LAB COPY
AM73.

ARCHAEOMAGNETIC DATING OF A FEATURE FROM EXCAVATIONS AT JOHN STREET, CARLISLE.

Z.Outram & C.M.Batt
Department of Archaeological Sciences
University of Bradford
Bradford BD7 1DP
Tel (01274) 233533 Email: z.outram@bradford.ac.uk

ABSTRACT
This report describes the archaeomagnetic investigation of a fired feature from the site of John Street, Carlisle. Samples were collected by the insertion of sampling tubes into the feature. The feature produced very low intensity measurements with varying magnetic stability. In general the data was consistently grouped with three clear outlying values. A possible date of 140-440AD, 1270-1330AD, or 1390-1475 AD was obtained for this feature. Based on the archaeological evidence the most likely date is either 1270-1330AD or 1390-1475AD. Corroborative dating evidence would be required to separate the two potential ranges.

An introduction to archaeomagnetic dating and an explanation of the technical terms used in this report can be found in Appendix 1. A sample inventory can be found in Appendix 2, with the detailed measurements and statistical analysis being located in Appendix 3.

1. INTRODUCTION
Orientated archaeomagnetic samples were taken from the feature. The objectives were to:

- Investigate the stability of burnt material of this nature and from this period and its suitability for archaeomagnetic dating
- To provide a date of last use of each hearth

Zoe Outram and Alan Powell carried out the sampling and measurement programme.

2. ARCHAEOLOGICAL CONTEXT
The site of John Street is located in the centre of Carlisle (54.98° N, 2.94°E) and is under excavation by the North Pennines Archaeological Unit. Feature C3 was composed of two lines of stone walling set approximately 40-50cm apart, marking the edges of the possible furnace, and was half-sectioned before sampling collection commenced. Within this feature lay areas of vitrified clay, which sealed a very thick layer of charcoal and coal. This in turn sealed a series of closely laid flags set in soft orange clay (see figure 1) which was expected to be burnt. The orange clay, context [234] was sampled for archaeomagnetic dating.

Figure 1: Feature C3 (Source: Powell 2004)

3. Sampling

Samples were taken from cleaned horizontal surfaces within the fired deposits. The material was soft so tubes were easily pushed into the feature. There were no visible signs of slumping within the feature. As the entire feature was not exposed on the day the samples were collected, only 12 samples were collected rather than the preferred 15 samples. A small sample group (i.e. less than 8 samples) can have an adverse effect on the precision of the outcome, but it was anticipated that this would not be a problem as this number was exceeded (Eighmy & Mitchell 1994, 447). Figure 2 shows the position of the tubes on the feature.

In the laboratory, the exposed surface of the samples was cleaned and the Munsell reference code recorded. A full listing for each sample has been recorded in Appendix 2. They were then sealed and stored in a damp, refrigerated environment.

4. Measurement

The direction of the remanent magnetisation for each sample was measured using a Molspin fluxgate spinner magnetometer and listed in Appendix 3. The stability of the magnetisation was investigated by the stepwise demagnetisation of pilot samples in fields of 2.5, 5, 7.5, 10, 12.5, 15, 20, 30, 40, 50, 60, 80, and 100mT (peak applied field), with the remanence being measured after each step (Appendix 3). From a study of the pilot sample behaviour, an alternating field was chosen to provide the optimum removal of the less stable component, leaving the magnetisation of archaeological interest. After partial demagnetisation in this field, sample remanences were re-measured (Appendix 3). The pilot demagnetisation data was also used to provide an indication of the magnetic stability of the measurements and therefore the validity of the results produced; this was assessed using methods defined by Tarling and Symons (1967).

5. Results

All of the 12 samples were measured to determine the NRM of the feature. It was noted that some of the sample directions were widely scattered, indicating that these individual samples did not all record the same magnetic field: there was a spread of over 100° in the declination values and 40° in the inclination values. This was reflected in the large alpha-95 value for the NRM data of 7.6°, being significantly larger than used for dating purposes (Clark *et al.* 1988: 606). However, it was clear that there were three clear outlying samples that caused this scatter: C3/8, C3/10 and C3/11. All three of these samples exceeded the critical angle defined by McElhinny and McFadden, which is discussed within Appendix 1, and could therefore be regarded as outlying values (McElhinny & McFadden 2000: 92). The samples may have been anomalous due to the very weak magnetic moment recorded which may relate to a low concentration of magnetic minerals, but there is always the possibility that the samples suffered some disturbance in antiquity. Further work on the magnetic mineralogy of the samples would be required to be able to determine the exact cause of the outlying values.

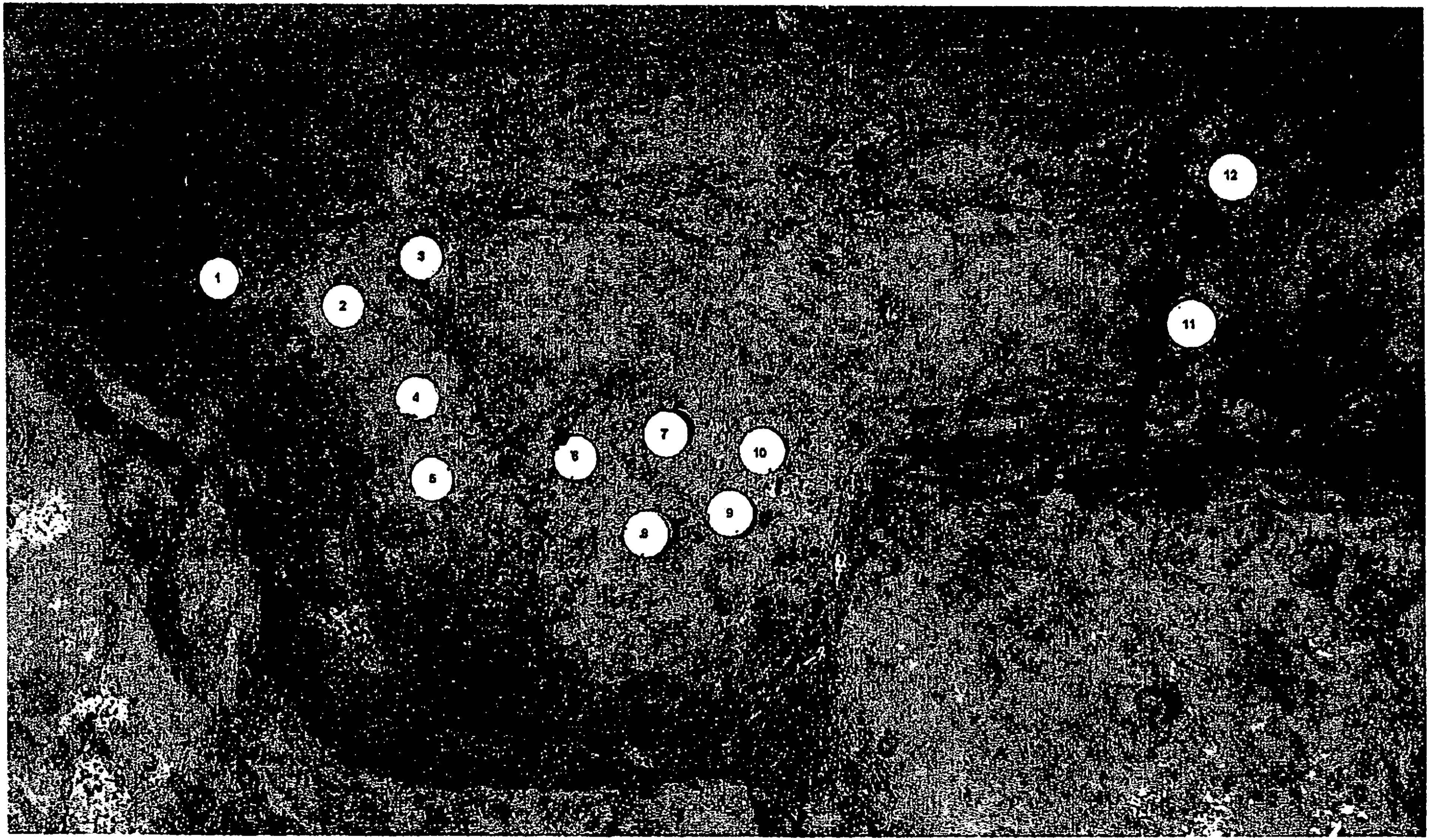


Figure 2: Feature C3 with samples in position (Source: Powell 2004)

It was also noted that the majority of the samples recorded very low intensity values, being indicative of either poor firing or low concentrations of magnetic minerals within the sample. It was unclear which of these conclusions were correct but it was observed that all three features sampled from this site produced low values (Suteu *pers.comm.* 2004). This may suggest that the magnetic mineral concentrations within the clay were low but this cannot be concluded without further analysis. Two of the samples measured produced intensity values that were below the background noise levels of the spinner magnetometer: C3/5 and C3/8. This may explain why sample 8 produced an outlying value.

