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SOME CONSTRAINTS ON THE ORIGIN AND TIMING OF MAGNETIZATION FOR MIO - PLIOCENE SEDIMENTS FROM NORTHERN GREECE

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ABSTRACT

Detailed paleomagnetic and rock magnetic studies were undertaken in the Late Miocene and Pliocene sediments from Northern Greece in order to constrain the origin and the possible age of the magnetization. A fold test applied to a group of sites suggests that the magnetization is slightly younger than the tilting. Magnetic properties indicate that in some of the best sites the minerals are unstable above 350°C. The maturation of the underlaying lignite levels could favour formation of sulphides but their presence has not been detected in the thermomagnetic curves.

A second group of sites displays more stable magnetic properties whereas in exposed outcrops the initial characteristic remanent magnetization has been lost.

The reliable mean directions are compared to previously obtained ones in lavas and sediments of neighbouring areas and an attempt is made to better constrain the space distribution of the recent clockwise rotation of Western and Northern Greece.

INTRODUCTION

In the last decade, several paleomagnetic studies have shown that important clockwise rotations occured in Western Greece during the Upper Tertiary (Laj et al.,1982;Horner and Freeman,1983; Kissel et al., 1985). Other studies (Kondopoulou, 1982; Kondopoulou and Lauer,1984;Kissel et al.,1986,a,b; Kondopoulou and Westphal,1986;Kissel and Laj, 1988; Pavlides et al.,1988; Atzemoglou et al., 1994) demonstrated that these rotations are not limited to the external parts of the Dinaric-Hellenic belt, but are also found in more internal parts (North Aegean, Serbomacedonian zone, Rhodope massif).

In 1988, 1989, 1990 several formations of Mesozoic and Cenozoic age were sampled in North-West and North-Central Greece by a French-Greek team, in order to complete this pattern. The preliminary paleomagnetic and magnetostratigraphic study of the Mio-Pliocene sediments from this area showed that several sites had very scattered directions of magnetization whereas others displayed a stable characteristic component either almost North-South or with a clear NE direction (Kondopoulou et al., 1990;Westphal et al., 1991). Additionally the fold test of McElhinny (1964) suggested a possible post-tilt age for the characteristic magnetization,but this suggestion needed further confirmation.

In the present study a number of stability tests as well as a detailed

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investigation of their magnetic properties have been performed on these sediments in an attempt to improve our understanding of the origin of the magnetization and its reliability. The objective of this detailed analysis is to determine whether or not and to what extent the internal parts of the Aegean had the same rotational behaviour as the external parts, as previously stated (Westphal et al., 1991).

GEOLOGY AND SAMPLING

The study area extends approximately from 21,5°E to 23,5°E and from 40,4°N to 41,1°N and comprises three different geotectonic units : the Pelagonian, Vardar and Serbomacedonian zones from West to East.

The formations sampled were (Fig. 1) :

A: continental deposits of Upper Miocene age in the Pelagonian zone (Ptolemais region)

B: continental deposits of Pliocene age in the Serbomacedonian zone (Chalkidiki region)

C: continental deposits of Late Miocene age in the Vardar zone (Lower Axios Valley).

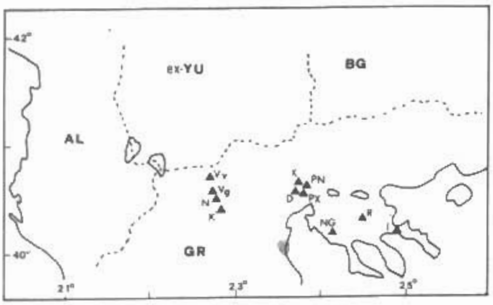


Fig.1: Position of the sampling localities in northern Greece (triangles).AL: Albania,BG: Bulgaria,GR: Greece,YU: ex Yugoslavia,Vv: Vevi,Vg: Vegora,N: Neapolis,K: Kariochori,NG: Nea Gonia,R: Riza,I: Ierissos,X: Xirochori,D: Dytiko,PX: Prochoma,PN: Pentalofos.

A. The Neogene-Quaternary sediments which fill the Ptolemais basin overlie unconformably both the Paleozoic basement and Mesozoic crystalline limestones. They can be divided into three lithostratigraphic formations (Pavlides,1985 and references therein):

a) The lowest formation(Vegora) consists of basal conglomerates which pass transitionally upwards to green-blue marls, sands and clays containing old lignite beds. The age is considered as late Miocene-Early Pliocene.

b) The middle formation (Ptolemais) contains alternating beds of clays,marls,sands and lacustrine calcareous marls. The formation is of lacustrine or fluvial origin and is Early Pliocene (4.5-4.0 Ma) for the lower part and Late Pliocene for the middle part,according to mammal and pollen occurrences.

c) The third formation consists of fluvioterrestrial conglomerates, lateral fans, alluvial deposits.An important member is the lower one of Villafranchian age.

