Regional Heat Flow: An Aid to Geothermal Exploration in Chattisgarh, India

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Abstract. A well known anomalous mineralization of Uranium up to 4400 ppm in the Abujhman Basin in Central India and the data on regional heat flow studies depicting a heat flow pattern ranging from 60 to 105 mW/m^2 has given a lead to locate a potential geothermal field in Proterozoic crystalline basement rocks of the Chattisgarh Basin, North of Abujhman Basin. The Proterozoic rocks comprise coarse granite/gneiss which is found in juxtaposition with Lower Gondwana sandstone by a ENE-WSW trending fault. On the basis of the above measurements and the geology of the region, five shallow wells have been drilled in the Tattapani area in Chattisgarh to exploit geothermal resources for various purposes including the generation of electricity.

Introduction

Geothermal reservoirs located in the earth's interior constitute an important energy source currently being sought after for meeting energy demands. Various mega features associated with geothermal energy resources that can be observed near the surface of the earth are spreading ridges, transform faults, subduction zones etc., which form a vast network that divides our plant into distinct lithospheric regions. The plate boundaries comprising to fractured zones, seismicity, large number of volcanoes and radio elemental distribution of the basement rocks are some of the typical source regions for the geothermal energy. Surface manifestations such as geysers, hot springs etc. can be seen near these features which can be investigated for delineating geothermal sources.

In a geothermal system, water transports the heat through convection from deep crustal levels i.e., from a heat source at depth to the heat sink, usually the surface of the earth. The system consists mainly of the three elements – heat source, a reservoir and a fluid. The heat source could be magnetic intrusion or radioactive decay. The reservoir is permeable rock with high temperature from which the circulating fluids absorb the heat. The fluid in many geothermal systems is water. Among these three elements, the prime requisite is a heat source at deeper levels. The other two elements under favorable conditions can be created.

Though, geophysical investigation of such structures relevant to geothermal sources is important but for our present studies, the investigated Uranium mineralization has played a significant role in the identification and delineation of Tattapani geothermal areas in Chattisgarh Basin.

The Study Area

The study area is located near the border of the Chattisgarh and Bihar states and falls close to the regional Balarampur fault zone and spread over an area of about 400 m x 600 m and perhaps, the ENE-WSW trending Narmada-Son Lineament (NSL) zone is one of the most significant lineament in the Indian shield. Tattapani fault is a major fault in the region forming a boundary between Archean formation towards the south and the Gondwana formation towards the north (Fig. 1) in the western part of the study area.

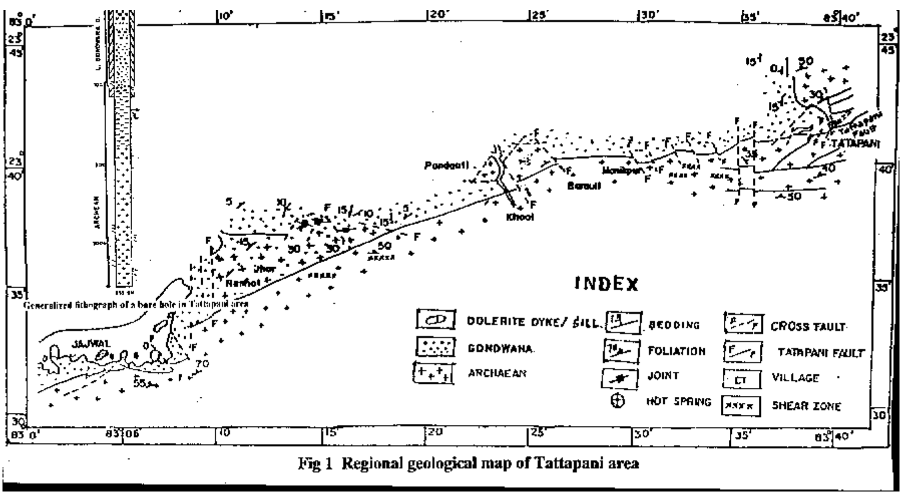

Fig. 1. Regional geological map of Tattapani area

Geology of the Area

Detailed geological studies have been carried out by Geological Survey of India (G.S.I.) (Thussu et al. 1987). The surface geology presents different rock types, which include quartzite, schist, gneisses and phyllite of Proterozoic Archean age.

