

**PALEOMAGNETIC DATA AND BIOSTRATIGRAPHY OF THE MIDDLE MIOCENE
VERTEBRATE LOCALITY OF THYMIANA (CHIOS ISLAND, GREECE)**

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A B S T R A C T

A Greek-French team worked in this important but poorly documented area with the aim of obtaining new mammalian remains and determining the magnetic stratigraphy. Mammals were found at three different horizons. We also sampled a 46m thick section at 32 horizons for a paleomagnetic study. The I.R.M. shows that the main magnetic carrier is magnetite. Stepwise thermal demagnetization of 80 specimens allowed to identify the presence of two components, the soft secondary overprint and the hard primary one. The section presents a long reverse polarity zone interrupted by a normal zone. This succession can be only partly correlated with the polarity timescale since the Middle Miocene is a period with a high frequency of reversals. This study also leads to some tectonic results as the mean declination implies about 25° counterclockwise rotation of this island since Middle Miocene.

**ΠΑΛΑΙΟΜΑΓΝΗΤΙΚΑ ΚΑΙ ΒΙΟΣΤΡΩΜΑΤΟΓΡΑΦΙΚΑ ΣΤΟΙΧΕΙΑ
ΑΠΟ ΤΗΝ ΑΠΟΛΙΘΩΜΑΤΟΦΟΡΟ ΘΕΣΗ ΤΟΥ ΜΕΣΟΥ ΜΕΙΟΚΑΙΝΟΥ ΤΩΝ ΘΥΜΙΑΝΩΝ
(ΧΙΟΣ, ΕΛΛΑΔΑ)**

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Π Ε Ρ Ι Λ Η Ψ Η

Μια Ελληνογαλλική ομάδα εργάστηκε σ' αυτήν την σημαντική αλλά ελάχιστα γνωστή περιοχή με σκοπό να μελετήσει νέα απολιθώματα θηλαστικών και την μαγνητοστρωματογραφία της. Θηλαστικά βρέθηκαν σε τρεις διαφορετικούς ορίζοντες. Επίσης μελετήθηκαν με παλαιομαγνητισμό δείγματα από 32 ορίζοντες σε τομή πάχους 46m. Η ισόθερμη μαγνήτιση δείχνει ότι ο κύριος μαγνητικός φορέας είναι ο μαγνητίτης. Η θερμική απομαγνήτιση σε 80 δείγματα έδειξε την παρουσία δύο συνιστωσών, μιας δευτερεύουσας "μαλακής" και της ανθεκτικής πρωτεύουσας μαγνήτισης. Η τομή παρουσιάζει μια ζώνη αναστροφής πολικότητας που διακόπτεται από ένα κανονικό συμβάν. Η διαδοχή αυτή είναι μερικώς μόνο συγκρίσιμη με την

κλίμακα του Μειοκαινίου το οποίο είναι περίοδος μεγάλης συχνότητας αναστροφών. Η μελέτη αυτή οδηγεί και σε τεικτονικά αποτελέσματα αφού η μέση απόκλιση συνεπάγεται μια αριστερόστροφη περιστροφή 25° από το Μέσο Μειόκαινο.

INTRODUCTION

The island of Chios is situated in the eastern part of the Aegean Sea (Fig.1). The greater part of the island consists of Paleozoic clastic rocks, mainly greywackes, shales, conglomerates and limestones. The Mesozoic sediments are mainly recrystallized limestones which are overlain unconformably by the Tertiary formations (Kiliyas, 1982). Neogene continental deposits, known by their middle Miocene mammalian fauna, are exposed in the southeastern part of the island (Fig.1). The earliest reference about the occurrence of mammalian fauna in one locality, Michalou clay pit, is that of Paraskevaidis (1940) who described a faunule from this locality. Later a Greek-German team visited the area several times and some small collections of mammals and micromammals have been described (Melentis and Tobien, 1967; Tobien, 1968, 1977). Parallel to these palaeontologic researches the geology of the Neogene deposits has been studied (Besenecker, 1973), while Rothausen (1977) has presented a detailed lithostratigraphy of the mammal bearing horizons. Nevertheless the few collected fossils and the doubtful determinations cannot give a certain age for the deposits. More recently a team of Greek and French geologists has begun to work in the area. The main aims of the group are a) to collect more mammalian fossils and to use these in the biochronology, b) to study the palaeomagnetism of the deposits for a magnetostratigraphic age determination and c) to correlate all these data with the lithostratigraphy for the detailed dating of the deposits. The work began in 1991 and it is planned to be continued this year (1993). The first results of this investigation, mainly palaeomagnetic, are presented in this paper.

