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Geothermal, A Viable Eco-friendly Source of Energy for India

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ABSTRACT

Geothermal exploration carried out in India, so far, has generated valuable data through extensive surface, geoscientific studies backed up by exploratory drilling down to depths of about 500 meters at selected geothermal localities generated valuable data concerning structural, geological, geochemical, hydrological and thermal parameters of geothermal systems. About 340 geothermal hot springs which are characterized by Tertiary and Quaternary orogenic activity in the Himalayas, Mesozoic and Tertiary block faulting and epiorogenic activity in the shield areas, and moderately active seismicity and intense neotectonism have been identified by the Geological Survey of India (GSI). A total of about 10,000 MW could be generated from Himalaya, Naga Lushai, Andaman-Nicobar Islands, West Coast, Cambay Graben, Aravalli, Son-Narmada-Tapi, Godavari and Mahanadi, South Indian Cratonic geothermal provinces in India. However, the geothermal reservoirs in India are of low to medium enthalpy type where surface temperatures vary from 80 to 1050C thus requiring a Binary Power Plant to convert their geothermal energy into electricity.

1. INTRODUCTION

The GSI has identified about 340 geothermal hot springs throughout the country (Ravi Shankar and Guha S.K. 1992).

A detailed Geothermal Atlas for India was also prepared by the GSI which gives details about the potential geothermal energy sites in the country. In this Atlas, the GSI has identified the following ten geothermal provinces in the country, which are characterized by the Tertiary and Quarternary orogenic activity in the Himalayas, Mesozoic and Tertiary block faulting and epiorogenic activity in the shield areas, and moderately active seismicity and intense neotectonism. Figure 1 shows these geothermal provinces of India giving regional heat flow patterns in mW/m 2. Solid bigger and smaller dots represent the high and low to normal heat flow sites respectively, while triangles indicate thermal springs :

(I) Himalayan Geothermal Province : (II) Naga Lushai Geothermal Province : (III) Andaman- Nicobar Islands Province : (IV) West Coast Geothermal Province : (V) Cambay Graben Geothermal Province : (VI) Aravalli Province : (VII) Son- Narmada - Tapti Geothermal Province : (VIII) Godavri Geothermal Province : (IX) Mahanadi Geothermal Province and (X) South Indian Cratonic Province

Large numbers of thermal springs are found in the Himalayan Geothermal Province (I). Many of whom are of boiling point temperatures respective to the elevation of their respective location. The thermal activity is strongest adjacent to the Indus - Tsungbo Suture Zone in the northwest Himalayas. Puga and Chhumathang areas are examples of this type of manifestation with temperature gradients exceeding 100oC / km., and heat flow in excess of 200 mW/m2 However, the majority of the hot springs are located between the Main Central Thrust and the Central Himalayan Axis.

The hot springs of the Parbati valley, Sutluj valley and Alaknanda valley are the typical of manifestations having 60 ^{o} ± 20^{o} C/km temperature gradient and 130 ± 30 mW/ m^{2} heat flow values. Lukewarm thermal springs with low temperatures (geochemically computed) are generally located along the outer margin of the Himalayas. The foothill Himalayan belts exhibit low temperature gradients of 17 ^{o} ± 5^{o} C and low heat flow values of 41 ± 10 mW/m^{2}.

In northeastern India, along the Naga- Lushai hill ranges bordering Myanmar (II), the thermal springs studied are similar in nature as those observed in the foothills of northwestern Himalayas. The Andaman - Nicobar Islands (III) represent Tertiary ranges with late Tertiary folding, faulting and Quarternary mud volcanism. Geothermal energy can be harnessed in this province.

Coast (IV) geothermal belt manifested by a series of thermal springs along the West Coast of Maharashtra (4), is one of the continuous belts (300 km x 20km) in the country that has been systematically explored. The area exhibits high gravity, recent seismicity, Tertiary down faulting, Temperature gradients of the order of 55 ^{o}± 5^{o} C / km and heat flow values in the 130 ± 10 mW / m^{2} range.

Cambay Graben Province (V) is a 200 km long and 50 km wide down faulted area with late Tertiary reactivation, plutonism,and recent seismicity. Moderate temperature gradients of 40 ^{o} ± 15 ^{o} C/ km and heat flow of 75± 18 mW/m^{2}, and bottom hole temperature in the range of 100 ^{o} to 145 ^{o} C have been recorded in oil wells at depths between 1.7 km and 1.9 km. Steam blowouts have been recorded in some of the oil wells at depths ranging from 1.5 km to 3.4 km.

Thermal wells are found along the northeast-southwest ridge in parts of Rajasthan and Haryana. Most of the ridges are fault bound with evidences of neotectonic activity. The temperature Gradients of 41 ^{o} ± 100^{o} C/ km and heat flows of 100± 25 mW / m^{2} have been recorded in the Aravalli Province (VI).

