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ARCHAEOMAGNETIC DATING: THE ROYAL MINT, LONDON

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Summary

A fired clay surface, thought to have been a hearth, was discovered during archaeological excavation at the Royal Mint site in London. Archaeomagnetic dating suggests that the feature was last fired towards the end of the 13th centry AD although, owing to crossovers in the archaeomagnetic calibration curve used, two date ranges in the Roman period must also be considered. The archaeomagnetic measurements also suggested that the feature had been disturbed slightly since this date.

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Archaeomagnetic Dating: The Royal Mint, Royal Mint Street, London.

Introduction

The land previously occupied by the Royal Mint in London was excavated during 1986 and 1987, before the site was redeveloped. During the excavation a layer of burnt clay, thought to have been a hearth, was discovered, associated with contexts containing medieval remains.

This layer, feature number 4052, was sampled for archaeomagnetic dating to help establish a chronology for the site. Sampling was carried out on the 10th of December 1986 by the author and A David of the Ancient Monuments Laboratory. Laboratory measurements were made by N Linford and evaluated by the author.

Method

Samples were collected using the disc method (see appendix, section 1a) and orientated to True North with a gyro-theodolite. Fourteen samples were recovered, all were of a mottled orange yellow colouration. Whilst the feature appeared to be intact, there was some evidence of cracking on its surface; also a hole, related to a later phase of occupation, had been cut through it at one side; hence, it is possible that the feature was disturbed after its last firing.

Results

All the measurements discussed below were made using the equipment described in section 2 of the appendix. Measurements of the directions of Natural Remanent Magnetisation (NRM) of the samples are tabulated in table 1; the corrections discussed in sections 3b and 3c of the appendix have been applied. A graphical representation of the distribution of these directions is depicted in figure 1.

It can be seen from the this figure that the directions do not form a single cluster. Six of the samples form a close group, with three more forming a subgroup with a higher declination. The remaining samples are scattered apparently at random and three of these, MINT02, MINT05 and MINT08 do not fall within the graph area. Therefore, their NRM measurements were excluded from the calculation of the mean thermoremanent direction (see appendix, section 3d).

A graphical representation of this mean, superimposed on the calibration curve (see appendix, section 4a), is depicted in figure 2. This mean direction is:

Dec = 5.905 +/- 4.507°; Inc = 62.201 +/- 2.102°;
Alpha-95 = 3.945°;

The alpha-95 statistic shows that the precision of this estimate of the mean thermoremanent direction is poor. Furthermore, it does not coincide with any point on the calibration curve and no date range can be derived from it.

The anomalous scattering of the remanent directions, could be caused by an unstable, viscous, component in the magnetisation, or by disturbance of the feature since it was last fired. To investigate the stability of the remanence, a pilot sample, MINT07, was partially demagnetised in 2mT increments, to a maximum value of 30mT (see appendix, section 2b). Measurements of the remaining remanent magnetisation at each stage are tabulated in table 2. The decline in intensity of magnetisation with increasing AF demagnetisation is plotted in figure 3; the variation in the remanent direction is depicted in figure 4.

The characteristic, smooth reverse "S" shape of figure 3 shows that the magnetisation of the sample was stable. However, at low values of demagnetisation this curve is steeper than would be expected for an ideal sample, suggesting that some viscous remanent magnetisation has been acquired since the clay was last fired. Inspecting figure 4, it can be seen that there was a marked increase in the declination of the remanent magnetisation at partial demagnetisations up to 4mT before the direction stabilised in the range between 4mT and 12mT.

Since viscous magnetisation had clearly affected the measured NRM directions of the samples, it was decided to remeasure their thermoremanent magnetisations after partial demagnetisation in a 6mT AF field. The choice of this value was based on the range of partial demagnetisations for which the remanent direction was stable in the pilot demagnetisation of sample MINT07. These measurements are tabulated in table 3, corrected according to sections 3b and 3c of the appendix, and their distribution is depicted in figure 5.

