

Topographic Features of the Gumani River Basin, Rajmahal Volcanic Province, Jharkhand: An Example of Exhumed Topography or Palaeotopographic Control?

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Abstract: *The Gumani Basin lies within the early Cretaceous Rajmahal (24°–25°15' N, 87°29'–87°45' E) Continental Flood Basalt Province (CFBP) at the rifted margin of the Peninsular shield of India. The basalts structurally overlie the north–south oriented Rajmahal Gondwana Basin (RGB) of Permo-Carboniferous period. About nine pairs of spur-projections and the consequent planform of the valley floor of the Gumani basin suggest the probable presence of a series of east–west topographic barriers and resultant palaeodepressions along the length of the valley. Due to the absence of dyke-swarms and the untenability of the predominance of central eruption in Rajmahal Volcanic Province, it seems that the RGB did not experience in situ volcanicity and it was a zone of lava accumulation from a distant focus of eruption, located perhaps to the southeast of the Rajmahal hills. This follows that the likely topographic modifications that occurred after the first episode of Rajmahal eruptions must have involved drainage disruption through ponding of rivers and formation of shallow lakes. The lacustrine fossil flora and associated intertrappean beds substantiate this suggestion. These lakes were the sites of steam explosions after each lava flow leading to the formation of autochthonous pseudo-craters. From the analysis of topographic inconsistencies it is concluded that the anomalies are not a result of exhumation of topography as is expected in a volcanic area, rather they reflect the strong influence of a combination of the pre-volcanic topography and the topography after the first episode of eruption.*

Introduction

The Gumani River Basin, Jharkhand (24°–25°15' N, 87°29'–87°45' E), lies within the Rajmahal Volcanic Province (RVP), a Continental Flood Basalt Province (CFBP) of the early Cretaceous age (c. 117 Myr BP) (McDougall and McElhinny, 1970; Duncan, 1992:610). The Gumani rises in the northwestern slopes of Singarsri range and flows northwestward up to Simlong. Thereafter it flows northeastward up to

Berhait and finally turns east from south of Borna Pahar and debouches into the alluvial plains of the Ganga (Fig. 1). The basin can be approached by Sahibganj Loop Line of Eastern Railway from Kolkata, located at a distance of about 300 km to its east-southeast and also from Bhagalpur lying to its northwest. The principal towns and railway stations of the area are Sahibganj in the north-central and Barharwa in the east-central margins of the Rajmahal hills.

The inferred relief pattern of the area thus seems to consist of a series of broad flat areas alternated by highly constricted flat areas, the former representing the floors of a number of hypothetical lake basins and the latter the breached inter-basin areas. Similar conclusions were perhaps arrived at by Waters *et al.* (1981:24) for 'the course of the Spokane and Columbia rivers ... (which) represents the pieced-together portions of rivers dammed by flows of Yakima Basalt'. From the spatial arrangement of spurs on the valley floor, it appears that each pair of spurs was topographically continuous forming the rim of a series of lake basins enclosed within them in the past. Subsequently, these rims were probably breached and the spur projections on the present valley floor therefore appear to represent the breached remnants of these basin rims (Fig. 3). The lacustrine depositional environment of the fossil flora found in the intertrappean beds and the presence of amygdales like agate, calcite etc (Ball, 1877; Raja Rao, 1953a) also constitute favourable evidences of the presence of palaeolakes.

