POTENTIAL GEOTHERMAL FIELDS IN THE CONTEXT OF NATIONAL SCENARIO ON NON-CONVENTIONAL ENERGY RESOURCES DEVELOPMENT PROGRAMME IN INDIA

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ABSTRACT

Geothermal exploration carried out by the Geological Survey of India. has generated valuable data through extensive surface geoscientific studies, backed up by exploratory drilling down to a depth of 500 m at selected localities, establishing structural, geological, geochemical, hydrological and thermal parameters of the geothermal systems, in India. These studies have established that most of the hot spring belts exist either along margins of Indian and Asian plates involved in Tertiary orogeny; or along major structural lineament-belts with active Tertiary and neotectonic reactivation manifesting increased seismicity; and also sometimes incorporating oil and coal basins.

Majority of the potential resources are of low to medium grade (60' - 120°C), but the possibility of encountering higher grade resources at deeper levels cannot be ruled out.

Computations of the magnitude of geothermal resources have indicated that they can contribute significantly to energy scenario in areas especially where full evaluation and development has been done.

1. INTROOUCTION

Percapita energy consumption in India is merely one quarter of the global average (2kw/cap) and just about half of the average of developing countries grouped together. There is urgent need to develop all forms of conventional, non-conventional and renewable energy resources for which there is ample Scope to do so in India. In order to avoid a serious energy crisis, which may take place in India by the middle of next century due to complacency, a major national effort is required to consider all alternatives. Gradual introduction of renewable energy resources in the total energy consumption systems of our country, on a long term basis, is the only sensible option Open to us (Krishnaswamy & Ravi Shankar 1982 Guha 1986).

2. PROSPECTS OF GEOTHERMAL ENERGY IN INDIA

The geothermal manifestations are not widespread in India, there being only 340 hot spring localities. with a few of them with near boiling point temperature. There exist large tracts of hot ground Waters with 15-20°C excess temperatures over mean ambient values, and high bottom hole temperatures (140°-200°C) recorded in many of the boreholes drilled in various sedimentary basins for hydrocarbon, These manifestations are localised along certain well defined and Structurally controlled Geothermal provinces (Krishnaswamy 1976). Systematic geothermal exploration carried out by the Geological Survey of India during last 15 years has generated considerable basic data to facilitate evaluation of the prospects of geothermal resources and possibility of their utilisation. Potential geothermal fields in India identified on the basis of studies carried out so far are presented in Table-1. The geographical distribution of Geothermal provinces in India is exhibited in Fig.1.

Table-1. Geothermal Provinces of India (from Geothermal Atlas of India)

Sr.No.	Geothermal Province	Locality	Temp. Gradient	Heat Flow
I.	Himalayan Geothermal Province.	i. Indus-Isungbo Suture Zone ii. Puga-Chumathang iii. Parbati valley, Satluj valley, Alakananda valley	100°C/km 60° ± 20°C/km 17±5°C/km	200 mw/m^2 130 ± 30 mw/m^2
II.	Naga-Lusai Province	Naga Lusai hill range bordering Burma	Not Available (N.A.)	70-100 mw/m^2
III.	Andaman-Nicobar Islands province	Barren and Narcondam Islands	N.A	100-180 mw/m^2
IV	West Coast Province	West coast in Ratnagiri, Raigad and Sindhudurg districts.	55' ± 5°C/km	130 ± 10 mw/m^2
V.	Cambay Graben Province	Springs located along Tertiary reactivation, oil and gas deposits	25 to 55 °C/km	130 ± 10mw/m^2
VI.	Aravalli Province	Northwest ridges of Aravalli in Rajasthan and Haryana, Neotectonic activity.	41 ± 10°C/km	100 ± 25° mw/m^2
VII.	Son-Narmada-Tapi province	Salbardi. Anhoni-Samoni, Tatapani Geothermal field.	40-120°C/km	70 to 300 mw/m^2
VIII.& IX.	Godavari and Mahanadi Provinces	Post Gondwana and late Tertiary reactivations in Godavari and Mahanadi valley.	39° ± 10°C/km	80 ± 21 mw/m^2
X.	South Indian Cratonic Province	Isolated springs in shield area	30°C/km	60-90 mw/m^2

