CHAPTER III
GEOLOGY
3.1 Regional Geology

The Tapi (Tapti) river valley, which extends over 250 km from Burhanpur to little beyond Jhiria in Dhule district, is flanked by Satpura ranges in the North and the Ajanta ranges in the South. Both these ranges are made up of basaltic flows of the Deccan trap. Most of the thermal springs of the area are located at the southern foothill of the Satpura ranges i.e. also the northern side of Tapi river valley. Blanford (1886) has given general account of geology of the region between Tapi and Narmada valley.

The Geological Succession of the area as established by Ravishankar, (1983) is given in the table 3.1.

3.1.1 The Deccan Traps

The exposures of Deccan traps are essentially restricted to the area South of the Tapi river as the northern stretch is covered by thin alluvium of Quaternary age resting on the southern foothills of the Satpura hills. However, intermittently crops of basalt are seen in the alluvial tract.

The basaltic flows are highly fractured and jointed. Two sets of dykes along faults, trending ENE-WSW to ESE - WNW and NW-SE to NE-SW are noticeable. The traps are tilted along the faults with dips of varying magnitude (up to 70°) and directions. The lower flows exposed at the foot hills of the Satpura hills belong to ‘compound pahoehoe’ type whereas those at the higher levels to the alternating sequence of ‘a a’ or ‘pahoehoe’ types (Ravishankar and Dubey, 1984).
It is important to note that the 70 m thick ‘compound pahoehoe’ flow characterised by phenocrysts of feldspars (up to 5 cm in length, photo. 6) are exposed at the height of 232 m from mean sea level makes the upper limit of the hot springs of Tapi valley region. This flow is best exposed 1 km north of Lasur (21° 18'; 75° 25') near Nateshwar temple, 1 km north of Unabdeo hot spring (21° 16'; 75° 25') and near Anakdeo hot spring (21° 42'; 74° 25').

3.1.2 Quaternary Alluvium

Quaternary Alluvial deposits of varying thickness within a 55km wide belt occupy the western and southern parts of the area. They lie unconformably over the basaltic horizons. The maximum reported thickness of Tapi alluvium is 250 m (Ray, 1961 and Prasad, 1979).

The Quaternary Alluvial deposits of Tapi valley have been subdivided in two parts based on degree of compassion.

(i) Older Alluvium

The Older Alluvium consists of indurated layers of pebbles and boulders of basalt, intercalated with hard compact clay and sand beds. These beds are conspicuously seen in the Tapi valley (Photo. 14).

(ii) Newer Alluvium

The Newer Alluvium unconformably overlies the Older Alluvium. It however, consists of loose, unindurated sequences of interlayered clay and sand beds with occasional ‘kankar’ pebbles, cobbles, and boulders of basalt, and also pebbles of Older Alluvium found along the Recent and the Palaeo-drainage lines (Photo. 14).
3.2 Regional Tectonism

The entire length of the Tapi Valley from Khadgaon hot spring (21° 04'; 75° 42') in the east, and Kundva (21° 38'; 74° 03') hot spring in the west is covered by a belt of thick deposits of alluvium as discussed above. The belt continues up to south of Satpura Hills where it rises abruptly and remains confined into a narrow zone running parallel to the foothill of the Satpura ranges.

Ravishankar and Dubey (1983) mentioned that the area has undergone intense tectonism and as a result several fault bound blocks moved both laterally and vertically with respect to each other (Fig. 3.2). The enormous thickness of alluvium suggests narrow depression limited by E-W trending fault on either side. This depression is occupied by the cross faults trending NNW-SSE to NNE-SSW. Disconnected exposures of the marker flow i.e. compound pahoehoe along the foothill of the Satpura indicates lateral shifts along these cross faults.

Geophysical study carried out by Mutta and Raghunath Rao (1983-84, vide, Dubey et al. 1987) along three sections in the area established the interferences between different lithounits and also to delineated precisely the faults inferred on the basis of geological observations as show in Fig. 3.3).