Discussion

Topographic depressions in volcanic terrains imply presence of craters. Conceptually, craters in a CFBP are not unusual because many basaltic eruptions start along a fissure, but activity may quickly localise to few point sources or nodes (Wilson and Head, 1981 & Delaney and Pollard, 1982 in Cas and Wright, 1988:64). Linear arrangement of crater rows associated with dyke swarms is thus not uncommon in a CFBP. However, in view of the absence of dyke swarms, the fault- and rift-dominated structural framework of RVP (Sengupta, 1966; Ghosal, 1986; Gaonkar, 1989) the presence of crater-like features in the Rajmahal plateau is anomalous. This is because they imply the predominance of central eruption which is contrary to the established

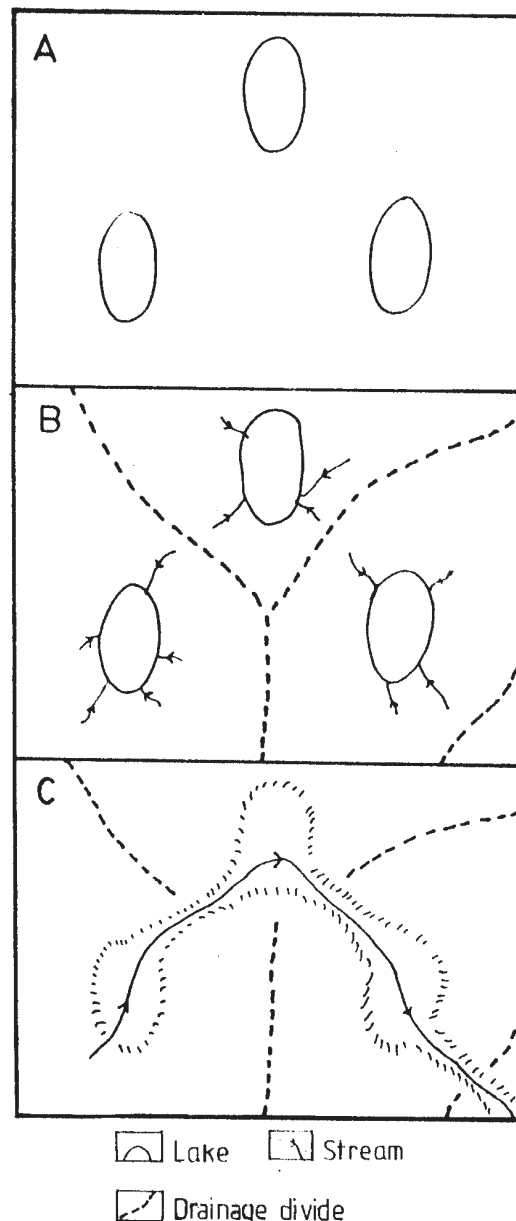


Figure 3. Schematic diagram showing the relation between the initial and present topography. (A) Presence of individual depressions. (B) Breaching of divides and coalescence of individual depressions. (C) Development of drainage lines and beaded planform of the valley-floor

fissure-fed origin of all CFBPs. The situation therefore is intriguing.

Several logical conclusions emanate from the above.

- (a) The predominance of central eruption in RVP is untenable.
- (b) The absence of dyke swarms in CFBP at a rifted continental setting is apparently anomalous indicating a distant (beyond the present surface expanse) focus of the Rajmahal Volcanics. This has also been established by the absence of intrusive bodies in the pre-volcanic flows (Ball 1877; Raja Rao, 1953a), and the findings of Sengupta (1966), Curray and Munasinghe (1991) and Mahoney *et al.* (1983) and their interpretation by Bhattacharji (1996) in the light of topographic features of RVP.
- (c) A distant focus rules out the possibility of *in situ* eruption in RVP.
- (d) The Rajmahal hills was thus a zone of lava accumulation alone
- (e) Lava accumulation modified the pre-volcanic topography of the river basin.

In view of the last conclusion, the effects of lava accumulation on the pre-volcanic topography is attempted in the following section.

Pre-volcanic configuration, extent and paleo-slope of Rajmahal Gondwana Basin (RGB)

The Rajmahal hills occupy a 275 km long isolated north-south Gondwana basin (Khan, 1987) in the highly rifted and faulted northeastern margin of the Indian shield (Mukhopadhyay *et al.*, 1986). Originally, the basin extended much beyond the present northern, eastern and southern surface boundaries of the Rajmahal volcanics (Verma and Mukhopadhyay, 1977; Rao, 1973a; Sengupta, 1966). The volcanics together with the sub-surface sedimentaries were deposited in a long trough measuring 275 km (Mukhopadhyay *et al.*, 1986; Sengupta 1966; Baksi *et al.*, 1987). The present Rajmahal represents only a part (about 30%) of the original area of deposition (Khan, 1987).

