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Ancient Monuments Laboratory
Report 35/90

ARCHAEOMAGNETIC DATING: ROXBY, HUMBERSIDE.

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Summary

A clay surface thought to have been the floor of a kiln was discovered overlying Roman remains at Roxby in Humberside. Archaeomagnetic dating suggests that the feature was last fired towards the end of the 11th century AD, although the date is in some doubt owing to an anomalous scattering of the declination component of remanent magnetisation in the samples. Disturbance since the last firing is suggested as the cause of this scattering.

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Introduction

A well-preserved burnt clay surface, thought to have been part of a kiln, was discovered during the excavation of Roman remains at Roxby, near Scunthorpe in Humberside. It was in a context that overlay the Roman remains but the age of the feature could not be determined using the available archaeological evidence.

Consequently, samples were taken from the surface in the hope that an archaeomagnetic date could be obtained. The feature was sampled on the 29th November 1989 and, since excavation on the site had finished, it was located and re-excavated by John Farrimond of the Humberside Archaeology Unit for this purpose.

Method

Samples were collected using the disc method (see note 1a) and orientated with a compass. Measured declinations were subsequently corrected to take account of the variation between the direction of the magnetic pole and true north. Fourteen samples were recovered, all of which were of a deep brown colouration at the top, tending to red towards the bottom. Unless otherwise specified, all measurements were made using the equipment described in note 2.

Results

Measurements of the directions of Natural Remanent Magnetisation (NRM) of the samples are tabulated in table 1; the corrections discussed in notes 3b and 3c have been applied. A graphical representation of the distribution of these directions is depicted in figure 1. This figure shows that, whilst the variation in the inclination component of the NRM directions is within the bounds expected owing to measurement errors, an anomalous degree of deviation has occurred in the declination components.

Also, sample ROX11 is clearly a statistical outlier, its NRM direction falling well away from the group defined by the other samples. Sampling error is the most likely cause of this problem, the top surface of the sampling disc (see note 1a) not having been levelled correctly. Hence, the NRM measurements for this sample were excluded from the calculation of the mean thermoremanent direction (see note 3d). A graphical representation of this mean, superimposed on the calibration curve (see note 4a), is depicted in figure 2. This mean direction is:

Dec = 15.873 +/- 2.781°; Inc = 66.792 +/- 1.096°;
Alpha-95 = 2.026°;

Whilst the alpha-95 statistic shows that this mean is not unreasonably imprecise, it does not coincide with any point on the calibration curve, allowing no date range to be derived from it.

The anomalous dispersal of declinations could have been caused by a viscous component in the remanent magnetisations of the samples, acquired during storage in the laboratory. To investigate the stability of the remanence, a pilot sample, ROX13, was partially demagnetised in 2mT increments, to a maximum value of 32mT (see note 2b). Measurements of the remaining remanent magnetisation at each stage are tabulated in table 3. 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 extremely stable. Furthermore, figure 4 illustrates that there is little change in the thermoremanent direction until high demagnetising fields are applied. The direction is most stable at demagnetisations between 10mT and 20mT.

These results suggest that viscous remanent magnetism (VRM) was not the cause of the anomalous scatter of declinations present in the NRM results. Before the end of the stable range at 20mT, the only change in the direction of magnetisation is a slight shallowing of the inclination. The only significant changes in declination occur after the 24mT increment by which time only 15% of the initial magnetisation remained. It is likely that the domains remaining magnetised at this point had a high blocking temperature and were never completely aligned by the firing of the feature.

Despite the evidence suggesting VRM was not the cause of the scatter of declinations, it was decided to remeasure all samples after partial demagnetisation in a 10mT alternating field to remove the slight steepening of the inclinations caused by the low coercivity component of the magnetisation. These measurements are tabulated in table 3, corrected according to notes 3b and 3c, and their distribution is depicted in figure 5.

It is clear from this figure that the distribution of declinations is little improved after partial demagnetisation, as predicted by the pilot demagnetisation measurements. Consequently, the mean thermoremanent direction (see note 3d), again calculated excluding sample ROX11, was close to its previous value:

Dec = 16.830 +/- 2.799°; Inc = 66.315 +/- 1.125°;
Alpha-95 = 2.078°;

This mean is plotted graphically, superimposed on the calibration curve, in figure 6. Since it still does not coincide with any point on the curve, no date range could be derived from it.