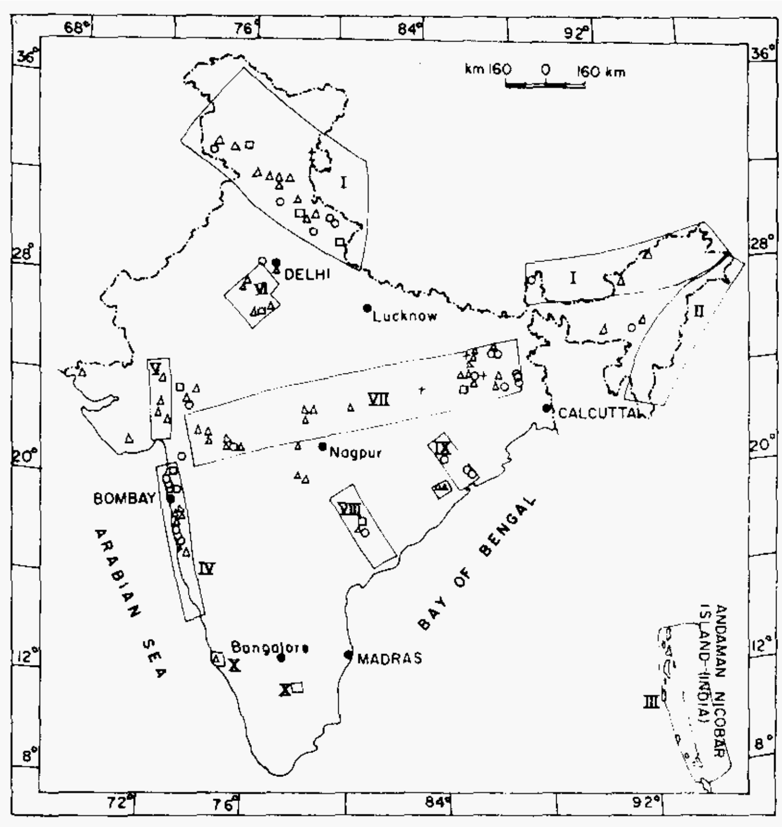

Fig. I Geothermal Provinces in India

I -Himalayan Province II. Naga-Lusai Province III. Andaman Nicobar Islands Province IV. West Coast Province V. Cambay Graben Province VI. Aravalli Province VII. Son Narmada Tapi Province VIII. Godavari Province IX. Mahanadi Province X. South Indian Cratonic Province

Geothermal Characteristics : Thermal Springs	Surface Temp.(°C)
+	75-100
o	55-75
▲	35-55
□	<35

The perusal of the Table-I would indicate that

Puga-Chumathang area in Ladakh, Tatapani-Jhor belt in M.P. and parts of "Cambay Graben" in Gujarat are some areas where reservoir temperatures in 175' ? 25°C range could reasonably be expected. While all other areas investigated, so far, are likely to produce Only low to intermediate type of resources with 110° ± 20°C reservoir temperature as indicated by silica geothermometry

The Possibility exists that these low computed reservoir temperatures may indicate Only Secondary equilibration at shallower levels: and it is possible that reservoirs with much higher temperatures may be existing at deeper levels. Such phenomenon are already known to occur elsewhere, in the world.

The maximum temperature recorded in boreholes at Puga, Chumathang, Tatapani, Manikaran, Tapovan, and Sohna are 125 - 145°,110-115°,110°,109°, 92°,55°C respectively. In Cambay graben, temperatures between 100-145°C is generally encountered in the depth range of 1500 m - 3400 metres in highly **porous** and permeable sedimentary formations. Steam blow outs have also been recorded from 1700-1950m depth range in **some** of the oil wells.

