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BRITISH GEOMAGNETIC MASTER CURVE 10,000-0 yr B.P. FOR DATING EUROPEAN SEDIMENTS

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Abstract. Palaeomagnetic inclination records are demonstrated for the first time to be repeatable between lakes. These magnetic variations can now be interpreted with confidence as being a true geomagnetic record. New radiocarbon age determinations refine the time scale of secular changes recorded in Britain over the last 10^4 years. The paired D & I magnetic measurements form a detailed master curve of 23 features for dating European sediments. The improved records and time scale show that neither the declination nor inclination fluctuations have been periodic. Tight or clockwise looping of the geomagnetic vector has been dominant over Britain since 10,000 B.P.

Triplicate cores of sediment have been collected from Loch Lomond, Scotland, and Lake Windermere, N.W. England, using pneumatically controlled Mackereth corers (Mackereth, 1958). Two different coring machines were used in each lake to check that they were not systematically influencing the palaeomagnetic records, e.g. by twisting of the core tube as it enters the sediment.

Whole-core measurement of declination, the horizontal component of remanence and magnetic susceptibility confirmed that the cores were suitable for further investigation. Each core was then split in half lengthwise, and oriented sub-samples taken in 8.2 ml cubic boxes, at 2.5 cm intervals. These samples were stored in zero magnetic field prior to measurement in a slow speed spinner fluxgate magnetometer (Molyneux, 1971). Special care was taken to ensure the sediment remained fresh and did not dry out.

Finer detail and better reproducibility were recorded in declination and inclination logs (Fig. 1) from both lakes, than had previously been attained, indicating that they provide a reliable geomagnetic signature. Ten declination and 13 inclination features are identified in all the records (with the exception of the top metre of W3, which was disturbed in coring). Partial alternating field demagnetization of a representative selection of samples used in this study, up to peak fields of 90 mT, showed stable magnetization, with an average median destructive field of 25 mT in Windermere and 40 mT in Lomond. No low stability or viscous components with directions different from the NRM were detected. Thus, both the NRM and partially demagnetized remanence record the past directional changes of the geomagnetic field.

Thirty published radiocarbon age determinations and palynological age controls (Mackereth, 1971; Thompson, 1975; Dickson et al, 1978; Thompson & Wain-Hobson, 1979), from cores with palaeomagnetic records from 5 British lakes, have been used to construct a time scale summarized in Table 1 and used in plotting Fig. 1. Features a, b, c, and α, β, γ, δ, have been located on the time scale by comparison with the archaeomagnetic results of Aitken (1970) & Thellier (1968) and observatory records.

The Windermere cores were internally correlated using thin clay bands; the Lomond cores were internally correlated using magnetic susceptibility features. Thus, since both lithology and susceptibility are dependant only on the material input to the lake, these correlations are completly independent of the palaeomagnetic direction changes. The Windermere and Lomond records were then matched at the top of the cores, and at the pollen assemblage zone boundary of the Ulmus decline, which lies between magnetic features of g and ι. The records were finally stretched so that the declination oscillation f-e-d also correlated between the lakes.

The calibrated time scale (Table 1) was then used to convert the depth scale into equal intervals, using linear interpolation between adjacent data points so as to minimize the dependance introduced between new data points. As the cores were not absolutely oriented a reference system had to be chosen, in which comparison of the palaeomagnetic records could be made. The records of each core were rotated ('transformed') so that its mean vector, calculated by averaging over the direction cosines, had zero declination and inclination. This reference system has the advantages that (a) equal weight is given to both the transformed declinations and inclinations and (b) smoothing methods such as that of Clark & Thompson (1978) can be adapted to process the paired data.

The major features in the new records can be recognised, with hindsight, in the original Windermere declination measurements (Fig.2). Also in the new records extra detail can be seen to be repeatable between cores. The palaeomagnetic logs show that there has been no dramatic change in the style of secular variation in Britain over the last 10,000 years.

It is clear that the fluctuations in both declination and inclination are not periodic over many cycles. For example, the duration of declination cycles steadily decreases from 4,000 to 1,700 years. The secular variations are probably built up from a number of disconnected, short, variable features associated with the growth, movement and decay of magneto-hydrodynamic centres in the Earth's core. Such a combination of features would be expected to lead to the power spectrum obtained from these records, which peaks in a spread of periods between 2,000 and 3,000 years. Bauer plots, of transformed declination against inclination, averaged over the whole suite of cores, show that the geomagnetic vector has