Paleomagnetic samples were taken mainly from the two first formations.

B. In Chalkidiki, the red beds of Riza belong to the Gerakarou formation of the Mygdonia (Langadas and Volvi lakes) system of recent sediments. These sediments (conglomerates, pebbles, sands) have been created along the southern side of the pre-Mygdonian system of lakes during late Pliocene and early Pleistocene (4.0-1.0 Ma). The Gerakarou formation is mainly of late Pliocene age, but recent mammalian discoveries determined the uppermost beds of the formation to be of early Pleistocene age. In comparison with other members, this sandy limestone may be of Biharian age (1.0-0.7 Ma). Red beds and sandy limestones are affected by the youngest extensional deformation of the region which is still active (Syrides,1989 and references therein).

C. The late Miocene deposits of the Lower Axios Valley are known for their richness in mammals since the beginning of the century (Arambourg and Piveteau,1929). They can be divided into three formations (de Bonis et al.,1988; Koufos,1990; de Bonis et al.,1991).

- Nea Messimvria mammal zone (MN 10), consisting of red-beds, rich in sand and gravels (localities PNT and XIR)
- Vathylakos (MN 10-11),consisting of light coloured sediments, usually marls and sands (locality PXM)
- Dytiko formation (MN 13), also of light coloured sediments, usually sands, marls and limestones (locality DTK).

Samples were cored directly in the field either in very fresh outcrops from active quarries, or in road cuts and water streams still fresh, but exposed for a longer time. Samples were spread over several tens of meters in each site (Table 1).

Table 1: Paleomagnetic sampling sites

name	age	number of sites	samples	lat (N°)	long (E°)
Pelagonian zone (Ptolemais)					
Neapolis	Pleisto/Plioc.	4	21	40.65	21.70
Kariochori	Up. Pliocene	1	11	40.55	21.75
Vevi	Up. Mioc.- L. Plio.	2	32	40.80	21.60
Vegora	Up. Mioc.- L. Plio.	3	39	40.70	21.70
Serbomacedonian zone (Chalkidiki)					
Riza	Villafranchian	2	11	40.50	23.45
Ierissos	Upper Pliocene	1	6	40.40	23.90
Nea Gonia	Ruscinian	2	16	40.35	23.10
Axios zone *					
Prochoma	Turolian	8	34	40.75	22.85
Dytiko	L. Turolian	8	30	40.75	22.85
Xirochori	L. Valesian	7	28	40.75	22.85
Pentalofos	L. Valesian	3	10	40.75	22.85

* The Axios zone localities have been used for a magnetostratigraphic study, thus sites refer to different beds.

PALEOMAGNETIC MEASUREMENTS AND RESULTS

The natural remanent magnetization was measured with a modified Digico spinner with a root mean square noise level equivalent to 0.03 mA/m (I.P.G.,Strasbourg) or with a Molspin magnetometer with a noise level equivelant to 0.1 mA/m(Univ. of Thessaloniki).In a few cases where the NRM was low a CTF cryogenic magnetometer was used (I.P.G.,Paris)

A pilot AF demagnetization on some samples was effective only in a few cases, so the majority of the specimens were thermally demagnetized by stepwise heatings and the Zijderveld diagrams were analysed by a least square method in order to determine the principal components. The results are shown in Table 2 and are summarized here:

For areas A and B,normal and reversed directions are displayed (Figs. 2 and 4). The samples contain one,two or even three components:

i) A first soft component is often present and was eliminated at 180°-200°C.This component, with a high positive inclination is, at least partly, of viscous origin and its direction is close to the direction of the present field (Fig. 2).

