



ARCHAEOMAGNETIC DIRECTIONAL DETERMINATIONS ON VARIOUS ARCHAEOLOGICAL MATERIALS FROM THE LATE MINOAN DESTRUCTION SITE AT MALIA, CRETE

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ABSTRACT

An archaeomagnetic directional study of Late Minoan archaeological materials, (burnt mud brick, a clay/ash horizon and hearth material), was carried out at locations within the archaeological complex at Malia, Crete. The study aimed to establish the suitability of materials for archaeomagnetic sampling and to obtain archaeomagnetic directions for comparison with other Late Minoan "fired" sites on Crete. Results from 42 oriented samples measured on a fluxgate spinner magnetometer from homogeneously distributed burnt mud brick (constituting low elevation, in situ, partition walls), gave precise values of ancient field directions for, Malia Palace (area 13) and Maison Δα. These directions are statistically identical (at a 95% confidence level) and also identical to directions obtained from other Late Minoan archaeological sites, on Crete. This, may suggest, simultaneous 'fire-involved' destruction. Other archaeomagnetic directions obtained from Malia (Quartier ε), from a 'clay/ash' horizon (34 samples) and hearth (19 samples), produced some spurious results, with detrimental consequences for directional accuracy. For the burnt mud brick, small viscous components were easily removed and evidence from coercivity spectra obtained, after step-wise alternating field demagnetizations, suggests that, the magnetic carriers are single domain, (low titanium), titanomagnetite.

KEYWORDS: dating, burnt mud-brick, titanomagnetite, stability, grain-state, Malia, Crete

INTRODUCTION

The Minoan archaeological site at Malia is situated on the plain of Malia on the northern coast of Crete (Fig. 1).

The palace was discovered by the Greek archaeologist, Hazzidakis in 1915 and has, in more recent years been excavated by the Ecole Française d'Athènes (Davaras, 1976). The site was occupied in the Late Neolithic and Early Minoan period and the first palace dates from Middle Minoan I. Subsequent palaces were built on the main outline of the first palace. The final destruction was in the Late Minoan period, believed by some archaeologists to be 1450 B.C. (Davaras, 1976). General descriptions of the palace and its surrounding quarters can be

found in (Tiré and Éffenterre, 1966), (Davaras, 1976). The construction consists of materials such as hard grey limestones and soft red sandstones, partition mud-brick walls, wooden support beams and staircases. Unlike Knossos, no gypsum was used at Malia.

The Minoan periods of occupation have been given a nomenclature by the Ecole Française d'Athènes, to meet the archaeological realities of the region of Malia. These are, together with the more generally accepted nomenclature:- Minoen Recent (MR) \equiv Late Minoan (LM), Minoen Moyen (MM) \equiv Middle Minoan (MM), Minoen Ancien (MA) \equiv Early Minoan (EM). These are further subdivided into phases, e.g. Phase IIIB \equiv LM IB.

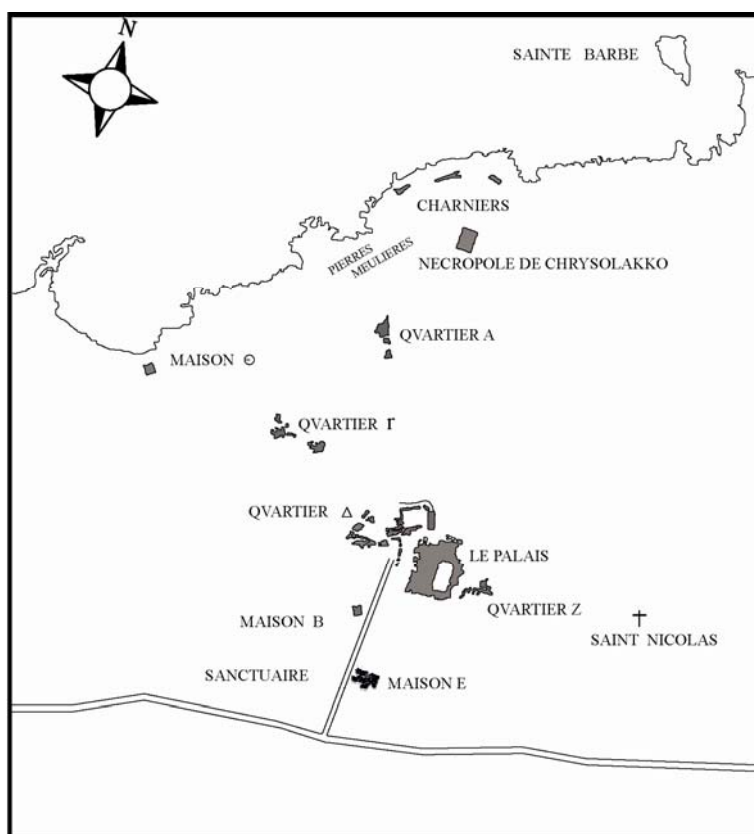


Figure 1. General sketch plan of the Malia Palace, modified after Tiré and Éffenterre. Guide de Fouilles Français en Crete, (1966).