Since the anomalous scattering of the declinations of remanent magnetisation prevents the dating of the feature, the possible causes were considered, in the hope of improving the accuracy of the mean direction:

a) **Magnetic Refraction:** Systematic deviations of declination have been noted by Harold (1960) and more recently by Hoye (1982). Such deviations were observed to have a sinusoidal dependence on the azimuth of the sample relative to true north; declinations of samples taken from the west of the kiln were too easterly, those from the east too westerly. Aitken and Hawley (1971) have suggested that magnetic refraction may be the cause of this phenomenon (cf. Weaver 1962). In the case of the Roxby feature there was no evidence for the type of dependency described above, so this cause may be discounted.

b) **Random errors of alignment:** Since the samples were aligned by hand using a compass it is possible that their alignment to magnetic north was not exact; in this case a random scattering of the sample declinations would result. Nevertheless, previous experience suggests that the spread of declinations produced is unlikely to be more than two degrees to either side of the mean declination; this is far smaller than the magnitude of scatter on this case.

c) **Crystalline anisotropy:** Rogers et al. (1979) investigated magnetocrystalline anisotropy as a cause of anomalous deviation; Aitken et al. (1981) have shown that deviations of up to 11 degrees may be caused assuming an easy plane model for this effect. Clark, Tarling and Noel (1988) suggest that disc samples taken from horizontal surfaces may be particularly vulnerable to such anisotropy, caused by systematic smoothing of the clay before firing. However, Tarling et al. (1986) have cast doubt on the magnitude of the deviation resulting in this case. This explanation could account for the scatter observed although the magnitude of the anisotropy within the samples would have to be much higher than that usually encountered.

d) **Movement since firing:** It is also possible that, despite the feature appearing to be intact, the clay surface had been disturbed since it acquired its magnetic remanence. The occurrence of disturbance cannot be ruled out in this case and may well have caused the scattering.

To investigate the possibility that anisotropy, discussed in c) above was the cause, a pilot sample, ROX04, was tested for the presence of this effect. The method used was suggested by Aitken et al. (1981) but, since an oven with associated remagnetisation coils was not available (Walton 1977), an explosive pulse magnetiser (Thompson and Oldfield 1986, p60) was used.

The sample was first demagnetised in a 100mT AF field to completely remove its remanent magnetisation. It was then remagnetised using a 20mT pulse aligned with the direction of the declination component of the thermoremanent field. The precision of the alignment procedure was estimated to be about 0.2 degrees. The declination of the resulting magnetisation was measured and found to be 0.6 degrees to the west of the applied pulse. The procedure was repeated, this time with the pulse aligned 0.7 degrees to the east of the thermoremanent declination. In this case the resulting direction of magnetisation coincided with the thermoremanent direction to within the precision limit of the experiment.

This experiment suggests that, whilst a small degree of magnetocrystalline anisotropy was present, it was at least an order of magnitude too small to account for the observed anomalous scatter of declinations. The evidence is not conclusive, however, for two reasons:

i) The magnetisation was induced by a high intensity pulse at room temperature, rather than a constant, low field at the blocking temperature of the clay.

ii) The shape of the sample itself would produce a small degree of anisotropy (Thompson and Oldfield 1986, p7), not present when the clay constituting the sample was part of a continuous surface.

For these reasons it is possible that the crystalline anisotropy present in the sample when it acquired its thermoremanent magnetisation, was not the same as that observed in the experiment. Nevertheless, it is unlikely to have been of the degree necessary to account for the scattering observed.

It was thus concluded that disturbance of the surface since the time the feature was last fired, was the the cause of the anomalous scattering of declination. To obtain a date for the feature it was assumed that the subset of samples consisting of ROX05, ROX06, ROX07, ROX08, ROX16 and ROX17, which made up the largest and tightest group, gave the best indication of the true field direction. The mean of this subset of samples, plotted graphically in figure 7, was calculated to be:

Dec = 22.586 +/- 1.779°; Inc = 66.024 +/- 0.723°;
Alpha-95 = 1.466°;

It can be seen that this mean still lies slightly off the calibration curve, suggesting that these samples had also been slightly disturbed. However, it was possible to obtain a date range for the surface of (see note 4):

Circa 1061 - 1102 cal AD at the 68% confidence level.

