Geological and hydrogeochemical studies on the non-volcanic hot springs and associated groundwater system around Atri and Tarbalo, Eastern Ghats Province, India

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Abstract

The origin of nonvolcanic hot springs within Neoproterozoic granulites of the tectonically stable Eastern Ghats Province (EGP) in the Indian shield has been investigated through geological and hydrological studies. Geological studies show that the area is multiply deformed, with the D_1 and D_2 shortening deformations accompanying granulite facies metamorphism that peaked at temperatures >900°C, at ~955 ±28 Ma. Following hydrous fluid infiltration at ~808 ±10 Ma, the entire northern EGP was affected by an extensional deformation event D_3 that reoriented all earlier fabrics into an E-W trending, northerly dipping orientation. Deformation microstructures and results of geothermobarometry indicate that D_3 operated at ~600°C at 711 ±18 Ma, and was probably associated with break-up of the supercontinent Rodinia. Dextral strike-slip deformation (D_4) along the Mahanadi Shear Zone, associated with WNW-ESE trending, subvertical pseudotachylite-bearing faults and fractures, operated under greenschist facies conditions and did not reset monazite isotope systematics in the region. Hydrological studies reveal that tube and dug wells in the area yield both thermal (~60°C) and non-thermal (~28°C) water. Thermal water is richer in Na^+, K^+ and Cl^-, with lower bicarbonate content. Stable isotope analyses (δ^2H and $\delta^{18}O$) of both thermal and non-thermal waters plot on the Global Meteoric Water Line; tritium and ^{14}C ages indicate that non-thermal water is relatively modern, while thermal waters are older. Water-rock interaction modelling indicates that thermal waters are chemically more evolved than non-thermal waters. The results of the hydrological studies are consistent with derivation of both waters from distinct reservoirs. Intense water-rock interaction also causes dissolution of fluoride-bearing minerals, resulting in excessive groundwater fluoride contamination in parts of the area. Very low frequency electromagnetic studies show that water circulates through D_4 fracture systems, but also exists in isolated pockets within the crystalline country rock. Elevated thorium concentrations within monazite and thorite lead to high heat production in some basement rocks. Meteoric waters entrapped for longer times near these heat-producing element-rich pockets undergo radiogenic heating, and are shielded from non-thermal groundwater circulating within the fracture system. The high thorium concentration in the crust resulting from Neoproterozoic geological events has, thus, elevated the present-day equilibrium geotherm in the EGP, forming heat sources for shallow-level, non-volcanic hot springs within the tectonically inactive terrane.

Keywords: *Non-volcanic hot springs; Eastern Ghats Province; mid-crustal extension; monazite chemical ages; Rodinia breakup; hydrogeochemistry; tritium dating; water-rock interaction; fluoride contamination; elevated equilibrium geotherm*