STRATIGRAPHY

The main bedrocks of the Chios Neogene basin are the Mesozoic limestones which outcrop in both its north and west edges (Fig. 1). The Neogene deposits have been subdivided by Besenecker (1973) into four lithostratigraphic units which are, from the bottom to the top, as follows:

a) The Thymiana Formation, consisting of pink or red colored sandstones and siltstones.

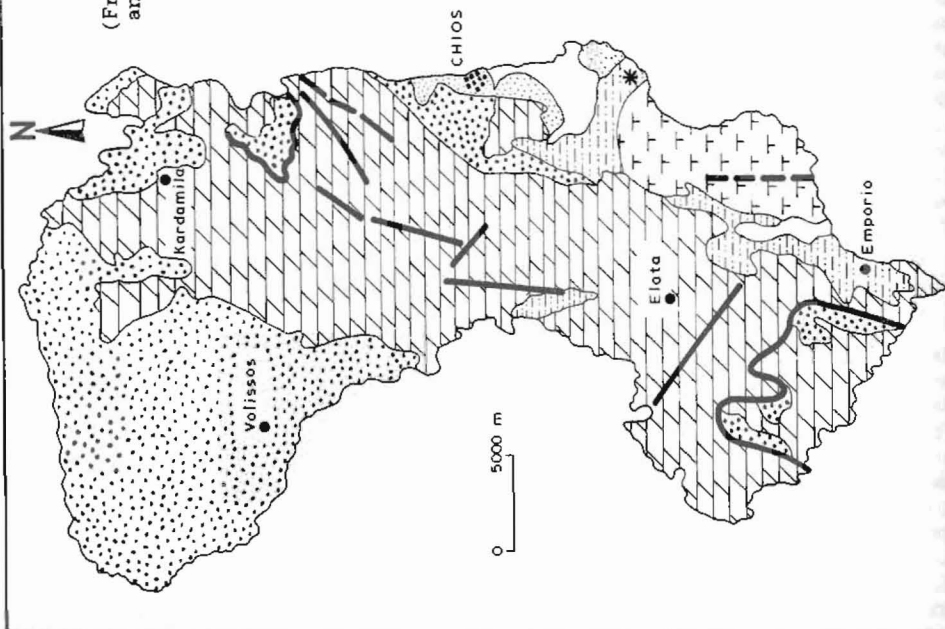
b) The Zyfia Formation is quite similar in colour and lithology to (a), but with intercalations of marls and clays.

c) The Keramaria Formation consisting of various lithologies, from sandstone to clay; several channel deposits with limited lateral extent can be observed. The main part of these deposits are obviously formed in a floodplain environment with sporadic water ponds. Remains of vertebrates are found only in this formation.









d) The Nenita Formation. This covers the southern part of

GEOLOGICAL MAP OF CHIOS ISLAND

(From the geological map of Greece (1:500.000) and Chios (1:50.000) edition I.G.M.E., with some modifications of the authors)



LEGEND

-  Holocene
-  Fresh-water limestones with intercalations of marls and clays. Upper Miocene-Pliocene.
-  Green sands, gravels and reddish-violet silts. Middle Miocene.
-  Brownish to reddish ferruginous sandstones. ? Lower-middle Miocene.
-  Dolomites and limestones. Mesozoic.
-  Clastic rocks, mainly greywackes with intercalations of conglomerates, shales and limestone lenses. Palaeozoic.
-  Faults
-  Fossiliferous site.

the Neogene basin. The sediments are an alternation of limestones and blue-green gray marls and clays. These deposits contain several lenticular intercalations of black (lignitic ?) clays with fresh water molluscs.

