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ARCHAEOMAGNETIC ANALYSIS OF SAMPLES FROM A BELL PIT AT GREYFRIARS, NORWICH

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Summary

An archaeomagnetic study has been carried out of material recovered from a bell pit excavated in 1994 at Greyfriars in Norwich. The samples were found to contain a stable thermoremanent magnetisation which has provided a record of the geomagnetic field at the time of firing. Comparison of the mean archaeomagnetic vector in the structure with the UK Master Curve indicates that it was last fired either between 1010 and 1095 AD or between 1490 and 1525 AD. From a study of the components which comprise the natural remanent magnetisation, the later date appears to be favoured.

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INTRODUCTION

This report describes the archaeomagnetic analysis and dating of oriented samples obtained from a bell pit, of possible Medieval date, at Greyfriars in Norwich. The research was carried out on behalf of the Ancient Monuments Laboratory of English Heritage, with the aim of determining the time of last firing and casting in the bell pit.

SAMPLE PREPARATION

Archaeomagnetic sampling was carried out by Paul Linford on 9th February 1994 using the button method described in Appendix A. The collection initially comprised 19 specimens of which 11 were taken from the red clay tile floor of the excavated bell pit, while 8 were obtained from a black-brown area surrounding this floor. The samples were delivered to GeoQuest Associates in October 1996.

As received, the specimens were extremely friable and hence were immediately consolidated by impregnation with a dilute solution of PVA in acetone. Each sample was then cut with a water cooled diamond saw until the button retained a volume which fitted the standard 25x25mm specimen holder inside the archaeomagnetic magnetometer. After drying at room temperature, a further protective coating of PVA was applied to the samples.

Unfortunately, owing to the weakness of the fired material (despite PVA impregnation) a number of specimens disintegrated during the cutting procedure, leaving a total of 10 samples for archaeomagnetic study.

MEASUREMENT

The natural remanent magnetisation (NRM) of all the samples was measured in a Molspin fluxgate spinner magnetometer (Molyneux, 1971) with a minimum sensitivity of around $5x10^{-9}Am^2$. Remanence directions were corrected for field orientation in accordance with data supplied by the Ancient Monuments Laboratory. The resulting vectors are plotted on the stereogram of Figure 1 in which the specimens from the red clay floor are represented as circles while those from the surrounding black-brown material are plotted as squares. These data are also listed in Table 1.

Generally, the NRM of an archaeological material will comprise a primary magnetisation, (in this case presumed to be of thermal origin), together with secondary components acquired in later geomagnetic fields due to diagenesis or partial reheating. Usually, a weak viscous magnetisation is also present, reflecting a tendency for the remanence to adjust to the recent field. If the secondary components are of relatively low stability, then removal by partial demagnetisation will leave the primary remanence of archaeological interest. A pilot specimen (NGF16) with typical NRM characteristics was demagnetised incrementally, up to a peak alternating field of 40mT and the changes in remanence recorded in order to identify the components of archaeomagnetism and their stability (Figure 2).

From a study of the pilot sample behaviour, an alternating field of 2.5mT was chosen which would provide for the optimum removal of secondary components of magnetisation in the remaining samples. After partial demagnetisation in this field, sample remanences were remeasured and the results are shown in Figure 3 in which the circle and square symbols again distinguish between the red clay floor and black-brown materials.

RESULTS AND DISCUSSION

General

Measured magnetic moments of natural remanent magnetisation in the set of samples varied from 2.0 to 375.5 $\mathrm{mAm^{-1}x10^{-3}}$ reflecting differences in sample volume rather than significant variability in specific magnetisation. No contrast in remanence intensity was detected between samples from the red clay floor and those from the black-brown material. Moreover, as Figure 1 and 3 show, the two sets of vectors (circles and squares in the stereograms) are indistinguishable and hence they have been statistically combined in the analysis which follows.

Analysis

Despite their friable composition the two sets of specimens (with two exceptions) have provided a well-defined grouping of archaeomagnetic vectors which has clearly been geomagnetically controlled. The two outliers, NGF1 and NGF9, were exceptionally small and it is possible that the remanence of the plastic buttons has contributed a significant error to their archaeomagnetic vectors: these samples have therefore been rejected from the remaining analysis.

