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MAGNETIC DATING OF SOME ABORIGINAL FIREPLACES FROM THE LAKE VICTORIA REGION, N.S.W.

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When oven stones and the soil underneath are heated in an Aboriginal fireplace, any weak magnetization they may already possess is destroyed. As they cool again after the fire has been extinguished, a new magnetization is frozen in; this remanent magnetization is exactly in the direction of the Earth's magnetic field and its intensity is directly proportional to the strength of the Earth's field. Careful measurement of the intensity or the direction of remanent magnetization makes it possible to estimate the age of an ancient Aboriginal fireplace by comparing the results with known changes of the ancient geomagnetic field in that region.

During the past few thousand years there have been significant changes in both the direction and intensity of the geomagnetic field. In general, variations in the *direction* are quite different for places a few thousand kilometers apart (Aitken and Weaver 1965), so it is not possible to use data from one place to estimate the variation in another part of the world. On the other hand, variations in the *intensity* of the geomagnetic field are essentially the same, and previous measurements from other parts of the world can be applied elsewhere.

Data on ancient changes in the geomagnetic *direction* is not available from SE. Australia, so it is not yet possible to use this method of dating. However, sufficient data has been collected from other parts of the world to define global changes in geomagnetic intensity, and this paper describes how estimates of the ages of some Aboriginal ovens were obtained using this data. The locations of the ovens and types of material are given in Table 1.

A method of determining the ancient geomagnetic field intensity from baked clay was first described by Thellier and Thellier (1959), and the theory is straight-forward. Thermoremanent magnetization is acquired by baked clay containing a small percentage of magnetic minerals as it cools from the Curie temperature (675°C for haematite) in a magnetic field. The partial thermoremanent magnetization acquired in any given temperature interval (for example, between 450°C and 400°C) is independent of

Table 1

Details of Ovens

Oven	Location†	Material analysed	Comment
CHA 10	site 2, Keera Station, V.	baked clay ovenstone	Aboriginal oven on surface
CHA 27	site 5, Keera Station, V.	baked clay ovenstone	Aboriginal oven on surface
CHA 203	Near Dickies gate, Scrub paddock, Kulcurna Station, N.S.W.	two pieces of baked sandstone	Aboriginal oven on surface (nearby oven has radiocarbon age 1930 ± 80 B.P., Gak-2007, Gill 1973).
CHA 332	outlier 3, Dunedin Park Station, N.S.W.	baked clay ovenstone	Aboriginal oven set in hardpan

† For description of location see Gill (1973).

