# CHAPTER - IV

# CHAPTER - 4

## MODE OF OCCURRENCE

In this chapter the author has classified the bentonite deposits occurring in the study area and discussed in detail the various characters observed in the field. The relation of the bentonites with the underlying and the overlying horizons and the texture and structure present within the different horizons of the weathering profiles have been discussed.

The weathering profiles have been described based on Bardossy & Aleva's (1990) pattern wherein the bentonites have been considered to represent the saprolite horizon developed in a single gradational residual weathering profile over the basalts.

A generalised weathering profile is given below.

| Weathering Profile | | |
|---|---|---|
| | Soil | |
| | Laterite | Duricrust |
| | Lithomarge | Saprolite |
| | Bentonite | |
| | Weathered Basalt | Parent rock |

A complete weathering profile has not been encountered in the study area; one or other horizon has been missing or is unexposed. The bentonites in the study area occur as pockets and tabular bodies scattered along the contact of Deccan Trap Basalts and laterites and also appear to fill small basins in the trap country. The laterite belt occurs as a narrow elongated band, 1 to 2 km in width extending to a length of about 30 km, commencing from east of Adhevada to Mithivardi, passing thorough Budhel, Tagadi, Thoradi and Alang.

The topography of the areas where the bentonite is devoid of a lateritic overburden is gentle, wheras, small isolated mounds ranging in altitude fom 10 to 20 m are seen where laterites are exposed. Towards the coast the country side is even with a low muddy fore shore of marsh and swamps partly muddy and partly rocky. Inland, the terrain is quite hilly in the north western and southern parts with hills rising upto an altitude of 180 to 200 m. The important rivers and streams flowing through the area are the Kalubhar, Shetrunji, Bagad and Malan, which passing through the bentonite bearing areas drain into the Arabian sea.

**Classification of the Deposits**

In the study area all exposed sections are of high silica type, in which the saprolite horizon is composed of both bentonite and kaolinite (Sahasrabudhe, 1961; Talati, 1968, 1970; Valeton, 1983). The bentonite deposits of the study area can be classified into Primary and Secondary based on their genetic and physical characters.

Primary bentonites were formed in-situ by the alteration of the trap and may be subdivided into -

i) massive bentonites with no relict structures of the parent rock, and

ii) bentonites with relict structures of the parent rock

Boulders of partly bentonitized basalts occur within these bentonites. The primary bentonites are slightly gritty and contain impurities of calcite, gypsum and basaltic material. Calcite and gypsum contents decrease with depth. Many bentonite deposits show spheroids analogous to exfoliation weathering ranging in diameter from few centimetres to about 70 centimetres. It is observed that the bentonite covers the periphery and successively less weathered basalt is seen towards the centre. The bentonite content decreases from the outer rim of the spheroid to the core.

The Primary type of bentonites occur around Rajpara, Padwa, Morchand, Thalsar, Alang, Mathwada, Sakhavadar and Devaliya.

The secondary bentonites are reworked and redeposited bentonites. They overlie the eroded surface of the basalts, with or without

