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SECONDARY MAGNETIZATION OF SOME PALAEOZOIC ROCKS FROM TASMANIA

by

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(With four text figures.)

ABSTRACT

A variety of igneous, sedimentary and metamorphic Palaeozoic rocks from Tasmania have similar directions of NRM—steeply upward. Although the mean direction is not significantly different at the 95% confidence level from the present field, its inclination is slightly steeper. Moreover, the palaeomagnetic pole calculated from these directions is closer to Tertiary poles from Australia than to the present pole. On this data it is statistically more probable that the NRMs are of Tertiary rather than recent age. Their characteristics are the same as viscous PTRMs, and they are likely to have been acquired during a period of slightly elevated rock temperatures. This warming-up may have been associated with Tertiary basaltic activity in Tasmania, or with slightly later regional heating over wide areas of eastern Australia, which has previously been suggested on petrological grounds.

1. INTRODUCTION

Although a considerable amount of palaeomagnetic work has been carried out in Carboniferous and younger rocks in Australia, the only published data on pre-Carboniferous rocks from Australia are those of Irving and Green (1958) and Green (1961) who studied small collections of sediments and igneous rocks of Proterozoic, Cambrian and Siluro-Devonian age, and of Briden (1966) concerning the NRM in a single, small igneous body of late Silurian age which had been the subject of preliminary work by Green. In these studies, evidence was presented which suggested that the NRMs which had been measured were primary (same age as the host rocks) and hence gave information on the geomagnetic field at the time when the rocks were formed.

In the present study, results are described from a variety of igneous, sedimentary and metamorphic rocks of pre-Carboniferous age in Tasmania (particularly from the Cambrian and Devonian of North-Western Tasmania). The NRMs of most of the rocks studied are likely to be secondary (younger than their host rock), and evidence is presented in support of the view that the probable age of the NRMs is early Tertiary, and that they were acquired during a period of slightly elevated rock temperature and were stabilised by cooling to near present-day temperatures. Experimental tests of the physical plausibility of this hypothesis have been described elsewhere (Briden 1965).

Between 1 and 10 oriented rock *samples* were collected at each *site* and 2 *specimens* were cut from each sample. Most of the results are of measurement of total NRM, but certain samples were selected for alternating field or thermal demagnetization with a view to testing the stability of remanence. Directions of NRM in individual specimens may be represented as unit vectors at a point; the resultant R_N of N vectors at a site is a measure of precision. Those site mean directions which are shown to be significant at the 95% confidence level (Watson, 1956) are then represented by unit vectors in calculating the mean direction of NRM for the group of rocks. The resultant (R) of the site mean vectors is related to the estimate (k) of between-site precision by the equation

$$k = \frac{B - 1}{B - R} \qquad \text{(Fisher, 1953)}$$

where B is the number of sites. The palaeomagnetic pole (ϕ, λ) was calculated on the assumption of a geocentric dipole configuration of the geomagnetic field at the time when rocks were magnetized.

2. RESULTS

Pre-Cambrian at Burnie, Tasmania

On the coast between Burnie and Cooee (Figure 1) the Cooee Dolerites invade the Burnie Slate and Quartzite Formation (Spry, 1957). One sample of dolerite was dated radiometrically by Richards (in Spry and Banks, 1962) at 700 m.y. Three oriented samples from the dolerite sills and four from the intervening grey quartzite were very weakly magnetized (intensities less than 10^{-6} gauss) and only one specimen of quartzite contained detectable NRM. Directions in the dolerite were steeply upward, but no analysis can be made on the basis of measurement of three specimens from only two samples (the third having no detectable remanence), and no further work seemed justified.