This date range has been prefixed with the word "circa" to represent the uncertainty associated with the assumption that this subset of samples provides the best indication of the true thermoremanent direction.

Conclusions

In the absence of further evidence there is no reason to discount the quoted date range of **Circa 1061 - 1102 cal AD**. However, it should be treated with caution owing to the assumptions required to derive it. The disturbance mentioned above is most likely to have been caused by a plastic squeezing of the clay caused by the weight of earth above it; this would account for the absence of significant visible cracking in the clay surface.

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12th March 1990

Table 1; Corrected NRM measurements.

Sample	Declination (deg)	Inclination (deg)
ROX03	14.299	68.204
ROX04	2.246	67.565
ROX05	20.557	66.794
ROX06	18.591	65.818
ROX07	20.593	65.178
ROX08	18.667	64.974
ROX09	10.659	64.576
ROX11	-8.093	60.438
ROX12	10.468	66.310
ROX13	4.526	66.660
ROX14	32.601	67.876
ROX15	3.109	65.245
ROX16	28.477	68.001
ROX17	23.522	67.690

Table 2; Variation of remanent field with increasing partial demagnetisation for sample ROX13.

Demagnetisation (mT)	Declination (deg)	Inclination (deg)	Intensity (M/M_o)
0	6.036	67.083	1.000
2	5.553	67.031	0.991
4	5.528	66.764	0.968
6	5.726	66.400	0.928
8	5.506	66.360	0.858
10	5.575	66.057	0.769
12	5.886	65.900	0.672
14	5.504	66.143	0.537
16	5.556	66.083	0.418
18	5.055	66.168	0.329
20	5.011	65.954	0.252
22	4.268	66.093	0.193
24	1.728	66.743	0.152
26	2.983	67.271	0.120
28	1.053	66.965	0.097
30	2.294	66.782	0.082
32	3.663	67.870	0.070

Table 3; Corrected measurements after 10mT AF partial demagnetisation.

Sample	Declination (deg)	Inclination (deg)
ROX03	13.564	67.433
ROX04	3.669	67.158
ROX05	21.646	66.364
ROX06	22.326	66.164
ROX07	20.676	65.044
ROX08	18.704	64.425
ROX09	10.500	63.679
ROX11	-6.733	60.267
ROX12	12.503	65.210
ROX13	5.575	66.057
ROX14	34.910	68.297
ROX15	4.725	64.829
ROX16	28.490	66.378
ROX17	24.160	67.583

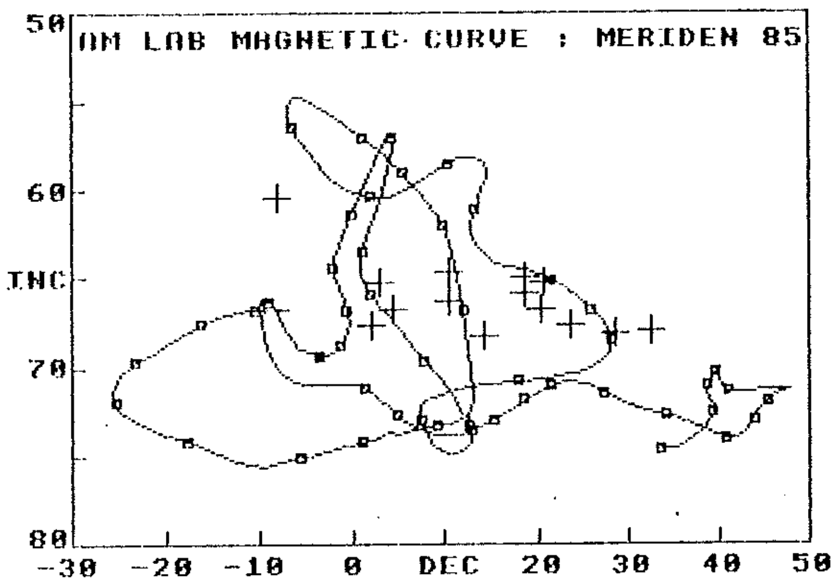

Figure 1; Distribution of NRM results.