The time span covered by these four formations is thought to be from the late Oligocene or early Miocene to the Pliocene. This is based on the mammalian occurrences in the Keramaria Formation and on the molluscs studied by Schutt and Besenecker (1973). These deposits are often faulted, indicating an active tectonic regime in the area since their deposition. The dips measured in the vertebrate bearing horizons are about 12° S.

MAMMALIAN FAUNAS

The first mammals described by Paraskevaidis (1940) come from the Michalou clay pit, and were collected by workmen when they were digging in this quarry for clay to be used in the local tile factory. The German team later numbered nine fossiliferous localities (Rothausen, 1977) belonging to different stratigraphic horizons, but all in the Keramaria Formation. In the subsequent faunal list published by Melentis and Tobien (1960) by Tobien (1968, 1977, 1980) and by Lehmann and Tobien (in press) the origin of different mammalian taxa is not indicated. Therefore, by compilation of these faunal lists, the following species of large mammals have been found by the previous workers in and near this quarry; *Choerolophodon chioticus*, *Deinotherium bavaricum*, *Sanitherium leobense*, *Listriodon lockharti*, *Dorcatherium* aff. *crassum*, *Tragocerine* indet., *Eotragus* of *sansaniensis* aff. *Euprox furcatus*, cf. *Palaeomeryx eminens*, aff. *Turcocerus gracilis*, cf. *Caprotragoides potwaricus* and *Cazella stehlini*. Moreover, Tobien (1968) published a preliminary list of small mammals found in this quarry; *Cricetodon* sp. I (large) and II (small), *Megapedetes* sp., *Phiomidae* indet., *Prolagus* sp. and *Insectivora* indet. This mammalian assemblage was correlated with MN5 or MN6 (middle Miocene).

Our investigation in this quarry during 1991 allowed us to find mammalian remains in three different horizons which are situated from the bottom of the quarry at 22m (Loc. THA) at 29.30m (Loc. THB) and at 35m (Loc. THC). The two localities THA and THC include only micromammals while THB includes macromammals. Since most of the collected material is still under study the determinations are quite uncertain. Nevertheless the following species were found: *Choerolophodon chioticus*, *Lophocyon* sp., *Giraffokeryx* sp., *Sanitherium* sp., and *Hypsodontus* sp.

MAGNETOSTRATIGRAPHY

A) Sampling and measurements

A 46m-thick section with fresh outcrops was sampled for magnetostratigraphy. 32 horizons (sites) have been chosen among which 24 were drilled, while oriented hand samples were taken from the remaining 8 because of their fragility. The intervals between sites are irregular, according to the quality of the exposure and

the lithology which varies from sandstone to clay. Nevertheless the principal units have been sampled and our collection is representative of the section.

Cylindrical cores of standard volume have been obtained in the laboratory. All the paleomagnetic measurements were carried out at the Paleomagnetism laboratory of the "Institut de Physique du Globe" (Paris). A three-axis C.T.F. cryogenic magnetometer was used to measure the magnetic remanences. NRM intensities were in general strong with values ranging between 95 mA/m and 1mA/m.

B) Palaeomagnetic analyses.

After room temperature measurements of the NRM, at least one specimen from each core was chosen - minimum 3 specimens per site - for the demagnetization process. A total of 81 specimens have been demagnetized in steps from 100°C up to 650°C (15 steps with intervals of 30°-50°C). The low-field magnetic susceptibility was measured on pilot samples after each heating step, using a susceptibility bridge. The susceptibility shows no significant change up to 200°C. After this step a regular and progressive decrease is displayed by almost all samples except for site 5 where an increase is noticed. This appears to be linked to transformation of magnetic minerals due to heating (Fig.2a).

