AN ARCHAEOMAGNETIC STUDY OF MGUNGUNDLOVU

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The chronology of the Iron Age in southern Africa is being built largely on the basis of pottery sequences and radiocarbon dating. The radiocarbon method has several potential drawbacks relating to association between carbon samples and cultural materials, variation of atmospheric carbon-14 activity over time, and standard deviation. The latter two make it impossible to distinguish events spaced as much as 50 years apart, as in the case of buildings in a long-term settlement. One answer to these problems may lie in the use of archaeomagnetism for dating fired clay objects such as furnaces, tuyeres, floors, hearths and pottery. This method dates archaeological features directly, rather than by association. It may also, in optimum conditions, offer more accurate age determinations.

Before archaeomagnetic dating can be used, it is necessary to know accurately the curves of secular variation (magnetic change through time) applicable to the area of study. While some records exist from the 17th century onward for Cape Town (Brock 1977), secular variation is a localised phenomenon and measurements at Cape Town have not, as yet, been related to the rest of South Africa. This means that independent curves will have to be produced for separate areas. Accordingly, the Mgungundlovu project had a two-fold purpose: to establish whether hut floors and hearths have a measurable, stable thermo-remanent magnetization (TRM); and to establish the first points on a set of secular variation curves for Natal.

Mgungundlovu (28° 26′ S; 31° 17′ E) (Parkington and Cronin, this volume) was chosen because of its known time of firing. Within days of the Battle of Blood River (16 December 1838), Dingane fired the huts of his own household (Bird 1965: 235); this, presumably, would have been the *isiGodlo* area. The remaining huts, which may have included the *Bheje* area, were fired by Pretorius, who was back at the United Laagers by early 1839 (Morris 1966: 149). The year 1838 may thus be accepted as sufficiently accurate for the firing of the site.

METHOD

Reid (1978) discusses in detail the field methods used in the project. The somewhat friable nature of the floors and hearths dictated the sampling methods. Using a commercial masonry cutter, slots were cut into the material so that a square aluminium collar (10,0 cm on a side) could be placed over the sample and the whole set in plaster. The sample block was oriented with a theodolite and the orientation tied into trigonometrical survey beacons with an accuracy of about 10 minutes. Inclination of the upper edges of two perpendicular sides of the collar was measured to within 20 minutes using the vernier inclinometer of a Brunton compass. The sample block was then removed with a bolster chisel.

Six samples (*isiGodlo* and *Bheje*) were measured for intensity in the Research Laboratory, Oxford Uni-

TABLE 1. DIRECTIONS OF MAGNETIZATION GROUPED AT SAMPLE-LEVEL.

	NRM				After Cleaning			
Sample	D	I	κ	α_{95}	D	I	κ	α_{95}
9..	341,2	−57,3	521	5,4	340,0	−58,7	697	4,6
10..	328,5	−59,9	498	5,5	330,9	−57,5	269	7,5
11..	336,6	−63,6	94	12,7	334,1	−60,8	193	8,8
12..	325,5	−58,2	369	6,4	332,8	−60,5	90	13,0
13..	323,8	−56,6	1 250	3,4	324,6	−56,3	455	5,7
14..	347,3	−44,5	587	5,0	350,5	−44,4	540	5,3
15..	346,1	−54,0	206	8,5	343,8	−54,4	254	7,7
16..	327,8	−58,3	1 093	3,7	328,8	−57,0	1 063	3,7
17..	327,4	−52,8	275	7,4	326,1	−55,3	669	4,7
18..	330,4	−50,9	1 081	3,7	331,5	−50,5	523	5,3
19..	337,4	−54,8	777	4,4	337,2	−56,1	428	5,9
20..	322,9	−59,3	95	12,7	316,3	−60,6	87	13,3
21..	318,4	−50,0	146	7,6	324,1	−50,6	421	4,4
22..	321,4	−56,9	698	4,6	321,0	−57,7	1 501	3,1
23..	322,7	−50,4	1 169	3,6	325,0	−50,6	1 962	2,7
24..	324,8	−61,0	198	8,7	318,6	−60,5	1 819	2,8
30..	333,9	−65,0	138	10,5	331,4	−62,0	117	11,4
31..	317,8	−50,1	230	8,1	317,6	−49,2	180	9,2
32..	334,8	−48,3	1,24	3,0	337,1	−48,2	429	5,9
33..	335,6	−56,0	384	6,2	334,4	−55,9	204	8,6
35..	327,1	−50,4	206	8,6	326,1	−502	406	6,1

