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PALEOMAGNETISM OF THE NEA SANTA RHYOLITES AND COMPARISON WITH THE PELAGONIAN PERMOTRIASSIC

J. P. Lauer* and D. Kondopoulou**

ABSTRACT

In the Serbo-Macedonian rhyolites of Nea Santa-upper Carboniferous to lower Triassic in age- a stable and hard component is found and considered primary;corrected for dip its direction is: D=339°/I=+8° (α_{95}=6.5°); coordinates of the pole are:49°N/236°E.This is comparable with results from the Pelagonian lavas of Atalanti.Secondary components were originally NE-directed and favour the model of an older anticlockwise and a younger clockwise rotations. Accordingly,a first attempt is made to describe the evolution of the paleofield directions in Northern continental Greece since the Permian.

ΠΕΡΙΛΗΨΗ

Μελετήθηκαν οι ρυόλιθοι της Σερβομακεδονικής στη Νέα Σάντα-ηλικίας Άνω Λιθανθρακοφόρου ως κάτω Τριαδικού. Βρέθηκαν μία σκληρή και σταθερή συνιστώσα μαγνήτισης που θεωρήθηκε πρωτογενής και της οποίας η διεύθυνση, μετά από τεκτονική διόρθωση είναι: D=339°/I=+8°(a95=6.5°). Οι συντεταγμένες του πόλου είναι: 49°N/236°E. Τα αποτελέσματα αυτάείναι συγκρίσιμα με εκείνα των λαβών της Πελαγονικής στην Αταλάντη. Οι δευτερογενείς συνιστώσες κατευθύνονταν προς ΒΑ στην προέλευσή τους καιστηρίζουν το μοντέλο μίας παλιότερης αριστερόστροφης και μίας νεότερης δεξιόστροφης περιστροφής.

INTRODUCTION

About 25km to the North of Thessaloniki J.MERCIER (1968) described, inside the sedimentary cover of the crystalline basement of the Serbo-Macedonian zone,a mighty volcanosedimentary unit containing "quartziferous porphyries",i.e. rhyolites with a paleovolcanic facies.The best section is found along the brook of Kourou Dere,to the East of Nea Santa (fig.1).The edging sedimentary layers are strongly tilted and the arguments given by MERCIER show that the whole series is overturned.

The rhyolites are younger than the Serbo-Macedonian pegmatites (300 Ma) but older than the middle Triassic limestones of Deve Koran:thus their stratigraphic age is upper Carboniferous,Permian or lower Triassic.No trace of metamorphism is observed.

PALEOMAGNETIC STUDY

-Sampling

Looking for suited sampling sites we were advised,by Prof.D.MOUNTRAKIS,to undertake a study on these rhyolites.Sampling was performed,in 1986, 87 and 88,on three sites spread over 1km (fig.1).The rock appeared to be

+Institut de Physique du Globe,Laboratoire de Paleomagnetisme,Université René-Descartes,F-67084 STRASBOURG,France.
++Aristotle University,Geophysical Laboratory,540 06 THESSALONIKI,Greece.

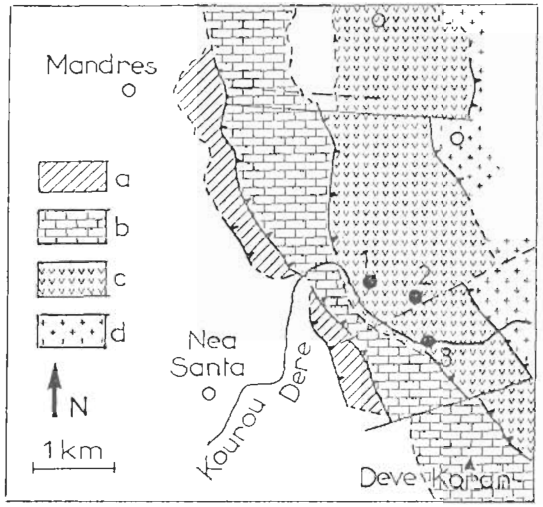

Fig.1. Location of the paleomagnetic sites 1 to 3 near Nea Santa. The geological background is from MERCIER(1968): a=Liassic marls and limestones; b=Triassic limestones of Deve Koran; c=volcanosedimentary unit including the quartziferous porphyries; d= crystalline units of the Serbo-Macedonian zone.