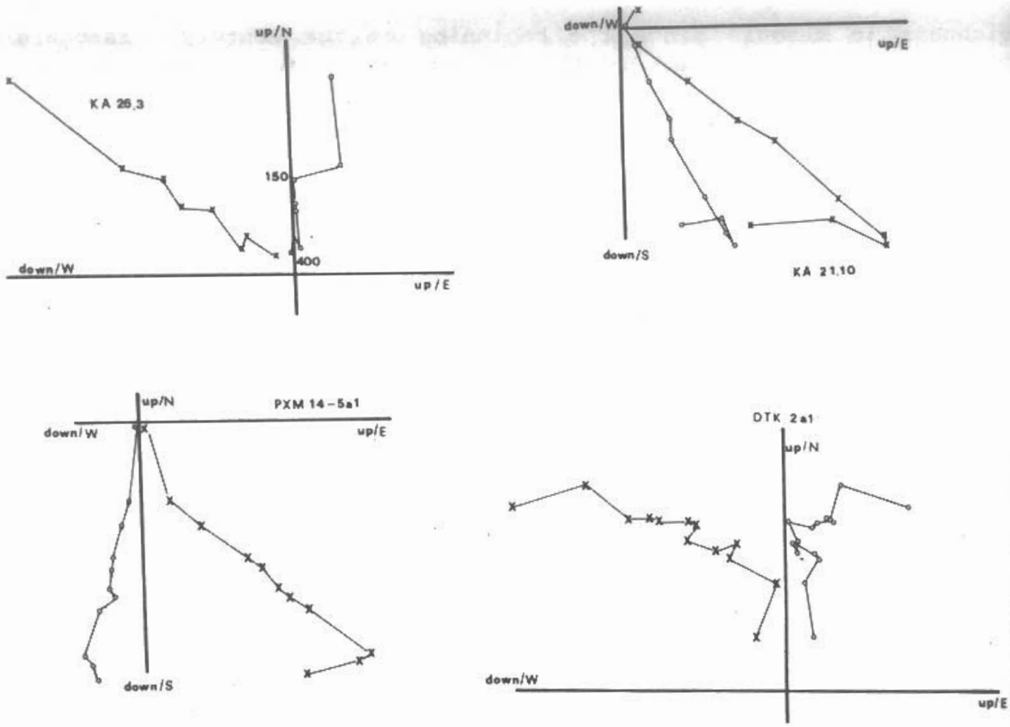
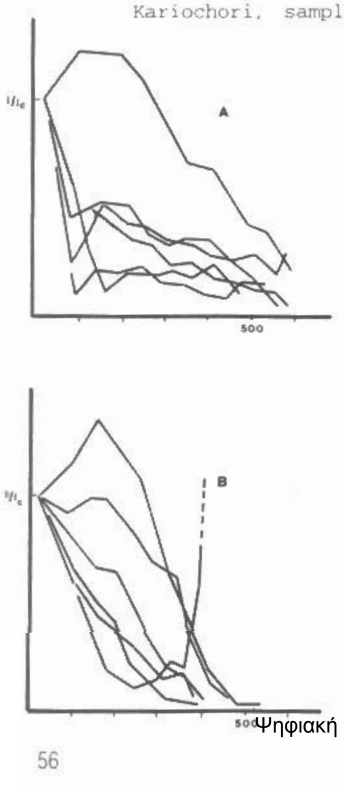


Fig.2: Example of thermal demagnetization.Circles: horizontal plane,triangles: north - south vertical plane.Sample KA 26.3 comes from Vegora, KA 23.2 from Kariochori, sample PXM 2.1b from Prochoma and sample DTK . from Dytiko.



ii) A second component was eliminated at higher temperatures.A clear difference appears between the samples coming from Vegora and Vevi quarries and the other sections (Kariochori, Neapolis, Riza). This component was destroyed at about 350°-400°C for the samples coming from the quarries (Fig.3)whereas at higher temperatures strong modifications occured: colour changes, sharp increase of the remaining magnetization and of the susceptibility. The magnetization directions were well grouped. Samples from the other sections showed blocking temperatures above 500°C,but the characteristic magnetizations were more scattered (Fig.4I,4II).

The four localities of area C were sampled for the purpose of a magnetostratigraphic study.Unfortunately only one of them (PXM) yielded a clear polarity succesion which, in combination with biostratigraphic data,

Fig.3: Relative variation of the intensity of the NRM *during thermal demagnetization.* A:samples from Riza,Kariochori,Neapolis.B : samples from Vevi and Vegora.

Table 2: Paleomagnetic results

site	N	D	I	k	a_{95}	tilt	D+	I+	Ref.
low temperature components:									
Riza	12	26	65	11	13				*2
Neapolis	16	351	83	31	7				*2
Vevi21	7	261	72	23	13				*2
Kariochori	8	1	68	44	8				*2
Prochoma	11	349	63	27	9				*3
Dytiko	6	357	28	12	19				*3
medium and high temperature components :									
Neapolis	18	191	-48	4	18	245/15	184	-35	2
Vevi21	7	176	-51	13	17	340/20	195	-42	*2
Vevi55	14	171	-70	86	4	25/15	217	-73	*2
Vegora26	13	20	49	25	8	215/8	12	46	*2
Vegora27	6	353	58	122	6	225/10	345	50	*2
Vegora54	5	346	48	39	12	230/12	341	37	*2
Kariochori	6	247	-60	4	34	0/0	247	-60	2
Ierissos	5	212	-17	6	38	0/0	212	-17	*2
Riza	7	195	-45	61	8	0/0	195	-45	*2
Nea Gonia	4	217	18	9	32	0/0	217	18	2
Prochoma	15	23	46	16	10	0/0	23	46	*1
Dytiko	9	18	36	10	17	0/0	13	36	*3
Xirochori	6	16	67	9	22	0/0	16	67	3
Pentalofos	6	21	35	8	24	0/0	21	35	3

N : number of samples used, D,I :declination and inclination before tilt correction, k,a_{95} : Fisher statistical parameters,D+, I+ : declination and inclination tilt corrected.Reliable results with k > 10 are starred.

