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Geochemical Characters of Hot Springs of West Coast, Maharashtra State, India

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ABSTRACT

West Coast of India hosts a string of hot sprigs along a narrow stretch nearly 300 km long parallel to the coast. Thermal water composition of these hot springs indicate that chloride content varies from 78 to 4800 ppm, sulphate from 85 to 225 ppm, sodium from 76 to 410 ppm, silica upto122 ppm and low boron and fluoride. Hg varies from 20 to 110 ppb in soil. Cl- SO_4 -HCO_3 ternary diagram suggests that most of the thermal water is mixed type while the thermal water from Sativali, Geneshpuri and Unhavre (Khed) show more affinity to geothermal water. Mixing of hot water with ground water is common in these hot springs. The Na-K-Mg plot indicates that the thermal water from Unhavre (Khed) and Sativali is more mature as compared to the hot water from the other springs. The stable isotope analysis suggests that the geothermal water is mostly of meteoric origin. Geochemical characters of these hot springs are not similar to each other and suggest that these hot springs may be independent occurrences.

Though, silica geothermometer indicated reservoir temperature of 120°C in Tural and Na/K geothermometer indicated temperature of 180°C in Unhavre (Khed), the maximum temperature recorded in the borehole logging is 75.5°C at the depth of 170m, which is much less than the indicated reservoir temperature, hence, the actual reservoir temperature needs to be ascertained by deep drilling.

1. INTRODUCTION:

Numerous hot spring locations dot along the west coast of India. These hot springs are grouped under West Coast geothermal province (Padhi et al 1995). These hot springs are spread over a linear stretch of nearly 300 km and width of 20 to 30 km, trending NNW-SSE, parallel to the west coast. Koknere, Thane district is the northern most hot spring and Rajapur, Sindhudurg district is the southern most hot spring. Most of these hot springs are of low to intermediate enthalpy.

The hot springs on West Coast record temperature varying from 42°C at Rajapur, Sindhudurg district, to 71°C at Unhavre (Khed), Ratnagiri district. Sativli, Ganeshpuri, Tural, Rajawadi and Unhavre (Khed) are the main hot springs in this belt having consistent discharge and temperature (Fig.1). Gaseous activity is noticed in some of these springs viz. Unhavre (Khed), Rajawadi and Sativli. Geochemistry of hot springs at Sativli, Ganeshpuri, Tural, Rajawadi, Unhavre (Khed)

and Rajapur was studied to assess water quality, geothermal characters and utility for direct uses.

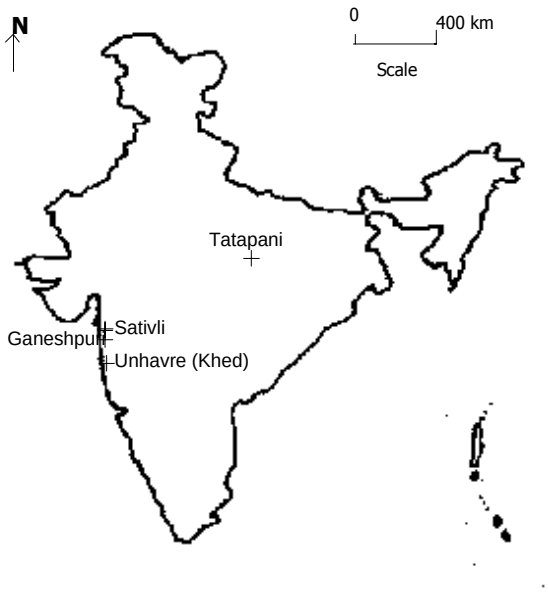

Figure 1: Location map

2. GEOLOGY

The terrain is covered by thick flows of Deccan Trap Basalt. The basalt flows are both "Aa" and "Pahoehoe" type. "Pahoehoe" type flows are mainly confined to the northern part of Thane district and "Aa" type flows are exposed in the southern part of Ratnagiri and Sindhudurg districts. Some flows are non-porphyritic while main flows are highly porphyritic and contain phenocrysts of feldspar. The individual basalt flows vary in thickness from 10 m to 120 m, and are nearly horizontal while some of the flows show dip of 6°-8°. In southern part, the dip of lava flows varies from 1:100 to 1:300.

