Δελτίο Ελληνικής Γεωλογικής Εταιρίας τομ. XXX/5, 89-96, 1994
Πρακτικά 7ου Επιστημονικού Συνεδρίου, Θεσσαλονίκη, Μάιος 1994
Bulletin of the Geological Society of Greece vol. XXX/5, 89-96, 1994
Proceedings of the 7th Congress, Thessaloniki, May 1994

PRELIMINARY ACCOUNTS OF A TECTONOMAGNETIC EXPERIMENT IN EAST - CENTRAL GREECE

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ABSTRACT

This paper presents the preliminary results of a tectonomagnetic experiment in the broader area of Aghialos (Eastern-Central Greece) as part of a multidisciplinary earthquake prediction program. The applicability of the tectonomagnetic phenomenon related to earthquake energy release is the main target of this experiment at this initial phase. A network of 10 total field magnetic stations, distributed along the almost E-W trending fault system, was established in the area and remeasured few time since 1992. Simultaneous data recording was performed at the base and at the other stations of the network, and magnetic differences were then possible to be established. A pattern of significant amplitude of magnetic differences was observed at the western part of the network, ranging between 20-180 nT, decreasing gradually to the east, where the magnetic differences attain negative values of about -15 nT. The strong amplitude of the observed magnetic change at the western distribution of the stations should rather be attributed to the abundant ophiolite outcrops, which are expected to be connected at depth. It is difficult to interpret these magnetic field changes in terms of the seismomagnetic effect and make any other assessment related to earthquake prediction phenomena, without longer period observations and detailed consideration of the local seismicity pattern, which is at a very low level in the present stage.

INTRODUCTION

A possible relationship between a large magnitude earthquake and a local geomagnetic change in the epicentral area of a seismogenic zone has long been one of the important problems in solid geophysics (Nagata, 1972). Recently interesting accounts on this subject were outlined: In Japan, the detection of a 5 nT precursory and coseismic event was reported (Rikitake, 1968). In California, several magnetic anomalies, which may be related to precursory seismic events have been observed (Mueller et al.,1980). A possible interpretation of these observations is that perturbations of the stress field in the epicentral region may produce detectable variations in the magnetization of rocks prior to and during the seismic event. In fact, existing laboratory data show that magnetic susceptibility and remnant magnetization exhibit a pronounced stress dependence.

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In our study area, it seems appropriate to apply the experimental procedures for the detection of magnetic field changes related to precursory seismic phenomena in a region where active tectonics exist and produce large magnitude earthquakes. Besides the existence of ophiolitic exposures, which usually exhibit strong intensity of magnetization, is favorable for detailed study and application of seismomagnetic experiments.

BRIEF GEOTECTONIC ACCOUNT

Most of the study area is covered by Holocene alluvial deposits and clays of Pleistocene age. However, the most interesting feature is the ophiolitic exposures (Fig. 1), the presence of which play an important role in the applied experiment, enhancing the signal of the seismomagnetic effect. Two theories have been outlined related to the origin of the ophiolites. One theory considers the ophiolithic mass of the Pelagonian zone as autochthonous (Brunn, 1961). However, more recent aspects adopt the idea that the Pelagonic ophiolites are allochthonous; they have been transported from the east, from the Axios Zone (Mercier, 1975; Vergely, 1976), and have been deposited over the pre-Cretaceous basement of the Pelagonic or even the "sub-Pelagonic" Zone more to the west. The overthrusting of the ophiolites took place during the Upper Jurassic.