Stepwise demagnetisation of sample NGF16 produced a slight reduction in the remanence inclination which decellerated as the strongest alternating magnetic fields were imposed. This result can be interpreted as indicating that the natural remanence contains two components: a single primary vector partly overprinted by a weaker secondary magnetisation acquired in a later geomagnetic field with steeper inclination and similar declination. Since the secondary magnetisation is relatively weak and of low coercivity, it was decided to partially demagnetise the remaining samples in a field of 2.5mT in order to better isolate the primary archaeomagnetic vector of interest for dating. Only minor changes in the samples vectors and grouping were brought about by this procedure (Figure 3).

Absolute Dating

A standard correction was used to convert the mean archaeomagnetic vector to Meriden, the reference locality for the British Master Curve (Noel & Batt, 1990).

Figure 4 then compares the new vector and its associated error envelope to the Master Curve segment 600AD-2000AD.

The mean archaeomagnetic vector is positioned within a loop of the curve which leads to a possible ambiguity in the absolute dating. The dotted lines in Figure 4 show the dates which can be inferred on the basis that some error has arisen in the archaeomagnetic record of the geomagnetic declination. Such an error may have arisen from 'magnetic refraction' of the Earth's magnetic field in the fired structure or may be due to some consistent mis-orientation in the field samples (less likely).

Two possible date ranges have been estimated by considering the extent of overlap between the vector circular standard error and the Master Curve. These are as follows:

1010-1095 AD
or
1490-1525 AD

Geophysically, the later date of 1490-1525AD may favoured since the demagnetisation results show that the secondary magnetisation in the fired material was acquired in a steeper geomagnetic field (whereas the field after 1010-1095AD became *shallower*).

CONCLUSIONS

The results of this research can be summarised as follows:

1 An archaeomagnetic study has been carried out of material recovered from a bell pit excavated in 1994 at Greyfriars in Norwich. The samples were found to contain a stable thermoremanent magnetisation which has provided a record of the geomagnetic field at the time of firing.

2 Comparison of the mean archaeomagnetic vector in the structure with the UK Master Curve indicates that it was last fired either between 1010 and 1095AD or between 1490 and 1525AD. From a study of the components which comprise the natural remanent magnetisation, the later date appears to be favoured.

REFERENCES

Clark, A.J., Tarling, D.H. & Noel, M., 1988. Developments in archaeomagnetic dating in Britain, *Archaeometry*, 15, 645-667.

Molyneux, L., 1971. A complete result magnetometer for measuring the remanent magnetisation of rocks, *Geophys. J. R. astr. Soc.*, 24, 429-433.

Noel, M. & Batt, C.M., 1990. A method for correcting geographically separated remanence directions for the purpose of archaeomagnetic dating, *Geophys. J. R. astr. Soc.*, **102**, 753-756.

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TABLE 1

ARCHAEOMAGNETIC RESULTS FROM NORWICH GREYFRIARS

Sample	LITH	J	D	I	A.F.	D	I	
NGF1	RCL	45.1	351.4	-46.3	2.5	349.9	-46.8	R
NGF4	RCL	38.1	20.8	68.2	2.5	17.4	67.4	
NGF5	RCL	102.8	17.0	62.6	2.5	15.6	63.4	
NGF8	RCL	23.8	5.5	70.8	2.5	9.3	70.8	
NGF9	RCL	2.0	10.2	43.0	2.5	11.1	41.2	R
NGF10	RCL	33.1	5.2	65.3	2.5	4.2	65.7	
NGF16	BBR	255.4	19.0	68.0	2.5	20.1	67.5	
NGF17	BBR	375.5	15.0	68.0	2.5	13.8	68.9	
NGF18	BBR	310.4	31.0	67.8	2.5	29.5	68.4	
NGF19	BBR	294.9	27.1	66.0	2.5	25.5	66.2	
Mean of Feature			17.7	67.3		2.5	57.8	
			alpha95=2.9	k=358.4		alpha95=2.6	k=438.7	
						c.s.e.=1.4		
AT MERIDEN						**16.5**	**66.9**	

NOTES: LITH = Lithology, 'RCL' = red clay, 'BBR' = black-borwn material. D = declination, I = inclination, J = intensity of measured magnetic moment in units of $mAm^{-1}x10^{-3}$. A.F. = peak alternating demagnetising field in milliTesla. alpha95 is the semi-angle of the 95% cone of confidence, c.s.e. is the circular standard error and k is the precision parameter. Samples marked 'R' have been rejected from the analysis.

