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Some Observations on the Occurrence of Dykes and Faults in the Rajmahal Volcanic Province

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Abstract

The general stratigraphy of a Continental Flood Basalt Province (CFBP) near the source region of the basalt should bear the signatures of diastrophic activity in the form of faulting of the volcanic and pre-volcanic formations and dyke intrusions into the volcanic flows, with or without visible continuity into them. Such features are however practically nonexistent in the Rajmahal Volcanic Province (RVP). Faulting in RVP is limited upto the lower Gondwanas only. The upper Gondwanas (infra trappeans) are almost unaffected and at places overlap the fault zones. It is therefore suggested that the faulting which had formed the Gondwana basins continued during the lower Gondwana period, but had ceased during upper Gondwana period when the traps were being deposited. Dykes are absent too barring a few isolated ones whose intrusive relationship with the gneisses is clear everywhere but indistinct with the infra-trappeans. In fact, none of them show a visible continuity upto any trap flow. These features are anomalous and suggest the absence of significant crustal disturbance in the upper Gondwana period (i.e. during volcanic episodes).

The observations made above tend to suggest that the focus of the Rajmahal volcanic eruption lay somewhere outside the areal extent of the Rajmahal hills, as we know it today. This inference is also corroborated by the high Grade metamorphic composition of the linear basement ridges and depressions below the surface exposures of the Rajmahal volcanics.

The study concludes that the foci of the Rajmahal volcanic eruption appears to lie somewhere beyond the present surface exposures of the Rajmahal volcanic, probably in the adjoining Bengal Basin.

Key words: *Dykes, Faults, Continental Flood Basalt Provinces, Volcanic Foci, Infra Trappeans, Undisturbed Basement, Crustal Disturbance*

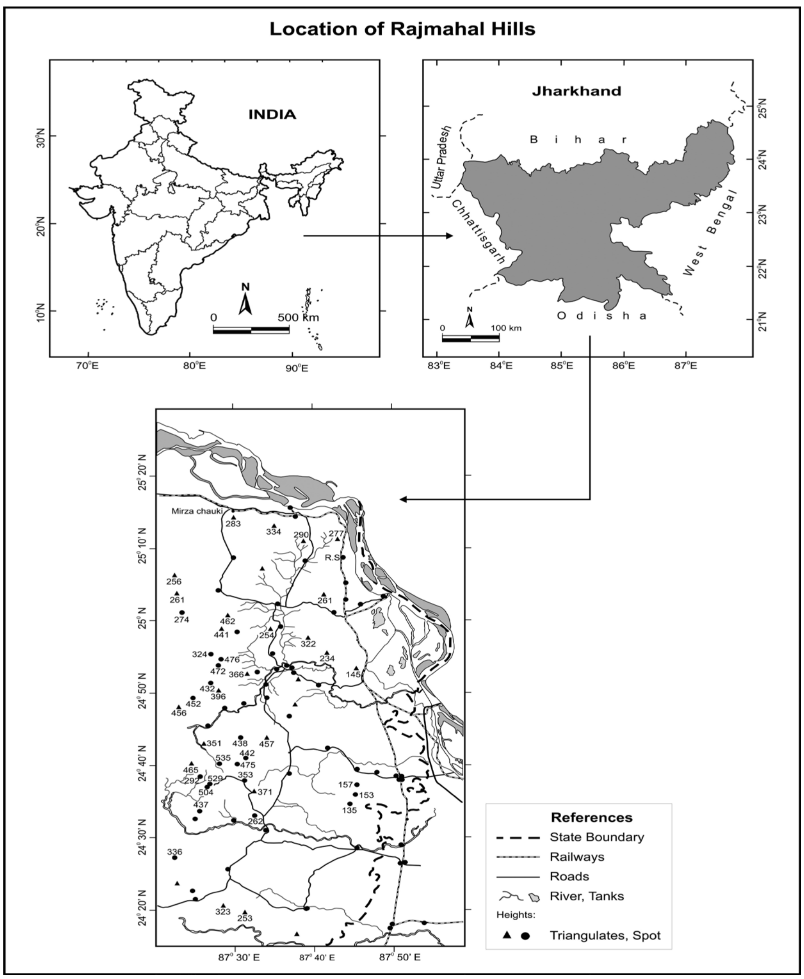
Introduction

Ideally, the general stratigraphy of a Continental Flood Basalt province (CFBP) near the source region of the basalt should bear the signatures of diastrophic activity in the form of Faulting of the volcanic and pre-volcanic formations and Dyke intrusions into the volcanic flows, with or without visible continuity into them (Rubin and Pollard, 1988:413; Abdallah et al., 1979; Bjorsson et al., 1979; Pollard et al., 1983; Murray and Fullen, 1984).They represent the foci of the repeated / intermittent crustal disturbances associated with fissure eruption and basalt lava outpouring in continental flood basalt provinces.

