Phreatomagmatic eruptive centre from the Deccan Trap Province, Jabalpur, central India

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Three volcanic vents in the Deccan Trap Province have been found 15 km SE of Jabalpur near Barela. They are close to a ENE striking lineament in the Narbada valley. The small diameter of the vents (60 to 80 m), low relief, highly granulated nature of the pyroclastic fill of the vents, lapilli and coarse to fine ash grain size, nonvesicularity of the lapilli fragments, abundance of sideromelane over tachylite – all suggest that these vents represent sites of phreatomagmatic eruption.

DECCAN Trap Province constitutes one of the largest flood basalt provinces in the world. It covers more than 500,000 sq. km of the Indian Peninsula. The lava pile is about 2 km thick in the west and less than a few hundred meters in the eastern part in central India. Compound pahoehoe and simple aa flows comprise the volcanic pile. The compound lavas are dominant in the western sector.

One of the major problems in the geology of the Deccan Trap is the location of centers of volcanic eruption. Although it is generally believed that the main centers are located in the west, it has been appreciated that dynamical considerations[1] rule out the possibility of the lava flows (especially compound type) poured out in the west to have travelled nearly 700 to 900 km eastward to account for the occurrences in the eastern part of the Deccan Trap Province. West has suggested that in the eastern region the source vents could be along the Narmada lineament[2]. However, from this region only few eruptive sites have been documented. A feeder dyke has been reported by Crookshank near Kamalpur[3]. Clots of clinopyroxene in basalts, pointing to the proximity of source vent, have been described near Chindwara by Mahoney[4]. Small vent-like features, about 12 m in diameter with radial dykes have been recorded near Lakhnadon[5]. During the course of studies in the Narmada valley near Jabalpur, we have come across another centre of eruption. This communication describes and discusses this new find.

Three nearly circular vent-like features (Figure 1) are observed in the Deccan Trap terrain in the valley north of Bonapahar hill about 2.5 km east of Barela, a village 15 km SE of Jabalpur on the Mandla road (Figure 2). They can be approached by a dirt road connecting Barela and Junvani villages. The diameter of the circular vent-like features ranges from 60 to 80 m. They have a very low relief, hardly 1 to 2 m above ground level and they are filled upto the ground level by black cotton soil so that the inward dip of the rim is not immediately evident. However, pitting close to the rim shows that it dips steeply inward. Compact basalt surrounds the circular vent-like features and constitutes 10 to 12 m thick screens between them. Quarries in the immediate vicinity of the circular vent-like features expose hard columnar basalts upto a depth of 3 to 3.5 m beneath less than half a metre veneer of red soil. These basalts show uralitization and carbonation in the vicinity of the circular vent-like features, especially on the northern lower flanks of 532 hill (see inset in Figure 2). In contrast, volcanic tuff underlies ~ 1 m thick black cotton soil within the circular vent-like features. Pits excavated close to the centre of these features show persistence of tuff upto a depth exceeding 2 m. Base of the tuff has not been met in the pits. The tuff is composed of lapilli set in coarse to fine ash. The rock is strongly oxidized to a brick red colour, although in a few cases it has a golden tan.

The lapilli are of basaltic and rarely felsic lava fragments, pyrogenic feldspars and clinopyroxene. Accidental ejecta derived from subvolcanic basement are virtually absent. In the Jabalpur region the subvolcanic basement is composed of Archean schists and granitoids, Mesozoic sandstones and limestones. Although no scoria was observed in the material excavated, fragments of scoria have been recovered from the northern slopes of Bonapahar in the immediate vicinity. The rock shows crude lamination on millimetre scale and volcaniclasts are poorly sorted. The ejecta is set in more felsic matrix.

Thin section studies confirm that lapilli are dominantly of basaltic glass. Transparent sideromelane fragments dominate, although globular tachylites are also present (Figure 3). Most of the fragments are well-rounded to subrounded. Some are cauliflower shaped. Broken euhedral crystals of pyrogenic minerals are also seen. Rare instances of armoured lapilli and fiamme have been noted. The glassy fragments are nonvesicular. The feldspar fragments show fracturing and undulose extinction. Clinopyroxene ($Z \wedge C = 30$ to $32°$) occuring in clots are generally prismatic. Basaltic glass at places shows variolitic structure. Felsic glass in the ground mass surrounding the ejecta shows devitrification. Extinction cross is noted in these instances. Kaolinization of feldspar and felsic ash, and plagonitization of basaltic glass has been noted.