FIGURE 1

Directions of natural remanent magnetisation in samples from the bell pit shown on an equal area stereogram. In this representation, declination increases clockwise while inclination increases from zero at the equator to 90 degrees at the centre of the projection. Circles are used to represent vectors from the red clay floor and squares vectors from the surrounding black-brown material.

CONTEXT 12257, NRM

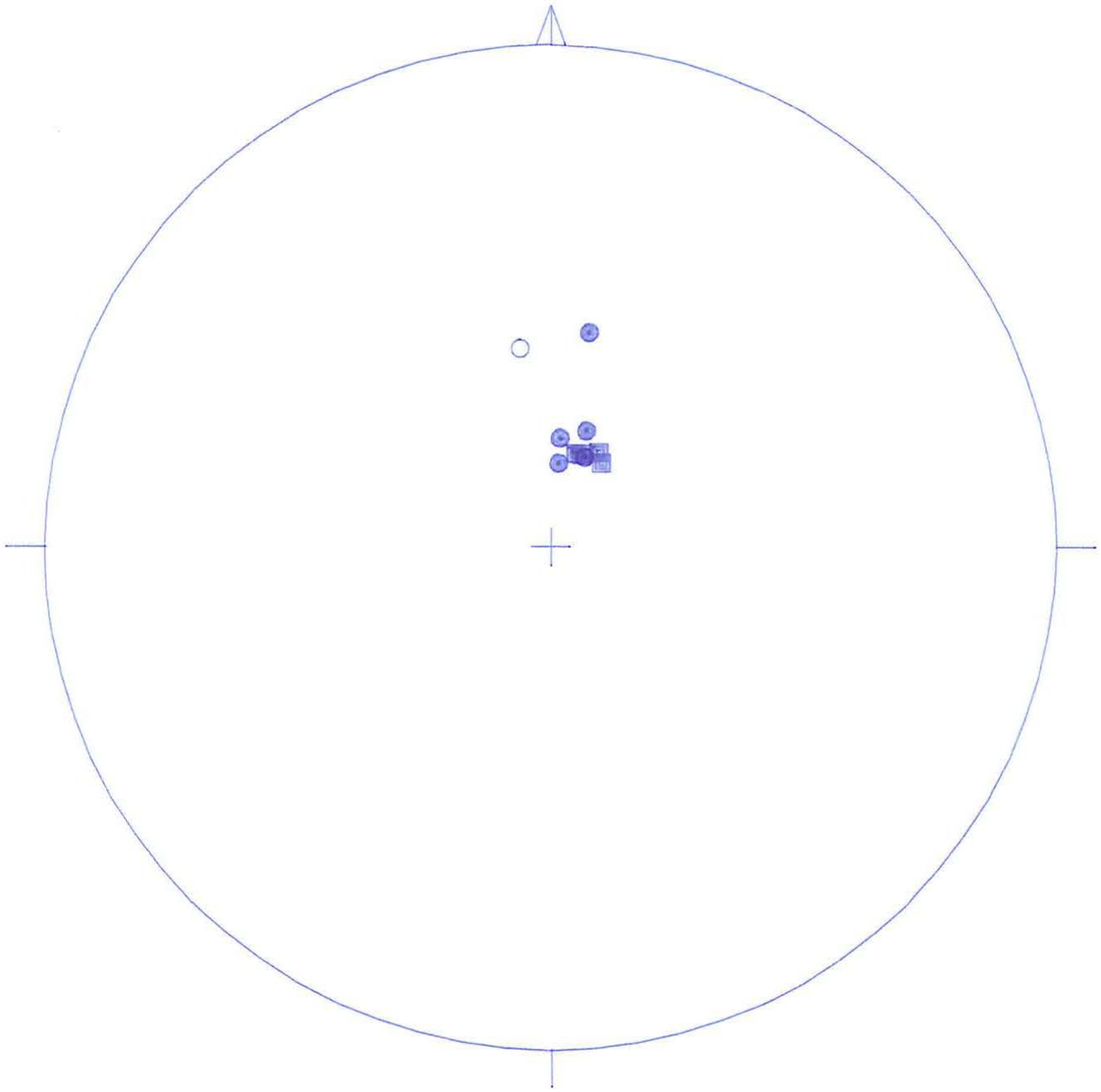


FIGURE 2

Changes in the direction and intensity of remanent magnetisation in a test sample from the structure during stepwise demagnetisation by alternating magnetic fields.

