Groundwater helium: An indicator of active tectonic regions along Narmada River, central India

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ABSTRACT

Results of a survey of dissolved helium, fluoride and electrical conductivity in groundwater from across the main stem of the Narmada River, between Bharuch in the west and Amarkantak in the east, are reported. This survey was undertaken to identify active tectonic regions, based on locations of high helium concentrations, interpreted as indicative of upward migration of deep fluids. Existence of deep fluids in this region has been hypothesised earlier based on various geophysical studies in the Narmada Rift Basin—a major tectonic feature in central India. Samples with high helium concentration are clustered in two broad regions with known intersecting faults, indicating the possibility of plumes with high helium concentration being injected into shallower groundwater in these regions, facilitated by these faults and fractures. Locations of groundwater samples having excess fluoride remarkably correspond to these two clusters of excess helium. This suggests a possible commonality between the causal factor of excess helium and higher fluoride in groundwater, which needs to be further investigated.

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1. Introduction

The Narmada Rift Basin (NRB) is a part of Central Indian Tectonic Zone (CITZ) which is over 1000 km long ENE–WSW seismically active belt. The CITZ divides the Indian Peninsula into northern (Archean Bundelkhand Craton) and southern (Dharwad, Bastar and Singhbum Cratons) crustal blocks (Naganjaneyulu and Santosh, 2010). The CITZ includes a system of several E–W or ENE–WSW trending major deep seated faults and two rifts, namely, Narmada rift (Fig. 1) and Tapti rift to its south, along with several orthogonal faults. The CITZ is one of the several Precambrian continental–continental collision zones in Peninsular India and has witnessed several major tectono-thermal events since its formation, including voluminous flood basalts and magmas associated with the late Cretaceous Deccan volcanism (Radhakrishna and Naqvi, 1986; Jain et al., 1995; Acharyya, 2003; Dessai et al., 2010; Naganjaneyulu and Santosh, 2010, 2011). In the Indian geology, the Narmada–Son Lineament (NSL) Zone within the CITZ is an important tectonic feature after Himalayas.

Geophysical (magnetotelluric, seismic, gravity and heat flow) investigations in CITZ have revealed several conspicuous features such as the following: (i) anomalously high conductivity in the deep crust; (ii) high-density bodies in the southern part and low-density bodies in the northern part of the CITZ; (iii) several Moho penetrating faults; (iv) both anomalously high and low seismic velocity beneath different regions in the deep crust in this region; and (v) high heat flow (Kaila et al., 1985, 1987; Ravisankar, 1988; Kaila et al., 1989, 1990; Ravisankar et al., 1991; Verma and Banerjee, 1992; Ravisankar et al., 1996; Rao et al., 2004; Patro et al., 2005; Naganjaneyulu, 2010; Naganjaneyulu and Santosh, 2010; Naganjaneyulu et al., 2010; Naganjaneyulu and Santosh, 2011). It has been shown that the observed high conductivity in the CITZ could be related to the presence of underplated magmas and fluids at depths, particularly around the major faults in the region. It is also argued that density and seismic velocity could also be correspondingly related to presence of melt and fluids because these are also similarly governed by the prevalent pressure–temperature conditions, tectonic environment, pore geometry, and resistivity (Naganjaneyulu and Santosh, 2011). Several provinces within CITZ are reported to have high heat-flow (from 100 to >180 mW/m²) and anomalously high (50–80 °C/km) thermal gradient (Ravisankar, 1988; Ravisankar et al., 1991, 1996).

Some of the faults and fractures facilitate percolation of groundwater to deeper layers which, in a high heat-flow regime, can establish a convective circulation with thermal waters of meteoric origin emerging as springs (Curewitz and Karson, 1997; Gupta and Deshpande, 2003; Agarwal et al., 2006). Around 400 geothermal springs have been mapped in India by GSI (1991) of which Tattapani group associated with Son–Narmada–Tapti lineament system is reported to have emergence of 23 thermal springs. Based on chemical and isotopic signatures of some of these thermal springs it is concluded by Minissale et al. (2000) that water emerging from these thermal springs is meteoric in origin with low equilibration temperatures (90–150 °C). Additionally, the NRB with fractured basement of Proterozoic Archean age, overlain unconformably by the younger sandstones, is suggested to be one of the favourable