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Palaeomagnetic dating and stratigraphy of a Cainozoic lake near Cooma, N.S.W.

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ABSTRACT

Palaeomagnetic dates for two sites on the Southern Tablelands of New South Wales, at Bunyan and Bredbo, indicate that basal lake sediments and underlying bedrock were ferruginised during the late Tertiary. The dates provide further evidence of a regional episode of intense weathering and ferruginisation in the late Tertiary.

INTRODUCTION

Recent investigations into the Cainozoic stratigraphy of the Southern Tablelands of N.S.W. are beginning to provide a more detailed understanding of the tectonic, sedimentary, vegetational and climatic history of the region (Taylor & Smith, 1975; Pillans, 1977; Singh et al., 1980; Ruxton & Taylor, 1980). In this paper we report on palaeomagnetic dates from lacustrine sediments and weathering profiles between Cooma and Bredbo, N.S.W. (Taylor et al., 1980). The stratigraphy and palaeomagnetic data of the Bredbo site described by Pillans (1977) are also reassessed.

STRATIGRAPHY

A lacustrine sequence in the valley of Middle Flat Creek near Cooma was inferred many years ago from the presence of a large diatomite deposit in that area (Browne, 1914). A recent study has shown the lacustrine deposits to be thicker and more extensive than was previously thought (Taylor et al., 1980). They occur in scattered outcrops between Cooma and Bredbo (Fig. 1) and overlie deeply weathered Silurian bedrock. The basal clays of the lake deposits also contain large nodules (up to 1 m diameter) and beds of iron oxide. The lithological similarity and the stratigraphic sequence at both the Bunyan and Bredbo sites suggest that these deposits relate to the same palaeo-lake. The stratigraphy at the two sites that produced reliable palaeomagnetic results are described and summarised in Figures 2 and 3.

Bunyan site (36°9′30″S; 149°11′40″E)

At Bunyan the study site is situated in an erosion gully on the eastern margin of the main lake deposit which, immediately to the west, is up to 50 m thick. The basal unit, A, at this site (Fig. 2) is weathered Silurian acid volcanics, and consists of light-grey sandy silt with prominent red and yellow mottles. It contains quartz sand, clay and numerous quartz veins in place. This unit is overlain unconformably by a pebbly sandy clay (unit B). The pebbles are concentrated along the unconformity, and at the eastern end of the unit, beds of pebbles occur up to

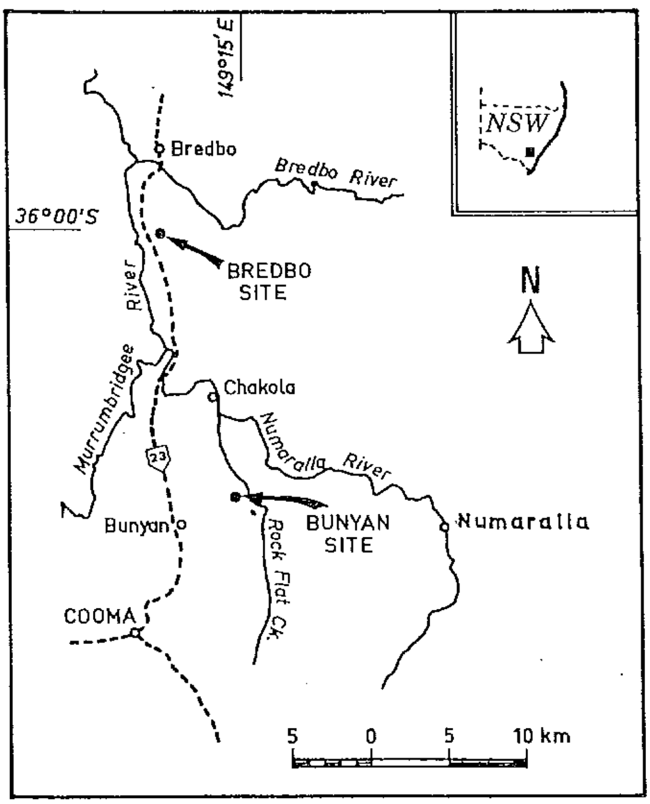

Fig. 1. Map showing the location of the Bunyan and Bredbo sites.

