CHAPTER III

 GEOLOGY

Physiographically, the Indian sub-continent has been divided into three distinct units viz., Peninsular shield, the Himalayas, and the Indo-Gangetic plain (Fig. 10).

Peninsular shield is composed of geologically ancient rocks of diverse origin, most of which have undergone much crushing and metamorphism. Structurally, the Peninsula represents a stable block of the earth crust which has remained unaffected by mountain building movement since close of pre-cambrian era.

The Extra-Peninsula or the Himalayas is a region of folded and overthrust mountain chains of about 65 million years old. Their curvilinear structure is very striking. They consist mainly of circular arcs which are convex towards Peninsula i.e. towards the rigid crust against which they appear to have been thrust (Krishnan, 1968). Though the Extra-Peninsula contains some very old rocks, is predominantly a region in which sediments were laid down in a vast geosyncline continuously from the Cambrian to early Tertiary age.

Apparently, the Himalayas foot hills are separated from the northern border of Indian Shield by a vast plain known as Indo-Gangetic plain, covered by the Quaternary alluvium which forms the major unit in the geology of the Indian sub-continent. It includes...
Great alluvial tract of the Ganges, Brahmaputra and Indus covering an area of 85,000 square kilometre (Krishnan, 1968).

The Indo-Gangetic plains are broad, monotonous, level expanses built up of Quaternary alluvium, through which the rivers flow sluggishly towards the seas. The Gangetic alluvium effectively conceals the solid geology of its floor.

Earlier, there has been much speculation regarding the sub-surface geology of the Indo-Gangetic plains. The plumb line deflection and gravity data obtained by Survey of India, were too meagre to give any concrete indications of the sub-surface geology. However, with the advent of geophysical exploration in these plains about five decades back, a fairly large volume of data indicating the nature of sub-surface geology and structure has been obtained which was further substantiated by number of deep exploratory wells drilled in these plains by Oil and Natural Gas Commission.

Although, the Indo-Gangetic plain appears as one vast stretch from one end to other geologists have held for a long time the opinion, that the floor of this plain is not an even one but there are hidden ridges and depression which lies under the alluvium (Rao, 1973).

The term "ridge" as applied to the structural features of the Ganga plains refers only to the linear aeromagnetic anomalies and should not be understood in the normal sense of the term. These might
have formed important topographic divides at the time of Vindhyan deposition, but subsequently peneplained, and the overlying Siwaliks occur with nearly uniform thickness across the ridges. Similarly the word "basin" applied to areas between these ridges should not be understood as representing truly synclinal depression (Karunakaran et al., 1976).

The most important basic data regarding the basement configuration and sedimentary basin of the Indo-Gangetic plains are provided by Agcos, (1957). Basement depth contours for the whole of Indo-Gangetic plain have also been computed by aeromagnetic data which show that sedimentary section sometimes even exceed 833 metres thickness towards the northern part (Agcos, 1957).

The maximum depth to the basement indicated in seismic surveys in all these plains is about 6 kilometers.

The Indo-Gangetic plain can broadly be divided into the following basins (Fig. 11).

1. Indus basin of Pakistan
2. The Punjab basin
3. Hrihamputra basin
4. Bengal basin which also includes Bangladesh
5. Ganga basin.
MAP OF THE INDO-GANGETIC PLAINS INDICATING THE MAIN DIVISIONS
(THE THICK LINE SHOWS THE BOUNDARY OF THE PLAINS)

FIG. 11

INDEX

ARCHAEOG OUTCROPS
1 DELHI, LAHORE, SARGODHA BASEMENT HIGH
2 DELHI MUZAFFARNAGAR RIDGE
3 FAIZABAD RIDGE
4 MANGHYR SAHARSA RIDGE
5 RAJMAHAL GARO GAP RIDGE
1. **Indus Basin**

The largest part of Indus basin lies in Pakistan. It is filled up by sediments extending back in age from Perm-Carboniferous to Quaternary and possibly also by Vindhyan remnants which are found in western Rajasthan (Krishnan, 1968). The basin is 6000 m deep. A large thickness of Tertiary and Mesozoic Sediments have been met under the alluvium. This thick marine sequence has thinned out towards Rajasthan Platform.

2. **Punjab Basin**

The Archean basement rocks either outcropping or occurring under moderate thickness of alluvium in Lahore-Sargodh area separate the Indus basin in the west from the Punjab depression in the east. The Seismic survey by the O.N.G.C. (Datta et al., 1964) has indicated that the basement surface as well as sediments below the alluvium gently dip towards the foothills. However, the basement becomes deep as foot-hills are reached with corresponding increase in the thickness of sediments. The maximum depth of basement is 4.5 km (Datta et al., 1964).

