CHAPTER – I
INTRODUCTION
Geothermal energy is one of the so-called alternating energy sources whose use does not yet rival that of the main energy sources, like oil, natural gas, coal, hydropower etc. However, there is abundant geothermal energy in the earth’s crust, which has the potential to make an impact on the energy economics of many countries throughout the world.

Geothermal systems are referred to as the potentially useful energy resources. The energy is stored here as hot water or steam under favourable geological situations, within the top few kilometres of the earth’s crust. Hot water and/or steam is released in the form of hot-springs at the earth’s surface.

It may also be considered as an area of high heat flow which may manifest itself in any of the following forms:

(i) Steaming ground;

(ii) Wet geothermal system;

(iii) Hot-dry rocks systems; and

(iv) Geopressuries systems

Wet geothermal systems, characterised by the thermal springs are dominant among the different hydrothermal manifestations. The occurrence of the thermal spring is a coincidence of many factors such as heat source, water source, and good vertical and horizontal conduits.

In general, the geothermal systems are of three major types: Hot-igneous, conduction dominated, and hydrothermal type. The last system consists of high temperature water and/or steam, which are stored in porous and permeable
reservoir rocks. Because of the convective circulation of water and/or steam through faults and fractures, the heat is transported to near the earth’s surface. Hot water reservoirs are called “liquid dominated” whereas the reservoir containing steam are referred to as “vapour-dominated”.

The Dhule and Jalgaon district of Khandesh region of Maharashtra state hosts seven hot springs which are situated in between the southern foot hill margin of the Satpura hills and northern bank of the Tapi river. The belt of these hot springs extends over a length of 160 km and a width of 50-60 km.

Khandesh thermal springs are perennial, liquid dominated and discharge thermal waters through either faults or dykes in the Deccan volcanic terrain at a constant rate through out the year. Regular observation indicates that the one of these i.e. Kundva also releases gas bubbles. All of these are low to medium enthalpy springs with the surface temperature varying from 38°C to 60°C and with a discharge rate of 10 l/min to 42 l/min (14400 l/day to 60480 l/day).

Thermal springs discharging water of low to medium enthalpy have been extensively tapped as non-conventional energy sources in many countries viz. New Zealand, United States of America, Japan and United Kingdom. India has yet to start utilisation of its geothermal energy resources as a substitute to the commercial energy resources. Therefore, in order to establish the feasibility of utilisation of thermal spring water of Khandesh region as alternate source of energy, they are evaluated in this study in terms of hydro-geochemistry and geothermometry.

1.1 Location and Accessibility

Geographically all the thermal springs of Dhule and Jalgaon district fall in the Khandesh region (Tapi valley) flanked by the Satpura hills in the north and the Tapi valley in the south. One hot spring namely Indve, however, is located south of the Tapi river valley. Covering a large area about 9000 sq. km these springs are
limited within 74° 02’ to 75° 45’ longitudes and 21° 03’ to 21° 37’ latitudes (Fig. 1.1, Tab. 1.1).

All the seven thermal springs are situated at the foot hills of Satpuras except the two namely Indve and Khadgaon, which are located within Tapi Alluvium.

Out of the seven, four thermal springs are approachable through motorable roads throughout the year from the district headquarters. The remaining three, viz. Kundva, Ramtalab, and Nazardeo are approachable only in the summer and winter months (Fig. 1.1).

1.1.1 Thermal Springs of Dhule District

Kundva hot spring is situated at the foothills of Satpura range, at the height of 240 m and unapproachable by road. This is located at a distance of about 140 km NW of Dhule and 18 km of Akkalkuwa, which is well connected with other major cities of Maharashtra, and Gujarat (Fig. 1.2).

Anakdeo thermal spring comes out at the height of 260 m. It is located 14 km away from Shahada on Shahada-Dhadgaon road (Fig. 1.2).

Indva hot-spring, which is situated in the south of the Tapi at the height of 248 m, is connected by road from Dondaicha, 52 km far from Dhule.