# TABLE- 4

## TABLE SHOWING THE THICKNESS OF THE VARIOUS HORIZONS EXPOSED IN DIFFERENT SECTIONS

| LOCATION | SECTION No. | SOIL | LATERITE | LITHOMARGE | BENTONITE | TRAP |
|---|---|---|---|---|---|---|
| Budhel-I | 3 | -- | 1m | 1.5m | 3.4m | -- |
| Tagadi | 4 | 2.0m | -- | 1.2m | 8.6m | -- |
| Thoradi-I | 5 | 1.1m | -- | -- | 12.5m | -- |
| ThOradi-II | 5 | 0.5m | -- | -- | 5.2m | -- |
| Rajpara | 6 | 0.5m | -- | -- | 5.7m | -- |
| Badi | 7 | 0.5m | -- | 15m | 8.0m | 0.5m |
| Padwa | 8 | 0.5m | -- | 20m | 3.5m | 1.5m |
| Morchand | 9 | 1.2m | -- | 2.3m | 5.3m | -- |
| Thalsar-I | 10 | -- | 1.2m | 1.0m | 3.8m | -- |
| Thalsar-II | 10 | -- | -- | 2.7m | 4.2m | -- |
| Alang-I | 11 | -- | 1.0m | 2.0m | 2.00m | -- |
| Alang-II | 11 | 0.5m | -- | -- | 0.7m | -- |
| Mathwada | 12 | 0.5m | -- | -- | 3.5m | -- |
| Devaliya | 13 | -- | 0.8m | 0.6m | 4.6m | -- |
| Sakhavadar | 14 | 0.5m | -- | 0.9m | 2.0m | -- |

# TABLE-5

## TABLE SHOWING THE THICKNESS OF VARIOUS HORIZONS ASSOCIATED WITH SEDIMENTARY STRATA

| Location | Section No. | Soil | Conglo-merate | Bentonite | Intercalasted clay and conglomerate |
|---|---|---|---|---|---|
| Adhevada | 1 | 0.6m | 1.4m | 4.0m | --- |
| Malanka | 2 | 0.5m | -- | 1.5m | --- |
| Budhel-II | 3 | 0.5m | -- | 2.2m | 1.5m |

intermediate sedimentary layers. The chief intercalating layer is a hard conglomerate with pebbles cemented by a siliceous clayey matrix. The secondary bentonite show slaty cleavage, are gypsiferous and less sticky. Shards and spotted characters are absent and are less swelling and less plastic. Adhewada, Malanka, Thoradi and Tagadi areas show occurrences of secondary bentonites.

**SECTION WISE DESCRIPTION OF THE BENTONITE DEPOSITS**

**Type I (Primary)**

**BUDHEL (Section 3)**

Budhel village is located about 14 km south of Bhavnagar on the Bhavnagar-Talaja road. Most of the quarries near Budhel are on the Budhel-Gogha road. The area has sparse vegetation dominated by thorny bushes. The laterite belt runs in a NE-SW direction near Budhel.

The measured lateritic weathering profile is given in Fig 3, (Plate 1).

The laterite is reddish brown in colour, hard and concretionary (Plate 2). The three different quarries in this area show a variation in the thickness of the lateritic horizon.

Underlying the laterite is a yellowish coloured lithomarge clay which is slightly moist and comes out in lumps when freshly dug. The contact between the lithomarge and the laterite is irregular with the lithomarge penetrating upwards into the laterite (Plate 1).