This figure shows that the grouping of remanent directions has been improved by partial demagnetisation. Sample MINT06, MINT10 and MINT14 still form a subgroup of slightly higher declination and, since these three samples all came from the northern edge of the feature, this suggests that some disturbance since firing has occurred. Only one sample, MINT01, lies outside the graph area and its direction is so different from the others that it is likely that it was not aligned correctly during sampling. MINT01 was therefore excluded from the recalculation of the mean thermoremanent direction (see appendix, section 3d):

Dec = 2.148 +/- 2.317°; Inc = 60.770 +/- 1.131°;
Alpha-95 = 2.091°;

This mean is plotted graphically, superimposed on the calibration curve, in figure 6. The alpha-95 statistic shows that the precision of this estimate is much improved and it can be seen in figure 6 that the mean direction now coincides almost exactly with a point on the calibration curve, giving a date range of:

1286 - 1309 cal AD at the 68% confidence level.
1271 - 1325 cal AD at the 95% confidence level.

Unfortunately, two other segments of the calibration curve pass within the circle formed by the estimated mean's precision limit. Hence, two other date ranges for the feature must be considered, since they cannot be ruled out by the archaeomagnetic evidence alone (see appendix, section 3c):

200 - 226 cal AD at the 68% confidence level.
177 - 239 cal AD at the 95% confidence level.

269 - 289 cal AD at the 68% confidence level.
261 - 298 cal AD at the 95% confidence level.

Conclusions

Although three date ranges are quoted above, all valid in archaeomagnetic terms, it is hoped that the archaeological context of the feature will allow the two Roman dates to be discounted. The final mean thermoremanent direction lies a slight distance away from the segment of the calibration curve that corresponds to the medieval date range given. This lends further weight to the suggestion that the feature has been slightly disturbed since it was last fired, possibly adding a degree of unquantifiable error to the final result.

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Table 1; Corrected NRM measurements for all samples.

Sample	Declination (deg)	Inclination (deg)	Intensity (Am^2x10^{-8})
MINT01	28.307	50.447	6.368
MINT02	-1.538	22.399	8.650
MINT03	-2.520	57.203	86.982
MINT04	-5.693	64.790	97.238
MINT05	6.134	48.320	18.791
MINT06	10.815	63.334	145.476
MINT07	-0.389	64.502	110.432
MINT08	-2.742	49.133	19.016
MINT09	-0.696	62.227	40.845
MINT10	-3.873	65.618	46.108
MINT11	14.277	62.745	19.597
MINT12	16.396	61.132	18.820
MINT13	-3.565	63.640	184.387
MINT14	2.448	63.633	57.055

Table 2; Variation of remanent field with increasing partial demagnetisation for sample MINT07.

Demagnetisation (mT)	Declination (deg)	Inclination (deg)	Intensity (M/M_o)
0	-10.091	67.561	1.000
2	-5.576	66.374	0.949
4	-1.284	65.304	0.848
6	-0.528	64.904	0.737
8	0.157	64.432	0.591
10	3.201	64.156	0.431
12	3.343	64.207	0.311
14	4.316	65.667	0.233
16	10.484	66.609	0.168
18	9.068	70.436	0.131
20	6.721	71.977	0.101
22	6.095	72.603	0.083
24	16.914	69.619	0.072
26	14.983	76.735	0.063
28	29.939	69.871	0.060
30	14.172	70.409	0.057

Table 3; Corrected measurements for all samples after 6mT AF partial demagnetisation.