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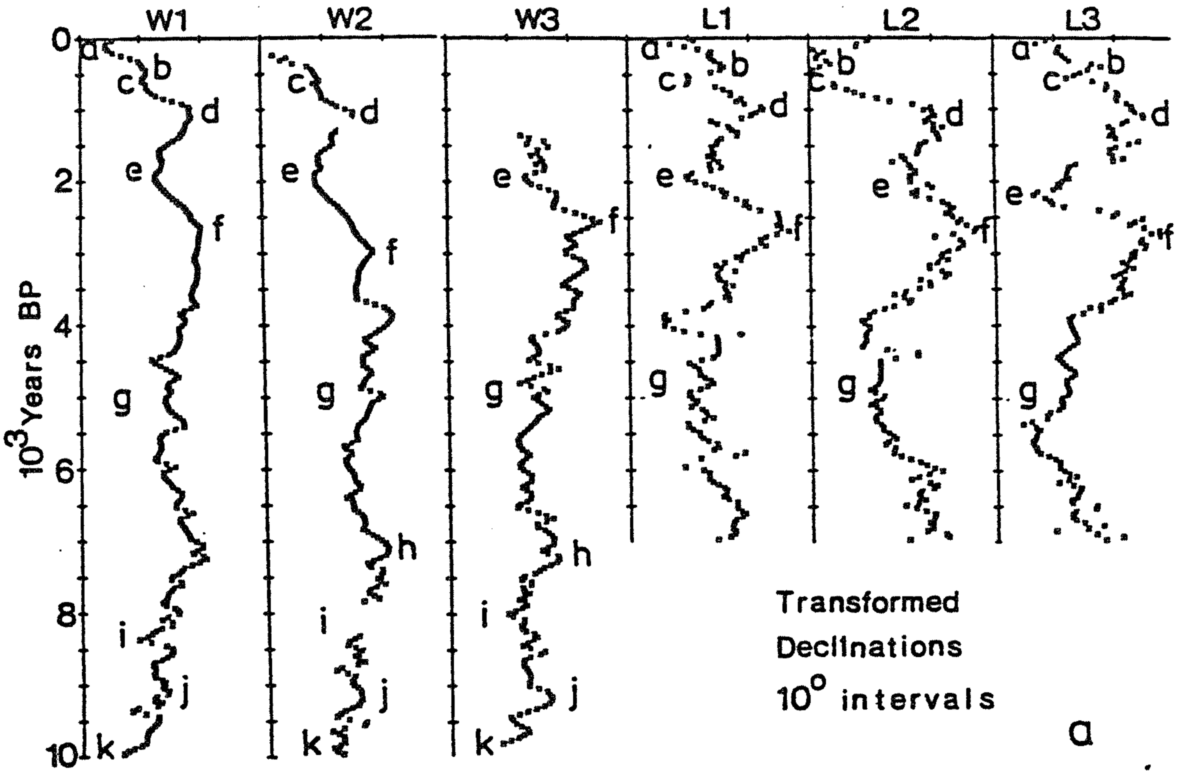

Fig. 1a. Transformed declinations plotted against preferred time for three Lake Windermere cores (W1-3) and three Loch Lomond cores (L1-3). Symbols refer to characteristic features which may be sharp (e.g. 'f') or drawn out (e.g. 'g').

moved in tight closed loops between 10,000 and 7,000 yrs B.P. This behaviour is followed by more open, clockwise looping, interrupted only by one extensive period of anticlockwise movement from 1,100 to 600 B.P. which is also seen in archaeomagnetic curves. The rate of change of direction varies considerably and the magnetic vector shows periods of unusually slow movement, for example, around 1,600 B.P.

The nature of the British variations suggests that assignment of magnetic ages by interpolation or extrapolation from major secular variat-