1.1.2 Thermal Springs of Jalgaon District

Unabdeo thermal spring is situated 6 km north of ‘17 km mile stone’, near Adavad on ‘Chopda-Yaval State Highway’. The height of its release is 242 m from the MSL.

Ramtalab and Nazardeo are also situated at 242m elevation north west of Unabdeo thermal spring, and can be approached on a motor bike in dry season.
Khadgaon hot spring is 17 km away from Jalgaon, and well connected by roads (Fig 1.3).

1.2 Geography

Most of the thermal springs of the Tapi valley are located in a nala or a river bank nearly at the same height from mean sea level. Only one thermal spring Nazardeo is situated in a riverbed.

Tanks have been constructed around Kundva, Anakdeo, Indva, and Unabdeo thermal springs while others viz. Ramtalab, Nazardeo, and Khadgaon are in natural condition. At three hot springs namely Indve, Anakdeo, and Unabdeo the place of emergence of water is not visible. No sinter or other types of deposit are seen near any spring.

1.3 Regional Geology

Khandesh thermal springs are located in the Deccan volcanic terrain. Blanford (1886) described a general account of regional geology of the area between Tapi and Narmada River valley, which consists mainly of basalts.

The alluvial deposits are found in the Tapi valley region. All the three thermal manifestations of the Dhule district are controlled by dykes, whereas, all the four thermal springs of Jalgaon district are discharging water through faults or other weaker planes. The detailed geology is described in chapter-III.

1.4 Drainage and Drainage Patterns

The Tapi river which drains towards west is the main river of the area joined by three tributaries: Gulnadi, and Amaravati from north, and Vaghur from south. Nazardeo hot spring is located along the Gulnadi river while Indve and Khadgaon are located along Amaravati and Vaghur rivers, respectively.

Mainly four types of drainage patterns: namely rectangular, dendritic, subdendritic, parallel and subparallel can be distinguished around the thermal
springs of the area. Rectangular and dendritic patterns are predominant in the scarp face and back-slope regions. However, in the regions of pediment and valley-flat subparallel arrangement of drainage pattern is conspicuous. Parallel drainage patterns may be seen in the alluvial fill valleys.

The Kundva hot spring falls in rectangular pattern (Fig. 1.4), Anakdeo in dendritic pattern (Fig. 1.5), Indve, Khadgaon, and Unabdeo in parallel to subparallel patterns (Fig. 1.6, 1.7), and Ramtalab and Nazardeo in subdendritic pattern (Fig. 1.8).

The study of drainage pattern facilitates identification and/or delineation of several joints and faults in the area.

1.5 Geomorphology and Land forms

The southern part of Satpuras is a hill-range trending in ENE-WSW direction with linear distribution of peaks. Well-developed valley slopes occupied by the sediments of the Tapi river system are seen in the south of this range.

Regionally, the hill range assumes an arcuate shape (convexity pointing south-west). A typical land form has usually developed in homoclinal mountain ranges in semi-arid regions which received monsoonal rains (Fig. 1.9). Locally, some very characteristic landforms likeuesta and hogbacks are well developed in Unabdeo, Nazardeo, Kundva, and Anakdeo areas (Fig. 1.9).

1.6 Climate and Rainfall

Climatically, the Khandesh region falls in sub-tropical zone where the average temperature ranges between 44.5°C (maximum) and 18.5°C (minimum) in the summer season, and between 32.6°C to 5.5°C in winter months.

Mainly monsoon rain is experienced in this region during June, July, and August (SW monsoon). A short spell of rain for a few days during November and
December is also received (SE monsoon). The average rain fall in Dhule district is 675 mm / year and in Jalgaon 740.5 mm / year.

1.7 Scope of the Present Study

There are so many hot springs distributed globally and tapped in the developed countries like New Zealand, Italy, USA, Japan, Russia, Britain. In developed countries projects are already working and producing electricity to satisfy small scale industrial activities like dye manufacturing, domestic purposes for space heating, water heating, fruit drying etc. The developing countries are also trying to tap geothermal energy.