The eruptive centre near Barela comprises < 100 m sized vents. Nature of pyroclastic material is fine grained granular (subrounded to rounded lapilli in coarse to fine ash). The material shows crude bedding and poor sorting. Glassy sideromelane fragments are dominant and volcaniclasts are nonvesicular. Armoured lapilli have also been noted (Figure 4). These foregoing characters are

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Figure 1. Circular vent-like features 2.5 km east of Barela. View from the top of Bonapahar.

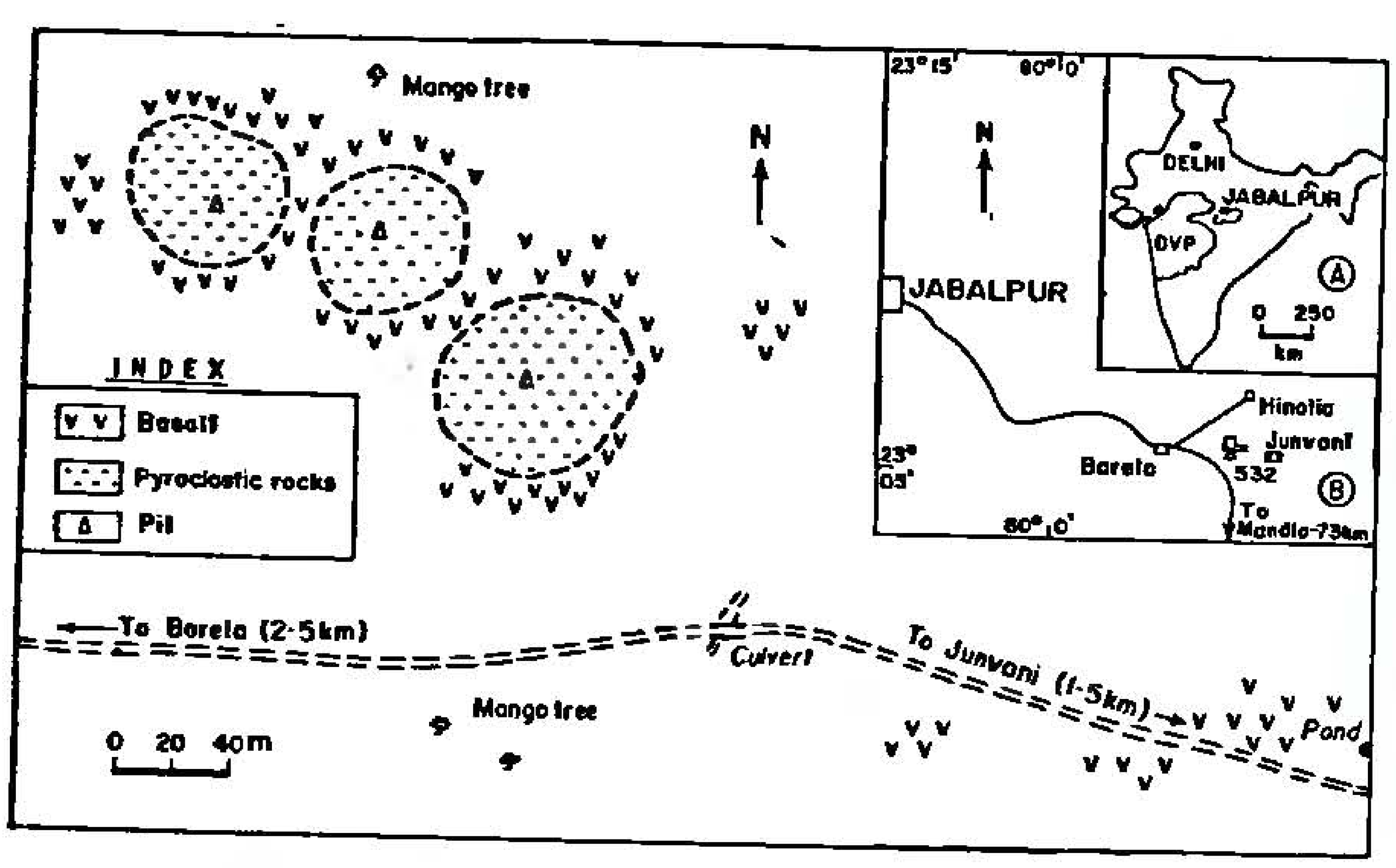

Figure 2. Map of the Deccan Trap area near Barela showing the vents to scale. While the vents are filled by pyroclastic rocks beneath black cotton soil, hard basalt surrounds them.

