CORRESPONDENCE

Comments on Early Tertiary tectonism and lateritization

SIR – Nilsen & Kerr (1978) and Nilsen (1978) documented a laterite, or latosol, encountered at Site 336 of the Deep Sea Drilling Project on the Iceland–Faeroe Ridge, and discussed its significance in the tectonic and climatic history of the North Atlantic region. The present note intends to put that laterite in a bipolar context, drawing attention at the same time to parallels between tectonism and climatic change at the degree of geohistorical resolution discussed by Berggren *et al.* (1978). The events referred to are plotted against a composite time scale in Figure 1.

1. Tectonism

1.a. North Atlantic Ocean

Anomalies 24 and 19 mark two major changes in the spreading history of the North Atlantic (Laughton, 1975). Berggren *et al.* (1978) suggested that the first of those changes might predate Anomaly 24 slightly, although recent studies indicate that it is close in time (Montardet, Roberts *et al.* 1977; Larsen, 1978). Among the various records of volcanism reviewed by Nilsen & Kerr, the lavas of the Blosseville Group in East Greenland show good evidence of pronounced subsidence during their rapid extrusion (Soper *et al.* 1976); the date of 53-51 Ma for that extrusion follows Berggren *et al.* A similarly pronounced subsidence has been demonstrated for the Rockall Bank, using changes in foraminiferal biofacies (Berggren, 1974). On quite independent evidence, Berggren *et al.* (1978) concluded that the Wasatch Stage, the time of free trans-Atlantic faunal interchange among terrestrial mammals (Savage, 1977), ended about 49-50 Ma, probably 'somewhat after the inundation of the last available dry land linking Greenland with England and France'. Thus, the end of Wasatchian time, shown in Figure 1 as the onset of endemism, is close to the end of a brief period of oceanic and marginal subsidence, even though the Iceland–Faeroe Ridge itself may have remained stationary before subsiding in the Oligocene (Detrick, Sclater & Thiede, 1977).

1.b. Indian and SW Pacific Oceans

Anomaly 24 is axial in the Tasman Sea, signifying cessation of spreading (Weissel & Hayes, 1977). Anomaly 22 is close to a time of critical change in the Indian Ocean (Sclater & Fisher, 1974; Johnson, Powell & Veevers, 1976) when rapid transform movement essentially ceased along the Ninetyeast Ridge (Norton & Molnar, 1977) and when active spreading began between Australia and Antarctica and in the Coral Sea. Evidence for collision at that time is summarized by McGowran (1978*a*) and Sillitoe (1978). Rapid subsidence of the Ninetyeast and Chagos-Laccadive Ridges and of the Mascarene Plateau, demonstrated by changes in foraminiferal biofacies, is interrupted by a remarkably parallel unconformity across the Paleocene/Eocene boundary whose significance, however, is not clear (McGowran, 1977, 1978*a*). There is no obvious event in the Indian Ocean in the vicinity of Anomaly 19. However, the dating of the Hawaiian-Emperor bend on the Pacific Plate at 42±1.4 Ma (Dalrymple & Clague, 1976) is rather close.

Thus, major plate tectonic change accompanied by rapid subsidence occurs in concert between Anomalies 24 and 22 in the North Atlantic, Indian and SW Pacific Oceans. Although Rona & Richardson (1978) did not specifically identify it as such, a culmination in the latest Paleocene and Early Eocene is the main component in their 'major reorganization of global plate motion from Mesozoic to Cenozoic patterns that occurred primarily during the Eocene epoch (53.5–37.5 m.y. B.P.)'.

2. Climate and laterite

2.a. Stratigraphic configurations and climatic change

I have summarized elsewhere the foraminiferal–biostratigraphic evidence for recognizing two Early Tertiary 'sequences' on both Australia and the Indian subcontinent (McGowran, 1977, 1978*a*, *b*). The first of those extends from the Danian (Zone P.1) to a maximum in Zone P.4, and concludes with regression which is most evident from Zone P.7 onwards. The second is of Middle to Late Eocene age and begins with a transgression

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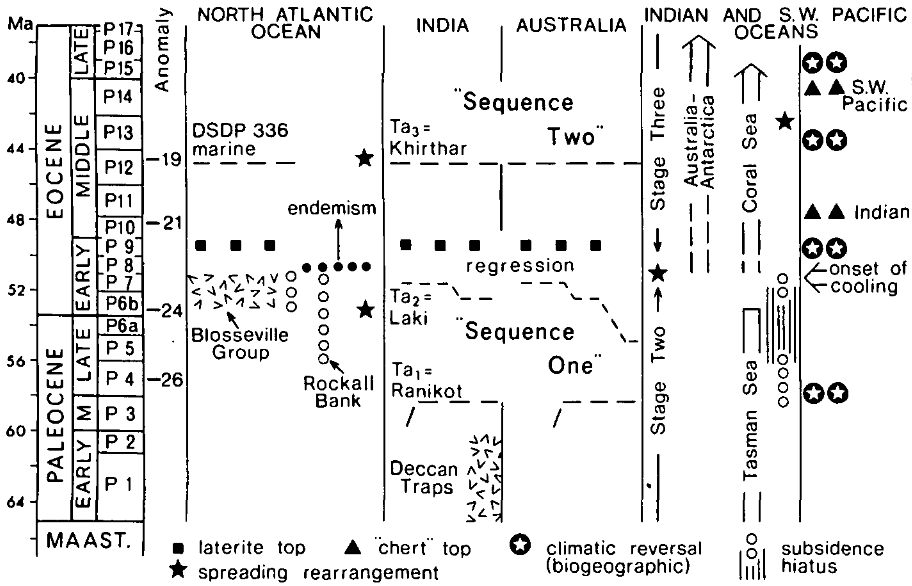