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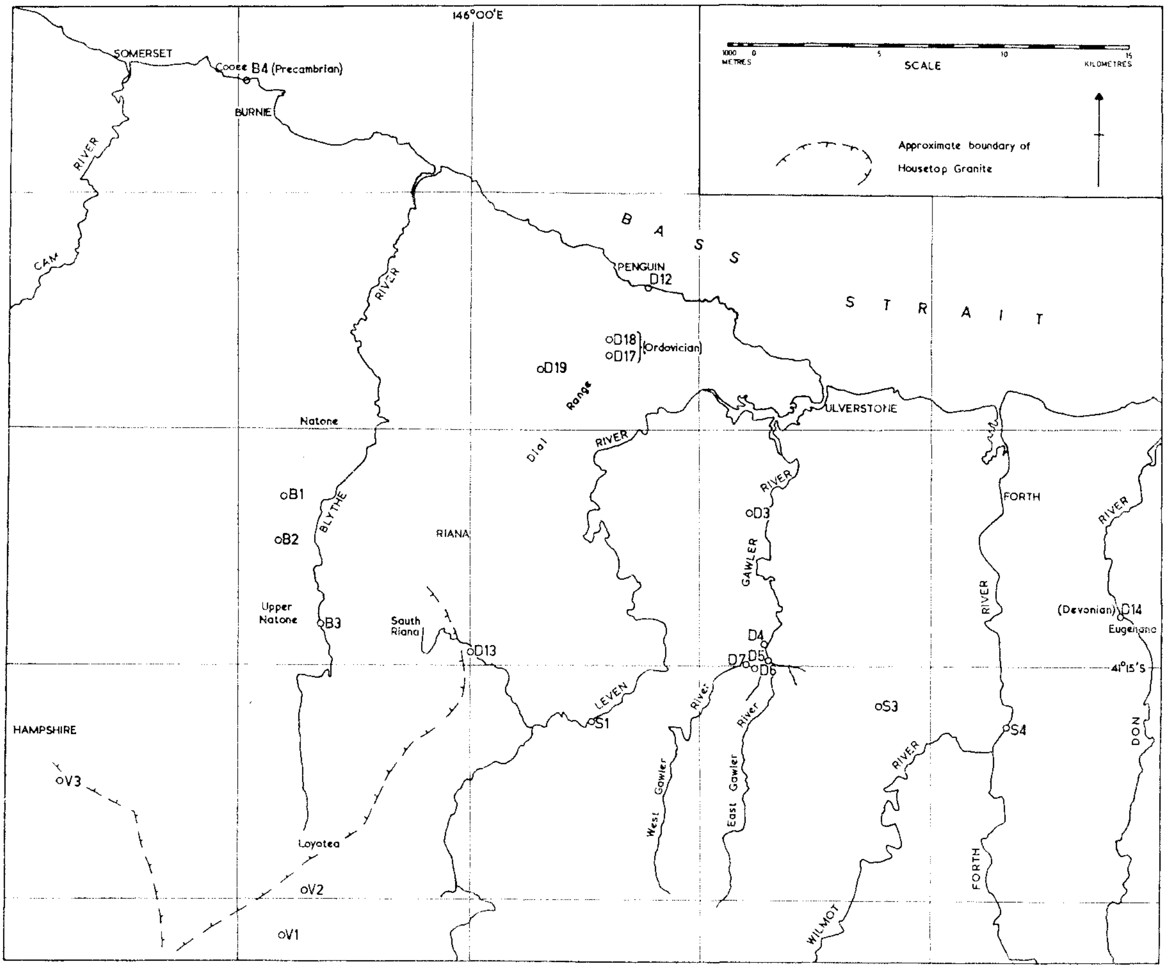

FIGURE 1.—Palaeomagnetic sampling sites in the Penguin district, northwestern Tasmania. The map is based on topographic (Lands and Surveys Dept., Tasmania), soils map (C.S.I.R.O.) and aerial photographs (Division of National Mapping, Dept. of National Development, Canberra). For rock types see Tables 1 to 3.

Cambrian, North-Western Tasmania

From a structurally complex trough of Cambrian rocks south of Penguin, mudstones and sandstones, trachytic lavas and tuffs, hornfels, a syenite boss and a reef of hematite ore, all of Middle and Upper Cambrian age (Burns, personal communication), were sampled (Figure 1). Six samples of red-brown sandstones were collected from a 700 m. section near Stony Point, Montagu, which was correlated on lithological grounds with the Dundas Group (Middle and Upper Cambrian) by Gulline (1959). Twelve of the site means are significant (Table 1) and all are directed steeply upward relative to the present horizontal. " Correction " for folding is made by " unwinding " folds about their axes, on the assumption that all folding is purely rotational about horizontal axes. Where field evidence indicates more than one period of folding about different axes, correction is made by successively unwinding the folds in order of increasing age. The dispersion of site mean directions is increased by " correction " for folding. Although this may in part be due to the inadequacy of the assumptions about folding, it remains evident that the NRM is independent of the dip of individual beds, which suggests that NRM is younger than the folding (Graham, 1959).

