PROMISING REGIONS FOR GEOTHERMAL POWER GENERATION IN INDIA

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ABSTRACT

There is a good potential for developing geothermal energy in India. Tapping of this ecologically clean and environmentally friendly resource requires a good understanding of deep structures below geothermally anomalous regions. Most of these regions comprise zones of high electrical conductivity due to the presence of hot fluids and associated minerals. The most suitable geophysical methods to delineate these zones are deep electrical and magneto telluric (MT) methods.
In India, deep electrical and MT investigations for geothermal energy have been conducted in three different geological settings, namely: Konkan Geothermal Province along the western coast, Tatapani Hot Spring Area in the Narmada-Son Lineament Zone, and Puga Geothermal Area, Ladakh, Jammu and Kashmir. Encouraged by the results of these studies, other areas in Himalayan belt region and also Jharkhand region are being taken up for detailed studies. A brief description of the salient results from these studies is followed by the detailed modeling results from the Puga Geothermal Area. 1-D and 2-D analysis of 35 MT soundings from this area reveal shallow (< 400 m) and deep (2km) conductive zones related to the geothermal reservoir. Multi-profile modeling and dimensionality indicators suggest that the reservoir is a 3-dimensional feature with sharp variations towards east and west. Govt. of India, intends to develop it for power supply in Ladakh region.

1. INTRODUCTION

The oil crises during 1970s had a severe effect on the developing counties and geothermal energy has gained importance as an alternate energy resource. Since then search for geothermal energy has increased with more number of field studies to identify the potential regions for possible exploitation. There are about 400 thermal areas in India with hot or warm water springs. Out of these, 46 thermal systems have been considered as high temperature with an estimated base temperature of >150^{0}C for electric power generation. The remaining thermal areas are considered to be of intermediate in nature with an estimated base temperature of 90^{0}C - 150^{0}C and low temperature thermal areas with less than 90^{0}C base temperature [8].
The major geothermal manifestations are distributed mainly in three different regions – Himalayan region, Himalayan fore deep region and peninsular shield region. These three regions have been further divided into 14 geothermal provinces. The distribution of geothermal provinces can be classified into orogenic provinces and non-orogenic regions. Examples of geothermal provinces in orogenic regions are Himalayan geothermal province, Naga Lushai geothermal province, Andaman – Nicobar Islands geothermal province and the examples of non-orogenic regions are Cambay

garben geothermal province, Son – Narmada –Tapi garben geothermal province, West coast geothermal province, Damodar valley geothermal province, Mahanandi valley geothermal province, Godavari valley geothermal province, North Indian peninsular geothermal province, East Indian geothermal province, South Indian geothermal province [10].These provinces have been systematically studied by Geological Survey of India using geochemical, geological and shallow geophysical techniques. Some of the hot spring areas have also been explored with shallow drilling. This led to large database for geothermal potential in the country Ravishanker, (1988) has compiled the geothermal data for the entire country and presented in the form of a heat flow map of India (Fig. 1). From the heat flow data five different zones have been identified with zone -1 being the most important with heat flow value more than 180 mw/m^2 and zone five with less than 40 mW/m^2 [8].