Sample	Declination (deg)	Inclination (deg)	Intensity (Am^2x10^{-8})
MINT01	-13.190	46.225	5.121
MINT02	-4.330	56.093	15.837
MINT03	-2.610	57.842	57.493
MINT04	-2.097	62.388	75.349
MINT05	3.220	57.572	13.388
MINT06	13.296	62.099	112.744
MINT07	-0.528	64.904	88.717
MINT08	1.709	56.735	4.818
MINT09	1.889	62.823	34.516
MINT10	10.188	64.708	37.000
MINT11	-3.128	61.279	10.605
MINT12	4.206	58.055	17.938
MINT13	-1.869	62.454	187.310
MINT14	9.981	61.640	46.567

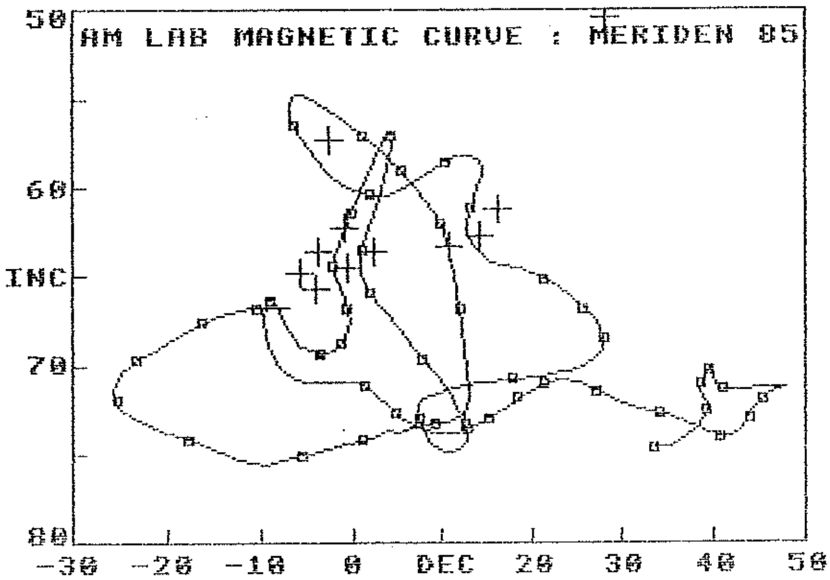


Figure 1; Distribution of NRM results.

