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Geochemistry of Permo-Triassic mudstone of the Satpura Gondwana basin, central India: Clues for provenance

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ABSTRACT

Major and trace element data of the Permo-Triassic mudstones from the intracratonic Satpura Gondwana basin, central India have been used to investigate provenance. The Satpura succession (~5 km thick) unconformably overlies the Precambrian basement. Sediment dispersal pattern suggests that the Precambrian rocks straddling the southern margin of the Satpura basin were the most probable source for the sediments. The lowermost unit of the Satpura succession comprises glacio-marine and glacio-fluvial deposits. The rest of the succession largely represents a variety of fluvial depositional systems with some records of fluvio-deltaic and fluvio-lacustrine sedimentation under a climatic spectrum of temperate, humid to warm, semi-arid. The present study is confined to the lower six formations namely Talchir, Barakar, Motur, Bijori, Pachmarhi and Denwa, arranged in that order from bottom to top.

The oldest rocks of this sequence, the Talchir Formation, are enriched in mobile elements such as Na, Ca and Mg, depleted in alumina and have high ICV (0.93–1.29) and lower CIA values (61.82–74.89) compared to those of the younger mudstones. K_2O/Al_2O_3 ratios of the Talchir mudstones (0.24–0.28) are higher than the younger mudstones in this sequence. These results suggest that the Talchir mudstones were weathered less intensely and are thus more immature than the younger mudstones. This is consistent with the prevailing cold climate and relatively higher rate of basin subsidence. In contrast, the majority of the mudstones from the younger formations are depleted in mobile elements, have relatively low ICV (0.18–0.87) and K_2O/Al_2O_3 values (0.07–0.26), higher CIA values (76.99–92.86), and appear compositionally more mature reflecting moderate to high intensity source rock weathering. Among them, the Barakar mudstones likely have been more intensely weathered than mudstones from any of the other formations.

The trace element compositions and ratios are consistent with most mudstones being derived from a felsic source with some mudstones being derived from a more mafic source. For example, La/Sc (0.805 and 0.114), La/Th (6.245, 5.072, 7.418, 6.245, and 5.072) and Eu/Eu* (1.431, 0.868, and 0.805) of some mudstones indicate mafic source. Bivariate plot of Th/Sc and Zr/Sc indicates considerable enrichment of zircon that suggests recycling from meta-sedimentary rocks.

Prominent negative Eu anomaly, high LREE/HREE, and flat HREE pattern reflect sediment derivation from predominantly felsic rocks of the old upper continental crust. SiO_2/Al_2O_3 versus K_2O/Na_2O plot for the mudstones suggests that they formed in a passive margin. Also, total REE content of most of the mudstones is conformable with passive margin tectonic setting and craton interior type of provenance. Plotting in La–Th–Sc, Th–Sc–Zr/10 and La/Sc versus Ti/Zr diagrams largely indicates continental margin settings for majority of the mudstones but fails to differentiate between active and passive continental margins.

1. Introduction

Chemical composition of sediments provides important clues on source rock characters and tectonic setting of the depositional basins (Taylor and McLennan, 1985; Johnsson, 1993; McLennan et al., 1993). Geochemical data can also provide valuable information about the sedimentary processes such as weathering, transport, and diagenesis (cf. Mader and Neubauer, 2004).

Major and trace element distributions reflect different aspects of provenance of mudstones. The major element oxide composition of sediments and that of source rocks does not correlate entirely, as weathering in the source region may lead to compositional changes (Barshad, 1966; Tardy et al., 1973; Nesbitt, 1979; Heckroodt and Buhmann, 1987; Middleburg et al., 1988; McLennan, 1989; Weaver, 1989). The bulk chemical changes that take place during weathering are

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used to quantify the weathering history of sedimentary rocks, primarily to understand past climatic conditions (Nesbitt et al., 1980; Nesbitt and Young, 1982, 1984; McLennan et al., 1993; Young, 1999).

Many trace elements such as most HFSE and transition trace elements and the rare earth elements are transferred from source to sediments without significant fractionation and preserve the signature of the parent materials (cf. Floyd et al., 1990). Hence, trace elements as compared to major elements are expected to be more useful in discriminating tectonic environments and source rock compositions (Balashov et al., 1964; Nesbitt, 1979; Davies, 1980; Bhatia and Crook, 1986; McLennan, 1989; Condie, 1993; Bierlein, 1995). The trace element content of fine sediment is usually higher than those of sandstones for reasons discussed elsewhere (Balashov et al., 1964; Cullers et al., 1975; Aubert and Pinta, 1977; Nesbitt, 1979; Davies, 1980; Taylor and McLennan, 1985; Cullers et al., 1987; Marsh, 1991; Lee, 2002) and thus can be more useful provenance indicators (Young, 1999).

There have been no provenance studies of the Gondwana succession of India other than that of the Raniganj basin in eastern India (Suttner and Dutta, 1986). In the present study we have analyzed the geochemical characters of the Permo-Triassic mudstones from the intracratonic Satpura Gondwana basin (central India, Fig. 1) to investigate provenance. We have also included geochemical data

