

Thermal Discharges at Manikaran, Himachal Pradesh, India

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ABSTRACT

Based on major ion chemistry, the thermal discharges at Manikaran can be classified as Na- HCO₃ - Cl type. Salinity of the thermal discharges indicates mixing between saline and fresh water components. The source of the saline component (Cl) is probably ancient formation waters trapped in the geological formations, or magmatic or hydrothermal fluids. Considering the topography of the area, it is quite likely that the thermal discharges at Manikaran are not local but that of Puga Geothermal System, but there is no concluding evidence about it. Cations and silica geothermometers give reservoir temperatures between 150 and 250°C. The reservoir temperature obtained using the values of the cold water fractions from the mixing model varies from 190 to 210°C, with an average value of 202°C. Considering high temperature of the geothermal system, excellent prospects exist for the utilization of thermal discharges for power generation and direct uses, which are at present are being used for therapeutic and recreation purposes.

1. INTRODUCTION

In this work thermal discharges at Manikaran in Parbati Valley Geothermal Field, Kullu District, Himachal Pradesh, India has been studied, in order to understand the geochemistry of the thermal as well as cold waters, evolutionary history of the thermal discharges and to evaluate the prospects of thermal springs as geothermal energy resource of the area. Another problem that has been addressed is whether the thermal discharges at Manikaran are local or it is a discharge of the Puga Geothermal System, Ladakh in NW Himalayas.

Manikaran (32°02'N, 77°21'E) is a small village on the banks of the Parbati River, a tributary of the Beas River, in the Kullu District of Himachal Pradesh (India), at an elevation of 1760 m in the North-Western Himalayas. Reconnaissance surveys on some of the springs have been carried out earlier by a few workers (Chaturvedi and Raymahashay, 1976, Gupta et al., 1976; Jangi et al., 1976; Giggenbach et al., 1983). The present work aims at study of the chemical characteristics of thermal discharges and their use for direct and indirect applications.

2. METHODOLOGY

For this purpose, detailed geological mapping in and around Manikaran has been done (Figure 1) and chemical analyses on thermal and cold waters in and around Manikaran have been carried out following the methods prescribed by the American Public Health Association (APHA, 1985). The results of chemical analyses are shown in Table 1.

3. LOCAL GEOLOGY

The major rock type in the area, exposed around Manikaran village and along the road to Kasol from Manikaran, is a well jointed, white to greyish, thick sequence of quartzite, which has been named the Manikaran Quartzite (Srikantia and Bhargava, 1998), along with minor phyllites and slates. In the western and northern part of the area, near Gohar Village, granitic gneisses are exposed. The contact between the quartzite - phyllite group and the overlying schistose rocks is a thrust contact. This thrust forms a part of the Central Himalayan Thrust, which is an extensive feature related to Cenozoic folding in the Himalayas (Srikantia and Bhargava, 1998). It is marked by brecciated and at places tightly folded schists. The thrust contact is inferred based on the higher grade of metamorphism of the gneissic rocks that overlie the quartzites and it runs in a north-westerly direction (Alam, 2002). Due to the inaccessibility of the terrain between Gohar Village and Bareona Village, the contact between the two is inferred on the map (Figure 1).

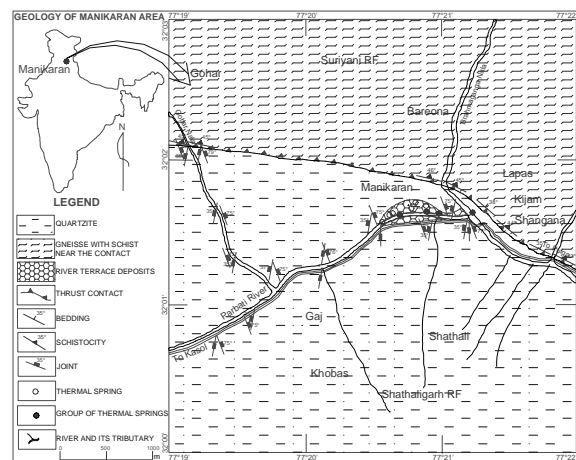


Figure 1: Geology of Manikaran (Alam, 2002)

Three sets of shear-joints in the quartzites with the average spacing of joints varying from 0.3 to 0.5 m (Alam, 2002). Two sets of joints have strike parallel to the strike of the formation (~NW-SE) and one set strikes perpendicular to that of the above two sets of joints (Alam, 2002). The most prominent joint is a bedding joint striking N 50° W across the river dipping around 75° NE (upstream).