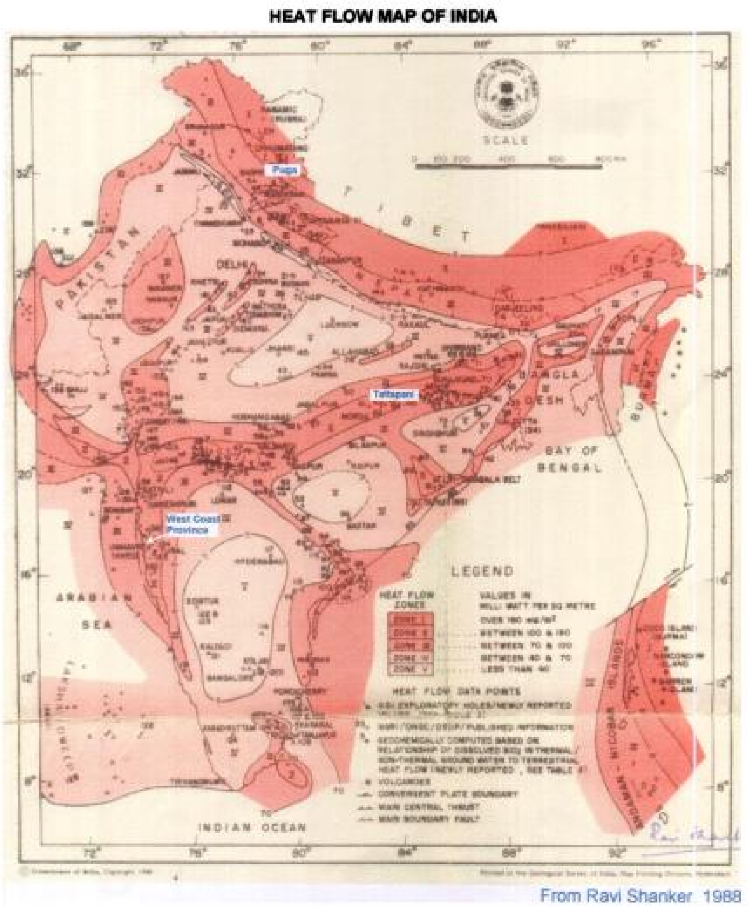

Fig.1 Heat Flow map of India (Ravishankar, 1988).

Although wealth of database has been generated, the deep structure of geothermal region is poorly understood. Towards this direction, telluric and magnetotelluric field studies have been taken in some of the important geothermal provinces and the results are described briefly in the following.

2. KONKAN GEOTHERMAL PROVINCE

This province spreads nearly a few hundred kilometers in Deccan basalt along the west coast of India. In this region, hot springs are known to be located at 23 locations, 9 located north of Bombay and 14 in the southern part. The entire province is covered by basalt of upper Cretaceous – Paleocene age. It is believed that water from the springs is of meteoric origin. Originated from the steep hills of Western ghats situated at a few kilometers away from the springs towards the east, the water must have seeped into the subsurface through deep fractures and got heated up down below due to anomalous geothermal gradient and emerge to the surface through suitable conduits to appear a hot springs. Regional geophysical studies have indicated several basement features near west coast Regional gravity studies over Deccan traps indicated a major lineament along the west coast. Krishnabramham and Negi [5] suggested the possible existence of two rift valleys, Koyna and Kurduvadi rifts. In Koyna region, deep seismic sounding (DSS) studies provided the crustal structure. From deep electrical soundings in the south east of the present study region [4] obtained a thickness of 500 m and a resistivity of about a few hundred ohm-m for the basalt. The traps are reported to become thicker towards the west, the thickness reaching a value of about 1.5 km.

A reconnaissance telluric field study in the northern part of Konkan geothermal province has indicated a distinct subsurface conductive anomaly [9]. Further work has been taken up with additional telluric and a few experimental MT measurements in the area. These studies have not only confirmed the presence of the conductive anomaly near Sativili-Koknere group of hot springs, but also helped further in extending the earlier telluric field anomaly. The analysis of the data shows that the telluric field parameter, 'μ' varies from 1.0 to 0.7 in the southern part of the study area near Ganeshpuri-Akloli group of hot springs and tend to decrease northwards to about 0.2 towards the Sativili-Koknere group of hot springs. It is observed that this decreasing trend continues even further towards north of Koknere from the telluric field contour map. The contour map also indicated that the telluric anomaly representing a subsurface conductive anomaly is not a localized feature but covers a large region.

2-D modeling along a profile across the telluric field anomaly has been carried out using forward algorithm of Jupp and Vozoff [3]. In its simplest form the anomaly may be explained by a near surface horizontally extending conductive zone (2-5 ohm-m) located at shallow depths (<1 km). But for the reasons discussed in greater detail (Sarma et al, 1983; Harinarayana and Sarma, 1998) and from the observation that it is improbable that such a high conductive zone could be explained from any known geological or any hydrological considerations. It is inferred that the anomaly should be attributed to deeper source. Accordingly, from a detailed modeling studies, it is concluded that a deeper conductive zone with a 1 km (Harinarayana and Sarma, 1998) would account for the observed telluric field anomaly in addition to the shallow conductors indicated from deep electrical resistivity soundings results.