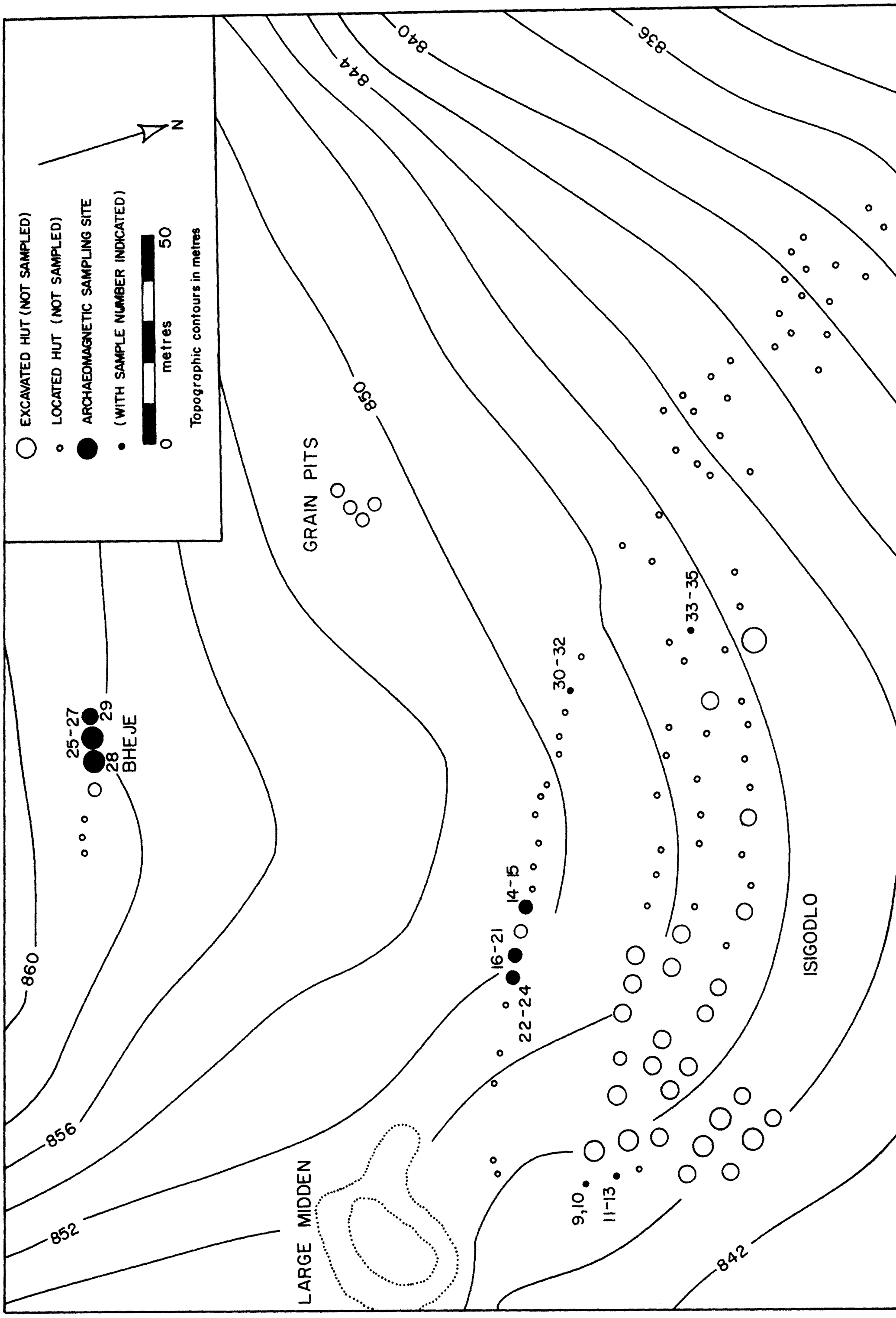

Fig. 1. Archaeomagnetic sampling points at Mgungundlovu. Numbers refer to sample blocks. Acknowledgements: H. Rüther and M. Cronin.

versity (Fox, Appendix B); four samples (*Bheje*) for declination/inclination in the Department of Physics, University of Rhodesia (McFadden, Appendix C); and 21 samples (*isiGodlo* and warrior huts), for declination/inclination in the Palaeomagnetic Laboratory of the Geological Survey, Pretoria (this report). Sampling locations are given in Fig. 1.

To prepare the samples for measurement in the Pretoria laboratory, they were clamped in a radial arm saw which was fitted with a masonry cutting blade. Three cubic specimens having sides of 22,0 mm, parallel to the sides of the aluminium collar, were cut from each of the sample blocks. The magnetic remanence was measured by a Digico complete-results spinner magnetometer, which rotates at a slow speed (7 Hz) and is ideally suited for measuring friable material.

The natural remanent magnetization (NRM) of each specimen was measured (Table 1) and one sample (No. 11: 3 specimens) was progressively demagnetized in an alternating field demagnetizer (after McElhinny 1964) at 5,0 mT (microtesla) steps to 20,0 mT. Best grouping of the directions of magnetization occurred at the 10,0 mT step and all specimens were subsequently demagnetized at this flux density. Owing to the shape and nature of the specimens, they could not be tumbled and were therefore arranged in the centre of the demagnetizer coil in such a way that any induced ARM (anhysteritic remanent magnetization) would be minimal.

RESULTS

The measurements were treated in two ways (Table 2): by giving unit weight to each oriented sample, and by giving unit weight to each hearth. There was no significant difference between the results obtained by either treatment, and probably all samples were magnetized at the same time. The intensity of magnetization of each individual specimen was sufficiently high to have been due to firing. After completion of demagnetization, the grouping of directions in many of the samples had improved but in others had deteriorated. The change in every sample, however, was not significant at the 95% level of confidence and this is reflected in the combined statistics (Table 2 & Fig. 2).