On the other hand, the Son- Narmada-Tapti lineament zone is a fault bound mega lineament belt in Central part of the country (VII), with a large number of hot springs manifestations. Temperature gradients in the 40 ^{o} to 120 ^{o}C/km range and heat flow values from 70 to 300 mW / m^{2} have been recorded at several locations in the Son-Narmada- Tapti province (J. and Rao A. 1987).

Godavari (VIII) and Mahanadi (IX) valleys are fault bound grabens with post Gondwana and possibly late Tertiary/ Quarternary reactivations. Moderate temperature gradients of $39^o \pm 10^o$ C/ km and heat flow values of 80 ± 21mw/sq.m have been recorded in the Godavari Valley. Isolated warm springs are found in Southern India (X). A systematic study and geothermal exploration is required in this province.

It is necessary to strengthen the database for different geothermal systems that occur in India. Only reconnaissance studies have been nearly completed in the northwest Himalayas and also in Madhya Pradesh andBelt in parts of Andhra Pradesh, Bihar, Gujarat, Madhya Pradesh and Maharashtra, temperature gradients in the range of 60^o C ± 150^o C/ km may be postulated in the depth range of 300 to 500m (Ravi Shanker 1987).

Fluids with higher computed base temperature may be encountered at depths ranging from 1.5 to 3 km, depending upon local geological/ geohydrological conditions. In the shield areas the heat flow values generally range from 70 to 130 mw / m^2 with isolated regions having values even up to 300 mW/m^2. There are only a few areas where a geothermal fluid temperature in the range of 175 ^{o} ± 25 ^{o} C could be expected in Tattapani- Jhor belt of Madhya Pradesh with its extension in Bihar and Cambay, in Graben in Gujarat and Puga- Chhu-Mathang areas in Jammu & Kashmir. The areas so far explored, low-to-intermediate type of geothermal resources with 110 ± 20 C temperatures are expected.

2. WHY GEOTHERMAL ENERGY

Oil and gas have a head start on various other forms of energy. They are easily transported, easily converted and, in today's market still relatively available. But due to its exhaustible nature, more attention is now needed to develop alternative non-conventional energy sources in parallel to keep the energy requirements going. It is in this context that the geothermal resources stands out as a promising long term salvation due to its bounty in nature among various non-conventional energy sources in India. Nearly 10,000 MWe power generation potential has been estimated from the total geothermal resource base in India and it can be used for space heating and cooling, heating of green houses for cultivation, cooking etc. especially in the high altitude and the colder regions. Geothermal springs are also used for balenotherapy and the promotion of tourism in several countries of the world. Electricity can be generated from geothermal fluids where higher temperatures are available with the help of binary power plants based upon the Organic Rankine Cycle (ORC).

3. PROMINENT GEOTHERMAL POWER GENERATION SITES

The Tattapani geothermal field, situated in Surguja district of Chattisgarh has several hot springs with moderate gas activity and silica deposits around their vents Fig.1. The surface temperature of the hot springs varies from 50^o to 98^o C and their cumulative discharge is about 60 liters per minute (Sarolkar P.B. 1987).

Under the geothermal exploration program jointly executed by the GSI and the ONGC for experimental utilization of heat from thermal fluids, as many as 26 bore holes were drilled to depths varying from 100 to 620m (Thussu et al 1987). Drilling of these bore holes was completed in the period April - December, 1993. However, only five of the bore holes were found to be suitable for production as they were producing 60 litres of hot water per hour per bore hole at about 105 ^{o} C. The ONGC has established a total of 300 KWe electric generation potential based on the cumulative geofluid discharge of 1800 liters/ minute at 105^0 C. This low to medium enthalpy reservoir will require the Organic Rankine Cycle based power plant to convert heat energy into electricity (Muffler, P and Cataldi, R 1978).

Deeper drilling was necessary in order to reach the actual reservoir where still higher temperature /pressure thermal fluids could be found. However, deeper drilling could not be carried out at the Tattapani geothermal field during the initial stage, mainly due to non availability of needed deep drilling equipment and other infrastructure facilities. Geothermal heat is extracted through geothermal production wells of diameters large enough to yield the highest possible rate of flow of geothermal fluid flow. It was considered essential to go for deeper drilling down to 1500 to 3000 m to obtain geothermal fluids of adequate temperature / pressure for commercial exploitation.

The following Table 1 shows the well test data and the Table 2, the chemical analyses of the water from the geothermal wells of the Tattapani area (Sarolkar 1993).

