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Geochemistry of lower Vindhyan clastic sedimentary rocks of Northwestern Indian shield: Implications for composition and weathering history of Proterozoic continental crust

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ABSTRACT

The western margin of the ~1600 Ma Vindhyan basin of the Indian shield is marked by the presence of lower Vindhyan Group (LVG) comprising shales and sandstone with minor limestone, conglomerate and mafic volcanic flows at the base. Major and trace element compositions of sandstones and shales of the LVG have been investigated to infer the nature of provenance, weathering processes, and tectonic setting. Provenance analysis using trace elements and petrography suggests that the Archaean Banded Gneissic Complex (BGC) of Rajasthan is most likely the source of these clastic rocks. The shale and sandstone comprising lower part of LVG namely Khardeola Formation are distinctive in having high LILE such as Th, Rb, and K_2O, high ferromagnesian trace elements and also higher values of K_2O/Na_2O, Rb/Sr and $(La/Yb)n$ ratios in comparison to succeeding sedimentary units comprising upper formations of the LVG. The significantly different geochemical characteristics of Khardeola Formation suggest change in provenance with sediments in the lower formation being derived from proximal source and those of upper formations from distal source. Based on REE patterns and Eu/Eu^* values, the clastic sediments of Khardeola formation can be modeled by a mixture of 60% Berarch Granite and 40% mafic volcanic rocks of Hindoli belt. On the other hand, the upper formations are best modeled with a mixture of 60% BGC granitic gneisses, 20% BGC mafic enclaves and 20% Berach Granite. CIA (chemical index of alteration) values and A–CN–K plot suggest that the source area experienced moderate to high degree of chemical weathering under warm and humid conditions. The shift of sediment source from local in the beginning to distal during later period suggests sedimentation in a tectonically active basin.

1. Introduction

The geochemical compositions of sedimentary rocks have long been proven to be a useful tool in the crustal evolution studies (Taylor and Mclennan, 1985; Jahn et al., 1981; Condie,1993) and provide constraints on the provenance, paleoclimatic conditions and often tectonic setting of ancient sedimentary sequences (Wronkiewicz and Condie, 1987; McLennan, 1989; Jahn and Condie, 1994; Hofmann, 2005; Roddaz et al., 2006, 2007; Absar et al., 2009; Raza et al., in press). The geochemical signatures of tectono-magmatic events of contemporary upper continental crust are believed to be preserved in the sedimentary rocks. Therefore the sediment geochemistry has been used extensively to collect information on the composition and weathering history of Archaean and Proterozoic continental crust. In such studies the trace elements which are considered immobile or less mobile during chemical weathering, diagenesis and metamorphism are generally used (Holland, 1978; Taylor and McLennan, 1985; Totten and Blatt, 1993; Chaudhuri and Cullers, 1979). While large Ion lithophile elements (LILE) are considered as being variably mobile during secondary processes, the rare earth elements (REE) and high field strength elements (HFSE) are generally not affected (e.g. McLennan et al., 1983; Crichton and Condie, 1993). Since these elements are transferred virtually quantitatively from the upper continental crust into sedimentary basin, the trace element geochemistry of clastic rocks has been effectively used to determine the composition of source terrains (e.g. Sugitani et al., 2006; Payne et al., 2006). In this regard the REE are considered to be more reliable and have been used widely in provenance studies (Taylor and McLennan, 1985).

In the present study we discuss the geochemistry of sandstones and shales of the late Palaeoproterozoic (⩾1600 Ma) lower Vindhyan Group (LVG; Prasad, 1984) which occur at the western margin of the Vindhyan basin in the southeastern Rajasthan (Fig. 1). The aim is to define the geochemical characteristics of Lower Vindhyan