The most prolific N-S fracture system in the Western Ghats gradually becomes less prominent and disappears in Tapi valley zone where their E-W/ENE-WSW trends become very prominent as revealed in satellite imageries (Bhate, 1983 and Sharma, 1985, vide, Dubey et al. 1987). The Main Tapi North fault extends from north of Shahada to north of Burhanpur in a curvilinear manner with a general E-W trend and marks the boundary between Satpura ranges and the Tapi alluvium. In the west, after a little shift, it is traceable from east of Virpur (near Anakdeo hot spring) in the east to Sagbara (21° 35': 73° 47') in the west over a distance of about 100 km, having ENE-WSW trend. All the hot springs (except Indve) are located near the North Tapi fault (Fig. 3.4).
Ravishankar (1987) suggested that the Tapi valley is an actively subsiding graben with Satpura forming the corresponding horst. The Tapi graben is marked by several E-W trending faults aligned blocks, which are offsets, by N-S to NNE-SSW trending cross faults. Surface discharge of thermal springs in this graben is controlled by ENE-WSW trending shears/faults and all the hot spring areas in Tapi valley are interconnected through a set of deep faults. These faults or fault bound blocks show evidences of Quaternary movements.

Bouguer Gravity map of Tapi valley (Fig. 3.5) reveals a low gravity anomaly from Khadgaon to Nazardeo hot springs. All hot springs of the Jalgaon district are located within this zone.

The magnetic data has revealed a ‘NW-SE trending feature’ across the Tapi Valley, that coincides with the margin of gravity low anomaly as discussed above (Fig. 3.6).

The deep resistivity sounding survey (DSS) in the Tapi valley reveals that the basement is at 1100m depth in western part, and at 400-500 m depth in the eastern part. The central part of Tapi valley area (i.e. from Chopda in the west to Kundva hot spring in the east) in between these, however, did not indicate any high resistive layer up to depth of 1.5 km. This may be due to the presence of a thicker sediment horizon in this section or to faulting along NW-SE trend as suggested by the gravity and magnetic surveys (Venkatarao, 1996). The number of evidences of neotectonic activities in the area suggest that the older tectonic grains have been rejuvenated from time to time.

3.3 Local Geology

Twenty-three basalt flows were identified in the area having a cumulative vertical thickness of 380m. Based on their lithological and textural characteristics they could be grouped into five mapable stratigraphic units (informal). Correlation of flows was done on the basis of their physical characteristics such as type of
weathering and soil, pattern of jointing, size and frequency of phenocrysts, presence of vesicles, type of secondary fillings, break in slope etc. The contact between two successive flows have been deciphered by the presence of red boles. (red and weathered techylitic basalt) green boles (green weathered techylitic basalt) fragmented material, emergence of springs, sudden change in megascopic characters of flows etc. The attitudes of flows around the hot spring vary considerably from 7° to 35° in multiple directions influenced by the faults. The stratigraphic sequence of these flows in the area is given in the table 3.2.

3.3.1 Group I

The lower most basaltic flows mapped in the area are placed in Group I, and seen along the Satpura foot hills where they are not covered by alluvium. The best exposure are seen near Vardi village (21° 15′; 75° 24′). The lower two (flow 1 and 2) show almost non-porphyrritic nature whereas the third (Flow 3) shows sparse to moderate distribution of phenocrysts. The other fine-grained flows (Flow 4 to 8) are seen along the highly dissected sloping terrain around the Ramtalab and Unabdeo. The fourth flow of this group shows moderate porphyritic texture with needle shaped phenocrysts of grey feldspar embedded in a medium grained ground mass. The top most flow (Flow 8) of this group is the marker “compound pahoehoe flow” characterised by giant size phenocrysts (up to 5 cm in length) of grey feldspars as mentioned earlier also. It is by far the most important marker horizon and facilitates mapping of boundary between flows of the Group I, and II. It weathers into light greyish to whitish material with small pellets of irregular shapes and sizes and disintegrates into small pieces on breaking. The top and bottom of this flow are at an elevation of 390 and 320 m, respectively.
3.3.2 Group II

The flows of Group II (Flow 9 to 15) are sparsely to moderately porphyritic megascopically. They occupy steep slope and scarp portion of the main hill ranges facing south and west. Most of these flows fragmented, top elongated and twisted vesicles filled by secondary minerals like silica, zeolites, calcite, and green earth. The sparsely porphyritic members of this group (Flow 9, 12, and 14) show spherical weathering.

3.3.3 Group III

This group is entirely composed of pahoehoe flows and occupies the highest reaches of the hill ranges. It is dark grey, compact, sparsely porphyritic to non-porphyritic and abounds in bugs and cavities filled by quartz, agate, chalcedony and at times zeolites also. Due to differential weathering of these compound flows very characteristic and gently undulating plateform like surfaces have developed. On the southern slopes of these ranges flows of ‘Group III’ crop out. Their top is seen at 574 m that continues all along the dip slope up to the bed of the Gulpadi river, showing a dip of 7° northwards.