These are generally folded and cross-folded. The Archean rocks show foliation in the direction N 70^0E –S 70^0 W and N 80^0W -S80^0E with dips of 75^0 to 85^0 towards north. Granites, granodionites, pegmatites, amphibolites and quartz veins represent the intrusive rocks of the region. The phyllites are mainly carbonaceous and graphites are associated with Pyrite mineralization. The granites and granodiorites occur as plutons while the amphibolites occur as dykes and sills and the pegmatite as intrusive. Quartz veins are associated with magnetic mineralization. Table 1 presents the stratigraphic sequence of the formations.

Gondwana sequence of formations in this area, lying unconformable over the Proterozoics, consists of conglomerates, sand stones, shale and minor coal beds. These show low dips (15^0) with a general strike direction of N 80^0 W – S 80^0 E.

Fig. 1 above presents the geological and structural map together with the generalized lithograph of a bore hole in the Tattapani area (Thussu et al. 1987). In general, as can be seen from the figure, the major geological formations are separated by ENE-WSW regional faults, which in turn are affected by a number of cross faults striking in NNW-SSE and NE-SW direction. Several faults are also observed towards south of hot spring near Balarampur and Lurgutta and are located within the Proterozoic sequence in the area (Ravishanker et al. 1987).

Table 1. Stratigraphic sequence of Tattapani area, Chattisgarh Basin (Thussu et al. 1987)

Age	Formation	Rock Type
Recent		soil/river alluvium
Quaternary		hydrothermal altered clay
---------- Unconformity ----------		
Lower Tertiary To Upper Cretaceous	Deccan Trap	dolerite sills and dykes intruding Gondwana sediments (near Jajawal)
Mesozoic to Lower Permian	Gondwana Post Barakar Super Group (Mahadeva)	brown to reddish brown possibly sandstone showing current bedding and ripple marks and subordinate conglomerate, no coal seams
Permian	Barakar Formation	Sandstone and shale with grit bands, gray shale with plant fossils and coal seams.
	Talchir Formation	green splintery shale sandstone with minor grit bands and conglomerates
---------- Unconformity ----------		
Proterozoic		phyllite, graphitic at some places, quartzite, grey gneiss, biotite schist, actinolite, remolite schist kyanite-sillimanite schist, garnet gneiss, hornblende gneiss, granulite, amphibolite, augengneiss, diorite, granulite and pink gneiss.

Uranium Mineralization

The discovery of uranium occurrence at Bogan, lead to investigations in detail and a number of uranium/thorium anomalies were located all along the northeastern margin in the Gundul sandstones spread between Bogan and Gundul in south of Tattapani area. Table 2 shows radiometric assay results of upper and lower horizons of all the escarpments indicating average U/Th ratio from 3.5 to 21.57 in the lower zone and from 0.17 to 0.23 in the upper zone (Chaturvedi et al. 1998).

Table 2. Radiometric Assay Results of Gundul Sandstone* (NE-Abujhmar)

Escarpment	Horizon		%eU3O8	%U3O8	%ThO2	U/Th
	Upper	n=4	0.046	0.016	0.090	0.172
Bogan						
	Lower	n=11	0.050	0.054	0.003	17.386
	Upper	n=5	0.049	0.023	0.084	0.274
Maram						
	Lower	n=11	0.066	0.067	0.003	21.572
	Upper	n=3	0.059	0.024	0.107	0.217
Kachor						
	Lower	n=3	0.006	0.007	0.002	3.500
	Upper	n=4	0.027	0.012	0.051	0.227
Gundul						
	Lower	n=11	0.010	0.016	0.003	5.473
	Upper	n=3	0.021	0.007	0.040	0.169
Mangdon						
	Lower	n=5	0.010	0.013	0.002	6.278

*After Chaturvedi et al. 1998

Discussions

Provenance for the Abujhmar sediments particularly of northeastern part, is Bengpal Granite-Gneisses, Bailadila Iron Formation and Nandgaon rhyolites and sandstones. All these basement rocks have anomalous concentration or uranium (2 to 120 ppm) and thorium (4 to 880 ppm) which might have been mobilized and concentrated in the sediments of Abujhmar Basin (Cahaturvedi 1998).