3. **The Brahmaputra Basin**

The Brahmaputra basin of Assam may be divided into western and eastern part lying in between Shillong and Mikir hills and the Himalayan foot-hills has been named as "Northern Shillong Shelf".

The eastern part lying in between Naga Hills and the Himalayas has been named as "Assam Shelf". The western part is shallow in most of the southern portion and near the foot-hills the sediments, mainly the equivalent of Siwaliks attain appreciable thickness. The gravity data indicate steep dip of basement to the north (Ratnam, 1963).

The Ganga Basin

The Ganga basin is the most extensive in the area and comprises more than half of the total Indo-Gangetic Plain. The plain is a great long sedimentary area, flat and monotonous which is drained by the river Ganga and its tributaries.

The western margin of the basin is limited by the Middle Proterozoic Delhi-Hardwar ridge and the eastern margin by the Monghyr-Saharsa ridge of Satpura Metamorphics. To the north, the Ganga basin is limited by outer most Siwalik foot-hills of the Himalyans bounded by series of reverse faults. Along the southern fringes of the basin Bundelkhand granite, Delhi and Upper Vindhyan group of rocks are exposed.

In Uttar Pradesh and Bihar Plains lying between Delhi-Hardwar and Monghyr-Saharsa sub-surface ridges, the Vindhyan of the Peninsular Shield can be followed upto foot-hills into Sarda and Gandak depressions (Karuna Karan et al., 1976). The Ganga basin represents a large scale regional depression on the northern margin of the Indian Platforms and is considered as super order crustal structure of negative
character most probably forming a northerly continuation of Vindhyan synclise (Sastri, 1971). The deep bore hole data obtained from Ujhani, Tilhar, and Puranpur suggest the northward continuation of upper Vindhyan sediments into the Ganga basin.

ORIGIN OF THE GANGA BASIN

As regards the origin of the Ganga basin various shades of views are there, some of which are as follows.

It was interpreted to be a foredeep (Suess, 1904-1924) or a great rift valley (Burard, 1915), filled up with alluvium of thickness 4.5 km (Oldham, 1917) to 20 km (Pascoe, 1964).

According to Krishnan (1968) the Indo-Gangetic alluvial trough is a region whose origin and structure are closely connected with the formation of the Himalayas. He suggested that the Gangetic plains owe its origin to a sag or depression which has been formed by buckling down of the crust in obedience to pressure exerted on the borders of the Peninsula by compressive forces. Valdiya (1982) interpreted it as a resultant effect of sagging of the northern flank of platform around the Bundelkhand shield following the main episode of the Himalayas orogeny. The depressed platform became the site of sedimentation by vigorous fluvial agencies predominantly from the newly risen Himalayas.
FIG. 12

MAP SHOWING CONTINENT-CONTINENT COLLISION OF INDIA AND ARABIAN PLATES WITH ASIA (After, Reading, 1986)

1. ZAGROS THRUST
2. HIMALAYAN FRONTAL THRUST
3. INDONESIAN TRENCH (SUBDUCTION ZONE)

MAJOR SEDIMENTARY BASINS

INDIAN OCEAN
Canser (1964) has emphasized that the Ganga basin in front of the Himalayas does not represent a sediment filled foredeep but the depressed part of the peninsular shield which is in all likelihood, faulted against the outer Himalayan front.

According to Dickinson (1974) major sedimentary basins developed between fold-thrust belts and the craton, over which the mountain belt is thrust. "We call these basins fore-land basin, rather than fore deeps" (Miall, 1981; Rally, 1981). Fore-land basins are asymmetrical, and deepest near to the fold thrust belt; they migrate towards the fore-land and have resulted from down-ward flexuring of the lithosphere by over-riding fold thrust belt (Beaumont, 1981).

Dickinson (1974) considers the Indo-Gangetic trough as the most impressive. Present day peripheral fore-land basin (Figure 12) formed as result of continent-continent collision between Indian and Asian plates. The basin has developed on the under thrust Indian plate and due to loading of thrust sheets in Himalayas causing a viscoelastic flexure in the crust allowing sediments to accumulate under fluvial process.