Such features are however wanting in the Rajmahal Hills (RH). Thorough reasoning vis-à-vis the basement configuration and regional geotectonic features collectively provide interesting clues to the location of the foci of eruptive vents and the nature of lava deposition in the Rajmahal Gondwana basin. Survey of available literature on these themes reveals that geologists have only mentioned them in a speculative and piecemeal manner. Therefore, a thorough discussion on this issue through a comprehensive analysis of the existing literature has been attempted in this article.

Study Area

The study area is the Rajmahal Hills in the state of Jharkhand in Eastern India. It can be approached by Sahibganj Loop Line of Eastern Railway from Kolkata (West Bengal) located at a distance of about 300 kms to its east-southeast and also from Bhagalpur of Bihar lying at its northwestern corner. The principal town and railway station is Sahibganj in the north-central margin of the hill and Barharwa in east-central margin of the hill (Fig.1).



Generalised stratigraphic succession of the Rajmahal Hills

The general geological succession of the area is necessary to follow the arguments presented in the paper. This is given below (Table 1).

Table - 1

Rock Groups	Composition	System	Thickness (in metres)
Recent	Soil, alluvium		
Rajmahal Stage	Flows of basalt with inter – trappean sediments and dolerite dykes intruding upto the Barakars	Upper Gondwanna	600
Dubrajpur Stage	Ferruginous sandstones, shales and conglomerates	Lower Gondwana	122 – 137
Barakar Stage	Felspathic sandstones, carbonaceous shales and conglomerates (intruded) by dolerite dykes		Varies form 0 - 152
Talchir Stage	Sandstone, clays and boulder - beds		55(appx.)
Archeans	Pegmatites, quartz veins, granite, hornblende and biotite, gneisses with inclusions of amphiboles and pyroxene granulites	Archean	

Source: Shrivastava & Shah, 1966, Raja Rao, 1953a, 1953b.

Observations

A noticeable and rather enigmatic feature evident from the table is the absence of intrusive bodies in the infra trappeans. Ball (1877) and Raja Rao (1953a) also highlighted it. This is intriguing because under ideal conditions, due to intermittent volcanic outbursts that characterize CFBPs, the general stratigraphy of a flood basalt province near the source region of the basalt should bear the signatures of diastrophic activity in the form of

- Dyke intrusions into the volcanic flows, with or without visible continuity with a particular flow occurring as prominent features of landscape (Rubin and Pollard, 1988:413; Abdallah et al., 1979; Bjorsson et al., 1979; Pollard et al., 1983; Murray and Fullen, 1984).In fact dykes (being the passage ways for lava flows) form conspicuous topographic features of flood basalt terrain and
- Faulting of the volcanic and pre-volcanic formations.

Dyke Swarms of important CFBPs

- Extensive dyke-swarms are reported from the major continental flood basalt provinces of the world as shown in table 2 below.

TabIe-2: Density of dykes in some flood basalt provinces

Area	Source	Density of dykes
Eastern Iceland	Walker (1959)	13/km at right angles to the dyke swarm; 50/km at the centre of the dyke swarm 19/km
Mull	Deshmukh and Sehgal (1989)	
Arran	Deshmukh and Sehgal (1989)	22/km
Greenland	Wager and Deer (1938)	62/km
Gujarat	Auden (1949)	2/km
Narmada and Tapti dyke swarm (Deccan basalts)	Deshmukh and Sehgal (1989)	7/km
West coast dyke swarm (Deccan basalts)	Deshmukh and Sehgal (1989)	3/km
Columbia River province Lebombo monocline zone (KVP)	Swanson et. Al. (1975) West (1985)	21,000 dike in 9,000 km^2. 3% to 4% of the area is covered by dykes.

Evidences of direct connections of dykes and lava flows

Evidences of direct connections between dykes and flows are reported from several volcanic provinces. For example, dykes petrographically and chemically similar to the Roza Member and Ice Harbour flows of the Columbia river basalt province are reported by Swanson et al, (1975:881). Similarly, the relationship of the Grande Ronde Swarm with the Columbia river basalts has been established by Gibson (1966: 205) on the basis of petrographic similarity of the lavas and dykes; presence of rubbly, scoriaceous or brecciated flows (typical features of flows adjacent to a feeding vent) near the dyke swarm; the upward termination of all observed dykes within the basalt pile etc. Such instances are also reported from Deccan Volcanic Province (DVP) by Ghosh and Pal (1984: 108). For example, the dyke intrusions in Alibag-Panvel area, the Bombay group of islands in the Dadiapada areas and in the Amba-Dongar area (Powar, 1981: 48-49) etc. Large parallel or sub-parallel basalt dykes with a general direction of [L]east by north to west by southwest' occur in the Rajpipla hills, northwest of Surat. Here the traps are much disturbed and frequently dip at considerable angles (Pascoe, 1964: 1387).