The ophiolitic mass is subsequently covered by the Middle-Upper Cretaceous

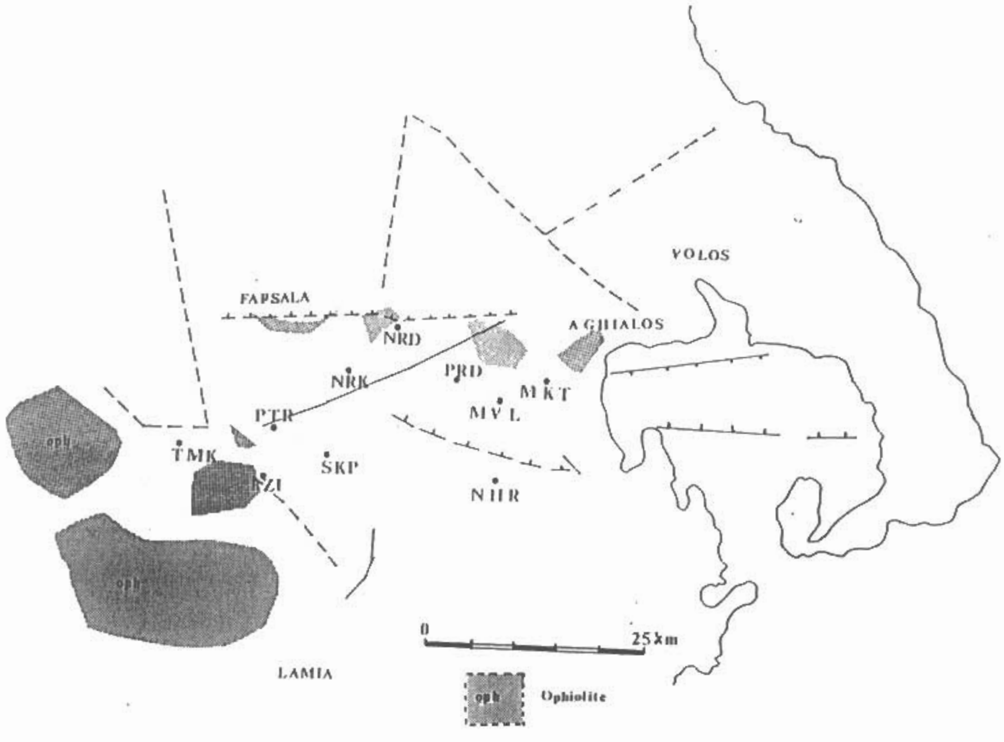


Fig. 1: Distribution of the total field magnetometric station in the broader area of Aghialos, together with the main faults and outcrops of ophiolites.

sediments. The schist-chert formations (radiolarites, sandstones, pelites with white limestone lenses and enclosed ophiolitic bodies) of Lower Cretaceous, take the form of tectonic melange and underlie the ophiolitic cover. Finally, the flysch of the Pelagonic Zone occurs at a few places (Mountrakis, 1983).

Three main tectonic phases characterize the study area (Caputo & Pavlides, (1991):

(i) A compressional one with ENE-WSW directional stress, which was active during the Middle Miocene, (ii) A Late Miocene - Pliocene tensional one, acting in a NE-SW direction, which reactivated the latest Alpine structures of a NW-SE direction, and (iii) An active Middle Pleistocene - Holocene tensional one, having an almost N-S direction, which created recent faults of almost E-W direction. These E-W directional active faults seem to attract the interest of the present research.

DATA AQUISITION

A network of 10 permanent total field magnetometric stations was installed in the broader area of Aghialos, in August 1992. The distribution of the stations, together with the main faulting features, can be seen in figure 1. The main seismogenic faults have approximately an E-W direction. The stations have been distributed on both sides of the fault system, covering thus the whole of the study area.

An aluminum pole of about two meter length inserted vertically in a permanent construction into the ground. The sensor of the magnetometer was firmly placed in a wooden base on top of the pole. In this manner, the sensor is always at a standard height above the ground, and orientation with respect the N-S direction, for all recordings of the magnetic field, and all periods of the remeasurement of the network. The station at Neochoraki was permanently chosen to be the station, that is all other station values are referred to for the formation of the magnetic differences. This is mainly because it is a few kilometers away from the faults of the study area, it is located on the flysch of Pelagonic zone (which is not generally magnetic), and it seems to be characterized by a low anthropogenic noise.

The recording of the geomagnetic field was taking place simultaneously at Neochoraki and at two or three other stations of the network, depending on the number of magnetometers, which were available during each remeasurement. The recording was preferably taking place during the night period to avoid the day-time variations of the geomagnetic field and the probable industrial interference. The type of the instruments used is the total field magnetometer manufactured by GEOMETRICS, model G-856 with digital memory, storage and clock. The digital clocks of the magnetometers were set up to be perfectly synchronized and were tested before they start recording in order to succeed simultaneous recording at a 30 or 60 seconds time interval. The remeasurement of the network was planned to take place every 3-4 months, approximately .