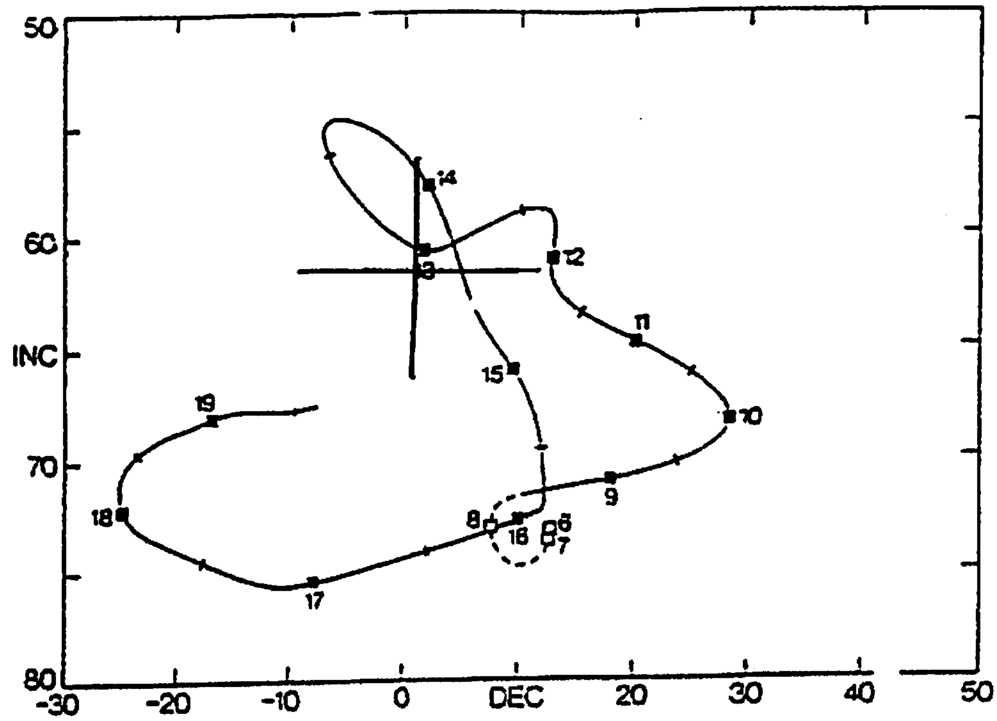
Two samples were subjected to the pilot stepwise demagnetisation: C3/12 and C3/3. In an ideal situation samples representing the central group and an outlying value would be assessed as pilot samples, but this was not possible due to the low intensity values recorded. Therefore the samples were selected as they recorded the highest values. The assessment of these samples indicated that they were both composed of soft magnetic minerals, such as magnetite. It was also clear that each sample had 2 magnetic components, the component of lower stability being removed at 5mT. After the lower stability component was removed the remaining signal for C3/12 was classed as very stable using the criteria set by Tarling and Symons (1967), and poorly stable for C3/3. This suggests that either the feature was inhomgeneously fired or that the magnetic minerals are not evenly distributed throughout the feature. This cannot be determined without further assessment.

For the final assessment of the sample directions the NRM values were used as the partial demagnetisation of the samples increased the scatter of the data; this may be due to the low intensity measurements recorded from the feature with several of the values being close to the background limit of the magnetometer after demagnetisation. The three samples classed as producing outlying data were removed from the final analysis to produce a mean declination of 0.9° and a mean inclination value of 61.4°. The scatter was only just outside the recommended value at 5.1° and was therefore considered suitable for dating purposes.

6. Dating of Magnetic Direction

The mean declination and inclination after demagnetisation for the features were corrected to Meriden, the reference locality for the British calibration curve, using the standard method (Noel & Batt: 1990). The corrected mean site direction was then dated by comparison with the Clark calibration curve in the conventional manner (see appendix 1).

On calibration (Figure 3) it is clear that the position of this sample on the Clark curve covers a period where the geomagnetic field changes rapidly in declination and inclination, but that there is a repetition in the direction of the geomagnetic field, creating a loop. In archaeomagnetic dating it is often necessary to give multiple possible age ranges as the earths magnetic field has had the same direction at different times. This was the case for the sampled feature, producing four potential age ranges: 140-240AD, 260-440AD, 1270-1330AD, or 1390-1475 AD. Date ranges



Archaeomagnetic calibration curve for Britain

Figures are 100's of years, BC (-) and AD, ticks indicate half-century points. The declination and inclination scales are in degrees and the data has been normalised to Meriden. The curve above covers AD600-AD1975 and below covers 1000BC-AD600 (after Clark et al, 1988).

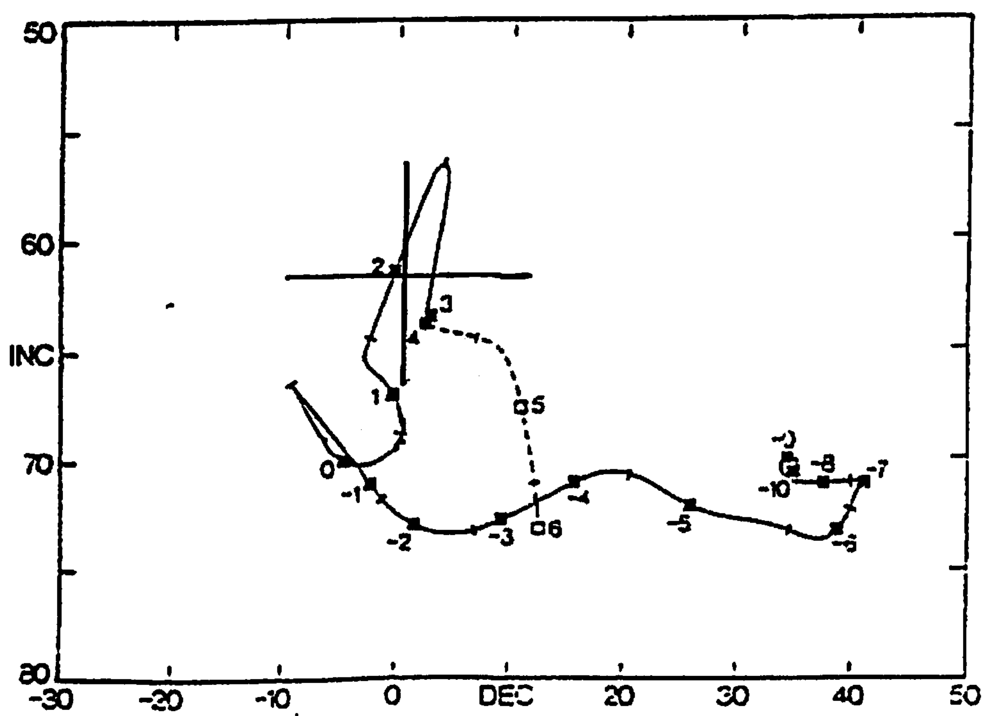


Figure 3: Clark curve calibration of feature C3 (Clark *et al.* 1988)

that are separated by 20 years or less are combined to produce one range, therefore combining the two earliest ranges to 140-440AD (Sternberg *et al.* 1991, 600). Corroborative artefactual evidence suggests that the earliest date range is not archaeologically likely, with the ceramic evidence supporting a Medieval date.