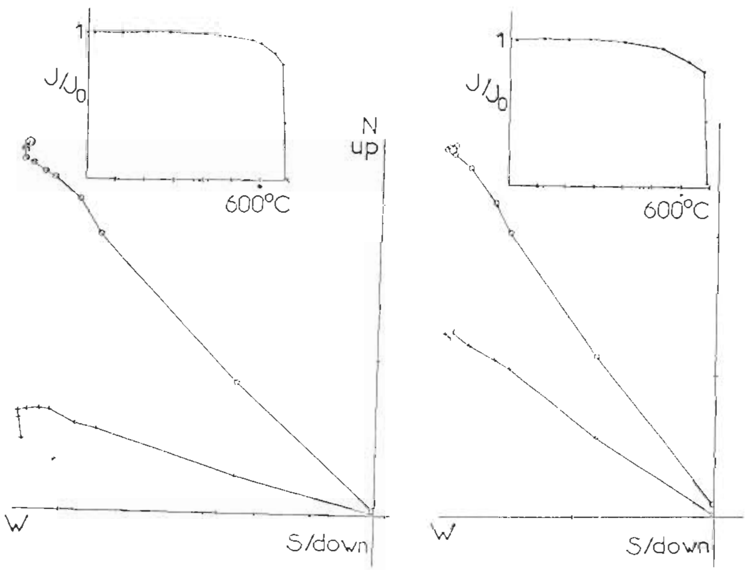

Fig.2. Two examples of demagnetization curves from site 2: normalized intensities (J/J₀) versus temperature - and orthogonal plots: discs are in the horizontal, crosses in the vertical plane.

especially hard and brittle: therefore, although site 3 was cored, the plaster technique was preferred for sites 1 and 2. The solar and magnetic compasses were both used for orientation.

As regard to the very strong tilt, special care was devoided to dip measurements which presented some difficulties too: inside the body itself no true dip can be measured and the figures of fluidality proved to be useless. The best estimate of the dip comes from site 3 in the vicinity of which the contact between the rhyolites and the Deve Koran limestones is visible; within the body, internal cracks and discordances tend to parallel the contact. For each site a local dip was calculated from numerous measurements. Then we calculated an average dip for the whole body in that area, also taking into account its draft on the geological map.

-Studies in the Lab

All samples were progressively demagnetized by heating (until 675°C) and cooling in a zero field. The remanence measurements were performed with the help of a MINISPIN apparatus. (Some susceptibilities were measured in the course of thermal demagnetizations).

In sites 1 and 2 the NRM intensities range from 2 to 100.10^{-3}A/m; in site 3 some lesser values were observed.

PALEOMAGNETIC RESULTS

-Before tectonic correction (see fig.3)

-Site 1: above 200°C only one magnetic component is present; it is very stable and very hard; its unblocking temperature is close to 675°C: the carrier is haematite. Its directions are rather well grouped:
D=343°; I=-11.4°; R=5.96; k=147; α_{95}=5.5° (N=6).

-Site 2: the 11 samples were collected along a lateral valley cutting the body of the rhyolites. In most of them (fig.2) the characteristics of the demagnetization (DM-) curves are the same as in site 1, but in some small irregularities can be noticed until 500°C. Nevertheless, the intensity practically does not change much below 550°C; the largest part vanishes between 550 and 675°C: this corresponds to the only coherent and well expressed component which is carried by haematite and the direction of which is:
D=320.3°; I=-15.5°; R=9.80; k=45.5; α_{95}=7.2° (N=10).