An archaeomagnetic investigation was carried out in three areas of the Malia site, known to have been subjected to fire; those of :- Palace, (area 13), Maison Δα (Quartier ε; coupe 2, salle 3) and a LM hearth in salle 3.

ARCHAEOMAGNETIC DIRECTIONAL RESULTS FROM MALIA PALACE (AREA 13)

Archaeomagnetic Sampling

Archaeomagnetic samples were taken from the south-eastern corner of the palace site (area

13), to the east of L'entree sud (Photo 1), (Fig.2). The area showed evidence of extensive burning, possibly during the final destruction in the late Minoan period.



Photo 1

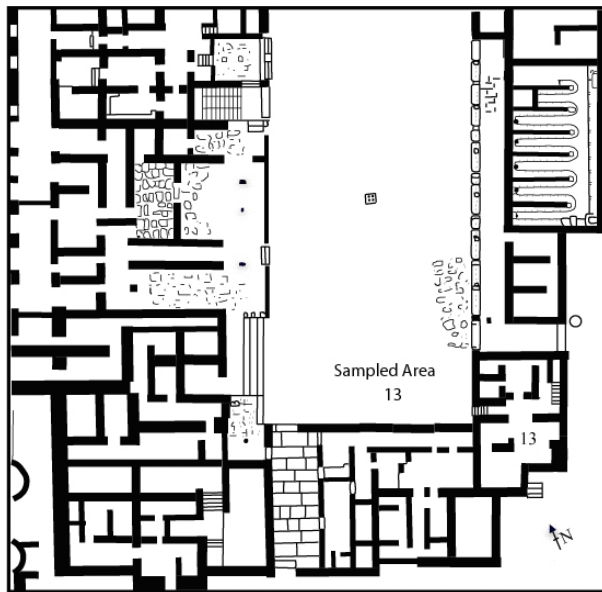


Figure 2. Detailed plan of the Malia Palace showing sampled area 13. (modified after Davaras, 1976).

Twenty samples were taken from burnt mud brick walls of low elevation. The vertical walls, at right angles to one another, appear to be “in situ” and samples were taken from their surfaces and interiors of bricks, where exposed. A sun compass and inclinometer were used for orientation as there was no protective roof in place at the time and all samples were measured using a fluxgate spinner magnetometer (Molyneux, 1971).

Archaeomagnetic Directional Results

The initial NRM (Natural Remanent Magnetization) values ranged in strength from relatively low to very high (Table 1), suggesting that, magnetic grains are inhomogeneously distributed. The NRM directions are shown in Fig.3(a) and the mean direction for (N = 20) :- Dec. = 355.0°, Inc. = 59.5°, $\alpha_{95} = 1.4^\circ$, k (precision parameter) (Fisher,1953) = 497.3.

TABLE 1. Archaeomagnetic Directional Results, Malia Palace (area 13).

Malia Palace (area 13)					
Sample No.	N.R.M.			Stable Mean.	
	Dec. ^o	Inc. ^o	Int. (mAm ⁻¹)	Dec. ^o	Inc. ^o
MP1	354.2	61.4	2019	354.5	61.4
2	5.9	52.7	511	5.8	53.2
3	354.4	58.2	1633	354.0	58.1
4	356.7	56.2	185	355.4	56.8
5	355.1	62.6	653	356.7	63.0
6	352.9	58.8	223	355.1	58.1
7	350.8	57.5	1963	355.8	56.9
8	1.5	57.5	4977	2.0	57.8
9	354.0	60.2	685	352.7	59.9
10	352.0	56.2	10625	353.5	56.7
11	348.1	58.8	7317	348.0	59.4
12	355.0	58.6	746	356.7	58.5
13	357.3	60.7	635	357.4	61.2
14	358.6	64.1	2121	0.2	64.1
15	356.6	62.5	1996	357.7	62.3
16	357.4	61.5	569	0.6	61.7
17	354.9	59.3	2087	354.8	59.3
18	344.5	61.7	714	347.2	63.4
19	357.0	57.9	678	358.6	57.2
20	352.0	62.5	833	353.5	62.5

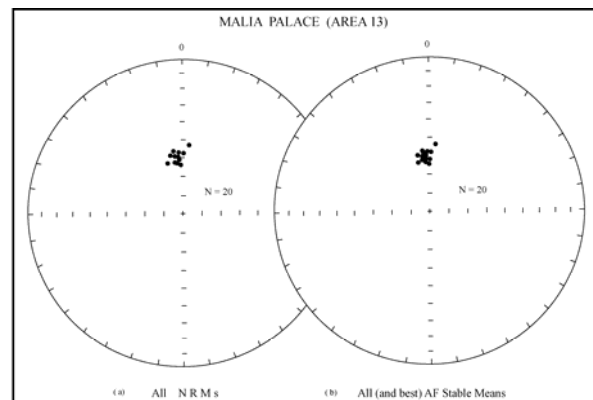


Figure 3. Lower hemisphere stereographic projections showing the archaeomagnetic remanence directions for Malia Palace (area 13).

