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Geology, petrochemistry, and genesis of the bimodal lavas of Osham Hill, Saurashtra, northwestern Deccan Traps

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ABSTRACT

The Saurashtra region in the northwestern Deccan continental flood basalt province (India) is notable for compositionally diverse volcano-plutonic complexes and abundant rhyolites and granophyres. A lava flow sequence of rhyolite–pitchstone–basaltic andesite is exposed in Osham Hill in western Saurashtra. The Osham silicic lavas are Ba-poor and with intermediate Zr contents compared to other Deccan rhyolites. The Osham silicic lavas are enriched in the light rare earth elements, and have ε_{Nd} (t = 65 Ma) values between −3.1 and −6.5 and initial $^{87}Sr/^{86}Sr$ ratios of 0.70709–0.70927. The Osham basaltic andesites have initial ε_{Nd} values between +2.2 and −1.3, and initial $^{87}Sr/^{86}Sr$ ratios of 0.70729–0.70887. Large-ion-lithophile element concentrations and Sr isotopic ratios may have been affected somewhat by weathering; notably, the Sr isotopic ratios of the silicic and mafic rocks overlap. However, the Nd isotopic data indicate that the silicic lavas are significantly more contaminated by continental lithosphere than the mafic lavas. We suggest that the Osham basaltic andesites were derived by olivine gabbro fractionation from low-Ti picritic rocks of the type found throughout Saurashtra. The isotopic compositions, and the similar Al_2O_3 contents of the Osham silicic and mafic lavas, rule out an origin of the silicic lavas by fractional crystallization of mafic liquids, with or without crustal assimilation. As previously proposed for some Icelandic rhyolites, and supported here by MELTS modelling, the Osham silicic lavas may have been derived by partial melting of hot mafic intrusions emplaced at various crustal depths, due to heating by repetitively injected basalts. The absence of mixing or mingling between the rhyolitic and basaltic andesite lavas of Osham Hill suggests that they reached the surface via separate pathways.

1. Introduction

Most continental flood basalt (CFB) provinces of the world contain at least some silicic (rhyolite–dacite–trachyte) magmatism. These silicic magmas have been variably interpreted as products of crystal fractionation of mafic magmas, partial melting of underplated mafic rocks or the deeper parts of the CFB lava pile, combined assimilation and fractionation processes, or anatexis of the older basement crust (e.g., Lightfoot et al., 1987; Sheth and Ray, 2002; Melluso et al., 2008, 2009; McCurry et al., 2009; Cucciniello et al., 2011).

In the ~65 million year old Deccan Traps flood basalt province, covering an area of 500,000 km^2 in western and central India, rhyolitic and trachytic rocks are locally abundant (e.g., Subba Rao, 1971). Their main outcrops are located in the Mumbai, Pavagadh, Rajpipla and Chhota Udaipur areas, as well as the Saurashtra peninsula in the northwestern Deccan Traps (Fig. 1a) (e.g., Krishnamurthy and Cox, 1980; Lightfoot et al., 1987; Gwalani et al., 1993; Chatterjee and Bhattacharji, 2001, 2004; Sheth et al., 2011a; Kshirsagar et al., in press; Zellmer et al., in press). A small but significant rhyolite–pitchstone–basaltic andesite lava flow sequence is exposed at Osham Hill in Saurashtra (Fig. 1a). Maithani et al. (1996) have presented some major and trace element (including rare earth element) data on the Osham rhyolites, but not the associated basaltic andesites. Isotopic data on Deccan rhyolitic rocks are scarce, and are not available on the Osham rhyolites. Here we present a geochemical, mineral chemical, and Nd–Sr isotopic study of the Osham silicic and mafic lavas. We present a model for their genesis, and discuss the petrogenetic implications of the data with particular reference to the rhyolitic rocks in the Deccan Traps.

2. Geology of Osham Hill

The relatively flat and low-lying Saurashtra peninsula is covered largely by the Deccan lavas (Fig. 1b), except along its fringes where Tertiary and Quaternary sediments (limestone and alluvium) cover