The stepwise acquisition of isothermal remanent magnetization (IRM) was performed on samples from different lithologies in order to identify the magnetic carriers. The IRM saturation curves show a general tendency corresponding to the presence of magnetite (Fig.3). Furthermore the presence of magnetite is also deduced from the demagnetization process as the intensity of the magnetization decreases significantly between 550° and 625°.

The thermal demagnetization and all additional measurements were performed in a nonmagnetic room.

We initially followed the evolution of remanence directions during demagnetization in order to check the critical changes related to temperature (Fig. 2c,d).

The different components of magnetization were determined by means of a computer program applied to the Zijdeveld plot for each sample. We noticed the presence of a strong secondary component with normal polarity and a direction close to the present - day field (Fig.2). As thermal demagnetization progresses, directions change from normal to inverse polarities. Practically all samples were partially remagnetized thus the need to exceed at least 300°C in order to reach the primary component. After 300°C we can distinguish two cases:

- i) Samples with a strong remanence, where a well defined primary component can be identified.
- ii) Samples with a weak remanence, where directions are rather fluctuating.

In order to define the declination and inclination angles of the primary components we have taken into account the evolution of the susceptibility, rejecting data points above the temperature at which susceptibility changes drastically.

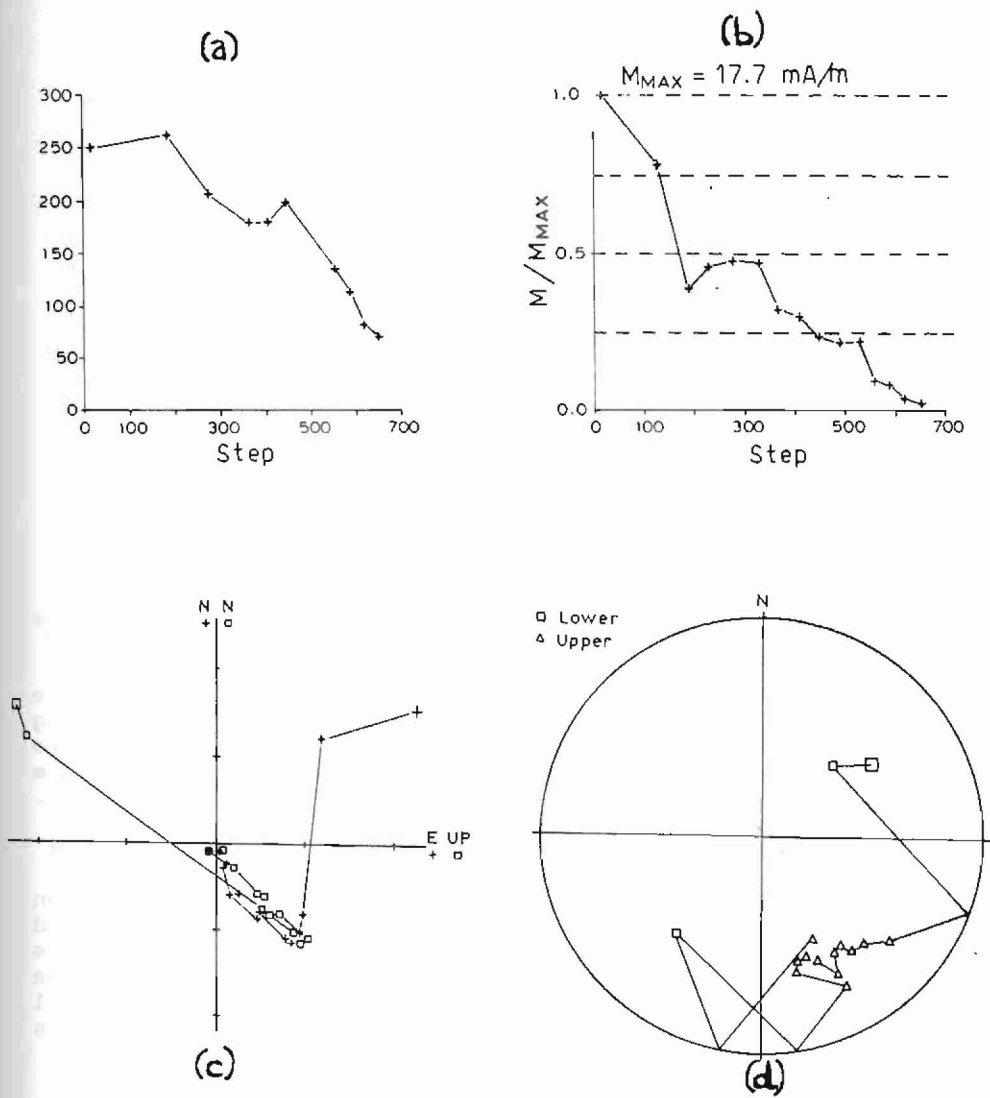


Fig. 2. Typical demagnetization diagrams during heating (a) evolution of susceptibility (b) normalized magnetization versus temperature (c), (d) Zijderveld and stereographic projections in stratigraphic coordinates.

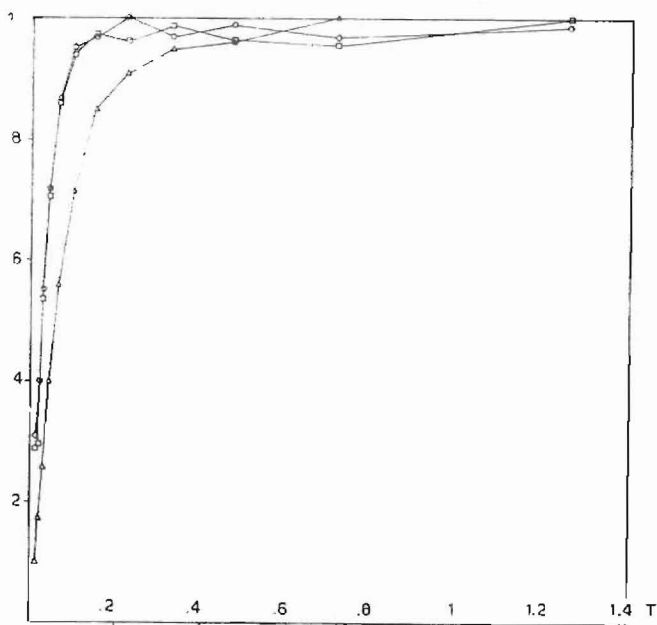


Fig. 3. Example of typical IRM acquisition curve indicating the presence of magnetite.

For about half the specimens we used a computer programme in order to define the best fit towards the origin. The remaining half (the low-stability samples) have yielded only indicative values and we considered as a characteristic magnetization the direction of one point. The selected D,I values appear in Fig.4.

C) Magnetostatic results.

The resulting magnetic stratigraphy of the Thymiana section is presented in Fig.5. which gives the declination and inclination for each sample plotted as a function of the stratigraphic position. We observe the presence of a long zone of reverse polarity interrupted by a short one of normal polarity, (about 3m thick) corresponding to site THY-3 which is preceded and followed by sites of intermediate polarities.

CONCLUSIONS

The quality of the sampled sediments turns out to be quite adequate for paleomagnetic study. The section is dominated by a long reverse zone interrupted by a short normal one. These results are not easy to correlate with the scale of inversions for Miocene. Nevertheless, the presence of the reverse zone and the biostratigraphic age given by mammals allow us for the moment to suggest a possible correlation either with CHRON 5B Reverse