1. Kondopoulou et al., 1990.
2. Westphal et al., 1991.
3. Present study.

Mean directions : (N=sites)

	N	D	I	k	a_{95}	tilt	D+	I+	Ref.
A+B areas	6	1	54	42	10		4	50	*2
C area	4	20	46	30	17		20	46	*3

allowed us to attribute to this locality an age of 8.9 Ma (Kondopoulou et al., 1990).

Nevertheless in all four localities the separation of components was successful in the majority of the cases and mean directions have been calculated (reliable for PXM and DTK and indicative for XIR and PNT,see Table 2).

The following components have been distinguished :

i) A first soft component is eliminated between room temperature and 150°C - 200°C or between 0 and 20 mT.This component is either important (cases of DTK and XIR where it represents 50% of the total intensity) or weak (case of PXM).

ii) A second hard component can be defined after this temperature and / or field values. This component is stable and, in most cases, easily determined.When its direction reached the origin it was assumed to be primary. This primary component has been accurately calculated for approximately 50% of the studied samples in this area. The remaining 50% has shown various complexities:unstable behaviour of the remanence (XIR) or extremely slow decrease of the intensity

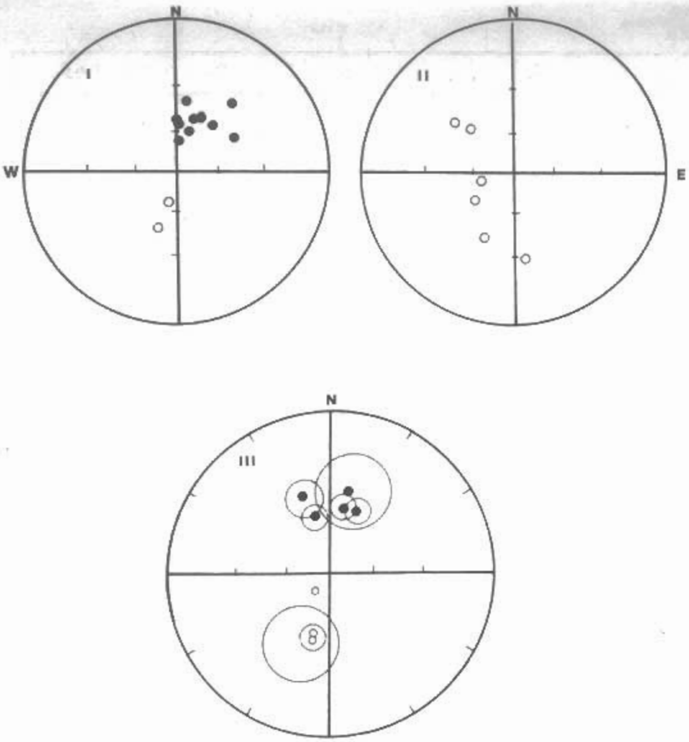


Fig.4: Stereograms showing characteristic remanent magnetization of I: site 26 (Vegora), II: site 23 (Kariochori).In III: mean characteristic directions for reliable sites (with confidence cercles). Black circles are positive inclinations and open circles negative inclinations.

(DTK) during thermal cleaning and unsatisfactory response to AF cleaning for a group of samples from DTK.

For the calculation of the mean directions from all three areas we used the best determined partial ones, both normal and reverse but converted through the origin for a better presentation (Tab.2 and Fig.4).

AGE CONSTRAIN AND STABILITY TESTS

1) Fold tests

The different layers in the areas A and B, are slightly tilted and a fold test can be performed.Only the sites with Fisher k parameter higher than 10 were used (Table 2).Tests were done 1) on the 6 sites which displayed the best directions and 2) on the 5 sites from Vevi and Vegora in order to compare only closely related sites (Table 3). The first fold test is McElhinny's test which compares the ratio of both k values of an overall mean, before and after tilt correction. The scatter increases after tilt corrections, but not to a significant level.It is only indicative that the magnetization may postdate the tilting.

We performed then the second McFadden's test. This test looks for a possible correlation between the distribution of the mean directions before (and after) tilt correction and the effect of these corrections on the overall mean.In this case a significant correlation is found between the distribution of mean site directions after tilt corrections, but not before them. This means that the magnetization postdates the tilting of these layers. The sediments in area C are practically horizontal and thus no fold test could be applied.