3.3.4 Group IV

The fourth group of the flows is represented by a sequence of four flows (Flow 17, 18, 19, and 20). The lower three flows (Flow 17 to 19) are moderately prophyritic whereas the fourth one (Flow 20) is dark grey, compact, and non-porphyritic in nature.

3.3.5 Group V

This group is represented by three flows (Flow 20 to 23) they show moderate distribution of phenocrysts of grey feldspars in an aphanitic and medium grained groundmass. This flow also dips by 7° southwards.
3.3.6 Intertrappean Beds

Several intertrappean beds are visible in vertical sections within the basaltic flows. The thickness of each bed varies from 1 to 4 m. They are found sandwiched between flow 17 and 18 belonging to ‘Group IV’, which are exposed about 3 km NNE of Unabdeo hot spring. It consists of brown to grey coloured silicified ash and tuff with thin cherty and sandy laminations.

3.3.7 Kundva Hot Spring

The Kundva hot spring emerges from the southern margin of a basic doleritic dyke trending ENE-WSW exposed at the foot of the steeply rising slope of the Satpura hills. The dyke is highly fractured and jointed. It is about 6 m wide, cutting across the country rock of basalt. Four basaltic flows have been recognised between 232 to 355m above the ‘mean sea level’ (Fig. 3.7). The flows between 258 to 320m above the MSL show pahoehoe characters. To the south of the Kundva hot spring the contact is inferred due to a fault running parallel to the base of the hill. The upper flows show ‘a a’ characters and dips gently northward. The alluvial plain to the south of the Kundva thermal spring has a good potential for ground water. The depth of the water table in alluvial plain varies from 5 to 15.6 m.

3.3.8 Anakdeo Hot Spring

This thermal spring also emerges through the northern margin of a basic doleritic dyke of 8.5m thickness trending almost EW flanked by prominent chilled margins. This thermal spring is located within pahoehoe lava flow. Here the flow dips vary from 9° to 12° northward. They are intruded by dolerite dykes trending ENE-WSW. The southern part of the area shows a thick pile of consolidated to semi-consolidated alluvium consisting of angular to subangular pieces of basalt, and calcareous matter cemented in clay matrix (Fig. 3.8).
Weathered basalt and overlying alluvium form a ground water aquifer in the area. The maximum depth of the water table around the hot spring is 6-8 m.

3.3.9 Unabdeo Hot Spring

Unlike other hot springs of this study, Unabdeo is situated in tectonically disturbed area at the southern margin of the hills and at the junction of two faults viz. F2 and F7 as shown in Fig 3.3. The area around this hot spring is mainly covered by trap flows of ‘Group – I’ as discussed. These flows are nearly horizontal and highly dissected. The region south of Unabdeo hot spring is occupied by Quaternary Alluvium of varying thickness. The older part of indurated layers consists of pebble and boulder beds, intercalated with hard compact clay and sand beds (Fig. 3.9).

The ground water condition in these alluvial deposits is good. The depth of water table here varies from 7 to 12 m.

3.3.10 Nazardeo Hot Spring

This hot spring is located at the of Gulnadi river bed where basaltic flow of Group–1 (Table 3.2) is exposed. A large fault trending E-W passes 3 m away from the mouth of the spring. The fault is recognisable by a 40cm wide secondary vein of zeolite. Very near to this spring, Older Alluvium shows inclination varying in amount from 4° to 25° and direction from north to west. The inclination seems to have been affected by neotectonism in the area (Fig. 3.9).

Groundwater conditions are fairly good and the water table here lies at a depth varying from 5.5 to 12.6 m.
3.3.11 Ramtalab Hot Spring

As shown in Fig. 9, this hot spring lies close to the southern margin of a fault running in the NE-SW direction (parallel to the strike of Satpura). The fault marks the north-easterly dipping lava flows and thick veneer of Tapi alluvium (500 m). Hot spring lies within the dissected flows of Group I.

The ground water condition is good because of the presence of planes of weakness and alluvial deposits. The depth of water table varies between 4.8 to 12 m.

3.3.12 Indve Hot Spring

This hot spring, located to the south of the river Tapi, emerges through a dyke running east-west. The thickness of basaltic flows varies from 184 to 220 m. The lower of the two flows show compound pahoehoe characters with several flow units marked by “pipe - amygdules” and “spherical vesicles”. The area around the spring abounds in doleritic dykes which are trending ENE-SWS and E-W. The thickness of dykes varies between 0.5 to 20 m some of these dykes are traceable up to 6 km in length (Fig. 3.10).

The area has poor ground water potentials owing to the amygdaloidal, non-fractured nature of basalts. The water table in the area is 5 to 14 m deep.