DATA ANALYSIS

The geomagnetic field at any point of the Earth's surface is the sum of (i) the Earth's magnetic field, (ii) the effects of the remnant magnetization, (iii) the magnetic field arising directly from the magnetizing susceptibility of the rocks, (iv) the effects of magnetic field generated by ionospheric and magnetospheric currents, (v) the effects of magnetic fields generated by telluric currents, and (vi) anthropogenic magnetic fields arising from industrial activity. Tectonomagnetic signals are expected to be due to changes by the effects of remnant magnetization and by the magnetic susceptibility of the rocks. All the other effects should be considered as not being related to the seismomagnetic effect and therefore should be removed.

The most straightforward method to remove these non-related effects is to make differential measurements of the geomagnetic field between two locations on the surface separated by a few kilometers. The base must be few kilometers away from the fault in order to avoid magnetic influence due to the crustal stress changes. The differential measurements of the geomagnetic field is calculated (Lagios et al., 1989) as:

$$\delta B_{bs}(t) = B_b(t) - B_s(t),$$

where $B_b(t)$ and $B_s(t)$ are the total field magnetic measurements at sites b (base-station) and s (station), respectively. Then the detection of any possible seismomagnetic effect is based on the evolution of B_bs with time. The method of simple differences of total geomagnetic field between base and station reduce the magnetic disturbances about 95% (Davis et al., 1981). The remaining 5% of the natural magnetic disturbance is due to electromagnetic induction which, being dependent on the subsurface conductivity distribution, is generally dissimilar between any two locations and therefore out of phase.

We can introduce a further degree of improvement to our results by minimizing the random fluctuations generated by instrumental electronic noise and high localized electromagnetic induction effects by applying various smoothing techniques. Such an attempt applied here was the removal of a linear trend, and then the application of a Fast Furrier Transform to low-pass filter data. The linear trend is reinserted in the original data set of the procedure (Press et al., 1986). The recordings of the Magnetic station at Pendeli were used in order to have an indication of the probable existence of magnetic storms or other magnetic phenomena which might be able to influence the measurements in our network.

Anthropogenic noise can be a serious problem because of its irregular characteristics. In order to minimize the probability of registering industrial noise we have carefully chosen the stations away from inhabited areas and industrial activity. This is the reason for recording data only during the night period.

RESULTS - DISCUSSION

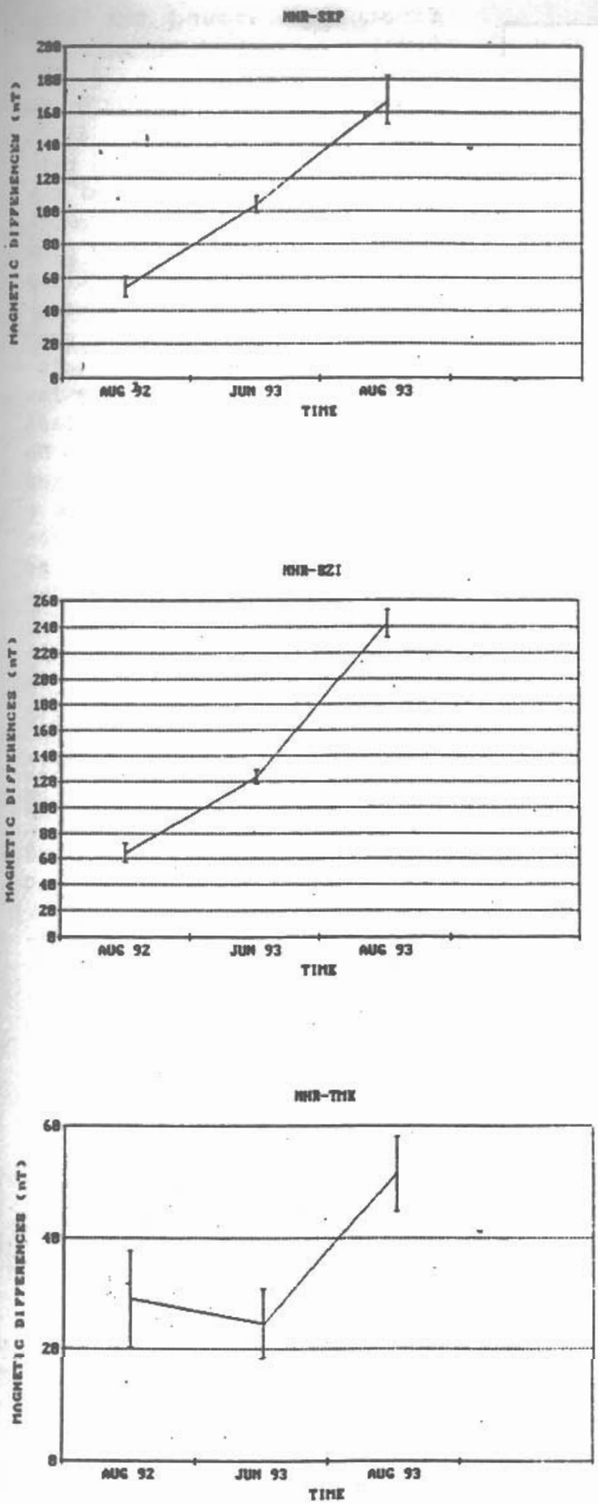
The simultaneous recording at the base station and at other stations of the network resulted in magnetic differences with respect to Neochoraki (base), having estimated accuracies shown in Table 1. It can be seen that relatively low standard deviation values of the magnetic differences were achieved, ranging from 1-5 nT for most of the stations. There were, however, three stations, BZI, MVR, SKP, which exhibited standard deviation values greater than 10 nT. This phenomenon, which is not generally desirable, does not systematically happen, but only once for each station.