From modeling of the MT data (1-100 sec), it is observed that an electrically high resistive basement lied below all the three stations. The MT curves located in the anomalous zone (MT2 and MT3 in Fig.) show relatively lower magnitudes of apparent resistivity values with a gentle gradient compared to that of MT1, located near the telluric base station. This indicates that the MT apparent resistivities also corroborate the presence of the conductor in the area corresponding to conductive anomaly delineated from telluric field studies. No attempt has been made to estimate the parameters of the conductive zone, as this cannot be resolved since the MT data considered in the region is limited to a narrow frequency range. The thickness of the Deccan traps estimated though 1-D modeling of the limited MT data is about 1.7 to 2.5 km (Fig.2).

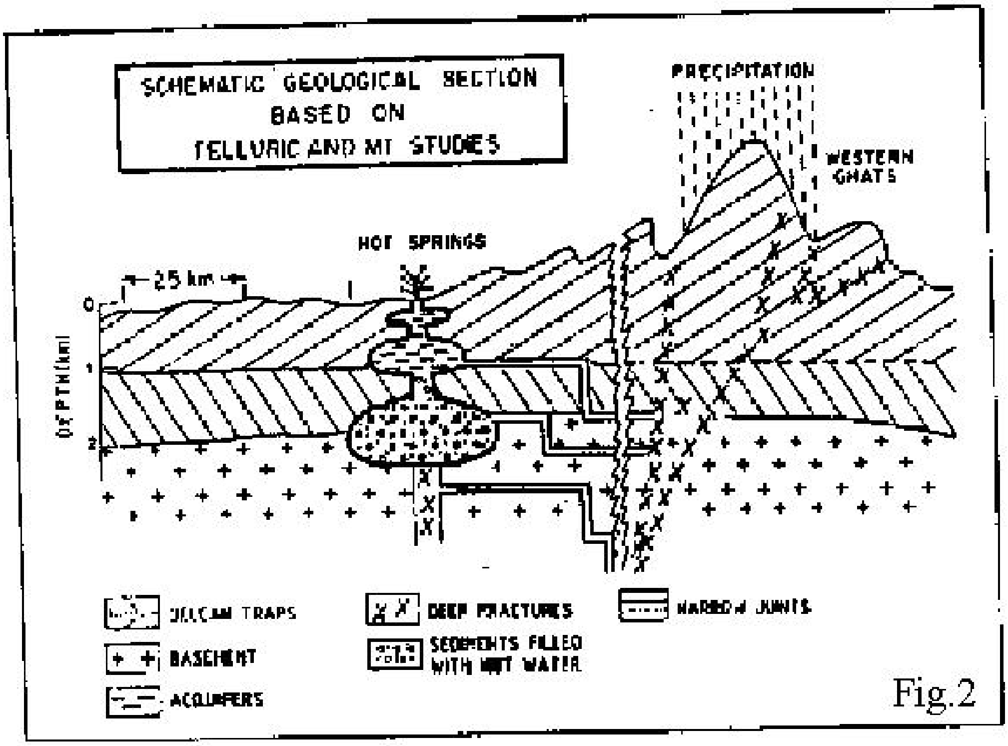

Fig.2. Schematic geological section from telluric and magnetotelluric results, Konkan geothermal province, west coast of India.