Figure 3. Photomicrograph of pyroclastic material showing sideromelane (dark gray) and subangular to subrounded felsic volcanic (white) and tachylite (opaque) fragments. Matrix is felsic lava, crossed nicols.

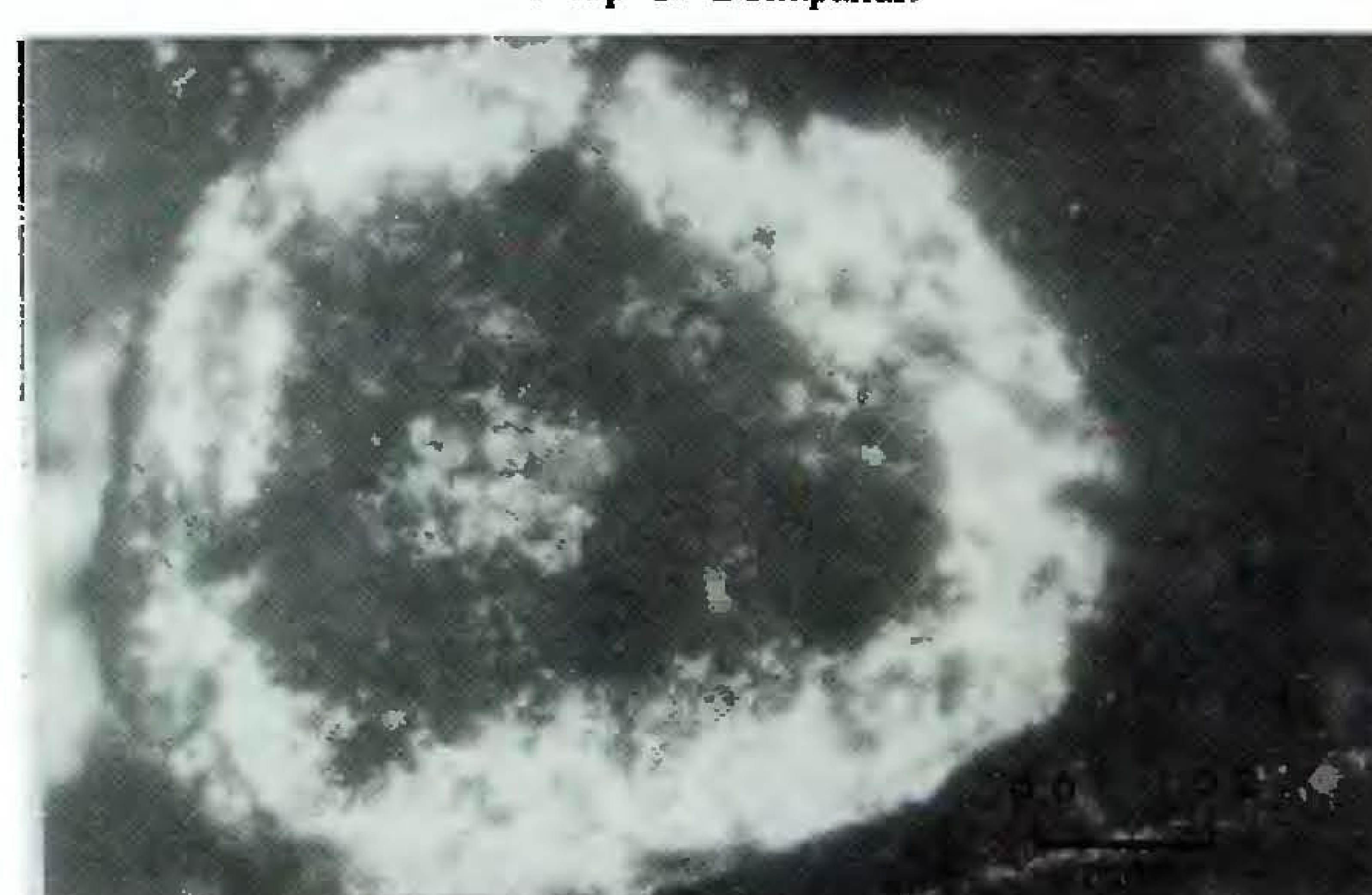

Figure 4. Photomicrograph of armoured lapilli, crossed nicols. Bar scale in figure is 0.2 mm.

all typical of hydroclastic or phreatomagmatic eruptions[6]. Observations by Born on industrial slags quenched in water[7], experimental studies by Dullforce *et al.*[8] and Swanson's personal communication[9] led Fisher and Schmincke to suggest that small dimensions and high eruption rates promote primary granulation of lava[6]. Rapid quenching of lava inhibiting vesiculation and formation of sideromelane points to interaction of basaltic lava with external water. Armoured lapilli corroborate the inference of hydroclastic origin[10,11]. The volcanism near Jabalpur occurred in an environment where intra-continental fresh water Mesozoic sedimentation was in progress. These are represented by sandstones, limestones, claystones and shales of the Lameta Group. This milieu might have promoted the lava–external water interaction.

