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Deccan volcanism in Rajasthan: ^{40}Ar–^{39}Ar geochronology and geochemistry of the Tavidar volcanic suite

Archisman Sen [a], Kanchan Pande [a], Ernst Hegner [b], Kamal Kant Sharma [c], A.M. Dayal [d], Hetu C. Sheth [a,*], Harish Mistry [c]

[a] Department of Earth Sciences, Indian Institute of Technology Bombay (IITB), Powai, Mumbai 400 076, India
[b] Department of Earth and Environmental Sciences, Ludwig-Maximilians Universität München, 80333 Munich, Germany
[c] Government Postgraduate College, Sirohi 307 001, Rajasthan, India
[d] National Geophysical Research Institute, Hyderabad 500 007, India

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ABSTRACT

The Tavidar volcanic suite in western Rajasthan, India, comprises a group of lava flows (and subordinate pyroclastic deposits) of highly diverse compositions ranging from basalt through trachyte to rhyolite. We have dated five samples of the Tavidar volcanic rocks by the ^{40}Ar–^{39}Ar incremental heating technique. One trachyte and two rhyolite samples yield very good plateau, isochron and inverse isochron ages of 67–65 Ma, typical of the Deccan Traps large igneous province. A subalkalic basalt and a basaltic trachyandesite yield saddle-shaped argon release spectra and show evidence for excess argon. Importantly, all five samples have very similar Nd–Sr isotopic ratios, and constitute a broadly cogenetic magmatic suite with the rhyolites possibly derived by closed-system fractional crystallization of trachytic magmas. The Tavidar rocks' isotopic data overlap, or are very close to, those of the Mahabaleshwar and Panhala Formation basalts in the Western Ghats type section 700–800 km to the southeast. We therefore infer that the Tavidar rocks, having initial Nd values of +3.2 to +0.7, have incorporated only small amounts of lower continental crust. The Tavidar volcanic suite attests to the great areal extent of the Deccan Traps, and reaffirms the great compositional diversity evident in the northwestern Deccan Traps.

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1. Introduction

Geology of Rajasthan

The Rajasthan region in western India is one of the oldest continental nuclei known, with a geological history spanning more than 3.3 billion years (e.g., Choudhary et al., 1984; Gopalan et al., 1990; Wiedenbeck et al., 1996; Roy and Jakhar, 2002). The Archaean basement termed Mewar Gneiss consists of gneisses, metasediments and ultramafic rocks, as well as granite intrusions (Roy, 1988, 1990). Major stratigraphic sequences of Rajasthan are the Proterozoic Aravalli (sedimentary) and Delhi (volcanosedimentary) Supergroups, and both are intensely deformed, metamorphosed, and intruded by granitic plutons (e.g., Biswal, 1988). A major, little deformed, Proterozoic sedimentary sequence in eastern Rajasthan is the Vindhyan Supergroup.

The Neoproterozoic time in Rajasthan was marked by major granite plutonism and rhyolitic volcanism, called the Malani igneous event (Fig. 1, Coulson, 1933; Kochhar, 1984; Bhushan, 2000; Bhushan and Chandrasekaran, 2002; Sharma, 2004, 2005). This is considered a silicic large igneous province (LIP), with subordinate mafic lavas and dykes (Sheth, 2007). Rb–Sr isochron and U–Pb zircon ages range from ~780 Ma to ~680 Ma (Crawford, 1970; Crawford and Compston, 1970; Kochhar et al., 1985; Dhar et al., 1996; Rathore, 1994; Rathore et al., 1996a, 1999; Torsvik et al., 2001; Van Lente et al., 2009). Based on $^{40}Ar/^{39}Ar$ dating work, Rathore et al. (1996a, 1999) also inferred a younger, Pan-African thermal imprint in Malani rocks. The Malani rocks have counterparts in the Seychelles islands, a submerged microcontinent in the Indian Ocean which was joined to western India until just after the main phase of Deccan volcanism (Devey and Stephens, 1992).