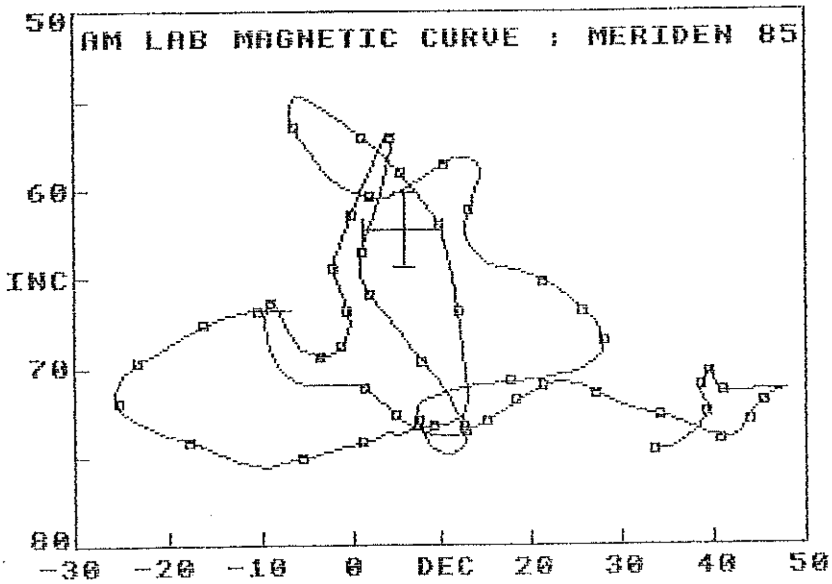
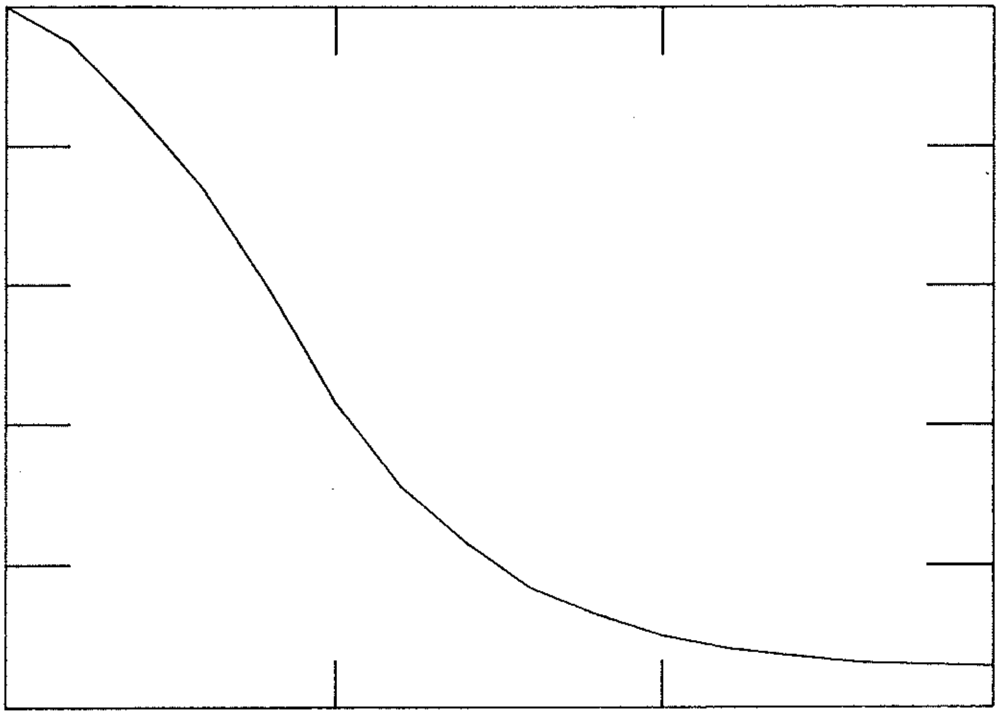
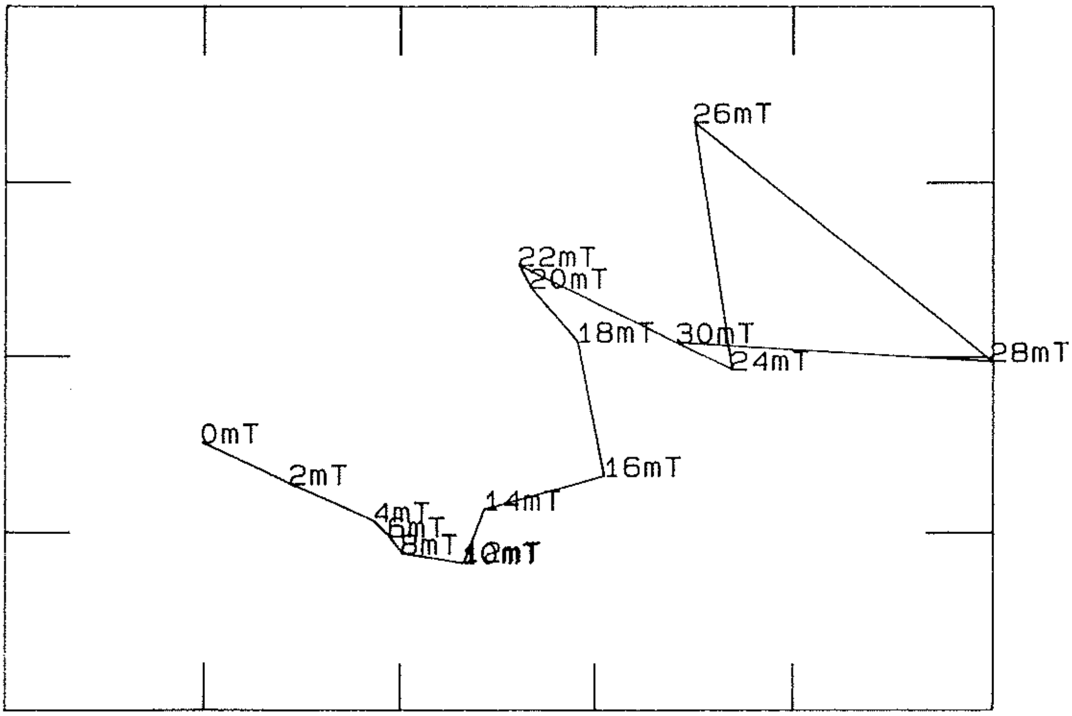