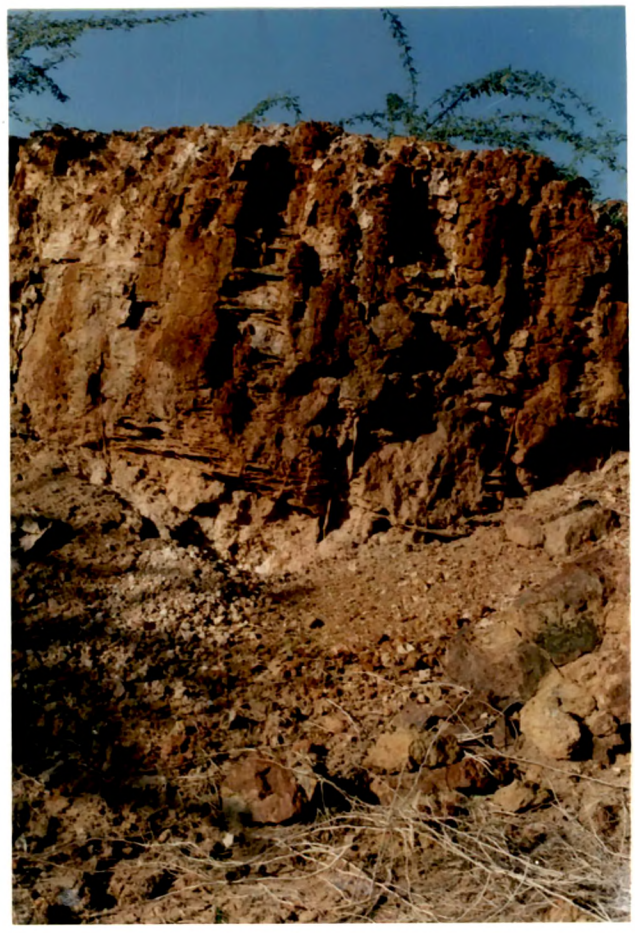

Plate-I The laterite weathering profile exposed at Budhel.

Plate-II The hard concretionary laterite overlying the lithomarge clay.

Plate-III Relicts of spheroidal weathering preserved within the bentonite.

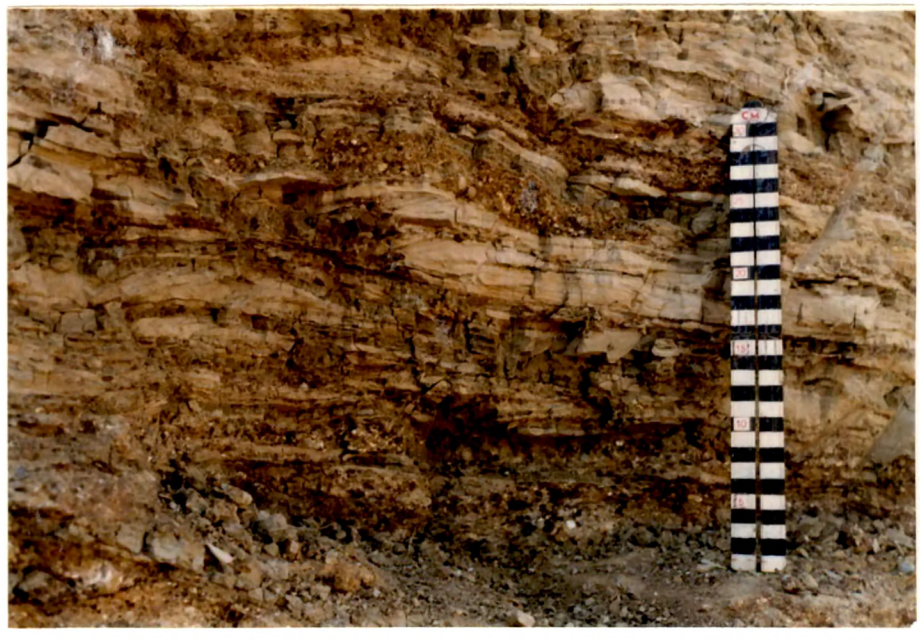

Plate-IV Intercalated conglomerate and bentonitic clay.

Underlying the lithomarge with a gradual and irregular contact is a purple and greyish coloured bentonitic clay which is extremely moist and plastic. When freshly dug the clay comes out in lumps, which on drying breaks down into smaller peds of varying sizes. Another important structure is the presence of circular pockets of bentonite very similar to the pattern produced by the spheroidal weathering of the basalt (Plate 3).

Two km east of Budhel village on the Budhel-Gogha road secondary bentonitic clay is seen overlying the conglomerate with a sharp contact. The bentonite is dry and gives a layered appearance. Because of its dry nature the clay comes out in small peds when dug. The horizon passes down into a mixed zone of clay and conglomerate (Plate 4). The intercalation points out to a syndepositional character of the clay and the conglomerate.

The thickness of the clay varies between 2 to 4 m and is yellow coloured and gritty.

**RAJPARA (Section 6)**

Rajpara village is located SE of Bhavnagar on the western side of the Gogha-Tansa road. The laterite belt runs in a NW-SE direction. Porphyritic basalt encircles the western margin of the bentonite pocket. The eastern boundary is marked by a laterite capping.