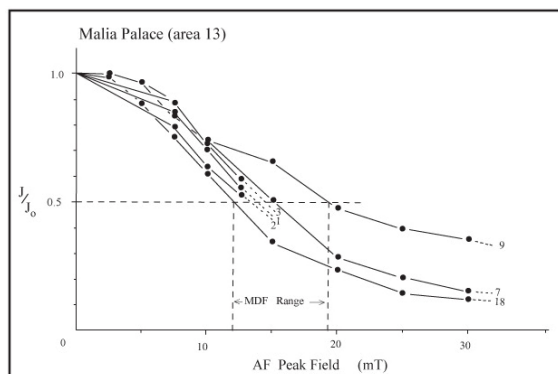


Figure 4. Normalized decay of NRM to stepwise AF demagnetization for typical samples of burnt mud-brick from Malia Palace (area 13).

AF (Alternating Field) Demagnetization

Samples were subjected to stepwise AF demagnetization in the steps 5.0, 10.0, 12.5, 15.0, 20.0, 50.0 mT. The mean directions (Fig.3b), for each individual sample over the most stable demagnetizing field range were calculated (Table 1). The decay of NRM to AF demagnetization (Fig. 4) shows the MDF (Median Destructive Field) in the range, 12-19 mT. Magnetic stability to AF demagnetization for all samples was high. The mean direction for all 'cleaned' samples ($N = 20$) :- Dec. = 356.1° , Inc. = 59.6° , $\alpha_{95} = 1.4^\circ$, $k = 509.9$. This direction is of course statistically identical to the NRM mean with the same error suggesting that only a minor amount of secondary magnetic components were present. Hus *et al.* (2003) points out that AMS (Anisotropy of Magnetic Susceptibility) measurements from 'bricks' whether pre-fired or of abode origin (Shaw, 1971) demonstrate a magnetic fabric which is induced in the moulding process; the degree of anisotropy averaging between 2% to 4.5%. Lanos *et al.* (1999), suggests, that, tightly grouped directions do not guarantee that the anisotropy effect is absent but its effects may be averaged out following Fisherian statistics (Fisher, 1953). Furthermore, (De Marco *et al.* 2008), suggest that TRM anisotropy corrections do not practically modify the mean directions at each site.

Magnetic grain state

Lowrie and Fuller (1971) devised a simple test which has proved useful as a general indicator of grain state (ie) in distinguishing M.D. (multi-domain) from SD (single-domain) carri-

ers of magnetic remanence. The most practical use of the test as used in this study involved the comparison of NRM, TRM (Thermoremanent Magnetization) and SIRM (Saturation Isothermal Remanent Magnetization) decays to stepwise AF demagnetization. As an example of typical behavior during step-wise AF demagnetization, the NRM of sample MP14 was stepwise treated and then given a laboratory TRM of $0.6 \times 10^{-4}T$ at $550^\circ C$. This again was subsequently step-wise AF demagnetized and normalized, (Fig. 5).

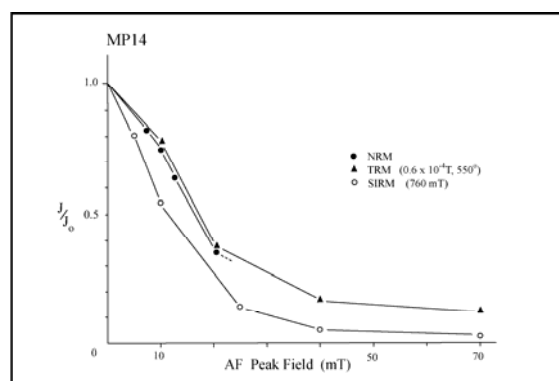


Figure 5. Normalized decays of NRM, TRM and SIRM to stepwise AF demagnetization. Note that the SIRM curve shows lowest stability.

Its low field magnetic susceptibility was monitored before and after the TRM treatment to check for any mineralogical changes that may have occurred during the heating process and found not to have significantly changed. Finally, a SIRM was applied to the sample using a laboratory inducing field of 760 mT. and demagnetized (Fig. 5). The NRM and TRM decay curves plot fairly close together with both exhibiting significantly higher stability than that of the SIRM decay curve, indicating that, the stable remanence is probably carried by single domain grains of titanomagnetite. Other sample results confirmed the same pattern of relative stabilities.

The burnt area 13 of the palace may have been involved in the conflagration destruction at the end of LM IB, however, there is no conclusive ceramic evidence to support this. Pelon. (1970), suggests that, the new motifs which characterize LM IB co-exist at Malia with the LM IA style and may represent a style rather than a period. This highlights the nature of the problem of positively dating pottery by sug-

gesting that the shape is “not before LM IB but the motifs suggest pre-LM IB”. The presence of this mixture of pottery styles at Malia therefore must cast doubt in any positively date of an LM IB destruction. There are few examples of positively identifiable LM IB style pottery from the palace at Malia.