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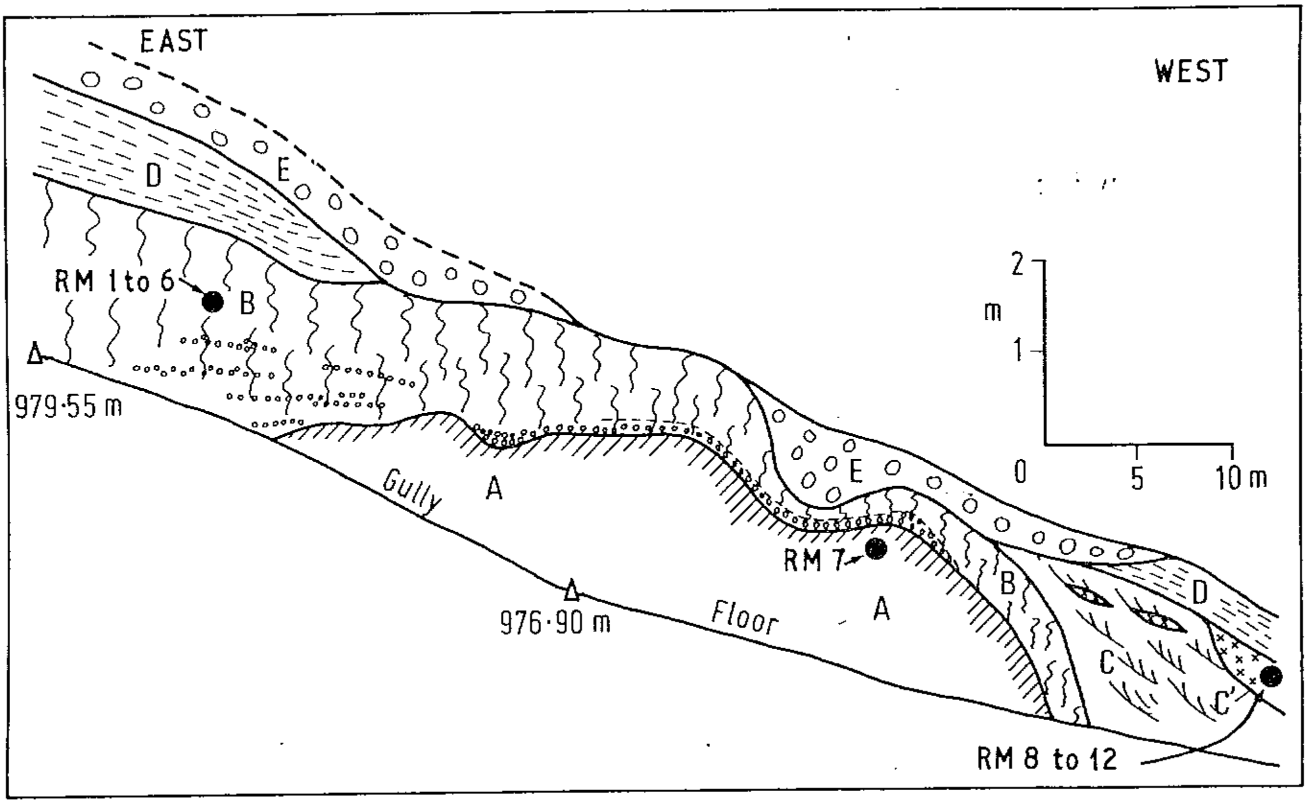

Fig. 2. Stratigraphy of a section in the Bunyan area. Unit A is weathered Silurian acid volcanics; B is strongly mottled pebbly sandy clay; C is pebbly fine sandy clay with trough cross-laminated beds and patchy ironstone; D is cracking grey clay (lacustrine); E is young colluvium. Sites where samples were taken for palaeomagnetic analysis are indicated by RM numbers.