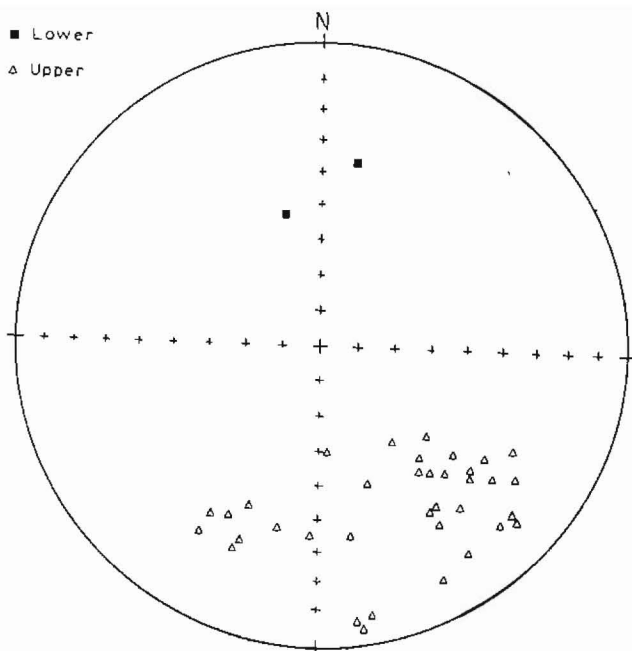


Fig.4. Selected D,I values for the calculation of mean direction.

or with CHRON 5C Reverse. This corresponds to possible ages either between 16.2 and 15.0 Ma or between 17.6-16.9 Ma. In 1993 we plan to continue the sampling towards the upper part of the section with the hope of finding zones with different successive polarities.

Our results have also been examined from a different point of view in order to attribute to them a possible geotectonic significance. After selecting the 40 specimens which gave the best results we calculated their mean direction (Fig.4). The mean declination $D=156^{\circ}\pm 5^{\circ}$ indicates a clear counterclockwise rotation of about 25° since the Early-Middle Miocene.

This is the first time that such a counterclockwise rotation has been obtained for the Eastern part of Aegean, though many tectonic models have been predicting one. (Kissel and Laj, 1988; Sonder and England, 1989; Jackson et al., 1992). The observation of a similar rotation in the lavas of Chios as well as its implications are discussed in a separate paper (Kondopoulou et al., this volume).