Considerable magnetic differences, well

Table 1: Magnetic differences* between base (Neochoraki) and station.

STATION		1992	1993	
CODE	**NAME**	AUG	JUNE	AUG
TMK	THAVMAKO	28.90±8.7	24.6±6.2	51.5±6.7
BZI	BOUZI	64.69±7.3	123.3±5.5	242.6±10.4
PTR	PETROTO	-	47.2±0.5	28.9±4.2
SKP	SKOPIA	54.30±6.1	104.5±4.9	167.2±14.6
NRK	NARTHAKI	-316.20±6.3	-274.7±5.0	-278.0±7.3
NRD	NERAIDA	-200.10±2.7	-189.1±1.9	-192.6±1.0
PRD	PERDIKA	-135.00±2.4	-119.8±1.0	-151.4±3.2
MKT	MIKROTHIVA	-101.86±4.0	-98.4±4.8	-106.9±3.3
MVR	MAVROLOFOS	-73.30±25.9	-77.5±4.9	-77.6±3.1

(*)ExpressedinnT(± standard deviation).

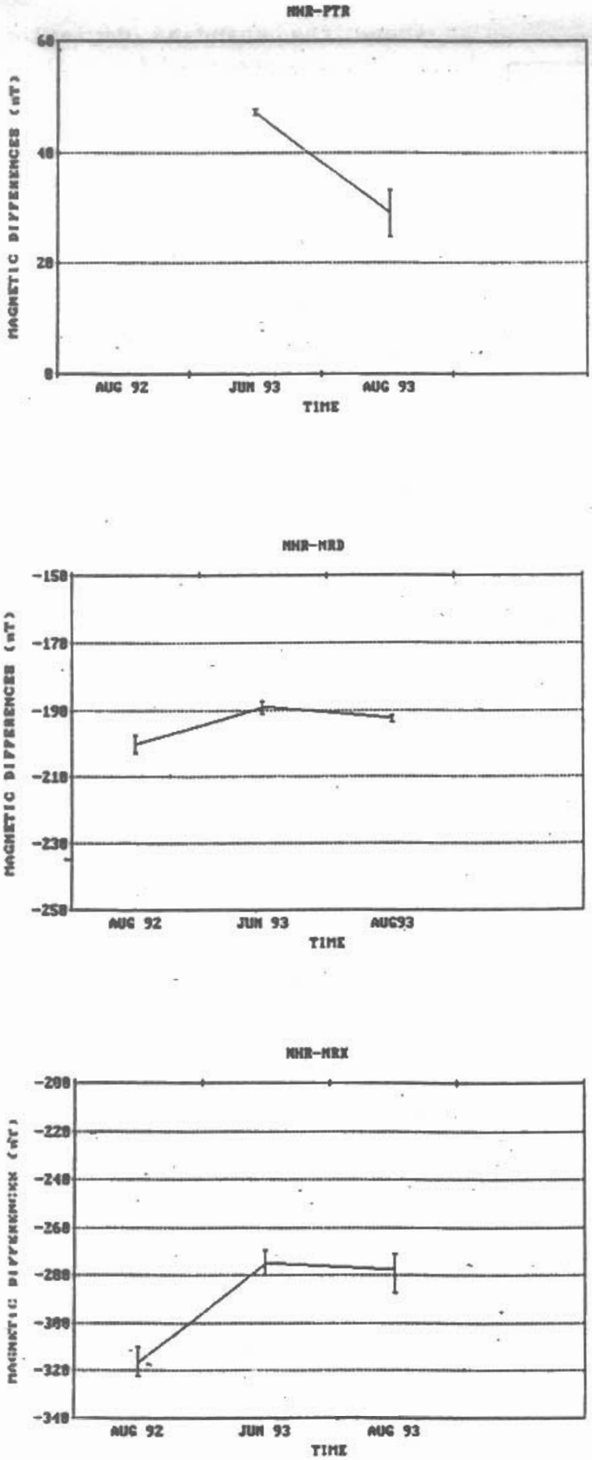


above the standard deviation level, are observed for most of the stations. The most significant changes take place at the western part of the network. Bouzi (BZI), Skopia (SKP), Narthaki (NRK) and Thavmako (TMK) show a differential magnetic change of about 180, 110, 35 and 20 nT, respectively, for the period August 1992 to August 1993. This is a positive magnetic difference, which is an order of magnitude larger than the estimated standard deviation level.

Stations at the eastern part of the network do not show differences of such a high amplitude for the same time period. Perdika (PRD), Microthiva (MKT), Mavrolofos (MVL) and Neraida (NRD) exhibit almost a negligible change. It is also noticed that the high amplitude magnetic changes observed at the western part of the network, gradually decline eastwards attaining non-significant values at the eastern part.

Time variation diagrams of the observed magnetic differences to show the actual change between 1992 and 1993, were made and are presented in figures 2, 3 and 4. The two stations Skopia (SKP) and Bouzi (BZI), which show the largest amplitude of magnetic change, present a steady positive increase, while Narthaki (NRK) and Thavmako (TMK) show a step-like positive change. The rest of the stations present a picture, which approximately

Fig 2: Variation of the total field magnetic differences at stations Skopia (SKP), Bouzi (BZI) and Thavmako (TMK).



fluctuates around the same level.

