Geothermal resource potential of Himachal Pradesh, India

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Abstract

Himachal Pradesh Geothermal sub-provinces (HPG) form a part of the large Himalaya Geothermal Province, which covers an area of over 1500 sq km enclosing more than 150 thermal manifestations, with surface temperatures varying between 57 and 97°C. High geothermal gradients (>260°C/km) and high heat flow values (>180 mW/m^2) are characteristic of HPG. Besides wet geothermal systems, the province is endowed with hot dry rocks at shallow depths. With such high geothermal gradients and heat flow values, HPG is well suited to commission geothermal based power projects and also to initiate feasibility study to tap hot dry rock resources. HPG geothermal resources can immediately be utilised to support several food processing industries and capture the entire fruit market of the country as well as that of the world.

Keywords: *Himalaya Geothermal Province, hot dry rock, geothermal power, geothermal energy, food processing.*

1 Introduction

The Himalaya Geothermal Province extends from northwestern part of India (Ladakh) to its northeastern part (Assam) covering an area greater than 1500 sq km and encloses over 150 thermal manifestations. They fall between the Main Boundary Thrust (MBT) and Indo-Tsangpo Suture Zone (ITSZ), which are parallel to the Indo-Asia collision zone. Himachal Pradesh geothermal sub-provinces form a part of this large Himalaya Geothermal Province. Thermal manifestations around Puga, Parbati and Kullu valleys are known for their high temperatures. Several workers (Sehgal 1963; Jangi et al., 1976; Gupta et al., 1976; Giggenbach et al., 1983; GSI, 1991; Alam, 2002) have carried out preliminary investigations in these areas. Recently, as a part of Indo-Italian collaborative research programme, detailed investigation on the thermal waters and thermal gases from thermal manifestation along Parbati and Kullu valleys have been carried out to understand the geochemical evolution of the thermal waters and gases and assess the geothermal potential of these sub-provinces. The results of this investigation will appear elsewhere. In the present paper, the geothermal resources potential of Himachal Pradesh geothermal sub-provinces (HPG) is discussed. Thermal manifestations occurring at Tattapani, Puga, Beas, Parbati, Sutluj, Bhagirathi and Alaknanda constitute these sub-provinces (Chandrasekharam, 2001a). The heat source available in these sub-provinces is best suited for developing power projects as well as for direct utilization (Chandrasekharam, 2001a). Further, these provinces are also best suited for initiating a hot dry rock feasibility study (Chandrasekharam, 2001b; 2002).

2 General Geology of HPG

HPG falls between the MBT and ITSZ (Figure1) located at an altitude extending between 1160 and 3660 m above mean sea level (Jangi et al., 1976). The temperature in summer varies between 27 and 14°C and winters are severe with snowfall varying between 60 cm and 2 m. The annual rainfall is about 120 cm (Srikantia and Bhargava, 1998).