Northward extent of RGB is indicated by

presence of Gondwanas—consisting of infratrappean Dubrajpur and Barakar formations (Ball, 1877)—underneath the alluvium as far as Purnea, about 80 km north of the Rajmahal hills and 100 km further north in the Rangit valley tectonic window of Darjeeling as shown in Fig 4A and 4B. (Mukhopadhyay *et al.*, 1986). Its eastward extension is proved by the presence of Gondwanas in the Bogra area of Bangladesh (Khan, 1987), while the southern extension is confirmed by the coal-bearing Gondwana formations below the volcanic rocks of Deocha-Pachami area of Birbhum district of West Bengal (Ghosh Ray, 1986).

Palaeodrainage studies of Rajmahal coalfields (Pachwara, Chuperbhita and Hura) indicate the presence of anastomosing or braided, low to moderately sinuous streams with steep slopes flowing from a southwest to northeasterly direction (Khan, 1987). The lithological characteristic of the infratrappeans (Dubrajpur formation) consisting of coarse sandstones and the associated rich assemblage of fossil flora indicating warm humid climate are evidences of the erstwhile presence of a large and prominent river system.

Onset of volcanism: Effect on valley-floor

The distant location of the focus of eruption suggests that the site of the Rajmahal hills was merely a zone of lava accumulation in the pre-volcanic regional topographic configuration of the N–S oriented Gondwana basin. Onset of vulcanicity at 117 Myr BP (Markl, 1978; Larson *et al.* 1979; Johnson *et al.*, 1980; Veevers *et al.*, 1985) perhaps to the southeast of the hills (Curray and Munasinghe, 1991) poured lava into this northward draining basin. This was perhaps followed by disruption of drainage lines through diversion and ponding forming a chain of lakes (Waters, 1960; Ollier, 1969) along the prevailing north-south river system. The ponded lakes became the sites of deposition of weathered material (i.e.