It is rather difficult to interpret these magnetic field changes registered by the network. Longer time period observations are required in order to establish a clearer picture of longer term variations of the magnetic field, associated with the seismic energy released in the area. The seismic activity was at a very low level during the first and last measurement of the network. No large magnitude earthquakes took place in the area. As a consequence, taking into account the low level of the seismicity picture and the relatively short time of observing the local magnetic field (approximately one year), it is not possible to confidently express views about the observed large amplitude magnetic differences particularly at the western part of the network.

It is very much interesting though to continue the remeasurements of the network, closely examine the local seismic events, and correlate their epicenters and time of occurrence with distinct patterns of observed magnetic differences probably registered by the magnetic network.

REFERENCES

BRUNN, J.H. (1960). Les zones Helleniques internes et leur extension. Reflexions sur l'orogenese alpine. Bull. Soc. geol. France, (7), 11, 470-486.

Fig. 3: Variation of the total field magnetic differences a stations Petroto (PTR), Neraida (NRD) and Narthaki (NRK).

CAPUTO, R. and PAVLIDES, S. (1991). Neotectonic structure and evolution of Thessaly. Bull. Hellen. Geol. Soc., XXV/3, 119-133 (in greek).

DAVIS, P.M., JACKSON, D.D., SEARLS, C.A. and MCPHERRON, R.L. (1981). Detection of tectonomagnetic events using multi-channel predictive filtering. J. Geophys. Res., 86, 1731-1737.

LAGIOS, E., TZANIS, A., CHAILAS, S. and WYSS, M. (1989). Surveillance of Thera volcano, Greece : Monitoring of the geomagnetic field. Proc. "Thera and the Aegean World III", Volume 2, 207-215.

MERCIER, J. (1966). Etude geologique les zones intermes des Helleniques en Macedoine centrale. Contribution a l' etude du metamorphisme et de l' evolution magmatique de zones internes des Hellenides. Ann. Geol. des pays Hell., (20).