Figure 2; Mean of NRM results with 68% confidence limits.



0 -x- 30 0 -y- 1

Figure 3; Variation of remanence intensity (y axis), M/M_0, with increasing partial demagnetisation in mT (x axis), for sample MINT07.



-20 -x- 30 60 -y- 80

Figure 4; Variation of Dec (x axis) and Inc (y axis) with increasing partial demagnetisation for sample MINT07.

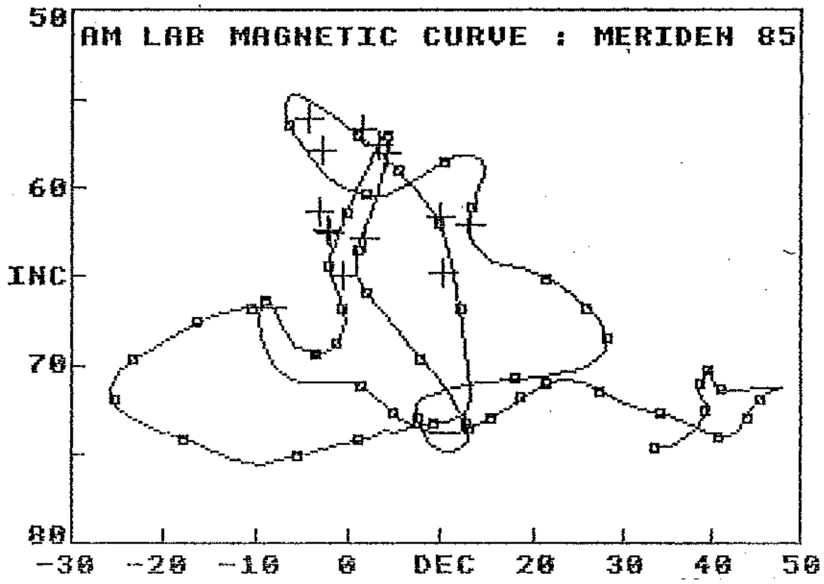


Figure 5; Distribution of partially demagnetised results.

