U-Pb zircon dating and Sr isotope systematics of the Vindhyan Supergroup, India

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**ABSTRACT**

The Vindhyan Supergroup of central India, the focus of many paleontological studies, has been reported to contain Cambrian small shelly fossils, Ediacaran fossils, trace fossils, and Proterozoic microfossils and carbonaceous megafossils. New U-Pb zircon and \(^{87}\)Sr/\(^{86}\)Sr isotopic data from the Lower Vindhyan Supergroup require that the rocks are latest Paleoproterozoic to earliest Mesoproterozoic in age. Two rhyolitic volcanic horizons from the Deonar Formation, between the Kajrahat and Rohtasgarh Limestones and below the unit containing trace fossils, yield U-Pb zircon ages of 1631 ± 5 Ma and 1631 ± 1 Ma. The Kajrahat and Rohtasgarh Limestones of the Semri Group that are below and above the reported Mesoproterozoic trace fossils have \(^{87}\)Sr/\(^{86}\)Sr ratios of 0.70460 and 0.70479, respectively. The Bhander Limestone from the Upper Vindhyan Supergroup has an \(^{87}\)Sr/\(^{86}\)Sr ratio of 0.70599, consistent with a Neoproterozoic age for this formation. These results indicate that the Kajrahat Limestone is of latest Paleoproterozoic age and the Rohtasgarh Limestone is of probable Mesoproterozoic age. These findings are in conflict with the report of Cambrian small shelly fossils and fossils of articulate brachiopods in the Rohtasgarh Limestone and argue for a Mesoproterozoic age for the formation that contains the alleged trace fossils. Reports of an Ediacaran fossil *Spriggina* (?) from the Lower Vindhyan Supergroup from the northern margin of the Vindhyan Basin suggest either incorrect stratigraphic correlation of units or misidentification of this fossil.

**Keywords:** Vindhyan Supergroup, metazoan evolution, U-Pb zircon dating, Sr isotope stratigraphy.

**INTRODUCTION**

The timing of the first appearance of multicellular organisms is a fundamental question of biological evolution on Earth. Ediacaran fossils have a reliable paleontological record that extends to ca. 565 Ma, whereas the oldest reliably dated traces of multicellular organisms extend to 555 Ma (Martin et al., 2000). Some workers (e.g., Wray et al., 1996) have suggested, on the basis of molecular clocks, a much longer and gradual evolution of animal life that may extend back into the Mesoproterozoic. This assertion was supported by the report of trace fossils from the southern margin of the Vindhyan Basin, from sedimentary rocks reported to be 1.1 Ga (Seilacher et al., 1998), and the description of the Ediacaran fossil *Spriggina* (?) in correlative sediments from the northern margin of the basin (Kathal et al., 2000). The discovery by Azmi (1998) of small shelly fossils and fossils of articulate brachiopods characteristic of the Early Cambrian in rocks just above the trace-fossil horizon further complicated the proper age assignment for the Lower Vindhyan Supergroup. The authenticity of all these fossils (e.g., Kerr, 1999; Kumar, 2001) as well as the age of the sedimentary sequence remain to be confirmed. Here we present new data relevant to the temporal assignment of the fossil-bearing strata of the Lower Vindhyan Supergroup.

The Vindhyan Supergroup consists of extensive, voluminous, unmetamorphosed, and mildly deformed sedimentary rocks that dominate the geologic record of the post-Archean and pre-Gondwana time period of the Indian subcontinent. In spite of its regional and global significance, precise ages for the Vindhyan Supergroup have been lacking. Earlier attempts to date these sedimentary rocks by K-Ar and fission-track methods on glauconites and authigenic clays have yielded a complex spread of dates that were subsequently questioned (Venkatchalal et al., 1996, and references therein). The assumed 1.1 Ga age for the reported trace fossil horizon is based on such dates (Seilacher et al., 1998). Recent paleontological reports of microfossils (e.g., Kumar and Srivastava, 1995) and carbonaceous megafossils (e.g., Rai et al., 1997; Kumar et al., 2001) are consistent with the conventional belief of a Mesoproterozoic-Neoproterozoic age for the Vindhyan Supergroup (e.g., Bhattacharyya, 1996). This view is also supported by the only reliable radiometric minimum age datum for the Lower Vindhyan Supergroup (ca. 1100 Ma, Rb-Sr isochrons) that comes from the dating of the Majhgawan kimberlite pipe, which intrudes the Semri Group along the northern margin of the Vindhyan Basin (Crawford and Compston, 1970; Kumar et al., 1993) (Fig. 1). However, the lack of proper correlation between the northern margin of the basin and the type area in the Son Valley (southern margin) precludes direct use of this age for evaluating the antiquity of trace fossils reported by Seilacher et al. (1998) and of body fossils reported by Azmi (1998). Here we report U-Pb ages for magmatic zircons from the Deonar Formation of the Semri Group from the southern margin of the Vindhyan Basin (Fig. 1). The Deonar Formation is ~50 m below the formation containing the trace-fossil horizon. We also report results of our Sr isotopic study on the limestone formations that are above and below the controversial fossil horizons (Fig. 1). U-Pb zircon ages and \(^{87}\)Sr/\(^{86}\)Sr ratios together provide a precise estimate of the timing of deposition of the Lower Vindhyan Supergroup and of the major part of the Upper Vindhyan Supergroup, thus defining the age of the supergroup and its fossil record.

**U-Pb GEOCHRONOLOGY**

The Lower Vindhyan Supergroup in the Son Valley (Fig. 1), encompassing the entire stratigraphic succession, is exposed in a relatively small region. The supergroup consists of four major groups, which contain sandstone, shale, carbonate, and a few volcaniclastic horizons; the maximum cumulative thickness is ~5 km (Bhattacharyya, 1996). The Deonar Formation, informally known as the Porcellanite Formation, of the Semri Group (Fig. 1) is composed of silicified volcanic rocks and very fine grained volcaniclastic sediments. Two samples were collected from this unit for U-Pb zircon geochronology. Both samples contain phenocrysts of quartz and rel-