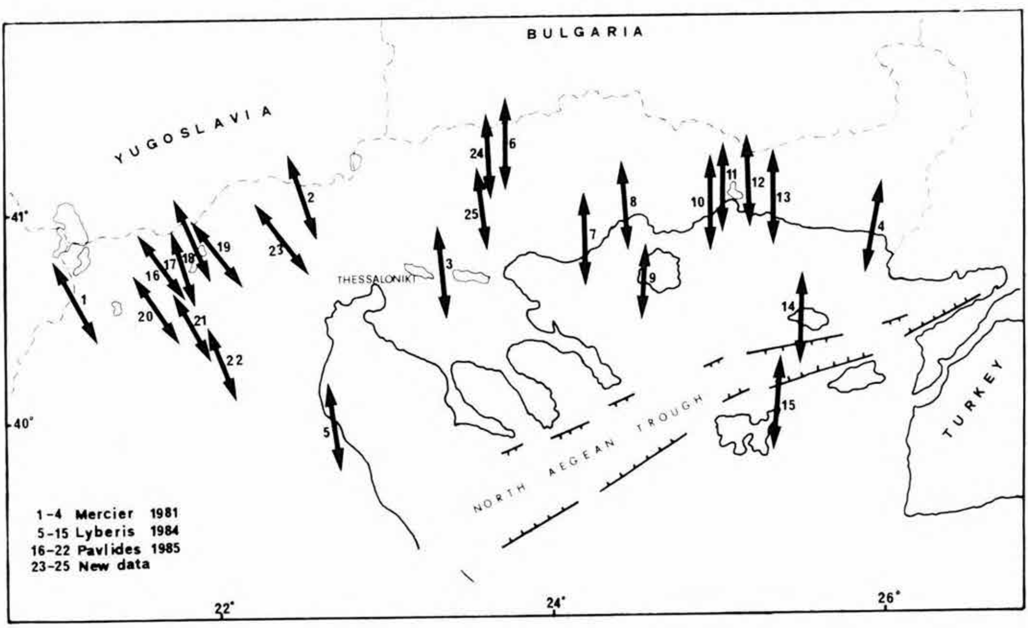

Fig. 2. Directions of tension for the period of Quaternary

As far as the palaeomagnetic sampling and measurements are concerned, we collected orientated handsamples from several sites, mainly volcanic, covering all the investigated area.

The samples were measured using standard laboratory techniques by a DIGICO spinner magnetometer and were demagnetized by A.C. field and thermally.

Geological regime

Ptolemais basin (western Macedonia): It has a clear tectonic origin and is filled up by Neogene and Quaternary deposits. According to biostratigraphic determinations the lower formations are of Latest Miocene—Pliocene age (Ruscinian) and the upper ones of Pleistocene age (Villafranchian and Biharian). Taking into account the chronology of the earliest deposits of the basin and the published results for the beginning of the neotectonic activity in the whole Aegean region, a Post Middle Miocene age could be considered as the most acceptable age for the initial creation of the Ptolemais basin.

Two phases of extensional neotectonics are distinguished in the area by detailed field observations and quantitative tectonic analysis. The first one of latest Miocene—Pliocene, has been calculated to be NNE—SSW. That is, the extensional axes, σ_3, are almost horizontal trending to NNE—SSW direction, while the compressional ones, σ_1, are vertical and those of intermediate, σ_2, trend to NW—SE direction. The second extensional phase of Quaternary trends to NW—SE (PAVLIDES, 1985). *Almopias basin:* The origin of Almopias basin is also tectonic and the volcanic centers of the area, as well as those of Kozuf (S Yugoslavia) are connected with large faults and subsidences. The volcanics of Almopias, occupying an area of approximately 200 km^2, are mainly of trachy-andesitic composition and they have been extruded along the Axios (Vardar) zone. Their Pliocene age is determined by *K/Ar* methods as 2.5 to 4 Ma. On the other hand, the lacustrine sediments, which have been determined as Pliocene too by palynological analysis, are in a close relationship with the volcanism (CHORIANOPOULOU et al., 1982).

Two neotectonic extensional phases have also been determined in the Almopias area, similar to that of Ptolemais basin. The *Serbomacedonian zone* and *Strymon valley:* In central and eastern Macedonia eleven exporuses of acidic volcanic rocks have been mapped. Nine of them lie in the Serbomacedonian geological zone and the rest in the western and eastern edges of the Strymon valley. Based on geological data, the age is considered to be Late Pliocene or Plio—Pleistocene.

There is no tectonic relation between this volcanism and any active subduction zone. This is inferred by the alcalic petrochemical character of the volcanic rocks and by the absence of any significant intermediate depth seismic activity in the area (PAPADOPOULOS, 1982).