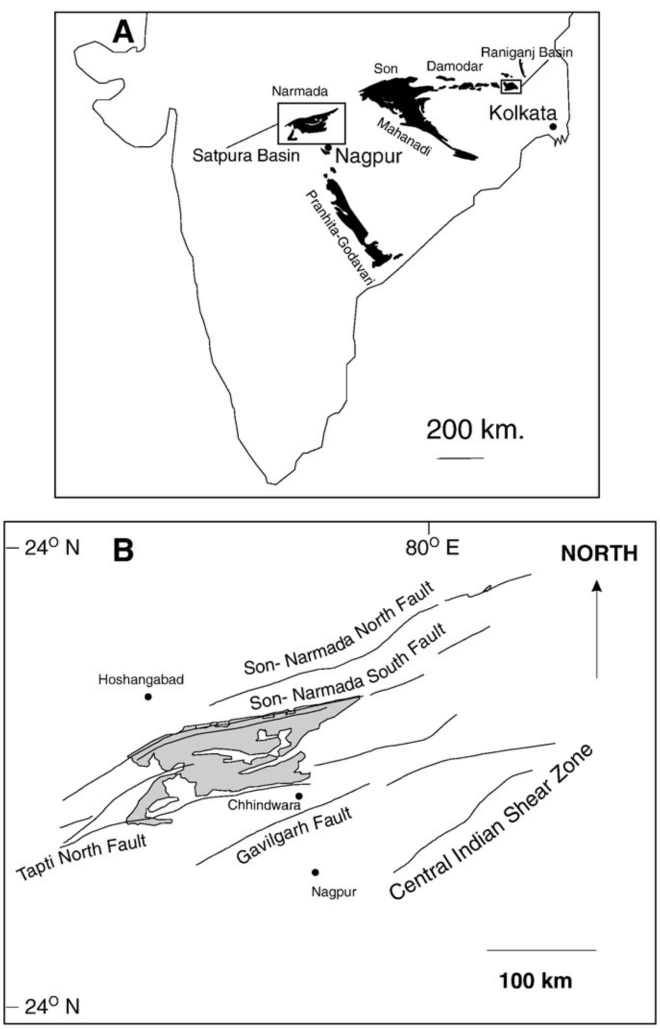

Fig. 1. (A) The major Gondwana basins of Peninsular India. Note that the Satpura basin is the westernmost Gondwana basin cropping out along the present-day ENE–WSW trending Narmada–Son–Damodar valley. Also note the location of the Raniganj basin. (B) Major boundary faults of the Satpura Gondwana basin (based on Narula et al., 2000). Shaded area represents the outcrop of the Satpura basin.

from a variety of probable source rocks of the Precambrian basement complex lying towards the southern side of the Satpura basin. The objectives of this present study are (i) to identify the source rock/s for Permo-Triassic sediments in the Satpura Gondwana succession, and (ii) to discern the tectonic setting of the basin as revealed from the geochemical signatures and to compare it with tectonic setting known from other evidence.

Provenance studies of strike–slip basin fills are conspicuously underrepresented in the literature (Ridgway and DeCelles, 1993). The outcome of this study may have important bearing on the general understanding of the role of relief, climate and source rock in influencing petrogenesis of siliciclastic sediments deposited in an intracontinental, pull-apart basin.

2. Geological setting

2.1. Precambrian basement

The Precambrian basement complex lying south of the Satpura Gondwana basin forms a conspicuous lithotectonic unit of a Proterozoic mobile belt, namely Central Indian Tectonic Zone (CITZ), between two Archaean cratonic nuclei, i.e. northern Bundelkhand and southern Bastar cratons. The CITZ covers an ENE–WSW trending linear tract lying between Son–Narmada North Fault in the north and Central Indian Shear zone in the south (Fig. 1). The Proterozoic belt is traversed by several ENE–WSW trending ductile shear zones (Roy and Prasad, 2001). The Precambrian basement complex comprises Palaeo- to Mesoproterozoic Betul and Tirodi gneissic complex, Mesoproterozoic volcano-sedimentary sequence and meta-sediments, Neoproterozoic acid and basic intrusives (District Resource Map, Chhindwara, Madhya Pradesh, 2003; District Resource Map, Betul, Madhya Pradesh, 2002; Geological Survey of India).

In the study area tonalite gneiss is the predominant member of the gneissic complex, which is the oldest in the Precambrian terrain. Mafic enclaves within the tonalite gneiss indicate the presence of a still older variety of rock in the complex. The typical mineral assemblage of the mafic enclaves is plagioclase–actinolite–tremolite–quartz–biotite–opaque. Non-porphyritic and porphyritic granitic rocks (c.1.5 Ga, Roy et al., 2004) show intrusive contact with the gneiss. Quartzite, phyllite and mica-schist, locally garnetiferous, occur over an extensive area. Epidote–hornblende–quartz–actinolite rocks are interlayered with quartzite–phyllite. At places these meta-sedimentary rocks occur as inliers within the granites, and the granites appear younger than the quartzite–phyllite and associated rocks. Bimodal mafic–felsic volcanics are relatively unaffected by deformation and metamorphism, lack any metamorphic fabric and appear younger than the meta-sediments. Typical mineral assemblage of these mafic rocks is actinolite–plagioclase–tremolite–chlorite–opaque–sphene. Acid volcanic rocks are mostly composed of quartz–K-feldspar–biotite–stilpnomelane–epidote–zircon–plagioclase–garnet. Mafic–ultramafic rocks of the basement complex occur as intrusives in volcano-sedimentary supracrustal assemblages (Roy et al., 2004). They show even grained interlocking hypidiomorphic texture, without any sign of directional alignment. Typical mineral assemblage is hornblende–quartz–plagioclase–sphene–opaque–apatite ± garnet.

Westward extension of this assemblage of Proterozoic rocks has been described as the Betul Group of rocks (Roy et al., 2004). They tentatively suggested a magmatic arc type tectonic setting for the Betul Group of rocks.

2.2. The Satpura Gondwana basin

The Gondwana deposits marks the resumption of sedimentation in peninsular India after a long hiatus since the Proterozoic. Gondwana sedimentary successions occur in several discrete, intracratonic basins in Peninsular India. The Satpura basin is the westernmost of the series,