In India, there is a vast scope of geothermal energy and as per an estimate up to 10% of the total requirement of electricity in 2000 AD nearly 10% may be contributed by tapping the hot springs of India. Ravishankar et al. (1987b) opined that 130 out of 340 hot springs could be utilised for non-electric energy applications to substitute 10,000 MW of power in India.

The present work aims at the following objectives:

(i) To evaluate the major and minor–ion chemistry of thermal, ground and surface water of the region and their relation with each other.

(ii) To find out certain properties of the thermal spring reservoir by chemical means and identifying the chemical processes that lead to the evolution of thermal spring water.

(iii) To find out the applicability of the conventional geothermometry to the Tapi basin thermal springs and to calculation the base temperature of the reservoir.

(iv) Assessing the geothermal energy to the best use for the local inhabitants of this region.
(v) To correlates with the neotectonism activities in the Narmada-Tapi-Son lineament.

1.8 Historical Résumé

1.8.1 Indian Thermal Springs

In India, the study of the different thermal springs commenced as early as 1862 when Schlaginwelt compiled a list of 99 thermal springs. Later, Oldham and Oldham (1882) gave a comprehensive account of the location of the thermal springs of India. Since then, it was continued by various workers including Holland (1905), Latouche (1918), Heim and Gansler (1939), Pranavanand (1949).

In the recent years Ghosh (1954) carried out investigation in a number of thermal springs in Bihar, former Bombay State, Madhya Pradesh, Punjab, Rajasthan, Uttar Pradesh and West Bengal. Later, Chatterji (1958) reported the physical properties of hot springs in Bombay, Bihar, West Bengal and suggested that there is a wide scope in utilising these thermal waters, and Guha (1976) deliberated on prospects of geothermal springs, as an alternate source of energy and opined that these springs can be utilised by industries that require low enthalpy fluids.

The first systematic study on the genesis of hot springs of Rajgir-Munghyr area, in Bihar was done by Guha (1969-70). In 1965 Krishanaswami analysed the setting of 23 thermal springs of the NW Himalayan and grouped them on a geochemical basis.

Realising that India has a vast potential in geothermal field the Geological Survey of India and Government of India constituted a “Hot-springs committee” in 1966 for its development. In 1968, the field parties of this committee, led by Krishanaswamy and Baweja, Geological survey of India studied some hot springs. The promising among these were Puga in Jammu
and Kashmir, Manikaran in Himachal Pradesh, Sohna in Haryana. West coast belt in Maharashtra and Tattapani in Madhya Pradesh, were recommended for power generation. In 1973 Geological Survey of India started systematic geothermal exploration at Puga. Since then this organisation has been handling 6 major multidisciplinary geothermal exploration projects viz. the Puga-Chumathang Geothermal Project in Jammu and Kashmir, the Parvati valley, the Beas Valley and the Satlaj Valley Geothermal Projects in Himachal Pradesh, the Sohna geothermal project in Haryana and the Alaknanda valley geothermal project in Uttar Pradesh.

Geophysical surveys around some of the Indian thermal springs were carried out by the scientist of the National Geophysical Research Institute. Gupta and Sharma (1977) carried out shallow thermal surveys and heat flow studies and to see the direction of movement of the thermal water in the shallow levels. A 100 m bore hole at Akloli thermal spring gave a high geothermal gradient of $5.9^\circ$C/100 m and a 'heat flow value' (hf) of 97 Mw/m². Heat flow values and the thermal gradients for springs occurring in the equivalent zone and in the Unabdeo were also reported.

Ravishankar (1983) documented tectonic, surface and subsurface landforms of Tapi valley geothermal region; documented the preliminary observations including the chemical characteristics, geothermal gradients and reservoir temperatures of thermal springs of India. Ravishankar (1987), measured the heat flow values in Tapi valley region using convensional and geochemical methods besides the temperature gradient (1988).