The ‘best’ mean direction result :- Dec. = 356.1°, Inc. = 59.6°, α_{95} = 1.4° was determined from high remanence samples of extremely high magnetic stability. Only a small amount of VRM was present and the magnetic carrier is, most likely, titanomagnetite, (probably single domain). There appears to be no systematic preference of the resulting magnetic directions from walls of particular orientations indicating that magnetic refraction was minimal or absent.

ARCHAEOMAGNETIC DIRECTIONAL RESULTS (MAISON Δα)

Introduction and Sampling

Demargue and De Santerre (1953) and (Tiré and Éffenterre, 1966) give full descriptions of Maison Δα. It is described as being of typical Minoan architecture of the second epoch, with all the objects and vases attributable to MMIIIB or MRI (LM I). The final fire destruction is thought to have been in the late Minoan period but there are no definite dates of LM IA and LM IB postulated. Twenty two orientated samples were taken from the house α in Quartier Δ. Figure 6 shows a sketch plan of the building with samples taken from areas listed by (Downey and Tarling, 1984). All samples were orientated using a magnetic compass because of the presence of a protective roof.

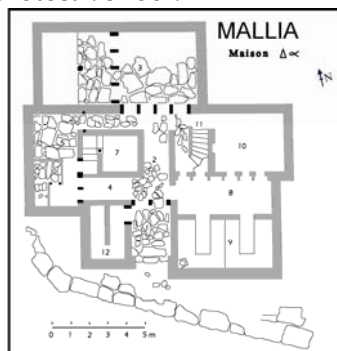


Figure 6. Sketch plan of Maison Δα (modified after Demargne and De Santerre, 1953). Fouilles a Mallia, Paris Libraire Orientaliste, Paul Geuthner.

*Initial NRM*s

The initial NRM intensities ranged from approximately 12 to 450 mAm⁻¹ (Table 2). This wide range is probably due to the inhomogeneous magnetic carrier distribution within the variety of materials sampled (burnt sandstone, plaster and mud-brick). The NRM's are represented in Fig. 7 (a), and listed in (Table 2). The mean direction for (N = 22):- Dec = 350.5° , Inc. = 64.2° , α_{95} = 13.3° . k = 6.0.

TABLE 2. Archaeomagnetic Directional Results, Malia, (Maison Δα, MDA)

Sample No.	Malia Δα (MDA)				
	N.R.M.			Stable Mean.	
	Dec. ^o	Inc. ^o	Int. (mAm ⁻¹)	Dec. ^o	Inc. ^o
1	0.1	53.4	60.2	1.4	55.9
2	342.1	64.8	36.8	344.8	66.3
3	359.3	68.2	40.1	1.8	68.5
4	341.1	62.3	76.7	0.2	64.1
5	357.3	50.3	11.6	356.6	56.1
6	353.1	58.3	18.5	355.1	43.2
7	337.1	67.4	56.3	350.3	60.2
8	352.9	53.3	45.3	9.6	52.7
9	353.5	72.9	14.5	8.1	65.1
10	345.2	59.8	122.4	349.8	162.5
11	322.8	61.1	36.9	350.1	62.3
12	321.3	69.8	12.6	356.6	60.3
13	341.6	73.7	28.5	359.9	60.1
14	330.2	43.2	96.3	354.1	45.8
15	38.2	56.9	17.4	20.1	58.1
16	348.4	63.6	24.3	346.4	62.1
17	78.3	48.6	29.6	16.1	53.4
18	347.4	57.1	68.2	350.1	58.5
19	1.8	60.3	451.1	2.3	60.4
20	332.7	65.8	66.1	333.2	65.8
21	343.6	63.9	176.1	341.6	64.3
22	342.9	63.4	63.2	343.3	64.1

AF Demagnetization

Alternating field demagnetization was carried out on all samples in progressive steps of 2.5, 5.0, 7.5, 10.0, 15.0, 20.0 and 25.0 mT. Normalized representative decay curves for the NRM's of burnt mud brick, plaster and sandstone samples after step-wise AF demagnetization are shown in (Fig. 8). The MDF range lies between 7-16 mT reflecting the relatively low coercivity of the constituent magnetic minerals. The stability indices ranged from approximately 1 to 41 (i.e metastable to extremely sta-

ble), (Tarling and Symons, 1967), however, more than half of the samples were in the stable to very stable range. The “cleaned” mean directions are shown in Fig. 7(b), with a mean value (N = 24):- Dec = 359.4°, Inc. = 55.6°, α_{95} = 11.7°, k = 7.0. The ‘best’ mean directions (N = 22) are shown in Fig. 7(c), with a mean:- Dec. = 356.2°, Inc. = 59.9°, α_{95} = 3.2°, k = 91.4.