2 m above the base. Unit B is strongly mottled in red and light grey. Its base is cemented by calcite, producing a prominent pebbly hardpan. Towards its eastern end, the upper half of unit B is cemented by iron oxide in irregular patches, up to 2.5 m thick and parallel to bedding. Unit C overlies unit B unconformably and consists of a pebbly fine sandy clay with large-scale (1.5 m), westerly dipping, trough cross-laminated beds. It lenses out rapidly towards the east. The upper half of unit C(C') contains patchy ironstone. These are ferruginous, pisolotic concretions, cemented by irregularly laminated iron oxide. Unit D conformably overlies unit C (and C') with a gradational boundary and, at the eastern end of the gully, overlies unit B. Unit D is a cracking grey clay with occasional pebbles, and is similar to the bulk of lacustrine clays further west (Taylor et al., 1980).

The stratigraphy of the Bunyan site is interpreted by us as a sequence of lake shore facies (units B, C and D) lapping onto weathered bedrock basement (unit A). The whole sequence is unconformably overlain by significant younger colluvium (unit E).

Bredbo site (36°0′20″S; 149°8′20 E)

The Bredbo site is located in a creek bank (Fig. 1) on the north-eastern margin of lacustrine deposits consisting dominantly of grey clays. This site has

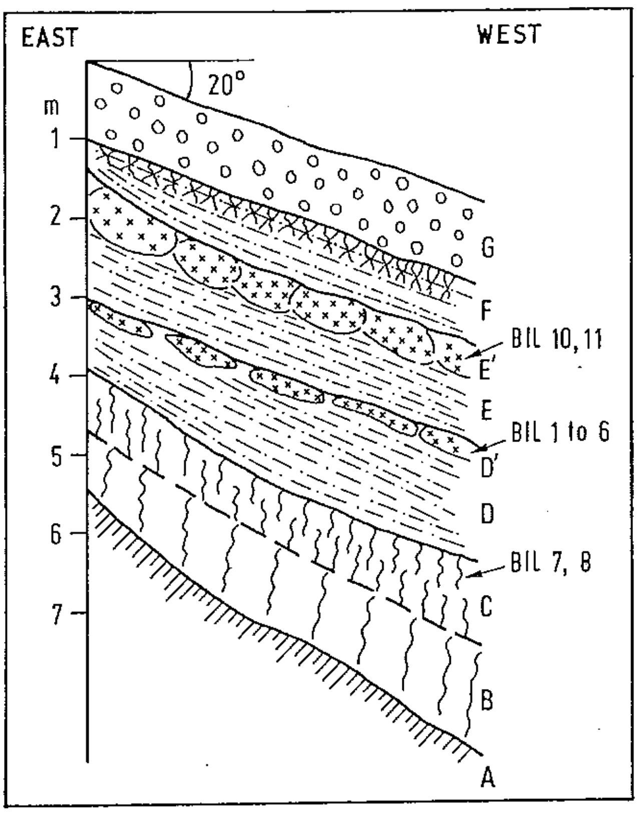

Fig. 3. Stratigraphy of a section in the Bredbo area. Unit A is weathered Silurian acid volcanics; B is dominantly red clay; C is red and white mottled sandy clay partially cemented by iron oxide; D is light-grey sandy clay partially cemented by by iron oxide; E is partially ferruginised grey sandy clay; F is light-grey sandy clay with secondary calcite cementation. Sites where samples were taken for palaeomagnetic analysis are indicated by BIL numbers.

previously been described by Pillans (1974, 1977) as an exposure of the Bredbo pedoderm.

