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Geological, geochemical and geoelectric studies for hydrological characterization and assessment of Bakreswar thermal springs in hard rock areas of Birbhum district, West Bengal, India

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Summary

A cluster of hot springs (35^{0}C -71^{0}C) in Bakreswar geothermal area which belongs to the Chotanagpur gneissic complex in the eastern part of Peninsular India is characterized by varying temperature and similar chemical composition. Vertical Electrical Sounding (VES) investigation in and around Bakreswar reveal the presence of two to four prominent lithologic layers under prevailing hydrodynamic conditions. The bottom most layer is the compact basement crystalline having mostly high resisitivity. Groundwater is mainly confined in intermediate weathered and fractured zones forming an unconfined aquifer. Lithology and groundwater conditions, as inferred from VES, as well as hydrological studies, are in agreement with the nearby borehole logs. 1 D interpretation of VES results reveals few promising groundwater potential zones in the eastern part of the region. Wenner resisitivity profiling, coupled with VES and geological studies, indicate the presence of a nearly N–S striking buried fault providing passage for hot water to emerge in the form of springs. Combined geological,geophysical,hydrological and geochemical studies on Bakreswar thermal springs indicate that the thermal spring waters are mixture of hot ascending water and shallow nonthermal ground water of the area .A quantitative estimation for the degree of mixing has been made from "Silica –Enthalpy Mixing Model" as proposed by Fournier et al(1974).From silica–enthalpy relationship,Degree of mixing of deep seated thermal water component has been estimated to be around 27% with an inferred temperature of about 188 ^{0} C. Water from the shallow aquifer is chemically of Na-HCO$_3$ type with near neutral pH and little F$^-$ in marked contrast to thermal spring water which is Na mixed anion type with alkaline pH and characteristically enriched in F$^-$. Convective geoheat discharge from Agnikund has been estimated to be about 1158 Kw-hr which is equivalent to heat liberated by burning 0.14 tonne of coal.

Keywords: *Thermal spring, Chotanagpur gneissic complex,Vertical Electrical sounding, Residence time,Aqifer*

Introduction

Bakreawar thermal spring system (Lat.23^{0}52 ^{I} N ; Long. 87^{0}25 ^{I} E) in Birbhum District ,West Bengal belong to a belt of thermal springs(35^{0}C to 71^{0}C) within a Precambrian craton in the Northeastern part of Peninsular India.The thermal springs belt are located on or close to major fault/shear zones within Precambrian crystallines.

The springs mostly issue out of fractures in a reactivated composite mass comprising predominantly granitic rocks (Precambrian) with an E-W belt of sparsely occurring sedimentary outliers of Gondwana formation(Lower Permian to Middle Jurassic).

Several workers have investigated Bakreswar group of thermal springs from time to time ,dealing with their geological mode of occurrence,chemical composition and geochemistry(Ghosh,1948;Chowdhury et al, 1964; Mukherjee, 1967; Majumdar et al 2009), genesis (Chaterjee and Guha,1968;Deb and Mukherjee,1969), natural gases with special reference to helium emanation (Chaterjee,1972),isotopic composition (Ghosh and Chatterjee 1978,Majumdar et al., 2005). Geophysical

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studies (Arora, 1986,Nagar et al.,1996, Majumdar et al.,2000) are also carried out to know about the subsurface grology related to hot spring activity. The present integrated geological ,geophysical and geochemical studies are aimed (1)to understand the relationship of shallow groundwater and thermal springs water and degree of mixing (2) to identify the various litho-units , examine the nature of aquifer system and hydrology of the spring (3) to examine the presence of any fault or fracture zone (4) to know chemically the type of thermal and nonthermal water (5) to calculate heat discharge from Bakreswar thermal spring.

2. Geological Setting

Bakreswar thermal springs are located in topographic low in an undulatory terrain of laterite and alluvial soil with sporadic exposures of granitic rocks,amphibolite,pegmatite and metadolerite as shown in Fig.1.The basement comprises granitic rocks with incipient gneissose structure.The other rock types in this area are metabasics and pegmatites which have been cut across the foliation plane in gneiss.Strike of foliation is usually NE-SW with low to moderate dip in southeasternly directions.A silicified shear zone traceable for 1.4 Km distance about 1.5 Km NNW of the springs site is a noteworthy feature.From a consideration of the trends of silicified zone,fold axis,joint planes and alignment of seven springs in the geothermal area,it is suspected that the emergence of hot water and gases is controlled by intersecting fractures trending N-S and NW-SE ,as well as NE-SW. Emergence of thermal water and gases takes place from seven distinct spots.Temperature variation in the temperature of Agnikund has also been noted.