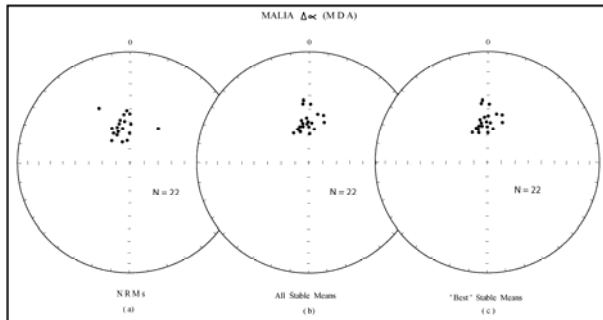


Figure 7. Lower hemisphere stereographic projections showing the archaeomagnetic remanence directions for (a) NRMs and after stepwise AF demagnetization (b). All stable mean directions and (c) “Best” stable mean directions.

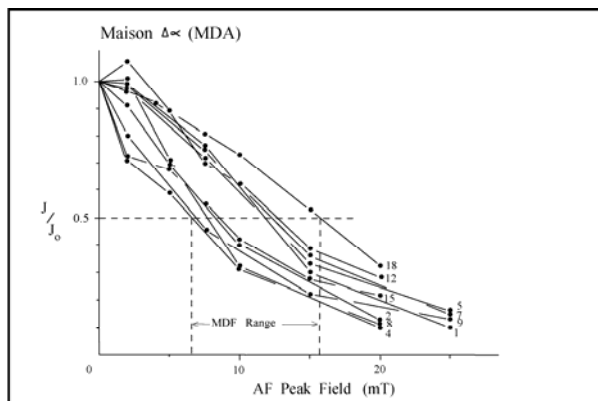


Figure 8. Normalized decay of NRM to stepwise AF demagnetization for Malia $\Delta\alpha$ (MDA) burnt mud-brick samples. MDF (Median Destructive Field).

DISCUSSION, (MAISON $\Delta\alpha$)

According to (Pelon, 1970), there is a general archaeological opinion that Maison $\Delta\alpha$, together with the palace area and other quarters were destroyed by fire at the end of LMIB and there is no ceramic evidence (i.e. LMIB style pottery) positively identified from Maison $\Delta\alpha$. Most of the pottery recovered from this quarter was common LMIA in style. The low, in situ, burnt walls of Maison $\Delta\alpha$ showed promise for the feasibility of archaeomagnetic sampling,

however, there must remain some doubt over the accuracy of the magnetic compass in these circumstances. It should be noted that, where, in other circumstances, magnetic and sun compass orientations could both be taken and able to be compared, strike directions were within a few degrees of each other. Samples were taken from walls at right-angles to one another and checked to see if any magnetic directional results were systematically influenced (magnetic refraction) by particular orientations of walls. This phenomenon does not appear to be present. The VRM components were removed at relatively low AF fields and the strength of magnetization allowed for a full AF demagnetization analysis in most cases to establishment of coercivity spectra and determine stability indices. The remanent magnetization proved to be generally very stable and the directions obtained exhibited a good directional grouping with a low α_{95} . The direction obtained is statistically the same as that obtained for the palace (area 13), possibly indicating simultaneous fire destruction of the two areas.

ARCHAEOMAGNETIC DIRECTIONAL-RESULTS FROM QUARTIER ϵ SALLE 3, COUPE 2)

Introduction

The site at the Quartier ϵ is described by (Tiré and Éffenterre, 1966) and (Pelon, 1970). It was discovered by Demargue and Dessenne in 1931 (in Pelon, 1970) and it is believed to be late Minoan (MR) and to have been reoccupied in its eastern area in LM II after the general catastrophe in Late Minoan times. There is a succession of layers of ash throughout its occupation history. Trenches A3 and A4, (layer 1), (Pelon, 1970) attributes to ceramic phase IV and reports the occurrence of pumice.

Archaeomagnetic Sampling of Salle 3, Coupe 2

A roofed excavated area (salle 3) to the west of Maison ϵ exhibits a vertical wall (coupe 2) with a very obvious “near-horizontal” burnt layer, believed by (Pelon, 1970) to correspond to ceramic phase IV = LM II. Thirty four samples were taken from this burnt horizon in coupe 2. The horizon is well carbonized with the fill in-

cluding some sherds. A magnetic compass had to be used and samples were extremely friable and coated with a plastic emulsion to prevent disintegration.

Initial NRMs

The NRM intensity values ranged from approximately 1 to 320 mAm⁻¹; a large range, possibly reflecting the magnetic composition type or abundances within the material. Small sherd fragments present in some samples, possibly contributed to the higher remanence. More than half of the samples gave a low NRM intensity value of less than 5 mAm⁻¹. The NRM directions are shown in Fig.9(a), with the mean direction for all samples (N = 34) :- Dec = 1.5°, Inc. = 44.9°, α₉₅ = 24.4°, k = 1.9. Eight samples had negative inclinations whilst a further 10 exhibited much lower inclinations than expected. The NRM directions which had directions consistent with a ‘normal’ magnetic field are represented in Fig.9 (b) and the mean value from (N = 15) :- Dec = 6.4°, Inc = 59.6°, α₉₅ = 7.4°, k = 27.1.(Table 3).

