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Highly heterogeneous Precambrian basement under the central Deccan Traps, India: Direct evidence from xenoliths in dykes

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Abstract

Crustal or mantle xenoliths are not common in evolved, tholeiitic flood basalts that cover huge areas of the Precambrian shields. Yet, the occasional occurrences provide the most direct and unequivocal evidence on basement composition. Few xenolith occurrences are known from the Deccan Traps, India, and inferences about the Deccan basement have necessarily depended on geophysical studies and geochemistry of Deccan lavas and intrusions. Here, we report two basalt dykes (Rajmane and Talwade dykes) from the central Deccan Traps that are extremely rich in crustal xenoliths of great lithological variety (gneisses, quartzites, granite mylonite, felsic granulite, carbonate rock, tuff). Because the dykes are parallel and only 4 km apart, and only a few kilometres long, the xenoliths provide clear evidence for high small-scale lithological heterogeneity and strong tectonic deformation in the Precambrian Indian crust beneath. Measured $^{87}Sr/^{86}Sr$ ratios in the xenoliths range from 0.70935 (carbonate) to 0.78479 (granite mylonite). The Rajmane dyke sampled away from any of the xenoliths shows a present-day $^{87}Sr/^{86}Sr$ ratio of 0.70465 and initial (at 66 Ma) ratio of 0.70445. The dyke is subalkalic and fairly evolved (Mg No. = 44.1) and broadly similar in its Sr-isotopic and elemental composition to some of the lavas of the Mahabaleshwar Formation. The xenoliths are comparable lithologically and geochemically to basement rocks from the Archaean Dharwar craton forming much of southern India. As several lines of evidence suggest, the Dharwar craton may extend at least 350–400 km north under the Deccan lava cover. This is significant for Precambrian crustal evolution of India besides continental reconstructions.

Keywords: Continental crust; Precambrian; Xenolith; Deccan; India

1. Introduction

The Precambrian Indian shield is one of the oldest in the world. At least six Archaean to early Proterozoic cratonic nuclei, and several fold belts, are recognized in India, and several major rift zones traverse peninsular India along Precambrian structural trends (Fig. 1; Radhakrishna and Naqvi, 1986; Naqvi and Rogers, 1987; Bhaskar Rao et al., 1992; Mahadevan, 1994; Rogers and Santosh, 2004; Sheth and Pande, 2004; Santosh et al., 2005; Manikyamba and Khanna, 2007). The Deccan flood basalts, ~66 m.y. in age (e.g., Pande, 2002) cover and effectively hide the basement rocks over a huge area (500,000 km^2) of western and central India. They are best exposed in the Western Ghats region (Fig. 1), where a stratigraphic thickness of ~3,000 m has been divided into various formations and subgroups (Table 1; Subbarao and Hooper, 1988 and references therein).

Whereas xenoliths in lavas and intrusions provide direct evidence on basement composition (e.g., Rudnick, 1992; Rudnick and Fountain, 1995), very few occurrences of mantle or crustal xenoliths are known in the Deccan Traps, because the basalt lava pile is largely made up of fairly evolved tholeiites that may be products of significant crystal fractionation in magma chambers (cf. Farahat et al., 2007). Our knowledge of the basement of the huge province is therefore necessarily indirect and inferential,