Brock (1977) suggests a tentative correlation between direction of magnetization and time, based on the premise that secular variation has a westerly drift of 0,22° a year. If this is applied to declination measurements made at Estcourt (the nearest place for which records are available) for the period 1903–1961, the theoretical value for 1913 measured at the same latitude, but at longitude 19,5° E, is 339,0°, which agrees with the value measured in 1913 (Beattie 1914). When extrapolated back to 1903, the theoretical value was 338,0°, whilst the measured value was 336,75°. Similarly, inclination (present value: −64°) gives theoretical values of −63,4° (1913) and −63° (1903), compared with measured values of −61,1° and −60,2° respectively.

Brock (1977) stresses that this method assumes secular variation to be largely westward drifting and without important non-drifting, variable-intensity components. Analysis of isoporic data for the area for the period 1912–1945 (Vestine *et al.* 1948) strongly suggests a non-drifting component of magnetization which grew and started to decay during the first half of the 20th century. Such a component obviously influences present-day maps and, depending on its areal extent, extrapolation from them.

The direction vector measured at Mgungundlovu has been compared with values tabulated by Vestine *et al.* (1948) for the best fit at this latitude. It appears to lie between the Greenwich meridian and 5° E and is within the circle of confidence of the archaeomagnetic result at the 90% level of confidence (although not at 95%). That no declination is as large as that measured archaeomagnetically is probably due to imperfections in the model; this has already been noted in the date for Estcourt, where measured declinations tend to be greater than theory predicts and inclinations steeper. Applying a drift date of 0,22°/year to the Mgungundlovu data suggests the firing to have been 130 years prior to 1945, i.e. 1815. This value is 23 years earlier than the true date of 1838, although the mean date lies within ± 30 years postulated from the 95% circle of confidence of the measured direction of magnetization. The result, however, does emphasize the need for establishing secular variation curves for Natal.

INTERPRETATION

The slight scatter in direction between adjacent specimens probably occurred because the fire of 1838 did not heat the samples to the Curie point of the magnetic material; thus, the direction was a hybrid of any previous direction of magnetization (random between specimens) and the partial TRM due to the firing. A second possibility, since specimens were cut from the inside portions of the hearths, is that the difference

TABLE 2. STATISTICAL ANALYSIS OF ARCHAEOMAGNETIC RESULTS.

MEAN DIRECTION GIVING UNIT WEIGHT TO SAMPLES						
NRM	D = 330,1	I = −55,7	N = 21	κ = 125,8	α_{95} = 2,8	R = 20,84
10 mT..	D = 330,0	I = −55,6	N = 21	κ = 152,0	α_{95} = 2,5	R = 20,87
GROUPED ACCORDING TO BEST KAPPA AT SAMPLE LEVEL						
	D = 329,8	I = −55,3	N = 21	κ = 146,6	α_{95} = 2,6	R = 20,86
MEAN DIRECTION GIVING UNIT WEIGHT TO HEARTHS						
NRM	D = 331,0	I = −55,2	N = 8	κ = 223,0	α_{95} = 3,7	R = 7,97
10 mT..	D = 331,2	I = −55,1	N = 8	κ = 217,0	α_{95} = 3,7	R = 7,97