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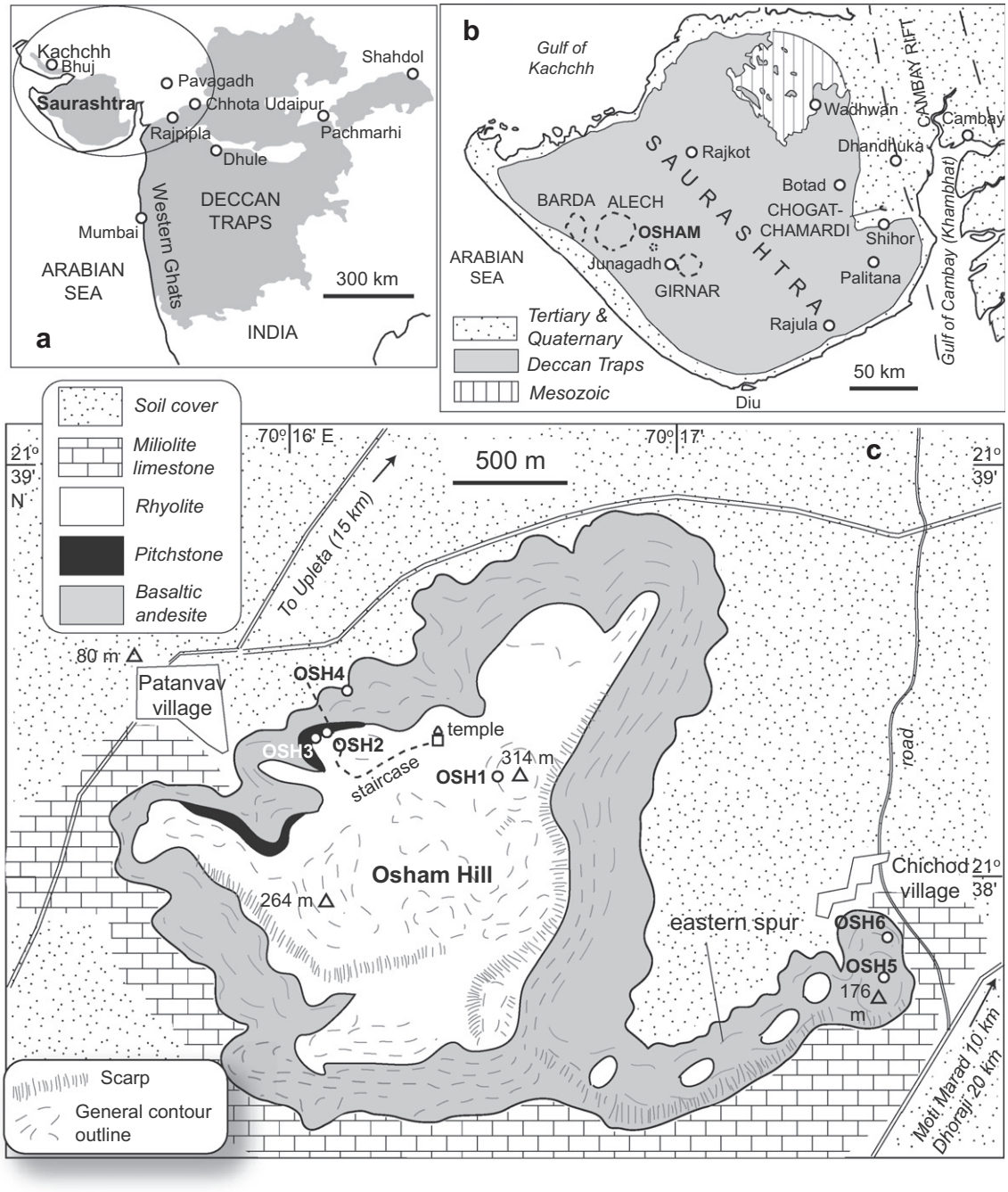

Fig. 1. Simplified geological maps of the Deccan Traps (a) and of Saurashtra (b), with the important central complexes and locations in Saurashtra marked (after De, 1981), as well as localities mentioned in the text. Dhandhuka, Botad, and Wadhwan are where basalts and picritic basalts have been encountered in boreholes (West, 1958). Elliptical area in (a) is the general northwestern Deccan region, with great compositional diversity. (c) Geological map of Osham Hill (from Maithani et al., 1996) showing the locations of the samples of this study, and the Quaternary Miliolite limestone and soil cover.

the Deccan rocks. In the northern part Mesozoic sedimentary rocks are exposed. No pre-Mesozoic rocks are known in Saurashtra from outcrops, borings, or xenoliths. Borings in northeastern Saurashtra have encountered intercalated basalt and picritic flows and some pyroclastic deposits totalling ~400 m thickness under the alluvium cover (West, 1958; Peng and Mahoney, 1995). The Saurashtra region has several features that make it strikingly different from the main Deccan Plateau in west-central India, composed of thick, extensive flood tholeiites (e.g., Najafi et al., 1981). These features include Saurashtra's various volcano-plutonic complexes, a great compositional diversity, and an abundance of rhyolite and granophyre (e.g., De and Bhattacharya, 1971; De, 1981; Melluso et al., 1995; Sheth et al., 2011a; Kshirsagar et al., in press). Compared to the our knowledge of the flood basalts of the Deccan Plateau and the Western Ghats escarpment (Fig. 1a), our knowledge of Deccan magmatism in Saurashtra is very rudimentary. The present contribution on the Osham Hill lava sequence expands our knowledge base of Deccan magmatism in Saurashtra and its place in the overall framework of Deccan flood volcanism.

Osham Hill, located in the Survey of India toposheet 41 K/6 (1:50,000 scale), is a table mountain situated between the Girnar and the Barda-Alech complexes (Fig. 1b). The hill is a few kilometers in lateral extent, is surrounded by soil cover and Miliolite limestone, and exposes a ~225 m thick Deccan lava sequence (Figs. 1c