PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A
MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Gauss-Matuyama Polarity Transition

J. C. Liddicoat

Phil. Trans. R. Soc. Lond. A 1982 **306**, 121-128
doi: 10.1098/rsta.1982.0072

Phil. Trans. R. Soc. Lond. A **306**, 121–128 (1982) [121]
Printed in Great Britain

Gauss–Matuyama polarity transition†

By J. C. Liddicoat
Lamont-Doherty Geological Observatory, Columbia University, Palisades, New York 10964, *U.S.A.*

The Gauss–Matuyama (G–M) polarity transition has been identified in a 9 cm rotary-drilled core from Searles Valley, California. The lithology, recovery and preservation of the sediments allow a detailed investigation of the transition. The transition is estimated to have lasted approximately 2000 years. About 2000 years earlier, a short reversal also occurred that lasted 2000 years. The relative field intensity decreased by at least 70 % both during this short reversal and the G–M transition.

The virtual geomagnetic poles path for the G–M transition is restricted to a meridional band 20° wide in the Atlantic Ocean and closely matches the v.g.p. path for the Matuyama–Brunhes transition recorded at Lake Tecopa, California. On the other hand, the pole path for the G–M transition recorded in Russia (about 180° in longitude from Searles Valley) is nearly antipodal at low latitudes to the Searles Valley pole path. These data indicate that the transition field associated with the reversal was dominated by non-dipole components.

1. Introduction

The Kerr–McGee Chemical Corporation rotary-drilled Searles Valley in southeastern California (35° 43′ N, 242° 40′ E) to 930 m and released the core to the U.S. Geological Survey for scientific study (Smith *et al.* 1982). An early investigation was the magnetostratigraphy of the valley fill in which the Gauss–Matuyama (G–M) boundary (N–R, 2.48 Ma (Mankinen & Dalrymple 1979)) was interpreted to be at 520 m (Liddicoat *et al.* 1980). The lithology, recovery and preservation at that depth allow a detailed study of the transition for comparison with data from Russia (Burakov *et al.* 1976). Although the approximately 180° meridional separation between the sites is desirable in a comparative study, data from the Southern Hemisphere are needed to interpret the record, as proposed by Hoffman & Fuller (1978) and Fuller *et al.* (1979). Nevertheless, well founded inferences can be made about features of the transitional field in terms of the pole path, the relative change in intensity, and the duration of the polarity switch.

2. Samples, sediment, and laboratory measurements

The core is 9 cm in diameter, and the interval used is mudstone from a playa (Smith *et al.* 1982). Those 5 m are centred at 522 m in two core runs separated at 524 m. Because I wanted consecutive specimens (each 1.5 cm thick) and did not want to destroy the core for other use, I used a single specimen for each horizon (302 specimens from 29 samples were prepared). The method seemed appropriate because there is little directional change between multiple specimens from the same depth (Liddicoat *et al.* 1980).

† Lamont-Doherty Geological Observatory contribution no. 3325.