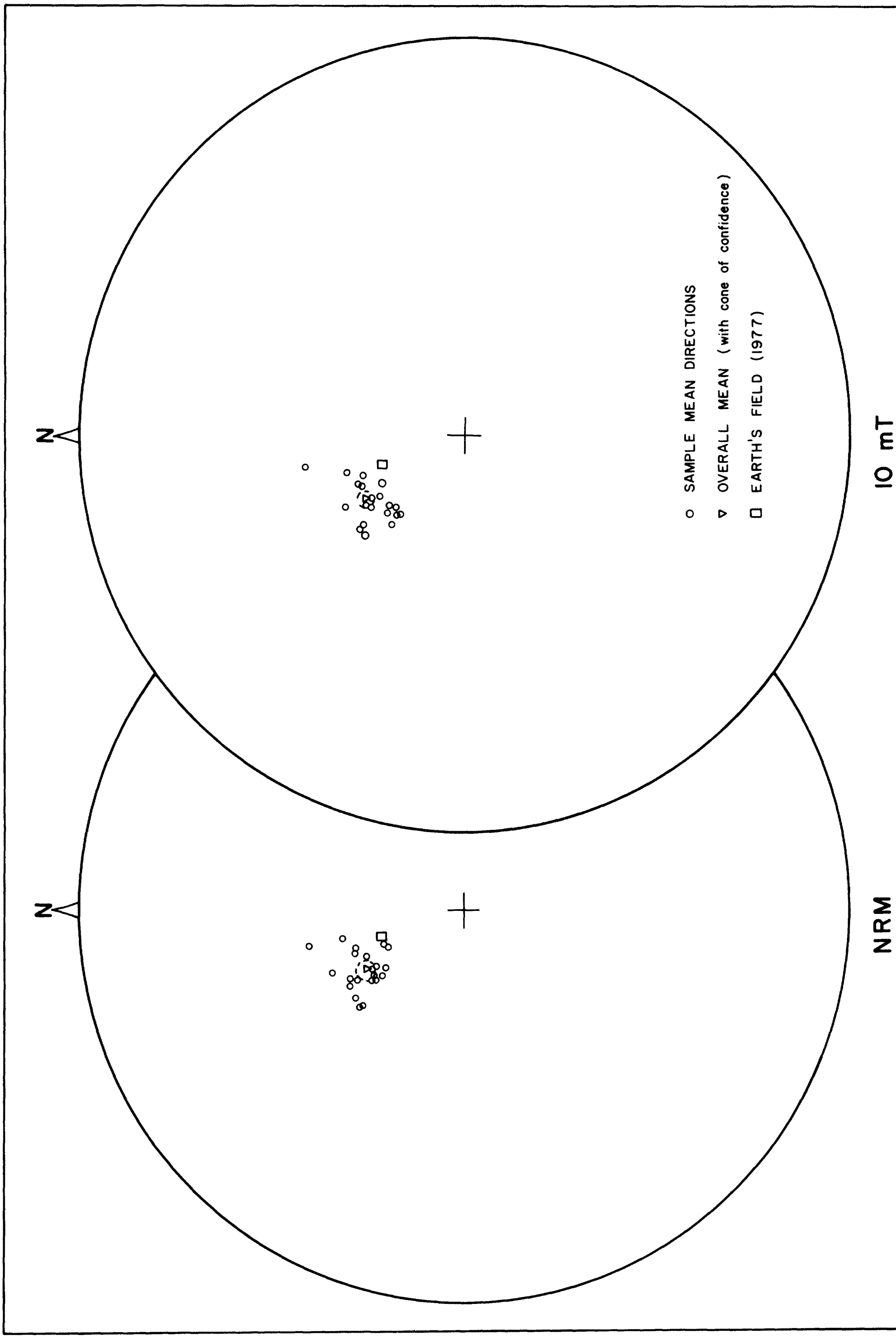

Fig. 2. Stereographic projection of directions of magnetization (*a*) NRM and (*b*) after cleaning at 10 mT.

was due partially to the change of field during the decade-odd when the hearths were in use.

As hearths might have undergone a more intense baking, most samples were collected from them. The measurements, however, showed that no noticeable advantage had been gained by using the hearths and, adversely, the material from the hearths was more friable than that of the floors and proved to be considerably more difficult to handle.

The present geomagnetic field at Mgungundlovu lies outside the 95% circle of confidence of the result and it therefore seems likely that the measured direction of magnetization relates to the year 1838. Remagnetization by lightning is ruled out as this would produce a scatter of results, whilst subsequent remagnetization from bush fires is improbable as the floors were excavated recently from a protective soil cover. In addition, the size of Euphorbia trees at the site precludes any major fire since 1838.

The direction of magnetization (D = 330,0°; I = −55,6°) with a semi-angle cone of 95% confidence of 2,5° — when considered as a time factor — implies, at the most recently available (1961) rate of change of declination for this area of 5′ a year, that this result has a confidence limit of ± 30 years.

CONCLUSIONS

The use of hut floors and hearths as suitable material for archaeomagnetic dating has been proved. Scatter of directions of magnetization from individual samples suggests that an archaeomagnetic date based on measurements of declination and inclination will not be better than ± 30 years.

The secular variation for northern Natal has been shown not to obey the simplified model of a constant westwardly drift and it will be necessary to establish a curve from measurements at a few sites (dated historically or by radiocarbon) and then to interpolate between these by measurements on lacustrine cores before archaeomagnetism can be used as a dating technique in its own right.

ACKNOWLEDGEMENTS

We thank the Director of the Geological Survey of South Africa for support of this project and authorisation to publish the data contained in an internal report of the Geological Survey (Gh 2373); Dr. M. J. Aitken and Prof. A. Brock for specialist advice; the field crew: Christine Sievers, Janet and Simon Hall, and David Killick; the Director of the Natal Museum, and Dr. Tim Maggs, for logistical support; J. G. G. Cordiner for making equipment; Heinz Rüther for on-site surveys, statistical analyses and interpretation; and J. M. W. Fox and Dr. P. L. McFadden for laboratory processing and interpretation. The Harry Oppenheimer Institute for African Studies and the University of Cape Town partially funded the project.

APPENDIX A

LAND SURVEYING ASPECTS OF ARCHAEOMAGNETIC SURVEYS

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The field work connected with the collection of samples for an archaeomagnetic survey requires firstly the establishment of a true North direction on site. This requires survey techniques with which many archaeologists will not be familiar. The following discussion aims at clarifying principles, methods and problems inherent in this type of field work.