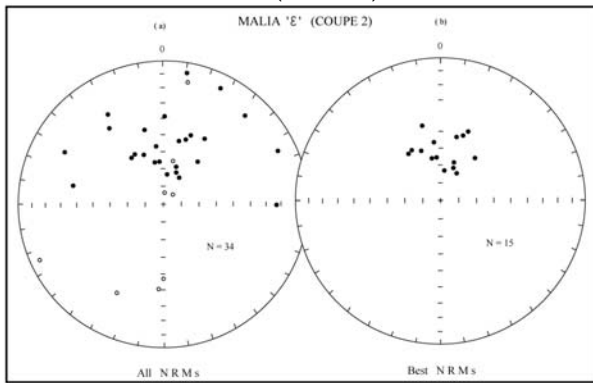


Figure 9. Lower hemisphere stereographic projections showing the archaeomagnetic remanence directions for (a) All NRMs and (b) “Best” NRMs.

Introduction and Archaeomagnetic Sampling

Salle III in the west of Quartier ε, appears to have been a kitchen area as some bones and burnt grain were found near a well preserved hearth (Fig.10). Pelon. (1970) dates the hearth to “mur de niveau III” (i.e.ceramic phase III equivalent to LMI).

Photo 2 and (Fig.10) show that two retaining “dressed” blocks sit upright and almost at right angles to the back wall of the hearth. There is

good evidence that the hearth stones are well baked but there is uncertainty over whether the two blocks are still in situ. Nineteen samples were taken using a magnetic compass from the well baked surface of the back wall of the structure which appeared to be in situ and against the large retaining wall of salle III. Many samples were very friable and made of a well-oxidized burnt red clay.



PHOTO 2.

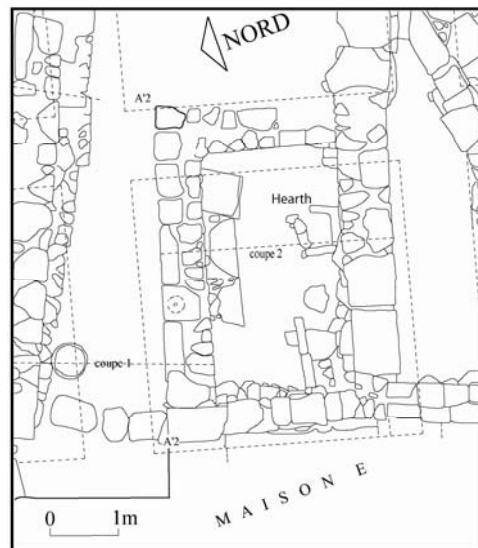


Figure10. Sketch plan of Salle 3 with hearth. Excavated area is to the west of Quartier ε. Modified after Pelon (1970). Fouilles Executees.

Initial NRMs

The initial NRM intensities range from approximately 10 to 680 mAm⁻¹ and the NRMs are shown in (Fig.11a) and (Table 4). The NRM mean direction for all samples (N = 19) was, Dec = 286.7°, Inc.= 59.3°, α₉₅ = 17.5°, k = 4.7. Only 7 samples had directions consistent with that of the expected ‘normal geomagnetic field’.

TABLE 3. Archaeomagnetic Directional Results, Malia ϵ (coupe 2).

Malia ϵ (coupe 2)							
N.R.M.							
Sample No.	Dec. ^o	Inc. ^o	Int. (mAm ⁻¹)	Sample No.	Dec. ^o	Inc. ^o	Int. (mAm ⁻¹)
1	354.1	64.9	3.4	18	338.9	59.3	5.1
2	349.4	65.3	17.2	19	14.4	52.6	106.1
3	331.1	56.6	19.5	20	38.9	58.1	4.8
4	329.8	27.8	3.7	21	4.1	-82.7	4.9
5	325.3	34.6	1.7	22	65.5	14.5	229.1
6	209.6	-31.1	247.1	23	31.1	72.1	2.8
7	183.5	-41.5	321.1	24	181.1	-47.7	5.3
8	10.5	7.8	11.5	25	22.6	70.2	7.6
9	44.1	-81.4	3.6	26	42.8	17.4	1.8
10	12.5	-64.1	16.1	27	353.4	55.6	1.5
11	32.1	44.7	18.6	28	90.5	23.5	1.6
12	8.8	73.1	2.4	29	11.9	-15.1	1.9
13	327.8	57.2	5.6	30	19.8	67.2	12.4
14	246.2	-6.7	168.1	31	283.5	36.1	1.4
15	19.8	50.2	4.3	32	299.3	22.9	1.8
16	1.3	39.1	6.8	33	26.3	10.9	1.6
17	346.1	45.2	12.6	34	21.1	46.7	2.8