Unfortunately the two remaining ranges are very close, only separated by 60 years. However, this is a large enough difference for the ranges to remain separate. It is unclear at present which of these ranges reflect the age of the feature accurately as both ranges are equally likely. At present it can only be concluded that the feature was fired at some point within the 13^{th} to 15^{th} centuries AD. Corroborative dating evidence would be required to allow one of the ranges to be selected.

Appendix 1: An Introduction to Archaeomagnetic Dating

Principles

Archaeomagnetic dating is based on a comparison of the ancient geomagnetic field, as recorded by archaeological materials, with a dated record of changes in the Earth's field over time in a particular geographical area. The geomagnetic field changes both in direction (declination and inclination) and in strength (intensity) and archaeomagnetic dating can be based on either changes in direction or intensity or a combination of the two. Dating by direction requires that the exact position of the archaeological material in relation to the present geomagnetic field to be recorded, and so material must be undisturbed and *in situ*. Dating by intensity does not require *in situ* samples but is less precise and experimentally more difficult. The laboratory at Bradford uses archaeomagnetic dating by direction.

Suitable materials for dating

For an archaeological material to be suitable for dating using magnetic direction, it must contain sufficient magnetised particles and an event must have caused these particles to record the Earth's magnetic field. Many geologically derived materials e.g. soils, sediments, clays, contain sufficient magnetic minerals. There are primarily two types of archaeological event which may result in the Earth's magnetic field at a particular moment being recorded by archaeological materials: heating and deposition in air or water.

If materials have been heated to a sufficiently high temperature (>600°C) they may retain a thermoremanent magnetisation (TRM), which reflects the earth's magnetic field at time of last cooling. Suitable archaeological features would include hearths, kilns, and other fired structures.

Sediments may acquire a datable detrital remanent magnetisation (DRM) from the alignment of their magnetic grains by the ambient field during deposition. Such an effect allows the deposits in wells, streams, and ditches to be dated. However, this aspect of archaeomagnetic dating is still under development, as factors such as bioturbation and diagenesis, can cause post-depositional disturbances of the magnetism.

Archaeomagnetic dating can be applied to features expected to date from 1000BC to the present day, as this is period covered by the calibration curve. However, as discussed below the precision of the date obtained will vary according to the period being dated.

Sampling

Samples of robust fired materials are taken by attaching a 25mm diameter flanged plastic reference button to a cleaned, stable area of the feature using a fast setting epoxy resin (Clark *at al*, 1988). The button is levelled, using a spirit level, and held in place with a small bead of plastecine while the resin sets. The direction of north is then marked on using a magnetic compass, sun compasses, or gyrotheolodite and the button removed with a small part of the feature attached to it. Samples are trimmed and consolidated in the laboratory with a solution of 10% polyvinylacetate in acetone. Sediments and friable fired materials are sampled by insertion of a 2cm diameter plastic cylinder, onto which the direction of north in marked. Magnetometers used are sufficiently sensitive for only small samples (c.1cm^3) to be required; approximately 12 samples are needed from each feature and it may be possible to select sampling location to minimise the visual impact, if the feature is to be preserved.

LABORATORY MEASUREMENTS

In the laboratory a spinner magnetometer is used to measure the remanent magnetisation of each sample (Molyneux, 1971). The measurement indicates the relative strength and direction of the magnetic field of the sample. The stability of this magnetisation is then examined by placing the sample in alternating magnetic fields of increasing strength and removing the magnetisation step-by-step. The demagnetisation measurements allow removal of any less stable magnetisation acquired after the firing or deposition event, leaving the magnetisation of archaeological interest. It can also be used to indicate the magnetic mineralogy of the samples using information relating to the field require to reduce the intensity to half its original value, known as the median destructive field (MDF): Higher values are indicative of harder magnetic minerals, such as haematite (Sternberg *et al.* 1999, 422). The results of measurements of the direction of a group of samples are represented on a stenographic plot, which shows declination as an angle measured clockwise from north and inclination as a distance from the perimeter.

STATISTICAL ANALYSIS

The magnetic directions from a number of samples expected to have the same date are combined to give a mean direction, the precision of which is defined using Fisherian statistics (Fisher, 1953). The alpha-95 (α_{95}) represents a 95% probability that the true direction lies within that cone of confidence around the observed mean direction, and would be expected to be less than 5° for dating purposes. A value larger than this indicates that the magnetic direction of the samples are scattered and therefore do not all record the same magnetic field.

Samples thought to be very different from the mean directional value were assessed using statistical tests defined by Beck (1983) and McElhinny and McFadden (2000: 92). The Beck '2-delta' test defines the samples that were located 2 angular standard deviations from the mean value. These samples were then tested using McElhinny and McFadden equations of $\cos\theta_{95}$, if the values failed this test they could statistically be classified as lying significantly form the mean and therefore could be removed from the analysis.

The stability of magnetisation of an individual sample on a demagnetisation is quantified using the Stability Index (Tarling & Symons, 1967). For a stable magnetisation this value would be expected to be greater than 2.5, a value less than this would indicate that the recorded magnetisation was not reliable for dating purposes.

CALIBRATION OF DATES

Once a stable, mean magnetic direction has been obtained this is dated by comparing it with a calibration curve showing changes in the Earth's field over time. The calibration curve is compiled from direct measurements of the field, which extended back to AD1576 in Britain, and from archaeomagnetic measurements from features dated by other methods. Because the geomagnetic field changes spatially, data for the calibration curve must be corrected mathematically to a central location (Noel & Batt, 1990). There is a single calibration curve for England, Scotland and Wales and directions are corrected to Meriden (52.43°N, 1.62°W). Conventionally British archaeomagnetic dates are calibrated by visual comparison to the calibration curve produced by Clark *et al.* (1988). However, this method takes no account of the errors in the calibration curve itself and an alternative method is also used (Batt, 1997). The latter method gives a larger error margin on the date but is a better reflection of the actual error.

The dating of the cores is usually carried out using radiocarbon or optically stimulated luminescence (OSL) dating but problems associated with this technique which may affect the reliability of this information includes:

- Post-deposition rotation of the sediment particles
- Changes in the rates of sedimentation
- Erosion of sediments and therefore a particular time period.
- The possibility of chemical change of the samples, which produces chemical remanent magnetisation
- Errors in orientation of the samples due to the actual coring process
- Bioturbation which will affect the directional information recorded and also the dating of the sediments through the introduction of older/younger materials into the sample (Tarling 1983, 174).

These problems require any information used from lake cores needs to be treated with caution, but the "geomagnetic importance" of this information is invaluable (Tarling 1983, 174).

Precision of dates

There are a number of factors that will influence the error margins of the dates obtained:

- Differential recording of the field by different parts of the feature
- Disturbance of the material after firing / deposition
- Uncertainties in sampling and laboratory measurements
- Error margins in the calibration curve itself
- Uncertainties in the comparison of the magnetic direction with the calibration curve
- Spatial variation of the geomagnetic field

The precision of the calibration curve varies according to the archaeological period and so the precision of the date obtained will depend on the archaeological date. As the geomagnetic field has occasionally had the same direction at two different times, it is also possible to have two or more alternative dates for a single feature. In most cases the archaeological evidence can be used to select the most likely of these.

Given the number of different factors it is not possible to give a general figure for the precision of archaeomagnetic dates but there will be an error margin of at least ±25 years. It is important to note that, since the method relies on the reliability of previously dated sites, the calibration curve can be improved as more measurements become available.

References

Aitken, M.J. 1990. *Science-Based Dating in Archaeology*. Longman Archaeological Sciences Series. Longman, London and New York

Batt, C.M. 1997. The British archaeomagnetic calibration curve: an objective treatment. *Archaeometry* 39: 153-168

Batt, C.M. 1999. Preliminary investigations into the acquisition of remanence in archaeological sediments. In Tarling, D.H. and Turner, P. (eds.) *Palaeomagnetism and Diagenesis in Sediments*: 9-19. London: Geological Society

Beck, M.E. 1983. Comment on: 'Determination of the angle of a Fisher distribution which will be exceeded with a given probability' by P.L. McFadden. *Geophysics Journal of the Royal Astronomical Society* 75: 847-849

Card, N., Downes, J., Murray, D., Sharman, P., and Whalley, T. 2004. *Mine Howe, Tankerness, Orkney Excavation 2003. Data Structure Report.* Orkney: Orkney Archaeological Trust/ Orkney College.

