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Origin of Late Palaeoproterozoic Great Vindhyan basin of North Indian shield: Geochemical evidence from mafic volcanic rocks

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ABSTRACT

On the western and southern margins of the sickle shaped Vindhyan basin of north Indian shield, there are basal Vindhyan mafic volcanic rocks referred to as Khairmalia volcanics and Jungel volcanics respectively. These volcanics vary in composition from low-Ti tholeiite to high-Ti alkali basalt showing close affinity with continental flood basalts (CFB) and ocean island basalts (OIB) respectively. The parental magmas of Khairmalia and Jungel alkali basalts were formed by different degrees of partial melting of a garnet lherzolite. The magma of Khairmalia tholeiites was generated by a relatively higher degrees of partial melting of a garnet + spinel lherzolite. The geochemical data coupled with available geological and geophysical data favour a rift type origin of this basin which evolved as a peripheral basin showing many similarities with Paleogene Himalayan foreland basin. The existing radiometric age data suggest that the origin of Vindhyan basin is linked with Aravalli–Satpura orogeny. At about 1800–1600 Ma collision occurred along the Aravalli-Delhi fold belt (ADFB) and Central Indian Tectonic Zone (CITZ) with west and south subduction respectively. During this process the subducting lithosphere suffered extensional deformation on its convex side and some pre-existing large faults in the already thin leading edge of subducted plate also reactivated and tapped magma generated by decompressional melting of the subcontinental mantle. The simultaneous processes such as flexural subsidence, reactivation of pre-existing faults, heating, thermal cooling and contraction during volcanism, resulted in the formation of curvilinear warp parallel to the emerging mountain front. The Lower Vindhyan volcano–sedimentary succession was deformed and exposed to erosion before the deposition of Upper Vindhyan rocks. The orogenic forces were active intermittently throughout the Vindhyan sedimentation.

1. Introduction

The Proterozoic Era of earth history was a period of accelerated crustal growth (Taylor and McLennan, 1985) during which orogenic belts, sedimentary basins and the first stable cratons developed (Windley, 1984). Therefore, to understand crustal evolution the tectonic framework of many crustal features needs to be known; most important among one includes the origin and evolution of large sedimentary basins. The Indian shield is characterized by the presence of several non-linear Proterozoic sedimentary basins collectively referred to as Purana Basins. The largest one is the Vindhyan basin (VB) of North Indian shield (Fig. 1A) resting on the Archaean Bundelkhand block and covering a surface area of over 1,00000 km^2 including those that is concealed under the Cretaceous-Palaeogene Deccan Volcanic Province in the southwest, in addition to its subsurface extension into Indo-Gangetic plane towards north up to Himalayan foot hills (Auden, 1933; Soni et al., 1987). The maximum thickness of the sedimentary fill, comprising sandstone, shales, carbonates, minor conglomerates and mafic volcanic products exceeds about 4500 m (Mishra, 1969; Gokaran et al., 1995). These rocks, except near the margin of the basin, are predominantly undeformed and unmetamorphosed and have been considered to deposit during the period from about 1400 to 550 Ma (Mishra, 1969; Vinogradov et al., 1964; Crawford and Compston, 1970). However, recent radiometric dates suggest the initiation of Vindhyan sedimentation at about 1600 Ma (Rb–Sr on glauconite, Kumar et al., 2001), 1631 Ma (U–Pb on Zircon, Ray et al., 2002), 1628 Ma (U–Pb on Zircon, Rasmussen et al., 2002) and 1601 ± 130 Ma (Pb–Pb on limestone, Ray et al., 2003). The striking feature of the VB is its location in front of the Aravalli-Delhi fold belt (ADFB) in the west and the Central Indian Tectonic Zone (CITZ) in the south (Fig. 1A). This configuration of the basin has led many workers to suspect a possible relationship between its origin and preceding tectonic events which were instrumental in the formation of these orogenic belts (Narain, 1987; Chakraborty and Bhattacharyya, 1996; Raza and Casshyap, 1996; Chakraborty and Karmakar, 1998). Although various plate tectonic models have been proposed to explain tectonic evolution of ADFB and CITZ and their surrounding terrains (Synchanthavong and Desai, 1977;