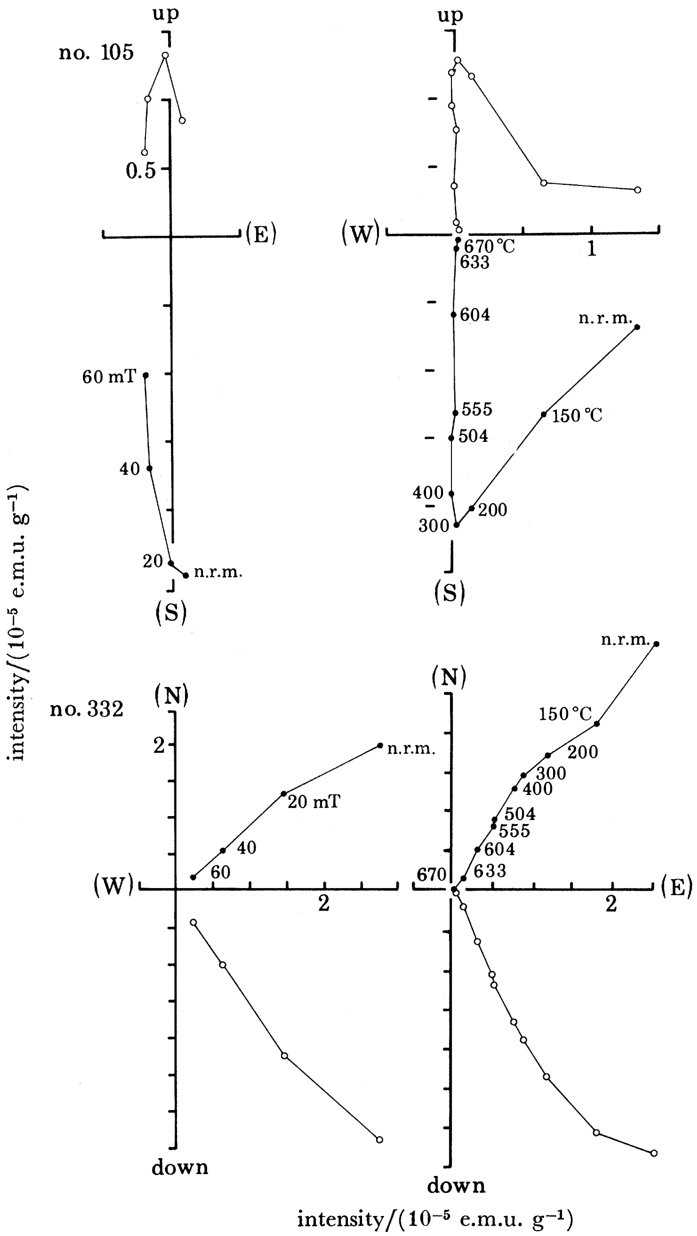
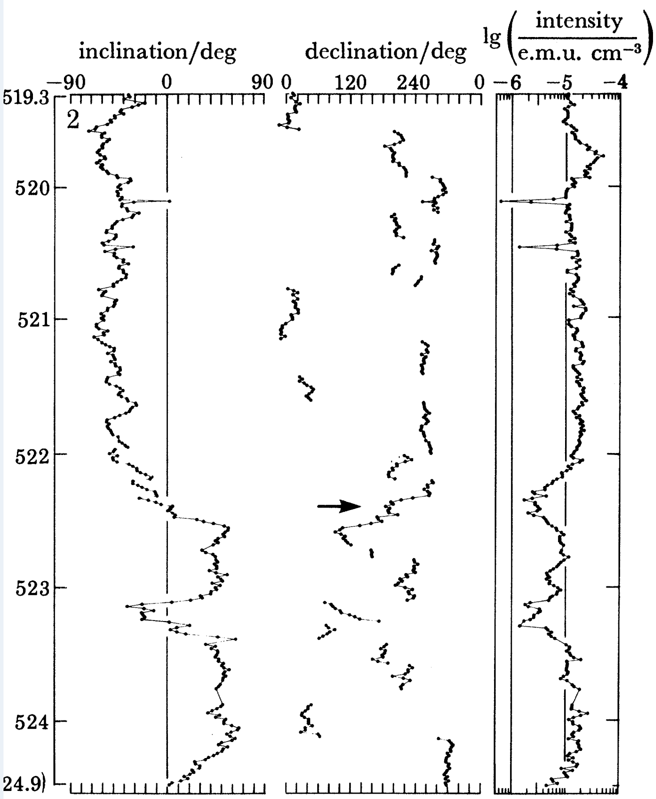


FIGURE 1. Vector plots of palaeomagnetic directions for paired specimens from 520.9 m (no. 105: reversed polarity) and 523.6 m (no. 332: normal polarity) subjected to alternating field (left) and thermal (right) demagnetization. Regardless of the demagnetizing method, similar directions of inclination and relative declination are isolated. Solid symbols are plotted on the horizontal plane, open symbols are plotted on the vertical plane. 10^{-5} e.m.u. $g^{-1} = 10^{-2}$ A m.