According to Singh (1989) the Gangetic plain is part of active fore-land basin (peripheral-type) developed on the under thrusting Indian plate, in response to the thrust fold belt loading in the Himalayas. Further, Singh and Ghosh, (1988) and Singh (1989) opined that during thrust-fold loading tectonics in the Himalaya, the Son-Narmada lineament much to the south of the fore-land basin was
FIG. 13

MAJOR TECTONIC FEATURE OF THE GANGA BASIN

SRINAGAR
JAMMU
DEHRADUN
MBF
Nepal
GANDAK DEPRESSION
BUNDUKHAND BASIN
NAMGAD RIDGE
SWALIOR
LUCKNOW
VINDHYAN BASIN
NARMADA GRABEN
SON NARMADA GRABEN
SATPURA BASIN
SON MAHANADI GRABEN
LINEAMENT
BENGAL BASIN
reactivated, causing uplift of Bundelkhand-Vindhyan plateau and development of northerly slope (Fig. 13).

The rate of subsidence of the old, rigid and cold crust of Indian shield was also low and sediment input by rivers high, so that no marine transgression of Neogene-Quaternary time could enter into this fore-land basin. The deep drilling data of the O.N.G.C. is contrary to this view of Singh, as the deposits of Neogene sediments are reported from all over the Ganga basin (Sastri, 1971; Rao, 1973).

TECTORIC FRAMEWORK OF GANGA BASIN

Tectonically the Ganga basin may be divided into the following sub-divisions (Fig. 14).

1. Monghyr-Saharsa Ridge
2. East Uttar Pradesh Shelf
3. Gandak Depression
4. Faizabad Ridge
5. West Uttar Pradesh Shelf
6. Kasganj-Tanakpur Spur
7. Ram-Ganga Depression
8. Delhi-Hardwar Ridge

1. Monghyr-Saharsa Ridge

It trends in northwest direction and denotes the sub-terranean continuation of Satpura orogenic belt of Chota-Nagpur
Tectonic Map of Ganga Basin & Adjoining Areas

Legend:

Sedimentary Cover of Ganga Basin
- Neogene
- Paleogene
- Mesozoic
- Gondwana (Lower and Upper Undifferentiated)
- (Upper Carboniferous, Lower Cretaceous)
- Vindhyan
- (Upper Proterozoic, Lower Palaeozoic)
- Limits of Mesozoic Effusives
  (Deccan Traps, Ra Amahal Traps, etc)

Tectonic and Structural Features
- Structures of Super Order Synclises
- Structures of First Order Negative
- Structures of First Order Positive
- Structures of Second Order Negative
- Structures of Second Order Positive
- Structures of Third Order Local High
- Faults (Major)
- Thrusts (Limiting the Platform Margin)
- Other Thrusts
- Trend Lines
- Anticlinal Axes
- Synclinal Axes
- Basement Depth Contours
  (Based on Aeromagnetic Data)

(After Tectonic Map of India, 1966 by Oil & Natural Gas Commission)
Plateau. It marks the eastern bounding limit of the Ganga basin.

2. **East Uttar Pradesh Shelf**

   It is delineated by Monghyr-Saharsa Ridge to the east and Faizabad Ridge to its west. The outcropping Vindhyan of Son valley and the granitic basement form the southern border of this zone. This shelf merges to the north into the Gandak depression. The basement here is assumed to be the continuation of the Bundelkhand massif, overlain successively by Vindhyan, Neogene and Quaternary alluvial sequences. A major north easterly trending fault, with a down throw to the southeast is traced from near Sahasram in south west through Muzaffarpur upto Nepal border. It is probably northward extension of Narmada-Son Lineament (Srivastava, 1983).

3. **Gandak Depression**

   This depression is bounded to the west by Faizabad Ridge and to the east by Monghyr-Saharsa Ridge. Here the thickness of sediment is considered more than 6000 metres.

4. **Faizabad Ridge**

   The Bundelkhand Massif occupies the central part of the Vindhyan Basin. The north eastern extension of this Massif in the sub-surface is known as the Faizabad ridge. This ridge has played a significant role during the deposition of the Vindhyan sediments (Fig.14).
further the distribution of the Vindhyan sediments east and west of this ridge in the Ganga basin shows that the ridge has been a positive area throughout the sedimentation during the Vindhyans, dividing the basin into the eastern and western shelf (Srivastava et al., 1983).

5. **West Uttar Pradesh Shelf**

The Western Uttar Pradesh shelf may be divided into two sub divisions, namely, the area to the east of the Moradabad fault and the area west of it. The eastern part of west Uttar Pradesh shelf which lies between Moradabad fault and western flank of Bundelkhand massif is one of the most well studied area of the Ganga basin. Not only the magnitude of ground-magnetic, gravity and detailed reflection and refraction seismic surveys are more, but the area has been explored by two deep and four structural wells by the O.N.G.C. The drilling data show that the Upper Vindhyan directly overlies the Bundelkhand granite which is in turn overlain by Neogene sequences that is Siwaliks. Further, the upper Siwaliks is overlain by the Quaternary alluvium.