TRUE NORTH, MAGNETIC NORTH AND GRID NORTH

Three types of North directions are relevant:

(i) true (or geographic) North – the direction of the meridian through a given point P;

(ii) magnetic North – the direction of the magnetic meridian through P (or direction of the tangent to the magnetic field line through P);

(iii) grid North in Northern Hemisphere, equivalent to grid South in Southern Hemisphere – the direction of the parallel to the Standard Meridian (Lo) at the co-ordinate system which is relevant for P. (The South African Co-ordinate System is a Gauss-Conformal system with Standard Meridians at 2° intervals starting with the 17° Meridian. The nearest odd-numbered meridian is the Standard Meridian for the site, as all trigonometrical beacons in the area will have co-ordinates with reference to this meridian). Whenever trigonometrical beacons are used to find a North direction on site – and this will in most cases be the best method for a "non-surveyor" – the result will be an orientation to grid North or grid South (in Southern Hemisphere), which has to be converted into true North.

The following relations exist amongst the three North directions (Fig. 1):

(*a*) declination

δ = angle between true North and magnetic North,

δ is counted positive if magnetic North is East of true North;

(*b*) meridian convergence

γ in Northern Hemisphere = angle between grid North and true North,

γ is positive for points East of the Standard Meridian;

γ in Southern Hemisphere = angle between grid South and true South,

γ is positive for points West of the Standard Meridian.

A sufficient approximation for γ is:

$$\gamma = \ell \sin \phi \qquad (1)$$

where ℓ = longitude of point P = longitude of Standard Meridian,

ϕ = latitude of point P (negative for Southern Hemisphere).

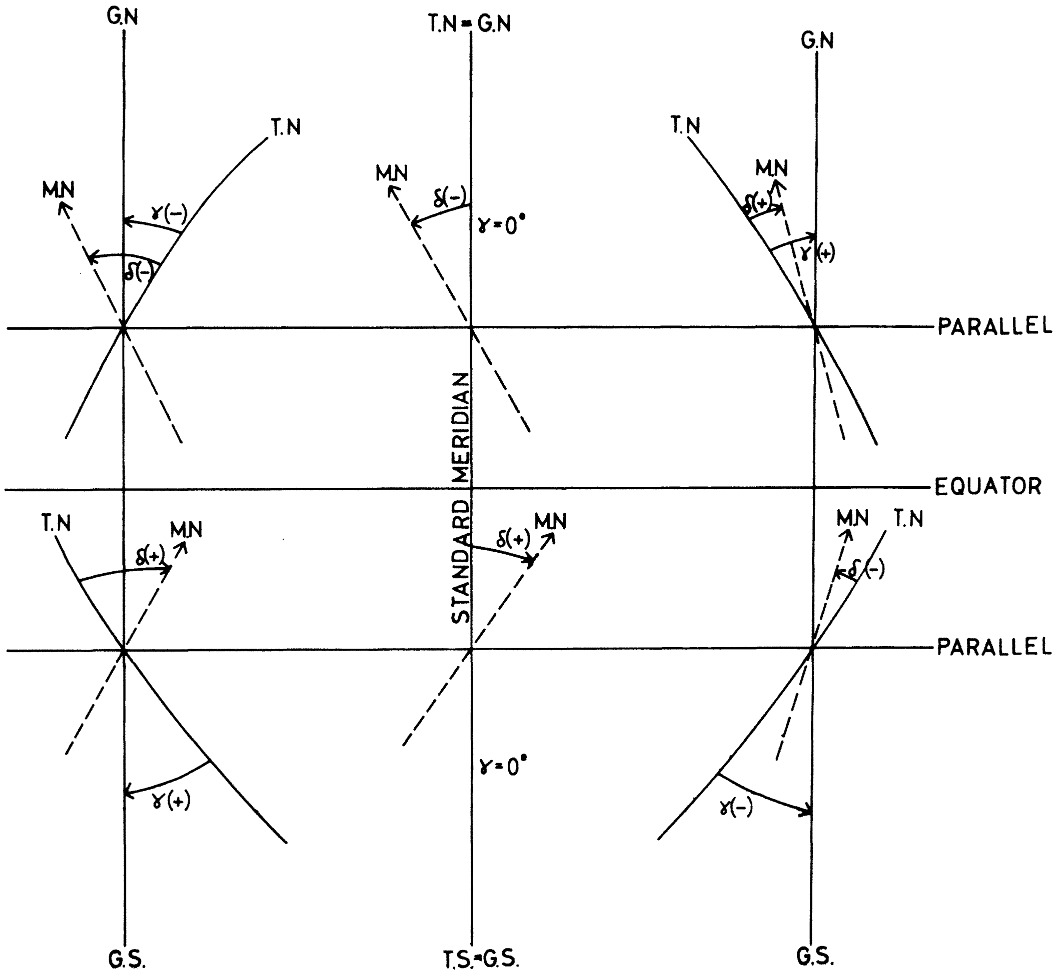

Fig. 1. Diagram showing relationships between grid, true and magnetic North.

To obtain a true North direction for a point P, (Yp, Xp), which was fixed on site using trigonometrical beacons, a theodolite observation to another beacon A (of known co-ordinates: Ya, Xa) has to be carried out and the observation has to be corrected for meridian convergence γ.

Fig. 2 shows a situation in the Southern Hemisphere, West of the Standard Meridian. The formulae (2) to (5) are valid for all other possible locations as long as the sign convention for δ and γ as defined above is adhered to.