NGF16

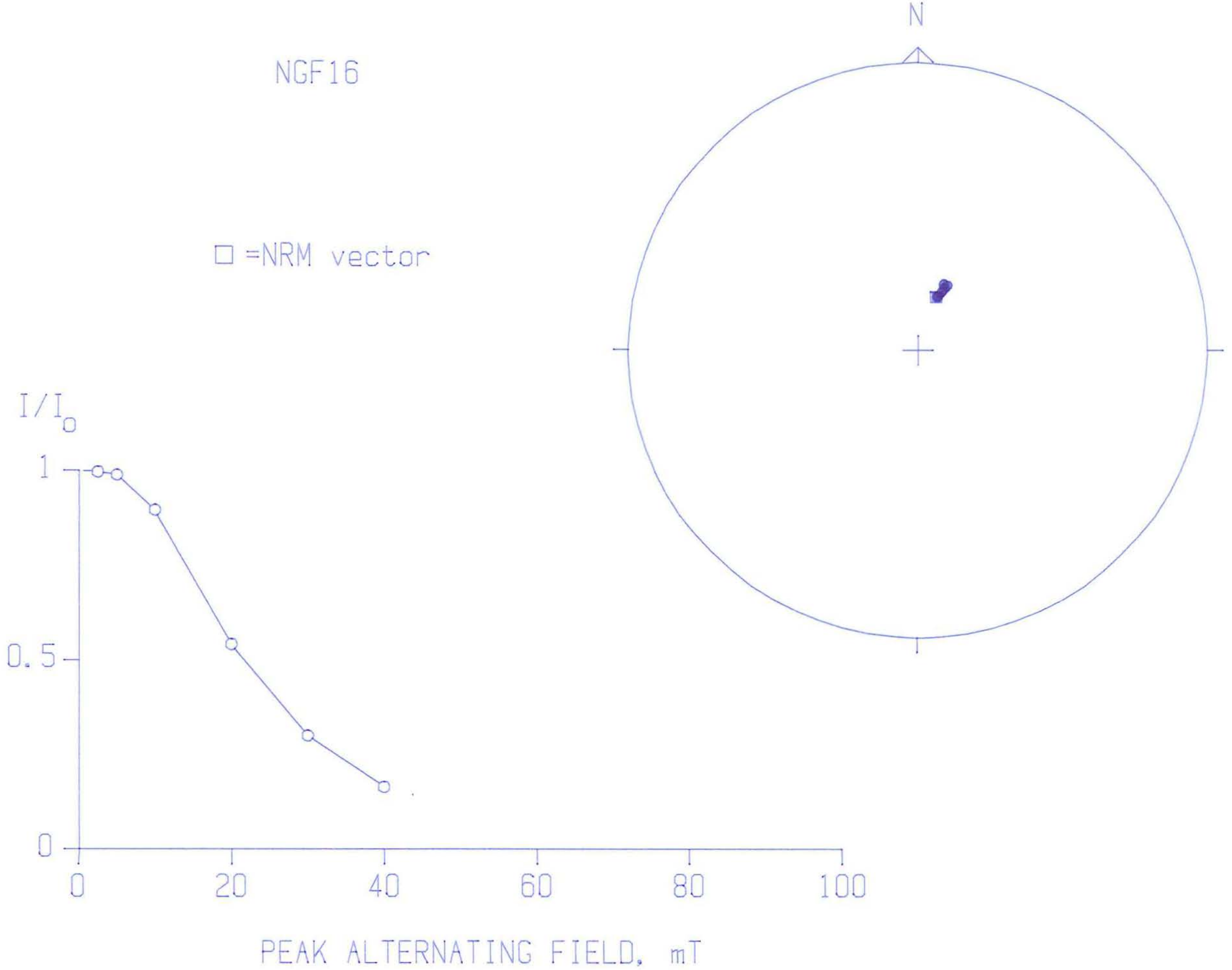

□ =NRM vector
N
I/I$_0$
1
0.5
0
0
20
40
60
80
100
PEAK ALTERNATING FIELD, mT

FIGURE 3

Directions of remanent magnetisation in samples from the bell pit after partial demagnetisation in an alternating field of 2.5mT. Circles and squares are used to represent the red clay and black-brown material, as in Figure 1.