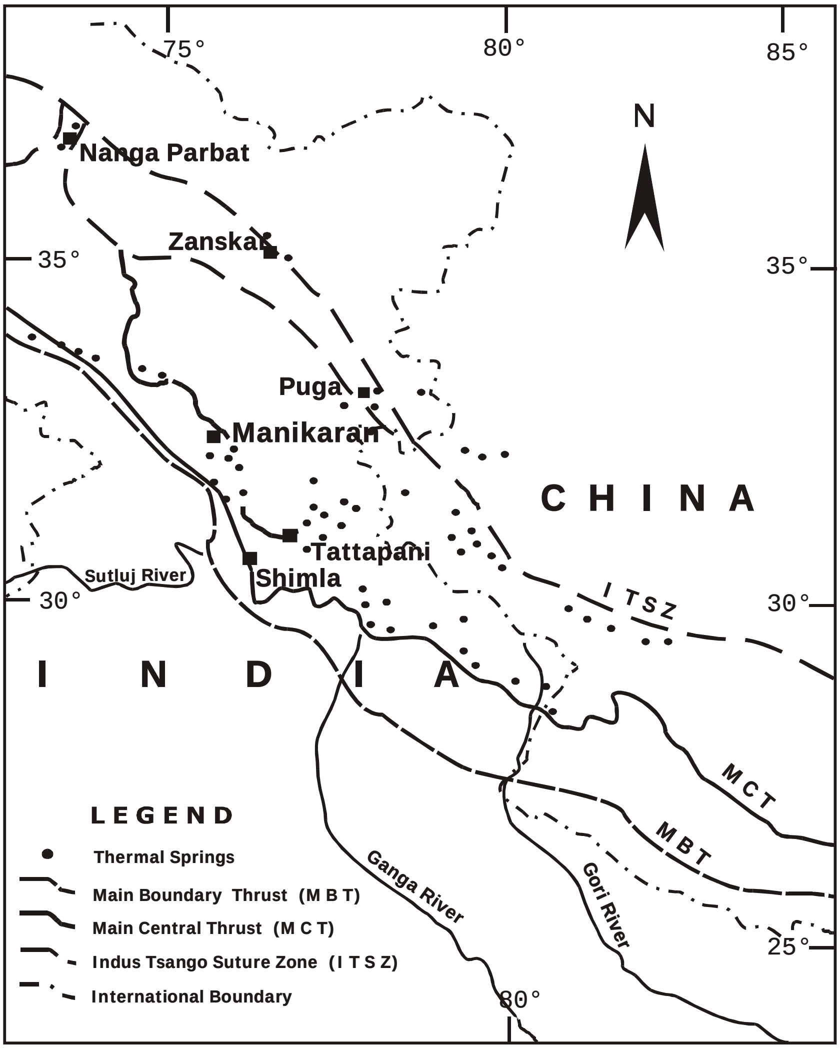

Figure 1. Geothermal manifestations in northwestern part of Himalayas.

The Manikaran Quartzite intercalated with phyllite constitutes the upper most Formation of the Rampur Group (Srikantia and Bhargava, 1998). Schist and gneiss of the Kullu Formation of the Chail Group tectonically overlies the Manikaran Quartzite (Sinha et al., 1997). The Manikaran Quartzite is underlain by metabasics, grey and green phyllite, with bands of carbonaceous schist (Jangi et al., 1976). The Manikaran Quartzite is highly jointed (shear joints with joint spacing of about 3-5 cm) and the contact between the quartzite and phyllite represents a thrust. The thrust zone is marked by tightly folded schist, which are highly crushed and at places been transformed into high-grade gneiss containing garnet. At places carbonaceous schist and graphite lenses are seen along this thrust. Folding pattern in these rocks is intricate and complex. The phillyte shows drag and overturned folds and puckering with the drag fold axes trending N-S and NE-SW and overturned folds axes trending N-S and E-W. The regional dip of the Manikaran Quartzite is NE with dip amount ranging from 30 to 50°. These joints are of great significance since all of them are the channels for upraising thermal waters and thermal gases in the region.

3 Geothermal manifestations and heat source in HPG

HPG experiences high geothermal gradient, reaching values as high as 260°C/km and high heat flow values of 70 - >180 mW/m^2 (Ravi Shanker, 1988). The surface temperature of the thermal springs varies from 57 to 98°C (GSI, 1991; Alam, 2002) and at some places (e.g. Manikaran) steam emergence is commonly seen. Recent investigation on thermal waters from Manikaran in Parbati valley (Alam, 2002) shows that the thermal waters issuing here can be considered as a mixture of two end members, one represented by paleo-brine rich in Na-Cl and the other represented by calcium carbonate rich water produced by the interaction of meteoric water with calcite veins traversing the lithological formation. The estimated reservoir temperatures (Na-K thermometry) vary from 260°C (GSI, 1991) and 310°C (Alam, 2002). Thermal water flow rates measured from the shallow exploration bore-wells, drilled by the Geological Survey of India, varies from 200 l/m to more than 1000 l/m (GSI, 1991).

Besides subduction tectonic regime, high heat flow and geothermal gradients in this region is due to younger shallow magmatic activity within MBT and ITSZ. This younger magmatic activity is represented by large number of granite intrusive, whose age vary from 60 to 5.3 Ma (Schneider et al., 1999a,b; Searle, 1999a,b; Le Fort and Rai, 1999; Haris et al., 2000; Harrison et al., 1998, 1999; Chandrasekharam, 2001b; 2002). These granites occurring as lopoliths, sheets and dykes (leuco-granites), with thickness varying from a few meters to several meters, are either exposed on the surface or covered by a layer of sedimentary formation. Permian granite of 268 Ma also occurs in the western Zanskar (Noble et al., 2001).