Table 1

TESTING DATA OF GEOTHERMAL WELLS OF TATTAPANI (M.P.) DURING THE YEAR 1999

Sl.	PARAMETERS	TAT-6	TAT-23	TAT-24	TAT-25	TAT-26
1.	DEPTH (m)	322.00	353.00	244.00	350.00	239.00
2.	CASING SHOE DEPTH (m)	120.00	115.00	110.00	237.00	191.00
3.	CLEAR UPTO (m)	322.00	352.00	175.00	219.00	173.00
4.	INITIAL FLOW RATE (lpm)	290.00	364.00	361.00	405.00	380.00
5.	FINAL FLOW RATE (lpm)	255.00	270.00	360.00	290.00	330.00
6.	SBHP(KG/Cm^2)	30.86	32.66	110.8	20.82	16.78
7.	FBHP (KG/Cm^2)	30.19	32.51	-	20.60	16.48
8.	SBHT (^OC)	107.44	106.06	110.7	109.39	106.33
9.	FBHT (^OC)	106.72	109.50	-	112.11	111.56
10.	MAXIMUM TEMP. (^OC) (FLOWING)	111.17	112.28	-	112.11	111.56
11.	FLOWING TEMP. (^OC) (AT SURFACE)	101.00	103.94	-	104.28	103.50
12.	TEMP. REVERSAL DEPTH (m)	220.00	240.00	137.00	-	-
13.	DECLINE IN PRESSURE AFTER CONTINUOUS FLOW (KG/Cm^2)	-	0.22	-	0.22	-
14.	FLOWING THP (KG/Cm^2)	0.30	0.75	-	0.52	0.45
15.	STATIC THP (KG/Cm^2)	0.52	0.52	-	0.52	0.60
16.	TOTAL LIQUID RATE 1800 (lpm)					

Table 2

SOURCE OF WATER : TATTAPANI GEOTHERMAL FIELD

APPEARANCE : COLOURLESS

ODOUR : ODOURLESS

ANALYTICAL RESULTS

pH 9.35

ANIONS/CATIONS	Mg/litre (ppm)
F	17.32
Cl	37.90
NO2	46.16
Br	0.35
SO4	64.12
COOH	0.001
NO3	NIL
HCO3	93.53
CO3	32.00
Na (observed)	68.71
Na (calculated)	128.91
K	5.14
Ca	0.10
Mg	0.0053
Total Hardness as CaCO3	0.2710
TDS (calculated)	356.56

Puga geothermal field is considered as one of the potential sites from the point of view of utilizing for power generation/ heat applications provided there is an application very close to or at the geothermal site. In the course of exploration of Puga geothermal field (by GSI) the following results were obtained (Krishnaswami and Ravi Shankar 1982) .

1. Shallow geothermal reservoir covering an area of about 5 km long and an average width of 500m and aquifer thickness ranging between 80 and 200m containing hot water- steam mixture at around 140^{o} C.

2. Geothermal discharge of the order of 250 tons / hour from geothermal bore holes.

3. There is a possibility of a deep reservoir in the area where high temperature gradient of about 200^{o} C could be expected with deep geothermal drilling.

Groups of hot springs lying in Satluj and Spitti valleys, falling within the region of Mandi, Simla, Kinnaur and Lahaul- Spitti districts of Himachal Pradesh, belong to four hydrothermal systems.Fig.1. The first three systems - those of the Satluj valley are genetically related, where as the Sumdo-Chuza system has a separate entity. The highest estimated base temperature rangeing from 112^{o} C to 144 ^{o}C are indicated for the Nathpa-Karchham sector. Tapri with high base temperature of up to 180^{o} C and Sumdo-Chuza with a base temperature of 84 ^{o}C hold promise from the point of view of supplying large quantities of hot water.

The Beas valley geothermal system extends for about 45 km between Bashist in the North and Takoli in the South. Thermal manifestations in the form of isolated groups of geothermal hot springs have temperature ranging from 21^{o} C to 53^{o} C. Application of chemical geothermometry indicates a maximum temperature of 120^{o} C ± 10^{o}C. Low enthalpy geothermal fluid available in the Beas valley may be used for space and greenhouse heating, for promotion of tourism etc. With deep exploration, it may be possible to generate electricity at some selected geothermal sites.

Thermal springs of Badrinath and Tapoban are located in the Alaknanda and Dhauliganga valleys respectively at elevations of 2000-3000m above MSL, in the Himalayan terrain Fig.1. Silica geothermometer estimates reservoir temperature of Tapoban geothermal area to be 100^{o} C and for Badrinath geothermal area as 120^{o} C.

The base temperature of most of the hot springs of Bihar ranges from less than 90 ^{o}C to 165^{o} C Fig.1. Hot springs with high fluid temperature could be used for power generation and also for uses like agrarian products, forestry products, sericulture, cold storage and tourism etc.