Table 1. Centres of eruption of Deccan Trap

Feature	Area	Data source
Feeder dykes		
A. Dykes connecting to lava	(a) Macherwa and Harid rivers	Medlicot[15]
	(b) Mewasa (21°18′: 71°15′)	Fedden[16]
	(c) Thana (22°37′: 71°08′)	
	(d) Kamalpur–Bodal Kachar, Pachmari (22°27′: 78° 27′)	Crookshank[3]
	(e) Dhamond lake (22°13′: 75°28′)	
	(f) N. of Banderkach	Ghosh and Pal[17]
	(g) S. of Phalghat	
	(h) Langidi (21°28′: 73°59′)	Raja Rao[18]
	(i) Ambarnath (19°12′: 73°13′)	
	(j) 0.8 km of Jale (19°32′: 72°11′)	
	(k) Igatpuri	Beane *et al.*[19]
B. Dykes passing into breccia close to surface	(a) Kurla (19°4′: 72°53′)	Auden[20]
	(b) Sutaikeda, Nasik Dist. (20°19′: 74°18′)	Ghosh and Pal[17]
	(c) Hebardi, Saurashtra (21°13′: 69°22′)	
	(d) Manawar area (22° 6′ to 22°15′) (75°0′ to 75°16′)	
	(e) Koyna	Agashe and Gupte[21]
	(f) Ghod	
	(g) Alandi	
C. Greater thermal alteration in wall rock	(a) Godhan, western Gir forest	Chatterjee[22]
D. Compositional similarity of dykes and lavas	(a) S. of Phalghat	Ghosh and Pal[17]
	(b) Nasik, Kalsubhai	Hooper and Subba Rao[23]
E. Vents (central)	(a) Kalyan (19°14′, 73°8′)	Clarke[24]
	(b) Shivle (19°16′: 73°27′)	Fedden[16]
	(c) Kulbhera R.	Fermor and Fox[25]
	(d) Koyna and several places in Konkan	Agashe and Gupte[21]
	(e) Balsein Nala, Mandla (22°03′: 80°22′)	Hemmady[26]
F. Radial and arcuate dykes	(a) Ranpur, Barda Hill (21°48′: 69°46′)	Auden[20]
	(b) Girnar S. of Potwar (21°31′: 70°36′)	
	(c) Chamardi (21°48′: 71°54′)	
	(d) Dedan (20°59′: 71°16′)	
	(e) Viswadhar (21°22′: 71°01′)	
G. Clots of cumulus pyroxene	(a) Chindwara	Mahoney[4]