The area is traversed by lineaments in NNE-SSW, NNW-SSE direction and few lineaments traverse in E-W direction. The NNE-SSW lineament is rather prominent. Some lineaments are marked by shears and fractures in an echelon manner. Joints in basalt flows trend in NE-SW, NW-SE directions. Columnar joints are very prominent in basalt.

3. DISCHARGE PARAMETERS:

Salient features of these hot springs are enumerated below. The hot spring locations are shown in Fig.1.

Sativli- These hot sprigs are located 100km north of Mumbai. Six hot springs are located on the banks of Vandri stream flowing near Sativli. The main hot spring (56.3°C) is located on south bank and small sprouts (59.3°C) are located on north bank of the stream. The main spring shows profuse gas emission. This hot spring is protected from human activity by constructing a concrete tank. Discharge from main tank is diverted to secondary

tank and used for bathing purpose. A borehole drilled nearby discharges hot water of ≈ 52°C.

Ganeshpuri: Ganeshpuri hot springs discharge through a concrete enclosure into tanks constructed for bathing purposes. Hot water of 52°C flows out @15 lpm. The water is mostly used for hot water bath. Ganeshpuri, besides being a temple is also a place of tourist attraction.

Akloli: The hot springs at Akloli are located on the left bank of Tansi river. Ten hot springs are aligned along a N10°W-S10°E and N55°W-S55°E, trending set of dykes. A concrete enclosure is constructed at each hot spring location. The hot water temperature of the individual springs varies from 45°C to 48°C. Sporadic gaseous activity is also reported.

Unhavre (Khed): The hot springs are located on the north bank of E-W trending creek near Unhavre village. A large area of marshy ground is observed around the hot spring locations. Two different sprouts are observed. Each spring is covered by a concrete enclosure. The main sprout has temperature of 71°C. The hot springs water flows through two tanks, which are used for bathing purpose. Heavy discharge of 860 lpm is reported (Pitale et al 1987).

Tural –Rajwadi: Tural and Rajwadi hot springs are located 10 km north of Sangmeshwar, on the banks of tributary joining Shastri river. The hot springs are confined to N20°W- S20°E fracture zone. Cement tanks are constructed around both the hot springs to protect the sprouts from human activity. Intermittent gas activity is noticed in Rajwadi hot springs. The hot springs are aligned along a N20°W-S20°E fracture zone. At Tural, hot water of 59°C - 60°C is discharged @ 250lpm. The hot springs at Rajwadi discharge water of 53°C -55 °C @ 50 lpm. Intermittent gas emission in form of bubbles is observed in hot water tanks at Rajwadi. Rajwadi hot springs are situated on a riverbank; hence, some of the sprouts are submerged under river water during monsoon.

Rajapur: The hot spring at Rajapur is located on the flood plain of Kondavi river. The spring water is diverted to RCC constructed bath facility. Hot water of 42°C temperature flows through the outlet provided in the bath facility. Pitale et al (1987) reported discharge of 60 lpm.

4. GEOCHEMISTRY:

The water from these hot springs is mostly sodium chloride type with high sulphate content. pH of thermal water varies from 7.6 in Tural to 8.6 in Akloli and Rajapur, Chloride content is rather high, ranging from 340 ppm in Tural to 875 ppm in Sativli to 1060 ppm in Unhavre (Khed); sulphate content varies from 3 ppm in Rajapur to 100 ppm in Tural, and 144 ppm in Akloli. Sodium content varies from 87 ppm in Rajapur, 244 ppm in Tural, 410 ppm in Sativli, 470 in Rajawadi to 604 in Unhavre (Khed). SiO_2 content varies from 20 ppm in Rajapur, 54 ppm in Unhavre (Khed), 84 ppm in Tural to 88 ppm in Rajwadi. Calcium varies from 152 to 186 ppm, K from 14 to 26 ppm and TDS ranges from 1723 to 2331 ppm. Fluorine content varies from 1.3 to 1.9 ppm.

The thermal water contains high chloride with appreciable amount of sulphate. The thermal springs in West Coast have high salinity as compared to ground water (Misissale et al, 2000). The West Coast thermal water has prevalent Na-Cl composition but different salinity and Na/Cl ratio is generally very similar to the seawater ratio (Misissale et al 2000). High chloride content may suggest direct access to geothermal fluids reservoir or mixing of seawater with thermal water. Silica geothermometer indicated reservoir temperature of 120±10°C for West Coast geothermal springs (Pitale et al 1987). The reservoir temperatures indicated by aqueous geothermometers are presented in table below.