2) Susceptibility and anisotropy

The low field susceptibilities and their anisotropy were measured with a Digico system or with a Kappabridge KLY-2. Special care was taken in order to work with the best sensitivity and the lowest noise level. For instance, the effect of the sample holder was removed from the measurements. The susceptibilities vary from practically 0 to 450×10^{-6} SI. The anisotropy of low field susceptibility was measured on samples with susceptibilities higher than 40×10^{-6} SI and we retained only samples with

Table 3: Fold tests

Characteristic magnetizations McElhinny's tests (1964)					
N	K1	K2	K1/K2	95% test value	significance
6	42.4	21.1	2.09	2.97	no
5	45.1	18.0	2.51	3.44	no

McFadden's tests (1990)			
N	Σcosξ i	95% test value	significance
a. in situ directions			
6	1.397	2.862	no
5	1.716	2.601	no
b. corrected directions			
6	2.131	2.862	no
5	2.907	2.601	yes
c. half corrected directions			
5	0.36		no

Characteristic magnetizations using AMS as tilt indicators McElhinny's tests				
N	K1	K2	K1/K2	significance
5	44.6	28.9	1.58	no

McFadden's corrected directions		
N	Σcosξ i	significance
5	2.566	no

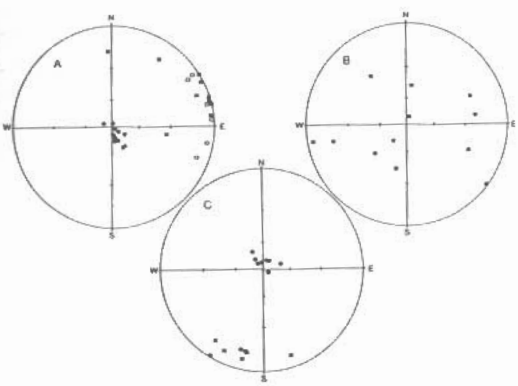


Fig.5: Anisotropy of magnetic susceptibility for *three sites: A: Vegora* site 26 (the same as in Fig.3 A), B: Neapolis, C: Vevi. Circles correspond to k/min and squares to k/max. Intermediate directions are not represented.

anisotropies higher than 0.8 %.

The five sites from Vevi and Vegora quarries show oblate susceptibility ellipsoids. The axis of minimal susceptibility (k min) is close to the pole of the bedding plane (Fig. 5A,5C). The good grouping of these directions allows a calculation of the mean directions directly with Fisher statistics instead of the more elaborate and complex Jelinek method. The scatter also increases after tectonic corrections, but to a smaller extent than for the characteristic remanent magnetizations. Clear trends of the k max axis are also visible although the lineation factor *is low. These directions* are N-S in Vevi and E-W to ESE-WNW in Vegora. They correspond possibly to directions of water currents during sedimentation

Table 4: Anisotropy of susceptibility

Mean directions of k_{min}

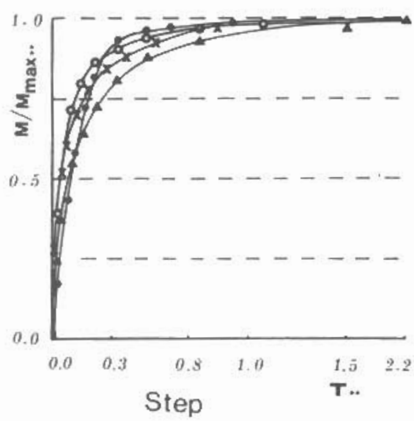
Site	N	D	I	k	a_{95}	pole of bed		dist.	D'	I'
Vevi										
21	8	190	-81	46	8	50	-70	26	232˙	-64
55	7	89	-75	35	10	115	-75	7	12	-75
Vegora										
26	14	333	-80	58	5	305	-82	5	25	-85
27	7	345	-73	104	6	315	-80	10	15	-80
54	14	179	-88	34	7	320	-78	14	145	-78
mean	5	17	-87	40.5	12					
	5			25.7	15				224	-88

fold tests

McElhinny :
N = 5 K1/K2 = 1.57 95% test value = 2.09 not significant

McFadden, in situ directions :
N = 5 Σcosξ i = 1.493 test value = 2.601 not significant
McFadden, tilted directions :
N = 5 Σcosξ i = 3.123 test value = 2.601 not significant

N is the number of measurements used, D, I, k, a_{95} are the mean declination, inclination and the Fisher statistical parameters of kmin, before tectonic correction and D', I' after bedding correction. Pole of bed is the direction of the normal to the bedding plane and dist. the angular separation with k_{min}.



▲ sample X-4.. C area x sample PX-6.. C area

o sample RT-1.. B area • sample VE-6.. A area

Fig.6: Example of IRM acquisition curves for pilot samples.

