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Archaeomagnetic results from Volubilis, Central Morocco.

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ملخص

نتائج أركيومغنطيسية من وليلي. تقع مدينة وليلي الرومانية (34.1° شمالا، 5،5° غربا) قرب مولاي ادريس زرهون. مكن اختبار عينات لثلاثة مواقع من وضع المنحنى الاركيومغنطيسي المرجعي الاول بالنسبة للازمنة الرومانية بالمغرب.

كما أن الازالة الجزئية للتمغنط باستعمال حقل مغنطيسي تناوبي كشفت عن وجود مكونة واحدة ثابتة جدا. وتقارن هذه النتائج مع تلك المحصل عليها في دراسات أركيومغنطيسية أخرى لمواد من هذه المدينة نفسها ومن أصيلة كذلك.

ABSTRACT

The Roman city of Volubilis (34° 1N, 5, 5° W) is situated close to Moulay Driss Zarhoune. Three sites have been sampled for the establishment of the first archaeomagnetic dating curve for Roman times in Morocco. Partial demagnetization by alternanting magnetic field reveal cnly one stable component to be present. These results are compared with those of other archaeomagnetic studies obtained on materiel from this city and from-Asilah.

RESUME

Résultats archeomagnétiques de Volubilis. La cité romaine de Volubilis (34. 1° Nord, 5,5° Ouest) est située à proximité de Moulay Driss Zarhoune. Un échantillonnage de trois sites à été effectué pour l'établissement de la première courbe archéomagnétique de référence relative aux temps romains au Maroc. Les désaimantations partielles par champ magnétique alternatif révèlent la présence d'une seule composante très stable. Ces résultats sont comparés à ceux obtenus dans d'autres études archéomagnétiques faites sur du matériel de cette même cité et de celle d'Asilah.

GENERAL INTRODUCTION TO ARCHAEOMAGNETISM

Archaeomagnetic dating is based on two basic facts. These are (i) the Earth's magnetic field gradually changes in both direction and strength, and (ii) many archaeological materials, particularly those that have been fired, are able to retain a memory of the geomagnetic field from the time when they were fired, deposited or chemically altered. The measurement of the directions preserved in fired samples can usually be measured within 2-3°, and by collecting several samples, the final errors can be reduced to 1-2°. Observatory records of the changes of the geomagnetic field in London and Paris extended back to 1600 A.D., show average changes in direction of 0.25° per year so that dating within some ±5 years is theoretically possible. In practice the errors are somewhat larger (reflecting anisotropy, inhomogeneity, refraction - see AITKEN, 1974 ; TARLING, 1983) but are still generally of the order of ±10-25 years. However, such an accuracy also depends on knowing the direction of the geomagnetic field throughout archaeological time. Such records can only be constructed using the magnetization of archaeological materials of known age to determine an archaeomagnetic curve.

At the moment, the French, British and Bulgarian archaeomagnetic curves are the only reasonably well defined curves in Europe. These areas are somewhat distant from Morocco and so any extrapolation of such curves to this country is uncertain. It is therefore necessary to obtain precisely detailed archaeomagnetic data in order to construct a reference curve for Morocco. Such studies have already been initialed by KOVACHEVA (1983) in Volubilis and Asilah. It seems sensible that an archaeomagnetic reference curve for Morocco should be initially centred on Volubilis as this

location is central to major occupation sites in Morocco during both Roman and Islamic periods.

The process of study involves the sampling of archaeomagnetic materials in the field. For directional studies, these are ideally *in situ* fired materials such as hearths and kilns (unoriented materials can be used for ancient intensity determinations, but the techniques are more sophisticated and more sensitive to experimental error). The samples can be very small, less than 1 cm side cubes, as long as they can be accurately oriented, and usually some 6 to 12 are required for any single age determination.