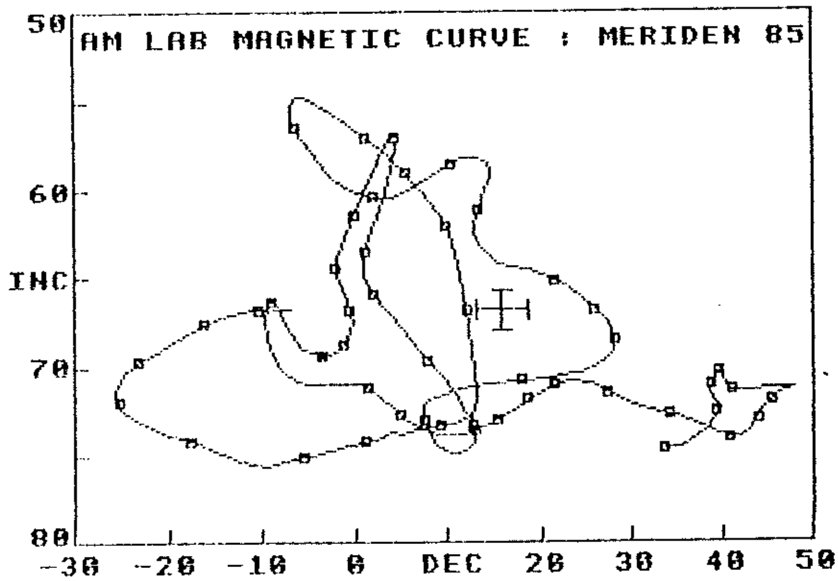

Figure 2; Mean of NRM results with 68% confidence limits.

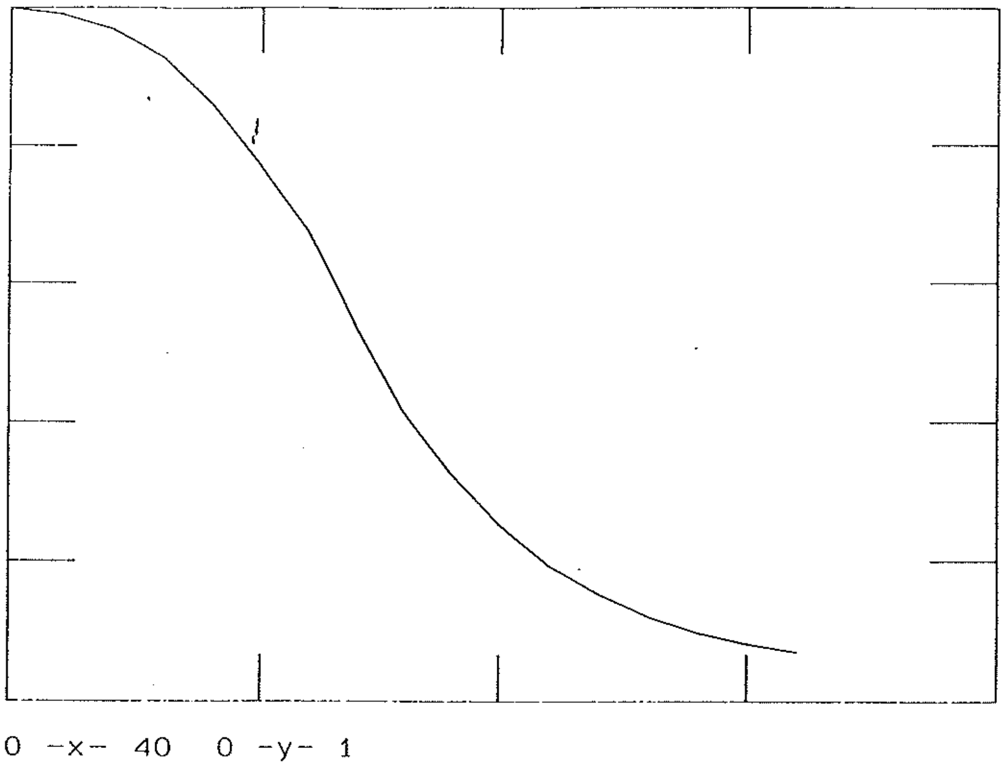

Figure 3; Variation of remanence intensity (y axis), M/M_o, with increasing partial demagnetisation in mT (x axis), for sample ROX13.

