Revised plate motions relative to the hotspots from combined Atlantic and Indian Ocean hotspot tracks: Comment and Reply

COMMENT

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Müller et al. (1993) presented an updated model for global plate motions during the past 130 m.y. and concluded there was no major motion between hotspots over the past 84 m.y. Further, they suggested that at the time of formation, the Rajmahal Traps lay ~1000 km north of the Kerguelen hotspot. Several recent studies have evaluated a genetic link between the Kerguelen hotspot, the Ninetyeast Ridge, and the Rajmahal Traps (Mahoney et al., 1983; Weis et al., 1991; Class et al., 1993). Geochemical parameters have been used to link the Ninetyeast Ridge and the Kerguelen hotspot. It is more more difficult to evaluate a similar link between the hotspot and the Rajmahal Traps; geochemical signatures of the hotspot are altered during eruption through the continental lithosphere, and a linear progression of ages (the "Hawaiian model") in continental settings is unlikely. Paleomagnetic results place the relevant section of eastern India at ~50°S (Klootwijk, 1971) at ~118 Ma, the time of formation of the Rajmahal Traps (Baksi, 1988, and unpublished data). This is ~10° farther south than in the Müller et al. (1993) model (see their Fig. 2). As Müller et al. noted, given close geographical proximity a genetic link between the Kerguelen hotspot and the Rajmahal Traps may result from decompression melting over a mantle plume ~1000 km in radius.

This Comment is directed primarily to the ages used by Müller et al. (1993) for finite reconstruction poles of major plates relative to hotspots. The ages listed in their Table 1 apparently represent the end of some chrons (13y, 25y, 31y, M-0y and M-10y) and the time of initiation of others (5o, 6o, 18o, 21o and 34o). The source of the ages in Müller et al. (1993) is not listed, but they appear to be taken from Berggren et al. (1985) for the Cenozoic time and from Kent and Gradstein (1985) for Cretaceous time, relying primarily on K-Ar data. A number of recent studies using $^{40}Ar/^{39}Ar$ dating yield more accurate ages for these chrons. I list these in Table 1 here, and I inquire whether utilization of these new ages leads to conclusions different from those listed earlier.

TABLE 1. NEW AGES FOR CHRONS

Chron	Listed age (Ma)	New age (Ma)	Reference
5o	10.4	11.1	Baksi et al. (1993)
13y	35.5	33.5	Cande and Kent (1992)
18o	42.7	~40	Cande and Kent (1992)
21o	50.3	~48	Cande and Kent (1992)
25y	58.6	55.5	Cande and Kent (1992)
31y	68.5	67.2	Cande and Kent (1992)*
33y	73.6	~70	Cande and Kent (1992),* Obradovich (1992)*
33o	80.2	~78	Cande and Kent (1992), Obradovich (1992)
34y	84.0	~82	Cande and Kent (1992), Obradovich (1992)
M-0y	118.7	~121	Obradovich (1992)
M-10y	130.0	~127	Obradovich (1992)

*Adjusted to an age of 64.5 Ma for the K-T boundary (Baksi, 1993). All ages quoted relative to 162.9 Ma for the U.S. Geological Survey standard SB-3 biotite, and 513.9 Ma for MMhb-1 (Lanphere et al., 1990).

As noted by Müller et al. (1993), the older part of their model (~130–85 Ma) is subject to relatively large uncertainties. Of particular interest would be a reevaluation of the postulated links among the Kerguelen hotspot and the Ninetyeast Ridge, the 85°E Ridge, and the Rajmahal Traps.

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REPLY

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The plate-motion model presented in Müller et al. (1993) is based on the Berggren et al. (1985) and Kent and Gradstein (1986) time scales. Baksi asks in his Comment how much our model would change if we used a different time scale. For chrons 5 to 34, the differences between the Berggren et al. (1985) time scale and Cande and Kent's (1992) time scale range from 1 to 3 m.y. However, minor modifications of individual hotspot tracks in a revised model would only affect the period from 85 to 30 Ma, the time interval which is best covered by radiometric dates from volcanic chains in the Atlantic and Indian oceans. For the post–30 Ma time period radiometric dates constraining plate velocities were used only for the Tasmanid Seamounts. For other seamount chains such as the Walvis Ridge and the Mascarene Plateau, we must linearly interpolate ages from 30 Ma to the present because there is a lack of young dates.

The central argument of Baksi's Comment concerns the pre–chron M-0 part of our model. For this time interval, there are only two well-dated hotspot tracks available in the Atlantic Ocean (and none in the Indian Ocean). These are the Walvis Ridge/Rio Grande Rise and Paraná and Etendeka flood basalts as their continental extensions, and the White Mountains and Monteregian Hills (see Fig. 1 of Müller et al. 1993). From a purely geometrical point of view, given only two hotspot track tiepoints for any pre–M-0 time, and considering the width of the Rio Grande Rise and the Paraná flood basalts, the resulting orientation of the reconstructed plate assemblage for chrons M-0 and M-10 is subject to errors, which can be estimated to be at least of the order of ±300 km.

Baksi points out that the ages from Kent and Gradstein (1986) differ from Obradovich's (1992) ages by 2.3 m.y. (M-0) and 3 m.y. (M-10). His main question is, What effect would this have on our model and in particular, on the position of India and the Rajmahal Traps with respect to the Kerguelen hotspot? A simple calculation shows that the poles of rotation tabulated in Müller et al. (1993) result in a plate velocity for India of about 35 km/m.y. relative to the mantle for the time from chron M-10 to M-0. Thus, India would move about 100 km in 3 m.y., which is roughly equivalent to the error that would be introduced in the model by a 3 m.y. error in the time scale. As a result, our conclusion would be that the Rajmahal Traps would be located 1000 ±400 km north instead of 1000 ±300 km north of the Kerguelen hotspot at chron M-0. Basically, our conclusion would remain the same. Because Obradovich's (1992) new ages for chrons M-0 and M-10 are only published in an abstract and are not available in published, peer-reviewed paper, we are hesitant to use these ages instead of a published, widely used time scale.