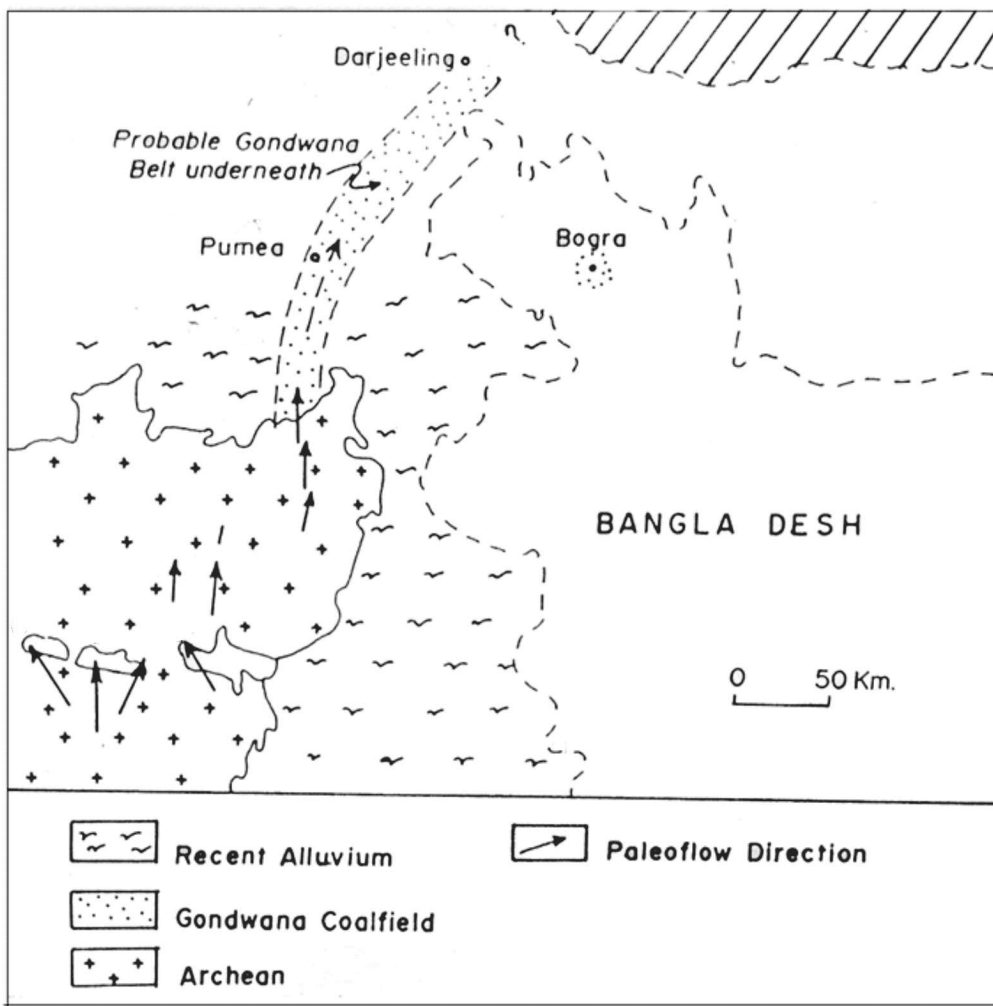


Figure 4A. Palaeoflow (pre-volcanic) direction of the RGB inferred from the palaeodrainage direction of Barakar streams. Note the possible pre-volcanic northern extent of the RGB and the northerly outlet of the palaeostreams of Barakar times (Source: Khan, 1987).

intertrappean beds) during the intervening quiescent period. Fresh inflow of lava from time to time, following renewed eruptions, probably led to their interaction with the lake water resulting in steam explosion and formation of pseudo-craters at the site of ponded lakes as is commonly found in Iceland (Ollier, 1969:91–92). The biggest such pseudo-crater was probably formed around Berhait, a centrally located place in the RGB. From the nature of the confluence of rivers Gumani and Morang here, it appears that it is the confluence of three individual rivers (Fig. 1).

The sequence of events as outlined above was repeated following each volcanic episode. The lakes thus appear to have maintained their autochthonous origin. The events as described above are given below in brief and shown diagrammatically in Fig 5.

- (i) Volcanic outburst to the southeast of the Rajmahal hills (perhaps in the Crozet hotspot)
- (ii) Pouring of lava into the RGB.
- (iii) Ponding of drainage lines in the RGB, forming localised lakes.