There are two quarries in this area showing a section as shown in fig 3.

The soil is spongy in both the quarries, a typical surface

Plate-V Different coloured bands present within the bentonite.

feature indicating the occurrence of bentonite in the sub-surface. Here there is an absence of a laterite capping and a lithomarge horizon. The soil is underlain by a thick bentonite horizon. The contact between the soil and the underlying bentonite is irregular. The bentonite shows different bands of colours (Plate 5). A thick grey band is underlain by a reddish coloured bentonite, followed by a pinkish and yellowish bentonitic clay.

The bentonite is of a massive variety devoid of the reliot structures of the basalt. The bentonite is extremely moist and plastic.

**BADI (Section 7)**

Badi village is located on the Gogha-Tansa metalled road. The vegetation here is sparse and consists of thorny bushes. A generalised sequence exposed in the Malesari river cutting is as shown in fig 3, (Plate 6).

The section is about half km south of Badi village. The soil cover is irregular in its occurrence. The contact of the soil with the underlying lithomarge is abrupt and irregular. The lithomarge is yellowish in colour. The texture falls within the clay class and the structure is angular blocky when dry. When freshly dug the clay is wet which on drying break down into small peds of varying sizes. The clay which is about 1.5 m thick on the western flank pinches out towards the east.

Plate-VI Bentonite overlying the weathered basalt at Badi.

Plate-VII Bentonite exhibiting circular rims with a basaltic core.

Underlying the lithomarge with a gradual and irregular contact is the bentonite horizon, about 8 m thick and is consistent in its occurrence. The bentonite clay is yellowish brown in colour and shows relicts of the spheroidal weathering of the basalts (Plate 7). The bentonite clay is dry due to the exposure to the atmosphere but when dug deep it is wet and has a soapy feel.

The bentonite horizon passes gradually into weathered basalt. The rock shows spheroidal weathering and the colour varies from yellow to brownish red. Down stream along the river about 300 to 400 m, fresh basalt is seen esposed. The rock is fine grained and black in colour.

**PADWA (Section 8)**

Padwa village is located on the Gogha-Tansa metalled road. The laterite belt widens in this area. In the northern part the conglomerate is seen overlying the laterite. Chalcedony and quartz pebbles are scattered on the flat plain.

The section exposed in the area is as shown in fig 3, (Plate 8).

The top soil is brownish black coloured with its surface marked with cracks. The boundary between the soil and the underlying lithomarge is abrupt and irregular.

The lithomarge is whitish to greyish in colour. The thickness of the lithomarge varies in the two quarries. Small amounts of reddish material is seen in the cavities which are supposed to be the original phenocrysts. The lithomarge is angular and blocky

Plate-VIII Mine section exposed at Padwa.

Plate-IX Remnants of exfoliation weathering preserved in the bentonite.

when dry, but comes out in wet lumps when freshly dug. On drying they break down into small pieces of varying sizes.

The lithomarge is underlain by a 3 to 3.5 m thick bentonitic clay horizon. The thickness of the bentonite horizon in both the quarries is almost the same. The boundary between the bentonote and the lithomarge is gradual and irregular. The bentonite is light gren to dark grey in colour. The texture falls within the clay class and the structure is angular blocky when dry. When freshly dug the bentonite is in the form of lumps which are extremely moist and plastic, but on exposure to the atmosphere, break down into smaller peds. The bentonite has preserved the exfoliation weathering of the underlying basalt (Plate 9).

Boulders of exfoliated or spheroidally weathered basalt are found embedded within the bentonite. These boulders exhibit the exfoliation pattern which is so common in the basalt. The outermost rims of the boulders consist mainly of pure bentonite but the inner rims exhibit lesser and lesser weathering until a hard basaltic core is met with.

Underlying the bentonite is the weathered trap. The rock is brownish black in colour. There is a gradual transition from the weathered trap to the bentonite indicating an in-situ nature of the bentonite.