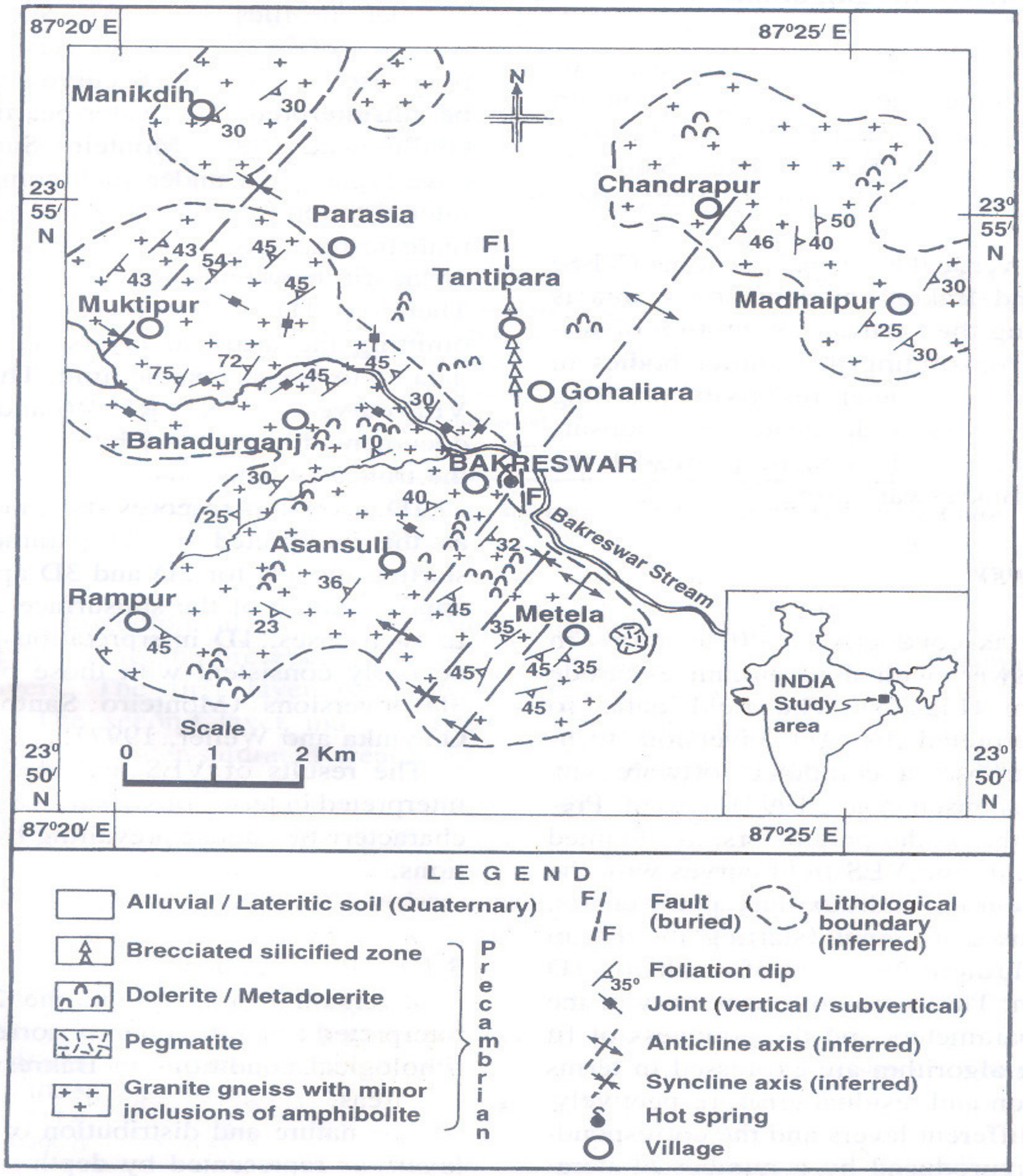

Fig. 1: Geological context of Bakreswar geothermal area (modified after Nagar et al., 1996).