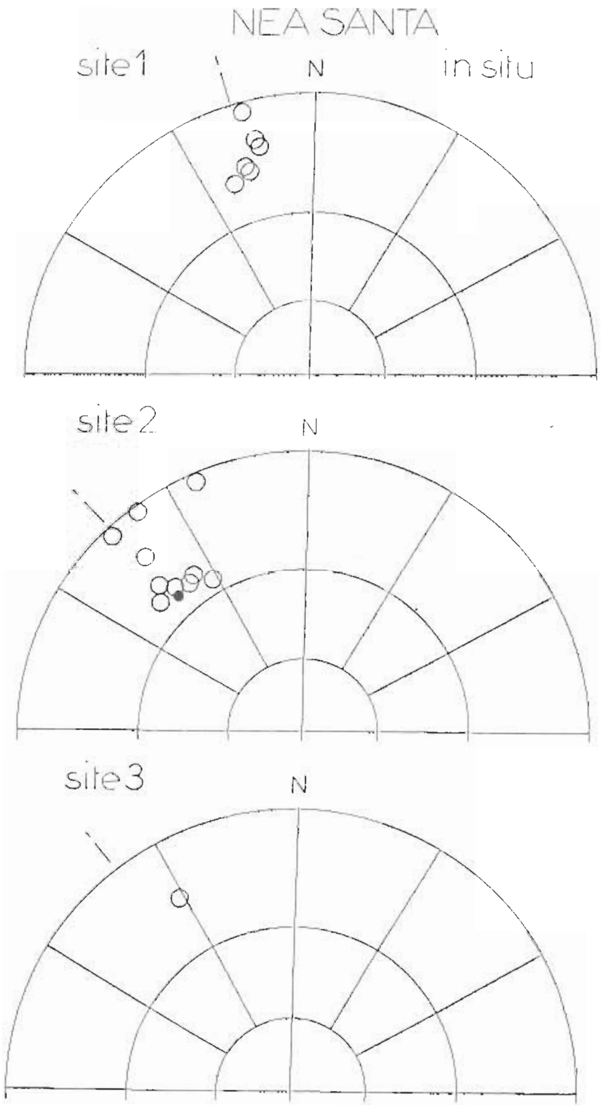

Fig.3. High temperature characteristic directions from the three sites of Nea Santa before tectonic correction.All these components are carried by haematite.The dotted line represents the axis of tilting.(Open symbols in the upper hemisphere).

One sample (among 11) yields a clearly different direction: D=320°;I=+25°.The DM curves do not fundamentally differ from the preceeding,but the intensity is the lowest in the section. That sample is considered remagnetized.As other directions of that type will be found (see E from site 3,fig.4),it becomes clear that even very stable components carried by haematite can be secondary.

-Site 3:the location is at the edge of the rhyolites,clcse to the ("minor") tectcnic contact.There is a slight angular dis-conformity with the limestones.The rock is more inhomoge-neous as before,penetrated by numerous quartzitic and calci-tic veinlets;it is softer and makes possible a sampling by drilling.

Only two samples exhibit a unique component only carried by haematite:

-in the first ($J(NRM)=20.10^{-3}A/m$):D=334°;I=-14°:this is the direction found in sites 1 and 2;

-in the second ($J(NRM)=5.10^{-3}A/m$):D=288°;I=+34.5°.

In the other samples the NRM intensity is around $1.10^{-3}A/m$ or lesser;most of the DM curves are more or less irregular. The multicomponent analysis reveals very scattered direc-tions (fig. 4).

Let us summarize:the study evidences a strong component carried by haematite in each of the three sites;its directions are coherent and well defined in sites 1 and 2 but the declinations differ slightly:320° instead of 343°;this may be due to internal deformations of the unit:site 2,f.i.,is close to a presumed small fault.

Thus this only coherent component is considered as the oldest and its direction

D=329°;I=-14°;R=16.5;k=30.6;α_{95}=6.5° (N=17)

will be corrected for dip.

-After tectonic correction

The amount of tilting we measured locally,in each of the three sites,is as following:

Site 1:strike:N 162°;dip: 119° to the SW;

Site 2:strike:N 137°;dip: 110° to the SW;

Site 3:strike:N 141°;dip: 118° to the SW;

Average:strike:N 147°;dip: 115° to the SW.

After a correction for local dip, the presumed primary direction turns to

D=338.5°; I=+7.9°; R=16.5; k=31.3; α_{95}=6.4°,

and to

D=338.9°; I=+8.0°; R=16.5; k=30.7; α_{95}=6.5°

after correction for the average dip.

These two results are very similar and represent the direction of the magnetic field in respect to the unit before the latter was tilted.

SOME REMARKS ABOUT THE SECONDARY COMPONENTS

In site 3 the occurrence of steep negative inclinations to the North is surprising. Because of the weakness of the intensity and irregularities of DM curves, most of these directions are not very accurately defined; but the