**MORCHAND (Section 9)**

Located south east of Bhavnagar the village has an approach from the Gogha-Tansa metalled road. South of Morchand small laterite

Plate-X White veins of calcite within the Bentonite.

hillocks can be seen running in a NE-SW direction. The laterite belt, however, thins out in this area. Vegetation is sparse and is dominated by thorny bushes.

The mine is located 1 km south of Morchand village. In the vicinity of the mine there are several hillocks of laterite. The lithological variation in the mine section is as shown in fig 3.

The laterite is reddish brown, hard and concretionary. The contact of the laterite and underlying lithomarge is not sharp but has the lithomarge penetrating upwards into the laterite. The lithomarge is yellowish brown in colour and is marked with white spots in it. These are in the form of concentric rims of clays.

A white clay band separates the lithomarge with the underlying bentonite horizon with a sharp contact. The bentonite is bluish grey coloured with small yellow tinges in the middle. The clay is moist and plastic. When freshly dug the bentonite comes out in the form of lumps which on drying breaks down ito smaller pieces of varying sizes. Light green veins of clay occur within the bentonite.

In another pit of the same mine, but at some distance away from the laterite hillock, the section is completely different. Bentonite occurs directly below a soil cover about 0.5 m thick. The bentonite is mainly bottle green coloured, but is interspersed with blebs of whitish bentonite. White irregular

veins occur within the bentonite which is of a calcitic composition (Plate 10).

Another megascopic texture is the relict amygdaloidal structure present in the green bentonite. The bentonite is moist and plastic when freshly dug. On drying they break down into smaller peds which are angular blocky and range in size from 5 to 10 mm.

**THALSAR (Section 10)**

Thalsar village is located about 32 km south east of Bhavnagar. The laterite belt widens in this area. Laterite mounds can be seen on the western side of the bentonite bearing area. The mounds rise to a height of about 40-50 m. Hard massive basalt hill ranges separate the low lying laterite mounds. The low lying valley portion between the laterite mounds is the potential zone for the bentonite clay. The gentle slope is towards the sea. A quarry pit about one km north of Thalsar village shows a sequence as shown in fig 3, (Plate 11).

The laterite is reddish brown to dark brown in colour and due to the exposure to the atmosphere it has become hard and concretionary.

Underlying the laterite with an irregular contact is reddish brown ferruginous clay which gradually terminates into greyish clay. This grey clay is wet and comes out in lumps which on drying breaks down into small peds of varying sizes.

These are underlain by a thick horizon of bentonitic clay. The contact is sharp. The bentonite shows various colour bands. Here

Plate-XI Mine section showing the various colour bands within the bentonite.

the contact of the various colour bands is sharp. The yellow bentonite is underlain by a pink coloured bentonite which in turn is followed by violet, yellow and greyish black bentonitic clay. When freshly dug the bentonite lumps are in an extremely moist and plastic state. On drying they break down into smaller peds of varying sizes. The texture falls under the clay class while the structure is angular blocky when dry.

Another quarry about half km south of the first one shows an absence of laterite (fig 3).

The lithomarge shows an absence of soil cover. The lithomarge is greyish white in colour and slightly moist. The texture falls under the clay class and the structure is angular blocky when dry.

The bentonite is bottle green in colour and does not show any trace of the spheroidal weathering of basalt. The bentonite is extremely moist and plastic when freshly dug. The hard rock was not exposed in this section.

**ALANG (Section 11)**

A quarry section about 5 km north of Alang village shows a section as shown in fig 3, (Plate 12).

The quarry is situated beneath a small laterite mound. The laterite is brownish black in colour, hard and concretionary.

Underlying the laterite with an irregular contact is a pale yellow coloured lithomarge clay. The lithomarge penetrates

Plate-XII A bentonite mine beneath a laterite mound.

Plate-XIII Bentonite clay directly underlying the soil.

upwards into the laterite. The texture of the lithomarge falls under the clay class and its structure is angular blocky when dry. The lithomarge horizon is followed by a pale green coloured bentonitic horizon.