The Mygdonia basin, which extends in the central part of the Serbomacedonian massif, was created during Middle to Late Miocene. Two different extensional tectonic phases could be distinguished during its evolution; the first is of Miocene—Pliocene age and the second of Early Pleistocene one (PSILOVICOS, 1977).

Palaeomagnetic results

The up-to-date published palaeomagnetic results of Greece, suggest that northwestern Greece has undergone two distinct clockwise rotations, of about 20°—25°.

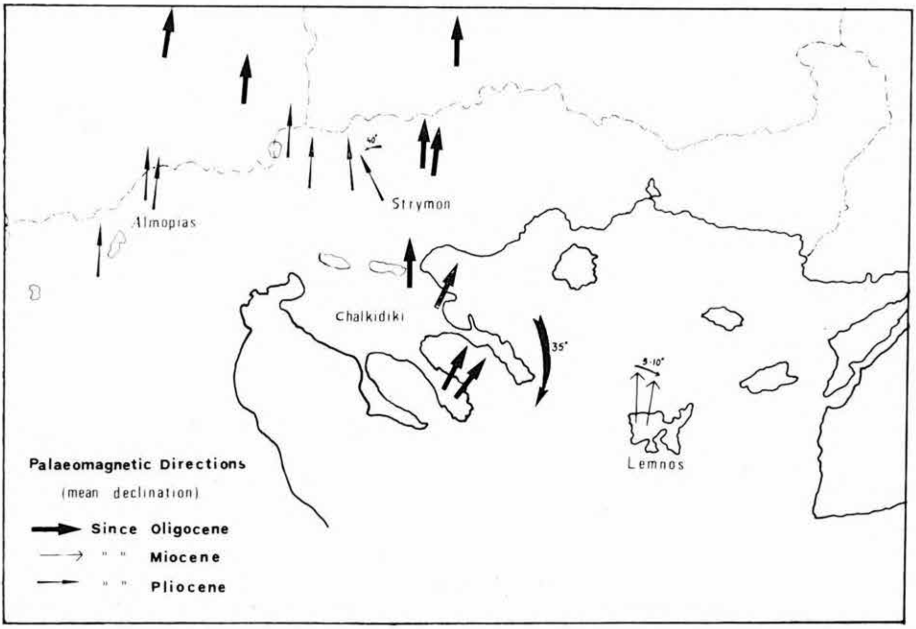

Fig. 3. Paleomagnetic directions (mean declinations) as arrows. Those of Bulgaria and Yugoslavia are from NOZHAROV and PETKOV 1976, 1977, NOZHAROV et al., 1977a (see KONDOPOULOU and WESTPHAL, 1985 for references) and STEFANOVIĆ and VELJOVIĆ 1972

The first one took place between Early to Middle Miocene and the second, also known from Peloponnesos and Ionian islands (west edge of the Hellenic arc), during the Pliocene and Quaternary. These two rotational phases are separated by a period of, at least, 7 Ma (Late Miocene) during which no major rotation occurred (LAJ et al., 1982; KISSEL et al., 1984).

Concerning Northern Greece and according to our palaeomagnetic results, as well as those refering to the Bulgarian Rhopode massif and south Yugoslavian Serbo-macedonian zone, no clear rotation occurred during Late Tertiary in this region (see also KONDOPOULOU and WESTPHAL, 1985). Only one segment of Chalkidiki peninsula has undergone a clear clockwise rotation of about 35°, since the late Oligocene. So only this part of the studied area is close to the rotation of western Greece, but the limit between the unrotated part and the rotated one is still unknown (Fig. 3).

Furthermore, according to our latest palaeomagnetic results from Pliocene formations (Table 1), we can conclude that no significant rotation has been detected in the Almopias volcanics and those of Strymon area. The results from one site of the west edge of Strymon valley (Strymoniko, SRY) indicate a large scatter, the reason of which is not fully understood. Another site from the same area (WW) is very coherent, with a mean direction close to Almopias results, that is no clear rotation has been detected for this site. Similar evidence arises from some measured samples of Pliocene sediments (marls and lacustrine limestones) of Ptolemais basin.

The only case which looks significantly different is that of PW situated close to WW (central Macedonia). It is the first time that a strong counterclockwise rotation

Table 1

Palaeomagnetic results of Neogene formations in Northern Greece

ALMOPIAS (2.6—4 Ma)

N° of sites	D°	I°	k	a_{gs}	Ref.
4	17	54	32	16	Kondopoulou (1982)
6	195	—66.5	40	10	Bobier (1968)
3	356	56.4	36	14	This paper

STRYMON AREA (Plio—Quaternary?)

