LERBEKMO *ET AL.* REPLY—Butler and Lindsay have focused attention on some of the problems in magnetostratigraphic correlation. They point out that our palaeomagnetic data show considerable scatter and do not provide a well defined polarity zonation. This reiterates the statement in our original article. Nevertheless, there is a stratigraphic zonation present—the data are not randomly scattered. We believe the key to interpretation of this type of data is the recognition of the importance of viscous and/or chemical overprinting; nature has not provided ideal material and we have attempted a rational interpretation following the reasoning of Hillhouse *et al.*[1]. A closely comparable study involving the same problems, and following essentially the same scheme has been reported by Brown *et al.*[2]. We are convinced that a real pattern of normal and reversed polarity emerges from our data, although some overprinting may still be present.

Butler and Lindsay suggest that we have used circular reasoning in our anomaly matching, which we have not. This can probably be attributed to the limited palaeontological background information contained in our original article. In fact, we believe that our correlation of the Red Deer Valley section with the Gubbio section in Italy is unambiguous for the following reasons.

The palynomorphic change which takes place just above the Nevis coal seam in Alberta[3] and at the Hell Creek (Lance)–Fort Union contact in Montana and Wyoming[3], also takes place at the Hell Creek–Ludlow (Lignite Beds) contact in North Dakota in the type area of the Cannonball Formation[4]. The Ludlow there is 5–20 m thick and is overlain by the marine Cannonball which reaches a thickness of 125 m in the subsurface at Garrison Dam[5]. Foraminifera recovered from the Garrison Dam core place the entire formation in the *Globigerina edita* zone, which is the lowest Palaeocene foraminiferal zone and is equated[5] to the *Globorotalia pseudobulloides* zone plus the thin *Globigerina eugubina* zone (which occur in the Gubbio section). The Cannonball Formation spans the *Globorotalia pseudobulloides* zone and is separated from the Cretaceous–Tertiary boundary below, as defined by palynomorphs, by about 20 m of Lignite Beds (=Ludlow)[4,5]. The *Globorotalia pseudobulloides* zone at Gubbio encompasses part of anomaly 28, all of anomaly 29 and part of the reversed zone between anomalies 29 and 30 (ref. 6). Therefore, if the palynomorphic change equated with the Cretaceous–Tertiary boundary in Alberta, Montana, North Dakota and Wyoming[3] is essentially synchronous throughout this area, as believed[4], this palynomorphic boundary and the highest occurrences of dinosaurs are in the same reversed zone in which the foraminiferal Cretaceous–Tertiary boundary takes place in Italy (that is between anomalies 29 and 30).

The anomaly matching by Butler *et al.*[7] and Lindsay *et al.*[8] is not infallible; whether or not the results summarised in Fig. 2 of ref. 8 constitute a "strong correlation with the magnetic polarity time scale" is debatable. The problem of 'extra' polarity intervals arises. In their comment above Butler and Lindsay question the validity of an additional normal interval between 29 and 30. However, in Fig. 2 of ref. 8 two 'extra' polarity intervals are shown which do not appear in the seafloor polarity record[9]. We expect that detailed palaeomagnetic studies of this type will reveal short magnetic zones not now recognised in the seafloor anomaly pattern, but much further work will be required to separate these from fictitious overprinted intervals.

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British Tertiary Igneous Province probably not associated with East Greenland lavas

IN their recent article Carter *et al.*[1] discuss the source regions of continental basalts extruded round the North Atlantic in the early Tertiary. They made the common assumption that the British Tertiary Igneous Province (BTIP) was formed as a result of the rifting which led to the separation of Greenland from Europe. Their reason for this assumption was presumably that the formation of the BTIP was close in space and time to the rifting. However, this similarity may be more apparent than real and be misleading by concealing significant differences, summarised below.

Carter *et al.* give the duration of activity in the BTIP as 66–50 Myr ago. Although such a spread of dates— and greater—can be found in the literature, note that the province has proved particularly difficult to date accurately, and many published dates are inconsistent with the stratigraphy, for example K–Ar dates for Faeroes[2] and Mull dykes[3]. If only the most reliable dates are used, which means chiefly $^{40}Ar/^{39}Ar$ plateau and Rb/Sr isochron ages, most activity is found to have occurred about 60 Myr ago (Table 1). (All dates quoted here have been adjusted to the decay constants and so on of Steiger and Jäger[4].) Only Lundy is clearly younger.

The time of opening of the North-east Atlantic is not yet agreed, but is usually assumed to have just preceded the formation of magnetic anomaly 24. The age of this anomaly is deduced by calibrating the anomaly pattern of Heirtzler *et al.*[5] at various points; because the spreading rate was probably not uniform this leads to a range of estimates for the age of anomaly 24. However, polarity time scales which have been calibrated in the Palaeocene[6–8] assign it ages of 50.3, 53.4 and 54.4 Myr, respectively. Although the Greenland basalts must be somewhat older than this, it seems unlikely that they are contemporaneous with the BTIP, with the possible exception of Lundy.

Another difference is that activity on the British side of the North-east Atlantic-to-be occurred in discrete areas. Most of these areas lie roughly on a line joining the Faeroes to Lundy (St Kilda and Rockall lie well to the west) which diverges at an angle of ~55° from the margin of the Atlantic, according to the reconstruction of Bullard *et al.*[9]. Thus Arran, for example, is a perpendicular distance of ~300 km from the margin, while Lundy (the part of the BTIP most likely to be contemporaneous with the rifting) is over 500 km distant. In contrast, the Greenland activity lies within 150 km of the margin.

The East Greenland coast has a flexure and associated dyke swarm. In contrast, the BTIP has no flexure and the regional dyke swarms of the separate areas, although roughly parallel to each other, are *en echelon*; these swarms are not what

Table 1 $^{40}Ar/^{39}Ar$ plateau and Rb/Sr isochron dating

Area and rock	Method	Age (Myr)	Ref.
Arran: Northern Granite	$^{40}Ar/^{39}Ar$ plateau	60.4±0.6	10
Mournes: granite	$^{40}Ar/^{39}Ar$ plateau	59.7±1.6	10
Mull: dyke cutting Loch Bà Felsite	$^{40}Ar/^{39}Ar$ plateau	60.3±3	10
Mull: centre 3 granite	Rb/Sr isochron	58.2±2.5	11
Antrim: basalts	K/Ar isochron	~60	12
Lundy: granite	Rb/Sr isochron	53±2, 55±3	13
Lundy: granite	$^{40}Ar/^{39}Ar$ plateau	53.4±1.4	14

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