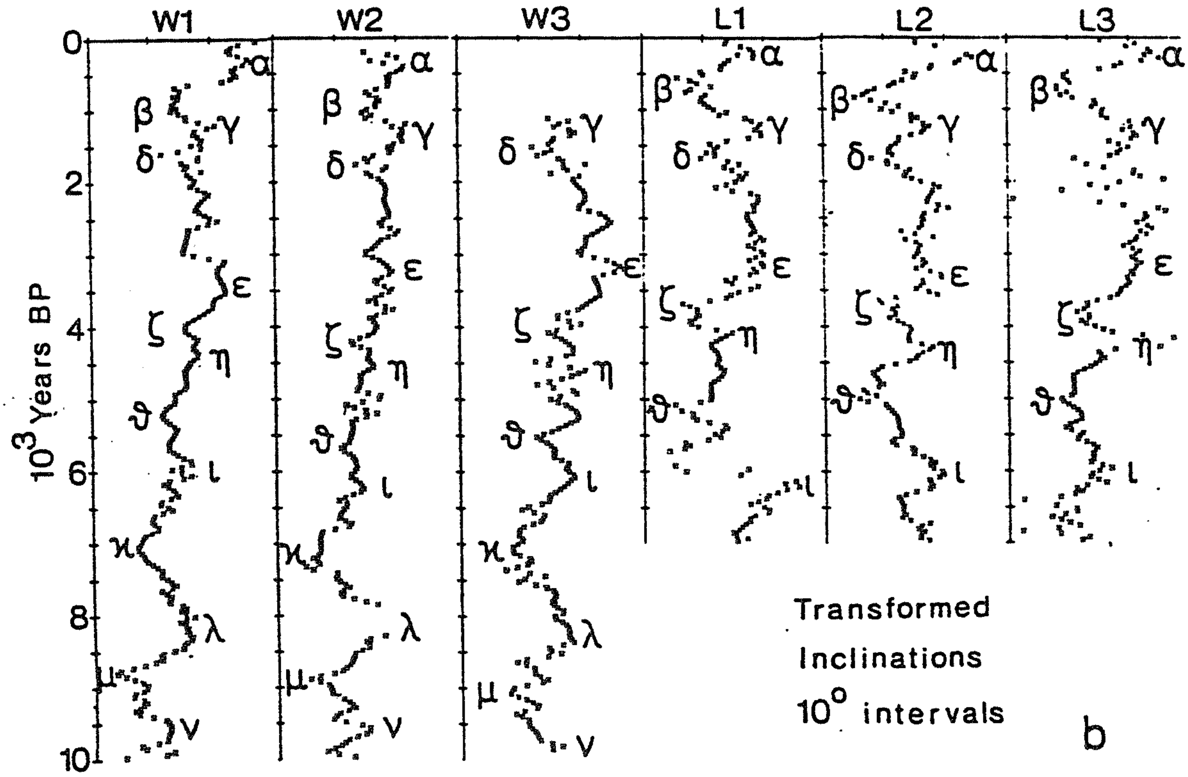

Fig. 1b. Transformed inclinations for the same six cores as Fig. 1a and the same time scale.

TABLE 1. Preferred time scale for declination and inclination features.

Declination			Inclination		
Feature	Calibrated date BP	Conventional date bp	Feature	Calibrated date BP	Conventional date bp
a	150	150	α	250	250
b	450	450	β	650	650
c	600	600	γ	1150	1150
d	1000	1000	δ	1650	1650
e	2000	2000	ε	3100	2900
f	2600	2500	ξ	3800	3500
g	4900	4200	η	4300	3800
h	7100	6200	θ	5000	4300
i	(8300)	7400	ι	6000	5200
j	(9100)	8800	χ	7100	6200
k	(10000)	10000	λ	(8300)	7400
			μ	(8800)	8400
			ν	(9700)	9700

Calibration of conventional radiocarbon age determinations based on Clark (1975) for features a to h and α to χ. For older features (calibrated ages in brackets), Mackereth (1971) is followed in assuming calibration changes smoothly from 6500 yr bp to zero correction at 10,000 yr bp.

ion peaks is liable to be a hazardous exercise, but it has been attempted by Stuiver (1978). The palaeomagnetic record can, however, be used as a rapid dating tool over the last 10^4 years by correlation of the declination features a to k and inclination features α to ν. Palaeomagnetic records from Finland (Stober and Thompson, 1977), Switzerland (Thompson and Kelts, 1974) and Greece (Creer et al., 1977) and historic records (Barraclough, 1974) suggest that the master curve of Fig. 1 will be useful over the whole area of Western Europe for the last 10^4 years.

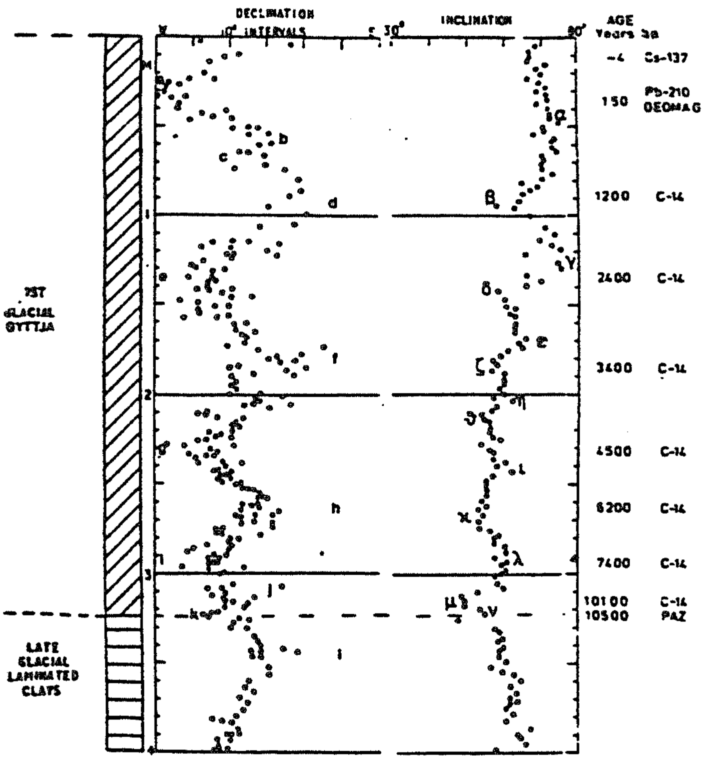

Fig. 2. Features a to l and α to ν identified in the original relative declination data of Mackereth (1971) and inclination data of Thompson (1977).

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