The temperature gradient of the order of 60°± 15°C/km. has been established for the geothermal belts in parts of Bihar, M.P., Maharashtra. along the West Coast of India, Gujarat and parts of Godavari valley, in the range of 300 to 500m. This would imply that the fluids with computed base temperature may be enountered in the depth range of 1.5 to 3.0 km. depending upon the local geological and geohydrological conditions. However, this presumption is yet to be confirmed by actual drilling.

The heat flow values for the geothermal belts of the Indian shield area, generally range between 70 and *130* mw/m^2, with isolated regions having values as high as 300 mw/m^2

A main reservoir of deep geothermal fluids may exist only in the fractured basement rocks underneath mare porous and permeable sedimentary basins or underneath the vast pile of flood basalt flows in the Central India.

Keeping in view the experience and examples from Europe, USSR, China and Central United states it is expected that higher temperature reservoirs are likely at depth upto 3-5 km even in India. Higher temperature reservoirs may underlie lower temperature shallower levels that nave already been established. For instance in Hungary, where hundreds of geothermal wells were producing waters of only 30°-70°C to 1 km or 80°-120°C to 2 km. depth, steam blow out took place when some of these wells were deepened to 3-4 km depth range. Similarly in Italy, where geothermal fluids in the temperature range 140-250°C were produced from the depths of 500-1000m for several decades, when drilling depths were increased to 2.5-3.5 km, high temperature (350-400°C) resources were encountered. All these deeper reservoirs were in fractured metamorphic basement rocks.

3. ESTIMATES OF MAGNITUDE OF GEOTHERMAL RESOURCES

Only shallow zones have been identified at few places like Puga, Chumathang. Manikaran, Tapovan, Jeori (Satluj Valley), Unhavre, Ganeshpuri Sativli and Tatapani where free flow of hot thermal fluids (54-128°C) have been encountered within 300 m depth range. Therefore actual reserve evaluation of each of these geothermal areas in particular and overall resources of the country has to await the completion of the exploration to at least 3000 m depth range.

An order of magnitude estimation of the available stored heat energy in the upper 3 km depth range has been attempted for about 1/3rd (113) of the known geothermal areas of India for which basic geoscientific data was available (Ravi Shankar and Krishnaswamy 1982). The value obtained was 40.9 x 10^{18} calories, which is theoritically equivalent to the heat energy that can be otained by the combustion of about 5730 million tonnes of coal or 28230 million barrels of oil. Though these figures are fairly attractive in the perspective of national energy scene and merit careful attention, they must be taken only as a broad guiding factor in making appropriate policy decisions concerning the likely role geothermal energy resources can play in meeting the future energy needs of the country once actual potential is established by deep drilling. Accordingly,decision on the scale of time,money and efforts required in exploration, development and utilisation may have to be taken. The relative role of this form of energy amongst all the other renewable sources must be carefully considered, as it is fairly suited to create decentralised centres of energy extraction around the available resource sites for area development, particularly in inaccessible hilly areas and tribal belts.

4. UTILISATION POTENTIAL OF GEOTHERMAL RESOURCES

The installed geothermal power was around 4760 MW in the world in 1985 and this figure was likely to reach 10300 mw by 1990 (Barbier, 1986). All this represent a very small fraction (<0.2) of total installed electric power capacity. But in certain specific areas its contribution is sizeable i.e from 3-18%. It may be mentioned here that a large proportion of world's energy consumption is in the form of heat rather than electricity. Thus, there is a vast scope for using heat energy available readily from solar or geothermal sources, even with existing technology, for low to medium temperature non-electrical applications. as preheated material before another source takes over to attain still higher temperature.