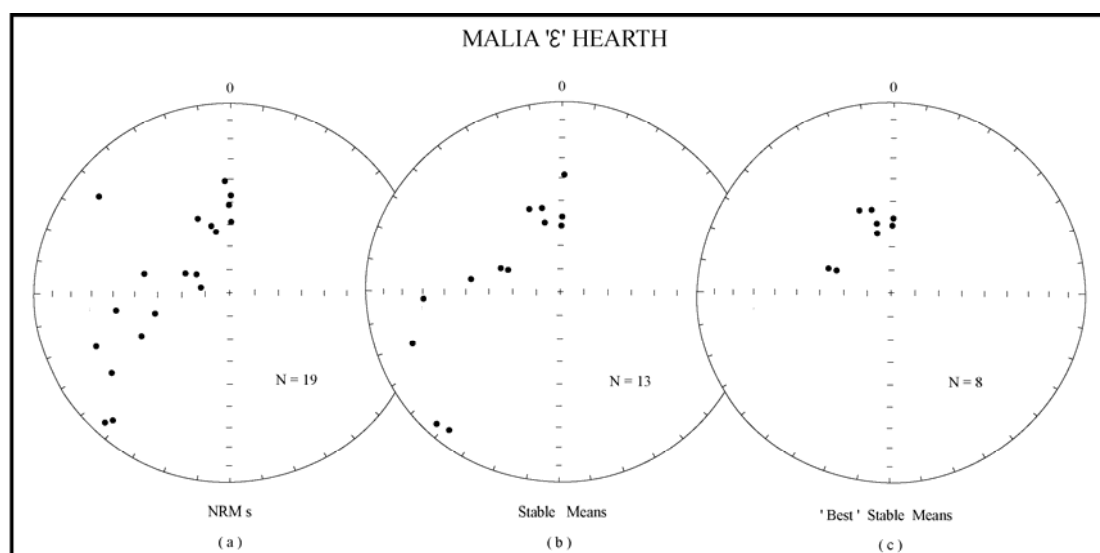


Figure 11. Lower hemisphere stereographic projections showing the archaeomagnetic remanence directions for (a) NRM s and after stepwise AF demagnetization (b). All stable mean direction and (c) "Best" stable mean directions.

AF Demagnetization

Samples with low initial NRM intensity, poor measurement repeatability or anomalous directions were excluded from any further AF demagnetization treatment. The 13 remaining samples of higher initial NRM intensities were stepwise AF demagnetized in steps of 5.0, 10.0, 15.0 and 20.0 mT and in some cases up to 30 mT peak field. Figure 12 shows typical behavior the remanence decay for 8 samples. The MDF range

is low and in a narrow range between approximately 12 and 16 mT. The stability indices ranged from, approximately 1 to 11, with 8 samples in the 'very stable' range (Table 4). The mean directions calculated over the most stable ranges of peak field values, (Fig. 11b) show that AF 'cleaning' did not significantly change the NRM directions. The mean direction from (N = 13) :- Dec = 291.2°, Inc. = 58.4°, α_{95} = 23.5°, k = 4.0. In fact the AF demagnetization has served to increase the scatter. The 'best' mean direction

was calculated using only samples whose directions were 'consistent' with that of an expected normal magnetic field and of extremely high magnetic stability (Fig.11c) for, (N = 8) :-Dec. = 327.8°, Inc.= 62.8° , $\alpha_{95} = 12.2^{\circ}$, k = 21.4.

TABLE 4. Archaeomagnetic Directional Results (Hearth in Maison ε, Salle 3).

Malia ε (Hearth)					
Sample No.	N.R.M.			Stable Mean.	
	Dec. ^o	Inc. ^o	Int. (mAm ⁻²)	Dec. ^o	Inc. ^o
1	223.8	10.9	131.9	218.5	8.5
2	245.5	48.1	12.4	unstable	
3	236.5	26.2	8.9	unstable	
4	348.1	62.9	202.1	347.1	63.4
5	357.6	40.5	7.2	unstable	
6	0.9	58.1	89.1	0.8	57.4
7	345.9	59.7	49.2	347.3	59.8
8	283.5	77.6	12.2	unstable	
9	255.9	57.1	10.2	unstable	
10	300.1	73.5	76.4	291.8	62.7
11	307.5	16.5	11.2	unstable	
12	224.4	7.3	750.0	223.6	6.2
13	0.1	47.1	128.2	1.7	39.4
14	359.5	61.1	66.4	0.5	60.3
15	284.3	52.9	329.1	278.4	51.3
16	262.1	41.2	69.2	267.3	30.1
17	337.5	55.4	239.9	338.8	51.8
18	248.9	27.6	159.8	251.1	20.2
19	295.3	69.1	67.9	292.9	64.8

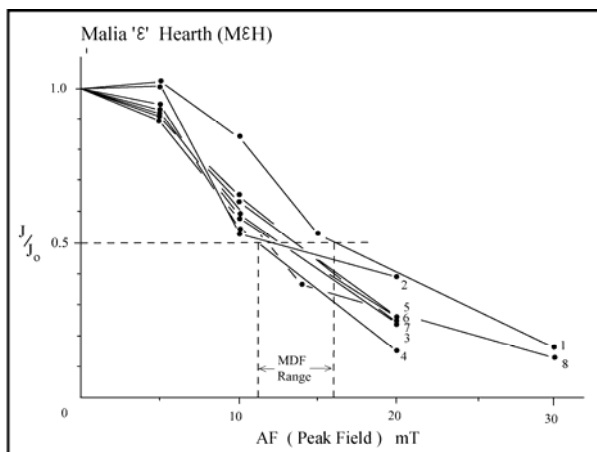


Figure 12. Normalized decay of NRM to stepwise AF demagnetization for Malia ε hearth samples. MDF (Median Destructive Field).