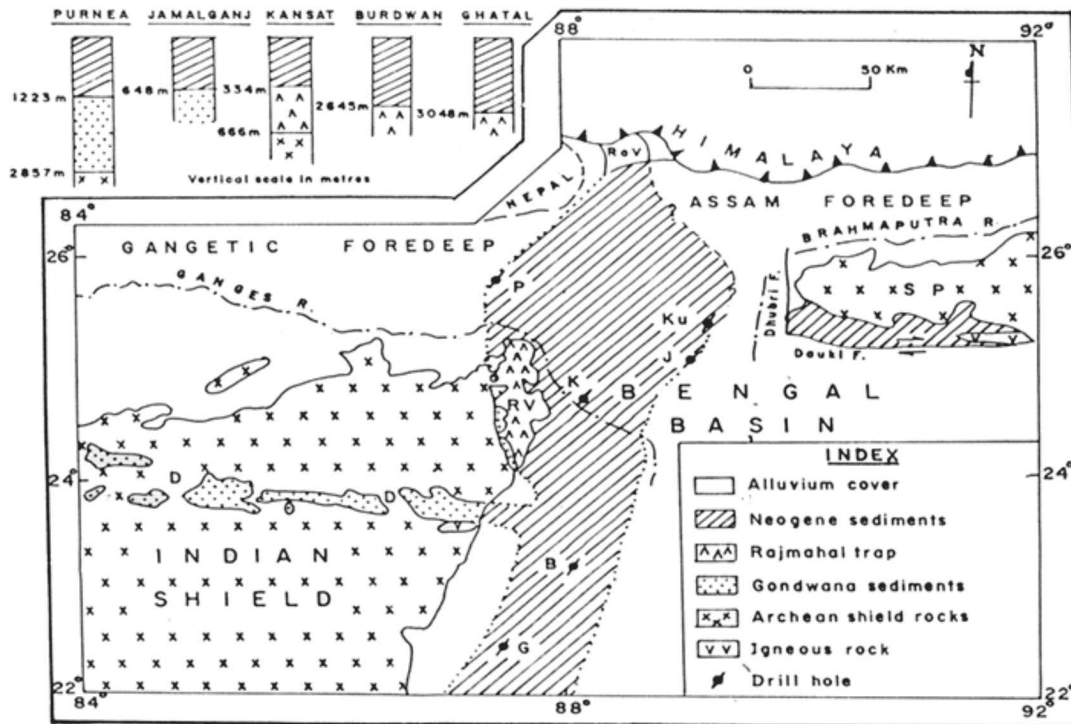


Figure 4B. Rajmahal Hills and adjoining structural units. SP: Shillong Plateau; RaV: Rangit Valley; D: Damodar Valley; Gondwana Basin; RV: Rajmahal volcanics. Figure also shows general lithology encountered in boreholes drilled into some selected sites around Rajmahal hills. Location of drillholes—P: Purnea; Ku: Kuchma; K: Kansat; B: Burdwan; J: Jamalganj; G: Ghatal. Note the absence of traps in the drill holes of Purnea and Jamalganj. Hachures indicate subsurface extension of Gondwana sediments from the Rajmahal Hills below the western part of the Bengal basin to the east and Gangetic foredeep to the north. The Gondwanas are overlain successively by the Rajmahal Traps and Tertiary sediments at the shield margin, below the western part of the Bengal basin. (Source: Mukhopadhyay *et al.*, 1986).

- (iv) Deposition of intertrappean sediments in the lakes.
- (v) Renewed volcanic activity accompanied by lava accumulation in the RGB.
- (vi) Interaction of lava with water bodies leading to steam explosion and formation of pseudo-craters, taking the form of localised lakes.
- (vii) Repetition of stages (iv), (v) and (vi)

The depressions as inferred from the relative relief map (Fig. 2) thus probably mark the site of such pseudo-craters.

Other such evidences are reported by Waters *et al.* (1981:24) from the Pasco River Basin of the Columbia Plateau. He suggests that 'the field evidences shows lava flow

spread north and west from the east central part of the plateau, and block the rivers that coursed towards the plateau from the adjacent highlands. Large but shallow fresh water lakes formed in the crease between highlands and advancing flow fronts, and such lakes were then repeatedly overrun and obliterated by later lava flows'.

Waters (1960:361) also reports similar sequence of events from Colombia River Basalts. He suggests that 'When flood basalts build an extensive lava plain, there is sure to be much disruption of former drainage. Streams are ponded against the margin of the lava flood and shallow lakes spread widely over the edges of the newly congealed lava.