All materials are lying in the Earth's magnetic field and gradually acquire new magnetizations, but these can be easily removed by either heating them (in zero magnetic field) to 100-150°C or by placing them in alternating magnetic fields of some 10-15 mT. In practice, most samples are subjected to alternating magnetic fields in a series of steps up to 50 or 60 mT and the direction initially changes as the later magnetizations are removed, and then remains constant when the original magnetization has been isolated. The reliability with which this has been isolated is measured using a stability index (TARLING & SYMONS, 1967) which corresponds to unstable if <1 and stable if = 2-5. These directions are then combined and the radius of an error circle (alpha 95) within which there is a 20 : 1 probability that the true direction lies.

NEW RESULTS

Volubilis is a Roman city, the remains of which are close to Moulay Driss Zarhoun, located at 34.1°N., 5.5°W. Within the site, there are numerous thermal baths, kilns and furnaces, many of which are in an excellent state of preservation. The precise age of abandonement is not clear, but many kilns are thought to have been abandoned around 300 A.D., while other continued in use until about 500 A.D. As part of a preliminary attempt to establish an archaeomagnetic dating curve for Roman times in Morocco, 3 sites have been sampled.

SOUTHERN . THERMAL BATH (KABITOUNE):

The heated areas of this bath are thought to have been last heated around 300 A.D. Samples were collected from two different walls of the structure, seven from a western wall and two from an eastern wall. The intensity of magnetization was generally high. mostly exceeding 100 mA/m/g (table I). With the noteable exception of the 2 samples from the eastern wall.

Table I : Southern Thermal Bath Results
Int = intensity (mA/m/g) ; S.I. = Stability Index range = stable range (mI)

Sample	Int.	Decl.	Incl.	S.I.	range
Eastern Wall					
VL1	1038	353.5	49.3	37	10-20
VL2	609	354.8	52.3	6	0-30
VL3	216	0.5	49.6	19	0-30
VL4	217	2.6	46.5	12	2.5-20
VL5	196	1.9	45.0	13	0-30
VL6	227	358.2	45.2	9	10-30
VL7	177	356.6	55.1	4	10-20
Western Wall					
VL8	21	356.3	41.6	7	0-30
VL9	14	359.4	42.8	1	0-30
MEAN DIRECTIONS					
All	N=9	358.2	47.5	α_{95} = 3.1°	
Eastern	N=7	358.4	49.0	α_{95} = 3.3°	

Partial demagnetization showed only one component of magnetization, souggesting that only the final heating was recorded by the individual samples. The demagnetization also showed that all of the samples, except VL9, were of high to very high stability to alternating magnetic fields. The two samples from the western wall were mutually consistent, but clearly shallower than those from the eastern wall. The samples from the eastern wall were reasonably similar, although somewhat more varied in inclination than in declination.

In view of the difference between the two parts of the structure and that only one of the samples from the western wall can be considered stable, the most reliable mean direction is considered to be that of the samples from the eastern wall, although there is little difference in direction if the western wall samples are included.

OVEN OPPOSITE PALAIS DE JUSTICE

Six samples were taken from the baking surface of a 3rd century bread oven. The intensities of remanence varied from low to moderate (table II) and all, except V6, were stable to A.F. partial demagnetization. The stable samples only showed one component of remanence, indicating that only the last firing was recorded.

Table II : Bread Oven Results.
Abreviation as Table I.

Sample	Int.	Decl.	Incl.	S.I.	range
V1	40	334.8	40.1	7	0-40
V2	7	328.5	45.4	6	0-40
V3	69	349.2	46.4	15	5-20
V4	88	1.4	55.0	8	0-30
V5	0.3	343.6	43.4	2	0-10
V6	0.2	354.4	43.1	2	0-5
Mean	N=4	351.6	47.2	α_{95} = 8.5°	

There is little consistency between the directions and it is not possible to ascribe a reliable archaeomagnetic age to this oven. The scatter probably indicates that the undulating nature of the surface is of secondary origin, i.e. the undulations developed as a result of differential subsidence after its last firing. It is possible that genuine archaeomagnetic directions could still be obtained from careful selection of areas that show the least distortion.