Muthuraman (1987) carried out experiments between on dilute (1% to 3%) sea water and basalts and noted enrichment of Ca and depletion of Mg in the resultant solutions.
Muthuraman and Mathur (1981) initiated experimental water/rock interaction studies in India. Based on the above Muthuraman (1986) gave a detailed account on the chemical reservoir temperature of some of the Konkan coast thermal springs. He (Muthuraman op cit.) opined that there is a possibility of striking enormous volumes of medium enthalpy fluids around Ganeshpuri area, which can be used for non-electric applications. Chandrashekaram et al. (1989,1992,1993) conducted water/rock interaction experiment work to understand the chemical evolution of thermal springs along the west coast and Narmada lineament. Their investigations reveal that the present day seawater does not seem to be the source of salinity. Further a possibility that the connate water of marine origin is present in the volcanics and is responsible for salinity in Konkan thermal water should not be over looked.

Muthuraman et al. (1982-84) carried out systematic preliminary investigation for the geothermal systems of Tapi valley. Venkata Rao et al. (1996) documented the Geophysical evaluation of structures and geothermal Regime in Tapi valley.

The first mineral fluid interaction and chemical equilibria for the prominent geothermal system in India was done by Saxena (1996).

1.8.2 Thermal Springs of the World

There is immense scope of geothermal energy and there is a lot of thermal springs world over. The main countries where the major work has been done are: New Zealand, Italy, Japan, United States of America, Russia, and Britain. These countries are exploiting their thermal resources for small scale industries successfully. The leading researchers, which have carried out work on these hot springs are: Ellies (1960), Mahon (1965), Seward (1968), Browne (1970) in New Zealand, Fournier (1950), Trensdel (1970),

Most of the geothermal systems of the world are located along the subduction zones, where the heat source is in near vicinity. Acharya (1989) concluded that the geothermal energy of Japan has no relation with the volcanic activity although it is confined in the zones of extension, and discontinuities of the underthrusting plates. These observations were based up on (i) the chemical data location of the thermal springs; (ii) reservoir temperature; (iii) heat flow values, discharge rate and frequency of volcanic activity. His studies are aimed at locating favourable zone for developing geothermal fields in Japan.

Geothermal systems are the components of the hydrothermal systems, the study of which helps to understand the hydrothermal process and ore formations (Fournier 1983).

Craig (1961) based on his isotope studies opined that most of geothermal waters are nothing but the recycled meteoric water.

Though the role of magmatic water, connate water, and seawater is insignificant in most thermal springs of the world, it becomes dominant source for thermal waters in some places. Sakai and Matsuvaya (1994) explained the role of sea water in the coastal geothermal system of Japan. Similarly, the role of seawater on the Reykjanes spring of Iceland is brought out by Amorsson et al. (1982).

Though thermal water is mostly recycled meteoric water, chemistry of this water differs from the meteoric and other surface waters. The various
processes that effect the chemistry of water are discussed by Ellis and Mahon (1977). Giggenbach (1977) noted that dominant reactions control the chemistry of fluids in New Zealand geothermal systems. These factors reflect stepwise conversion of thermodynamically unstable minerals through a series of intermediate and metastable phases, to stable minerals at temperatures ranging from 50°C to 300°C.

Laboratory experiments are being carried out to simulate the natural set-up of the rock-water interaction in order to understand the chemical processes occurring during interaction. The results obtained are used to interpret the variations of natural system based on such experimental results. Ellis and Mahon (1964) reported the source of New Zealand thermal system as meteoric water and ruled out the role of magmatic water in this system. Mottle and Holland (1978) conducted experiments using basalts and sea water to understand the nature of weathering of the ubiquitous basalts by the sea water. Savage (1986) conducted experiments on granite and water at elevated temperatures and pressures. Since the simulation of the natural set-up in the laboratory is tedious, no true simulation was found possible. The various discrepancies between the experimental conditions and natural set-up are explained by Grandstaff (1989).