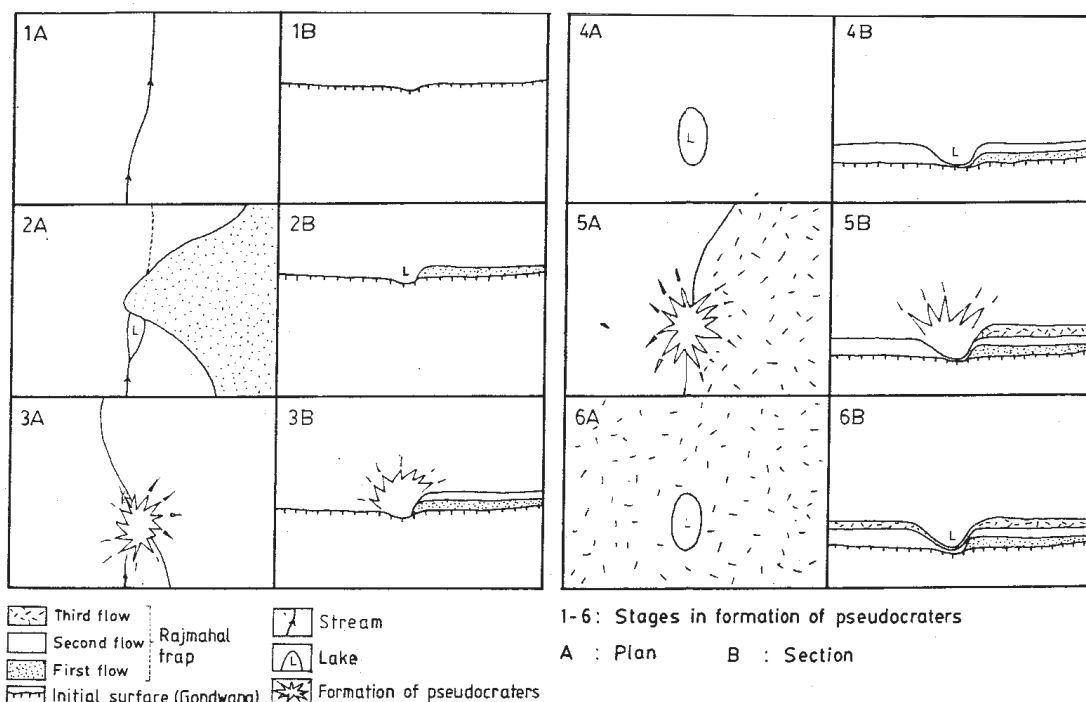


Figure 5. Stages of formation of autochthonous pseudo-craters in the Gumani basin. (1) Presence of a paleo-river. (2) Pouring of the first lava flow, ponding of drainage lines and formation of lakes. (3) Explosion at the site of ponded lakes and formation of pseudo-craters. (4), (5) and (6) Steam explosions at the sites of pseudo-craters following successive lava flows and prevalence of the depression at the lake site.

Flows from new eruption pour into these marginal lakes, filling them with a complex of pillow lavas and granulated basalt-glass. The process is repeated again and again'. He further states that 'the glass of these subaqueous breccias is nearly always partly altered to yellow earthy palagonite (Peacock and Fuller, 1928). Palagonite, too, is unstable and is generally at least partly decomposed to clay minerals, zeolites and other products'.

Here, it may be noted that pillow lavas are not found in the inferred pseudo-crater sites in the RVP, but the Rajmahal basalts contain 'plagioclase ... and glass ... mainly interstitial but also as inclusions in the plagioclase and pyroxene grain. Palagonite and chlorophaeite occur as alteration products of primary glass and pyroxene respectively and are noticed as irregular patches filling interstices, blebs and cavity fillings' (Deshmukh, 1964:65).

Concluding remarks

The evolution of planform of the Gumani basin floor together with the distant focus of eruption suggested above seems to offer a satisfactory explanation to the questions raised in this study. It explains the origin of the depression-like features which signify the presence of craters here.

The present topography reflects the inheritance of the modified pre-volcanic palaeotopography of RGB as it existed after the last episode of eruption. It is not a case of resurrected topography as in the Vindhyan plateau of Deccan Volcanic Province (West and Choubey, 1964; Choubey, 1971) because a complete burial of the valley is not envisaged here.

The study disproves the view of Linton (1957:67 in Twidale, 1976:77) that all the hills

and mountains we see today belong to Tertiary times, unless the present cycle of erosion is exhuming some earlier land surface.

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