3. Geoelectric studies

Geoelectric resistivity studies have wide application in hydrological and geothermal field investigation (Arora,1986;Raju and Reddy,1988; Majumndar et al.2000).Geoelectric vertical electrical sounding were conducted in 20 locations(Fig.2) in and around Bakreswar with maximum electrode spacings of 440m.The field data were interpreted by ID inversion technique.The ID inversion reserves its importance and utility,as the interpreted model parameters can serve as the starting models for 2D and 3D approaches for better approximation of the subsurface geology of the area.The inversion results of all the VES points are interpreted (Fig.3) and subsequently correlated to resolve the lithological conditions in Bakreswar and its adjoining areas.It reveals the presence of two to four prominent layers.The first layer is constituted of soil.The second layer may be compact basement or the water saturated weathered or fracture zone.The third layer is the crystalline basement.In some cases ,the water saturated fractured rocks form the third layer beneath the weathered zone;below its lie the high resistive compact basement(fourth layer having resistivity ranging from 416 Ohm.m to 9999 Ohm.m).The lithological variations as inferred from VES studies are shown in the Fence diagram (Fig.4).Here the depth of compact basement ranges from 24.7 to 69.9 m.Lithologs of four boreholes corroborate with the interpreted results of VES investigations.Bore hole lithologs reveal that groundwater occurs mostly in the fracture zones and to some extent within the overlying weathered rocks occurring at shallow depth and thus they substantiate the VES findings as regards lithology ,occurrence and distribution of weathered as well as fractured rocks,and their groundwater potentiality.Five parallel Wenner resistivity profiles P1 to P5 (Fig2) and VES sounding results indicate the presence of a nearly N-S trending buried fault with downthrown block in the east.Resistivity minima is seen over the fault zone .

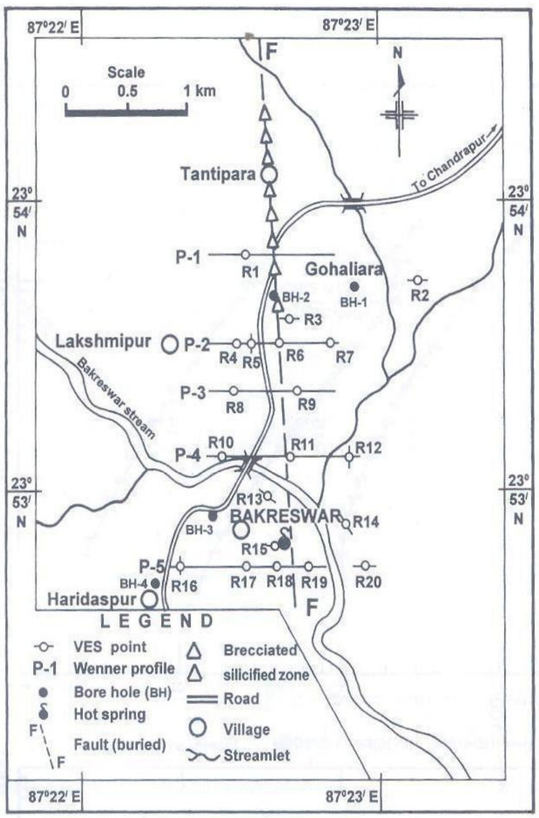

Fig.2 Locations of geoelectric resistivity investigations and bore holes: VES (Schlumberger) and profiles (Wenner).

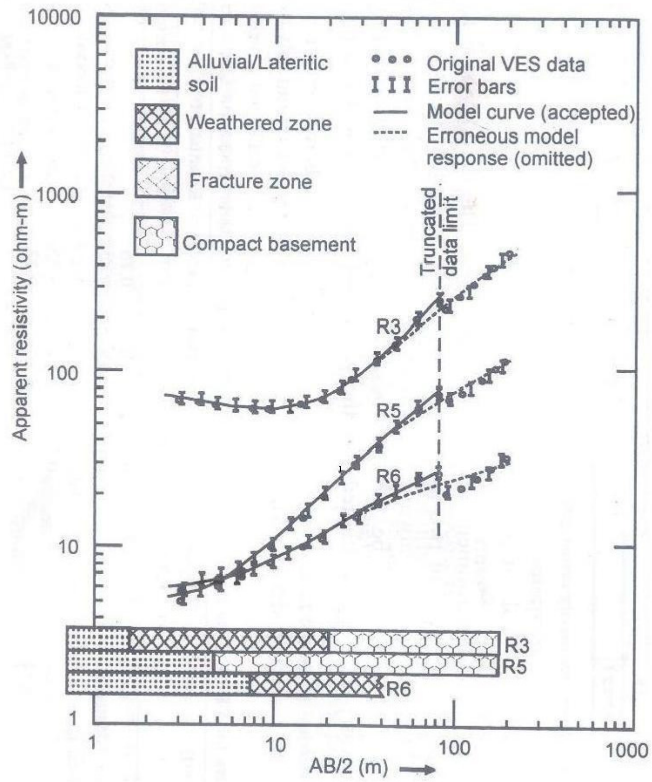

Fig.3: Documentation of behaviour of VES data and model curves with lithological interpretation for locations R3, R5 and R6, and AB / 2 = half current electrode spacing.