3.3.13 Khadgaon Hot Spring

This hot spring is located on the southern bank of Vaghur River, a tributary of Tapi controlled by a fault, that is trending in NNW-SSE direction. Basalt flows are exposed at places in the riverbed, which is otherwise covered by thick alluvium. The flows show infillings of secondary minerals in vesicles (Fig. 3.11).

The ground water condition around here is also good. The water table lies between 6 to 13 m depth.
3.4 Petrography

The petrographic studies of the rocks where there springs are located has been summerised as below:

3.4.1 Hot Springs of Dhule District

These springs are located along dykes of petrological variable rocks, which are varying in trends and thickness but of nearly similar petrographic composition. The dyke of Kundva thermal spring is doleritic, highly jointed and showing a sharp contact with the country rock i.e. porphyritic basalt. In thin section, it shows ophitic to sub ophitic texture. The pyroxene and feldspars are the predominant minerals besides iron minerals, which are also in appreciable quantities. However, the dyke at Anakdeo shows chilled contact with the country rock. Whereas, the dyke at the Indva thermal spring is concealed and can be seen only in dug well sections near the thermal spring.

Megascopically, the flows around these hot springs are aphinitic to porphyritic showing hydrothermal alterations at places for e.g. at Anakdeo. They also contain green coloured glass visible even in hand specimen near Anakdeo. Giant phenocrysts of feldspar (up to 5cm length) are also seen at a few places. (photo. 5)

Mineralogically, most of them are composed of augite and plagioclase feldspars constituting around 80 to 90 % of all the minerals besides, glass and iron. From the textural point of view porphyritic and non-porphyritic flows may be separated in both, the ‘pahoehoe’ and ‘a a’ types. Even in the porphyritic rocks, the degree of this texture varies from sparsely to coarsely porphyritic nature. This depends on the amount and size of the plagioclase phenocryst in the aphanitic ground mass. The pyroxenes are essentially represented by augite (Kundwa) and pigeonite in rare cases (Indve). The
amount of interstitial glass and iron minerals vary from less than 1% to as much as 15% in the different flows.

3.4.2 Hot Springs of Jalgaon District

Megascopically, as well as microscopically, the lava flows around these hot springs, shows non-porphyrctic to porphyritic textures. In the coarse grained flows, grey plagioclase forms phenocrysts at places. Grey and needle shaped phenocrysts of plagioclase feldspar are noticeable at a few places.

The flows show very little effect of hydrothermal alterations. Plagioclase feldspar and pyroxene are the predominant minerals found in the flows of Jalgaon region. Opaque minerals include euhedral grains of magnetite (Ramtalab and Nazardeo) interstitial glass (Khadgaon).

The plagioclase feldspar in the flows around Ramtalab and Nazardeo are altered while they are fresh in the flows around Unabdco.

3.5 Joints

In order to study the effects of weak planes on thermal springs of the study area the joints of the rocks of the area have been studied, (Appendix-2) and analysed to see the possible channel of water percolation in the area.

3.5.1 Joints in Dhule Area

The rose diagram of Kundva hot spring area reveals that three sets of joints are predominant in the area although most of them are vertical. Those trending in NNE-SSW are predominant. The other two sets of joints, however, trend in ESE-WNW, and SSW-NNE direction. Some of them are traceable for tens of meter in length. A doleritic dyke trending ENE-WSW is also seen at Kundva hot spring area.

At Anakdeo hot spring three sets of joints are seen. These sets trend in NW-SE, NNE-SSW and E-W directions, in the order of predominance. Two
dykes, one trending in ENE-WSE and other in E-W direction along the joints of corresponding trends were noticed. A shear zone trending in E-W direction was noticed in Anakdeo area.

At Indve thermal spring also, two sets of joints trending SE-NW and E-W are seen. The lava flows of this area have been intruded by a series of doleritic dykes trending E-W. These dykes are highly jointed, showing three perfect sets of joints. Two sets of these joints are vertical while third one is horizontal in nature. The former runs parallel to the dyke and is predominant than the other two sets.

3.5.2 Joints in Jalgaon area

Around Unabdeo, Ramtalab, and Nazardeo hot springs the country rock shows three predominant sets of joints trending in NE-SW, E-W and NNE-SSW in order of predominance. The dykes noticed in the area run in the east west direction.