CONTEXT 12257, 2.5mT

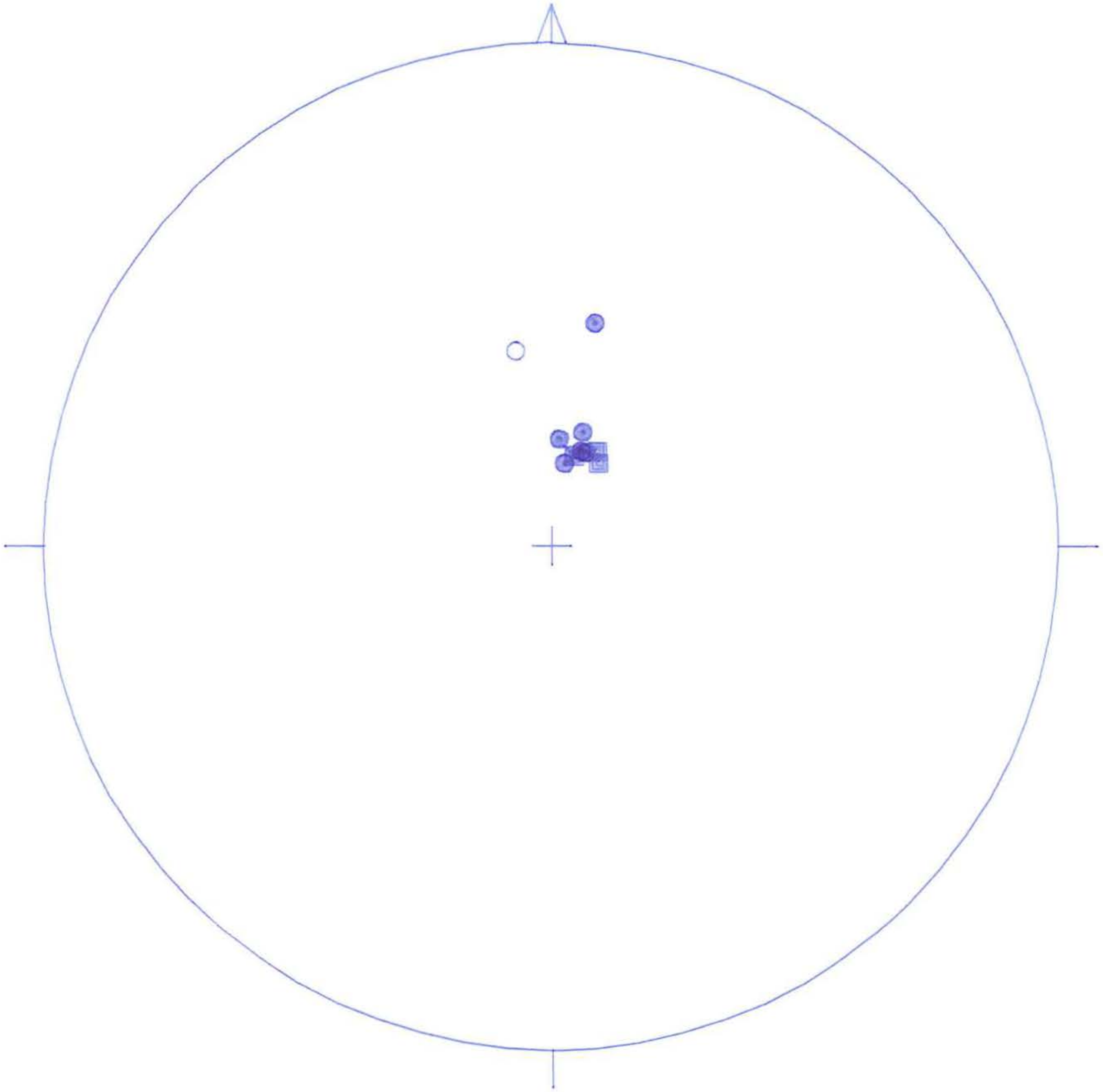
