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Geochemistry of Rajgir-Munger Metasedimentary Springs of Bihar, India

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ABSTRACT

Present investigation is based on the chemical composition of springs located along the Rajgir-Munger metasedimentary belt of Munger, Nalanda and Gaya district of Bihar. Thermal springs of Rajgir area are issuing through the quartzites hills of 358-420 Ma age. The pH of the thermal springs of Rajgir area are slightly acidic in nature (pH = 5.3 to 5.8 at 25 °C) with surface temperature range between 35 to 50 °C, whereas the cold springs of Munger are near neutral in nature. Piper diagram suggests that the water type of thermal and cold springs are Ca-HCO_3 type, due to their circulation through sedimentary formations. Na/K, Na/Ca and Cl/HCO_3 ratio suggests that the both thermal springs at Tapoban in Rajgir are fed by the same reservoir. Estimated reservoir temperature based on silica geothermometer in the range of 61 to 95 °C, which indicates a low enthalpy geothermal system. Rajgir thermal springs are characterized by the negative gravity anomaly (-50 mGal) and it shows that the circulation of the thermal springs are through the fault surface. Since this area is characterized as low enthalpy geothermal field, therefor it can be used for other geothermal uses like aquaculture, agricultural drying, bathing etc.

1. INTRODUCTION

Munger-Rajgir metasedimentary belt is situated in parts of Munger, Nalanda and Gaya districts of Bihar. There are several thermal springs occurring on the mega-fold structure of Rajgir belt with temperature range 35 to 50 °C. The geology of the area includes ferruginous phyllites, quartzite and soft phyllites (Fig. 1). K-Ar dating shows that these belts are 358-420 Ma old (Sarkar et al., 1964). Thermal gradient recorded from the bore wells in this region 32-39 °C/km. The Rajgie geothermal site is located NW of Tantloi and Bakreshwar (Fig. 1). The Tantloi-Bakreshwar geothermal province is discussed elsewhere in this proceeding.

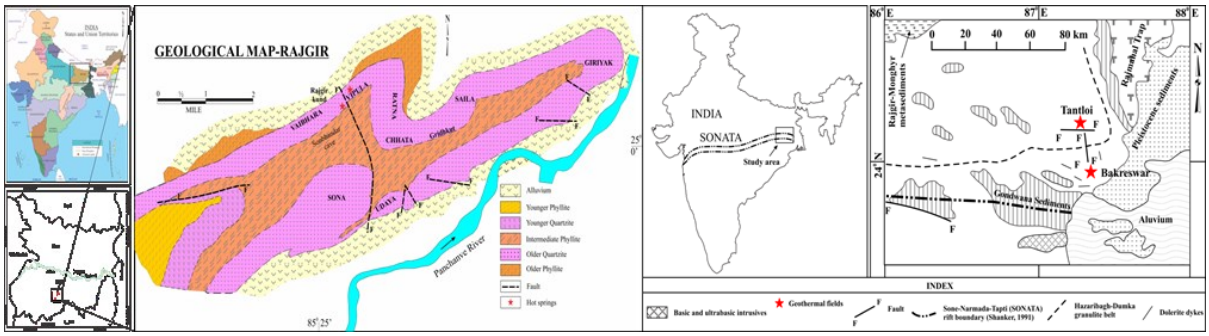

Figure 1: Geological and sample location map of Rajgir and the location of Bakreshwar-Tantloi geothermal site (modified after Srivastava and Sen Gupta, 1967 and Singh et al., 2014).

2. GEOLOGY

The most prominent geological feature in the area is the NE-SW trending Rajgir fold belt comprising alternate quartzite and phyllite. These folds comprise two distinct quartzite bands inter-bedded with phyllites (Srivastava and Sen Gupta, 1967) and bounded by upper and lower phyllite units (Thingarajan and Banerjee, 1967; Sarkar and Mallick, 1979) (Fig. 1). Rajgir hills are characterized by metasedimentary units while granitic and basic rocks can be found in the southern part of the hills (Fig. 1). The quartzite unit displays very well-preserved primary sedimentary structures such as stratification, cross-bedding, ripple marks, mud cracks and convolute-bedding. The phyllite unit is gradational as well as in sharp contact with quartzite and essentially thinly laminated with ferruginous material. The alternate quartzite and phyllite units of the Rajgir fold belt have preserved clear evidences of two phases of deformation (Srivastava and Sen Gupta, 1967), represented by sub-vertical to steep, south-easterly dipping axial-planar cleavage trending NE-SW (Sarkar and Mallick, 1979, 1982). This interference of the two fold systems has produced a structural basin at Rajgir. Tuff, basalt and rhyolites were also reported from this area (Ahmad and Wanjari, 2009). The thermal springs are located northern part of the fold axis and are controlled by N-S trending fault.