Clark, A.J., Tarling, D.H., and Noel, M. 1988. Developments in archaeomagnetic dating in Britain. *J. Arch. Sci.* 15: 645-667

√Eighmy, J.L., and Mitchell, D.R. 1994. Archaeomagnetic dating at Pueblo Grande. *Journal of Archaeological Sciences* 21: 445-453

Fisher, R.A. 1953. Dispersion on a sphere. *Proc. R. Soc. Lond.*, A217: 295-305

McElhinny, M.W. and McFadden, P.L. 2000. *Palaeomagnetism: Continents and Oceans.* London: Academic Press. Molyneux, L. 1971. A complete result magnetometer for measuring the remanent magnetisation of rocks. *Geophysics J. R. astr. Soc.* 24: 429-433

Noel, M. and Batt, C.M. 1990. A method for correcting geographically separated remanence directions for the purpose of archaeomagnetic dating. *Geophys. J. Int.* 102: 753-756

Sternberg, R.S., Lange, R.C., Murphy, B.A., Deaver, W.L., and Teague, L.S. 1991. Archaeomagnetic dating at Las Colinas, Arizona, USA. In Pernicka, E., and Wagner, G.A. (eds.) *Archaeometry '90*: 597-606. Basel: Birkhauser Verlag Basel.

Sternberg, R., Lass, E., Marion, E., Katari, K., and Holbrook, M. 1999. Anomalous Archaeomagnetic directions and site formation processes at archaeological sites in Israel. *Geoarchaeology* 14(5): 415-439.

Tarling, D.H. and Dobson, M.J. (1995) Archaeomagnetism: an error assessment of material observations in the British directional database. *Journal of Geomag. Geoelectr.*, 47: 5-18

√ Tarling, D.H., and Symons, D.T.A. 1967. A stability index of remanence in palaeomagnetism. *Geophys. J. R. astr. Soc.* 12: 443-448.

Turner, G.M., and Thompson, R. 1982. Detransformation of the British geomagnetic secular variation record for Holocene times. *Geophs. J. R. Soc.* 70: 789-792.

FURTHER READING

Aitken, M.J. 1990. *Science-Based Dating in Archaeology*. Longman Archaeological Sciences Series. Longman, London and New York.
For general information on scientific dating methods

Oldfield, F. 1991. Environmental magnetism – a personal perspective. *Quaternary Science reviews* 10: 73-85.
For details of wider applications of magnetic studies

Eighmy, J.L., and Sternberg, R.S. 1990. *Archaeomagnetic dating*. The University of Arizona Press, Tucson.
For an international perspective on archaeomagnetic dating

Tarling, D.H. 1983. *Palaeomagnetism*. Chapman and Hall, London & New York.

APPENDIX 2: SAMPLE INVENTORY

FEATURE C3: CONTEXT [234]

LAB CODE	MUNSELL REFERENCE	COLOUR	COMMENT
C3/1	7.5YR 4/3	Brown	
C3/2	7.5YR 4/3	Brown	
C3/3	7.5YR 4/3	Brown	
C3/4	7.5YR 4/3	Brown	
C3/5	5YR 4/4	Reddish brown	
C3/6	7.5YR 6/4	Light brown	
C3/7	7.5YR 4/3	Brown	10% of sample missing from the tube
C3/8	7.5YR 6/3	Light brown	
C3/9	7.5YR 4/3	Brown	
C3/10	7.5YR 4/4	Brown	
C3/11	5YR 4/3	Reddish brown	
C3/12	7.5YR 4/3	Brown	

SITE INFORMATION

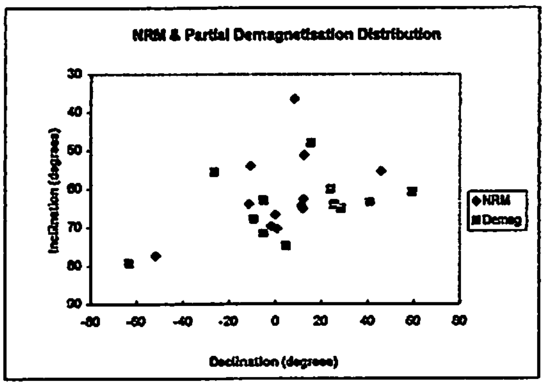
Site Name	John Street NPA04 MAL-B
Area	
Context No	234
Description	Thick orange clay layer associated to a possible furnace
Latitude (+ve N)	54.8944
Longitude (+ve E)	-2.9461
Magnetic Var	-4.223
Date Sampled	Nov-04

MAGNETIC MEASUREMENTS

Sample no.	NRM			Field	After partial demag			Pilot?
	D	I	Int		D	I	Int	
	degs.	degs.	arb	mT	degs.	degs.	arb	Y/N
C3/1	12.3	62.6	1.883	5	28.5	64.9	1.9305	
C3/2	0.7	70.3	1.4371	5	354.9	62.9	1.1689	
C3/3	11.3	64.3	4.7039	5	24.1	60.1	3.8601	y
C3/4	12.6	51.3	1.7153	5	15.5	48.1	1.4029	
C3/5	360	66.7	0.6812	5	4.6	74.8	0.5994	
C3/6	349.3	54	3.886	5	333.6	55.6	1.5679	
C3/7	348.7	63.8	2.6344	5	350.7	67.7	2.0239	
C3/8	8.3	36.6	0.3398	5	59.6	60.8	0.1336	
C3/9	12	65.1	1.2751	5	25.4	64	1.0931	
C3/10	308.4	77.4	1.771	5	296.8	79.4	1.4108	
C3/11	45.8	55.5	4.2332	5	41	63.4	2.9868	
C3/12	358.1	69.6	8.9	5	354.9	71.6	7.439	y

NRM DISTRIBUTION **PARTIAL DEMAG DISTRIBUTION**

Sample no.	NRM				Demag			
	D	I	D	I	D	I	D	I
	degs.	degs.	degs	degs.	degs.	degs.	degs	degs.
C3/1	12.3	62.6	12.3	62.6	28.5	64.9	28.5	64.9
C3/2	0.7	70.3	0.7	70.3	354.9	62.9	-5.1	62.9
C3/3	11.3	64.3	11.3	64.3	24.1	60.1	24.1	60.1
C3/4	12.6	51.3	12.6	51.3	15.5	48.1	15.5	48.1
C3/5	360	66.7	0	66.7	4.6	74.8	4.6	74.8
C3/6	349.3	54	-10.7	54	333.6	55.6	-26.4	55.6
C3/7	348.7	63.8	-11.3	63.8	350.7	67.7	-9.3	67.7
C3/8	8.3	36.6	8.3	36.6	59.6	60.8	59.6	60.8
C3/9	12	65.1	12	65.1	25.4	64	25.4	64
C3/10	308.4	77.4	-51.6	77.4	296.8	79.4	-63.2	79.4
C3/11	45.8	55.5	45.8	55.5	41	63.4	41	63.4
C3/12	358.1	69.6	-1.9	69.6	354.9	71.6	-5.1	71.6



STATISTICS FOR NRM DATA

Sample no.	Dec	Inc	x	y	z
C3/1	12.3	62.6	0.449636	0.098037	0.887815
C3/2	0.7	70.3	0.33707	0.004118	0.941471
C3/3	11.3	64.3	0.425252	0.084974	0.901077
C3/4	12.6	51.3	0.610185	0.136392	0.78043
C3/5	360	66.7	0.396546	-9.7E-17	0.918448
C3/6	349.3	64	0.577565	-0.10913	0.809017
C3/7	348.7	63.8	0.432947	-0.08651	0.897258
C3/8	8.3	36.6	0.794409	0.115892	0.596225
C3/9	12	65.1	0.411835	0.087538	0.907044
C3/10	308.4	77.4	0.135499	-0.17096	0.975917
C3/11	45.8	55.5	0.394879	0.406083	0.824126
C3/12	358.1	69.6	0.34838	-0.01156	0.937282

Number = 12
Sum x = 5.3132
Sum y = 0.5549
Sum z = 10.3781
R = 11.6705
x bar = 0.4553
y bar = 0.0475
z bar = 0.8891