Table1: Indicated reservoir temperatures

Area	Na/K	No st loss	Max St loss
Rajapur	154	106	106
Turnal Nala	151	127	124
Unhavre	145	130	127
Ganeshpuri	149	107	107
Sativli	168	106	107
Tural – 1	170	127	124
Rajwadi-2	282	64	69
Rajwadi-I	113	74	78

The Na/K geothermometer indicated reservoir temperature varies from 149°C for Ganeshpuri to 170°C at Tural. The data show that the temperatures indicated by quartz geothermometer are lesser than temperatures inferred by Na/K ratio which may be due to dilution of silica content by shallow cold water. The Na/K ratio might have been constant during ascend to surface and cooling, hence, the temperatures indicated by Na/K are more than those inferred from quartz geothermometer. The temperatures inferred by Na– K- Mg geothermometer are very high, hence, are not considered.

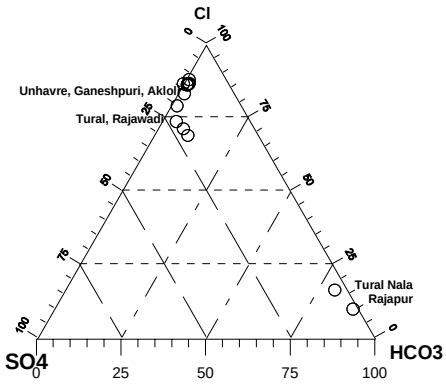

Figure.2: Cl-SO_4-HCO_3 ternary diagrams

On Cl-SO_4-HCO_3 plot (fig.2), the thermal water from Ganeshpuri, Sativli, Unhavre, Tural, Rajawadi and Akloli fall on Cl rich domain of geothermal water. Most of these waters fall on Cl-SO_4 axis, indicating appreciable sulphate content. The hot water shows dominance of SO_4 over HCO_3, suggesting that the thermal water might have been mixed with marginal steam heated water or during water rock reaction, interacted with sulphur bearing environment. Thus, the high SO_4 content may be attributed to oxidation of sulphur released in gaseous activity and water rock interaction.

The hot water from Rajapur falls in HCO_3 field; hence, may be bicarbonate water developed on margins of geothermal

system. These findings need to be verified by further intensive hydrological studies in surrounding areas.

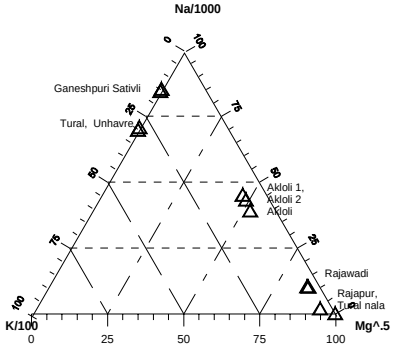

Figure 3:Na-K-Mg Ternary diagram, Tatapani.

On Na-K-Mg plot, the thermal water from Ganeshpuri, Sativli, Unhavre (Khed), Tural fall on Na- K axis away from the equilibrium curve. These waters are mostly marginal water, which may be steam heated water or condensate. The thermal waters from Rajawadi, Rajapur, Unhavre (Khed) and Tural, rivulet, fall in Mg domain and are immature waters. Thus, the waters from Rajawadi, Rajapur and Tural rivulet do not indicate contribution of geothermal component.

The Cl-SO_4-HCO_3 plot indicate that the Rajawadi thermal water is chloride rich geothermal water while on Na-K- Mg plot the Rajawadi water falls in the domain of Mg in indicating immature water. Thus, the Rajawadi water may be marginal water affected by dilution from cold water. The thermal water from Akloli plots on equilibrium curve of low temperature. Akloli thermal water indicates water rock equilibrium at low temperature corresponding to temperature of 120°C. Thus, Akloli hot springs represent geothermal water at equilibrium with surrounding during long circulation and cooling.

According to Mississale (2000), the temperature of <100°C for thermal springs in the West Coast are strongly supported by the fact that they lie along the full equilibrium line. The composition of average crust being basalt, the position of the springs reflects real condition of equilibrium. The data by Mississale (2000) suggest attainment of full equilibrium while the present data suggest that the water is not in equilibrium with surrounding or may be marginal water. The hot springs in West Coast area may be affected by mixing. This also indicates that intermediate to low temperatures may be encountered in these hot springs.