Discussion, (Hearth, Maison ε, Salle 3)

The hearth is archeologically dated as Late Minoan but the archaeomagnetic directions obtained are disappointing in that the scatter (α_{95}) is large and not easily explained. The magnetic

stability is generally good and there are little or no secondary components of magnetization that may have interfered with the isolation of the TRM direction. There appears, however, to be a tendency for the archaeomagnetic directions obtained to prefer a western declination. One possibility of explaining this may be that a systematic error was introduced during the field orientation stage caused by the use of the magnetic compass. It is possible that the magnetic moment of the structure (ie) the back supporting thick wall which aligns E-W, influenced the recorded strike directions. There are though, two difficulties with this argument. Firstly, some sample do appear to accurately recorded the ambient field direction and are thus apparently not affected by such an orientation error and secondly, the strength of the magnetic moment (inferred from the measured samples) of the hearth structure is regarded as too weak to affect the magnetic compass to any significant extent. Other possible but unlikely explanations are the development of a CRM (Chemical Remanent Magnetization) with the creation of some small amounts of hematite (of which there is little or no evidence) or the acquisition of a VRM which was not easily 'removed'. However, these types of 'secondary' acquisition would have to have been selective (i.e) in some samples and not in others. Another possibility is the transport of material by bioturbation although there is no obvious evidence. In view of these uncertainties, the results from this hearth are presented "as measured" but perhaps, further future sampling could be justified.

DISCUSSION-CONCLUSION

The archaeomagnetic directional result obtained from Malia Palace (area 13, sun compass oriented) appears to be precise and statistically identical to that obtained from Malia (Maison Δα, magnetic compass oriented). Liritzis and Thomas (1980) sampled kilns at Hagia Triada and Kato Zakros, orientating samples using both sun and magnetic compasses. Comparisons of the strike directions obtained for the two methods showed considerable discrepancy in both sites. Liritzis (1985) suggests that magnetic compass oriented results should be con-

sidered, in certain cases, as extremely dubious as they are affected by stray magnetic fields present in a magnetized structure such as a kiln, many pithoi, burnt mud-brick, metal fences etc. and that the sun compass provides more accurate results. Other possible effects that might alter the reliability of measurements of declination and inclination include earthquake activity in the Aegean seismic arc which produces tilting and local subsidence. For example, there is tectonic instability of the Knossos region in central Crete with respect to eastern Crete, (Pichler and Schiering, 1977). Such land movements must also have an effect on the supposed stable burnt structures and ash materials (Liritzis 1985). Inclination values are not affected by compass orientation and a comparison of the values obtained from Malia (area 13, Dec.= 356.1° **Inc.= 59.60** $\alpha_{95}= 1.4^\circ$) and Maison $\Delta\alpha$ (Dec.= 356.2° **Inc.= 59.9** $\alpha_{95}= 1.4^\circ$ with the kilns (Liritzis and Thomas 1980) at Hagia Triada, (**Inc.= 58.7** $\pm 0.6^\circ$) and Kato Zakros, (**Inc.= 56.6** $\pm 3.3^\circ$), indicates that they are statistically identical. Although magnetic compass orientations were necessitated at Maison $\Delta\alpha$, directions do not appear to have been affected by stray magnetic fields and are consistent with those results from Malia (area 13).

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The constituent magnetic grains, probably single domain titanomagnetite within the burnt mud brick, (especially in area 13), proved to be capable of carrying a unidirectional hard TRM. The archaeomagnetic directions from these two sites are statistically (within a 95% confidence level) identical to those of other sampled 'fired' sites on Crete (Downey and Tarling, 1984). (ie) :- Phaestos (Palace), Gournia (house Ac 16), Hagia Triada (Palace), Slavokambos (villa) and at Knossos (kiln 2, in the former stratigraphical museum extension site). These directions are, however, statistically different from the archaeomagnetic directions (particularly in inclination) from those obtained at Kato Zakros (Palace), Palaikastro and Makrygialos (villa). Liritzis (1985) however, has expressed reservations as to the existence of any significant or identifiable directional differences between these sites in central and eastern Crete.

Archaeomagnetic directions obtained, from the more friable material of the 'ash/clay horizon' and hearth, Malia (Quartier ϵ), despite the fact that some samples showed good magnetic stability, proved to be "disturbed" in some way and as a consequence produced less accurate results.

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