This west Uttar Pradesh shelf is traversed by the Great Boundary Fault which separates Aravallis from the Upper Vindhyans. This fault is a steep dipping reverse fault with a throw of 1500 m towards South-east, traceable for more than 500 kilometres from Chittorgarh to Agra with a NE-SW direction in the northern part,
becoming almost N-S in the southern part, along the arcuate eastern flank of Aravalli folded belt (Fig. 15). The great Boundary fault continues north-eastwards and joins the Badaun Fault and further extends to Tanakpur close to the Himalayan foot hills.

The Moradabad Fault which also trends in NE-SW is considered to be an offshoot of the Great Boundary Fault.

Besides, these longitudinal faults various transverse faults of varying ages are also found to impress upon the stratigraphic sequences, some of these may be the resultant of the most violent third phase of the Himalayan orogeny. (Fig. 16).

In the western Uttar Pradesh Shelf, the basement and sedimentary cover of Upper Vindhyan and Neogenes, (Siwallks), were cris-crossed by the longitudinal and transverse faults, generating thereby an uneven configuration of the sub-surface topography.

Sarda Depression

It represents the northern part of the west Uttar Pradesh shelf from which it is tectonically distinguished on the basis of inferred sedimentary thickness of more than 6000 m and by NW-SE trending structures. The large thickness of sediments in this depression may include partly the Mesozoic and Paleogene besides the Vindhyan Neogene and Quaternary Alluvium (Sastri et al., 1971).
THE STRUCTURE OF THE BASEMENT OF THE GANGLA-BASIN

(After Valdiya, 1976)
Delhi-Hardwar Ridge

Represents a north-north-eastward extension of Delhi folded belt. The western limit of Ganga basin is probably delimited by Delhi-Hardwar Ridge and the oldest sedimentary sequence in the basin namely upper Vindhyan, gradually thin out towards this Ridge.

Kasganj-Tanakpur Spur

It is northern extension of the Badaun arch in the Ganga basin. This spur marks the eastern limit of Aravalli horst. Eastern edge of this spur coincides with the sub-surface extension of the Great Boundary fault (Raiverman et al. 1983) of Rajasthan which separates the Aravalli rocks from the Vindhyan (Fig. 16).

Sub-surface Geology of the Area

The study area lies on the Kasganj-Tanakpur spur, eastern edge of this spur coincides with the sub-surface extension of the Great Boundary Fault which separates the early Proterozoic Aravalli rocks from the upper Proterozoic Vindhyan rocks in Rajasthan and beyond. The geophysical surveys by the O.N.G.C. have delineated an anticlinal structure below the unconformity (between the upper Vindhyan and overlying Siwaliks) at Kasganj and Ujjain (Fig. 17 & 18) under a cover of homoclinaly dipping Siwaliks.

The tentative basement depth contour of the upper Vindhyan for the Ganga basin have been prepared from the available seismic
ISOPACH CONTOUR MAP OF THE VINDHYAN EQUIVALENT SEDIMENTS IN THE GANGLA PLAINS
(After Hari Narain et. al 1982)

FIG. 17

All figures are in metres
data by (Harl Narain et al., 1982). The map (Figure 1A) in general, shows that the basement gradually slopes towards north and deepest part gradually lies close to the Himalayan foot hills. A large number of horst and graben structures within the Vindhyans have been mapped by seismic method which have been responsible for the abrupt variation in the thickness of Vindhyan sediments in the Ganga basin. Further, the sub-surface stratigraphic information obtained from deep and comparatively shallow structural wells drilled by the Oil and Natural Gas Commission in the Ganga basin has indicated the presence of Vindhyans below the Siwalik sediments. The geophysical and drilling investigation carried out by Oil and Natural Gas Commission, have yielded stratigraphic informations pertaining to the sub-surface geological framework which are as follows.