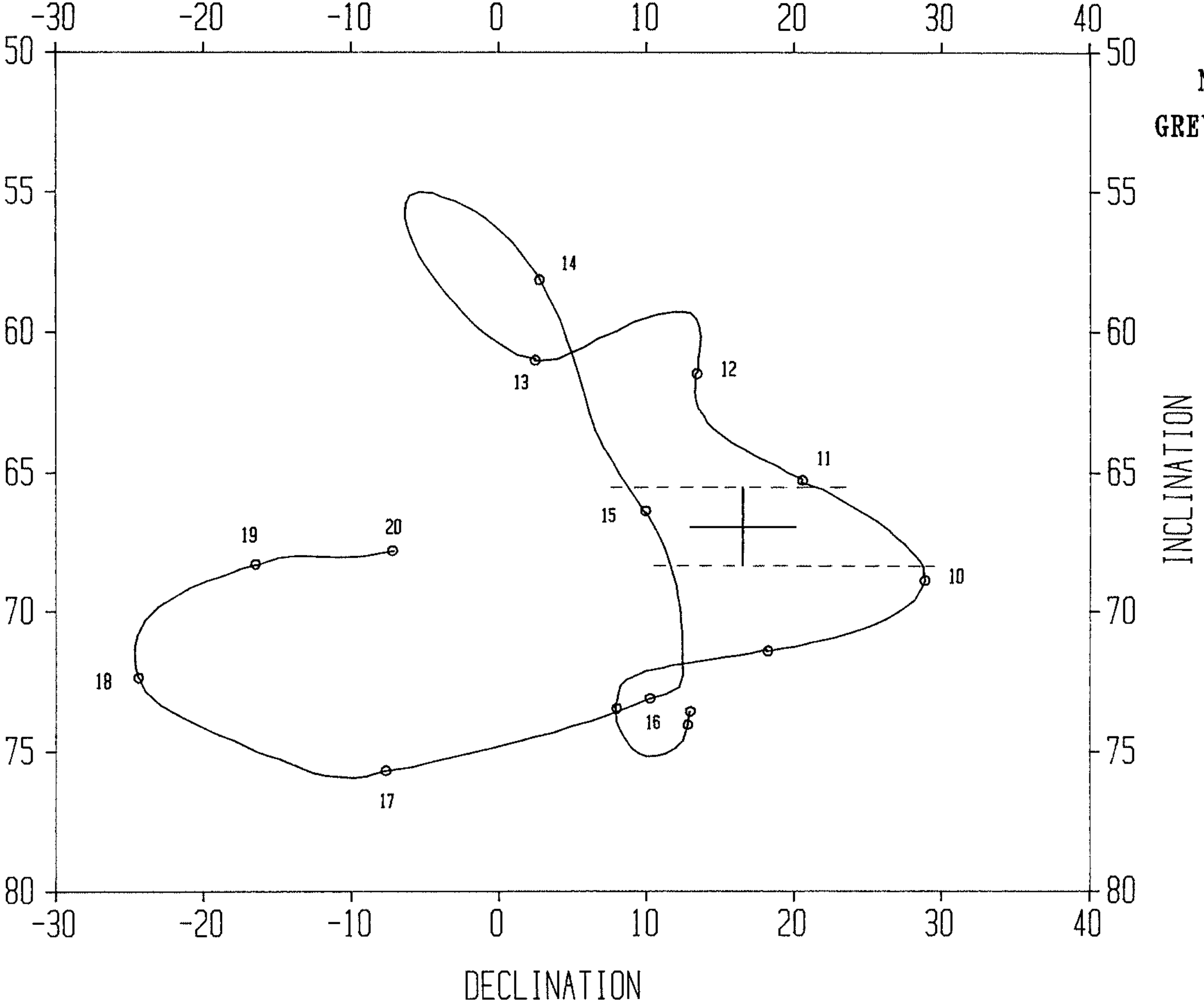