Site					
SRY (6 samples)	117	—30	5.9	33.9	This paper
WW (6 samples)	349.3	58.8	43.7	10.1	This paper
PW (6 samples)	318.9	42.1	13.9	18.5	This paper

of about 40° is detected in this area. The samples of this site are very strongly magnetized and a possible explanation for the direction mentioned above could be that they have been thundered. In this case, the results should not be coherent. This hypothesis is rejected because results are coherent and normal as well as reverse directions are present which is a good indication of stability. Another problem concerning this site is the age which is known only from geological estimations. We are aware of the fact that no definitive conclusions could be drawn out of this only site but we draw the attention to the peculiarity of this counterclockwise rotation.

Conclusion

From the overall neotectonic picture of Northern mainland Greece, it is inferred that the tectonics of the Late Tertiary times were uniform throughout its extent. The initial creation of the basins in the area was the result of the tectonic processes of Middle (?) to Late Miocene, while their evolution was completed in two principal extentional phases, the first one of the Late Miocene—Pliocene and the second of Quaternary.

According to the palaeomagnetic studies, no significant rotation has been detected in the area since Pliocene, except the clockwise one refering to southern Chalkidiki peninsula. Low values of mean declination (5°—10°) present in some sites (for instance Lemnos, Almopias) are not significant as they lie in the limit of the reliability of the method.

Only one site belonging to a rigid block of the western edge of Strymon valley (eastern Macedonia) indicates a strong counterclockwise rotation. More samples need in this area in order to establish this result more accurately.

A comparison of the neotectonic data with the palaeomagnetic ones from Macedonia leads us to investigate the following two possibilities.

a) If no significant rotation of the region can be seen, then the change of the direction of the stress field is not in relation with any rotation of the area. In this case the change of the stress field from NE—SW to NNW—SSE is rather the result of the mutual exchange of the principal stress axes δ_3 and δ_2.

b) If a real counterclokwise rotation exists are in some rigid blocks in the area, as it was observed in one case, then a hypothesis of the same rotation for the stress field with that of the region, could be examine. These two problems are open to future research.

REFERENCES

ANGELIER J. 1979: Néotectonique de l'Arc Egéen. — Thèse de Doctorat d'Etat. Soc. Géol. du Nord, France, Publ. 3.:1—418.

BOBIER C. 1968: Etude paléomagnétique de quelques formations du complèxe volcanique d'Almopias (Macédoine centrale, Gréce). — C. R. Ac. Sci. (267):1091—1094.

CHORIANOPOULOU P., GALEOS A. and IOAKIM CH. 1984: Pliocene lacustrine sediments in the volcanics of Almopia. — J. Geol. Soc. Lond. Special Publ. 17.

KISSEL C., LAJ C. and MÜLLER C. 1984: Tertiary geodynamical evolution of northwestern Greece: paleomagnetic results. — Earth planet. Sci. Lett. 72.:190—204.

KONDOPOULOU D. 1982: Paléomagnétisme et déformations néogènes du Nord de la Mer Egée. — Thesis, Dr. spec. Univ. Strasbourg (unpublished).

KONDOPOULOU D. and WESTPHAL M. 1985: Palaeomagnetism of the Tertiary intrusives from Chalkidiki peninsula (N. Greece). — Journal of Geophysics.

LAJ C., JAMET M., SOREL D. and VALENTE J. P. 1982: First paleomagnetic results from Mio—Pliocene series of the hellenic sedimentary arc. — Tectonophysics. 86.:45—67.

LYBERIS N. 1984: Géodynamique du domain Egéen depuis le Miocène supérieur. — Thése Doctorat d'Etat, Univ. P. et M. Curie, Paris VI.

MERCIER J.-L. 1981: Extensional—compressional tectonics associated with the Aegean Arc: comparison with the Andean Cordellera of south Peru—north Bolivia. — Phil. Trans. R. Soc. Lond. A 300.:337—355.

MERCIER J.-L., DELIBASIS N., GAUTHIER A., JARRIGE J., LEMEILLE F., PHILIP H., SEBRIER M. and SOREL D. 1979: La néotectonique de l'Arc Egéen. — Rev. Geogr. Phys. Geol. Dyn. 21.:67—92.

PAPADOPOULOS G. A. 1982: Contribution to the study of the active deep tectonics of the Aegean and the surrounding areas. — Sci. D. Thesis, Univ. of Thessaloniki.

PAVLIDES S. B. 1985: Neotectonic evolution of the Florina—Vegoritis—Ptolemais basin (W Macedonia, N Greece). — Sci. D. Thesis, Univ. of Thessaloniki.

PSILOVICOS A. 1977: Paleogeographic evolution of the Mygdonia basin (Langada, N Greece). — Sci. D. Thesis, Univ. of Thessaloniki.

STEFANOVIĆ D. and VELJOVIĆ D. 1972: Paleomagnetism and Tectonics of the Carpatho-Balcanic arc. — Acad. Sci. Art. Slav. Mer. Symp. of the Moho, discontinuity.

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