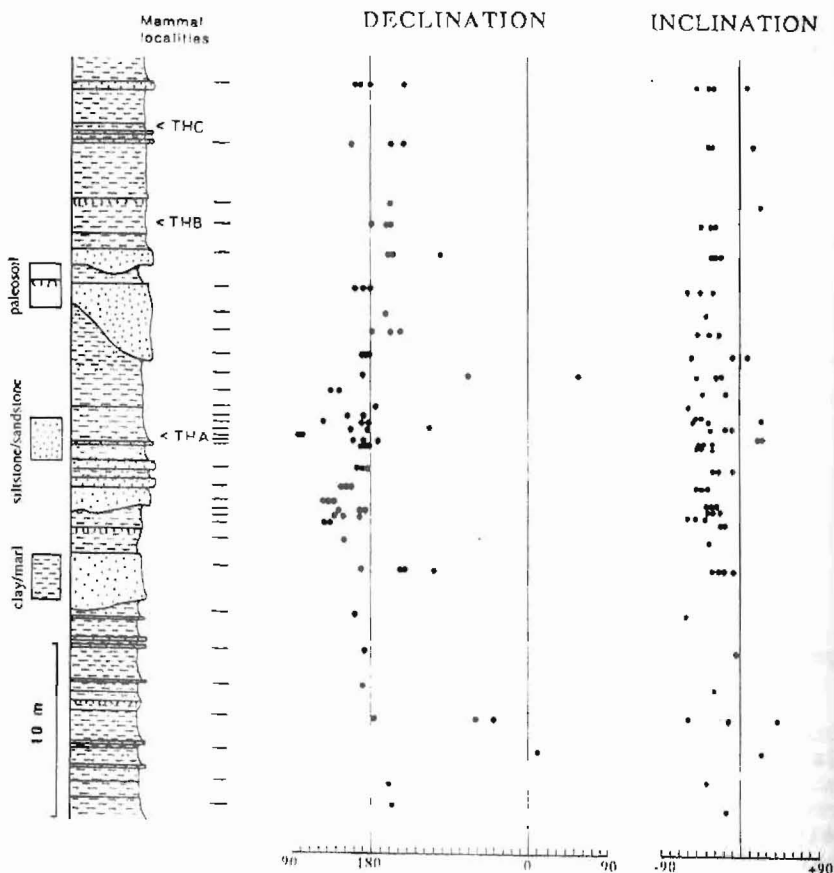


Fig. 5. Declination and inclination of the primary magnetization for the studied section. The mammal bearing horizons THA, THB, THC are indicated. Small bars correspond to the levels sampled for paleomagnetism.

ACKNOWLEDGEMENTS

We feel indebted to the owner of the investigated area Mr. Michalos and his lawyer Mr. Misovoulos who kindly provided their permission for excavating the section. Dr. P. Voidomatis is also acknowledged for efficient help in the field. The majority of the experimental work was performed in Paris (IPG) and we thank Prof. V. Courtillot for providing laboratory facilities. This work was supported by the Aristotle University of Thessaloniki, the National Research Foundation (E.I.E.) of Greece and the French C.N.R.S.

REFERENCES

- Besenecker, H., (1973). Neogen und Quartar der Insel Chios (Agais). Diss. thesis, 196pp.
- Jackson, J., Haines, J., and Holt, W., (1992). The Horizontal velocity field in the deforming Aegean sea region determined from the Moment Tensor of Earthquakes. *J. of Geoph. Res.* 97, B12, pp. 17657-17684.
- Kilias, A., (1982). Kleintektonische Untersuchungen im nordlich Teil der Insel Chios. *Sci. Ann. Fac. Phys. Math. Univ. Thessaloniki* 22:3-20.
- Kissel, C. and Laj, C., (1988). The tertiary geodynamical evolution of the Aegean arc: a paleomagnetic reconstruction. *Tectonophysics*, 146, 183-201.
- Lehmann, U. and Tobien, H., (1993). Artiodactyle fossilien (Mammalia) aus dem Miozan van Thymiana, Chios. *Ann. Geol. Pays Hell.* (in press).
- Melentis, J. and Tobien, H., (1967). Palaontologische Ausgrabungen auf der Insel Chios (eine vorlaufige Mitteilung). *Prakt. Akad. Athen*, 42: 147-152.
- Paraskevaïdis, J., (1940). Eine obermiozane Fauna von Chios. *N. Jb. Min. Geol. Palaont.*, 83:363-442.
- Rothausen, K., (1977). Die mittelmiozanen Wirbeltierfundstellen sudlich Thymiana (Insel Chios, Agais, Griechenland) 2. Teil: Geologie: Die Fundstellen und ihre Abfolge. *Ann. Geol. Pays Hellen*, 28:495-515.
- Schutt, H. and Besenecker, H., (1973). Eine Molluskenfauna aus dem Neogen von Chios (Agais) *Arch. Moll.*, 13:1-29.
- Sonder, L., and England, P., (1989). Effects of a Temperature-Dependent Rheology on Large-Scale continental extension. *J. of Geoph. Res.* 94, B6, pp. 7603-7619.
- Tobien, H., (1968). Palaontologische Ausgrabungen nach jungtertiaren Wirbeltieren auf der Insel Chios (Griechenland) und bei Maragheh (NW-Iran). *Soud. Jahrb. Vereinigung "Freunde der Universitat Mainz"*, 51-58.
- Tobien, H., (1977). Die Mittelmiozanen Wirbeltierfundstellen sudlich Thymiana (Insel Chios, Agais, Griechenland). *Ann. Geol. Pays Hell.*, 28:489-494.
- Tobien, H., (1980). A note on the skull and mandible of a new choerolophodont mastodon (Proboscidea, Mammalia) from the middle Miocene of Chios (Aegean sea, Greece). In: "Aspects of Vertebrate History: Essays in Honor of Edwin Harris" (ed. L.L. Jacobs). Flaystaff, Arizona, 299-307.