The specimens were subjected to alternating field (a.f.) demagnetization at 20 mT or smaller increments to a peak field of 60 mT, and a second specimen from two depths was thermally demagnetized (figure 1). The stable direction of magnetization was usually isolated before 40 mT, and a low blocking temperature component was removed at 300 °C. The remaining high blocking temperature component has a Curie point above 600 °C, indicating that some of the remanence is attributed to haematite.

3. Interpretation

Figure 2 is a plot of the palaeomagnetic directions and remanence for 40 mT a.f. demagnetization. Declination is relative to the split face of each sample, and the large shifts indicate where the core broke during drilling. Such interruptions could produce havoc in a study of a transition, but fortunately the 0.5 m sample starting at 5.22 m in which relative declination changes by 180° is where inclination switches from positive to negative. I assumed that reversed polarity corresponds to south declination and keyed the top of that sample to 180°; I then matched the declination end-to-end for all samples to reconstruct declination for the entire interval (figure 3). For the short reversal at about 523.2 m, I made an additional assumption that declination reached a southerly position, then returned to north (a portion of the core could be missing because there is a gap in the depths in the core box). Using the directions shown in



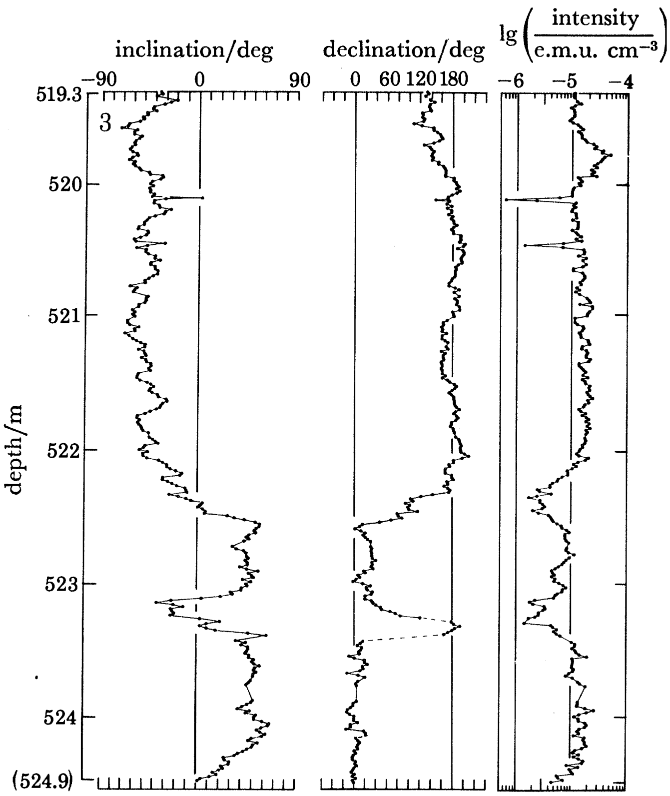


Figure 2. Plot of inclination, declination (relative to the split face of the core) and intensity after 40 mT alternating field demagnetization. The shifts in declination are where the core broke during drilling or storage before the core was split. Although 29 samples were used, some could be pieced together to make larger ones. The sample indicated by the arrow at 522.3 m is where declination changes by about 180° when inclination switches from positive to negative.