3. MT STUDIES IN TATTAPANI GEOTHERMAL REGION

Tatapani hot spring area in Surguja district, Madhya Pradesh is considered to be associated with Narmada-son lineament (NSL) zone. The NSL stretching nearly a few hundreds of kilometers in E-NE and W-SW direction across the Peninsular India, forms a major tectonic feature in Indian geology. There are several groups of hot springs located towards south of Damodar graben, Cambay graben (Tawa hot springs), etc., in which Tatapani group of hot springs occupies a significant place [6]. This area is considered to be important in view of the relatively high temperature (60-80^{0}C) of the discharged water. Tatapani group of hot springs are distributed at 23 different locations lying in a zone oriented nearly in an EW direction. Extensive geological and geothermal studies were carried out by the Geological Survey of India [7] in this region. Several shallow drill holes were also carried out in order to assess the geothermal conditions of the area. In one of the bore hole (480 m) near the hot spring a temperature of about 110^{0}C is reported from a depth of about 70m [9].
The study area is occupied mostly by Archaean and partly by Gondwana rocks. The possible occurrence of a fault striking approximately in EW direction near the springs has been reported [6]. The Archaean rocks in the area comprise granite gneisses, pegmatites, metamorphosed basic rocks such as hornblende schists, pegmatites, granite bearing amphibolites etc. The strike of the schists and gneisses varies over a wide range of directions with the east-west strike being more common.

The Gondwana rocks, towards the west and northwest in the study area, consist of Talchirs and Barakar formations, mostly coal bearing [6].
To prepare a subsurface geoelectric section of the Tattapani hot spring region, one of the most promising geothermal fields, MT investigations were carried out in the region. Data have been acquired at 50 stations and a clear indication of the subsurface geoelectric anomaly was observed in the data. The results have delineated anomalous deep conductive structure at a depth of about 2.0 km extending towards west of Tattapani, related to the geothermal manifestation of the region. (Fig.3).

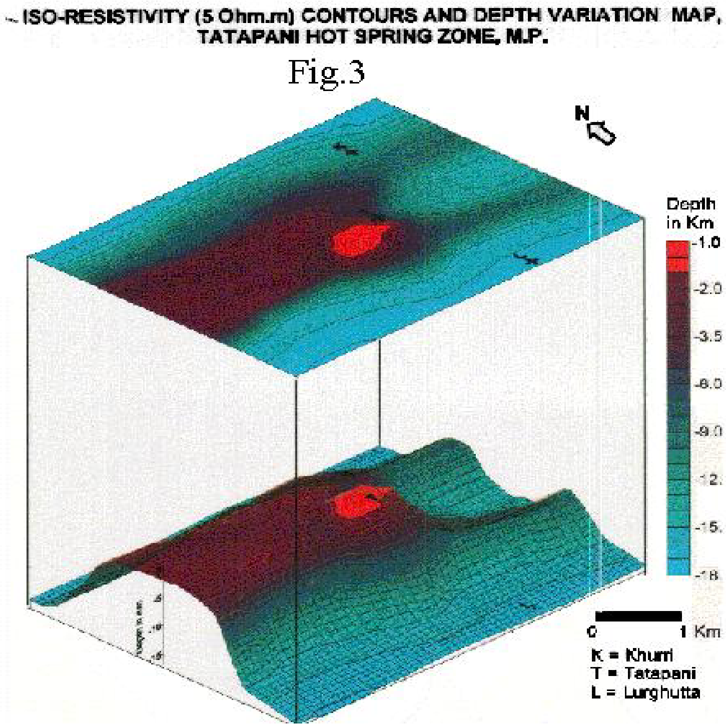

Fig.3. Iso-resistivity contour map indicating the geothermal reservoir boundary, Tatapani, Surguja district, Chattisgarh.

4. MT INVETIGATIONS IN PUGA GEOTHERMAL REGION, JAMMU & KASHMIR

Puga geothermal area is located in the Ladakh district of Jammu & Kashmir state. Puga is a part of great Himalayan range in the Indus valley. It is located at an altitude of about 4400 m. Although the Indian subcontinent has about 400 hot spring occurrences, the Hot springs along the Himalayan belt regions are the most promising area because of the high heat flow and temperature values measured from this area. The heat flow and temperature maps of India shown in Fig.1 give an idea of the actual values. Among the thirty thermal spring localities in Jammu and Kashmir, Puga valley and its adjoining areas (Chumathang) are well known for their geothermal potential as is evident from various pre-feasibility studies carried out in this area. Their exploration as well as exploitation assumes importance because of the absence of any alternative source of energy in this region.
A total number of 50 MT stations were occupied with a close station interval of 0.5 to 1.0 km in the Puga geothermal region and surrounding areas of Jammu & Kashmir during June – July 2001. Wide band magnetotelluric data acquisition systems (GMS 05) were used for data collection. As the study area is far away from human habitations and civilization, no manmade noise was present in the

vicinity and this provided an opportunity for collection of high quality MT data. The data have been subjected to qualitative and quantitative interpretation. The data revealed the presence of a high conductive zone towards west of Sumdo village in the valley. The conductive zone shows a shallow conductor (100 – 500m) underlain by a resistive structure followed by another deep conductor at a depth of 1.5 km (Fig.4). The deleneation of a deeper conductor is related to deep geothermal reservoir has open up the region for possible exploitation of the heat energy for electric power generation.