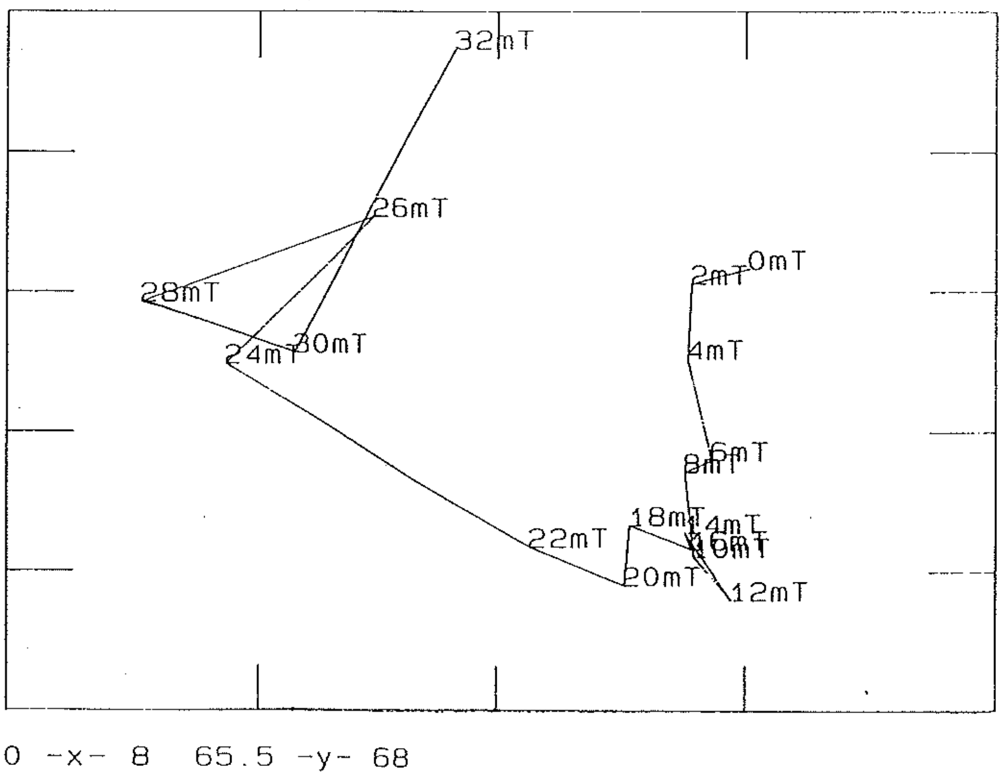

Figure 4; Variation of Dec (x axis) and Inc (y axis) with increasing partial demagnetisation for sample ROX13.

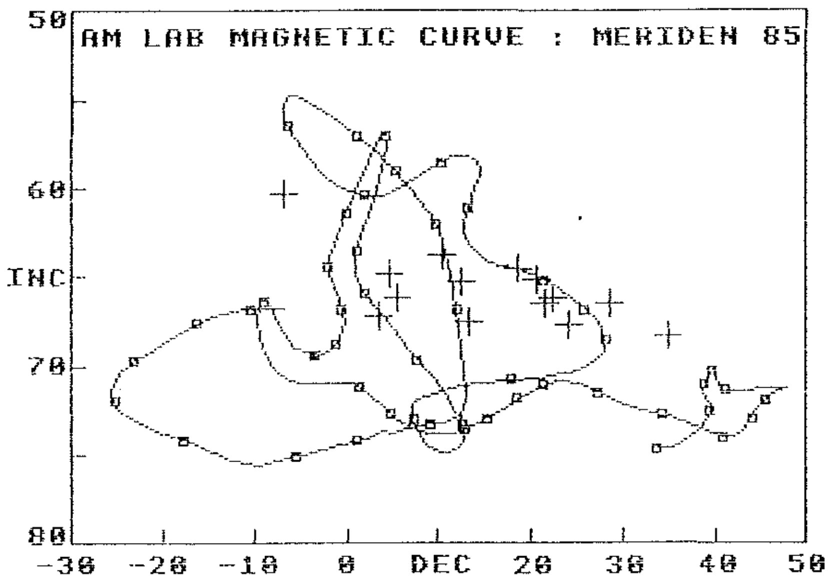

Figure 5; Distribution of partially demagnetised results.