Multiple dykes i.e. newer dykes intruding older ones testifying the successive volcanic intrusions are reported by Crookshank (1936). Dudhi river near Jamgaon, Here the older rock, a coarse ophitic dolerite has been intruded by a newer medium-grained dyke. The former is thus seen as great angular blocks of weathered materials surrounded by fresh black trap. Another such instance is reported from Kotra. Here two fine-grained basaltic dykes with well-marked tachylite selvedges occur in the centre of a large dolerite one. The multiple natures of the dykes are attributed to the presence of secondary fissures near the centre of the dykes. These fissures are reportedly caused by contraction of lava on cooling. Later on these fissures act as channels for subsequent intrusions. This explanation is corroborated by the presence of cores of secondary calcite suggesting the presence of open cavities formed along their central axis subsequent to consolidation. Such cavities were probably due to shrinkage on cooling

Dykes in the Rajmahal Hills: Comparison with other CFBPs

In comparison to other CFBPs as described above, dykes are rare in the Rajmahal area itself but not absent altogether. Dolerite dykes intruding into the gneiss are found near Ramgar. Six dikes can be traced here; all aligned in an N 35°W direction cutting across the gneissic bands. Other such dykes occur to the southeast of Sukribadar, at the hilltop southeast of Kusumghati, east of Amjora and Dighibathan, north of Narganj (running upto Sapadhar) and Tharihat. All of these places are located along and west of Sundarpahari (western boundary of Rajmahal hills) adjoining the southwestern corner of the Gumani River Basin. Apart from these, other isolated instances of dykes are found in Sakrigalighat (Raja Rao, 1953a; Ball, 1877: 66), Tinpahar and Brindaban (Sarbadhikari, 1968: 157).

The intrusive relationship of these dykes with the gneisses is clear everywhere but indistinct with the Gondwanas except in two localities i.e. at Sakrigalighat and Narganj. In the former (Raja Rao, 1953a) the dyke is seen to disturb the edges of the plant bearing shales exposed here, and, in the latter, (to the north of Narganj) they are traced continuing upto the Barakar Formation (Raja Rao, 1953a, Ball 1877 : 66). None of these dykes however show a visible continuity upto any trap flow. In this connection, it would be pertinent to mention the observations of Ramaswamy, (1954) regarding resemblance of the texture and mineral composition of these dyke rocks with that of the Rajmahal basalts. There is however difference in the texture, but this has been attributed to the difference in the modes of their emplacement.

On the basis of the resemblance of the texture and mineral composition of these dyke rocks with that of the Rajmahal basalts and their intrusive relationship with the Barakars, the dykes have been assigned the same age as that of Rajmahal traps (Ramaswamy, 1954). However, it is difficult to agree with this because; their relation with trap flows or even the infra trappeans is highly indistinct as stated above. Secondly, all the aforementioned dykes are located along or west of the western boundary of the area. They are a virtual non-entity within the Rajmahal Hills proper, except the dykes at Sakrigalighat (Ramaswamy, 1954) Tinpahar and Brindaban (Sarbadhikari, 1968).However it is again difficult to postulate these three isolated dikes as the source of the vast plateau basalt province. Similarly it is also difficult to relate the doleritic and the lamprophyre dykes, with the Rajmahal volcanic episode because, many of them lie beyond the western margin of the RH, and those lying along the western margin of RH do not have any visible continuity with a particular flow. Dykes are seen to intrude upto the Barakars only and hence all of them are of pre-volcanic age.

Evidences of Faulting of lava flows in other CFBPs

General stratigraphy of flood basalt province as well as the topography, near the source region should bear evidences of faulting. Crookshank (1936: 284) reports extensive faults in the 'lower flows' along the Trap-Gondwana scarp in the northern slope of the Satpuras and from along the edge of the Narmada valley. Since most of these faults cut the lower flows it has been inferred that they 'moved at some time, subsequent to their outpouring'. Other reported evidences of post-trap faulting include, instances of block-faulting with small throws in 'Central Provinces', the Ellichpur fault at the southern part of the Gawilgarh hills, the Chhindboh fault etc. (Pascoe. 1964: 1369)

Rarity of instances of faulting in RVP

Faulting in RVP is limited upto the lower Gondwanas only. The upper Gondwanas (infra trappeans) are almost unaffected and at places overlap the fault zones (table 1). It is therefore suggested that the faulting which had formed the Gondwana basins continued during the lower Gondwana period, but had ceased during upper Gondwana period (Ramaswamy, 1954:9) when the traps were being deposited. This perhaps suggests the absence of significant crustal disturbance in the upper Gondwana period (i.e. during volcanic episodes). Blanford (1861:144) also states that "however much evidence there may be of faulting and disturbance preceeding the Rajmahal Period, the rocks belonging to that formation have … scarcely been moved from their original position" and faults are very rare among them. These observations are anomalous as far as evidences from other CFBPs are concerned.