Thermal fluids in the range of 60-120°C can reasonably be expected to occur at many places in the Himalayan valley, Cambay graben, Tatapani (M.P.), West coast and few other areas of the Indian shield. The downhole well testing at Tatapani has indicated maxium temperature of 112.5°C in the boreholes (Pitale et.al 1994). Feasibility study for installation of a 100 KWe binary cycle pilot Dower plant is completed at Tatapani. The installation of geothermal power plant at Tatapani may open up a new avenue for electricity generation by utilisation of non-conventional energy resources in India. The possible utilisation patterns of Geothermal energy in different geographical situations are given below :-

* Tourist-cum-health resorts.
* Balneological centres and sanatorium.
* Space heating of homes, community centres, schools, primary health centres.
* Binary cycle power generation
* Refrigeration and cold storages for storage of fruits, potatoes; ginger and other perishable produce during periods of snow fall, rain/land slides which block the free flow to market areas.
* Setting up of plants for drying, processing, preserving and canning of fruits, fruit products.
* Public health and sanitation projects to facilitate biodegradation, even in extreme cold and humid conditions, of human-animal excreta, farm and forest waste in community biogas plants or methane producing pits.
* Large scale development of sheep breeding farms, animal husbandry. poultry and fish farming; wool processing, carpet-shawl-garment manufacturing centres.
* Samll scale industries based on farm and forest produce etc.
* Low temperature geothermal waters could be used for de-icing, soil warming and developing green houses. Seed and plant nurseries are the other uses. Effluent geothermal water can also be used for irrigation purposes.

The direct heat utilisation possible in these geothermal provinces is summarised in Table 2

Table-2

	Province	Surface/Wellhead Temperature	Uses
1.	Himalayan Geothermal Province	42°-125°C	Binary cycle power plant. electricity generation, space heating, primary health centre, tourist attraction place including sauna bath centre, Green housing, drying of fruits, animal breeding, fish farming.
2.	Naga-Lusai Province	35°-54°C	Food processing, animal farming, metal Dart washing, bio gas processes, mushroom cultivation, soil warming, furniture and leather industry.
3.	West Coast province	38°-72°C	Refrigeration and storage, mushroom cultivation. fish farming, fruit processing, sugar extraction and molasse industry, soft drinks industry and tourism.

4.	Cambay Graben area	44°-46°C	Drilling fluid, mushroom culture. metal part washing, furniture and leather industry, bio gas production, soft drink industry.
5.	Aravalli Province	30°-46°C	-do-
6.	Son-Narmada Province	42°-100°C	Binary cycle Power plant, electricity generation, coal drying, fruit and vegetable processing. bleaching and cooking, soil warming, Pasteurisation, concrete block curing, sericulture and animal farming, rice mills, soft drinks, leather industry, furniture industry, tourism, health resort, spa. sauna centre and skin-cure centre.
7.	Godavari-Mahanadi Province	30°-62°C	Coal washing, acqua culture, furniture and leather industry.

5. CONSTRAINTS IN EXPLORATION AND DEVELOPMENT

The constraints affecting the current exploratory efforts are mainly in the field of deeper drilling, certain laboratory inputs, inadequate facilities for geophysical data acquisition and processing and modelling of geothermal regimes for guiding exploration and development.

Besides, lack of proper linkage at appropirate levels between exploration. development and eventual utilisation agencies retard the exploration activity.

5.1. Technological and selected Reservoir studies:

Drilling

IT IS THEREFORE ESSENTIAL TO UPGRADE THE DRILLING EQUIPMENT AND TECHNOLOGY FOR DRILLING DEEP GEOTHERMAL EXPLORATORY AND DEVELOPMENTAL HOLES UNDER HIGH PRESSURE AND TEMPERATURE CONDITIONS. UNDP could assist in this area.