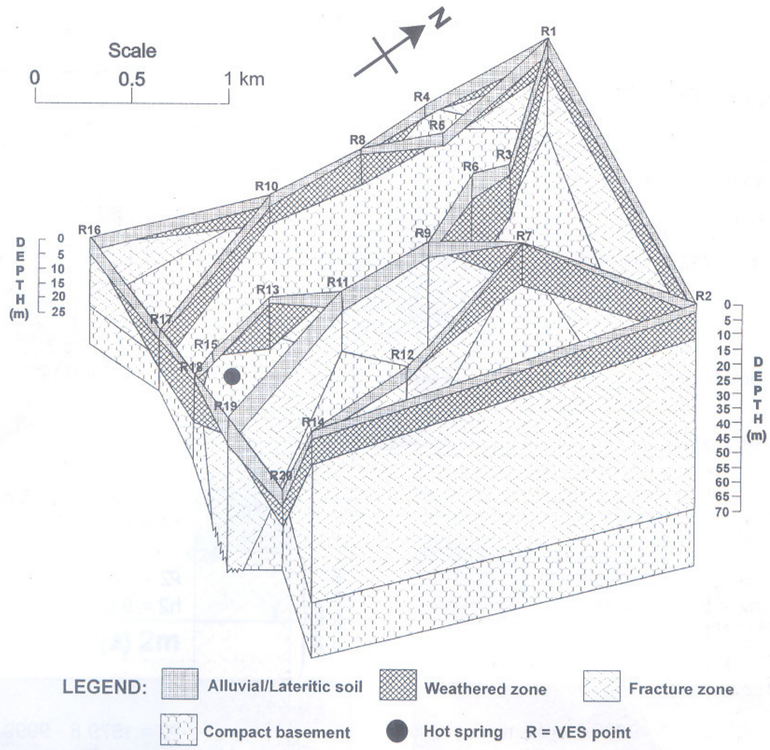

Fig.4: Fence diagram constructed from VES interpretation shows lithological characteristics in Bakreswar and its surrounding areas.

4. Geochemical studies of shallow groundwater and thermal spring water and Degree of mixing.

Chemically, shallow groundwater of the area is mostly of $Na\text{-}HCO_3$ type with near neutral pH (6.8 -7.4 at 25 ^{0} C) and with little F^- while thermal springs water is of a mixed anion type with alkaline pH (9.03 at 25 ^{0} C) and enriched in F^- (~ 13 ppm).Water samples of thermal springs have higher SiO_2.,Na^+ , Cl^- and lower Ca^{+2} , Mg^{+2} and HCO_3^{-2} contents compared to those of the shallow groundwater.

The above results indicate that deep seated thermal water is relatively enriched in silica ,Na^+ and Cl^- (both the ions being prevalent in deep seated water).A quantitative estimation for the degree of mixing has been made from "Silica –Enthalpy Mixing Model" as proposed by Fournier et al.(1974).The method of calculation uses a plot of dissolved silica versus enthalpy of liquid water as silica solubility is temperature dependent and is shown in Fournier et al(1974).From the temperature ,enthalpy and silica solubilities values of two springs Agnikund and Suryakund,the degree of mixing of deepseated thermal water with that of nonthermal water is about 27% and 22% repectively.

5. Convective heat discharge from Bakreswar thermal spring

Geothermal energy is a nonconventional energy source which is being increasingly utilized not only for power generation but also for various heat intensive processes in agricultural and industrial sectors in many countries of the world.In this context ,an estimate of geoheat from Agnikund has been made in the following way:

Total discharge =21600 lit/hr
Temperature of the spring =71^0C ~71Kcal/kg
Mean ambient temperature=25^0C~ 25Kcal/kg

Temperature difference=71^0C-25 ^{0} C=46 ^{0} C
Total Heat available =21600 x 46/860 = 1158 Kw-hr

6. Conclusion

Bakreswar thermal springs issue out of alluvium which is successively underlain by weathered /fractured rocks and crystalline basement as revealed from geological and geophysical studies.VES findings unearth few promosing groundwater bearing zones of appreciably high thickness at northeastern part(R2) and southern part (R14) of the region..Groundwater is mainly confined in the intermediate weathered and fracture zones (fracture basement)forming an unconfined aquifer system.Springs are fracture controlled and located in the disturbed zone of fault as interpreted from resistivity profiling.Chemically ,shallow groundwater and thermal spring water are of Na-HCO_3 and Na mixed anion type respectively,the latter being characteristically enriched in SiO_2 ,Cl^- and F^- and depleted in Ca^{+2} and Mg^{+2} compared to those in the former.Using silica enthalpy relationship model of Fournier (1974),deep seated thermal water component in Agnikund spring has been estimated to be about 27% while in Suryakund it is about 22%.Convective geoheat discharge from Agnikund has been estimated to be about 1158 Kw-hr which is equivalent to heat liberated by burning of 0.14 tonne of coal.

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