Intensities are variable. Hornfelses at sites V1 and V2 differed in mean intensity by a factor 27. In hematite from the vertical reef, intensity ranged from below the measuring limit of the magnetometer (about 10^{-7} gauss) to nearly 10^{-4} gauss. In trachyte at Paloona Bridge (sites S4A and B) the range was 50 to 370 (x 10^{-6} gauss), and in mudstones at D7 mean intensities in four samples were 8.6, 19.7, 4426.0 and 35.7 (x 10^{-6} gauss) respectively. Intensities at other sites were in the range 10^{-5} to 10^{-6} gauss.

TABLE 1

Site mean directions of NRM in Cambrian sediments and volcanics northwest Tasmania.

					uncorrected		corrected	
Site	Rock Type	S	N	R_N	D	I	D	I
V1	Hornfelsed tuff	2	4	3.96	32	—73	178	—79
V2	Hornfelsed tuff	6	12	11.42	12	—75	104	—70
D19	Hematite ore	3	6	1.18	....	....	....	....
D3	Acid tuff	5	10	8.52	334	—80	3	—42
D4	Trachyte	5	10	9.02	116	—78	87	—18
D5	Tuff	3	6	5.39	323	—58	281	—36
D6	Tuff	1	2	1.98	341	—48	29	—42
D7	Mudstone	4	8	7.79	71	—75	99	—46
D12A	Spilite lava	1	2	2.00	356	—53	356	—53
S1	Acid tuff	1	1	1.00	73	—60	62	—18
S3	Spilite lava	2	4	2.60	....	....	....	....
S4A	Trachyte	3	6	4.40	130	—87	201	—65
S4B	Trachyte	4	8	3.80	....	....	....	....
S4C	Chert & Sandstone	4	8	7.20	285	—88	63	—15
Stony	Point Sandstones	6	12	10.10	342	—81	290	—60

						pole	
	B	D	I	k	a	φ	λ
Uncorrected	12	9	—77	18	10.5	45W	66N
Corrected	12	47	—66	3	27.7	97W	57N

N = Number of specimens. S = Number of samples. B = Number of significant sites. R_N = resultant of N unit vectors (see section 1 of text). D = Declination (degrees E of true N). I = Inclination (degrees, downward positive). k = between-site precision. a = semi-angle of 95% cone of confidence.

TABLE 2

Site mean directions of NRM in Ordovician sandstones from Tasmania

Notation as for Table 1.

				uncorrected		corrected	
Site	S	N	R_N	D	I	D	I
D17	3	6	5.97	337	—78	106	—68
D18	3	6	5.98	1	—71	11	—69
Tim Shea	10	19	14.85	25	—65	121	—75

						pole	
	N	D	I	k	a	φ	λ
Uncorrected	31	14	—70	6.7	10.8	66W	75N
Corrected	31	95	—77	6.1	11.4	65W	35N

The only Cambrian intrusive rocks which were studied were from a syenite boss on the foreshore at East Penguin (site D9, Figure 1). In nine of the 10 specimens (five samples) inclinations were positive, but the mean was only just significant, at the 95% confidence level, and precision did not improve with alternating field demagnetization. Intensities were in the range 1.5 to 3.5 (x 10^{-6} gauss).

Ordovician Sandstones, Tasmania

In the Penguin district (Figure 1) and at Tim Shea (central Tasmania) sandstones and conglomerates underlie fossiliferous Ordovician limestones and are believed to be of Lower Ordovician age (Spry and Banks, 1962), although those at Tim Shea could possibly be Upper Cambrian (Spry, personal communication). Sixteen samples were collected from sandstones in these sections and NRM in all specimens was directed steeply upward; site mean directions are tabulated in Table 2. Because only 3 sites are distinguished, the precisions before and after correction for folding are compared by analysing specimen directions. These rocks are affected only by the gentle flexuring which is typical of the Tabberabberan (Middle Devonian) progeny in the region. Intensities of NRM were in the range 10^{-5} to 10^{-6} gauss.

Devonian, Northwestern Tasmania

Three samples of Eugenana Beds (cave fillings in Ordovician limestone) had mean direction D = 262°, I = +5° with k = 6, and mean intensity 10^{-6} gauss.

