JOURNAL OF THE BALKAN GEOPHYSICAL SOCIETY, Vol. 6, No. 3, August, 2003, p. 173 – 178.

The Balkan Peninsula and archaeomagnetism – a brief review

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Abstract: *During the past few decades our knowledge of past geomagnetic field behaviour has increased significantly thanks to enhanced work undertaken in the field of archaeomagnetism. The Balkan Peninsula has a very rich cultural heritage and is therefore a perfect area for the development of archaeomagnetic studies, especially Greece. Because of its well-dated archaeological sites it has for a long time drawn special interest from geophysicists aiming to study the characteristics of the past geomagnetic field. The accumulation of archaeomagnetic determinations of the direction and intensity of the past geomagnetic field is a long and difficult task, which requires updating and validation of old results parallel to the new methodological approaches. Thus a revision of all published data is required when compiling the archaeomagnetic databases from different regions. In this paper a review of Balkan's scientists achievements in revealing the past geomagnetic field variations is presented. The Reference list contains the publications that are known to the author by Balkan's scientists in the field of archaeomagnetism.*

Key Words: *archaeomagnetism, directional results, palaeointensity determinations, periods in the geomagnetic field secular variation, dating.*

INTRODUCTION

Archaeomagnetism as an interdisciplinary branch of geophysics basically aims to discover past secular variations of the geomagnetic field elements (declination - D, inclination - I and intensity - Fa) for a given territory (Aitken 1978). The solution to this task depends strongly on the discovery of well dated archaeological structures in the territory in question. Close contact between archaeologists and specialists is very important so that the discovery of the remains of "*in situ*" burnt clay by archaeologists is known to archaeomagnetic specialists. If the goal of the research is to determine only the palaeointensity of the Earth's geomagnetic field, then *ex-situ* pottery and bricks gathered in previous excavations can be used. However, when the full directional data (I and D) are required, the *in situ* structures are needed. Once sufficient quantity of experimental results have been accumulated for a given territory, reference curves can be constructed that act as tools for future dating of newly discovered sites on the basis of archaeomagnetic results. On the other hand, such reference curves also provide a very useful constraint for primary knowledge of the Earth's geomagnetic field origin and history. Due to the geophysical significance of archaeomagnetic data a joint project has been initiated by European archaeomagnetic specialists in order to investigate the archaeomagnetic applications for the rescue of cultural heritage (AARCH). This project is in the framework of the 5th EC Programme "Improving the human research potential and the socio-economic knowledge base 1999-2002." The main goal of this program is to create a skilled work-force capable of collecting and measuring samples from archaeological and cultural sites, particularly those likely to be destroyed, or made inaccessible, as a result of economic development. One of the issues of this 'Research Training Network'

will be a construction of a spatially and temporally coherent record of the behaviour of the Earth's magnetic field during the last 10,000 years. Of the Balkan countries both Greece (Thessaloniki University) and Bulgaria (Geophysical Institute of Bulgarian Academy of Sciences) are included in this project.

Evidence of geomagnetic secular variations of the Earth's field are often revealed by palaeomagnetic studies of lake sediments that have the advantage of giving a continuous record. However, a number of problems arise concerning the precise dating of such deposits, which depends on many factors, including climate change, variations in sedimentation rates and so on. Archaeomagnetic data is considered to be much more precisely dated but consists of spot readings and the compilation of all the obtained archaeomagnetic results for a given territory is a difficult task. As such, compiled databases should be updated and extended with the newest determinations of the past geomagnetic field elements so that the existing gaps in the time series can be filled. Old dating undertaken by archaeologists should be revised and compared with newly studied collections that cover the same time period.