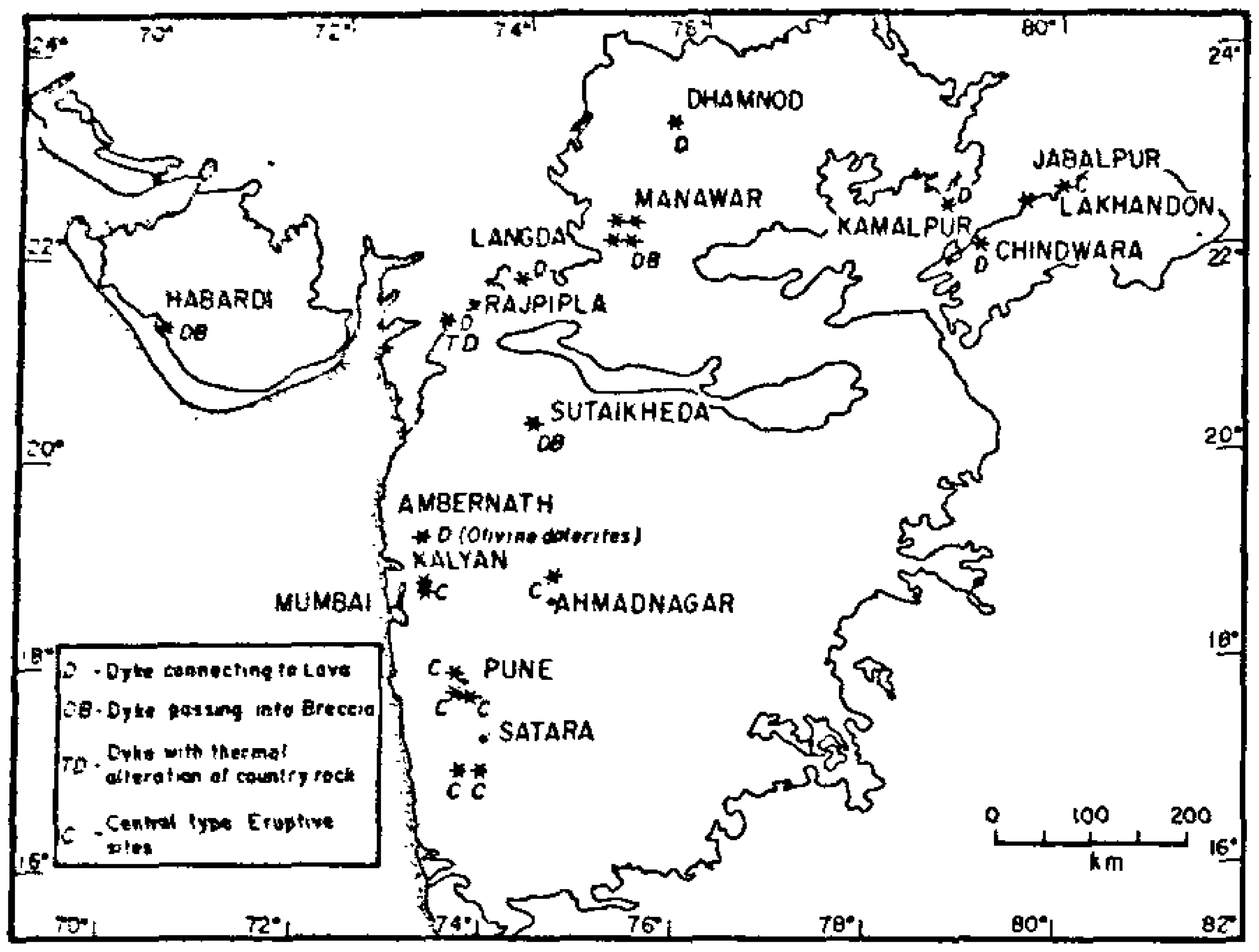

Figure 5. Map showing eruptive centres in the Deccan Trap Province. Both fissure and central eruptive sites are shown.

Phreatomagmatic deposits could be of the nature of cinder cones, tuff rings or maars [12]. Although the low relief of the vents at Barela is similar to tuff rings and maars, it is known that tuff rings are characterized by much larger craters and that the maar deposits are loaded with accidental ejecta derived from basement rocks. Because both these characters are absent in the Barela pyroclastic deposits, they appear to be of the nature of cinder cones built by mafic volcanism. According to Fischer and Schmincke[6], cinder cones are perhaps the most characteristic subaerial volcanoes in intraplate settings – a tectonic environment which seems appropriate for the Barela site near Jabalpur. The subdued relief of the vents under discussion may be the result of fluid-rich basaltic volcanism. However, post-Cretaceous erosion could have significantly modified the original relief. Occurrence of cinder cones along fissures is documented from several volcanic fields. They generally occur in groups[13]. The vents near Barela are located close to a strong E–W striking lineament[14].

Flood basalts like Deccan Traps are considered to be largely products of fissure eruptions. However, central type volcanism has been recognized in flood basalt provinces. So far, feeder dykes (dykes connecting to lavas, dykes passing into breccia, dykes with thermally altered wall rocks) have been described from Deccan Trap Province. Vents representing central type eruption (largely characterized by radial dykes and columns) have also been recorded. These various eruptive centres are summarized in Table 1 and shown in Figure 5. Large central type volcanics with a variety of volcanic rocks including abundant felsic lava flows are exemplifed by the Pavagad volcanic complex. Phreatomagmatic volcanic vents do not appear to have been commonly observed in the Deccan Trap Province. Barela eruptive centre reported in this study probably represents this mode of eruption also in the Deccan flood basalt province at the same time validating the prediction by West[2] that in the Narbada valley there may be some eruptive sites.

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