3. HYDROCHEMISTRY

Representative water samples were collected from Rajgir and Munger area. The samples include thermal springs, bore wells, and cold springs. Major ion concentration on the samples were carried out (Table 1) following the procedure recommended by APHA (1977).

Table 1. Physicochemical properties of the water samples from Rajgir (in mg/L)

Sr. No.*	pH	(°C)	pCO_2	Na^+	K^+	Ca^{++}	Mg^{++}	Cl^-	HCO_3^-	SO_4^{--}	SiO_2
1	5.4	35	-0.68	10.2	1.5	7.9	2.5	4.6	50	10.9	18.9
2	5.4	41	-0.78	10.2	1.6	5.4	2.1	3.1	40	12.9	19.5
3	5.3	41	-0.68	10.2	1.7	6.3	1.9	3.1	40	10.8	19.3
4	5.6	42	-0.89	10.3	1.6	8.1	2.1	3.2	50	12.6	19.5
5	5.8	50	-1.15	14.1	3.2	7.0	1.6	5.2	50	14.3	41.6
6	5.8	48	-1.09	14.2	3.3	7.1	1.8	3.5	50	14.2	40.9
7	6.4	27	-1.61	13.3	1.2	12.1	1.3	3.8	60	14.5	20.8
8	6.5	25	-1.23	32.7	22.3	36.2	14.5	44.2	190	15.2	42.6
9	7.1	27	-1.99	20.4	1.7	34.7	9.4	32.5	130	26.0	36.0
10	7.8	26	-2.51	55.9	6.0	38.9	11.9	63.4	200	18.1	3.4
11	8.4	25	-3.13	46.6	6.2	43.0	11.0	54.8	200	19.3	14.8
12	7.8	24	-2.58	56.3	5.1	33.8	11.6	62.1	170	28.7	19.1

* 1 to 6: thermal springs at Rajgir; 7: cold spring at Rajgir; 8: groundwater sample at Rajgir; 9 to 12 cold springs at Munger.

Thermal springs of Rajgir area are slightly acidic (pH = 5.3 to 5.8), whereas cold springs of Munger area are near neutral to slightly alkaline (pH = 7.1 to 8.4) in nature. Analyzed water samples from the study area (Table 1) were plotted in Piper diagram (Piper, 1944) (Fig. 2). All of the water samples from the study area fall in the Ca-HCO_3 field. It may be possible that the thermal waters interact with tuff laminations in the formation resulting in chemical exchange between Na-Ca. This chemistry suggests that the circulation of thermal springs is through the sedimentary formation. Similarly ratio of Na/K, Na/Ca and Cl/HCO_3 of two thermal springs (sample 5 and 6) suggests that they are fed by the same reservoir (Fournier and Truesdell, 1970).