This brief review of archaeomagnetic work will concentrate only on the work undertaken by Balkan specialists. There are good examples of the fruitful co-operation between specialists from different Balkan Peninsula countries that will be mentioned here. Because the Balkan Peninsula is extremely rich in archaeological deposits it is an ideal area for the success of such kind of investigation. For this reason many geophysicists from England, France and other countries have made several archaeomagnetic determinations on dated archaeological sites in the region, especially Greece. In Bulgaria archaeomagnetic studies have been undertaken since 1967 and in the former Yugoslavia these studies are a product of a joint initiative between the Geomagnetic Institute of Grocka and the Geophysical Institute in Sofia (Kovacheva et al., 1974; Kovacheva and Veljovich, 1976, 1977). In Romania there are a small quantity of determinations made long ago - in 1967. There is no published archaeomagnetic data from Turkey and Albania up to now, although there are plenty of potential sites for archaeomagnetic analysis in both countries.

DIRECTIONAL RESULTS

The first directional archaeomagnetic determinations made by Balkan scientists are those undertaken by Bucur (1967) in Romania. The well-expressed minimal value of the Earth's past geomagnetic field inclination during the 14-century AD was obtained. During the same year archaeomagnetic studies began in Bulgaria and the first results confirmed this minimum as being around the 14 century AD (Kovacheva, 1968; Kovacheva, 1969). What should be underlined about the intensive archaeomagnetic investigations undertaken in Bulgaria till now is that the directional and intensity results were always obtained from one and the same material. The list of publications on the obtained archaeomagnetic results is quite long and will not be included here. After multiple revisions of the existing data and the incorporation of new data, the Bulgarian archaeomagnetic database was published in Kovacheva (1997). Once more it is underlined that the updating of these databases is of great importance because of refined dating techniques in archaeology, and especially, because of evolution of ideas about the prehistoric period. Therefore, this database will soon be updated again following the development of further methodological requirements.

As far as the directional archaeomagnetic results are concerned, it should be noted that they are obtained from relatively better dated materials when compared with the sediment record. The latter have often been "dated" on the basis of similarities in the directional maximal and minimal values on the archaeomagnetic variation curves from the nearest territory. Thus Creer et al. (1981) used the Bulgarian archaeomagnetic curves (Kovacheva, 1980) to date palaeomagnetic records obtained from Greek lake sediments. The interplay

between the archaeomagnetic and sediment record is a common approach and there are many examples in world-wide literature.

Recently some new archaeomagnetic directional data from Greece appeared through the study of Evans and Kondopoulou (1998) followed by the joint paper of Tarling et al. (2003). This is of great importance for the necessary compilation of all the results, published by foreign authors on Greek materials. There is a great dearth of directional data from the other Balkan countries such as Albania, Romania, Turkey and countries within the former Yugoslavia.

INTENSITY RESULTS

In contrast to the general situation in Europe, where directional archaeomagnetic results prevail considerably over palaeointensity data, in Greece, there is an abundance of palaeointensity determinations. However, these determinations have been made by various foreign specialists using different techniques and methods. Liritzis (1985, 1990) has discussed some of the drawbacks of this situation. Valuable results from Cretan kilns were obtained by Liritzis and Thomas (1980). In a more recent paper Kovacheva et al. (2000) made a comparison of newly obtained determinations for Greece with those given by Liritzis and Thomas (1980). The newest archaeointensity results from Greece were published by Spatharas et al. (2000, 2003). Obviously further work is needed to clarify the observed discrepancies, which may be due to the unreliable dating of sites. Importantly, serious archaeomagnetic research is already being undertaken in Thessaloniki, which should encounter most of the difficulties of incorporating the old results. As far as the Bulgarian archaeointensity results are concerned they cover an 8000 years period and the master curve is given in Kovacheva et al. (1998). Here there have been many problems with the reliable juxtaposing of the available results of numerous prehistoric tells with the absolute scale of time (Kovacheva, 1995).

Palaeointensity is the most difficult archaeomagnetic characteristic to be determined. For this reason, a great deal of work has been done more recently to elucidate the reliability of these results. Such work includes detailed magnetic mineralogy analysis and the study of mineralogical changes during laboratory heating when applying the Thellier palaeointensity experiment (Thellier and Thellier, 1959). This problem has become one of the main research areas of the Sofia laboratory. Greek colleagues (Kondopoulou and Spatharas, 2002) have also manifested their interest towards this crucial problem. In a joint study Jordanova et al. (1995) describe the magnetic anisotropy observed in archaeological materials used in archaeomagnetism and together with more recent papers by Kovacheva and Jordanova (2001) and Jordanova et al. (2003) these methodological problems have been amply highlighted.