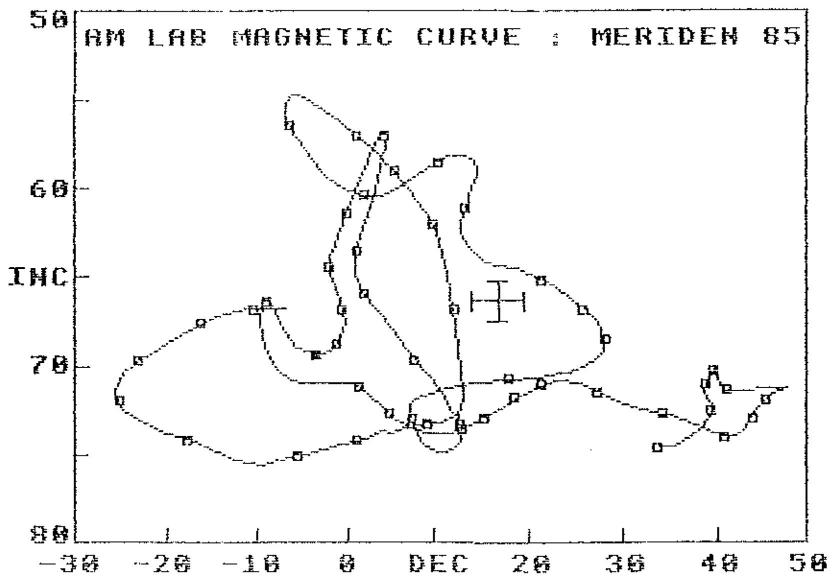

Figure 6; Mean of partially demagnetised results with 68% confidence limits.

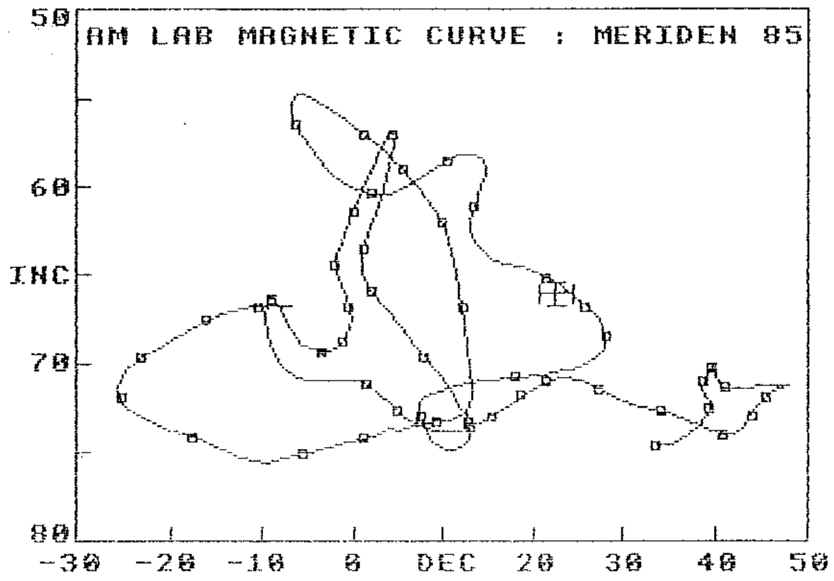

Figure 7; Mean of partially demagnetised results excluding possibly disturbed samples.

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 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; the smaller its value, the better the precision.

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 varve data compiled by Turner and Thompson (1982).

c) Dates are normally given at the 68% confidence level. However, both the quality of the measurement and the estimated reliability of the calibration curve for the period in question are 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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