Mean Dec = 5.9618
Mean Inc = 62.7585
Alpha95 = 7.6226

CORRECTIONS

Mean Dec = 5.96
Mean Inc = 62.76

Correction for magnetic variation
Mean Dec = 1.74
Mean Inc = 62.75851384

Correction to Meriden (CVP)

Uncorrected Dec = 1.738767244
Uncorrected Inc = 62.75851384
Latitude = 54.8944
Longitude = -2.9461

Kai = 45.83810138
Latitude of pole= 79.20921113
Beta1 = 6.676419345
Longitude of pole = 170.3774607
Geomag colat = 48.27550638
Corrected Inc= 60.72043619
Beta 2 = 8.002619345
Corrected Dec= 2.00132452

FINAL RESULT
Corrected Dec= 2.00132452
Corrected Inc = 60.72043619
Alpha95 = 7.62

STATISTICS FOR DEMAG DATA

Sample no.	Dec	Inc	x	y	z
C3/1	28.5	64.9	0.372794	0.20241	0.905569
C3/2	354.9	62.9	0.453741	-0.0405	0.890213
C3/3	24.1	60.1	0.455037	0.203548	0.866897
C3/4	15.5	48.1	0.643544	0.17847	0.744312
C3/5	4.6	74.8	0.261345	0.021027	0.965016
C3/6	333.6	55.6	0.506048	-0.2512	0.825113
C3/7	350.7	67.7	0.374468	-0.06132	0.92521
C3/8	59.6	60.8	0.246873	0.420786	0.872922
C3/9	25.4	64	0.395996	0.188033	0.898794
C3/10	296.8	79.4	0.08294	-0.16419	0.982935
C3/11	41	63.4	0.337928	0.293756	0.894154
C3/12	354.9	71.6	0.314399	-0.02806	0.948876

Number = 12
Sum x = 4.4451
Sum y = 0.9628
Sum z = 10.7200
R = 11.6449
x bar = 0.3817
y bar = 0.0827
z bar = 0.9206

Mean Dec = 12.2208
Mean Inc = 67.0099
Alpha95 = 7.9225

CORRECTIONS

Mean Dec = 12.22
Mean Inc = 67.01

Correction for magnetic variation
Mean Dec = 8.00
Mean Inc = 67.00995

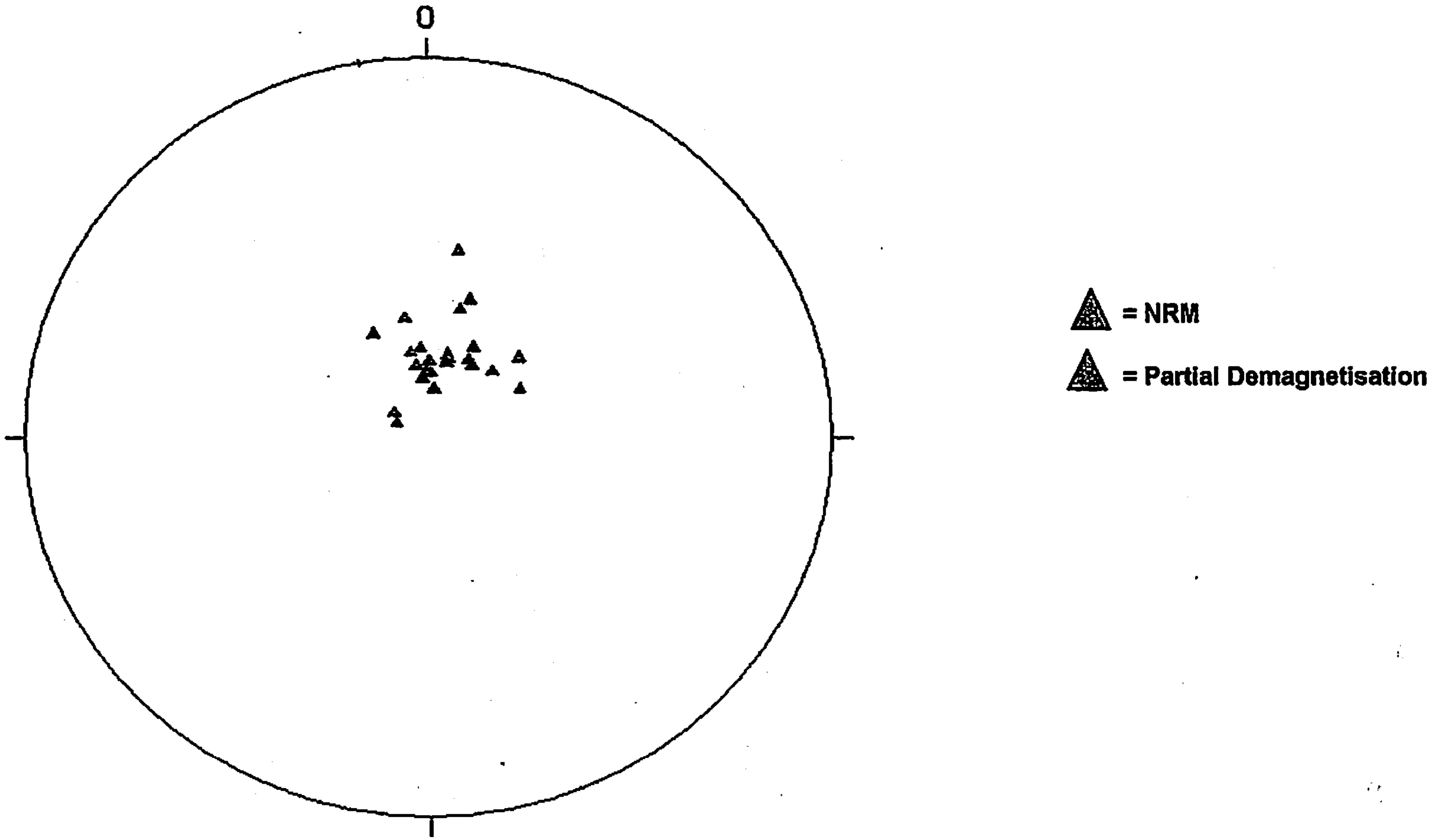
Correction to Meriden (CVP)

Uncorrected Dec = 7.997815
Uncorrected Inc = 67.00995
Latitude = 54.8944
Longitude = -2.9461

Kai = 40.31594
Latitude of pole= 82.86163
Beta1 = 46.42064
Longitude of pole = 130.6333
Geomag colat = 42.84901
Corrected Inc= 65.27093
Beta 2 = 47.74674
Corrected Dec= 7.802662

FINAL RESULT
Corrected Dec= 7.802662
Corrected Inc = 65.27093
Alpha95 = 7.92

NRM and partial demagnetisation data



STATISTICS FOR NRM DATA

Sample no.	Dec	Inc	x	y	z
C3/1	12.3	62.6	0.449636	0.098036538	0.887815
C3/2	0.7	70.3	0.33707	0.004118293	0.941471
C3/3	11.3	64.3	0.425252	0.084973826	0.901077
C3/4	12.6	51.3	0.610185	0.13639246	0.78043
C3/5	360	66.7	0.395546	-9.69204E-17	0.918446
C3/6	349.3	54	0.577565	-0.109132098	0.809017
C3/7	348.7	63.8	0.432947	-0.08651137	0.897258
C3/8	8.3	36.6	0.794409	0.115891681	0.596225
C3/9	12	65.1	0.411835	0.087538268	0.907044
C3/10	308.4	77.4	0.135499	-0.170957431	0.975917
C3/11	45.8	55.5	0.394879	0.406062639	0.824126
C3/12	358.1	69.6	0.34838	-0.011556968	0.937282

Number = 12
Sum x = 5.313203
Sum y = 0.554856
Sum z = 10.37611
R = 11.67055
x bar = 0.455266
y bar = 0.047543
z bar = 0.889085