ARCHAEOMAGNETISM AS A DATING TOOL

After the reliable archaeomagnetic master curves for a given territory has been obtained, archaeomagnetic data is useful beyond its geophysical significance in that it is also capable of helping archaeologists to date newly discovered sites on the basis of independently obtained past geomagnetic field characteristics. An interesting example concerning bricks from a well-dated Greek church is described in Kovacheva et al. (2000). Using archaeomagnetic methods Kovacheva et al. (2000) showed that earlier manufactured bricks can be re-used in later constructions. Archaeomagnetic dating in Bulgaria is already a common practice and numerous results have been published (not given here).

ANALYTIC STUDIES

Due to the important geophysical issues of archaeomagnetic determinations the first analytic studies of the up to the moment data soon appeared. Such kinds of papers are numerous in the world-wide literature beginning with the spherical

harmonic analysis of the archaeomagnetic data. However, this paper will concentrate on the work undertaken by Balkan scientists alone. Liritzis (1982, 1986) and Xanthakis and Liritzis (1986, 1989) published the first results concerning the maximum entropy and power spectrum analyses that revealed different periods in the archaeomagnetic data. In these papers the 200-year period is compared with different solar-terrestrial phenomena. Some years later the papers of Anufriev and Petrova appeared (1988; 1989a; 1989b) where an analysis of the secular variation, the westward drift of the non-dipole field and the so called MAC waves are discussed. This work was continued by other researches (Petrova and Anufriev, 1990; Petrova, 1990; Anufriev and Petrova, 1991).

It must be mentioned that a detailed study by Xanthakis and Liritzis (1991) appeared at the same time. In this work the results from archaeomagnetic time series are compared with those obtained from British lake sediments. Greek archaeointensity data is combined with data from Bulgaria and other European countries to obtain a sufficiently long and reliable time series. All existing analytic methods are used such as maximum entropy spectral analysis, auto-correlation, fast Fourier transform and so on. Thus, the most noteworthy period obtained from the analyses is 900-1000 years. For comparison, in Anufriev and Petrova (1989a) a period of a similar length is obtained on the basis of Bulgarian and Ukrainian archaeomagnetic data and is considered as the first harmonic to the main 2000 year period connected with the westward drift of the geomagnetic field. The monograph of Xanthakis and Liritzis (1991) contains all their previous results and is a prime example of the successful use of other researcher's data to draw valuable conclusions about past geomagnetic field behaviour. The analytical representation of geomagnetic field intensity as a sinusoidal variation dividing the longer and shorter periodic terms helped them to obtain a quite good correlation between the computed and experimentally observed values.

To finish this review of the contribution of Balkan scientist to archaeomagnetic studies we will mention the work of Lagios et al. (1992) entitled "A global archaeointensity data bank". This is an exceptionally valuable book because it gives chronologically distributed results of different authors normalised to the present dipole field for the corresponding latitude. Authors of the original data can easily recognise good coincidences and extreme discrepancies, which should call for a revision of the results or dating. As it is very important to work with updated and reliable results, a future task is to elucidate different sources of error in the older results. Only then can interesting and reliable conclusions be drawn from the data as attempted by Liritzis and Kovacheva (1992).

CONCLUSION

The main goal of this summary of Balkan geophysicists archaeomagnetic work is to suggest the establishment of an extended, reliable European archaeomagnetic database. The objectives of the AARCH EC joint project mentioned in the Introduction, move in this direction. Obviously a great amount of work remains to be done, especially in checking the validity of the old results and comparing them with the newly obtained data from synchronous, well-dated and carefully studied sites. We hope that this paper will be helpful for future archaeomagnetic studies by Balkans scientists into the extremely rich cultural heritage of the Balkan countries.

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