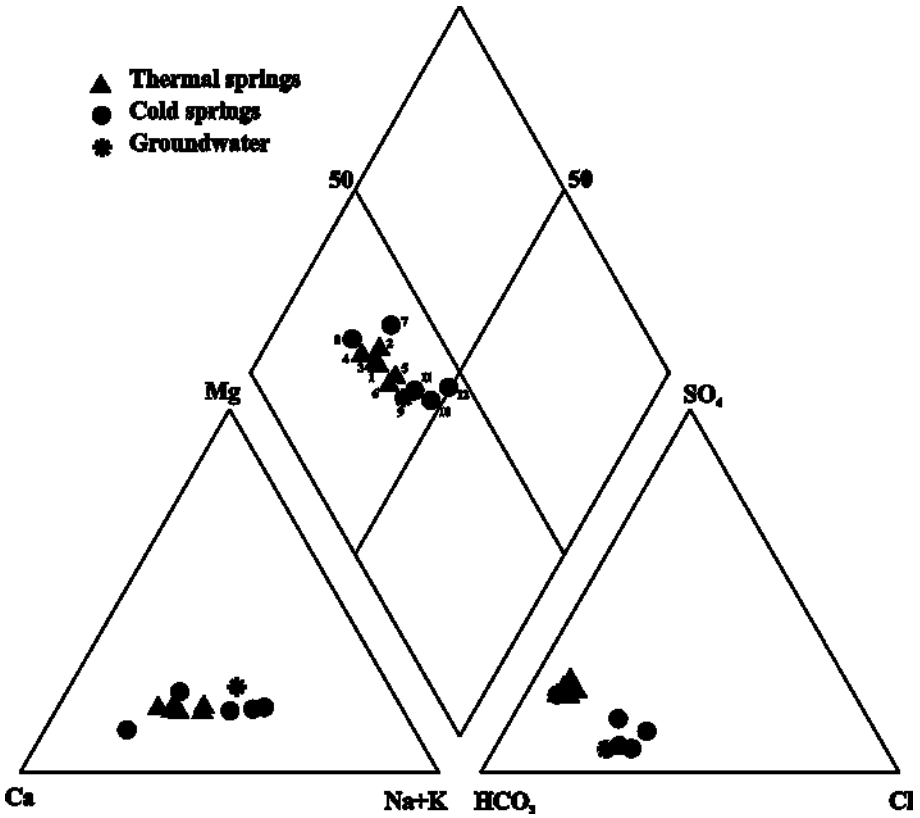

Figure 2: Piper (1944) trilinear diagram for chemical classification of different water type from study area.

4. GEOTHERMOMETERY

In 1973, Fournier proposed silica geothermometry for the estimation of reservoir temperature. On the basis of silica geothermometry estimated reservoir temperature ranges between 61° to 95° C. However if we consider Na-K-Ca geothermometery, it provides the reservoir temperature in the range of 160° to 191 °C. But in some cases Na-K-Ca geothremometry gave higher

reservoir temperature therefore Fournier and Potter II (1979) applied Mg correction for the better estimation of reservoir temperature (Table 2).

Table 2: Estimation of reservoir temperature based on different chemical geothermometry

Sr. No.	Silica		Na-K-Ca (Fournier and Truesdell, 1973)	Na-K-Ca - Mg corrected (Fournier and Potter II, 1979)
	No Steam Loss	Maximum Steam loss		
1	61.2	67.0	160.0	81.3
2	62.5	68.1	166.4	74.8
3	62.1	67.7	168.2	89.3
4	62.5	68.1	162.7	93.9
5	93.4	95.3	189.7	120.4
6	92.7	94.7	191.0	114.7

5. GRAVITY ANOMALY

Gravity anomy of Rajgir area (Fig. 3) is characterized by negative anomaly (-50mGal), which suggests presence of granites, like the Bakreshwar-Tantloi area. The granites could be the source providing heat to the circulating fluids.

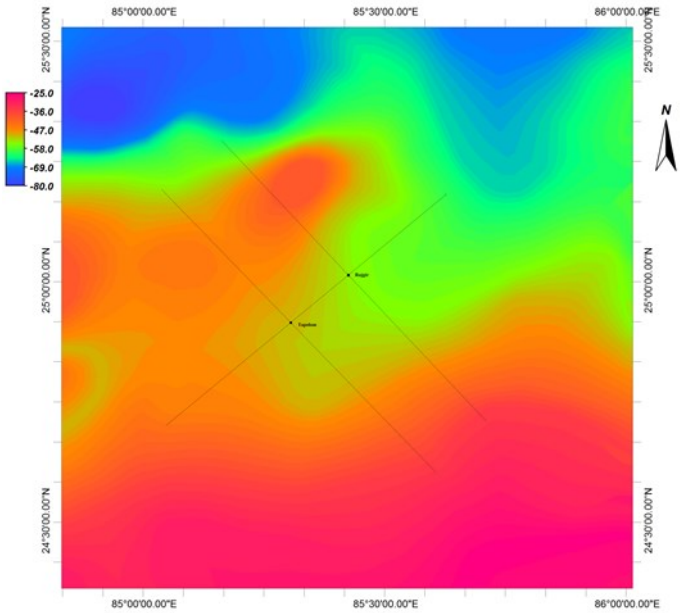

Figure 3: Bouguer gravity anomaly map with terrain correction of Rajgir geothermal field.

5. CONCLUSIONS

The Rajgir thermal springs appears to be local groundwater, heated by ascending thermal waters. The geothermal system is not visible around this region. Perhaps this system may be related to the major thermal belt located SE of Rajgir where high temperature Bakreshwar-Tantloi geothermal system is located. These springs can be utilized for direct application like space heating, since the region experiences cooler temperatures during winters (1 to 4 °C). Rajgir also attracts several tourists, since the town is an important Buddhist shrine. These thermal spring sites can become attractive spas.

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