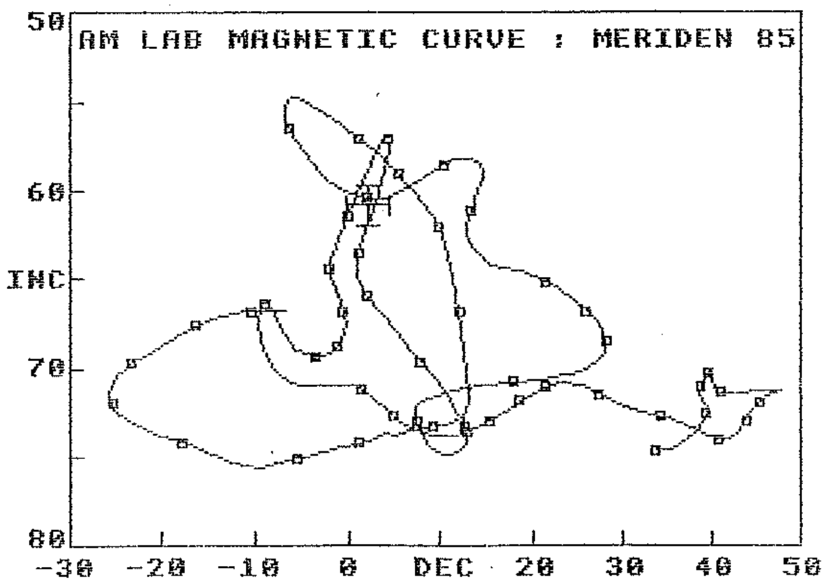


Figure 6; Mean of partially demagnetised results with 68% confidence limits.

Appendix: Standard Procedures for Sampling and Measurement

1) Sampling

One of three sampling techniques is employed depending on the consistency of the material (Clark, Tarling and Noel 1988):

a) Consolidated materials: Rock and fired clay samples are collected by the disc method. Several small levelled plastic discs are glued to the feature, marked with an orientation line related to True North, then removed with a small piece of the material attached.

b) Unconsolidated materials: Sediments are collected by the tube method. Small pillars of the material are carved out from a prepared platform, then encapsulated in levelled plastic tubes using plaster of Paris. The orientation line is then marked on top of the plaster.

c) Plastic materials: Waterlogged clays and muds are sampled in a similar manner to method 1b) above; however, the levelled plastic tubes are pressed directly into the material to be sampled.

2) Physical Analysis

a) Magnetic remanences are measured using a slow speed spinner fluxgate magnetometer (Molyneux *et al.* 1972; see also Tarling 1983, p84; Thompson and Oldfield 1986, p52).

b) Partial demagnetisation is achieved using the alternating magnetic field method (As 1967; Creer 1959; see also Tarling 1983, p91; Thompson and Oldfield 1986, p59), to remove viscous magnetic components if necessary. Demagnetising fields are measured in milli-Tesla (mT), figures quoted being for the peak value of the field.

3) Remanent Field Direction

a) The remanent field direction of a sample is expressed as two angles, declination (Dec) and inclination (Inc), both quoted in degrees. Declination represents the bearing of the field relative to true north, angles to the east being positive; inclination represents the angle of dip of this field.

b) Aitken and Hawley (1971) have shown that the angle of inclination in measured samples is likely to be distorted owing to magnetic refraction. The phenomenon is not well understood but is known to depend on the position the samples occupied within the structure. The corrections recommended by Aitken and Hawley are routinely applied to measured inclinations, in keeping with the practise of Clark, Tarling and Noel (1988).

c) Remanent field directions are adjusted to the values they would have had if the feature had been located at Meriden, a standard reference point. The adjustment is done using the method suggested by Noel (Tarling 1983, p116), and allows the remanent directions to be compared with standardised calibration data.

d) Individual remanent field directions are combined to produce the mean remanent field direction using the statistical method developed by R. A. Fisher (1953). The quantity "alpha-95" is quoted with mean field directions and is a measure of the precision of the determination (see Aitken 1990, p247). It is analogous to the standard error statistic for scalar quantities; hence the smaller its value, the better the precision of the date.

4) Calibration

a) Material less than 3000 years old is dated using the archaeomagnetic calibration curve compiled by Clark, Tarling and Noel (1988).

b) Older material is dated using the lake sediment data compiled by Turner and Thompson (1982).

c) Dates are normally given at the 68% confidence level. However, the quality of the measurement and the estimated reliability of the calibration curve for the period in question are not taken into account, so this figure is only approximate. Owing to crossovers and contiguities in the curve, alternative dates are sometimes given. It may be possible to select the correct alternative using independent dating evidence.

d) As the thermoremanent effect is reset at each heating, all dates for fired material refer to the final heating.

e) Dates are prefixed by "cal", for consistency with the new convention for calibrated radiocarbon dates (Mook 1986).

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