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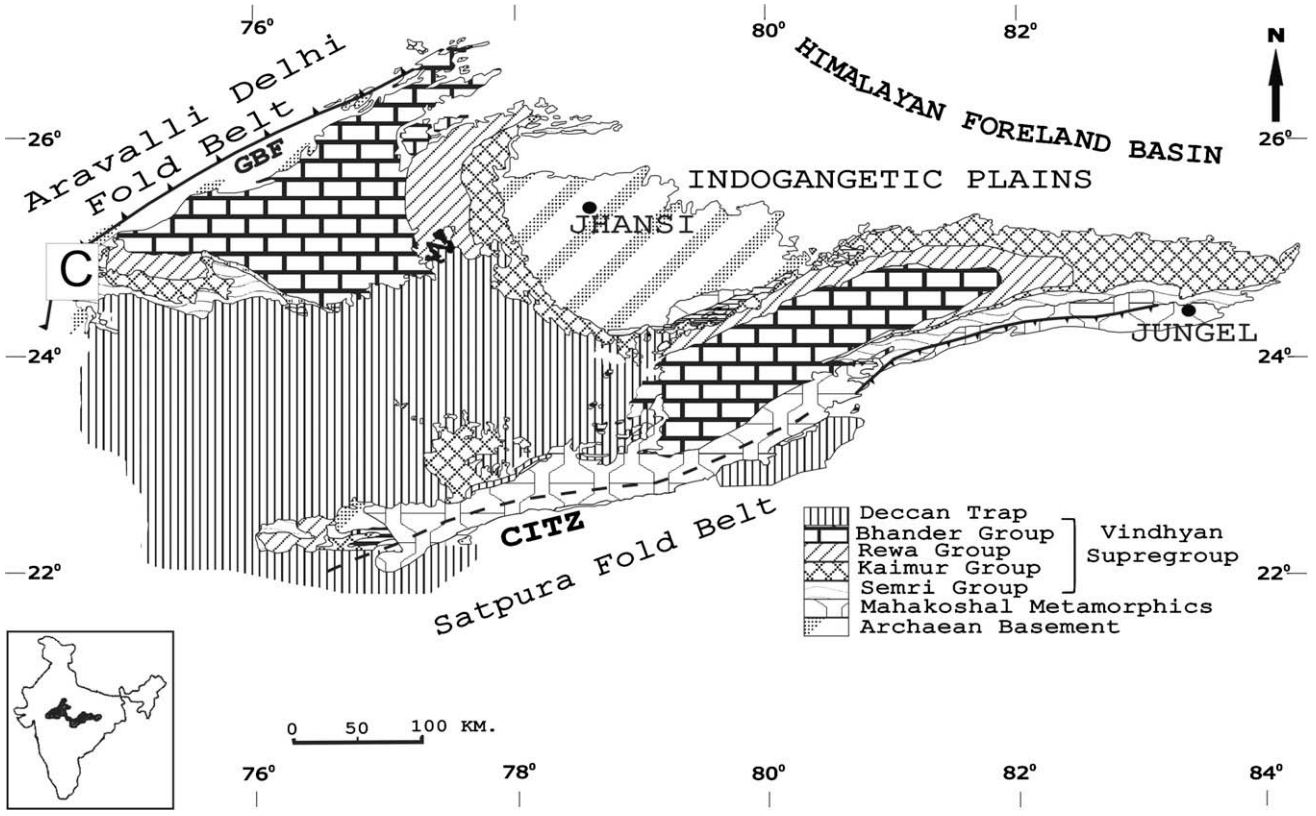

Fig. 1. Generalized geological map of Vindhyan basin showing distribution of various lithostratigraphic units. Inlet: outline map of India showing location of Vindhyan basin. CITZ-Central Indian Tectonic Zone; GBF-Great Boundary Fault; C-Study area around Chittaurgarh.

sediments based on major and trace elements and to discuss the provenance composition, weathering conditions and the tectonic setting of depositional basin.

2. General geology of the study area

Like many other shields of the world, the Indian shield is characterized by the presence of several non-linear sedimentary basins of Proterozoic age collectively referred to as Purana Basins. The largest among these is the Vindhyan basin of north Indian shield (Venkatachala et al., 1996) lying unconformably on the stable Bundelkhand block in front of the Satpura fold belt in the south and Aravalli fold belt in the west (Fig. 1). This basin covers an area of about 178,000 km^2 (Tandon et al., 1991). The age of deposition in the Vindhyan Basin has long been debated due to the absence of reliable fossils suitable for biostratigraphic dating. However, after the report of interesting but debatable fossils (Azmi, 1998; Seilacher et al., 1998) from lower sedimentary units of the basin the age of Vindhyan sedimentation has been assigned by radiometric means. The available radiometric age data (Kumar, 2001; Ray et al., 2002, 2003; Rasmussen et al., 2002; Sarangi et al., 2004; Ray, 2006) suggest that the Vindhyan sedimentation was initiated at about $\geqslant$1600 Ma. The western margin of the basin is marked by a major lineament called as Great Boundary Fault Zone (GBFZ) which separates the rocks of Vindhyan Supergroup from those of an Archaean basement called as Banded Gneissic Complex (Heron, 1953) or (BGC) and its Proterozoic supracrustals. In south eastern Rajasthan, the lower Vindhyan Group (LVG) rests directly on the BGC. It consists predominantly of shales and sandstones with minor amount of limestone and conglomerate and well developed synsedimentational mafic volcanics at the base (Prasad, 1984; Raza et al., 2001). The detail geology of the area has been worked out by Prasad (1984). The stratigraphic succession of the LVG is unequivocally equivalent to the Semri Group of Son Valley and shown in Table 1.

Table 1
Lithostratigraphy of lower Vindhyan Group developed on the western margin of the Vindhyan basin in Rajasthan (after Prasad, 1984).

Group	Formation	Lithology	Thickness meters (m)
Upper Vindhyan	Kaimur	Sandstone, conglomerate	20–70
	Suket	Shale	120
	Nimbahera	Limestone	100–150
	Bari	Shale	45
	Jiran	Sandstone	30–60
	Binota	Shale	250
Lower Vindhyan	Palri	Shale	30–50
	Sawa	Sandstone	30–60
	Bhagwanpura	Limestone	30–50
	Khardeola	Shale and sandstone	60–360
	Khairmalia	Volcanic flows and tuff	40–100
Unconformity			
Banded Gneissic Complex (BGC)			

3. Sampling and analytical techniques

Samples for this study were collected across the entire stratigraphic succession of the lower Vindhyan Group exposed to the south of Chittaurgarh. Fresh samples from different formations were collected from road cuts and quarries. They show no visible effect of weathering, veining or open system behavior. A total of 16 samples of lower Vindhyan shales and 15 samples of associated sandstone units occurring at different stratigraphic levels were selected for geochemical analysis. Two samples of late Archaean