A little-studied volcanic sequence of varied compositions is exposed near Tavidar village in southwestern Rajasthan, surrounded by granitic rocks of Malani age and Recent alluvial sediments. The Tavidar volcanic rocks were considered a part of the Malani igneous event by older workers (e.g., Coulson, 1933), possibly due to the abundance of felsic rock types. Rathore (1994) showed from unpublished ^{40}Ar–^{39}Ar dating work that the Tavidar volcanic rocks were Late Cretaceous in age, and thus belonged to the large Deccan Traps LIP. No dating results or geochemical data have been published on the Tavidar rocks. Here we present the first published ^{40}Ar–^{39}Ar ages, petrographic observations, major and trace

* Corresponding author. Tel.: +91 22 25767264; fax: +91 22 25767253.
E-mail address: hcsheth@iitb.ac.in (H.C. Sheth).

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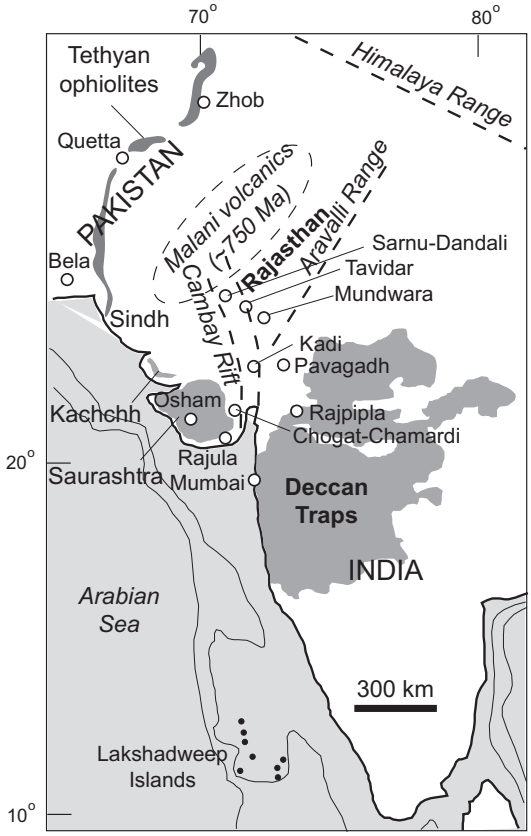

Fig. 1. Map of the Deccan Traps with igneous complexes and outcrops of rhyolitic rocks, including the study area of Tavidar. Also shown are locations of the Rajasthan, Kachchh, Saurashtra and Sindh regions, and approximate boundaries of the Malani LIP (Sharma, 2004). Pre-Deccan (72–74 Ma) Tethyan ophiolites in northern Pakistan are also shown. Simplified from Mahoney et al. (2002) and Sheth et al. (2011).

element data, as well as Sr–Nd isotopic data, on the Tavidar sequence, and discuss its place in the broader context of Deccan volcanism.

2. The Deccan Traps

The ~65 Ma Deccan volcanic province is exposed over an area of ~500,000 km^2 in west-central India (Fig. 1). Its original extent has been estimated as thrice this size (Krishnan, 1960). The main province comprises flat-lying flood basalt lavas, reaching >2 km thick in the Western Ghats escarpment. However, the northwestern Deccan Traps (the Saurashtra, Kachchh, and Rajasthan regions) show a great compositional diversity. The Saurashtra region hosts several volcano-plutonic complexes and has abundant rhyolite and granophyre (Sheth et al., 2011, 2012; Kshirsagar et al., 2012), whereas Kachchh shows both tholeiitic and mafic alkalic rocks (Kshirsagar et al., 2011). In Rajasthan, Deccan magmatism is represented in the Mer Mundwara and Sarnu-Dandali igneous complexes (Fig. 1) by a great variety of silica-undersaturated intrusive rocks, such as alkali gabbros, pyroxenites, nepheline syenites, lamprophyres, and carbonatites (e.g., Viswanathan, 1977; Subrahmanyam and Rao, 1977; Basu et al., 1993). Subsurface Deccan lavas and intrusions (e.g., Kadi syenite) covered by thick post-Deccan sediments are also known under the Cambay Rift, an important zone of post-Deccan subsidence and hydrocarbon accumulation in the northwestern Deccan Traps (Ramanathan, 1981; Sharma, 2007). The localities of Kadi, Sarnu-Dandali and Tavidar are located in the Cambay Rift, and the Chogat–Chamardi gabbro–granophyre–rhyolite complex of Saurashtra is located on the western edge of the Rift (Fig. 1; Sheth et al., 2011).