Based on the results of power generating capacity of 300 KWe from the shallow secondary reservoir of 105^{0} C at a depth of up to 500m estimated by the ONGC. Also on basis of the Magneto - Tellurics (MT) survey conducted by the National Geophysical Research Institute (NGRI) which revealed the presence of a vast primary reservoir of about 260^{0}C at nearly 3 to 3.5 km at the Tattapani Geothermal Field, The National Hydroelectric Power Corporation (NHPC) technical collaboration with the ONGC and with the financial assistance Ministry of Non-Conventional Energy Sources (MNES), is developing the Tattapani Geothermal Field for tapping the electric generation for 5 MWe capacity besides various direct heat applications. The project is likely to be operative early next year. This will also lead to developing other promising geothermal sites like Puga and Manikaran.

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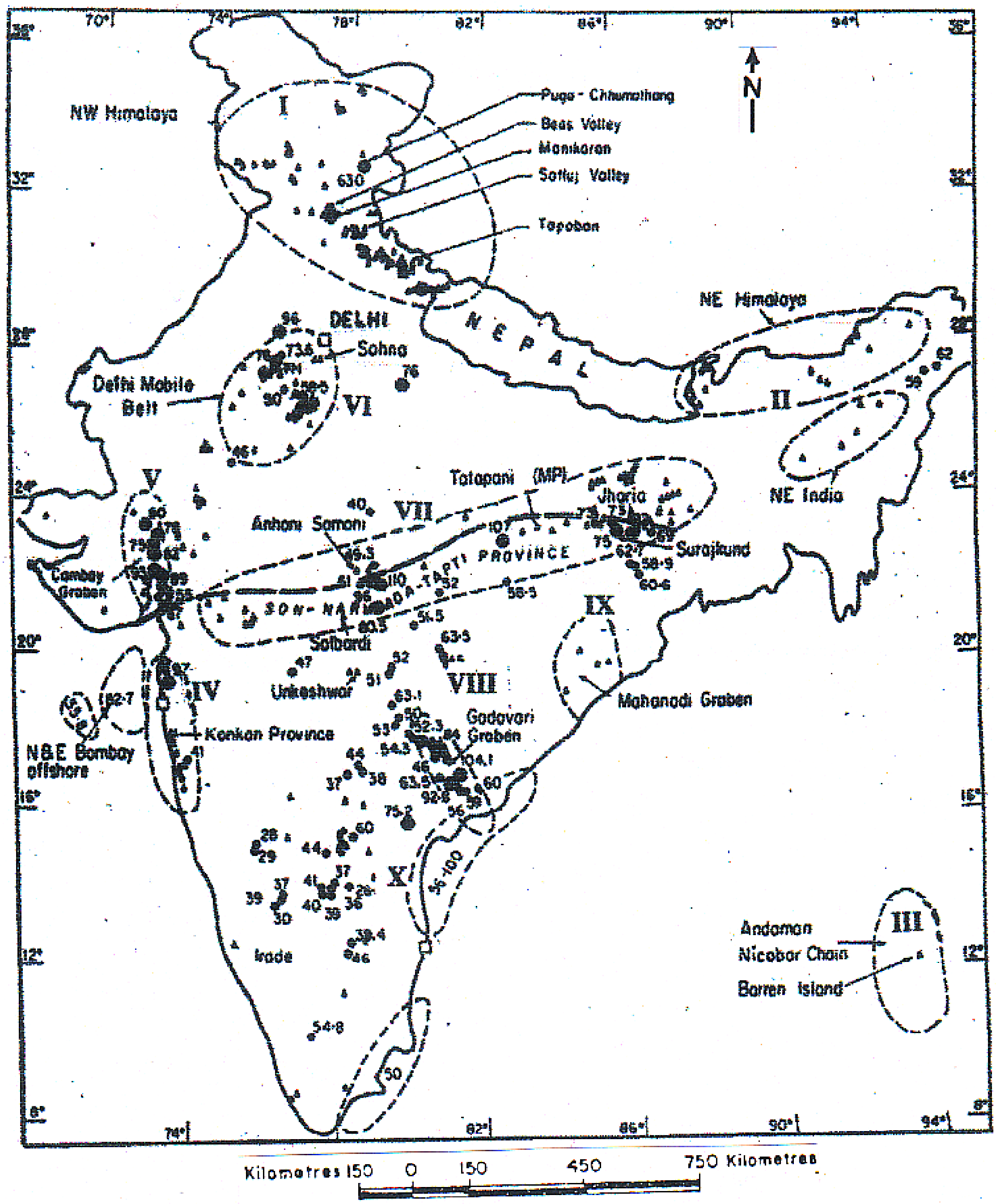

Fig.1 Geothermal provinces of India and regional heat flow patterns

(Data source: Ravi Shanker *et al.*, 1992)