MOUNTRAKIS, D. (1983). Lectures in the Geology of Greece. Public. Aristoteles University of Thessaloniki, 140 p. (in greek).

MUELLER, R.J., JOHNSTON, M.J.S., SMITH, S.E. and KELLER, V. (1980). U.S. Geological survey magnetometer network and measurement techniques in western U.S.A. Open-file report No. 81-1346, Menlo Park, Cali-

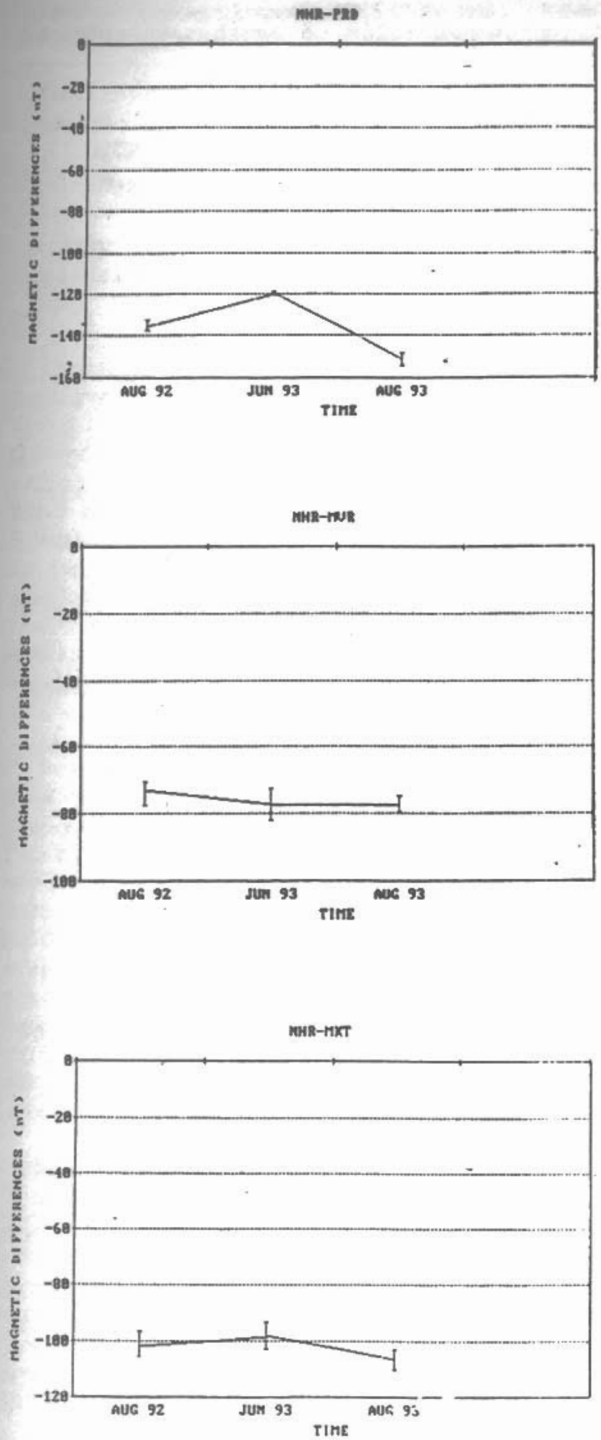


Fig. 4: Variation of the total field magnetic differences at stations Perdika (PRD), Mavrolofos (MVR) and Mikrothiva (MKT).

fornia.
NAGATA, T. (1972). Application of tectonomagnetism to earthquake phenomena. Tectonophysics, 14(3/4): 263-271
PRESS, H.W., FLANNER, B.P., TEUKOLSKY, S.A. and VETTERLING, W.T. (1986). Numerical recipes: The art of scientific computing. Cambridge University Press.
RIKITAKE, T. (1968). Geomagnetism and earthquake prediction. Tectonophysics, 6, 59.
VERGELY, P. (1976). Chevachement vers l' Ouest et retrocharriage vers l' Est des Ophiolites: deux phases tectoniques au cours du Jurassique superieur - Eocretace dans les Hellenides internes. Bull. Soc. geol. France (7) XVIII, No 2. p. 231.