4. GEOTHERMAL MANIFESTATIONS

Geothermal activity in the Parbati Valley manifests itself in the form of hot springs at Manikaran, Kasol, Jan and Khirganga, with surface temperatures up to 96°C, hottest springs being at Manikaran. All the thermal springs in the Parbati Valley, except the one at Khirganga, are located within 10 m of the river level. A majority of them releases from locations very close to the river level. According to

their location, the thermal springs of the Parbati Valley can be classified into two categories: (i) the springs found on the Manikaran terrace appear to emerge from the river terrace deposits, which display escape of steam. Most of them have thick deposits of travertine along their vents, (ii) quite hot water flows, which, in most cases, can be seen ascending directly along a steep joint. These flows generally have temperatures ranging between 70 and 80°C, but no escape of steam is observed. Unlike the first type, there is no noticeable deposition at the mouths of these flows.

Manikaran geothermal field extends from Harihar temple at the entrance of the village to the confluence of the Parbati River with the Brahmaganga Nala, spanning a distance of about 1 km in the east-west direction. At Manikaran, thermal springs generally emerge either from joints in quartzites or through the overburden of the terrace gravel deposits. The springs are in the form of spouts and pools, with temperatures as much as 96°C. Bubbling activity is also noticeable in some springs. Around most of the springs, deposits of aragonite coated with iron oxide have formed.

At Kasol too, the thermal springs emerge from quartzite and overburden. The temperature of water from the hottest spring is 76°C. Encrustation of calcium carbonate and ferruginous staining of the joints in the bedrock are noticeable around some of the springs. At Jan only one thermal spring is seen emerging from jointed quartzite, with 34°C temperature. There is vigorous gas activity in the spring. Deposits of ferruginous matter are noticed in and around the spring. The solitary thermal spring at Khirganga, about 25 km upstream from Manikaran, is situated on a hill slope about 100 m above the river level.

Table 1: Results of the chemical analyses of the Manikaran thermal and cold water samples.

S. N.	T (°C)	pH	SiO ₂ (ppm)	Major ions (ppm)							
				Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	SO ₄ ²⁻	Cl ⁻	HCO ₃ ⁻	
TW1	85	7.6	105	42	4.6	106	20	55	107	130	
TW2	86	6.4	104	38	4.6	78	17	51	104	140	
TW3	72	7.2	113	38	4.6	84	20	54	87	120	
TW4	73	7.3	117	42	6.9	88	21	53	126	160	
TW5	96	6.7	105	48	5.8	96	25	50	143	150	
TW6	78	7.6	86	70	10.4	75	15	70	117	200	
RW7	4	7.4	9.8	9.5	2.3	8.8	6.3	40	9.7	30	
RW8	6	7.6	11	13	3.5	3.8	1.3	39	7.3	30	

TW: Thermal water, RW: River water.

5. HYDROGEOCHEMISTRY

The analytical data on the water samples shown in Table 1 are plotted in Langelier Ludwig diagram (after Langelier and Ludwig, 1942; Figure 2). The thermal discharges are of Na-HCO₃-Cl type, while the cold waters are of Ca-SO₄ character. More clear distinction between these two groups of waters is seen in the anion variation diagram (Figure 3). Depletion in the Ca content in the thermal discharges can be explained in terms of the formation of travertine deposits along the vents of the thermal springs as a result of evaporation and loss of CO₂.

A comparison of relative chloride, bicarbonate and sulphate components shows the Manikaran thermal discharges to be very similar to those discharged at Puga, a definitely higher

temperature system situated in Ladakh. Considering the topography of the area, it is quite likely that the thermal discharges at Manikaran are not local but that of Puga Geothermal System, but there is no concluding evidence about it.