The interaction experiments of meteoric water with the host rock has not been carried out extensively. The interaction of meteoric water with the sandstone and carbonate sedimentary rocks also results in enrichment of Ca and depletion of Mg. In fact, most of the waters of sedimentary basins are of this type (Barnes, 1979).

Much work has been done on silica dissolution and it is found that the dissolution of silica is controlled mainly by temperature, and a particular species of silica will be in saturation for a particular range of temperatures. The rate of solubility of silica increases with temperature. At low
temperatures, the silica in water is controlled by the dissolution of silicates rather than the species of silica (Morey et al. 1962; Hawkins and Ray 1963).

Fournier and Truesdell (1973) and Fournier (1977) used the temperature dependent solubility of quartz and temperature dependent ion exchange reactions between Na, K, and Ca feldspars with the fluids to estimate the reservoir temperature. The external influence on the system such as ‘dilute cold water mixing’ and its effects on the reservoir temperatures are also brought out in detail by these authors. A set of empirical equations is provided as chemical thermometers and these are widely used in unexplored geothermal systems of similar kind, to estimate the reservoir temperature. These equations were used in many geothermal systems such as Yellowstone national park to find out the chemical analysis of the surface thermal waters (Fournier, 1989).

The estimation of reservoir temperature using these thermometric equations will be reliable if the geological set-up of the area under study is comparable to those, based on which the geothermal system had been evolved.
<table>
<thead>
<tr>
<th>S. No.</th>
<th>Name of Hot Spring</th>
<th>Location</th>
<th>Toposheet No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>KUNDVA</td>
<td>21° 30':74° 03'</td>
<td>46 K/2</td>
</tr>
<tr>
<td>2</td>
<td>ANAKDEO</td>
<td>21° 42':74° 27'</td>
<td>46 K/6</td>
</tr>
<tr>
<td>3</td>
<td>INDVE</td>
<td>21° 13':74° 27'</td>
<td>46 O/8</td>
</tr>
<tr>
<td>4</td>
<td>UNABDEO</td>
<td>21° 16':75° 26'</td>
<td>46 O/7</td>
</tr>
<tr>
<td>5</td>
<td>RAMTALAB</td>
<td>21° 17':75° 24'</td>
<td>46 O/7</td>
</tr>
<tr>
<td>6</td>
<td>NAZARDEO</td>
<td>21° 18':75° 23'</td>
<td>46 O/7</td>
</tr>
<tr>
<td>7</td>
<td>KHADGAON</td>
<td>21° 04':75° 42'</td>
<td>46 O/12</td>
</tr>
</tbody>
</table>

Table 1.1

Location of Thermal Springs

DHULE DISTRICT

JALGOAN DISTRICT
FIG. 1.2: LOCATION MAP OF DHULE DISTRICT HOT SPRINGS

SCALE: 1:20,000
DRAINAGE PATTERN OF ANAKDEO (DARA) AREA

FIG. 1.5

DIRECTION OF JOINTS

SCALE 1:20,000
1CM: 200MTS
FIG. 1.7: DRAINAGE PATTERN OF KHADGAON AREA
DRAINAGE PATTERN OF RAMTALAB-UNABDEO-NAZARDEO AREA

FIG. 1.8

DIRECTION OF JOINTS

SCALE 1:50,000
1 CM: 500 MTS

0 500 1000 1500 2000 2500
FIG. 19: MAP SHOWING THE LANDFORMS IN TAPI BASIN

INDEX

- HOT SPRING
- DIRECTION OF DRAINAGE SHIFT
- THE CUESTA SLOPE
- THE FREE FACE
- THE TRANSITIONAL SLOPE
- THE HOG BACK HOMOCLINAL RIDGE
- THE PEDIMENT SLOPE
- THE VALLEY FLAT
- BURIED CHANNELS
- PHOTO DIPS / INFERRED FAULT
- BACK SLOPE REGIONAL
- ESCARP FACE
- HOG BACK
- PEDIMENT UNIT
- VALLEY SLOPE
- VALLEY FLAT UNIT

SCALE 1 2 Kms

MODIFIED AFTER RAVISHANKER