The contact of the bentonite with the overlying lithomarge is gradual and irregular. The bentonite is moist and plastic when freshly dug. Another feature is the presence of circular pockets of white clay very similar to the pattern produced by the spheroidal weathering of the basalt.

Another pit in the same area away from the laterite hillock shows a section devoid of a laterite capping and lithomarge horizon (fig 3) (Plate 13). Here the bentonite is seen directly underlying the soil.

The contact between the soil and the bentonite horizon is abrupt and irregular. The bentonite is pale green coloured and has yellow patches in it. Relict structures of the spheroidal weathering has been slightly preserved within the bentonite (Plate 13).

**MATHWADA (Section 12)**

The laterite belt widens in this area. The quarry is located about 8 km SE of the Trapaj railway station. The area has a sub normal relief and the vegetation is sparse. The lithological variation in the quarry section is as shown in fig, 3 (Plate 14).

Plate-XIV Bentonite clay directly overlain by soil at Mathwada.

Plate-XV White calcite veins within the bentonite.

There is an absence of the laterite and the lithomarge horizon in this quarry. The bentonite is seen exposed directly under the soil with an abrupt and irregular contact.

The bentonite is pale green to light brown coloured and has retained the amygdaloidal structure of the basalt. The texture of the bentonite falls within the clay class and the structure is angular blocky when dry. When freshly dug the bentonite is in the form of lumps which are extremely moist and plastic, but on exposure to the atmosphere, break down into small peds. Another feature is the presence of white veins of calcite within the bentonite (Plate 15).

**DEVALIYA (Section 13)**

The mine is located under a small laterite mound. The area has a sub-normal relief and the vegetation is sparse dominated by thorny bushes. The laterite capping on the eastern flank is in the form of a hillock. The lithological variation in the vertical section is as shown in fig 3, (Plate 16).

The laterite exposed on the eastern end of the hillock is hard and concretionary. However at the mine section the top horizon is a reddish loose lateritic soil separated from the lithomarge horizon by a white clay band. The lithomarge is yellowish in colour. The lithomarge is moist and slightly sticky. On drying the clay breaks down into small angular pieces.

Bentonite underlies the lithomarge with a gradual and irregular boundary. Bentonites here show two different colour bands; a

Plate-XVI Boulders of basalts preserved with the bentonite.

Plate-XVII Relicts of spheroidal weathering preserved within the bentonite.

green band about 1 m thick followed by a brownish yellow coloured bentonite. The green bentonite when freshly dug is extremely moist. Another feature is the presence of the relict structures preserved within the bentonite. They resemble the spheroidally weathered basalt that has been converted into bentonite (Plate 17).

Boulders of exfoliated or spheroidally weathered basalt are found within the bentonite. The boulders exhibit the exfoliation pattern which is so common in the basalt. The outermost rims of the boulders consist mainly of pure bentonite, but the inner rims exhibit lesser and lesser weathering until the hard basaltic core is met with.

**SAKHAVADAR (Section 14)**

Located about one km SE of Talaja the mine is approachable by the Talaja-Sultanpur metalled road. The mine section exposes a sequence as shwon in fig 3, (Plate 18).

The soil is brownish black in colour and has its surface marked with cracks. Underlying the soil with an abrupt and irregular contact is a lithomarge horizon. The lithomarge is yellowish and greyish in colour. The lithomarge clay comes out in lumps when freshly dug. The texture falls within the clay class.

The lithomarge horizon passes gradually to an underlying green bentonite horizon. The contact is gradual and irregular. The bentonite is wet and moist and comes out in lumps when freshly

Plate-XVIII The irregular contact of the whitish lithomarge with the underlying greenish bentonite in a mine section at Sakhavadar.

dug. The bentonite is of a massive variety showing no relict structures of the basalt.