The basal unit A (Fig. 3) consists of red and yellow, mottled, weathered Silurian acid volcanic bedrock containing quartz veins in place. This passes upwards into the dominantly red clayey unit B, which contains some coarse sand. Unit B passes gradationally upwards into a deep red sandy clay (unit C) with prominent white mottles. Unit C is partially cemented by iron oxide, leading to the development of concretionary hardpan layers. Unit D is a light-grey sandy clay which, in the upper 0.5-1.0 m, is strongly cemented by iron oxide along its upper surface (D'). This unit is overlain by, and distinctly separated from, a grey sandy clay (unit E) which is partly ferruginised throughout; the upper 40 cm of unit E(E') is entirely cemented by iron oxide, producing a "bedded ironstone". Pillans (1974) noted that a stratum, which seems to correspond to unit E, consists of etched quartz sand in a titaniferous quartz matrix. Unit F is a light-grey sandy clay. In the upper 50 cm it is cemented primarily by ferruginous microquartz and secondarily by calcite. Unit G is gravelly colluvial mantle. We interpret units B through to F as lacustrine shoreline facies lapping onto a bedrock basement (unit A).

TECHNIQUES AND RESULTS

The palaeomagnetic method has been described by a number of workers (Irving, 1964; Collinson et al., 1967; McElhinny, 1973). Samples from three localities were oriented using both a sun compass and a magnetic compass. Some samples were drilled using a portable drilling machine in the field, although generally the material was too friable to use this method. Therefore, block samples were also collected. Preparation in the laboratory of these block samples proved difficult, with many samples completely disintegrating under the pressure of the drill. However, specimens (25 mm diameter × 20 mm height) from 20 samples were retrieved. Digico balanced fluxgate spinner magnetometers (Molyneux, 1971) were used to measure remanent magnetisation, and a Schonstedt thermal demagnetiser (model TSD-1) was used for demagnetisation.

At least one specimen from each sample was subjected to thermal demagnetisation to study its magnetic components. Results from one Bunyan site have been rejected, because samples were magnetically unstable. We think that this weak, unstable remanence is carried by goethite, which quickly breaks down when heated. Stable directions from the remaining two localities are summarised in Table 1. From the high thermal stability (>670°C) the magnetic carrier at these sites appears to be haematite. Previous results from Bredbo (Pillans, 1977) have been incorporated with the results of the present study. Although that study did not include demagnetisation procedures, the present study found an insignificant difference between NRM and cleaned directions from Bredbo.

Pillans (1977) reported that the sediments he sampled dip at 20° to the west, and argued that the tilt was the result of movement along the nearby Billilingra Fault. However, he applied an erroneous tilt correction to his results. Correcting his mean direction of dec = 351° and inc = −70° for a 20° westerly dip yields a pole position at 59°S, 91°E. This revised pole position lies well off the apparent

TABLE 1. Summary of palaeomagnetic results.

Site	Mean direction					Mean VGP			
	N	dec(°)	inc(°)	k	α_{95}(°)	lat(°S)	long(°E)	K	A_{95}(°)
Bunyan	10	353	-66	58	6.3	76	168	26	9.7
Bredbo	7	355	-62	164	4.7	82	171	80	6.7
Bredbo including results of Pillans (1977)	9	355	-64	151	4.1	81	167	85	5.6

dec = declination
inc = inclination
k,K = precision parameter of directions, poles
α_{95} = half angle of cone of confidence at 95% confidence level for directional distribution
A_{95} = half angle of cone of confidence at 95% confidence level for polar distribution (Fisher, 1953)
VGP = virtual geomagnetic pole as calculated from individual sample magnetic directions