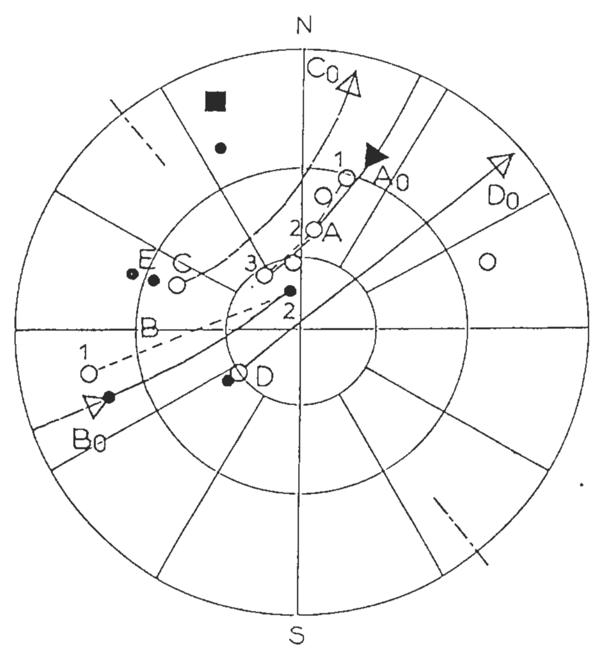

Fig.4. The final dip corrected and supposedly primary direction from Nea Santa (square) and the secondary components in site 3 (discs). The figure represents an attempt to clarify the timing of remagnetization. Syntectonic components from a same sample are joined by a broken line. The total dip correction is applied on A3, B2, C and D: the resulting extreme directions are at the head of the arrows; they constrain the field directions which created these components: the normal direction(s) of the field was (were) to the NE with shallow inclinations (seemingly between -2 and +25°).

average vectors stay in this strange position until the end of the demagnetization.

An explanation by horizontal rotations seems unlikely.

This is only an attempt to give a plausible explanation for these directions. Figure 4 shows them: they are very scattered and such components are usually neglected. Nevertheless, as they seem to have been created in accordance with past field directions, they may provide a valuable information about the tectonic evolution of the unit in respect to the field.

Two samples, A and B, yield secondary directions A_1, A_2, A_3 and B_1, B_2 which, on the stereograph, are located along small cercles; in the space, these small cercles happen to be centered on the horizontal axis of tilting (strike: N 141°): this strongly suggests that these components were created in the course of tilting; in addition they, obviously, cannot be recent. According to this hypothesis:

- A_3 is more tilted and thus older than A_2; A_2 is older than A_1;
- B_2, in the lower hemisphere, is older than B_1.

If we apply on A_3 and B_2 the maximum possible tectonic correction then we get points A_0 and B_0: the locus of the initial directions, before tectonic tilting, is:

- the spherical segment A_0A_1 for the initial direction of A;
- the spherical segment B_0B_1 for B.

The latter segment is rather short and B_1 seems to be as well as not tilted.

A similar treatment on C and D adds some constraints for the original directions of the field and especially for the inclinations.

E-type directions, although well defined and carried by haematite, will not be discussed here.

COMPARISON WITH RESULTS FROM PELAGONIAN PERMOTRIASSIC UNITS

TURNELL (1988, submitted Dec. 1986) found, in the Pelagonian lavas of Atalanti (probably Permian or lower Triassic in age): D=170°/I=-8° (supposedly reverse); this is very close to the (normal) direction in Nea Santa (D=339°/I=+8°). Thus it seems that the latitudinal distance between the Serbo-Macedonian and the Pelagonian zones did not change much in later times: not much space seems to be left for a megashear between both zones (SMITH and SPRAY, 1984). But the possible errors (ages, distinction between primary and secondary components) remain large.

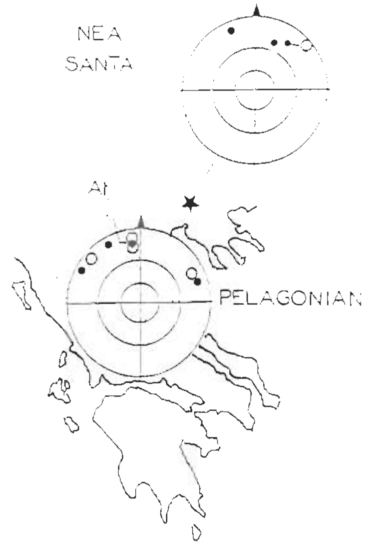

Fig. 5. A scheme for the comparison of paleomagnetic data from Permotriassic Serbo-Macedonian and Pelagonian units. Both primary (Western) and secondary (=Eastern) directions are shown. "At" represents TURNELL's result in Atalanti turned to a normal polarity. (Whereas the Pelagonian secondary directions are site averages, those from Nea Santa come from individual samples as shown in fig. 4).