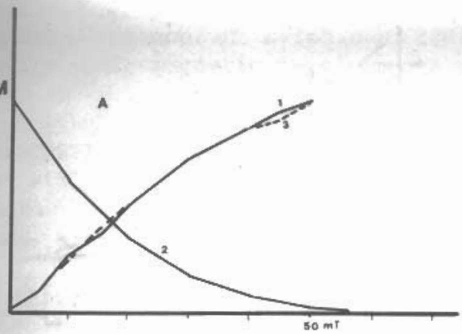
(Fig. 5). All results concerning these calculations appear in Table 4.

The other sites - areas B and C - display either more scattered anisotropic directions (Fig. 5B) or very weak fabrics not exceeding 0.03 % .

MAGNETIC MINERALOGY

1. Isothermal remanent magnetization

A first set of samples were submitted to increasing magnetic fields up to 1.5 Tesla. The curves show that saturation occurs at about 0.8 Tesla for areas A and B and at about 1.5 Tesla for area C (Fig. 6). Thermal demagnetization of the IRM of these samples gives unblocking temperatures between 300° and 500°C for areas A, B and over 600°C for C area. The above properties indicate a dominance of magnetite for areas A and B and magnetite with hematite for



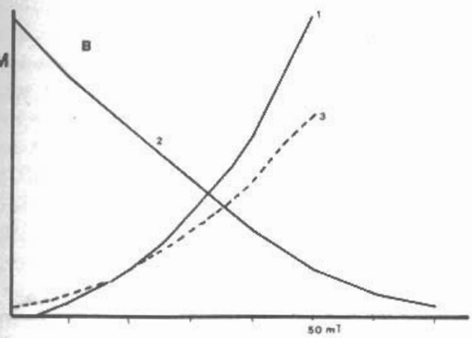


Fig.7: Low field (up to 50 mT) IRM acquisition curves. 1: first IRM (before any other treatment),2: alternating field demagnetization of this IRM,3: second IRM after A.F. treatment.
A: sample from Kariochori,B: sample from Vegora.

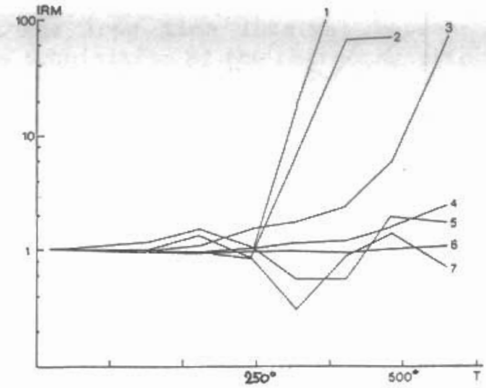


Fig.8: Behaviour of low field IRM (at 50 mT) after each thermal heating step. Samples from: 1: a limestone nodule from Vegora, 2: Vevi, 3: Neapolis, 4: Kariochori, 5: Vegora (site 26), 6: Riza, 7: Vegora (site 27). Note the log scale for the IRM.

area C. These observations will be confirmed by the thermomagnetic curves (see below).

On a second set of samples we concentrated our effort on the beginning of the IRM acquisition curves.Virgin samples (not heated, or a.f. demagnetized)were magnetized by steps of 5mT up to 50 mT. They were then A.F. demagnetized by steps up to 70 mT (peak field).A new IRM was given again to the samples as for the first time.

Samples from Riza, Kariochori, Neapolis and Vevi give linear or convex acquisition curves. The two IRM curves, before and after A.F. demagnetization are almost identical and a field of 50 mT is sufficient to destroy the IRM given at the same value (Fig. 7A).

Samples from Vegora gave different curves,being concave and more than 10 % of the magnetization still remains after demagnetization with a 50 mT a.f field. The second IRM curve is well below the first one (Fig. 7B).According to Neel's theory for multidomains (Neel 1955), this implies the existence of multidomain grains or interacting single domain grains in the case of Vegora and single or pseudo-single domain grains in the other cases.