Direction on line p→A with respect to

$$\text{grid South} = t = \text{arc tan}\,\frac{YA - Yp}{XA - Xp} \quad (2)$$

$$\text{true South} = t + \gamma \quad (3)$$

$$\text{true North} = t + \gamma + 180^\circ \quad (4)$$

$$\text{magnetic North} = t + \gamma + 180^\circ - \delta \quad (5)$$

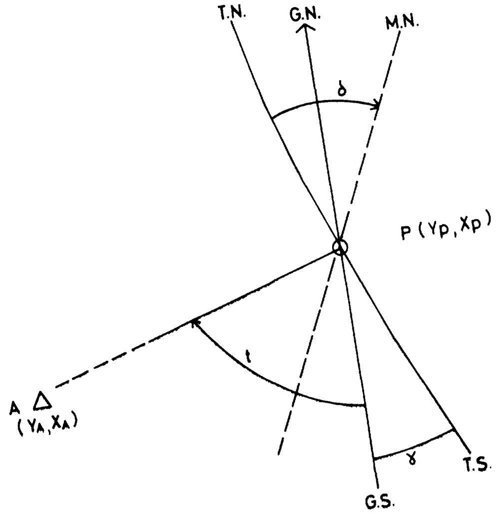

Fig. 2. Diagram illustrating meridian convergence, Southern Hemisphere – West of meridian.

DETERMINATION OF THE TRUE NORTH DIRECTION ON SITE

Before removing the sample blocks from their *in situ* positions, it is necessary, in order to re-establish their orientation and level in the laboratory, to mark each block with a line of known direction with respect to true North and to measure the inclination of the sample block. To find true North various methods can be used. Not more than one true North direction per site needs to be determined as this direction once obtained can be transferred easily to any required point.

In the following a number of methods are listed or described briefly; the first three are impractical for an archaeologist as they require special skills or instruments.

True North can be determined by sun observation, star observation, gyrotheodolite, and trigonometrical determination. This last method is highly accurate (± 10–20″) and can, after a study of some simple survey methods, be adopted by archaeologists. A minimum of four trigonometrical beacons of known co-ordinates must be visible from a point on site or close by, and a theodolite must be available. The method to be employed is known as "resection". The mathematics of resection can be consulted in any book on simple surveying. The result of the resection is the co-ordinates of the point over which the theodolite stood.

To relate the sample blocks to true North, the following procedure can be adopted:

1. Set up theodolite over resected point P on site, point to a known distant beacon and read the theodolite (the theodolite reading "th" is not oriented). It is advisable to read to a second known beacon for a check.
2. Point the theodolite to the sample block, mark a point A on the surface of the sample, align a second point B in the same direction on the sample and draw a line AB. The direction of this line can be evaluated. It must be borne in mind that the theodolite is not oriented and the zero of the theodolite circle can point in any direction (Fig. 3).

thTr = theodolite reading to trigonometrical beacon
thSB = theodolite reading to sample
(O.C.) = orientation correction applied to all theodolite readings to obtain readings with respect to grid South

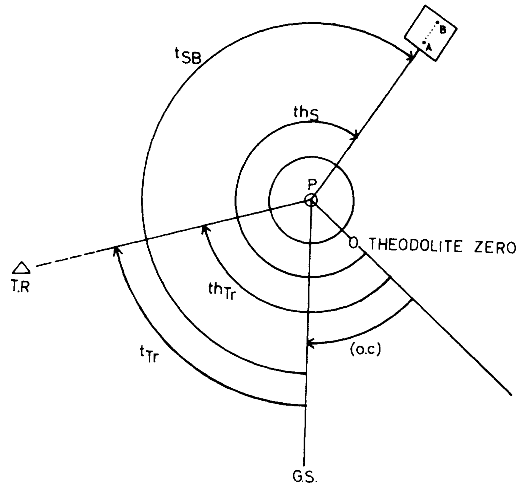

FIG. 3. Diagram illustrating theodolite method of relating sample blocks to true North.

tTr = grid South direction on line
tSB = grid South direction on line P – sample = line AB (O.C.) = thTR - tTR (6)

The direction of the line AB on the sample with respect to true North TSB can now be found (see also Fig. 2 and (4)).

tSB = thSB − (O.C.) from (6)
TSB = tSB + γ + 180° from (4)
TSB = thSB − (O.C.) + γ + 180° (7)

The theodolite can now be directed to all samples in turn and their orientation determined using formula (7). Should samples not be visible from the instrument as set up, or too far from it, an auxiliary point is established near those samples and a theodolite reading to the auxiliary point is taken. The instrument is now moved to this point and oriented on the central point P.

The trigonometrical method was employed at Mgungundlovu.

APPENDIX B

PALAEOINTENSITY RESULTS ON BAKED CLAY FROM MGUNGUNDLOVU

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Six samples were received for palaeointensity determinations: five from the *isiGodlo* area and one, M. FL.29/41B, from the *Bheje* area at Mgungundlovu (Parkington and Cronin, this volume).

These were subsampled in the laboratory, one-inch cubic specimens being obtained. The palaeointensity was determined for each of these specimens by the Thellier zero-field method, using a furnace of the type described by Barbetti (1972). The specimens were measured in a Digico large sample fluxgate magnetometer.