The ternary plots indicate that many data points fall on Na-K and Cl-SO_4 axis. The data points representing acid water and plotting on SO_4-Cl axis can therefore be assumed to be immature waters formed by absorption of volcanic vapours into groundwater at low temperature and shallow levels (Giggenbach, 1997). In New Zealand, Inferno Crater while containing high concentration of chloride contains high SO_4. This water likely derives its acidity from aqueous H_2S through contact with the atmosphere formed by the large surface area of Crater Lake (Simmons et al, 1995). Similarly, the SO_4 in thermal water of West Coast area, may be derived from absorption of H_2S or oxidation of pyrite, at shallow level.

Though, the SO_4 content is high in these waters, the thermal water from these hot springs is alkali chloride type. Pitale et al (1987) has reported intermediate values of chloride from the water in wells around the hot spring area, suggesting a zone of mixing of marine water with ground water at shallow level. Thus, high chloride and high sulphate content may represent origin due to different processes. As such, further investigation to prove characters of deep reservoir is warranted.

Pitale et al (1987) and Mississale et al (2000) have reported high He content from hot springs of West Coast. The large quantity of total He in the associated gas phase is a further evidence of long circulation underground. Such deep waters are meteoric originated and are locally mixed with marine waters and connate water in the West Coast (Misissale et al, 2000).

5. HYDROTHERMAL MINERALS:

Calcite, montmorillonite, laumontite and halite, are the hydrothermal minerals reported at Sativli (Pitale 1996). The occurrence of halite may be due to mixing of marine water with hot water at shallow level. Occurrence of these hydrothermal minerals also indicates that the geothermal system at Sativli operated at low temperature of around 120°C. Platy calcite, stellerite, mordenite, stilbite, chloritide and scolecite are reported as hydrothermal minerals from Unhavre (Khed) area. Association of chloritoid at the sites of calcite occurrence, also suggests higher temperature of 130-150°C, which does not match with the lower temperature recorded at present **(**Pitale, 1996). According to Schmitt(1950), alkaline hydrothermal solutions, with recent concentrations of soda, lime and silica, and of comparatively low temperature, would form well away from the interface of the meteoric water shell and the magmatic emanations. Therefore, zeolites develop near the end of the reaction series of hydrothermal solutions. This also suggests that the reservoir temperature may be low to moderate in West Coast Geothermal area.

The occurrence of platy calcite suggests that the zone of boiling of geothermal fluid was located at shallow level. Hydrothermal mineral assemblage with less hydration facies observed at greater depth suggests that the reservoir temperature may increase with depth (Pitale 1996). The present temperature reported in a boreholes at Unhavre (Khed) is 71°C. Comparison of temperatures indicated by hydrothermal mineral assemblages with thermal logs of the boreholes indicate that the zone of boiling i.e. high temperature zone, has shifted to greater depths. Thus, exploration to deeper level, > 1000m depth, is warranted to prove actual potential of geothermal systems in West Coast area. Missisale has studied isotope content of hot springs from West Coast. He has reported that in West Coast area, no high temperature oxygen shift, typical of thermal water in geothermal area, are evident in many of the areas sampled (Misissale et al, 2000), hence, the thermal water may be a product of dilution or steam heated water. Search for direct upflow zone has to be continued to locate hot water with higher enthalpy.

The monitoring of the hot springs on West Coast belt, indicate that the hot spring activity is continuous and the discharge is consistent. Geothermal resources on West Coast are mostly used for bathing. It is recommended that the feasibility of development of other direct uses viz. food industry; green housing; spa and tourist resort centers may be explored.

6. CONCLUSION

The hot springs of West Coast geothermal area form part of active geothermal systems having low to medium enthalpy.

The thermal water from West Coast hot springs is alkali chloride type with high sulphate content except in the hot spring at Rajapur, which discharges bicarbonate water. The indicated reservoir temperatures by quartz ($_{\text{max steam loss}}$) geothermometer varies from 107°C in Ganeshpuri to 127°C in Unhavre (Khed) and by Na/K method vary from 113 °C in Rajwadi to 170°C in Tural. The hydrothermal minerals indicate possibility of getting higher temperatures at greater depths. Exploration to deep reservoir > 1000 m depth is essential for assessment of deep reservoir potential and identifying the upflow zone. The present discharge may be used for direct heat uses viz. spa, greenhouse cultivation, food industry and tourist attraction.

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