3. The Tavidar volcanic suite: Previous studies

The Tavidar volcanic rocks (Fig. 1) outcrop ~25 km west of the town of Bhinmal in southwestern Rajasthan. They have been studied in three unpublished Ph.D. projects to our knowledge (Dashora, 1981; Agrawal, 1984; Rathore, 1994); we have been able to read a copy of the the latter. Fig. 2 is a map of the Tavidar volcanic rocks after Agrawal (1984), reproduced in Rathore (1994), with the locations of the samples of the present study added. Agrawal (1984) found a compositional diverse suite, including basaltic rocks, andesites, trachytes, and rhyolitic lavas and tuffs. He classified the basaltic rocks into hawaiite and mugearite, and also reported small outcrops of basement granite near Tavidar village and arkose and orthoquartzite beds separating the granite from the Tavidar lavas. Trachyte appears to be the dominant rock type in the area from his map.

Upadhyaya et al. (1988) and Agrawal and Upadhyaya (1991) explored the statistical aspects of major-oxide compositional data generated by Agrawal (1984) on the Tavidar rocks. The data themselves have not been published. They concluded based on statistical considerations (e.g., improved correlation coefficients) that whereas andesites, trachytes and rhyolites formed a cogenetic suite of rocks, the basalts were genetically unrelated. Rathore (1994) reported K–Ar ages of 44–76 Ma, ^{40}Ar–^{39}Ar ages of 63–67 Ma, and Sr isotopic data on some Tavidar rock samples, but did not provide major or trace element data. His work established the Deccan linkage of the Tavidar volcanic rocks. A few major oxide analyses of the Tavidar lavas have been published by Bhushan and Chandrasekaran (2002). Here we present field and petrographic data, together with ^{40}Ar–^{39}Ar ages, major and trace element data, as well as Nd–Sr isotopic data, on the Tavidar volcanics.

4. Field geology and petrography

The Tavidar volcanic rocks outcrop between the villages of Chatwara and Jalera Khurd (Fig. 2). They form ~N–S trending hills that rise up to ~100 m above sand-covered plains. The area lacks any sizeable vertical sections that can display stratigraphic relationships, and extensive sand cover often hides lateral relationships between rock units. The lava flows are of basalt, andesite, trachyte and rhyolite, and are associated with silicic tuffs. The volcanic sequence has a general northwesterly dip of ~25°. Intrusions, including dykes, are rare.

In thin section the Tavidar volcanic rocks show varied petrographic features. The Tavidar trachyte sample Tav01 is highly porphyritic (Fig. 3a and b), with plagioclase and clinopyroxene phenocrysts. The feldspar phenocrysts poikilitically enclose small clinopyroxenes (Fig. 3a), a possible indication of a mafic parentage of the trachyte. Small quartz grains can be seen in the groundmass which is made up of small feldspar laths. The rhyolitic tuff sample Tav02 taken near Tavidar village (Fig. 3c) shows a fragmental texture, with abundant broken quartz grains. The basalt sample Tav05, collected from a low-lying plain area east of Tavidar, was not depicted in Agrawal's (1984) map. The basalt is highly plagioclase-phyric with a very fine-grained groundmass (Fig. 3d). Rhyolite sample Tav07 from Lakhawas is aphyric and made up of fine-grained quartz and K-feldspar (Fig. 3e). The Chatwara rhyolite sample Tav8B from Chatwara village (Fig. 3f) shows well developed millimeter-scale flow banding and flow folding.

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