Figure 3. Plot of inclination, intensity and reconstructed declination where the top of the large sample at 522.3 m was set at 180°. The data are for 40 mT alternating field demagnetization. The broken lines for the small reversal at 523.3 m represent my assumption that declination reached north and south and that part of the record is missing (on the young end, the declination is making a large swing and only one or two additional data points could bring the declination to north; on the other (old) end, that assumption is not so easy to make, but part of the core could be absent because the core box contains 0.4 m less than the lowest depth indicated in the box). Note the relative change in intensity during the reversals. Also, there is a shallowing of inclination at the bottom of the record that is not accompanied by a change in declination or a reduction in intensity (normalized, see figure 8); thus I do not think that another small reversal was recorded.

figure 3, I then calculated the virtual geomagnetic pole (v.g.p.) for each horizon in the transition.

The v.g.ps for the G–M transition, when plotted on the hemisphere centred at 320 °E longitude, form a narrow band about 20° wide (figure 4). Tracing the poles from old to young, there is a rapid traverse to equatorial latitudes, a pause, and another rapid traverse to southern

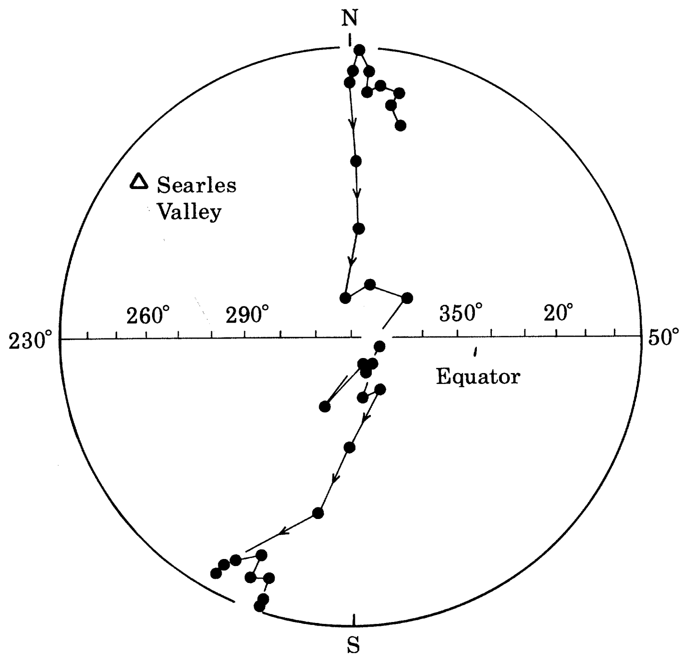


FIGURE 4. Plot of the v.g.ps in the hemisphere centred at 320 °E longitude. Note the pause near the equator and that the path is restricted to a narrow band about 90° east of the locality (open triangle). The v.g.ps are for the sample identified by the arrow in figure 2.

high latitudes. The path is about 90° east of the site longitude, which is also true for the small (earlier) reversal (figure 5). Both paths are borderline between 'near' and 'far' as defined by Hoffman & Fuller (1978) (the small reversal on its younger end is biased to the 'far' side, but the absolute declination is uncertain, as previously explained). Each transition covers about 2000 years, as does the interval that separates them (sedimentation rate for the playa is about 40 years per centimetre (Liddicoat *et al.* 1980)).

As indicated, the other detailed record of the G–M transition is for Russia (Burakov *et al.* 1976). There, the data were duplicated quite well at five sites and, as presented in Fuller *et al.* (1979), result in v.g.ps that traverse the western Pacific Ocean. The path is about 90° east of the site in the mid-latitudes, and near the south pole the poles nearly coincide with those from Searles Valley (figure 6).