KILN (NORTH-EAST SECTOR)

Six samples were collected from the floor of this 4m diameter circular pottery kiln in the northeastern sector of the city and attributed to the 3rd century. The samples were of fired bricks heated during the operation of the kiln.

The intensity of magnetization of all the samples was moderate to high - all exceeding 50 mA/m/g - and all showed high stability to partial demagnetization in alternating fields (table III). Only one component of remanence could be determined, indicating that all samples retained a record of only the last firing. The inclination of sample VO3 is some 10° shallower than the other samples, despite its very high magnetic stability. This suggests that this brick may have tilted southwards by this amount since last

Table III : NE Sector Kiln Results
Abbreviations as Table I

Sample	Int.	Decl.	Incl.	S.I.	range
VO1	179	358.5	44.7	8	0-30
VO2	73	1.2	45.3	3	0-30
VO3	57	4.7	36.7	12	0-40
VO4	60	0.7	44.1	4	0-40
VO5	70	11.4	44.0	3	0-30
VO6	71	14.0	46.0	2	0-30
Mean	N=5	5.1	44.9	α_{95}= 4.7°	
Mean	N=3	0.1	44.7	α_{95}= 1.8°	

fired. While the inclinations of the remaining samples are almost identical, the declination values of samples VO5 and VO6 are some 10° east of VO1, VO2 and VO4. It is not clear if this could be due to a rotation of samples VO5 and VO6, although these are also less magnetically stable than the other samples. A conservative estimate of the mean would therefore include all samples except VO3, while the true mean could well be represented by samples VO1, VO2 and VO4.

SUMMARY, COMPARISONS AND CONCLUSIONS

With the exception of some samples from the bread oven, all the samples showed moderate to high intensities of magnetization, single components of remanence and high stability to partial demagnetization. There seems no reason, therefore, for not assuming that the observed directions are genuine, reliable determinations of the geomagnetic field direction at the last time these structures were last used. The mean directions of the southern thermal bath and the bread oven are statistically identical (table IV), although this largely reflects the poor definition of the mean direction of the bread oven. The kiln yields a mean direction that is shallower and slightly more easterly than the other two structures. This difference may be real, suggesting an age difference, although this cannot be regarded as statistically established at a 95% confidence level.

KOVACHEVA (1984) reported studies on three structures in Volubilis and 2 in Asilah (table IV). These were all slightly steeper in inclination than the newer results, but the differences are

Table IV : Summary of Moroccan Archaeomagnetic Results. The Volubilis results are all of 3rd century A.D., except for the southern furnace (5 th century A.D.). Those from Asilah are of the 3rd to 2nd century B.C. (citabe and bath) or Ist century B.C. (Chkdakra). ()* Corrected to Volubilis assuming an inclined geocentric dipole field.

Structure	N	Decl.	Incl.	α_{95}	Reference
Volubilis					
Southern bath	9	358.3	47.5	3.1	This report
Bread oven	4	351.6	47.2	8.5	" "
NE Kiln	3	0.1	44.7	1.8	" "
"	5	5.1	44.9	4.7	
Bath	4	349.0	49.9	-	Kovacheva 1984
Big furnace	10	352.2	50.3	3.6	" "
Southern furnace	5	353.3	51.7	2.5	" "
Asilah (Corrected to Volubilis)					
Citadel	10	1.8	53.0	5.1	" "
		(1.8	51.7)	x	
Bath	2	-	41.0	-	" "
Chkakra	5	353.9	54.3	3.3	" "
		(354.0	53.0)	x	

close to the statistical uncertainty of the individual determinations. At this stage, therefore, the archaeomagnetic evidence suggests that there was little change in direction of the geomagnetic field in Morocco between the 3rd century B.C. and the 5th century A.D. This result is very different to the observations in France and Britain which show clear changes in inclination during Roman times. At this stage it does not seem practical to link the individual results to form an archaeomagnetic curve, although some of the differences may reflect age differences in the direction of the geomagnetic field.

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