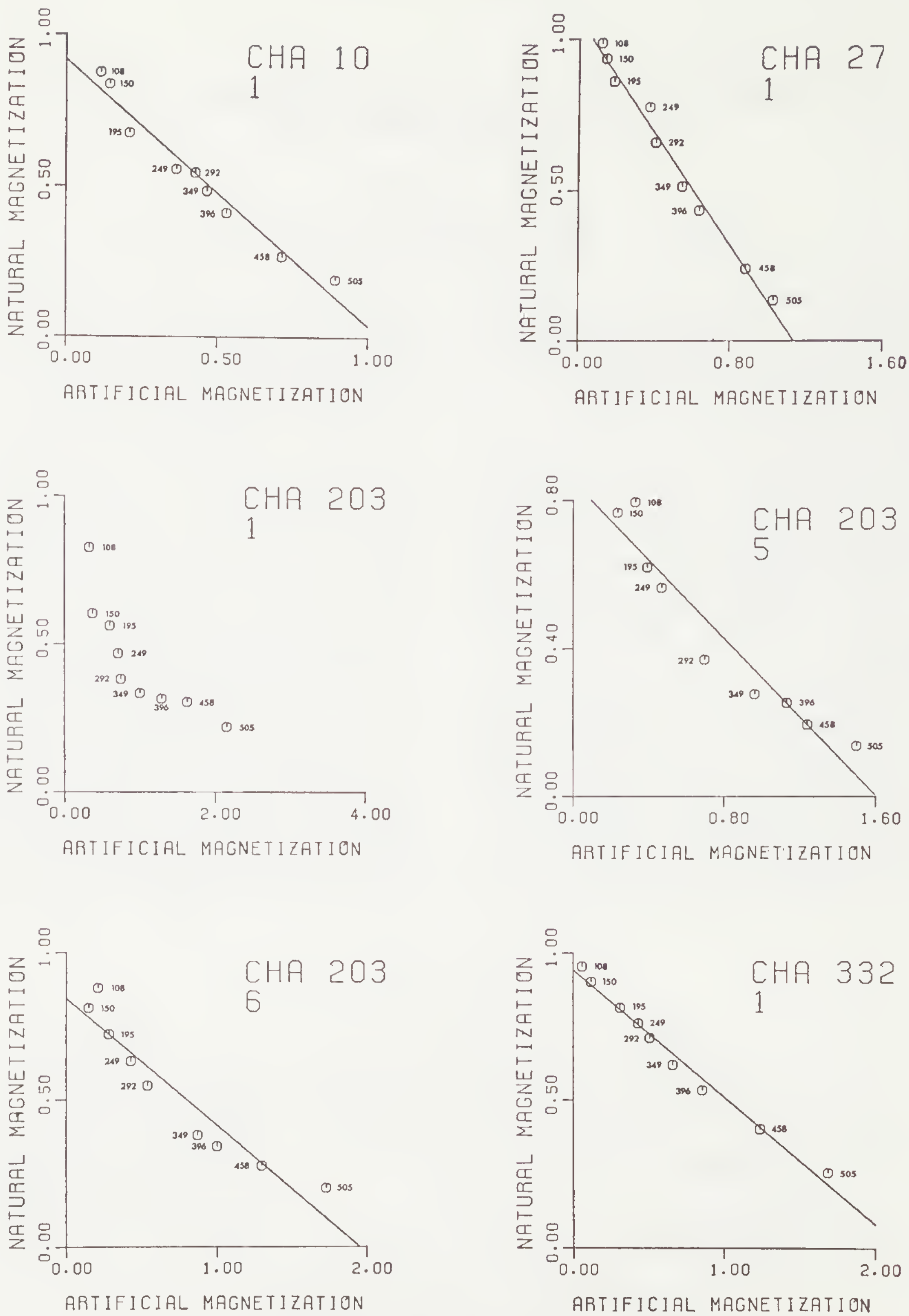

Fig. 1—Partial natural vs. partial artificial magnetization after each double heating. All values are normalized with initial total natural magnetization taken as unity. Numbers near points refer to heating temperatures (°C).

magnetization acquired outside that interval. In weak magnetic fields, such as the Earth's, the intensity of magnetization is linearly dependent on the field intensity.

In the laboratory, the natural magnetization is gradually removed by controlled heating and cooling cycles, repeated twice for each temperature, at successively higher temperatures. After the first heating, the specimen is cooled in the absence of a magnetic field, and the remaining natural partial magnetization is measured. The specimen is reheated to exactly the same temperature and cooled in a known weak magnetic field to give it an artificial partial thermoremanent magnetization in addition to the remaining natural partial magnetization. The double heatings are performed at progressively higher temperatures until the natural magnetization has been reduced to about a tenth of its original value (typically at about 550°C). For each temperature interval the ratio of the intensities of the ancient geomagnetic and laboratory magnetic fields is equal to the ratio of the intensities of the natural and artificial magnetizations.

One method of analysing the results thus obtained is to construct a graph of the partial natural magnetization remaining after the first cooling plotted against the partial artificial magnetization acquired during the second cooling, for each pair of heating and cooling cycles, and to calculate the best-fitting straight line by the method of least squares. The absolute value of the slope of this line is the ratio of the ancient geomagnetic and laboratory magnetic field intensities (Coe 1967).

Figure 1 shows the results from representative specimens and Table 2 summarizes the data obtained in this study. Most of the specimens (2·2 cm x 2·2 cm cylinders) exhibited linearity in the relationship between natural and artificial magnetization. However, three specimens of baked sandstone gave highly non-linear results (for example, CHA 203/1) because of magnetic instability, and no meaningful straight line could be fitted. Three other specimens of sandstone which seemed to exhibit linearity (for example, CHA 203/5 and 6) give significantly different values for the ratio of the ancient field intensity to the laboratory field, and the results were therefore rejected. Results from all specimens of baked clay showed good linearity, and five specimens from one oven stone (CHA 332) gave very consistent ratios from which a mean has been calculated. Ancient field intensities were obtained for three of the four Aboriginal ovens sampled (Table 2).

Since the intensity of the geomagnetic field varies slowly with latitude (the intensity at the

TABLE 2

SUMMARY OF ANCIENT FIELD MEASUREMENTS (WITH STANDARD ERRORS)

Oven	Specimen	Least squares ratio $F_{ancient}/F_{lab.}$	Mean ratio $F_{ancient}/F_{lab.}$	Ancient field intensity (oersted)
CHA 10	1	0·881 ± 0·078	0·881 ± 0·078	0·522 ± 0·046
CHA 27	1	0·936 ± 0·050	0·936 ± 0·050	0·555 ± 0·030
CHA 203	1	magnetically unstable	results from different specimens do not agree	—
	2	magnetically unstable		
	3	0·616 ± 0·057		
	4	magnetically unstable		
	5	0·529 ± 0·070		
	6	0·432 ± 0·062		
CHA 332	1	0·431 ± 0·024	0·438 ± 0·010	0·260 ± 0·006
	2	0·446 ± 0·027		
	3	0·445 ± 0·020		
	4	0·437 ± 0·027		
	5	0·432 ± 0·020		