Geophysical Studies

Major constraints felt *so* far in the field of geophysical technicques as applied to geothermal studies is lack of equipment for deep penetration surveys to locate deep conductive zones corresponding to geothermal reservoirs (like AMT units capable of tensor measurement; MT unit): also Suitable equipment capable of being useful in rugged mountainous areas. Besides, lack of proper data processing facilities both in field and headquarters affect the desired quality of interpretation. The absence of suitable laboratory equipped to measure the physical properties of rocks/cores was felt in simulating the results of the field investigation into possible geological models of the geothermal regimes in an investigated area. The available facilities for heat flow studies are also too meagre and need to be augmented. Creation/augmentation of facilities for rapid and intensive processing of voluminous geophysical data being generated during the course of the geothermal exploration cannot be over-emphasised.

5.2 Laboratory inputs

Isotope studies:

The stable isotope analysis of O, H in water samples is done by Bhabha Atomic Research Centre (BARC), Bombay. Samples collected all over India are analysed at BARC putting heavy work load on the laboratory. Thus, to augement the stable isotope stuides, establishing a separate laboratory in GSI is essential. Such a facility can also cater to requirements of environmental, glaciological, quarternary geological and mineral exploration work in India.

Helium measurements

Study of gases associated with geothermal fields, helium and helium isotopes is important for understanding the nature and depth of heat source. Such studies can be undertaken in BARC and National Geophysical Research Institute NGRI in India. More facilities need to be created to undertake analytical work concerning helium. The detection of helium susequent to the earthquake at Latur also warrants stress on helium isotope studies to decipher active geothermal fields in India.

6. FUTURE STRATEGIES

* Policy decision be taken at the Government level to support the exploration and development of geothermal resources at par with the other renewable resources like solar and biogas. Without this no other renewable energy resource has any chance of becoming a viable proposition.

* Deep drilling (upto 3 km) be undertaken in promising areas, already Short listed (table-1), to identify geothermal reservoirs and establish their parametres.

* Promote utilisation of low-medium enthalpy fluids from shallow reservoirs.

* To prepare thematic maps concerning geothermal regime of shallow crust underneath Indian sub-continent for better understanding of the geodynamics, tectonics and their relationships to known geothermal and mineralised (including coal & hydrocarbon) belts. It may possibly lead to new finds of mineral deposits generally associated with geothermal systems eg. Au, Ag, Sb, As, Hg, Cu, Li, Ce. Rb, F, S, He and evaporites.

7. CONCLUDING REMARKS

In conclusion it may be said that though geothermal energy may not play a major role in our total energy production or consumption scenario immediately, it can play a significant role in many areas in near future, especially when other energy options shrink. In the background of this energy scenario futher course of action for development of potential geothermal fields is being taken. Besides, Geothermal studies have another dimension. It may lead us to better understanding of our geological-tectonic-magmatichistory, operating geodynamic processes within crustal/sub-crustal levels which control the distribution of geothermal and mineralised belts, organic energy resources and seismic zones.

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REFERENCE

Ghosh S, and Dasgupta S. (1991) (editors) Geothermal Atlas of India, *Geol. Surv. Ind. Sp. Publi. 19* pp 1-10.

Guha S.K. (1986) status of exploration for geothermal resources in India, Geothermics V01.15 N0.56 PP665-675.

Krishnaswamy V.S. (1976) A review of Geothermal Provinces and their potential for energy utilisation Proc. 2nd *UN* symposium on development and use of Geothermal resources, San Francisco, *1975,* Vol. PP-143-156.

Krishnaswamy V.S. and RaviShankar (1982) scope of development, Exploration and preliminary assessment of Geothermal resources Potential of India, *Rec. GSI, 111 Pt.II*, pp 17-40

Pitale U.L., Karve A.K.. Sarolkar P.B.(1994)- Geothermal potential along Gondwana margins in Central India, Procee. *of IXth* Int. Gondwana *Sym.* Hyderabad, India (in press).

Ravishankar (1987) Status of Geothermal exploration in M.P. and Mahrashtra. *Rec. GSI. Vol. 115 pt.6* Pp-7-29