FIGURE 4

Comparison between the mean archaeomagnetic vectors in the bell pit, corrected to Meriden, with the UK Master Curve. Numbers refer to the time in centuries.

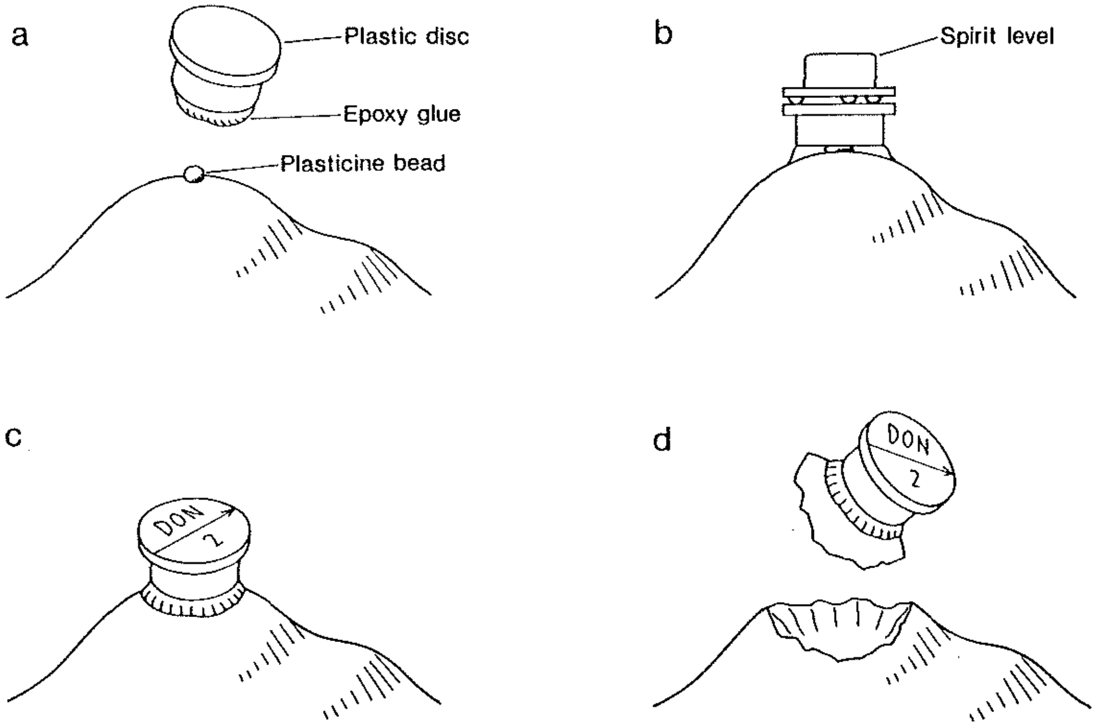

NORWICH
GREYFRIARS
-30
-20
-10
0
10
20
30
40
50
55
60
65
70
75
80
14
13
12
11
15
10
19
20
18
16
17
DECLINATION
INCLINATION

APPENDIX A

Principles of Magnetic Dating

Magnetic dating is based on comparing the remanent magnetisation in an archaeological structure with a calibrated reference curve for the geomagnetic secular variation. Two distinct methods have evolved. The *intensity* technique relies on obtaining estimates of the past strength of the Earth's magnetic field while *directional* magnetic dating uses archaeomagnetic measurements to derive the orientation of the geomagnetic vector in antiquity. Intensity dating can only be applied to fired materials which have acquired a thermoremanent magnetisation upon cooling from high temperatures (>600°C) while the directional method enables the age of a broader range of archaeological materials to be determined. For example, sediments and soils may have acquired a dateable 'detrital remanence' if magnetic grains had been aligned by the ambient field during deposition. The growth of magnetic minerals during diagenesis or as a result of manufacturing processes can also give rise to a magnetisation which may enable materials such as iron-rich mortars, for example, to be dated. However hearths, kilns and other fired structures are the most common features selected for magnetic dating primarily because their thermoremanence is generally strong, stable and sufficiently homogeneous that the ancient field can be determined with sufficient precision from a small set of specimens. An analysis of dated archaeomagnetic directions, largely from fired structures, together with lake sediment and observatory records has enabled a master curve for the UK region to be synthesised for the period 2000 B.C. to the present (Clark, Tarling & Noel, 1988).

For directional magnetic dating it is essential to obtain specimens of undisturbed archaeological material whose orientation with respect to a geographic coordinate frame is known. A number of sampling strategies have evolved, enabling specimens to be recovered from a range of archaeological materials with orientations being recorded relative to topographic features, the direction of the sun, magnetic or geographic north. For this feature the miniaturised 'button method', illustrated overleaf, was employed. Modern archaeomagnetic magnetometers are sufficiently sensitive that only small volumes of material (~1ml) are required for an accurate remanence measurement. This has the advantage of reducing the impact of sampling on archaeological features - of particular significance if they are scheduled for conservation and display.


a
Plastic disc
Epoxy glue
Plasticine bead
b
Spirit level
c
DON
2
d
DON
2

NOTES

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