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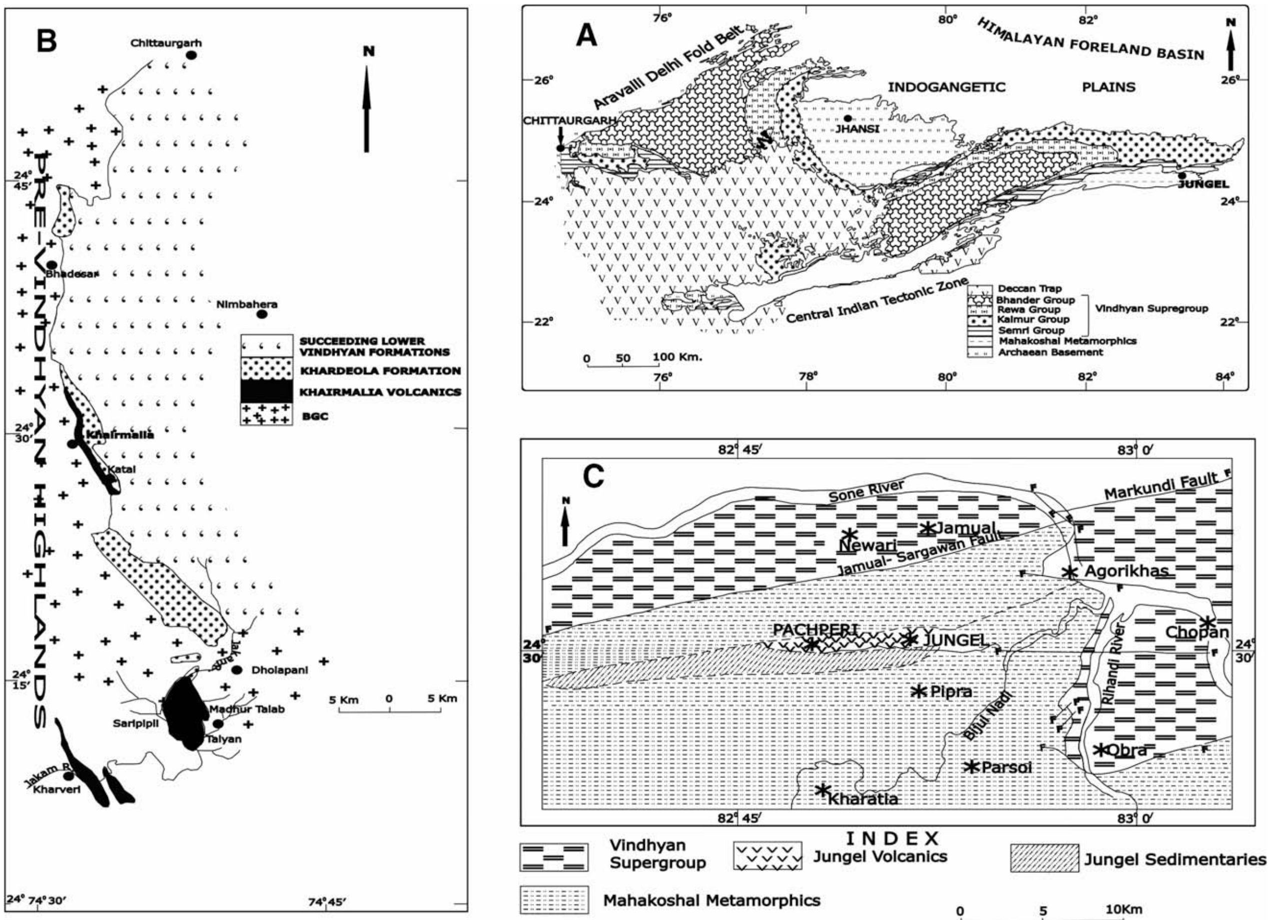

Fig. 1. Generalized geological map of (A) Vindhyan basin, (B) western margin of Vindhyan basin south of Chittaurgarh, Rajasthan (C) Southern margin of Vindhyan basin, around Jungel, Son valley.

Sinha-Roy, 1988, 2000; Sugden et al., 1990; Yadekar et al., 1990; Raza et al., 1993, 1995, 1998; Misra et al., 2000; Tiwari et al., 2000), none explains the origin and mechanism of VB formation. The rocks of Vindhyan Supergroup are generally flat but folded and faulted at margins showing tectonic contact with Pre-Vindhyan basement. Several faults have been identified in the deformed Lower Vindhyan strata both along the southern and western margins (Mathur, 1981; Srivastava and Iqbaluddin, 1981; Ameta, 1990; Srivastava and Sahay, 2003). At places, the older sediments from adjacent orogenic belts and lower parts of Vindhyan succession were thrusted over younger Vindhyan strata (Ameta, 1990; Raza and Casshyap, 1996; Sinha-Roy, 2004). The style of deformation at the western and southern margins is in conformity with those of the peripheral ADFB and CITZ respectively. The basin is also characterized by the presence of well developed volcanic sequences, i.e. (a) Jungel volcanics of Son Valley along the southern margin (Srivastava and Iqbaluddin, 1981) and (b) Khairmalia volcanics near Chittaurgarh, southeastern Rajasthan (Prasad, 1984; Raza et al., 2001).Geochemical data of these volcanic sequences, particularly mafic rocks, may provide important constrains on the nature of their mantle sources, condition for partial melting and degree of subsequent modification of mantle derived melts during their ascent and/or ponding in magma chamber. Because these factors vary from one tectonic setting to another the mafic volcanic rocks with distinct geochemical characteristics are generally associated with specific tectonic environment in the plate tectonic framework (Pearce and Cann, 1973; Floyd and Winchester, 1978). In the present study the geochemical data of Khairmalia and Jungel volcanics are used to distinguish the magma types and to understand the nature of their mantle sources at the time of their eruption which in turn may provide useful constraints on the tectonic setting at the time of initiation of VB. Furthermore, the available geophysical, geochemical, structural and geological data on Vindhyan basin and surrounding orogenic belts are combined to understand the origin and evolution of this great basin in the light of modern tectonic concepts.

2. Geologic and tectonic setting

2.1. Mafic volcanics

In southeastern Rajasthan, the western margin of VB (Fig. 1B) is marked by the presence of synsedimentary mafic volcanics (Prasad, 1984) forming a linear belt of about 50 km south of Chittaurgarh (Raza et al., 2001). The well developed volcanic occurrences in this area are (1) Khairmalia (2) Katai-Madhopur (3) Madhur Talab and (4) Jakham river near Kharveri (Raza et al., 2001). These rocks rest directly on Archaean basement referred to as Banded Gneissic Complex (Heron, 1953) and intercalate with rocks of the lowermost Khardeola Formation of Vindhyan Supergroup (Prasad, 1984). The volcanic sequence does not show significant effects of metamorphism. The stratigraphic succession (Fig. 2A) of the Lower Vindhyan sequence is considered as to Semri Group of Son Valley (Prasad, 1984). In the Jungel Valley of Sonbhadra district of Uttar Pradesh an outlier of Lower Vindhyan sedimentary rocks and mafic volcanics overlies the basement of Late Archaean–Early Proterozoic