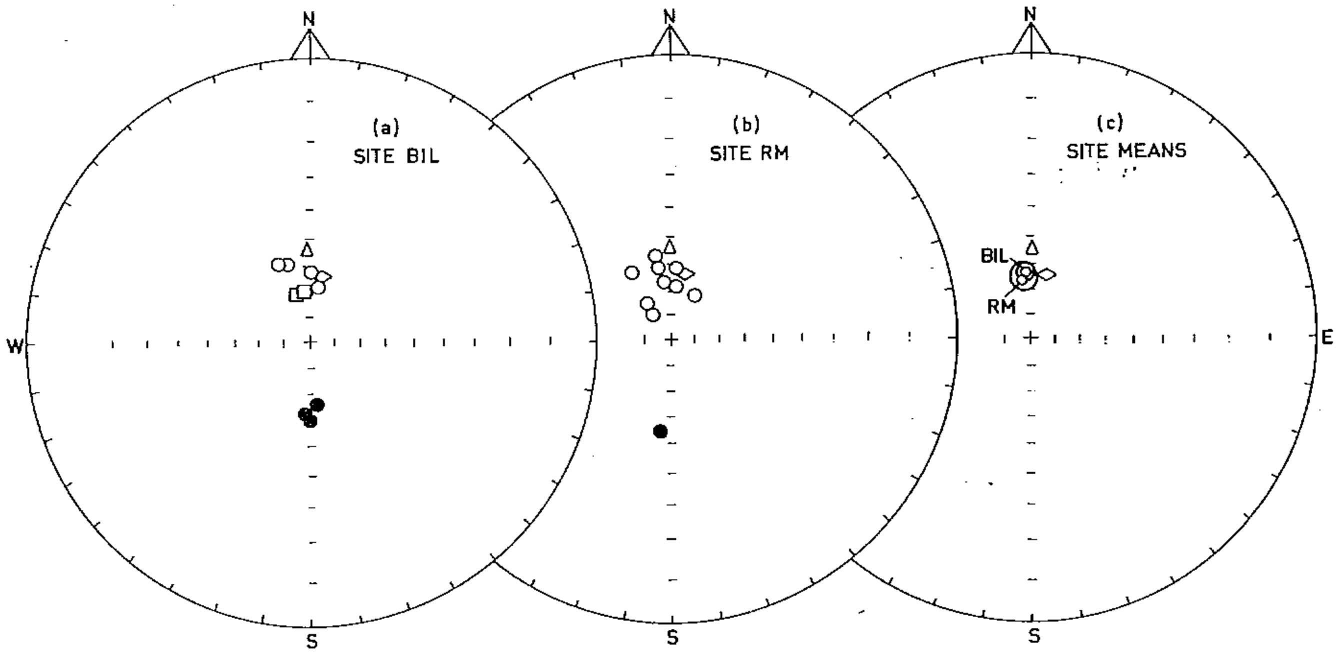

Fig. 4. Stereographic (equal-angle) projections of palaeomagnetic data: (a) site BIL thermally cleaned, (b) site RM thermally cleaned, and (c) site mean directions and circles of 95% confidence.
Open symbol = upper hemisphere
Triangle = dipole magnetic field direction
Square = directions from Pillans (1977)
Closed symbol = lower hemisphere
Diamond = present magnetic field direction
Circle = directions in this study

polar wander path (APWP) and suggests that at least a major part of the tilting pre-date the time of weathering or that the tilt was not tectonically induced.

The mean palaeomagnetic direction from the Bredbo site BIL is dec = 355°, inc = −64°, with an α_{95} = 4.1°. The mean palaeomagnetic direction from the remaining Bunyan site (RM) is dec = 353°, inc = −66°, with an α_{95} = 6.3°. Individual sample directions are plotted in Figure 4.

DISCUSSION AND CONCLUSION

The directions from the two localities are statistically indistinguishable. Therefore, the palaeomagnetic results indicate that the two localities have undergone ferruginisation at or about the same time. The mean directions are statistically different from the present and dipole magnetic field directions. This, and the presence of reversals, establishes the antiquity of the magnetisation.