Mean Dec = 5.961767
Mean Inc = 62.75851
Alpha95 = 7.622629

BECK 2-DELTA TEST
2-delta 28.03602

MCFADDEN 1982 DISCORDANCY TEST

STATISTICS FOR NRM DATA

			(N-1)		
Sample no.	Dec	Inc	x	y	z
C3/1	12.3	62.6	0.449636	0.098036538	0.887815
C3/2	0.7	70.3	0.33707	0.004118293	0.941471
C3/3	11.3	64.3	0.425252	0.084973826	0.901077
C3/4	12.6	51.3	0.610185	0.13639246	0.78043
C3/5	360	66.7	0.395546	-9.69204E-17	0.918446
C3/6	349.3	54	0.577565	-0.109132098	0.809017
C3/7	348.7	63.8	0.432947	-0.08651137	0.897258
C3/8	8.3	36.6	0.794409	0.115891681	0.596225
C3/9	12	65.1	0.411835	0.087538268	0.907044
C3/11	45.8	55.5	0.394879	0.406062639	0.824126
C3/12	358.1	69.6	0.34838	-0.011556968	0.937282

Number = 11
Sum x = 5.177704
Sum y = 0.725813
Sum z = 9.400192
R = 10.75635
x bar = 0.481363
y bar = 0.067478
z bar = 0.87392

Mean Dec = 7.979754
Mean Inc = 60.91746
Alpha95 = 7.212152

COS gamma(1-P) 31.0687

STATISTICS FOR NRM DATA (N-2)

Sample no.	Dec	Inc	x	y	z
C3/1	12.3	62.6	0.449636	0.098036538	0.887815
C3/2	0.7	70.3	0.33707	0.004118293	0.941471
C3/3	11.3	64.3	0.425252	0.084973826	0.901077
C3/4	12.6	51.3	0.610185	0.13639246	0.78043
C3/5	360	66.7	0.395546	-9.69204E-17	0.918446
C3/6	349.3	54	0.577565	-0.109132098	0.809017
C3/7	348.7	63.8	0.432947	-0.08651137	0.897258
C3/9	12	65.1	0.411835	0.087538268	0.907044
C3/11	45.8	55.5	0.394879	0.406062639	0.824126
C3/12	358.1	69.6	0.34838	-0.011556968	0.937282

Number = 10
Sum x = 4.383296
Sum y = 0.609922
Sum z = 8.803967
R = 9.853686
x bar = 0.444838
y bar = 0.061898
z bar = 0.893469

Mean Dec = 7.92166
Mean Inc = 63.31251
Alpha95 = 6.208195

COS gamma(1-P) 26.91831

STATISTICS FOR NRM DATA

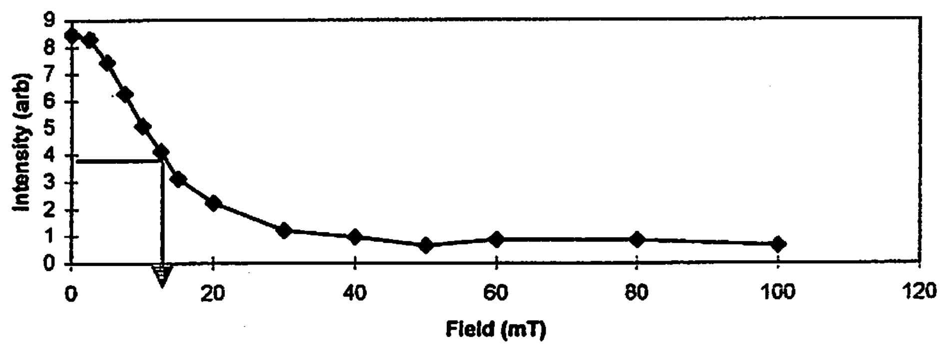
Sample no.	Dec	Inc	(N-3) x	y	z
C3/1	12.3	62.6	0.449636	0.098036538	0.887815
C3/2	0.7	70.3	0.33707	0.004118293	0.941471
C3/3	11.3	64.3	0.425252	0.084973826	0.901077
C3/4	12.6	51.3	0.610185	0.13639246	0.78043
C3/5	360	66.7	0.395546	-9.69204E-17	0.918446
C3/6	349.3	54	0.577565	-0.109132098	0.809017
C3/7	348.7	63.8	0.432947	-0.08651137	0.897258
C3/9	12	65.1	0.411835	0.087538268	0.907044
C3/12	358.1	69.6	0.34838	-0.011556968	0.937282

Number =	9
Sum x =	3.988417
Sum y =	0.203859
Sum z =	7.979841
R =	8.92339
x bar =	0.446962
y bar =	0.022845
z bar =	0.894261
Mean Dec =	2.925998
Mean Inc =	63.41368
Alpha95 =	5.06159
COS gamma(1-P)	22.24177

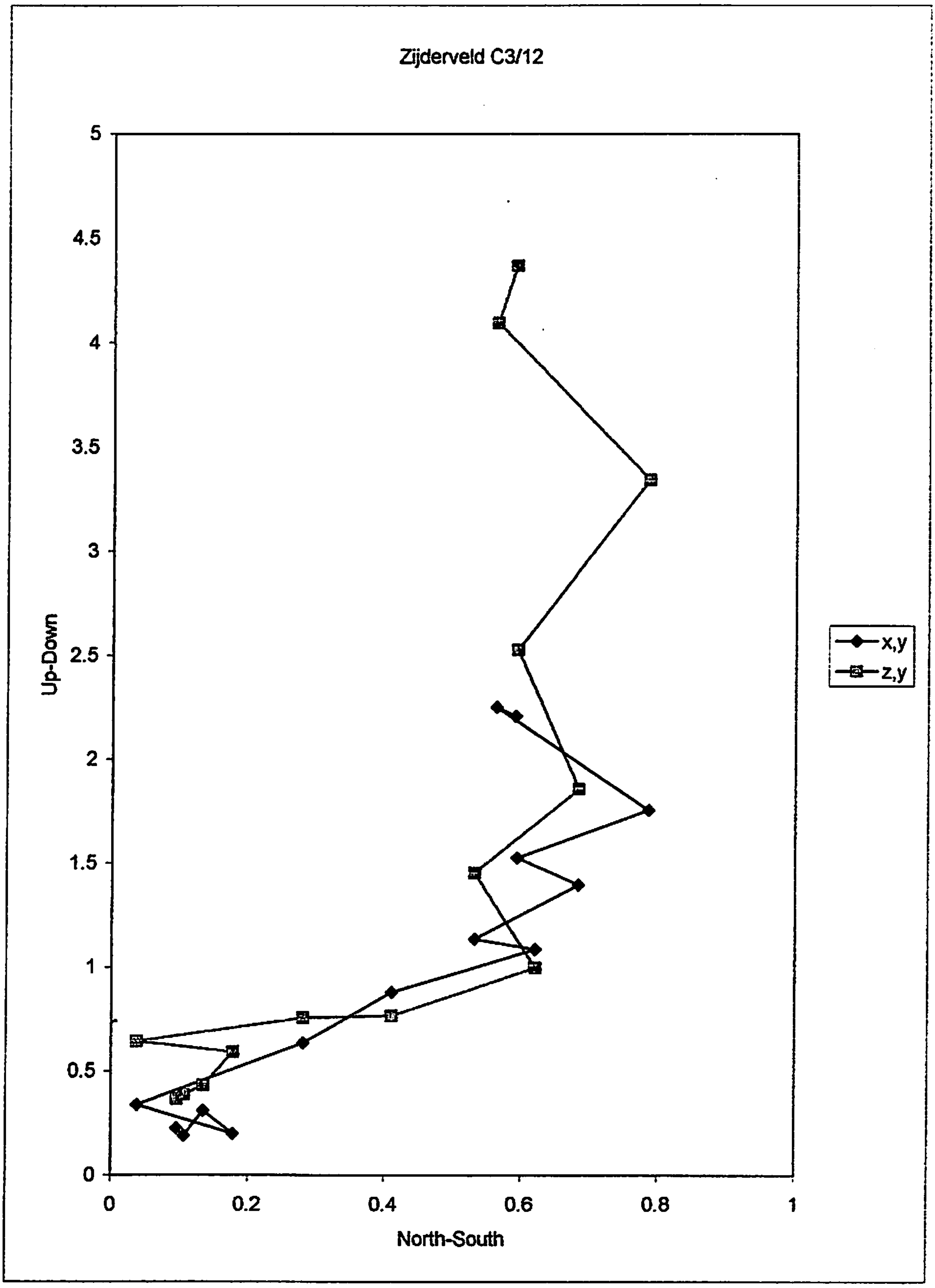
PILOT DEMAGNETISATION
Sample Number C3/12