International Deep Profiling of Tibet and the Himalayas (INDEPTH) project located '*seismic bright spots*' in Tibet region (east of HPG), which are 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). Though INDEPTH investigation has not been carried out, considering the proximity of INDEPTH site in Tibet, probability of occurrence of such seismic bright spots within the HPG is high. This inference gains strength from the 1 Ma anatexis process recognized in Nanga Parbat (Fig.1; Chichi Granite Massive) in Pakistan Himalayas (Schneider et al., 1999c). Similar processes must be in operation on the eastern side of Nanga Parbat also. These evidences confirm that the present day observed high heat flow value (>100 mW/m^2) and geothermal gradient is related to subduction tectonic related crustal melting process at shallow depth.

4 Regional Stresses in HPG

Regional stress analysis based on earthquake focal mechanism, bore-hole blow-outs and hydro-fracturing (Gowd et al., 1992) indicates that the entire Himalayan belt in general and the HPG in particular, is under compressive stress regime due to the northward movement of the Indian plate and net resistive forces at the Himalayan collision zone. Thus, the central and northern India including Nepal, the Greater Himalayas and Pakistan fall under this stress province characterized by NNE-ENE oriented S_{Hmax} (Chandrasekharam, 2001b; 2002). Investigation carried out around Zanskar (north of HPG) by Pierre Dèzes (1999) also shows compressive regime in this region. Compressional stress regime is favourable to create several sub-horizontal reservoirs in granites by hydro fracturing, interconnected by boreholes (Baria et al., 1999; Wyborn, 2001). Thus the entire subduction tectonic regime along the Himalayan Geothermal Province appears to be similar to HDR (Hot Dry Rock) prospect of Hijiori and Kansai provinces of Japan. International HDR feasibility study can be initiated in the region falling between MBT and ITSZ with local government support and support from the independent power producers to develop a geothermal power project.

5 Geothermal energy utilization in HPG

HPG, being a region with high altitudes and rugged mountain topography, it is not possible to transmit power to remote villages by conventional coal or hydropower grid. Though local government has installed transmission cables to remote villages, power supply has not been commissioned even after several years and the rural population are still using conventional lanterns to meet their power requirement. With the existing geothermal resources and available technology, it should be possible to generate power, which can provide at least one electric bulb in every home in these villages! In regions like Puga, which is covered by snow and ice throughout the year, geothermal heat will benefit to a large extent to the army personal. Thus besides power, direct utilization of geothermal energy (e.g. space-heating and greenhouse; Lund, 2002) will be more beneficial and economical in these regions.

HPG have varied agro-climatic conditions suitable for growing different varieties of fruits. This region is successfully growing apple, pear, peach, plum, almond, walnut, citrus, mango, raisin grapes etc. The total area under fruit cultivation in Himachal Pradesh (HP) alone is about 2000 km^2 with a production of about 5000 MT of all kinds of fruits annually. Apple is the major fruit accounting for more than 40% of total area under fruit cultivation and about 88% of total fruit production in HP. The present two fruit processing plants in HP has a combined capacity to process about 20,000 MT of fruit every year. But, then the region has to import other food products from other parts of the country. If local geothermal resources are put to use, this region can be one of the major food producing and processing regions in the country (Chandrasekharam, 2001a; 2002).

Greenhouses, dehydration of fruits and vegetables and aquaculture (fish farming) are the three primary uses of geothermal energy in the agribusiness industry (Lund, 2002), which are most suited under the existing Indian conditions. The relatively rural location of most geothermal resources in India also offers advantages, including clean air, few disease problems, clean water, a stable workforce, and low taxes. The HGP is best suited to initiate state-of art technology in food processing (dehydration and greenhouse cultivation) using geothermal energy. Beside the agro-based industry, large cold storage facilities can be commissioned along the west coast geothermal province where fishing is a major business.

6 Conclusions

The existing data on the geothermal resources on HPG indicates that both power and direct applications are possible over the entire area of the Himalaya Geothermal Province. Using locally available geothermal resources enable to adopt Clean Development Mechanism and reduce dependency on conventional power sources and also mitigate global climate change. When Yangbajing geothermal field in China, located north of ITSZ and east of HPG is able to produce 25MW of power (Chandrasekharam, 2000), considering similar tectonic setting, the HPG should also be in a position to produce similar amount of power thereby improving the socio-economic status of the local hill population.

7 References

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