The Housetop Granite was sampled at 3 sites near Natone; in its contact aureole amphibolites of Upper Cambrian mudstones and conglomerates were collected in a creek near South Riana, and a skarn of Ordovician limestone was sampled near Hampshire (Figure 1). Detailed age determina-

TABLE 3

NRM directions in Housetop Granite and its aureole

Notation as for Table 1.

Site	Rock Type	S	N	R_N	D	I
V3	Skarn	7	14	7.32	93	—75
D13	Amphobolite	5	10	6.42	19	—34
B1	Granite	3	6	5.38	36	—46
B2	Granite	2	4	3.91	348	—82
B3	Granite	7	14	12.87	163	—83

Rock Type	B	D	I	k	a	pole	
						φ	λ
Granite	3	35	—75	9.7	....	....	....
Thermal metamorphics	2	29	—60	4.6	....	....	....
Granite and aureole combined	5	32	—69	8.6	27.6	86W	66N

TABLE 4

Mean NRM directions from all Tasmanian Palaeozoic rocks described in this paper (except Eugenana Beds and syenite boss, East Penguin)

Notation as for Table 1.

Orientation	No. of Sites	D	I	k	a	pole	
						φ	λ
Uncorrected	20	17	—74	16.4	8.3	56W	68N
Corrected	20	45	—72	5.6	15.3	79W	58N

tion work by McDougall and Leggo (1965) by both Rubidium-Strontium and Potassium-Argon methods, on several samples including some of those collected for palaeomagnetic purposes, indicates the age of the Housetop Granite to be 375 ± 10 m.y. (Middle Devonian). The mean directions of NRM (Table 3) in the granite and its aureole are not significantly different, and have been combined by the conservative procedure of giving unit weight to each site. The results from Cambrian hornfels at sites V1 and V2 have been analysed with the Cambrian rocks (Table 1); it is possible that they lie within the aureole of the Housetop Granite, and perhaps should be analysed here. However, it will be shown later (Figure 2) that there is no significant difference between directions in Cambrian and Devonian rocks and all will be analysed together (Table 4).

3. CONCLUSIONS.

The only suggestion of primary NRM in the rocks described here is from the Eugenana Beds, and this cannot be discussed in detail because the collection was so small. Insufficient outcrop prevents further study, and there is little prospect of confirming the age of NRM in these beds.

The NRM in Cambrian sediments and volcanics is considered to be younger than the folding because precision is much greater before than after correction for folding. The agreement between directions before correction in these rocks and those in the Ordovician sandstones and the Devonian granite and its aureole—a wide variety of rock types—suggests that they all acquired their NRM at roughly the same time. Accordingly all site means from Palaeozoic rocks from Tasmania (except for the Eugenana Beds and the syenite boss at Penguin) have been combined (Table 4). As before, the precision of grouping of directions relative to the present horizontal and meridian is greater than that after an attempt to correct for folding, and supports the contention that NRM is younger than the folding. Although the mean direction is not significantly different from the present field ($p = 0.05$), its inclination is slightly steeper, and the palaeomagnetic pole position (55W, 68N) is closer to that postulated for Australia during the Lower Tertiary than it is to the present pole—the mean pole calculated by Irving (1964) from several studies of early Tertiary rocks being (50W, 65N).

Although the possibility that the NRMs reported here are of recent origin cannot be ruled out, it is more probable that they are of Tertiary age. Evidence for this is strongest for the Cambrian rocks, for which the circular standard error of the mean NRM direction excludes the present field direction. Thermal demagnetization curves of Cambrian tuff from site D3 and hornfels from site D9 (Figures 3 and 4), are characterised by a broad distribution of blocking temperatures, although this is masked to some extent at D9 by the alterations which are introduced by heating above 300°C. NRMs which have been built up over long period of time at slightly elevated temperatures ('viscous PTRMs') commonly have this same property (Briden, 1965). It is likely that the NRMs in these rocks are viscous PTRMs. It was previously suggested (Briden, 1964) that they might have been acquired at the time of Tertiary igneous activity in the area, which might have raised the temperature of rocks by a few tens of degrees for a prolonged period. Alternatively, the heating might have been on a regional scale. Hale and Spry (1964) have suggested that regional heating occurred after the basalt extrusion and that it might have reached 200°C in places. It may have been responsible for the occurrence of zeolite facies rocks of many ages (including Tertiary basalts in Tasmania) in various places in eastern Australia. The same regional heating could have given rise to the NRMs which have been detected in the Palaeozoic rocks.