These samples were then demagnetized by stepwise heatings, but after each step a new IRM was given to the sample at the same 50 mT value in order to document the variations of magnetic properties with temperature.Samples from Riza, Kariochori and Neapolis show either a constant value, or only a slow increase in IRM . Samples from Vegora show first an increase at 250°C,followed by a strong decrease between 300° and 400°C and an increase again after 450°C.A limestone nodule and the Vevi sample show a slight decrease at 300°C followed by a strong increase of two orders of magnitude after that (Fig. 8). The

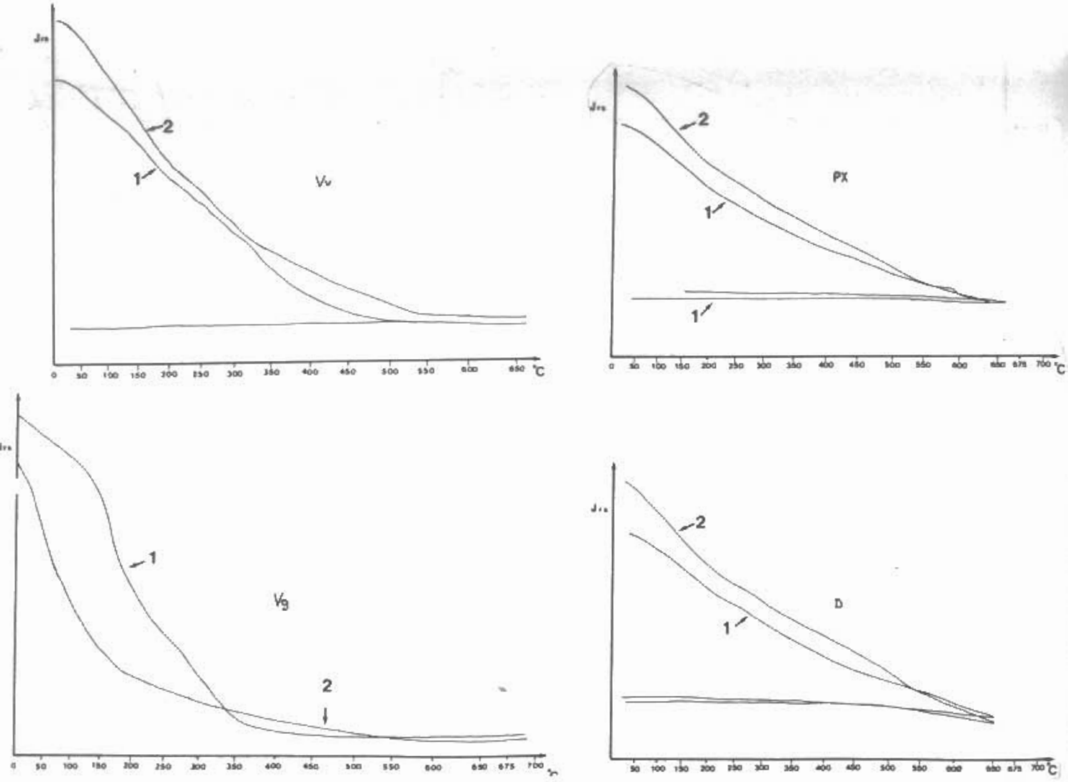


Fig.9: Examples of thermomagnetic curves for pilot samples.1-first heating curve;2 - second heating curve.

anomalous behaviour of the samples in the temperature range has already been observed during the thermal cleaning. The strong variations in the sample properties above 350°C associated with minera-logical transformations could be attributed to the presence of sulphides or deriving minerals.

<u>2. Thermomagnetic analysis</u>

The continuous thermal demagnetization in field - free space of the isothermal remanence (Irs) acquired in about 1 Tesla, served as the main method of identification of magnetic minerals . The (Irs) versus (T) curves recorded during the first heating of a specimen to 650°-670°C give the blocking temperatures (Tb) of magnetic minerals in rock in its natural state. The curves recorded during the second heating show the influence of the thermal treatment on the rock,resulting in changes in (Irs) and (Tb) spectrum (Kadziatko-Hofmokl and Kruczyk,1976).

Examples of thermomagnetic curves on pilot samples are given in Fig.9.

The following cases can be discerned:

a) presence of magnetite with a little left hematite (cases of PXM,XIR 5)

b) presence of hematite with a transformation phase arround 150°-200°C (cases of XIR 6)

c) presence of hematite with some impurities left(cases of DTK)

d) presence of magnetite with some changes at 200°C,300°C (Vevi).

e) presence of fine grained magnetite with small amount of Ti (Vegora).

From the above no evidence of sulphides can arize.Changes in (d) could be due to different grain size or structural effects.A possible explanation for thisapparent- absence of sulphides could be the long time interval between sampling -paleomagnetic measurements and the acquisition of the thermomagnetic curves.

DISCUSSION AND CONCLUSIONS

We will now proceed to the evaluation of the above results and look for possible tectonic implications in combination with data obtained in the broader area.

1. Areas A and B

Samples from the quarries (Vegora and Vevi) show the strongest modifications in magnetic properties (color changes, spurious magnetizations, increase of bulk susceptibilities), displayed at about 350°C. The levels sampled in these quarries are about 10 to 30 m above lignite and xylite beds presently mined. The presence of sulphur in these beds is quite obvious and contributes a lot to the pollution of the air around.