Klootwijk's (1971) paleopole for India from the Rajmahal Traps (7°N, 63°W) results in a paleolatitude of the traps at their time of formation (M-0, ~118 Ma) at 47°S (±400 km), whereas our model places them at about 40°S (±400 km) (Fig. 1). Considering the large uncertainties in both estimates, it is unclear whether the observed mismatch is significant or not. In order to better evaluate this mismatch, we have also computed the paleoaltitude of Ocean Drilling Program (ODP) site 758 during the Tertiary from both paleomagnetic data and from our model based on hotspot tracks (Fig. 1). We find that Klootwijk et al.'s (1991) inclination-only data from ODP Leg 121 agree very well with our model from 20–65 Ma. A distinct misfit is observed between the site 758 paleolatitude computed from Klootwijk et al. (1991) for 65 Ma and from Vandamme et al.'s Deccan Traps paleopole (1991) for 66 Ma. The Deccan Traps paleomagnetic data would locate India more than 1000 km farther south than Klootwijk et al.'s (1991) data or our hotspot model. This misfit between Deccan Traps paleomagnetic data and paleolatitudes from hotspot models has been interpreted as evidence for motion of the Réunion hotspot relative to the spin axis (Vandamme and Courtillot, 1990) or true polar wander (Courtillot and Besse, 1987; Duncan, 1991). In contrast, the good agreement between the ODP site 758 paleomagnetic data with our hotspot model, and the disagreement between the site 758 data with Deccan Traps paleomagnetic data may indicate that such interpretations are incorrect, as also noted by Klootwijk et al. (1991).

Our conclusions are as follows. (1) Our hotspot model agrees well with Klootwijk et al.'s (1991) paleomagnetic data from ODP site 758. (2) We do not find evidence for latitudinal motion of the Kerguelen hotspot relative to the spin axis during the Tertiary, comparing Klootwijk' et al.'s (1991) paleomagnetic data with our model. (3) Including uncertainties introduced by different time scales, our model would place the Rajmahal Traps 1000 ±400 km north of the Kerguelen hotspot, assuming a present-day location of the hotspot at Skiff Bank at the northwestern Kerguelen Plateau, which is uncertain as well (see Royer et al. [1991] for a discussion). (4) If relative latitudinal motion between the Kerguelen hotspot and the spin axis has occurred in the Late Cretaceous, we cannot resolve its magnitude given the combined uncertainties in paleomagnetic data and hotspot models. (5) Possible reasons for the mismatch between Deccan Traps paleomagnetic data and plate models based on hot-

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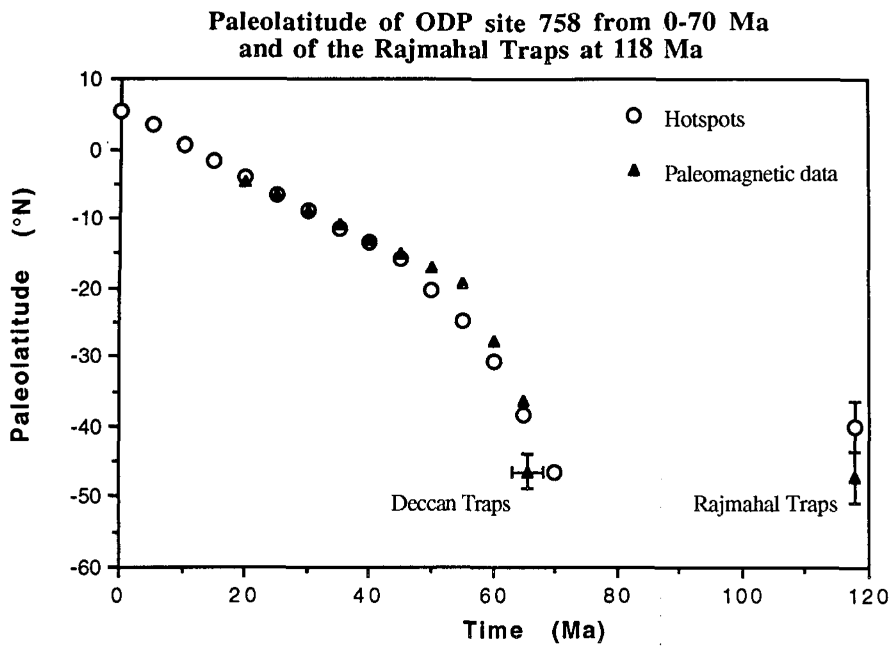

Figure 1. Paleolatitude of ODP site 758 calculated from paleomagnetic data (triangles) and Müller et al.'s (1993) plate model (circles). Paleolatitudes from 20 to 65 Ma were computed from inclination-only data from sediment, ash, and basement samples from ODP Leg 121 (Klootwijk et al., 1991), and for 66 Ma from Vandamme et al.'s (1991) paleopole from Deccan Traps. For 118 Ma we show position of Rajmahal Traps from Klootwijk's (1971) paleomagnetic data (triangle) and from our plate model (circle).

spot tracks include an older age of the Deccan Traps, neglect of dip corrections, and nondipole field components (Klootwijk et al., 1991).

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