It is interesting that when plotted with respect to a common site longitude (figure 7), these two v.g.p. paths at mid-latitudes appear very similar. Moreover, an even more striking similarity is seen (figure 7) when the Searles Valley v.g.ps are compared with those for the Matuyama–Brunhes (M–B) transition (R–N 0.73 Ma (Mankinen & Dalrymple 1979)) studied in sediment of ancient Lake Tecopa, California (Hillhouse & Cox 1976). Although there are nine plots of the M–B transition in Fuller *et al.* (1979) that could be used for the comparison, the plot for Lake Tecopa is most relevant because the locality is geographically close to Searles

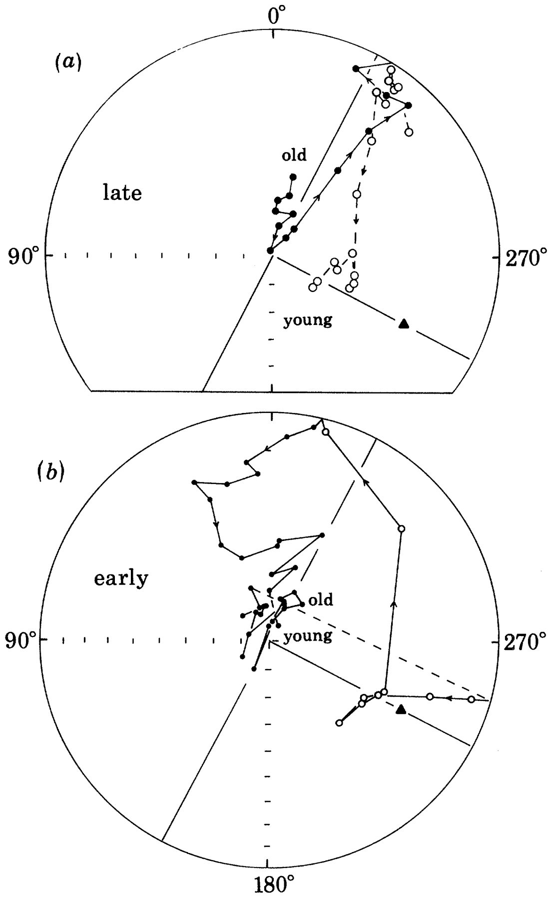


FIGURE 5. Equal-area plot of v.g.ps for (*a*) the G–M (late) transition and (*b*) the small (early) reversal that preceded it. For (*a*), the data are the same as in figure 4. Note in (*a*) that the path is about 90° east of the locality (filled triangle) and is borderline between 'near' and 'far' as described by Hoffman & Fuller (1978). In (*b*), the path for the younger half of the reversal (R–N) is 'far' if my assumption about the absolute declination is valid. Filled circles and triangles are plotted on the Northern Hemisphere, open circles are plotted on the Southern Hemisphere.

Valley and samples from an outcrop were used. However, before venturing conclusions about whether the similarity of these two California records is coincidental or not, data for the G–M transition from additional localities are needed.

Recorded in Searles Valley is a large decrease in relative intensity during the G–M transition and the reversal that preceded it (figure 2). In documenting that, I normalized the intensity by experiments of anhysteretic remanent magnetization (a.r.m.) in the fashion recommended by Levi & Banerjee (1976), and the decrease is most pronounced (70–80 %) when the ratio of n.r.m. to a.r.m. for 40 mT is examined (i.e. the level of a.f. demagnetization used for calculating the v.g.ps). Besides the drop-off, there are several fluctuations that accompany the small reversal, but a smooth reduction and return to the pretransition level is recorded for the G–M transition (figure 8).