Table : Vindhyans in Ganga Basin

<table>
<thead>
<tr>
<th>Wells</th>
<th>Depth interval (m)</th>
<th>Thickness</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kasganj structural</td>
<td>620 - 1250</td>
<td>630</td>
<td>Upper Vindhyan</td>
</tr>
<tr>
<td>Ujhani deep well</td>
<td>1010 - 2062</td>
<td>1052</td>
<td>Upper Vindhyan</td>
</tr>
<tr>
<td>Tilhar</td>
<td>1718 - 2225</td>
<td>507</td>
<td>Upper Vindhyan</td>
</tr>
<tr>
<td>Puranpur</td>
<td>3174 - 4235</td>
<td>1061</td>
<td>Upper Vindhyan</td>
</tr>
</tbody>
</table>
TENTATIVE VINDHYAN BASEMENT DEPTH CONTOUR MAP FOR THE GANGL PLAINS

After Hari Narain et al. 1982

FIG. 18

- Wells Drilled
- all figures are in metres
- Section lines
Based on the drilling data, sections were prepared and the stratigraphic correlation of the Vindhyan rocks and their equivalents in the Ganga basin are shown. (Fig. 19)

The figure shows that in Kasganj structural well the upper Vindhyan is encountered at a depth of 620 m which comprises limestone- sandstone-shale sequence with layers of anhydrite. The Siwaliks (middle and upper) unconformably overlies the upper Vindhyan and attains a thickness of 260 m (620-360 m) which is in turn overlain by the Quaternary sediments (0-360 m). Further, in a deep well at Ujhani drilled down to the depth of 2062 m, the stratigraphic sequence of various geological formations are as under.

<table>
<thead>
<tr>
<th>Sequence of Geological formations</th>
<th>Depth range (m)</th>
<th>Thickness</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary sediments</td>
<td>0 - 510</td>
<td>510</td>
<td>Quaternary</td>
</tr>
<tr>
<td></td>
<td>---------------</td>
<td>-----------</td>
<td>-------------</td>
</tr>
<tr>
<td></td>
<td>&quot;unconformity&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Siwaliks (Middle &amp; Upper)</td>
<td>510 - 1018</td>
<td>508</td>
<td>Neogene</td>
</tr>
<tr>
<td></td>
<td>&quot;unconformity&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper Vindhyan</td>
<td>1018 - 2062</td>
<td>1052</td>
<td>Upper proterozoic</td>
</tr>
<tr>
<td></td>
<td>&quot;unconformity&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bundelkhand rulitic basement</td>
<td>&gt; 2062</td>
<td></td>
<td>Upper Archean</td>
</tr>
</tbody>
</table>
In Ujhani, the upper Vindhyan comprising Quartz-wacke Quarts-arenite, dolomitic limestone, shale and limestone from bottom upward, directly overlies the Granitic basement. The Siwaliks unconformably overlies the Vindhyan and is further overlain by the Quaternary sediments. Further, the Upper Vindhyan limestone-sandstone-shale sequence is the same at the Ujhani as was met in Kasganj structural well.

The upper Vindhyan attains a maximum thickness of 1052 m at Ujhani deep well, down to the basement. Further, the thickness of upper Vindhyan, Neogene Siwaliks and the Quaternary sediments gradually increases due north and perhaps attain their maximum thickness close to the Himalayan foot hills (Figure 19).

In the light of the above discussions the stratigraphic sequence of the various geological formations from Archoan through upper Proterozoic to Quaternary are as follows.

Quaternary Alluvium Alternate layers of sand and clay with interbeds of calc-concretions.

----------unconformity----------

Upper Siwaliks Coarse to medium sandstone with variegated claystone and occasional carbonaceous streaks.

Middle Siwaliks (Neogenes)

----------unconformity----------
Upper Vindhyan (Upper Proterozoic) | Greenish-grey dolomitic Limestone  
Reddish-brown argillaceous Limestone. Quartz-wacke, Quartz-arenite.

----------unconformity----------

Archean | Bundelkhand granite basement

It appears from the above sequence that on the eroded surface of the basement, Upper Vindhyan were deposited sometimes during the upper Proterozoic era. Thereafter, they underwent Post-Vindhyan faulting and erosion since Cambrian to lower Miocene. During this long span of time encompassing about 500 M. years, the Vindhyan topography was reduced to almost peneplanations and on the eroded surface of upper Vindhyan the siwaliks were deposited, which was followed by the deposition of Quaternary sediments.

This Quaternary deposits healed up all the earlier depressions through the rapid sedimentation giving thereby a broad, monotonous level expanses, which is the present Ganga basin.

There are in all, three unconformities. The first lies between the Bundelkhand granitic basements and the upper Vindhyan, the second between the upper Vindhyan and the Neogene Siwaliks and the third though indistinct lies between the Siwaliks and Quaternary deposits. The indistinct nature of the Siwaliks and the
Quaternary sediments are due to the broad lithological similarities. Moreover the velocity data obtained by the seismic survey do not make unconformity very distinct.