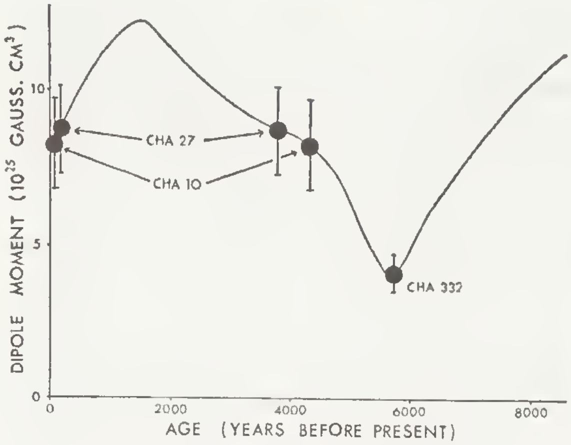

Fig. 2—Variation of geomagnetic dipole moment with time (solid line) after Cox (1968). Points for each oven show where their estimated GDM may be placed on the curve.

magnetic poles is approximately twice that at the magnetic equator), it is necessary to have some way of directly comparing ancient field intensities from different magnetic latitudes. A suitable method is to calculate the moment of a dipole at the centre of the Earth which would have produced the measured ancient field intensity at the site. In order to do this it is necessary to know the ancient magnetic latitude of the site. When the magnetic palaeolatitude is not known (as in this study) it is best to assume that it is the same as the present magnetic latitude because, although it has been suggested that the best-fitting dipole to the Earth's magnetic field has moved in the past few thousand years (Kawai and Hirooka 1967), there is not sufficient data to allow a correction to be made. The equivalent dipole calculated by this method is termed the *Reduced Dipole Moment* (RDM) (Smith 1967). However, although the Earth's magnetic field may be closely approximated by that of an inclined geocentric dipole, small irregularities (usually termed the non-dipole field components) may have contributed appreciably to the observed field at a particular time and place. Consequently, several RDM values from different parts of the world must be averaged to find the value of the *Geomagnetic Dipole Moment* (GDM) at any given time in the past. Smith (1967) compiled all available measurements of RDM and these were averaged in 500-year class intervals by Cox (1968) to obtain GDM values for the last 8,500 years. An examination by the author of the scatter of RDM values from the appropriate GDM value suggests their standard deviation is about 15 per cent. Figure 2 shows the variation of GDM for the last 8,500 years (after Cox 1968).

Table 3 gives the RDM values calculated from the measured ancient field intensity, assuming a palaeolatitude equal to the present *magnetic* latitude of the Lake Victoria region (48°S). In addition to the experimental error, a further 15 per cent variation has been allowed in the RDM value to obtain an estimated GDM for each of the Aboriginal ovens.

Provided only that there is no possibility that CHA 332 is older than 8,500 B.P., then a comparison of the estimated GDM with the curve (Fig. 2) indicates an age of 5,700 ± 300 B.P. The oven was set in a hardpan which is interpreted as the A2 horizon of a soil, and the indicated age is in good agreement with a

TABLE 3
AGES OF OVENS

Oven	Reduced Dipole Moment (10^{25} gauss. cm^3)	Estimated Geomagnetic Dipole Moment (10^{25} gauss. cm^3)	Age limits at 68% confidence level (yrs. B.P.)	Age limits at 95% confidence level (yrs. B.P.)
CHA 10	8·24 ± 0·73	8·24 ± 1·44	0–400 *OR* 2950–4800	0–800 *OR* 2150–5200
CHA 27	8·76 ± 0·47	8·76 ± 1·40	0–500 *OR* 2700–4750	0–1000 *OR* 1950–5100
CHA 332	4·10 ± 0·09	4·10 ± 0·62	5400–5950	5250–6200

radio-carbon age of 5,840 ± 90 B.P. (Gak-1429) from charcoal among Aboriginal skeletal remains excavated from a similar depth at Keera Station (Gill, pers. comm.). The other two ovens (CHA 10 and CHA 27) were situated on the present surface above the hardpan, but even assuming that they are younger than CHA 332 there are two possible ages for each (Fig. 2). Table 3 gives their possible age limits at the 68 per cent (one standard error) and 95 per cent (two standard errors) confidence levels; however, these limits should be regarded with caution, since in each case an RDM has been obtained using only one specimen. Perhaps the best conclusion is that neither oven is likely to have an age between 1,000 and 2,000 B.P.

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