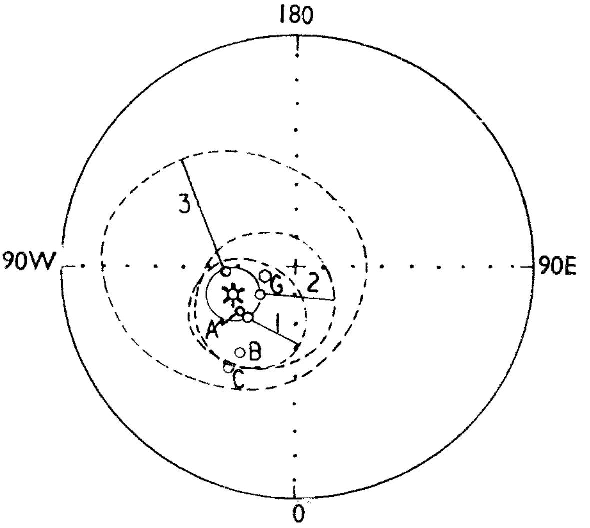

FIGURE 2.—Palaeomagnetic pole positions and approximate ovals of 95% confidence—
1. Cambrian sediments and volcanics.
2. Ordovician sandstone.
3. Devonian granite and aureole.
* Combined Palaeozoic of Tasmania.
C, B, A are the mean Jurassic, Cretaceous and Lower Tertiary poles relative to Australia (Irving, 1964).
G is the geomagnetic pole.
NORTHERN hemisphere equal-area projection.

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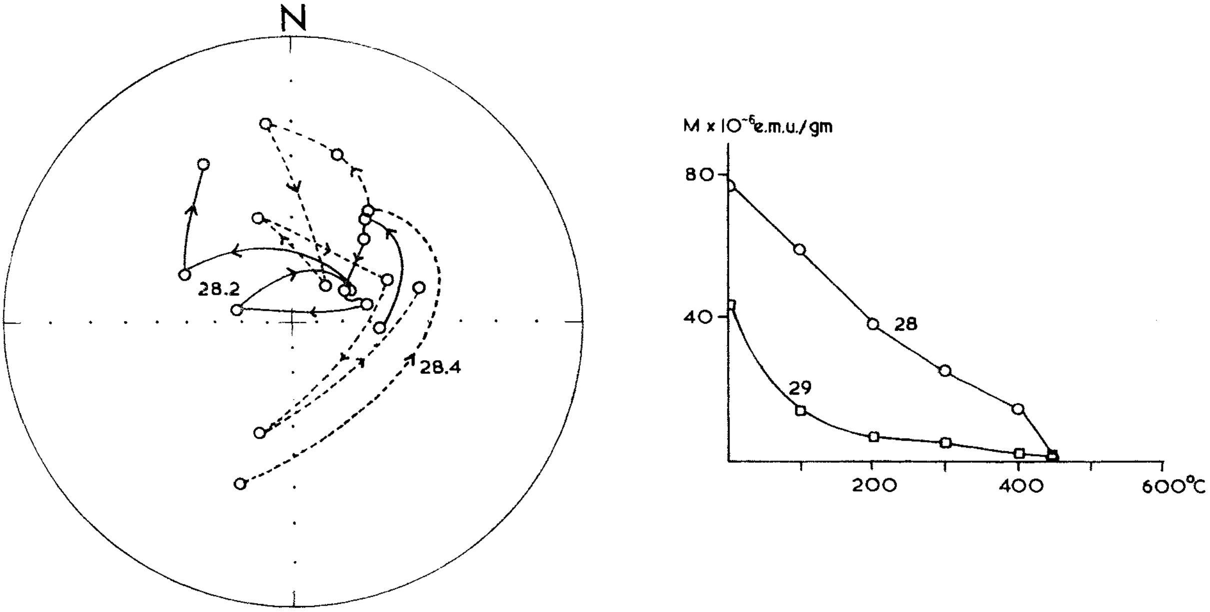

FIGURE 3.—Thermal demagnetization at site D3 in Upper Cambrian tuff. Stereogram shows direction changes in two specimens of CT28. Demagnetization curves show vectorial mean intensities of each of samples CT28, CT29. Intensities are given in e.m.u./gm for comparison with viscous PTRMs (Briden, 1965).