Because of a possible significant fold test (McFadden) performed on the 5 sites from these quarries it is suggested that magnetization may post-date the tilting while the anisotropy of magnetic susceptibility was acquired during deposition. The ChRM could probably be a chemical one due to the formation of sulphides.Nevertheless from the observation of the thermomagnetic curves sulphur does not seem to contribute to the magnetic mineralogy as no evidence for sulphides,especially magnetic ones, arises.Keeping in mind that the absence of sulphides could simply be due to a " time - interval " effect as stated before we cannot be positive about their contribution to the NRM.For Vegora the presence of multidomain grains or interacting single domains is also evident.

Magnetic minerals are possibly oxidized in a few sites from roadcuts and waterstreams which were exposed to weathering effects.Consequently, in these sites the initial ChRM is more or less destroyed, giving largely scattered directions. The anisotropy of magnetic susceptibility is also affected by these transformations.

2. Area C

All the magnetic properties of these sediments converge to the presence of a primary component which is syn-depositional. Though results of two out of four studied sites (XIR,PNT) are scattered their trend is clear and coherent

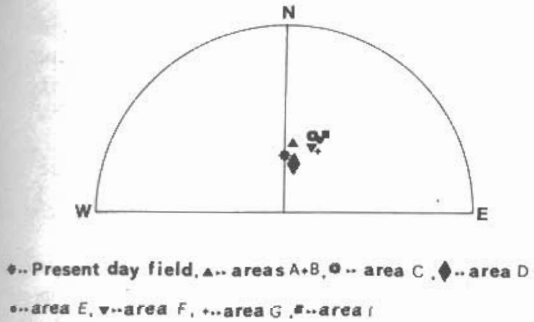


Fig.10: Stereographic projection of mean directions obtained in lavas and sediments of the broader area, for a period extending from Pliocene to Oligocene and from different authors (Bobier,1968;Kondopoulou, 1982;Laj et al.,1982;Kissel et al.,1986;Westphal et al.,1991; Atzemoglou et al.,1994).

A,B,C: sediments of the present study (4 - 11 Ma)

D : lavas of Almopias (2.5 - 4 Ma)

E : lavas of Kilkis - Strymoniko (Oligo - Miocene)

F : sediments of Messo - Hellenic Trough (Oligocene)

G : plutonics - volcanics of Greek Rhodope (Oligo - Miocene)

I : sediments of the Ionian islands (5 - 12 Ma) with the directions obtained in the other two (PXM,DTK).

Summarizing the characteristics of the studied rock properties we can draw the following conclusions :

a. A part of the samples (quarries of Vevi and Vegora) show evidence that their magnetization is post - formational and possibly associated with sulphide mineralization.

b. Another part (Axios valley) does not show a post - depositional but a syn - depositional primary component.

The study area is a key area between the strongly rotated Western Greece and the less rotated Greek Rhodope. For this reason it is important to examine closer the possible, if any, tectonic implications of the above results. We have plotted in the stereogram of Fig. 10 the following:

1. All the - statistically - reliable directions obtained in the sediments of the study area (A,B,C).

2. Results previously obtained in the vicinity of this area as well as further to the West and to the East, both in igneous and sedimentary rocks and younger than Oligocene.

Two distinct groupings can be observed :

i. A,B directions lie close to the present field. This could be due, as stated before, to a recent remagnetization but the arising problem is the following: D direction (obtained in lavas of 3Ma) is also close to the present field and A,B ones.As this is a different data set obtained further to the North - West it is difficult to assume another possible remagnetization. At the present state of knowledge no clear conclusion can be drawn for these sites.

ii. C directions are eastwards deviated by approximately 20 ,and lie close to the ones - I - obtained in the Ionian zone for the same period.

Directions from older (Oligocene and Oligomiocene) lavas, plutonics and sediments in the same area as well as in neighbouring ones (E,F,G) fall also within the same grouping.

Looking to the space distribution of these declination values we observe a quite homogeneous pattern where the magnitude of the angle progressively diminishes from the West to the East but is not reaching zero as previously stated (Kissel and Laj, 1988).

Thus the conclusion of Westphal et al., (1991) about the same rotational behaviour of the internal and the external parts of the Aegean is reinforced.

The almost N - S directions obtained in areas A,B are possible remagnetizations and further work there is already in progress.

Finally, we can suggest that the possible age of the rotation for the internal parts of the Hellenides is late Miocene as this arizes from the results obtained in area C.Though these results come from a limited number of sites their D, I values are perfectly consistent with the ones obtained in the neighboring Serbomacedonian and Rhodope massifs (Fig. 10). These well - constrained directions implied a post - Oligomiocene clockwise rotation of about 20° for the broader area. This rotation could now be better constrained by attributing to it a possible post Late - Miocene age.

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