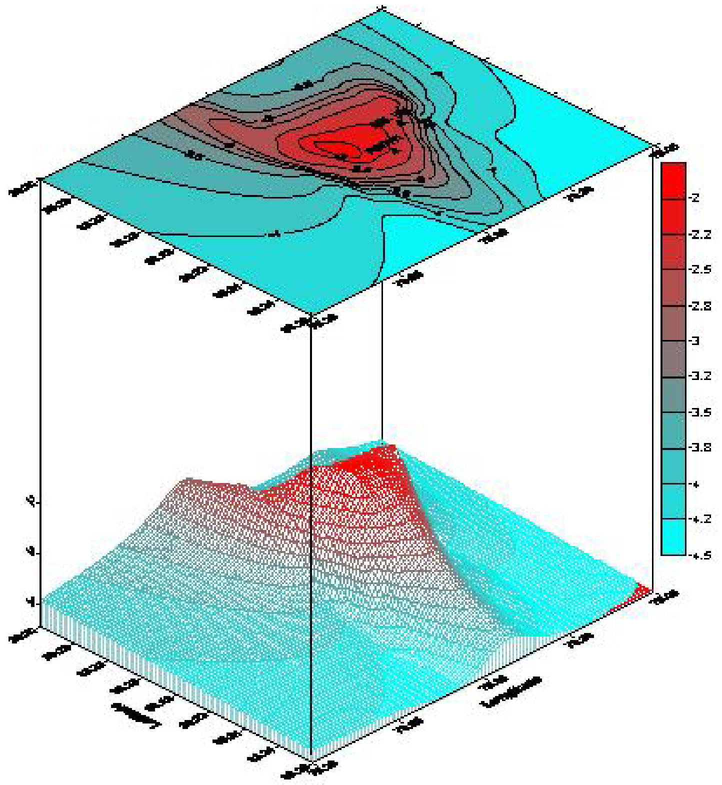

Fig-4. 3-D VIEW OF TOP SURFACE OF DEEPER CONDUCTOR SHOWING PRESENCE OF GEOTHERMAL RESERVOIR

Fig.4. 3-D view of top surface of the deeper conductor, Puga valley, J & K

CONCLUSIONS

Although India has great potential to develop geothermal energy for direct and indirect use of heat there is no substantial plan to develop this important renewable resource. This is mainly due to lack of deep drilling technology in geothermal region. At present, they are limited to therapeutic use at places and also in holiday resorts. From the recent telluric and magnetotelluric (MT) studies, the deep geothermal conditions are well constrained and proved the great potential of geothermal regions for electric power generation. Based on present day knowledge if one can give rank to the geothermal systems, Puga region, Ladakh district, Jammu and Kashmir top the list due to the estimated high temperature of geothermal reservoir (240^{o}C) and also the shallow nature of the deep reservoir (1.5 km). In a similar geological situation in Yonbajing geothermal field in south of Lhasa in Tibet, about 25 MW electricity being generated (Huttrer, 2001). Ladakh district is facing power shortage due to the disadvantage of its remote location and not connected to national grid power system. Energy being drawn from solar and mini hydropower systems is insufficient to meet the demand. Electricity from diesel power station is too expensive, as the fuel needs to be transported from long distances from plains of India. Freezing temperature during winter and silt during summer are some of the problems being faced by mini hydro power plant. In this scenario, there is a great need and demand to develop the geothermal potential for the energy starving Ladakh district. Since the technology is new in India, collaborative project on turnkey basis is sought from international agencies.

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