Demag Step	RM					
	D	I	Int	x	y	z
mT	*degs.*	*degs.*	*arb*			
0	7	67.9	8.4634	3.1661	0.391	7.8391
2.5	6.2	71.7	8.2944	2.5926	0.2805	7.8738
5	354.9	71.6	7.439	2.3423	-0.2075	7.0576
7.5	355.7	69.3	6.2709	2.2132	-0.1648	5.8651
10	351	69	5.0783	1.7972	-0.2841	4.7411
12.5	341.9	70	4.1316	1.3404	-0.4382	3.8835
15	4.3	73.3	3.1213	0.8942	0.0677	2.9898
20	354.9	71.2	2.2228	0.7152	-0.0632	2.1036
30	346	74	1.2023	0.3206	-0.0802	1.156
40	313.7	67.3	0.9756	0.2601	-0.2725	0.9
50	19.3	66.5	0.6563	0.2467	0.0864	0.602
60	316.4	53.4	0.8744	0.3776	-0.3598	0.7018
80	293.4	71.1	0.8527	0.1095	-0.2529	0.8069
100	94.3	68.1	0.6453	-0.0178	0.2396	0.5989

Pilot Demagnetisation: Intensity Spectrum
C3/12

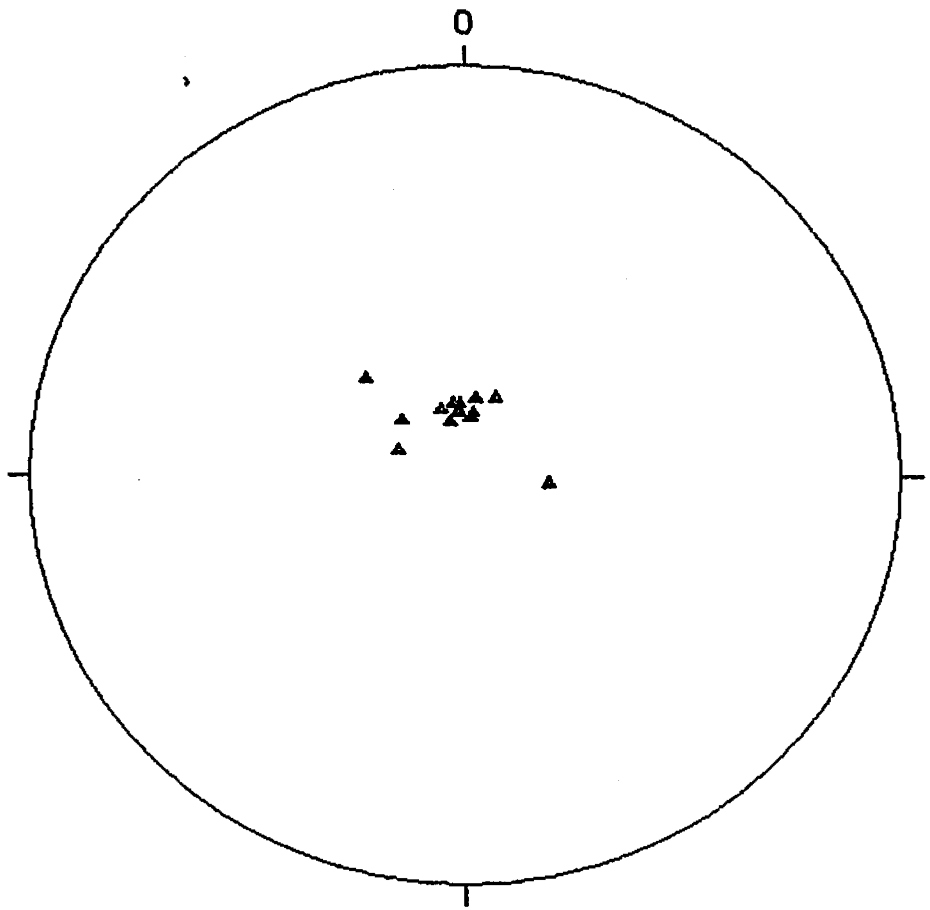


MDF = 12.5mT
% intenisty remaining = 7.62



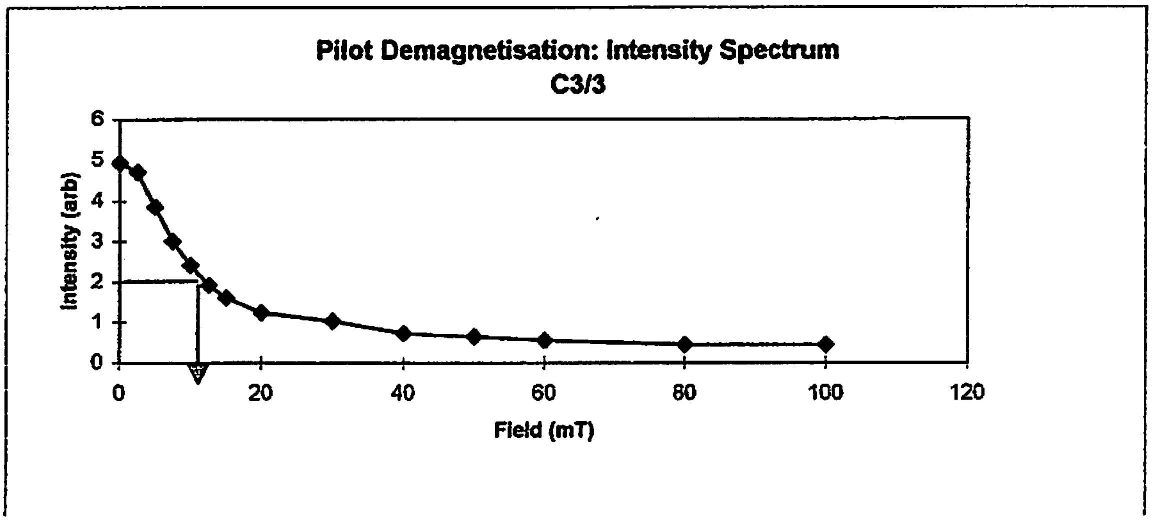
Zijderveld C3/12
Up-Down
North-South
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
0.2
0.4
0.6
0.8
1
x,y
z,y