An arbitrary fiducial mark placed on the specimens allowed a track to be kept on the stability of the direction of magnetization to see if the magnetization was composed of multicomponents. In all cases the arbitrary direction remained constant up to high tempera-

TABLE 1. PALAEOINTENSITY RESULTS FROM MGUNGUNDLOVU.

Sample No.	F_A ± s.d. (mT)	Temp. interval used for F_A (°C)	Average F_A for area (± s.d.)
M.FL. 12/49	42,2 ± 0,6	214 — 595	
M.FL. 34/46	42,3 ± 1,5	143 — 584	
M.FL. 34/47	43,9 ± 0,7	136 — 570	42,7 ± 1,5
M.FL. 35/50	42,3 ± 1,6	199 — 395	
M.FL. 48/48	42,7 ± 0,7	140 — 577	
M.FL. 29/41B	42,0 ± 0,8	211 — 551	42,0 ± 0,8

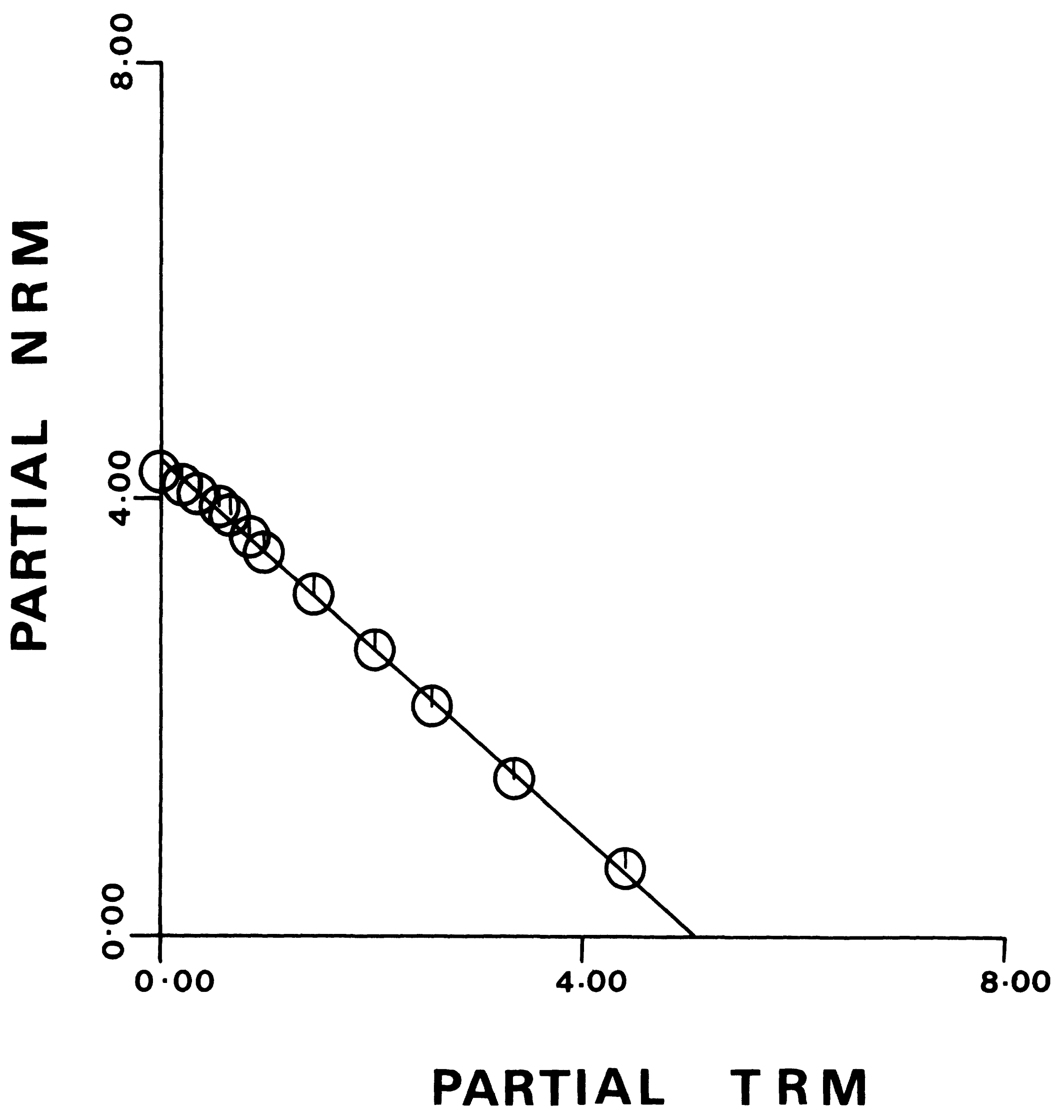

Fig. 1. Thermal demagnetization – thermal remagnetization for the sample M. FL. 12/49. The vertical axis shows the NRM remaining after heating to successively increasing temperatures and cooling in zero field; the horizontal axis shows the TRM acquired on heating to the same successive temperatures and cooling in a field of 49 mT. The units are 10^{-4} Am^2kg^{-1}.

tures (around 500° C), above which the specimens' magnetization was extremely weak.