Major lineaments and related faults have been the disposition of rocks in and around Abujhmar Basin. From the study of basin structures, it appears that some of the basement lineaments/faults, reactivated after the deposition of sediments and the emplacement of basic lava (Deccan Trap) took place along some of these major faults/lineaments and covered major parts of Abujhmar Chattisgarh basin.

Several episodes of basaltic emplacements are known. The extensive basaltic magmatism must have generated geothermal gradient within the basin and possibly remobilized uranium from within the sediments to suitable locales in Chattisgarh Basin. With analyses for U and Th in representative rocks, it has been possible to look at a plot of heat flow versus heat generation for nearly a dozen places, spread around the Tattapani area. A good number of thermal conductivity measurements have been affected by Verma et al. (1970) and Panda (1985) published the heat flow map of India in 1985, part of which has been used for the present studies to make plot (Fig 2).

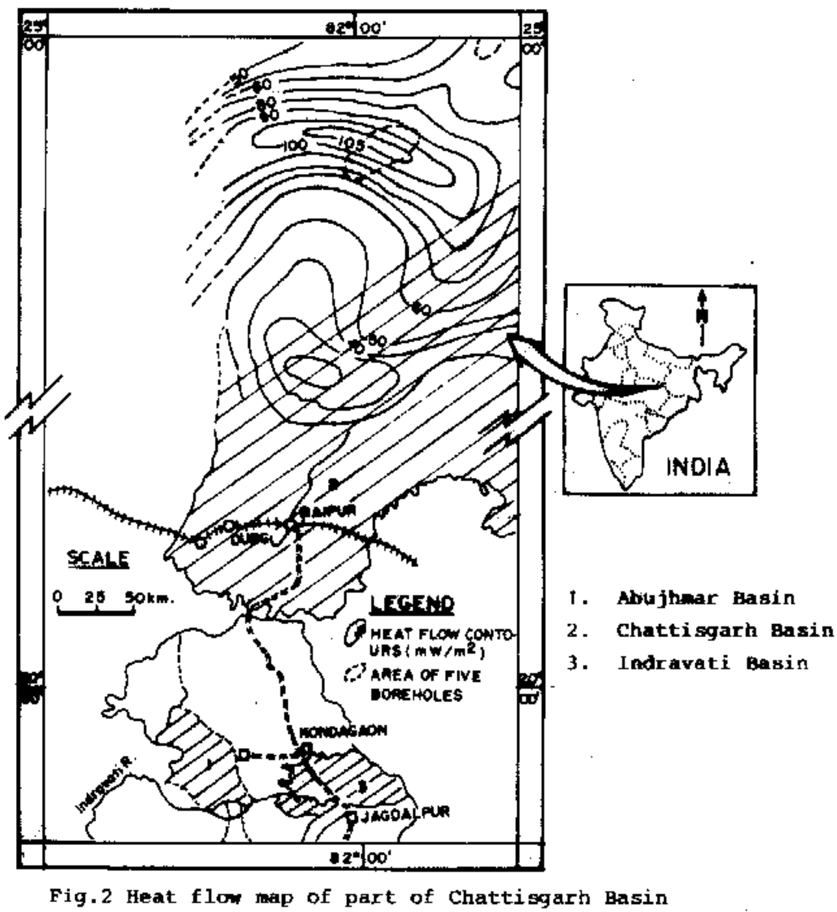

Fig. 2. Heat flow map of part of Chattiagarh Basin

Conclusion

A statistically significant correlation between heat flow and uranium concentrations was found, implying that variations in surface heat flow are primarily to be ascribed to variations in the heat generated by radioactivity in the crustal column. Thus it is envisaged that the uranium derived from granite-gneiss probably migrated upward towards north - east along certain fractures and yielded an heat flow source for hot springs in and around Chattisgarh Basin which from Abujhmar basin, of the order of around 100 mW/m^2 (Fig. 2). This formed the basis of geothermal exploration in Tattapani area, Chattisgarh basin in 1988 and as many 5 shallow bore holes have been drilled down to a depth of 350m in an area of 2 km^2 which yielded a cumulative geofluid at 60 L/min with a surface temperature of 105^0C. This hot geo fluid at this temperature is capable of generating 300 Kwe electricity through ORC based binary power plant besides various direct heat applications.

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