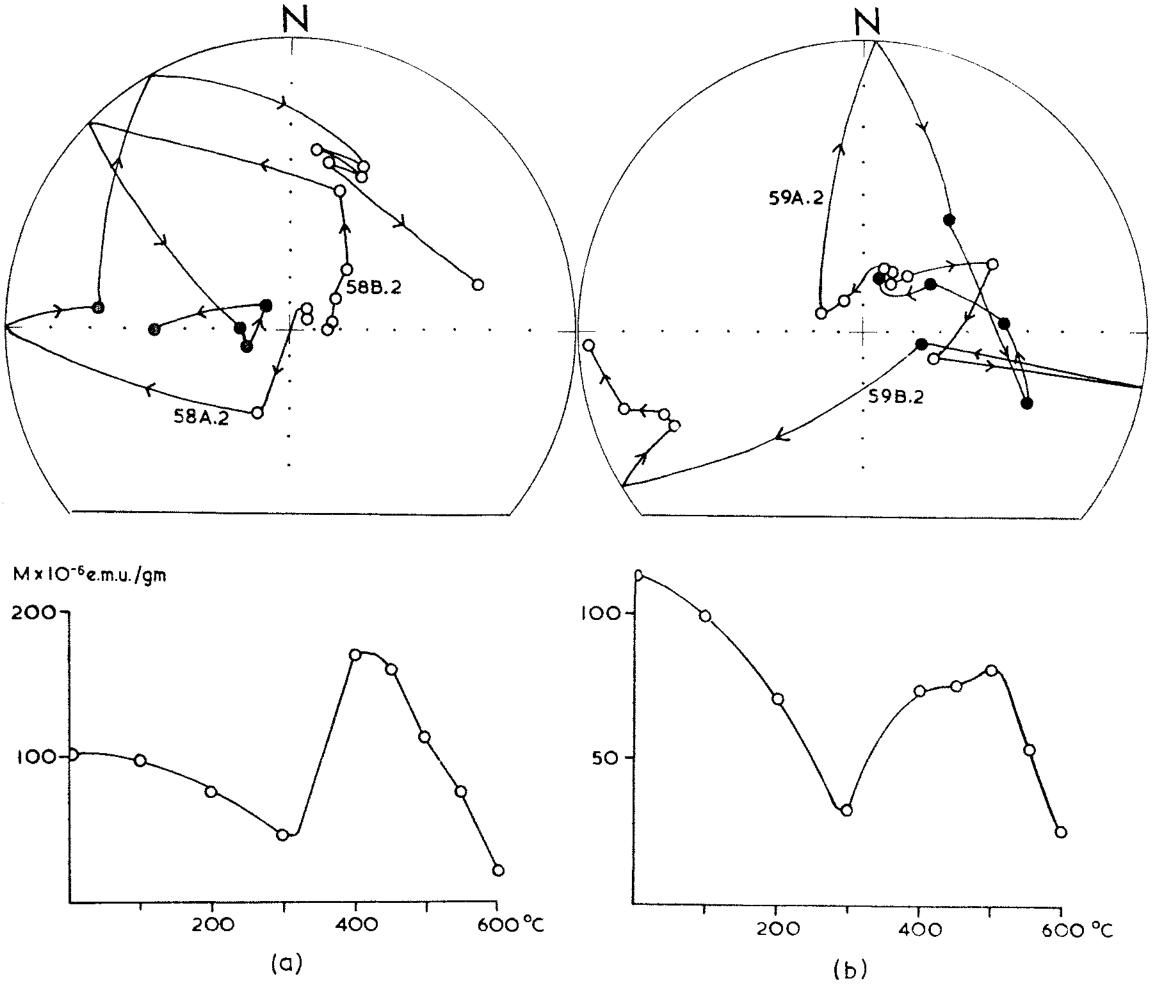

FIGURE 4.—Thermal demagnetization of Cambrian hornfels, site V2. Stereograms and demagnetization curves showing sample-mean intensities (*a*) sample CT58, (*b*) sample CT59.

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