The Khadgaon hot spring, located in the riverbed is surrounded by alluvium. Four sets of joints trending in SSE-NNW, E-W and NNE-SSW directions are seen. The rose diagram of these joints reveals that the intensity and prevailing directions of joints around the hot springs of this study area are same (Fig. 3.12 and 3.13).
TABLE 3.1
Geological Sequence in the Tapi Valley
(after: Ravishankar, 1983)

<table>
<thead>
<tr>
<th>Recent</th>
<th>Soil</th>
<th>In situ weathered product of basalt, redboles and Alluvium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartemary to Recent</td>
<td>Alluvium</td>
<td>Unindurated beds of loose layer and sandy bands with occasional kankar and siliceous material.</td>
</tr>
<tr>
<td>Older Alluvium</td>
<td>Angular Unconformity</td>
<td>Indurated layer of cobbles, pebbles and boulders intercalated with hard and compact clay and sandy bands.</td>
</tr>
<tr>
<td>Upper Cretaceous to Lower Eocene</td>
<td>Deccan traps</td>
<td>Lava flows of different thickness, a few of them show different megascopic characters. Intruded by dykes.</td>
</tr>
<tr>
<td>Base not exposed</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TABLE 3.2
Flow Groups of Deccan Basalt in the Area
(Modified after: Ravishankar, 1983)

<table>
<thead>
<tr>
<th>Group</th>
<th>Description</th>
</tr>
</thead>
</table>
| V (21-23) | Top not exposed  
Moderately porphyritic Basalt flows. |
| IV (17-20) | i. Moderately porphyritic Basalt flow.  
ii. Intertrappen beds.  
iii. Moderately porphyritic Basalt flow.  
iv. Non-porphyritic Basalt flow. |
| III (16)   | Non-porphyritic to sparsely porphyritic Basalt flow. |
| II (9-15)  | Sparsely to moderately porphyritic Basalt flow. |
| I (1-8)    | Almost non-porphyritic to moderately porphyritic Basalt flows. |

Angular Unconformity
FIG. 3.1: REGIONAL GEOLOGICAL MAP OF TAPI VALLEY

INDEX

- TAPI ALLUVIUM
- DECCAN TRAP
FIG. 3.2: TECTONIC MAP OF SON - NARMADA TAPI ZONE

INDEX

--- Lineament as identified on satellite
--- Lineament identified in the field as fault zone
--- Faults
50 Bedding
80 Foliation
△ Fold axis
FIG. 3.7: GEOLOGICAL MAP OF THE AREA AROUND KUNDVA THERMAL SPRING
DHULE DISTRICT, MAHARASHTRA

INDEX

ALLUVIUM
DYKE SWARM
BASALTIC FLOWS
FRACTURE
JOINTS

INFERRRED CONTACT
DUG WELLS
HOT SPRING/ COLD SPRING
DRAINAGE
SPOT HEIGHTS
FIG. 3.8:—
GEOLOGICAL MAP OF THE AREA AROUND ANAKDEO (DARA)
HOT SPRING DISTRICT DHULE, MAHARASHTRA

INDEX

Direction of volcanic flow as inferred from inclind pipe amygdules

Calcereous deposit

Quataeary alluvium

Flow Nos. 5 & 6

Inferred top of 'a a' flow (Flow No. 4)

Flow Nos. 1, 2, 3 & 4

Fair weather road

Location of water samples collected for completer analysis

Dykes

Dipping / Vertical joints

Shear Zone (Width oxagraterated)

Strike and dip of red bale horizons.
GEOLOGICAL MAP (WITH PHOTO AIDS) OF THE AREA AROUND
RAMTALAB-UNABDEO-NAZARDEO GROUP OF HOT SPRING IN PARTS
OF TAHI BASIN, DIST. JALGAON, (MAHARASHTRA)

INDEX

- FLOW GROUP V
- FLOW GROUP IV
- FLOW GROUP III
- FLOW GROUP II
- FLOW GROUP I

RAVISHANKAR AND R. DUBEY (1983)

FIG. 3.9

SCALE 1:50,000
1 CM: 500 MTS

0 500 1000 1500 2000 2500
FIG. 3-11: GEOLOGICAL MAP OF THE AREA AROUND KHADGAON HOT SPRING
DISTRICT JALGAON, MAHARASHTRA

INDEX
- Pahoehoe flow
- Flow with Columnar joints (a a flow)
- Pahoehoe flow
- Alluvium
- Inferred faults
- Joints and Fractures
- Bore hole
- Hot spring
- Dip of the bed
Fig. 3.12: Rose diagram showing joint pattern of Kundva Group of Hot Springs
FIG. 3.13: ROSE DIAGRAM SHOWING JOINT PATTERN OF UNABDEO GROUP OF HOT SPRINGS