The palaeointensity (F_A) was determined by plotting the natural remanent magnetization (NRM) against the thermo-remanent magnetization (TRM) (Fig. 1). Most of the samples were extremely stable with only minor mineral alteration occurring at the upper end of the temperature range. Only one sample, M. FL.35/50, showed severe mineral alteration in the laboratory, but enough data points remained to calculate the FA with reasonable accuracy. The results from the *isiGodlo* (Table 1) are well grouped and the single *Bheje* sample also gives a stable field value statistically the same as those of the *isiGodlo*.

The palaeointensity value obtained of 42,7 ± 1,5 mT (microtesla) is much higher than that of the present-day field value (31 mT), but the present-day field is decreasing by 0,09 mT per year. If this rate of decrease is assumed to have been approximately constant over the last 140 years, the field will have decreased by a total of 13 mT which would then give a field value, in 1838, of 44 mT – a value well within the error limits of the palaeointensity found from the samples.

APPENDIX C

ARCHAEOMAGNETIC SAMPLES FROM THE BHEJE AREA, MGUNGUNDLOVU

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Four samples (Block Nos. 25, 26, 27 and 28; Henthorne *et al.* Fig. 1) were received by the Salisbury laboratory. Specimens were obtained from these samples using a rotary diamond drill. The samples were clamped in the jaws of a dividing table and the table calibrated according to the azimuthal orientation of the sample. The plaster of paris was then removed and the sample drilled. Owing to the friable nature of the samples, several attempts were made in each case to obtain an acceptable specimen. As a result no more than three specimens were obtained from any sample. A scriber was then used to transfer the azimuthal orientation to the specimen. The *in situ* dip of the core (specimen) was then calculated from the inclinations given from the collar sides.

Specimens were measured on a Princeton Applied Research SM-1 spinner magnetometer. Several specimens were progressively demagnetized in an alternating field demagnetizer in 5 microtesla (mT) steps to 30 mT. In each case the natural remanent magnetization (NRM) was strong and stepwise demagnetization showed that only one component of magnetization resided in the samples.

TABLE 1. SPECIMEN DIRECTIONS OF MAGNETIZATION BEFORE AND AFTER ALTERNATING FIELD DEMAGNITIZATION IN A PEAK FIELD OF 30 mT.

	NRM		30 mT	
Specimen	D	I	D	I
25A	284,1	−51,6	284,3	−50,5
25B	285,6	−52,0	285,0	−50,4
26A	305,7	−58,0	304,4	−56,8
26B	296,8	−59,0	296,1	−57,8
27A	290,8	−55,2	290,6	−55,5
27B	292,1	−55,7	291,7	−55,1
27C	291,0	−55,0	289,4	−53,5
28A	087,8	−54,5	088,2	−54,5
28B	088,9	−52,6	089,0	−51,7
28C	089,7	−58,7	090,9	−57,2

TABLE 2. MEAN SAMPLE DIRECTIONS AFTER ALTERNATING FIELD DEMAGNETIZATION.

Sample	D	I	R	k
25	284,7	−50,5	2,000	62 928
26	300,3	−57,4	1,9984	623
27	290,6	−54,7	2,9995	4 192
28	089,3	−54,5	2,9975	802,2

RESULTS

The directions of magnetization for each specimen are given in Table 1 and the mean sample directions in Table 2. The direction of magnetization of Sample Block No. 28 indicates that an orientation error occurred with this simple and therefore its direction of magnetization should be excluded from any analysis.

INTERPRETATION

The overall mean direction of samples 25, 26 and 27 is D = 291,4; I = −54,4 with $\alpha 95$ (the semi-angle of the cone of 95% confidence in the mean direction) of 8,8° and the κ = 199,3. This mean direction is 21,9° from the mean direction established by D. I. Henthorn at the Geological Survey. Firstly it must be noted that these two directions are significantly different and secondly it must be noted that (apparently) no record exists of a magnetic declination as far to the west as is suggested by the *Bheje* results. Between-sample consistency indicates either that this result is real or that a systematic error exists in orientation of the samples. Discussion with H. Rüther (who did the survey) makes it evident that such an error did not occur. It is therefore concluded, at this stage, that the results are real and are not due to systematic error.

The small number of data from the *Bheje* area makes interpretation of this anomalously high westward declination difficult. At this stage in the study it is probably wise simply to leave these results as unexplained, but to note that further work may clarify the problem.

The magnetic behaviour of the samples indicates that the method is capable of producing reliable results from the type of sample collected. An interesting feature of the *Bheje* results is that they have an inclination almost identical to the mean inclination of the samples analysed by Henthorn and that the estimation of the precision parameter is very similar. This indicates great similarity in the magnetic properties of the samples even though the resultant declinations are different.

CONCLUSION

It has been shown by the study that hearths provide suitable (although physically intractable) samples for archaeomagnetic dating. The *Bheje* data at present are insufficient from which to draw age conclusions (particularly in the absence of a well-known secular variation curve for the area), but show that further work may well provide a basis for the use of archaeomagnetism as a standard tool in archaeological dating in South Africa.

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