Figure 1. Correlation of events against a composite Early Tertiary chronology modified after Hardenbol & Berggren (1978). With that modification the position of Anomaly 19 is a hopeful guess; Anomalies 21–26 are after Berggren *et al.* (1978). Other correlations are discussed in the text. The horizon marking the onset of endemism is the top of the continental Wasatchian Stage. 'Ta_1 = Ranikot', etc., are the larger foraminiferal assemblages ('Stages') of the Indo-Pacific region. 'Stages' in the evolution of the eastern Indian Ocean, from Johnson *et al.* (1976). Three ocean floor spreading episodes are also shown.

in Zone P.12; these patterns are shown very diagrammatically in Figure 1. The continental regression, hiatus or biostratigraphic non-recognition from Early into Middle Eocene is attributed to 'passive' oceanic subsidence subsequent to the plate tectonic culmination. What caused the following transgression is not known, but the plate tectonic events in the vicinity of Anomaly 19 may come to play some part in its explanation.

The distribution of benthonic 'larger' foraminifera parallels the development of sequences on the continents. As good indicators of warm conditions, they identify reversals in a general, stepwise cooling from the Early Eocene to the Early Oligocene. Four events are listed in Figure 1. The oldest event marks the first, very widespread occurrence of larger foraminifera near the Zone P.3/P.4 boundary around the western and northern Indian Ocean but not in southern Australasia (McGowran, 1977, 1978*a*); it is consistent with, but more precise than, the Danian-to-Thanetian warming seen in oxygen isotope data (Margolis, Kroopnick, & Goodney, 1977) and in floral changes in Australia (Kemp, 1978). The three Eocene events are excursions by larger foraminifera into southern Australasia which correlate with – and thereby confirm the reality of – isotopic reversals in Zones P.9, P. 13 and P.15 (McGowran, 1978*a*, *b*). The climatic deterioration from Zone P.7 to Zone P.11, based on isotopic data in Shackleton & Kennett (1975) calibrated biostratigraphically (McGowran, 1978*b*), correlates excellently with regression and the general disappearance of the Laki faunas of the Indo-Pacific region, with an overturn in the Australian flora (McGowran, 1978*a*; Kemp, 1978), and with changes in planktonic foraminiferal assemblages, such as the reduction in numbers of keeled *Morozovella* in Zone P.7 (Caro *et al.* 1975) and northward penetration by southern extratropical species in Zones P.10–P.11 (McGowran, 1977). Well-marked chert horizons in oceanic and neritic carbonates correlate with climatic lows (McGowran, 1978*a*). Of the two plotted here, the horizon in Zone P.11 is at the foot of the Early to Middle Eocene decline.

2.b. Lateritization

As reviewed by Nilsen & Kerr (1978) the lateritic paleosol on thickened oceanic crust at Site 336 seems to confirm floral indications of a 'warm, humid tropical climate' at high northern latitudes. In a more general perspective, the deep weathering of rocks of the Brito-Arctic igneous province prior to a Middle Eocene

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transgression adds significantly to our meagre stock of relatively well dated Tertiary 'laterites'. The transgression in Zone P.12 covers laterite in western India, where it developed on rocks ranging from Early Paleocene (Deccan Traps) to, perhaps, Early Eocene (Zone P.6) in age (Powell & Conaghan, 1973; McGowran, 1977). In Western and South Australia there is comparable evidence (cited in McGowran, 1978*a*) although none of those items give direct age control over most of the extensive remnants of the deeply weathered surfaces on both continents. Significantly, however, palaeomagnetic dating in Australia narrows laterites, far from marine strata of relevant ages, to ages of 60-40 Ma (Pillans, 1976) and of Maastrichtian to Early Eocene (Senior *et al.*, 1977).

As outlined above, isotopic and biogeographic evidence defines a 'warm interval' across the Paleocene/ Eocene boundary: Thanetian to Ypresian. Kemp (1978) concluded from a review of the floral evidence that southern Australia was warm and humid with extensive rainforests to beyond 60° S palaeolatitude. Laying more emphasis on the Early-to-Middle Eocene climatic deterioration than does Kemp, I suggest that the interval from Zone P.4 to Zone P.6b was a time of intense, bipolar lateritization which was terminated by that climatic event. Figure 1 shows the top of that geomorphic episode in Zone P.9 instead of Zones P.6b–P.7. That is merely to acknowledge the well documented, shortlived reversal in Zone P.9.

3. Concluding remarks

Geomorphic events are notorious for their intractable problems of age determination. The foregoing conjecture does not exclude younger episodes of lateritization: palaeomagnetic dating in Australia confirms a second major Tertiary episode in the Late Oligocene–Early Miocene (Schmidt *et al.*, 1976; Senior *et al.* 1977) and there is a third in the Pliocene (Doutch, 1976). They are distinct episodes, not the remnants of a continuous, diachronous process. Figure 1 attempts to demonstrate that the important elements of Tertiary geohistory – tectonism, climate, stratigraphic configurations – have to be resolved at the level of 10^6 years instead of 10^7 years at which level much discussion occurs (e.g. Kemp, 1978; Rona & Richardson, 1978; see also discussion of Eocene–Miocene resolution in McGowran *et al.* 1978). That point is thoroughly substantiated in the discussion by Berggren *et al.* (1978), notwithstanding that argument on the cross-correlation of biostratigraphic, geomagnetic and radiometric chronologies will continue.

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