**Type II (Secondary)**

**MALANKA (Section 1)**

Malanka village is located 10 km south east of Bhavnagar and is approachable by metalled road. The section exposed in the Malesari river cutting is shown in fig 3, (Plate 19).

The conglomerate contains rounded pebbles of agate, chalcedony and is cemented in a siliceous matrix (Plate 20). The conglomerate bed has a sharp contact with the underlying sub-bentonite clay horizon. The clay horizon is about 1.5 m thick and dry. The clay comes out in small peds when dug because of its dry nature. The clay horizon shows sedimentary layering and is gritty in nature.

**ADHEVADA (Section 2)**

Adhevada village is located about 6 km south of Bhavnagar on the Bhavnagar-Talaja road. The section exposed is in a river cutting and is as shown in fig 3, (Plate 21).

The conglomerate and the bentonite both show a dip of 28 due east. The contact between the conglomerate and underlying bentonite is sharp. The bentonite is ash coloured and dry and comes out in small peds when dug.

Another section along the river about 100 m north of the first one shows the same sequence. The thickness of the conglomerate bed is almost the same.

Plate-XIX Section exposed in a river cutting showing bentonite clay overlain by hard conglomerate.

Plate-XX Rounded pebbles of agate and chalcedony cemented in a siliceous clay matrix.

Plate-XXI Bentonite overlain by hard conglomerate showing dip of 26° due east.

The bentonite deposit here is a reworked one and shows sedimentary layering (Plate 21).

**TAGADI (Section 4)**

Tagadi village is located south of Bhavnagar on the Budhel-Gogha road. At present there are two quarries in operation on the and the section exposed in these quarries ia as shown in fig 3 (Plate 22).

The quarries are located half km east of Tagadi village. Here there is an absence of laterite horizon, instead there is a thick soil cover. The soil is reddish brown in colour and is underlain by a yellow coloured clay. The contact between the soil and the yellow clay is sharp and irregular. The clay is slightly moist and comes out in lumps when freshly dug.

A 0.6 to 0.8 m thick kaolinitic horizon separates the yellow clay from the bentonite (Plate 22). The contact is sharp and irregular.

Underlying the kaolinitic horizon is a dark grey coloured bentonite which is moist and plastic when freshly dug. On drying the clay breaks down into smaller peds of varying sizes. The bentonite does not show any relict structures of the basalt.

**THORADI (Section 5)**

Thoradi village is situated on the Budhel-Rajpara road. The bentonite bearing area lies on the left bank of the Thoradi-

Plate-XXII A mine section exposed at Tagadi.

Plate-XXIII Mine section exposed at Thoradi.

Bhuteshar nala. The area has a sub-normal relief and the vegetation is sparse.

The lithological variation in a quarry section is as shown in fig 3 (Plate 23).

Here the bentonite horizon is devoid of both laterite and lithomarge but lies directly beneath the soil horizon. The soil horizon is about 1.5 m in thickness and is brownish black in colour and has its surface marked with huge cracks. The boundary between the soil and the bentonite clay is abrupt and almost horizontal.

The bentonite is greyish coloured and is in an extremely moist state. When freshly dug it comes out in the form of lumps which on drying break down into small peds of varying sizes.

The bentonite shows an absence of any relict structures or textures of the basalt.

Another quarry section about one km north of the first one shows a sequence as shown in fig 3.

Here too the bentonite horizon lies directly beneath the soil horizon. The bentonite is brown coloured and is in a slightly moist state. Here an important structure is the presence of pockets of white clay within the bentonite (Plate 24). These white pockets are about 30 cms in diameter and are considered to be the relicts of the exfoliated or spheroidally weathered basalt which has undergone a transformation to bentonite. The clay is


PlateXXIV Pockets of white clay within the bentonite.

moist and sticky. Another feature here is the presence of veins of calcite within the bentonite.

The bottom of the quarry pit was filled with water which had accumulated during the monsoon. Due to the underlying bentonite, the drainage has become very sluggish and the water had still not drained off.