The age of magnetisation, and presumably the ferruginisation, may be inferred from a comparison with the Australian Tertiary APWP. Recently the reliability of the synthesis of Tertiary palaeomagnetic results, as originally presented by McElhinny et al. (1974), has been challenged on the basis of new Indian data (Klootwijk & Peirce, 1979). Current reinvestigations are proving that previously unresolved complex magnetisations are the source of this discrepancy (K. Hoffman, pers. comm. G. Mangold, pers. comm.). Embleton & McElhinny (1981) have suggested a less detailed (oversmoothed, APWP based on averaging laterite and weathered profile data, and have calibrated it on the basis of the average volcano palaeomagnetic results from Wellman et al. (1969). A curve that only permits the resolution of early, mid or late Tertiary timing is obtained. The divergence of the poles presented here from this curve may indicate that significant tilting has occurred since the ferruginisation/weathering event, as suggested by Pillans (1977) for the Bredbo site. However, if tilting has occured, it apparently has done so equally at the Bunyan and Bredbo sites, although there is no evidence of this at Bunyan. As mentioned above, the pole corresponding to tilt-corrected direction lies well away from the track. We are of the opinion that tilting is unnecessary to

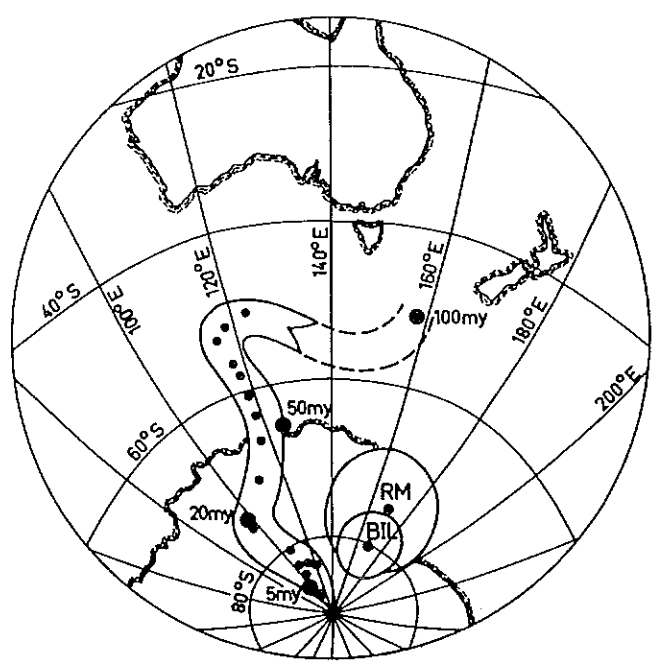

Fig. 5. Tertiary APWP (after Embleton & McElhinny, 1981) and pole positions from this study.

explain the dips at these sites. They are most directly interpreted as onlapping, lacustrine, shoreline facies.

Rejecting the possibility that tilting is the cause of the discrepancy leads us to consider whether secular variation (SV) of the palaeomagnetic field has not been fully averaged. Evidence that the poles may be regarded as palaeomagnetic poles is strong, namely: (a) both profiles contain a record of geomagnetic field reversals (close to 180° apart) and (b) the magnetic remanence has a chemical origin. However, we stress that the APWP is smoothed, particularly in the longitudinal sense; thus the significance of the discrepancy may be overestimated. Therefore, assuming the profiles represent an adequate time average of the geomagnetic field, a comparison of the poles with the Tertiary APWP suggests that the age of magnetisation may be bracketed within late Tertiary and mid Tertiary times. This conclusion conflicts with the early Tertiary age assigned by Pillans (1977), but it must be pointed out that his estimate was based on results from only two samples and an erroneous correction for bedding attitude.

The cleaned directions measured here are in best accord with a late Tertiary weathering age, even after incorporating the two directions reported by Pillans which, although slightly steeper in inclination, are assumed to belong to the same population. Irrespective of absolute age, there is good evidence that weathering and ferruginisation occurred at both localities at about the same time. These dates for weathering and ferruginisation appear to correlate with dates for deep weathering in the upper Shoalhaven Basin (Ruxton & Taylor, 1980) and suggest a regional episode of intense weathering and ferruginisation during the late Tertiary.

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