Directional changes of C3/12 between 0 and 100mT

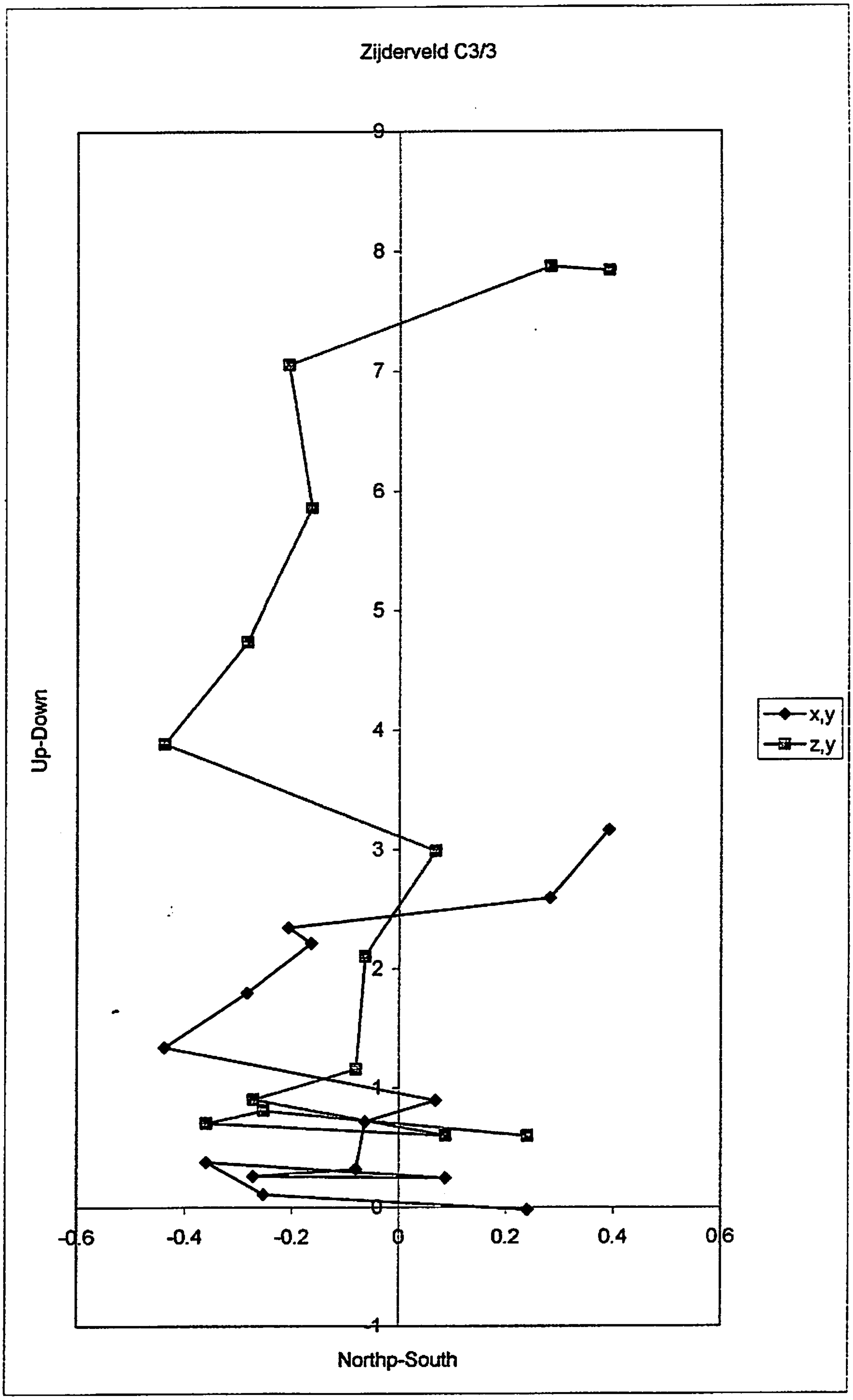


PILOT DEMAGNETISATION
Sample Number C3/3

Demag Step	RM					
	D	I	Int	x	y	z
mT	*degs.*	*degs.*	*arb*			
0	15	62.4	4.9337	2.2087	0.5905	4.372
2.5	14	60.5	4.7068	2.2514	0.562	4.095
5	24.1	60.1	3.8601	1.7581	0.7855	3.3456
7.5	21.2	57.1	3.0137	1.5274	0.5931	2.5293
10	26.1	50.1	2.4253	1.3974	0.6831	1.8609
12.5	25	49.2	1.9209	1.1382	0.5308	1.4535
15	29.7	38.6	1.6031	1.0883	0.6199	1.0006
20	25	38.3	1.2376	0.8808	0.4106	0.7664
30	23.9	47.5	1.0266	0.6341	0.2805	0.757
40	6.3	62.1	0.7268	0.3384	0.0374	0.6421
50	41.8	65.6	0.6486	0.1995	0.1781	0.5909
60	23.4	52	0.5499	0.3108	0.1345	0.4333
80	29.3	60.6	0.4448	0.1906	0.1069	0.3874
100	23	56.2	0.4424	0.2262	0.0962	0.3678

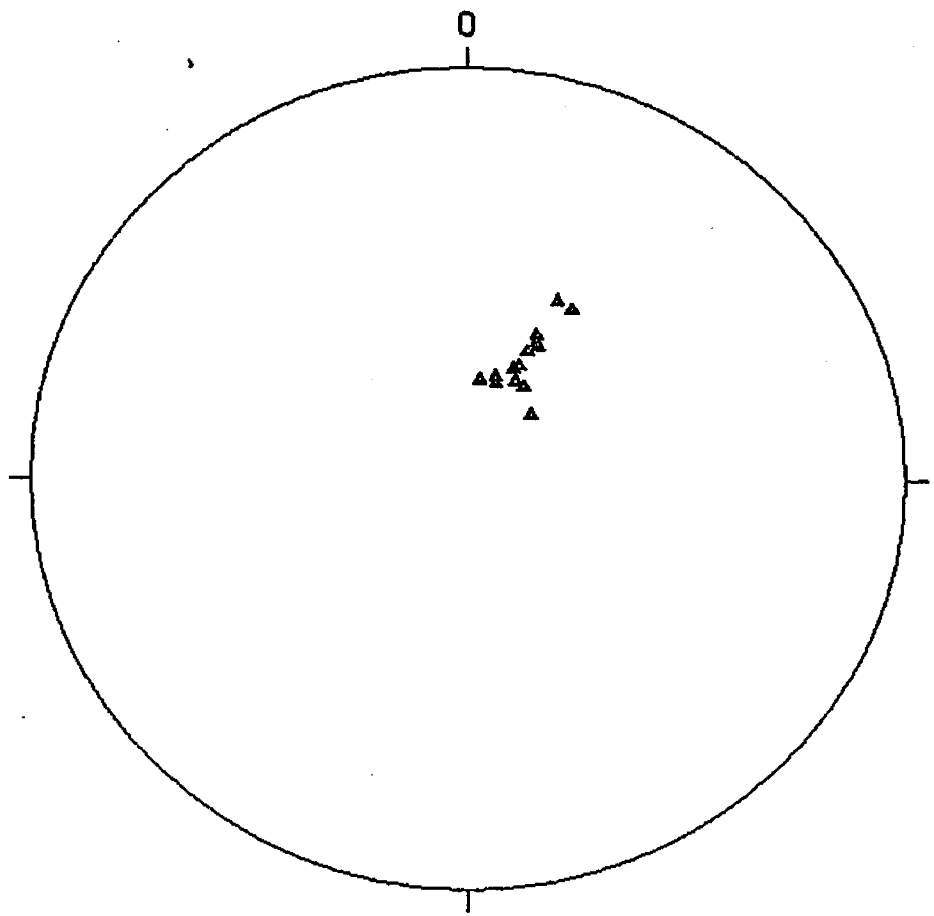


MDF = 10mT
% intenisty remaining = 8.97



Zijderveld C3/3
Up-Down
Northp-South
x,y
z,y
9
8
7
6
5
4
3
2
1
0
-1
-0.6
-0.4
-0.2
0
0.2
0.4
0.6

Directional changes for C3/3 between 0 and 100mT



FINAL STATS

Sample no.	Dec	Inc	x	y	z
C3/1	12.3	62.6	0.449636	0.098037	0.887815
C3/2	0.7	70.3	0.33707	0.004118	0.941471
C3/3	11.3	64.3	0.425252	0.084974	0.901077
C3/4	12.6	51.3	0.610185	0.136392	0.78043
C3/5	360	66.7	0.395546	-9.7E-17	0.918446
C3/6	349.3	54	0.577565	-0.10913	0.809017
C3/7	348.7	63.8	0.432947	-0.08651	0.897258
C3/9	12	65.1	0.411835	0.087538	0.907044
C3/12	358.1	69.6	0.34838	-0.01156	0.937282

Number = 9
Sum x = 3.988417
Sum y = 0.203859
Sum z = 7.979841
R = 8.92339
x bar = 0.446962
y bar = 0.022845
z bar = 0.894261

Mean Dec = 2.925998
Mean Inc = 63.41368
Alpha95 = 5.06159 **Alpha 68** 2.937715

CORRECTIONS

Mean Dec = 2.925998
Mean Inc = 63.41368

Correction for magnetic variation
Mean Dec = -1.297
Mean Inc = 63.41368

Correction to Meriden (CVP)

Uncorrected Dec = -1.297
Uncorrected Inc = 63.41368
Latitude = 54.8944
Longitude = -2.9461

Kai = 45.02658
Latitude of pole= 80.04442
Beta1 = -5.31443
Longitude of pole = 182.3683
Geomag colat = 47.50574
Corrected Inc= 61.37587
Beta 2 = -3.98833
Corrected Dec= -0.93443

FINAL RESULT
Corrected Dec= -0.93443
Corrected Inc = 61.37587
Alpha95 = 5.06159 **Alpha 68** 2.937715