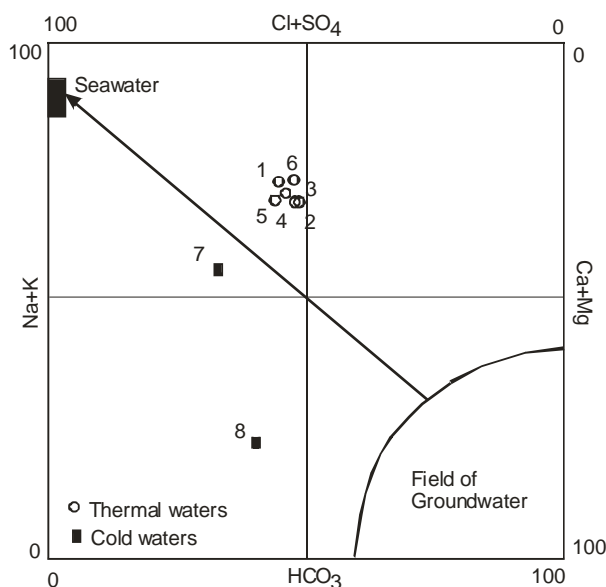


Figure 2: Langelier-Ludwig diagram (after Langelier, and Ludwig 1942). Samples 1-8 on this diagram are presented in Table 1.

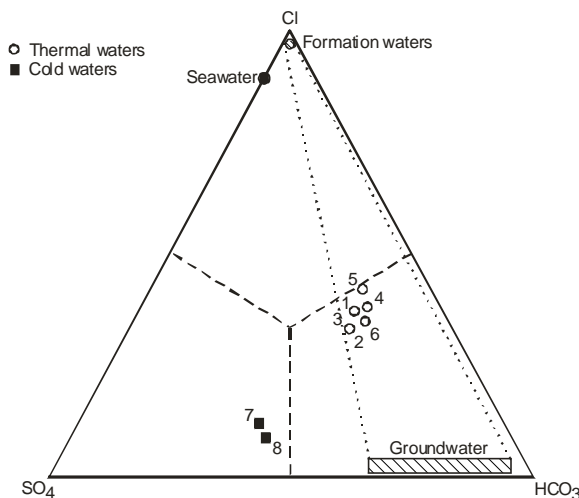


Figure 3: Anion variation diagram (after Giggenbach et al. 1983). Samples 1-8 on this diagram are presented in Table 1.

In fact, the thermal discharges fall between the formation water and groundwater fields of Giggenbach et al. (1983) indicating mixing between a saline (not yet identified) and freshwater source. It is probable that the saline waters represent ancient formation waters trapped in the geological formations or magmatic or metamorphic waters.

The presence of saline fluids in the older granitic rocks of the Himalayas has been reported based on INDEPTH (International Deep Profiling of Tibet and the Himalayas) studies carried out along the Indus-Tsangpo Suture Zone (Chandrasekharam, 2001a). The 'seismic bright spots' located during the INDEPTH studies in Tibet region, north-east of Manikaran, were attributed to the presence of

magmatic melts and/or saline fluids within the crust (Makovsky and Klemperer, 1999). Highly saline fluids are also found in Ladakh Granite (~60 Ma) as inclusions, which are attributed to the high volatile content in the granitic melts (Sachan, 1996). Although INDEPTH investigation has not been carried out in the Manikaran area, considering the proximity of INDEPTH investigation sites in Tibet, the probability of occurrence of such '*seismic bright spots*' in this area is high. This inference gains strength from the 1 Ma anatexis process recognized in Nanga Parbat (Chichi Granite Massif) in the Pakistan Himalayas (Schneider et al., 1999). Similar processes must be in operation on the eastern side of Nanga Parbat also (including Manikaran area). This evidence confirms that the present day observed high heat flow ($>100 \text{ mW/m}^2$) and geothermal gradient ($>100^\circ\text{C/km}$) values are related to a crustal melting process at shallow depth associated with subduction tectonics. These facts support the view that the source of the saline component is magmatic.

Fluid inclusion studies on the Manikaran Quartzite (Sharma and Misra, 1998), through which the thermal discharges are issuing, suggests the composition of the trapped fluid as $\text{H}_2\text{O-NaCl-KCl}$, since the biphasic aqueous inclusions show a eutectic temperature varying from -21.1 to -23.7°C (Crawford 1981) and with salinity varying from 2.7 to 10.6 wt% NaCl equivalents (Bodnar, 1993). Therefore, magmatic / hydrothermal fluids locked up in the granites and quartzites probably are the main sources of salinity in the geothermal system, due to a high degree of water-rock interaction at elevated temperatures.

Dilution of such saline fluids could have occurred during their ascent to the surface before emerging as thermal springs. This is indicated by large variation in the temperature and chloride content (a relatively non-reactive constituent) of the thermal discharges of the area. Thus on hydrogeochemical considerations, it could be concluded that thermal discharges of Manikaran area receive significant contributions from magmatic sources and dilution from the shallow groundwater.