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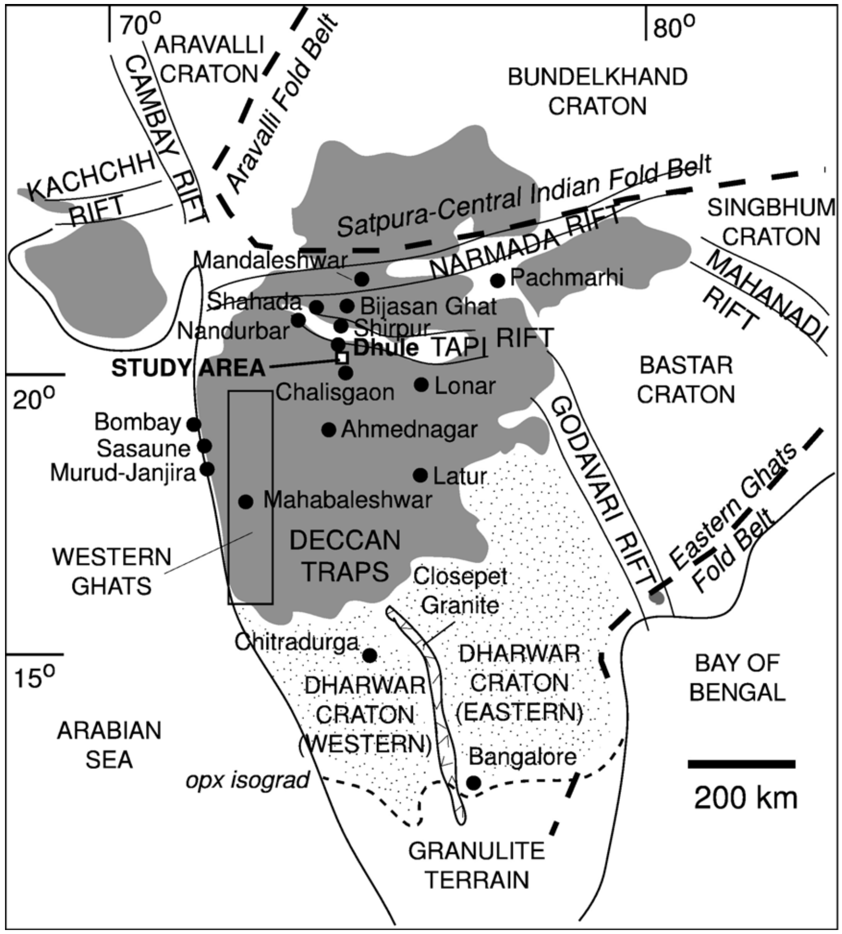

Fig. 1. Schematic map of India showing the outcrop of the Deccan Traps (shaded), the Precambrian cratonic nuclei and fold belts (mostly Proterozoic, heavy dashed lines), as well as the Proterozoic and Phanerozoic rift zones. Localities mentioned in the text are also shown. Based on Radhakrishna and Naqvi (1986), Naqvi and Rogers (1987), and Senthil Kumar et al. (2007).

and derives from geophysical studies (e.g., Rao and Reddy, 2002; Rai and Thiagarajan, 2007) as well as the geochemistry of the Deccan lavas and dykes themselves. For example, lavas of the Bushe Formation with high initial $^{87}Sr/^{86}Sr$ ratios are inferred to have been contaminated by ancient, Rb-rich, granitic upper crust, whereas the low-$^{206}Pb/^{204}Pb$ Mahabaleshwar Formation lavas have been considered possibly contaminated by U-poor, lower crustal granulites (e.g., Mahoney et al., 1982; Mahoney, 1988; Peng et al., 1994). Here we report direct, significant evidence on basement composition available from highly varied crustal xenoliths in two basaltic dykes in the central Deccan Traps.

Table 1
Stratigraphy and initial Sr isotopic values (at 66 Ma) for the Deccan flood basalts, Western Ghats

Group	Sub-group	Formation	$^{87}Sr/^{86}Sr_{(66\ Ma)}$
	Wai	Desur* (~100 m)	0.7072–0.7080
		Panhala (>175 m)	0.7046–0.7055
		Mahabaleshwar (280 m)	0.7040–0.7055
		Ambenali (500 m)	0.7038–0.7044
		Poladpur (375 m)	0.7053–0.7110
Deccan Basalt	Lonavala	Bushe (325 m)	0.7078–0.7200
		Khandala (140 m)	0.7071–0.7124
	Kalsubai	Bhimashankar (140 m)	0.7067–0.7076
		Thakurvadi (650 m)	0.7067–0.7112
		Neral (100 m)	0.7062–0.7104
		Jawhar–Igatpuri (>700 m)	0.7085–0.7128

*The Desur is considered by many as a "Unit" of the Panhala Formation itself. Table based on Subbarao and Hooper (1988) and references therein, and Peng et al. (1994).

2. Field geology

Many large dykes in the Deccan Traps trend ENE-WSW, the strike of the Satpura–Central Indian Tectonic Zone, and define a particularly fine and dense dyke swarm in the Nandurbar–Dhule region in the central Deccan (Fig. 1; Ray et al., 2007). Whereas none of these dykes contain any obvious xenoliths, we have found two ~E–W basalt dykes that outcrop a little to the south of the Nandurbar–Dhule swarm, and contain profuse xenoliths. These dykes outcrop some 30 km south of Dhule city and can be easily approached by the National Highway 211 connecting Dhule to Chalisgaon (Fig. 2). The dykes, spaced 4 km apart, form linear ridges over a largely flat lava landscape due to their greater resistance to erosion. These host lavas apparently belong to the Khandala Formation of the Western