Discussion

The observations made above tend to suggest that the focus of the Rajmahal volcanic eruption lay somewhere outside the areal extent of the Rajmahal hills, as we know it today. However, it is rather premature and farfetched to make such a suggestion on the basis of these observations alone because 'dykes may be obscured by the immense thickness of the overlying lava flows and upper crust' (White, 1992: 8). It may be mentioned here that the Rajmahal traps reach a maximum thickness of 600 m. (Baksi et al. 1987). Hence it is beyond the reach of direct observation and any drill hole is yet to penetrate that far.

Detection of concealed dykes is made possible only by 'wide angle siesmic measurements through the gravity anomaly these dense igneous rocks create'. (White and Mckenzie, 1989 In: White, 1992; 5). White, (1992:9) reports that generally, a large percentage of the melt generated on rifted continental margins is under-plated beneath or intruded in the lower continental crust of the areas lying adjacent to it. Excess volcanism also creates marginal highs as in the Norwegian and northeastern Greenland margins (Coffin and Eldhom, 1992:19). Menard and Chase (1964, In: Mutiny, 1970: 302) also suggests that the swells on the continents are related to mantle bulge and their immediate and superficial effects namely block faulting and volcanism is established. Beloussov (1962, In: Qureshy, 1969:150) pointed out that 'uplifts in geosynclines have granitic roots, whereas basaltic roots have been discovered under the uplifts on activated platforms'.

However, Mukhopadhyay (1986:363) reports that studies related to correlation of gravity anomalies and the subsurface geology of the Rajmahal Hills are meager so far. Nevertheless, as per available information, "the CGH (Central gravity High) and the linear basement ridges and depressions below the surface exposures of the Rajmahal volcanic are underlain by high Grade metamorphic"thereby indicating the absence of any basaltic intrusion into the basement. This contention seems to be corroborated by the fact that the base of the Rajmahal rocks (Archeans) are at the same level with that of the Archean terrain occurring to its west. (The latter is in part a continuation of the Archean Basement underlying the Rajmahal Formation). This suggests that the base of the Rajmahal Hills has never been uplifted 'since the lavas wee poured out' (Dunn,1939:138). Furthermore Ball (1877) Blanford (1861) and Ramaswamy (1954) also suggest that no significant crustal disturbance occurred in the post Archean period. All these evidences suggest the near absence of diastrophic activity at the site of the RH.

For the sake of understanding and comparison of this situation, the observation and interpretations about the RH as cited above, is being compared with the well known findings of the nature of basement in the DVP.

A CGH near Bombay (in the basement of DVP) is established as the 'basic remains of a secondary Deccan Trap magma chamber (Takin, 1966) while the CGH of RVP is established to be of Pre-Cambrian origin. Even the high positive gravity anomalies and the steep gravity gradients near Bombay have been interpreted as suggestive of the presence of a' great dyke under the sea off the coast, reflecting thinning of the crust and up warp of sial- sima boundary. These features probably suggests that this was an important focus of eruption'. (West, 1985:490). Even the high density bodies beneath the Girnar-Osham Barda and Chogat Chamardi regions are established to be of basic material perhaps remains of the same nature (Qureshy, 1981:190). Biswas and Deshpande (1973:139) and Qureshy (1981:195) states that all the localised positive gravity anomalies may be interpreted as the 'basic differentiated remains of a magma chamber that might have existed during the Deccan Trap Vulcanicity. Some of the positive gravity anomalies of this nature are associated with high heat flows, as in the Cambay Basin. They also report that it would logical to conclude that if such highs are found to be associated with high heat flows, then they may be suggestive of the presence of a magma chamber. However no such comments or conclusions tentative or otherwise have been suggested for the basement ridges or positive highs underlying the Rajmahal Volcanic Province (RVP).

Conclusion

The literature review reveals absence of faulting of the volcanic and pre-volcanic formations and absence of dyke intrusions into the volcanic flows in the RVP.

This is very much unlike other CFBPs where instances of faulting of the volcanic and pre-volcanic formations and dyke intrusions into the volcanic flows are many. Besides, even the correlation of gravity anomalies and the subsurface geology of the Rajmahal hills reveal that “the CGH and the linear basement ridges and depressions below the surface exposures of the Rajmahal volcanics are underlain by high Grade metamorphics”. All these features indicate absence of basaltic intrusion into the basement. Collectively such features indicate that the focus of Rajmahal vulcanicity is not located in the basement of the present surface exposures of the Rajmahal volcanics. The foci appears to lie somewhere beyond the present surface exposures of the Rajmahal volcanic probably in the adjoining Bengal Basin.

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