The fraction of shallow groundwater mixing with deep thermal discharges can be estimated using a graphical procedure suggested by Fournier and Truesdell (1974) with a set of enthalpy values and solubility of silica (quartz) at different temperatures. By this method, the estimated fraction of shallow groundwater present in thermal discharges turns out to be 0.54 to 0.65, with an average value of 0.60.

Detailed work on the trace elements and isotopic signatures of the thermal and cold waters is being carried out.

6. GEOTHERMOMETRY

Reservoir temperatures estimated based on cations and silica using the equations recommended by Fournier (1983), Fournier and Potter (1982), Fournier and Truesdell (1973), Giggenbach et al. (1983) and Verma (2000) give values between 150 and 250°C .

The reservoir temperature obtained using the values of the cold water fractions from mixing model, as explained above, varies from 190 to 210°C , with an average value of 202°C .

Considering the reported high heat flow (100 mW/m^2), high geothermal gradient (100°C/km) and presence of younger granites, coupled with ongoing shallow magmatic processes (Chandraskharam, 2001a), it is likely that temperatures

over and above those estimated may be encountered in this area.

7 GEOTHERMAL POTENTIAL

Manikaran thermal discharges at present are being used for therapeutic purposes but can be utilized for various direct and indirect applications. Manikaran is in a region with high altitudes and rugged mountain topography. Therefore, it is not economical to transmit power by conventional coal or hydropower grid. Although the local government has installed transmission cables to this remote village, the power supply has not been reliable. With the existing geothermal resources and available technology, it is possible to generate power locally, which can provide a regular supply of electricity to this village economically, without much loss of power as is incurred during transmission over long distances.

Besides power generation, direct utilization of geothermal energy will be more beneficial and economical in these regions. For direct use the thermal discharges of the area can be channelised and used for space heating of houses, community centres, schools, dispensaries, hotels, tourist complexes and other establishments as they grow with the development. Thermal discharges can also be used in the functioning of cold storages, which may give a great boost to the fruit industry by preventing damage to produce and loss of revenue at the time of disruption of road transport during rainy and snowy season. It can also be used in setting up plants for drying, processing, preserving and canning of fruits and fruit products at specially created centres near the sites of the thermal springs. It will reduce the manufacturing cost marginally and the food products could be sold at competitive prices.

Additionally, large scale development of sheep breeding farms under controlled conditions, wool processing, carpet shawl garment manufacturing, animal husbandry, poultry and fish farming, small scale industries based on timber and other forest based products are all well within the realm of possible uses for the geothermal resources in the area.

Successful experiments with winter cultivation, using geothermal greenhouses in Puga-Chhumathang area (Ravi Shanker, 1986), north of Manikaran, should encourage large scale greenhouse cultivation in the Manikaran area also. Using greenhouses, seed and plant nurseries can also be developed under controlled conditions for rapid increase in the production of vegetable and crops. This could become a flourishing and profitable industry and contribute to the development of the area, since fresh vegetables are being transported by air or road at exorbitant cost. The state of Himachal Pradesh cultivates 5000 tonnes of fruits per year and at present has only two fruit processing plants (Chandraskharam, 2001b). The region has to depend on other states for other farm products. This state can become one of the major food producing and processing regions, with Manikaran as a major centre, if available geothermal energy sources are utilized to their full potential.

8. CONCLUSIONS

Based on major ion chemistry the thermal discharges of the Manikaran area are characterized as Na-Cl-HCO_3 type. High salinity of the thermal discharges indicates possible mixing between a saline (not yet identified) and groundwater source. The source of this saline component is probably ancient formation waters trapped in the geological formations, magmatic or metamorphic waters. Presence of saline fluids in older granitic rocks of the Himalayas based

on the INDEPTH studies supports this view. The composition of the thermal discharges can be described in terms of the variations in the relative proportions of two end member components: saline water and fresh water. Depletion in the calcium content can be explained in terms of the formation of travertine deposits along the vents of the thermal springs.

Considering the topography of the area, it is quite likely that the thermal discharges at Manikaran are not local but that of Puga Geothermal System, but there is no concluding evidence about it.

The high heat flow (100mW/m²) and the high geothermal gradient (100°C/km) are due to the presence of younger granites and ongoing shallow magmatic processes.

Excellent prospects exist for utilisation of thermal discharges for indirect (power generation) as well as direct use (recreation, agriculture, space heating, cold storage, food processing, greenhouse farming, etc).

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