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

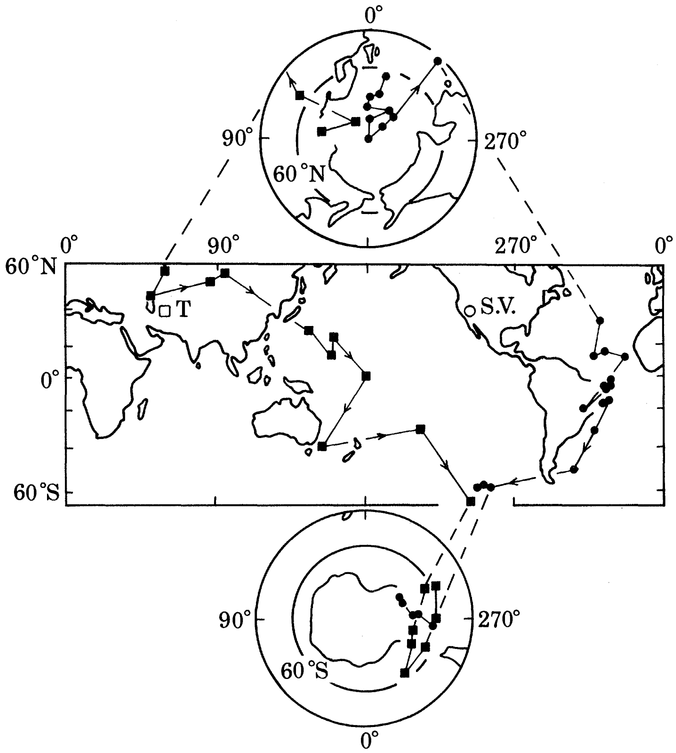


FIGURE 6. Plot of the v.g.ps for the G–M transition at Searles Valley (circles) and Russia (squares). Modified after Fuller *et al.* (1979) for ease of comparison with their plots. The localities are indicated by the open circle (Searles Valley) and open square (Turkmania, Russia).

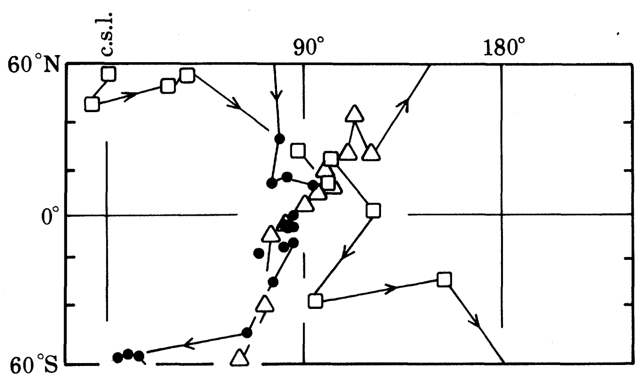


FIGURE 7. Plot of the v.g.ps from a common site longitude (c.s.l.) for Searles Valley (solid circles), Russia (open squares) and Lake Tecopa, California (M–B transition: open triangles). Note the similarity of the records in the mid-latitudes and especially how Searles Valley matches Lake Tecopa.

4. SUMMARY

1. The pole path for the G–M transition in Searles Valley is confined to a 20° meridional band in the Atlantic Ocean and in the mid-latitudes resides about 180° in longitude from the path recorded in Russia (Burakov *et al.* 1976). This is strong evidence that the transition field during the reversal was predominantly non-dipolar.

2. The v.g.p. paths for the G–M transition at Searles Valley and the M–B transition at Lake Tecopa, California (Hillhouse & Cox 1976), are very similar.