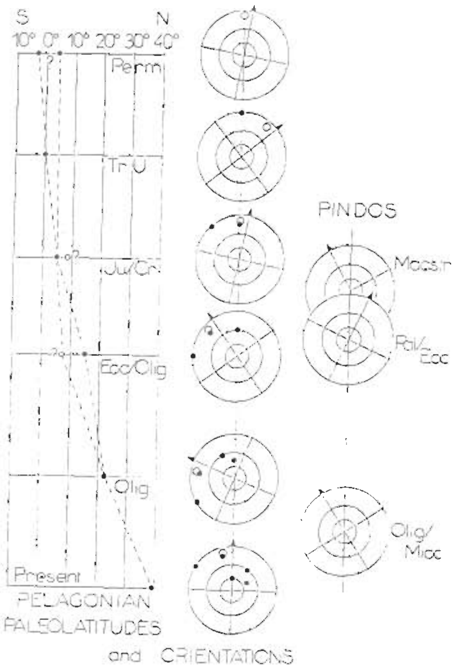

Fig. 6. A first model attempting to describe the evolution of the Pelagonian normal field direction since the Permian. The stereographs are attached onto the continent (Pelag. zone) and, at each period, they record the field direction. The azimuthal reference is the paleomeridian which is fixed. To the left are given the Pelagonian paleolatitudes which are still not very well defined. The model suggests that all oriental declinations are younger than the upper Cretaceous. (See text for the data which were used).

In Spring 1987 we presented (LAUER and KONDOPOULOU, oral communication, EUG IV, Strasbourg 1987) the average direction from 7 widespread Permotriassic sites of the Greek Pelagonian zone: D=352°/I=-7°. Taking in account numerous secondary components we concluded that, after the Permotriassic, counterclockwise (older) and clockwise (younger) rotations must have taken place; so did TURNELL (1988).

DISCUSSION

Corrected for dip, most of our "primary" directions had a negative inclination (fig.5); TURNELL's result corresponds to a positive inclination. But presently there is no place where the primary character is demonstrated (and even positive fold tests would be helpless because the last tectonic phases are very young). Therefore the question of the precise value of the inclination (slightly positive or negative) remains open. As the tectonic correction usually does not change much the declinations, the existence of old NNE directed components is trustable.

In Nea Santa the primary character is not demonstrated neither. Nevertheless, if the component were post-tectonic, the inclination would be negative (-14°), but the declination would be approximately unchanged. Thus it is too soon to conclude as for the respective paleolatitudinal locations of the Pelagonian and Serbo-Macedonian zones. To the opposite, the rotational stories seem to be comparable.

A PRELIMINARY MODEL FOR THE EVOLUTION OF THE FIELD DIRECTION

Taking in account the preceeding results and discussions, a first model (fig.6) is built up in order to visualize our present knowledge about the field evolution since the Permian and its bearings upon the geodynamic evolution. The model refers to the Pelagonian zone but, as seen above, it should be roughly valid for the Sero-Macedonian too, especially as for the rotational evolution.

The stereographs are fixed on the Pelagonian zone (as shown in fig.5). All rotations refer to the paleomeridian which is considered as fixed.

The story begins in the Permian with a small occidental declination. In the upper Triassic we observe strong occidental declinations (with inclinations near to zero): the corresponding rotation is still speculative because of our bad knowledge about the ages; it is based on a rough estimate of the relative ages within the Permotriassic.

After that we enter the succession of an anticlockwise and a clockwise rotation. For younger periods the model is completed by results from KONDOPOULOU and LAUER (1984) in NE Greece, KISSEL et al. (1985) in NW

Greece(Ionian zone) and KONDOPOULOU and WESTPHAL (1986) in NE Greece. Declinations from the Pindos (MARTON et al.,1988-inclinations still unpublished) are given for comparison.

It is noticeable that the Paleocene-Eocene inclination (paleolatitude :24.6°) found by HORNER and FREEMAN (1983) in the Ionian zone is seemingly higher than here.

The stereograph for the present times shows all the directions which can be found in an old Pelagonian rock sample.

The model is for the discussion and does not pretend to give all the details of the movements:the shallow inclinations to the ENE we found for some secondary components (fig.5) are not well interpreted.It does not concern the ophiolites.Numerous points need more information.The ages are approximative.

But this is a first attempt to explain the various (normal and reversed) paleomagnetic directions encountered in old rocks of northern Greece.

CONCLUSION

Despite a considerable tilt,the upper Carboniferous to lower Triassic rhyolites of Nea Santa yield a stable and hard component which is considered primary;its direction corresponds to:D=339°/I=+8° (Virtual Geomagnetic Pole:49°N/236°E).This is close to TURNELL's result in Atalanti (D=350°/I=+8° if turned to a normal polarity) and establishes the fact that,in northern Greece,old shallow inclinations to the NNW do exist despite a considerable subsequent clockwise rotation.

In old tectonized units unique magnetic components are rarely observed:numerous secondary components obscure the interpretation but they may provide a valuable information about the tectonic evolution,the timing (and thus the mechanism) of remagnetization,and about the field itself.An attempt is made which is open to discussion.

Finally,based on the "primary" and the secondary components we observed,and completed by other data from younger units,a first model is proposed for the evolution of the field direction in northern Greece since the Permian.

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