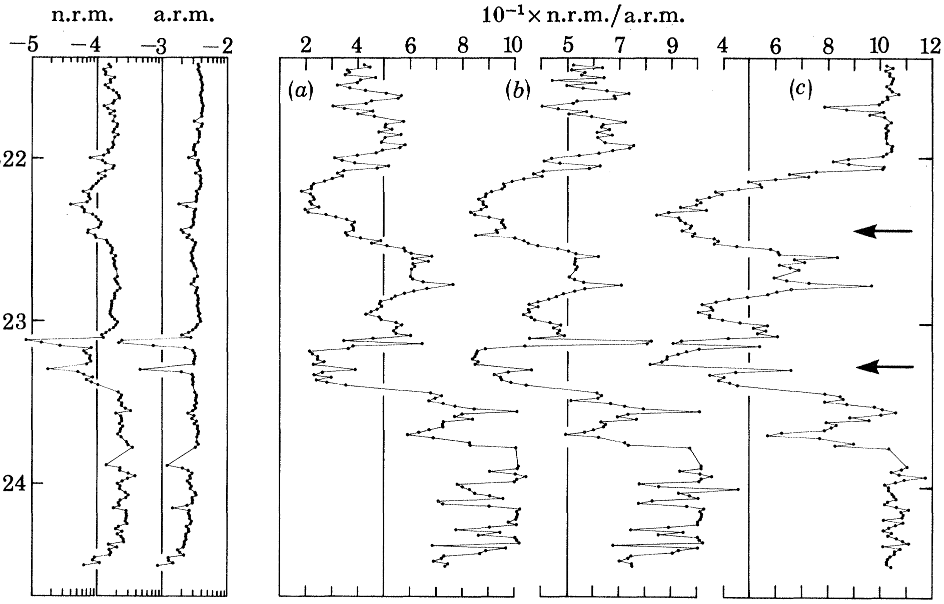


FIGURE 8. Normalized intensity for the portion of the record between 521.5 and 524.5 m. Plotted at the left are the moments (e.m.u.) for undemagnetized n.r.m. and a.r.m. (75 mT alternating field with 0.05 mT d.c. bias) and at the right the ratio of n.r.m./a.r.m. moments (*a*) before alternating field demagnetization, (*b*) after 20 mT demagnetization, and (*c*) after 40 mT demagnetization. The change in relative field strength is best seen in (*c*), where the midpoint of the reversals is indicated by an arrow.

3. The pole path for the G–M transition at Searles Valley is approximately 90° east of the site longitude, as it is for the Russian localities. Although the Searles Valley path is on the fence separating 'near' from 'far' paths in the hypotheses of Hoffman & Fuller (1978) and Fuller *et al.* (1979), some uncertainty exists because of the assumption about absolute declination that is used for calculating the v.g.ps.

4. There is more than one reversal during the entire transition, and that pattern was reported for Russia (Burakov *et al.* 1976). For Searles Valley, the overall duration is estimated at 6000 years; for Russia, the estimate is about 100000 years (Burakov *et al.* 1976), which seems long in the light of what is known about other transitions (Fuller *et al.* 1979).

5. The relative intensity in Searles Valley decreases by about fourfold for the G–M transition. There is a similar reduction during the short reversal that preceded it, and a partial build-up in the intervening 2000 years.

I thank D. A. McGee, Chairman of the Kerr–McGee Corporation, for permission to study the Searles Valley core. G. I. Smith assisted in the sampling and in the interpretation of the lake history. The reviews of the manuscript by K. A. Hoffman, D. V. Kent and J. E. T. Channell are very much appreciated. Funding for part of the investigation was provided by the Climate Program of the U.S. Geological Survey (contract no. 14-08-0001-18282).

References (Liddicoat)

Burakov, K. S., Gurary, G. Z., Khramov, A. N., Petrova, G. N., Rassanova, G. V. & Rodionov, V. P. 1976 *J. Geomagn. Geoelect., Kyoto* **28**, 295–307.

Fuller, M., Williams, I. & Hoffman, K. 1979 *Rev. Geophys. Space Phys.* **17**, 179–203.

Hillhouse, J. & Cox, A. 1976 *Earth planet. Sci. Lett.* **29**, 51–64.

Hoffman, K. A. & Fuller, M. 1978 *Nature, Lond.* **273**, 715–718.

Levi, S. & Banerjee, S. K. 1976 *Earth planet. Sci. Lett.* **29**, 219–226.

Liddicoat, J. C., Opdyke, N. D. & Smith, G. I. 1980 *Nature, Lond.* **286**, 22–25.

Mankinen, E. A. & Dalrymple, G. B. 1979 *J. geophys. Res.* **84**, 615–626.

Smith, G. I., Barczak, V. J., Moulton, G. F. & Liddicoat, J. C. 1982 *U.S. geol. Surv. prof. Pap.* (In the press.)

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES