CHAPTER IV

FIELD OBSERVATIONS

Stratigraphy

The Dhrangadhra sandstone and shales have been only slightly distrubed from their original horizontal position. Only a part of the succession of beds is exposed. Exposed thickness is estimated at 520 m. Base is not exposed in any part of the study area. Plant fossils studied by previous workers indicate that the deposition of Dhrangadhra Formation commenced in the Upper Jurassic and continued through Lower Cretaceous (Neocomian) to probably, Middle Cretaceous (Albian). Dhrangadhra Formation is divided into three stages on the basis of lithological variations.

Dhrangadhra Formation is conformably overlain by Wadhwan Formation. Ranipat, Suraj Deval and Than are described as stages by previous workers but as these divisions are made on the basis of lithological variations the present author feels that "Litho Stratigraphic Unit" is a better term.

TABLE IV.1

STRATIGRAPHY OF DHRANGADHRA FORMATION

Lithostratigraphic Unit	Gross Lithology	Geo-chronological Unit	Facies
Ranipat	Ferruginous Sandstone with Iron Concretions; Quartzite, Grit	Middle Cretaceous	D
	Conglomeritic bands; Graded bedding is common.	Lower Cretaceous	E L
Suraj Deval	Red friable shale and felspatic Sandstone, with Graded and Current bedding most common.	to	T A I
Than	Grey and Carbonaceous shale with thin coal seams and plant fossils, Fine grained sandstone with occassionally pyritic nodules.	Upper Jurassic	C

--------- Base is not exposed------

(Modified after Kathiara et al, 1971).

The generalized cross sections showing litholo-gical variations in areas of Saurashtra where fireclay occurs as underclays, are as follows:

Soil (Top)
Sandstone
Fireclay (Sagger Clay)
Coal
Fireclay (Body Clay)
Siliceous Finegrained Sandstone (Bottom)

Siliceous Fine Grained Sandstone

It is black due to the presence of little amount of coaly matter. Sometimes it shows pyritic nodules which are few cm to 10 cm thick. These pyritic nodules are formed by the combination of pyrite grains and angular siliceous grains. Presence of pyrite in this strata indicates swampy (reducing) conditions during deposition. Due to its finegrained nature, black color and appearance like fireclay, it sometimes confuses the miners. At most of the places where this bed is exposed, groundwater has flooded the mine pit putting the fire-clay miners into great difficulty. To avoid this, miners are taking care not to expose this bed.

Fireclay (Body Clay)

The contact between the fine grained sandstone and the overlying fireclay is gradual. Fine grained siliceous material slowly merges into very fine grained fireclay. Color of the two is nearly same. Thickness of fireclay varies from 2 to 6 m. Organic matter is more in the upper horizon of fireclay bed which is fairly plastic with low silica content. Fireclay is grey to black in color. Black color is due to the presence of coaly matter. Hardness of fireclay gradually increases downwards due to increasing overburden. This fireclay used in the body of ceramic wares is locally called as body clay.

C o a l

Coal seam overlies the underclay, at few places. Small stringers of coal few cm to 25 cm thick are observed at Thangadh, Songadh, Tarnetar and Khakhrathal mining areas. While at Sadala, Palasa and Khanpar mining areas, coal stringers are not observed but plant remains in the form of coaly matter are trapped in the upper horizon of fireclays. Coal at some places shows high grade (Bituminous) coal trapped in fireclay as laminae.

This coal is not economically important because of its poor quality and poor reserves.

Fireclay (Sagger Clay)

The contact between coal and sagger clay is very sharp, as the color of sagger clay is grey and that of coal is black. Thickness of sagger clay varies greatly from place to place. Its maximum thickness is about 5 m. At some places fireclay and sagger clay occur as alternate beds e.g. at Tarnetar, Songadh. This clay does not contain more organic matter like that of underclay. Because this clay is hard and shows conchoidal fracture, in the opinion of the present author, it can be named as "Flint Clay". Locally people are calling this clay as sagger clay because they are using this clay for the manufacture of saggers in ceramic industry. This grey colored flint clay contains more siliceous matter observed visually.

Sandstone

The contact between the sagger clay and the overlying sandstone is not gradual. Sudden change in color and grain-size in this sequence shows rapid deposition

and change in depositional conditions. If the quarry is situated at higher elevation, the sandstone is yellow to red (ferruginous) but when it is situated in low lying area, it is yellowish white. It means that sandstone at higher elevation contains more ferruginous matter while that in low lying area is free from ferruginous matter. Sandstone of upper horizon is coarse grained and changes gradually to medium grained. Graded beddings and major current beddings are most commonly observed in sandstone strata.

The generalized cross sections showing lithological variations in areas of Saurashtra where fireclay does not occur as underclays, are as follows :

Soil (Top)
Sandstone
Purple Clay and Siliceous White Clay
Fireclay
Sandstone (Bottom)

Sandstone

It is yellowish white, medium to fine grained, and devoid of any organic matter or pyrite. During mining as soon as this rock is exposed, it creates problems due to water flooding of mine pits.

Fireclay

It is generally grey at Makansar, Matel, Vinaygadh and Lunsar. Color variation is more at Ratidevali. The contact between overlying and underlying sandstones with fireclay is not gradual due to variation in color, grain-size and composition. Fireclay does not show any coaly matter trapped in it. It is siliceous and appears to be semi-refractory in nature. At Ratidevali some color bands are observed in fireclay bed. These faint brown and white bands hardly 1 cm thick when powdered, color changes to nearly white. At Saltanpur, Paneli, Jambudia the color of the fireclay is red because of impregnation of ferruginous matter leached from overlying sandstone. Leaching is well observed at Saltanpur mine. This leaching took place through small fractures present in the fireclay body and preserved as nodules. This red clay is extensively mined at Paneli, Saltanpur and Jambudia. Thickness of red clay varies from 5 to 8 m and that of grey and whitish clay is 2 to 4.5 m.

Purple and Siliceous White Clays

Grey fireclay have gradually changed to purple clays and at some places to white siliceous clays. Purple color

appears to be due to ferruginous matter. Thickness of this clay is upto one metre at some places. Siliceous white clay is observed on top of fireclay. This type of clay, is exposed in road cutting along Wankaner to Morvi road near Dhuva and Makansar villages. Both these clays are economically not important.

Sandstone

Thickness of this sandstone is upto 2 m in mines located in low lying areas, but where mining operations are carried out at higher elevations, e.g., Saltanpur and Matel, thickness of sandstone is more. Upper horizon of this sandstone is very coarse grained, sometimes gritty and even conglomeratic bands are observed. The maximum thickness of this sandstone upto 10 m is exposed at Makansar, Digvijay sandstone mine. Graded bedding is most common. Upper horizon of this sandstone, is ferruginous and gradually changes to yellow.

Occurrence

Fireclay occurs as bedded deposits in Surendranagar and Rajkot districts of Saurashtra. Fireclay beds are not showing uniform thickness at most of the places where

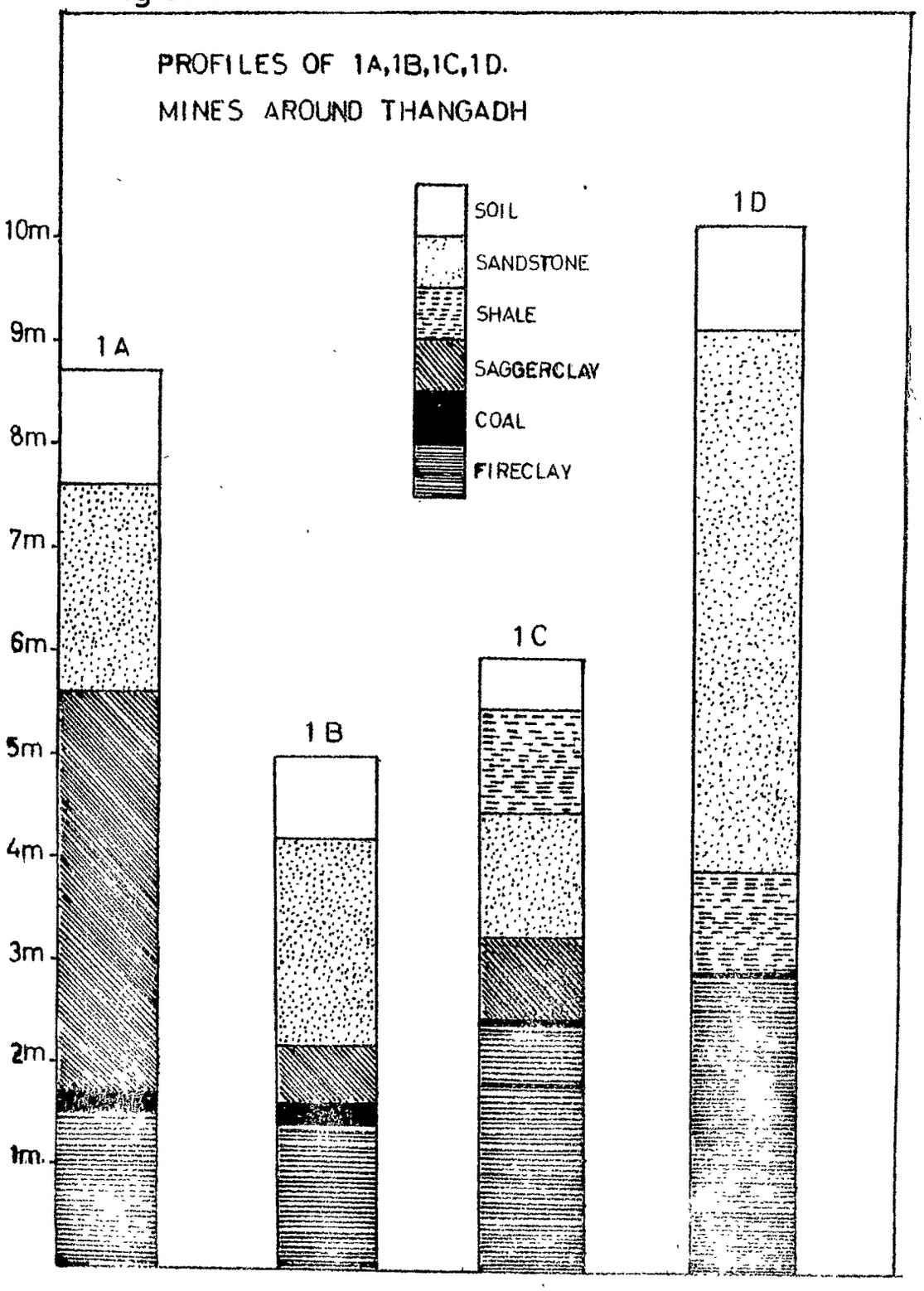
it occurs as bedded deposits. At Thangadh, Khakhrathal, Tarnetar, and Sadala fireclay occurs below thin coal stringers whereas at other localities it occurs below 0.5 to 2.5 m thick pile of sandstone and soil. Fireclay from Saurashtra is either plastic or non-plastic and shows great variation in quality. Only high grade fireclay is mined at 15 to 16 centres of fireclay mining in both the districts. Occurrence of fireclay from these localities is described in the following pages.

Locality : Thangadh

1A	Parshuram Pottery Works Mine	Kandolia
1B	K. P. Vaghela	Thangadh
1C	A. A. Kaladia	Songadh
1D	B. K. Rana	Bagagela

Opencast mines of fireclay are located around Songadh hill 2 km north of Than. Alternate beds of sandstone and fireclay are exposed on the slope of the hill. Fireclays are mined extensively from all possible sides of the hill. All the three "Litho Stratigraphic Units", viz., Ranipat, Suraj Deval and Than are well exposed in this area. The profiles of fireclay mine (Fig. IV.1) located near Thangadh are as follows:

Fig. IV.1


PROFILES OF 1A,1B,1C,1D.
MINES AROUND THANGADH
SOIL
SANDSTONE
SHALE
SAGGERCLAY
COAL
FIRECLAY
10m
9m
8m
7m
6m
5m
4m
3m
2m
1m
1A
1B
1C
1D

MINE 1A	Thickness (m)	MINE 1D	Thickness (m)
Soil	1.1	Soil	1.0
Sandstone	2.0	Sandstone	5.2
Saggerclay	3.88	Shale + Carbonaceous Matter	1.0
Coal	0.2	Coal	
Fireclay	1.0	Fireclay	2.9

Thickness of soil cover is about 1 m. Sandstone is loose yellowish in color and coarse to medium grained. As compared to other mines, sandstone overburden at 1D located at the foot of the Songadh hill, is thicker. Miner faults are observed on exposed mine face. Fireclay underlain by sandstone contains more siliceous matter and it is less plastic than fireclay from 1A, where it is underlain by by coal bed (Plate IV.2). In 1A, saggerclay is underlain by sandstone. It is a semi-flint clay similar to fireclay from 1D. Body clay, occuring below 25 cm thick coal bed, is plastic, dark grey and compact showing remains of organic matter. Fireclay in this area is not of uniform thickness and suddenly disappears at places due to extensive faulting. Fine grained sandstone is observed below the fireclay beds at some localities.

PLATE NO. IV.1

THANGADH

Pottery works (in the background) located near Fireclay mines.

PLATE NO. IV.2

SONGADH (1A)

Coal Stringers separating Sagger clay at the top from body clay at the bottom.

The profiles of fireclay mines (Fig. IV.1) located at slightly higher elevations than those of 1A and 1D near Thangadh, are as follows:

Mine 1B	Thickness (m)	Mine 1C	Thickness (m)
Soil	0.8	Soil	0.5
Sandstone	2.0	White Shale	1.0
Sagger Clay	0.5	Sandstone	1.2
Coal	0.25	Sagger Clay	0.8
Fireclay	1.4	Fireclay	2.4

The thickness of soil cover is less at 1B and 1C than that at 1A and 1D. About 1 m thick white shale occurring at 1C is not encountered at 1B. Below soil and shale cover is a 2 m pile of loose sandstone showing current bedding and white to yellow shaded colors. Sandstone -grades below into a low grade clay (locally called sagger-clay) containing more silica and micaceous material than underclays occurring below coal seam (Plate IV.3). This grey colored fireclay shows flinty fractures. Sandstone, saggerclay, coal and fireclay deposits are exposed on the mineface (Plate IV.4). Saggerclay (Plate IV.5), is underlain by coal bed (few cm to 25 cm thick). Abundant plant fossils and coaly matter (Plate IV.6), indicate its presence e.g. at 1C, where this bed is only 8 cm. Quality

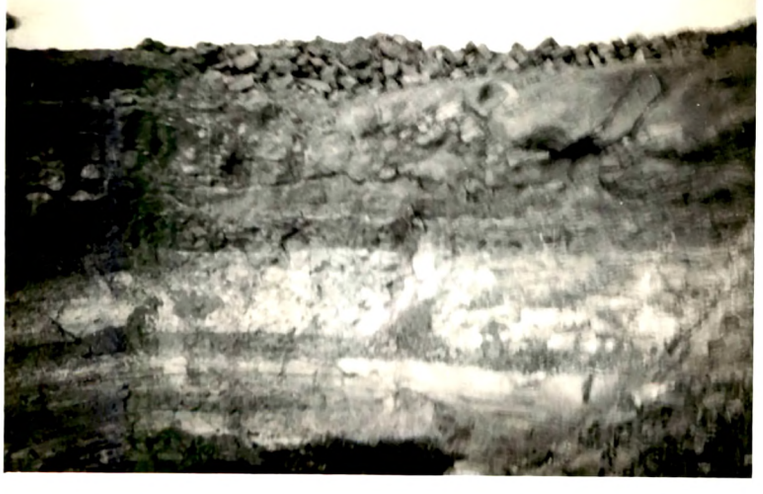
PLATE NO. IV.3

SONGADH (1B)

Fireclay(below Sagger clay) rich in plant fossils.

PLATE NO. IV.4

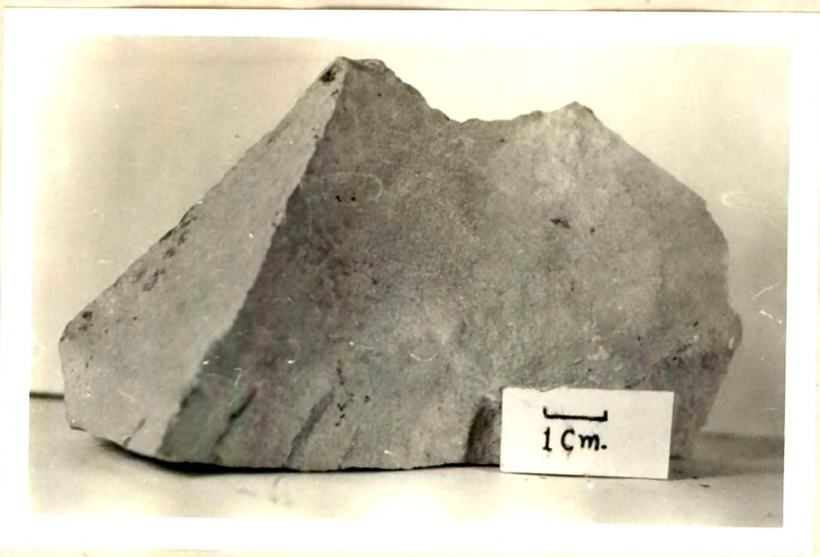
SONGADH (1C)



Alternate bands of Sandstone, flintclay, coal and plastic clay.

PLATE NO. IV.5

SONGADH (1C)



Sagger clay showing flinty fractures.

PLATE NO. IV.6

SONGADH (1B)

Coaly matter (Plant impressions) on upper layer of fireclay bed.

of fireclay from these mines is most suitable for ceramic use. The mines at Kandolia, Bagagela, Songadh and Thangadh are close to each other hence quality of fireclay does not differ much.

Number of hillocks around Thangadh and Tarnetar (central part of Dhrangadhra Formation) are the results of tectonic disturbance which took place after the deposition of Dhrangadhra Formation.

Locality : Khanpar

Fireclay Mines	2A	B.D. Rana
	2B	H.B. Sanghavi

Khanpar is about 6 km north of Thangadh. Fireclay opencast mines are located 2 km from Khanpar towards the Songadh hill. These mines are located at a short distance from the foot of this hill.

The profiles of the fireclay mines (Fig. IV.2) near Khanpar are as follows:

Mine 2A	Thickness (m)	Mine 2B	Thickness (m)
Soil	1.5	Soil	1.0
Sandstone	0.5	Sandstone	2.0
Saggerclay	1.2	Saggerclay	1.0
Fireclay	3.9	Fireclay	6.0

Fig. IV.2

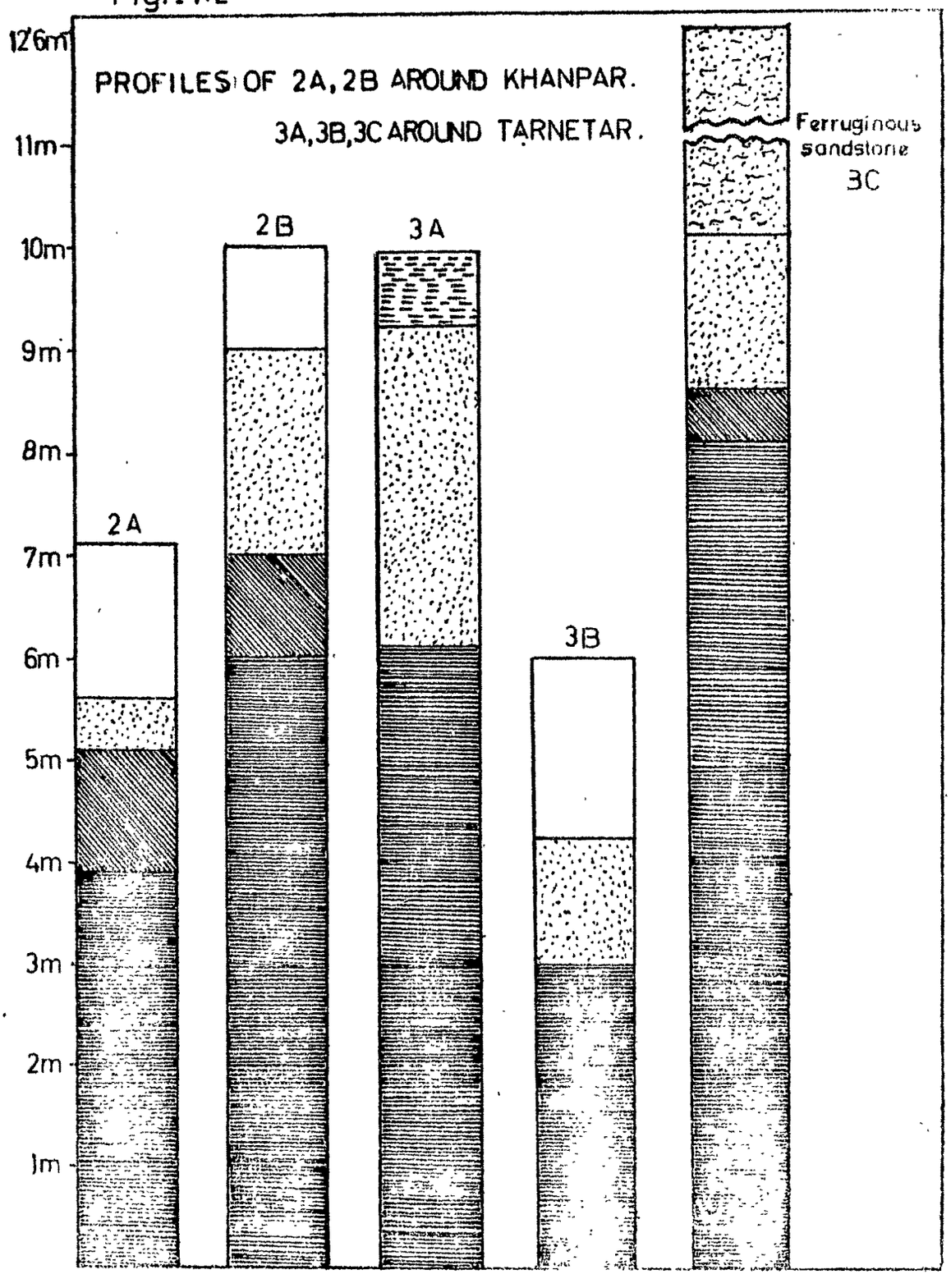

PROFILES OF 2A, 2B AROUND KHANPAR.
3A, 3B, 3C AROUND TARNETAR.
12·6m
11m
10m
9m
8m
7m
6m
5m
4m
3m
2m
1m
2A
2B
3A
3B
Ferruginous sandstone
3C

PLATE NO. IV.7

KHANPAR (2B)

Sharp contact between finegrained compact sandstone at the top and fireclay at the bottom.

Soil cover is 1 to 1.5 m thick. Thickness of sandstone varies from 0.5 to 1 m Overburden is easy to remove as it is of soil and loose yellow to white colored sandstone. At some places, fine grained compact white sandstone shows sharp contact with underlying fireclay (Plate IV.7).

The presence of coaly matter gives rise to dark grey color at the contact of Saggerclay and fireclay. Thickness of fireclay is comparatively more, hence mining in this area is more profitable. Saggerclay is 1 m thick and is an inferior fireclay containing more harmful materials. 4 to 6 m thick body clay is the best quality plastic fireclay containing organic material (plant remains). If underlying sandstone is exposed during mining of fireclay, the ground water floods the mining pit. This is prevented by removal of this water with the help of diesel pumps.

Locality : Tarnetar

Fireclay Mines

3A J.C. Rana

3B - do -

3C - do -

Tarnetar is about 8 km from Thangadh and 2 km north of Khanpar. It is on the Than-Dhrangadhra metal road. It is a famous pilgrimage centre having an ancient temple. The only extensive mining operations carried out around this temple are by J.C. Rama.

The profiles of fireclay mines (Fig. IV.2) near Tarnetar are as follows:

Mine 3A	Thickness(m)	Mine 3B	Thickness(m)	Mine 3C	Thickness(m)
Shale	0.7	Shale	1.8	Ferruginous Sand-stone	2.5
Sandstone	3.2	Sandstone	1.2	Yellow Loose Sandstone	1.5
Fireclay	6.1	Fireclay	3.0	Saggerclay	0.5
				Fireclay (Flint)	9.6

Overburden is mainly of shale and sandstone. At 3C maximum thickness of overburden is 4m. In this area all the three 'Lithostratigraphic units' are exposed viz., Ranipat, Suraj Deval and Than. All the mines are confined to 2 sq. km area. The thickness of fireclay bed is not uniform. At 3C which is nearer to the temple

the thickness of flint to semiflint fireclay is maximum i.e. 9.6 m (Plate IV. 8). These fireclays contain more silica and patches of ferruginous matter. There are no traces of coaly bands at 3C. At this mine blasting operations are sometimes carried out to remove 2.5 m hard ferruginous sandstone. Yellow loose sandstone underlying this is easy to excavate.

Ferruginous sandstone is not encountered at mines 3A and 3B, situated near the lake at lower elevations than 3C. Thickness of overburden is less and contains shale and loose white to yellow sandstone showing graded bedding. Thickness of fireclay is 3 to 6 m. Excavation below the fireclay bed gives rise to ground water flooding in mining pit (Plate IV.9). Water is continuously pumped out during the mining operation. Mining is unsystematic (Plate IV.10). Upper layer of fireclay contains numerous plant fossils (Plate IV.11), and ferruginous matter in joints, fine grained, siliceous, loose and black colored rock occurring below fireclay bed shows the presence of pyritic nodules (Plate IV.12), which indicates marshy (swampy) conditions and reducing environment during the deposition of these beds.

PLATE NO. IV.8

TARNETAR (3C)

Semi-flint to flint clay showing greatest thickness (9.6m).

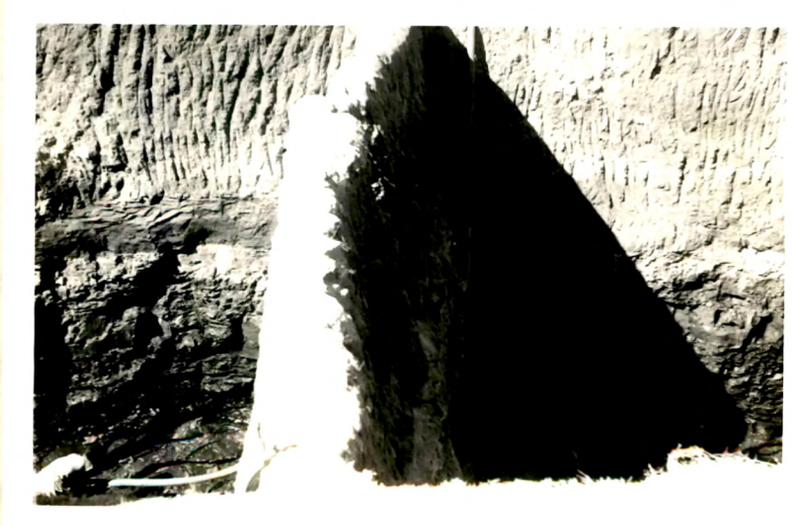
PLATE NO. IV.9

TARNETAR

Water flooding in mining pit excavated upto the bottom of the fireclay.

PLATE NO. IV.10

TARNETAR (3A)



The boundary wall between the adjacent mining pits is less than 0.5m. which is not in conformation to mining laws.

PLATE NO. IV.11

TARNETAR (3B)

Bituminous coal layer (1 mm) in upper fireclays

PLATE NO. IV.12

TARNETAR (3B)

Pyritic nodules below fireclay bed.

Locality : Sadala

Fireclay Mines

4A Gayatri Minerals

4B Prabhat Minerals

4C Parmar Minerals

Sadala is 20 km north west of Muli. Fireclay mining area is 1 km from Sadala. Five to six opencast mines are located in 1 sq km belt of fireclay. The profile of fireclay mines (Fig. IV.3) near sadala are as follows:

Mine 4A	Thickness(m)	Mine 4B	Thickness(m)	Mine 4C	Thickness(m)
Soil	1.0	Soil	1.0	Soil	1.0
Sandstone	0.6	Fireclay	2.0	Fireclay	4.6
Fireclay	1.3				

In this area, the soil cover is 1 m and sandstone patches occur as overburden only at 4A. Overburden is comparatively less thick and is easy to remove, hence mining in this area is very profitable. The thickness of fireclay bed increases from 1.3 m at 4A which is nearer to Sadala to 4.6 m at 4C (Plate IV.13) which is away from

Fig. IV.3

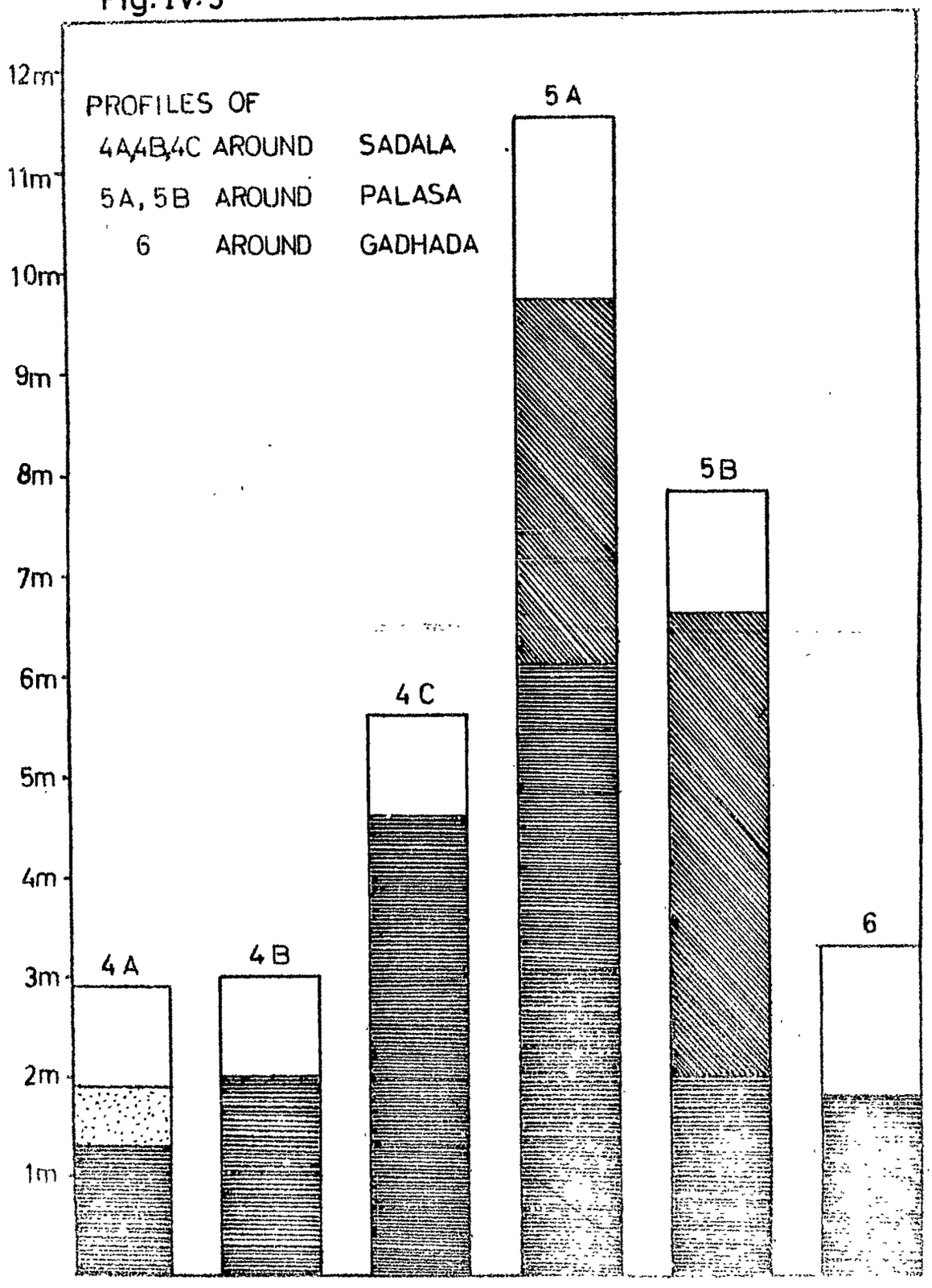

PROFILES OF
4A,4B,4C AROUND SADALA
5A, 5B AROUND PALASA
6 AROUND GADHADA
12m
11m
10m
9m
8m
7m
6m
5m
4m
3m
2m
1m
4 A
4 B
4 C
5 A
5 B
6

PLATE NO. IV. 13

SADALA (4C)

One meter thick over burden above fireclay.

PLATE NO. IV.14

SADALA (4C)

Mica flakes on the freshly cut surface of the upper most portion of fireclay bed.

Sadala. The fireclay bed appears to be lensoidal in shape. Fireclay shows good plasticity by hand feel and contains more micaceous matter (Plate IV.14). Silica content is more and coaly matter is occassionally present. Quality of dark grey fireclay is good. The presence of fine grained sandstone below fireclay is responsible for water flooding of mining pit when excavated below fireclay horizon.

Locality : Palasa

Fireclay Mines

5A B.D. Makwana

5B Parmar Minerals

Palasa is 20 km west of Muli. Mines are located 1.5 km from Palasa and 2.5 km from Rampurda railway station. The profiles of fireclay deposits (Fig. IV.3) near Palasa are as follows:

Mine 5A	Thickness (m)	Mine 5B	Thickness (m)
Soil	1.8	Soil	1.2
Saggerclay	3.6	Saggerclay	4.6
Fireclay	6.1	Fireclay	2.0

PLATE NO. IV.15

PALASA (5A)

Well developed mining pit showing benches.

PLATE NO. IV.16

PALASA (5B)

Mine pit showing 6m. thick semi-flint clays and water flooding.

PLATE NO. IV.17

PALASA (5B)

Fireclay showing plant fossils.

Mine 5A and 5B are adjescent to each other. The overburden is 1.2 to 1.8 m thick. Overburden is easily removed by peak and shovel. Fireclay mining is more profitable as cost of removal of overburden is less and fireclay thickness is more. Mining in this area, is more systematic as compared to mining operations in other areas of Saurashtra (Plate IV.15). 4m thick saggerclay underlies an overburden of soil. It shows flinty fractures and low plasticity by hand feel. The greater amount of silica and mica, the harmful constituents reduce its market value. Body clay is dark, compact, bedded and contains less silica. The plasticity by hand feel is fairly good. The thickness varies from 6 m at 5A to 2m at 5B (Plate IV.16). Upper layer of fireclays from both the mines shows presence of numerous plant fossils (Plate IV. 17).

Locality : Gadhada

Fireclay Mine 6 : Temubhai Parmar.

The profile of fireclay mine (Fig. IV.3) located one km from Gadhada is as follows :

Mine 6	Thickness(m)
Soil	1.5
Fireclay	1.8
Black Sandy Clay	-

1.8 m thick fireclay occurs below a soil cover of 1.5 m. This fireclay is more siliceous, compact and occassionally shows flinty fractures. It contains less organic matter. Vertical and oblique joints show presence of brown ferruginous matter. The fireclay is not of uniform thickness and appears to be lensoidal in shape. Black sandy clays exposed below fireclay bed, are confused for fireclay by miners.

Locality - Ratidevali

Fireclay Mines

7A Zala Vakhatsingh

7B Khengar Vira

Ratidevali is 3 km north of Wankaner. Fireclay mining area is located 2 km north of Ratidevali. Profiles of fireclay mines (Fig. IV. 4) near Ratidevali are as follows:

Mine 7A	Thickness (m)	Mine 7B	Thickness (m)
Soil	1.2	Soil	0.6
Sandstone	1.0	Sandstone	2.8
Fireclay	2.0	Fireclay	4.2

Fig.IV.4

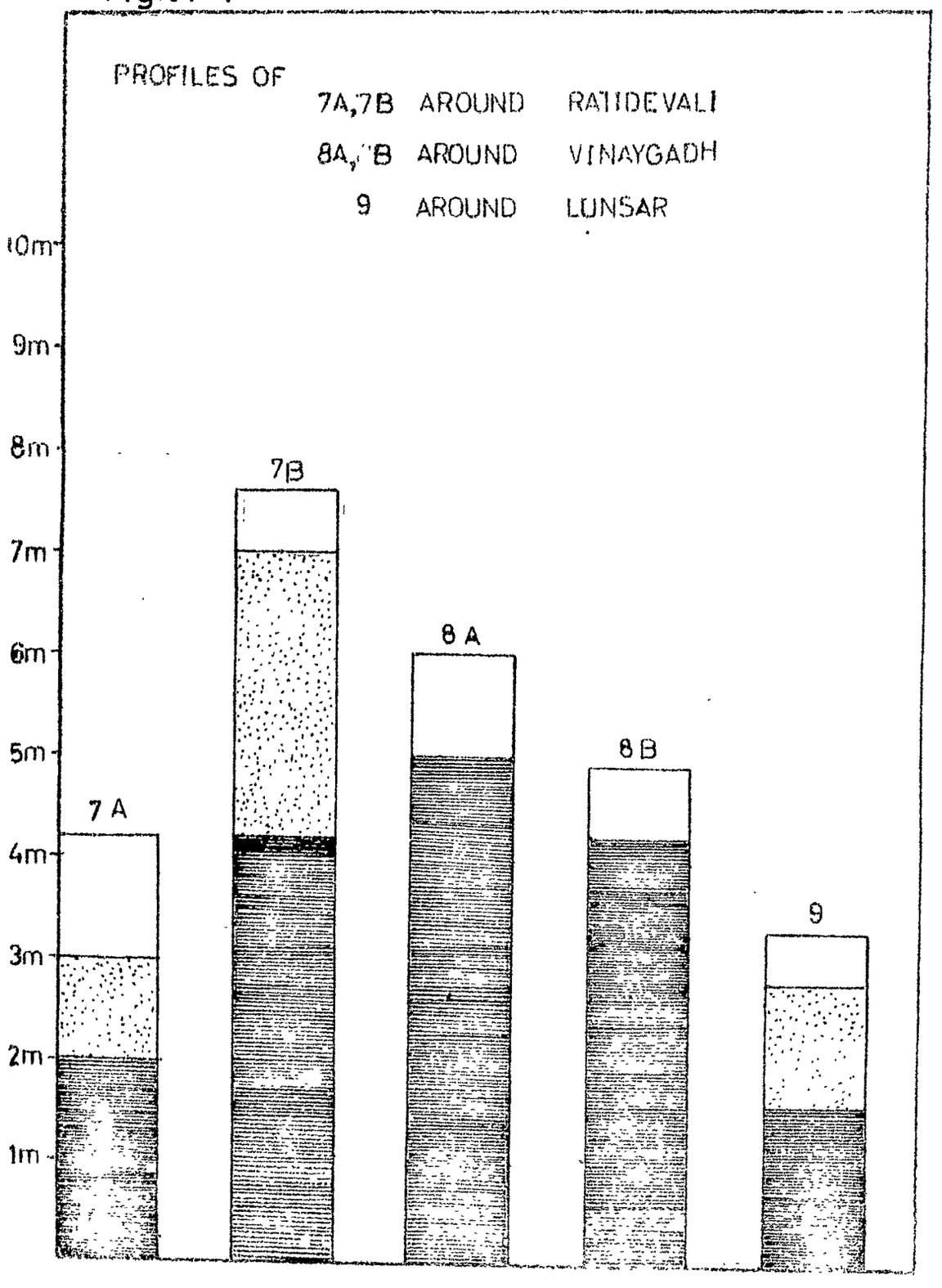

PROFILES OF
7A,7B AROUND RATIDEVALI
8A,8B AROUND VINAYGADH
9 AROUND LUNSAR
10m
9m
8m
7m
6m
5m
4m
3m
2m
1m
7 A
7B
8 A
8 B
9

PLATE NO. IV.18

RATIDEVALI (7A)

Pumping of water from the mine pit to keep it working.

PLATE NO. IV.19

RATIDEVALI (7B)

Sharp boundary between fireclay and overlying fine grained compact sandstone.

PLATE NO. IV.20

RATIDEVALI (7B)

Joints in fireclay below compact finegrained sandstone.

PLATE NO. IV.21

RATIDEVALI (7B)

Flinty fractures and color banding in fireclay.

Mine 7A is 0.5 km away from 7B. At 7A soil cover is 1.2 m and sandstone is 1 m thick. 2m overburden having 2m thick fireclay below is easily removed by peak and shovel (Plate IV.18).

Compact fireclay containing more silica is flint type. Ferruginous brown material is trapped in the joints of fireclay. At mine 7B soil cover is 0.6 m and 2.8 m thick sandstone is compact and fine grained. The contact of fireclay and sandstone is sharp (Plate IV.19). Vertical and oblique joints are most common in fireclay (Plate IV.20). Fireclay is 4.2 m thick and shows color banding (Plate IV.21), minor fault, slicken sided surfaces, and numerous vertical and horizontal joints. Fireclay is flint type, non-plastic white layers contain more percentage of Al_2O_3 while brownish or pale pink layer contains Fe_2O_3 more.

Locality : Vinaygadh

Fireclay Mines

8A Kailash Pottery Works Mine

8B Raghuvir Clay Supply Company Mine

Vinaygadh is 25 km south east of Wankaner. Fireclay mining operation are carried out 2 km from Vinaygadh.

PLATE NO. IV.22

VINAYGADH (8A)

Semiflint clay below 0.5m overburden.

PLATE NO. IV.23

VINAYGADH (8B)

Water flooding in fireclay mining pH.

The profiles of fireclay mines (Fig. IV. 4) near Vinaygadh are as follows:

Mine 8A	Thickness (m)	Mine 8B	Thickness (m)
Soil	1.0	Soil	0.6
Fireclay	5.0	Fireclay	4.2

Fireclay is overlain by hardly one meter overburden of soil. Sandstone strata is missing so it is very easy to remove overburden. Fireclay thickness is about 5m (Plate IV.22). Fireclay is grey to black and occasionally contains coaly matter and shows flinty fractures. It is bedded and uniform in thickness and shows good plasticity. Water flooding in fireclay mining pit is problem for miners (Plate IV.23).

Locality : Lunsar

Fireclay Mine 9 : Bhikalal Shah

Lunsar is 20 km north-east of Wankaner, a taluka place. Fireclay mining is located at about 1 km from Lunsar. Profile of fireclay mine (Fig. IV.4) near Lunsar is as follows.

Mine 9	Thickness (m)
Soil	0.5
Sandstone	1.2
Fireclay	1.6

1.7 m overburden consisting of soil and sandstone is very loose and easy to excavate. Bedded and dark grey fireclay though contains less organic matter shows good plasticity. It is underlain by very fine grain black siliceous sandstone, which when excavated creates severe water flooding due to higher water table.

Locality : Saltanpur

Fireclay Mines

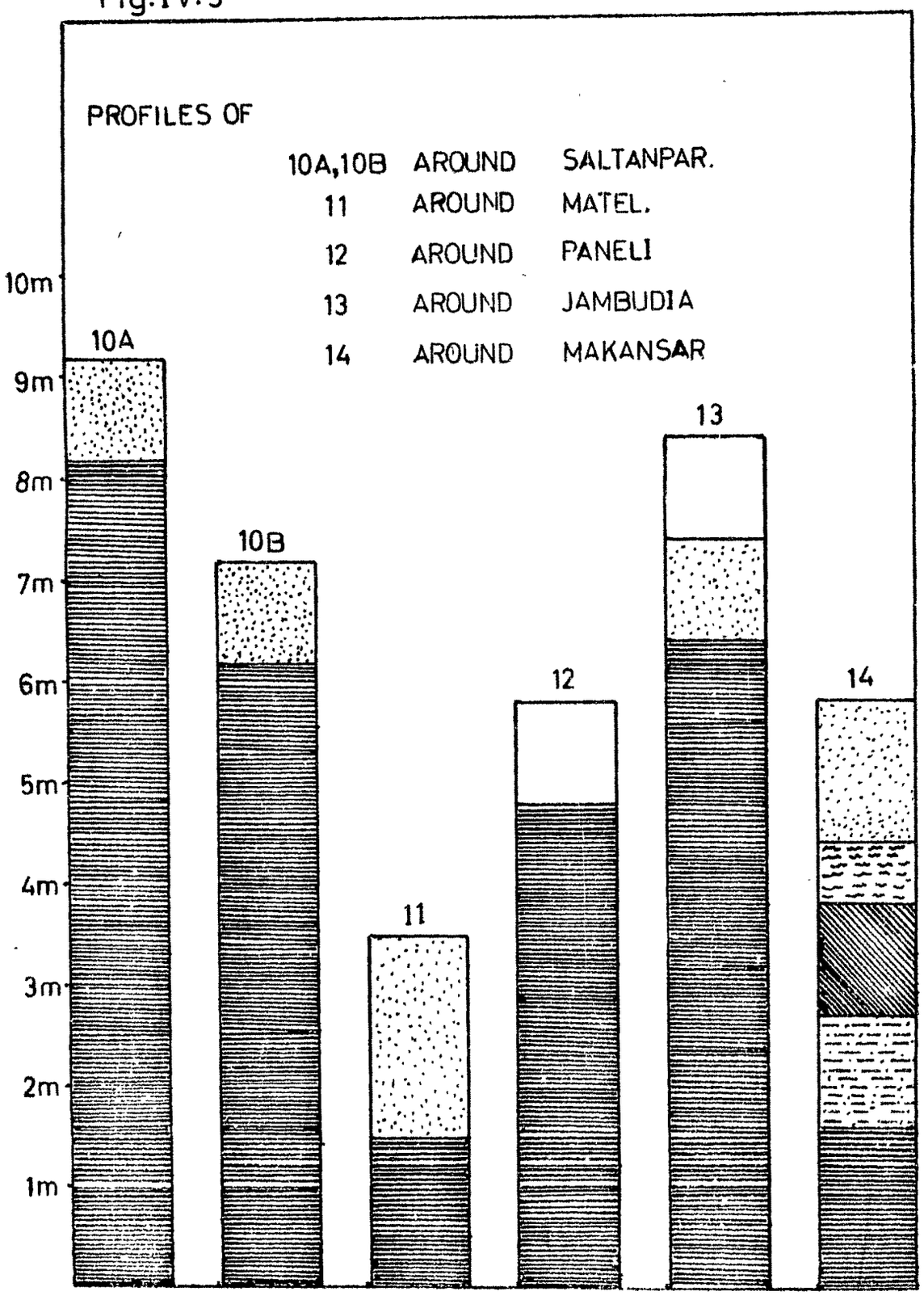
10A Bhadiad Pottery Works Mine

10B Taibali Mine

Saltanpur is about 18 km south-east of Morvi. The profiles of fireclay mines (Fig. IV.5) near Saltanpur are as follows:

Mine 10A	Thickness (m)	Mine 10B	Thickness (m)
Yellow Loose Sandstone	1.0	Yellow Loose Sandstone	1.0
Fireclay	8.2	Fireclay	8.2

Fig.IV.5


PROFILES OF
10A,10B AROUND SALTANPAR.
11 AROUND MATEL.
12 AROUND PANELI
13 AROUND JAMBUDIA
14 AROUND MAKANSAR
10m
9m
8m
7m
6m
5m
4m
3m
2m
1m
10A
10B
11
12
13
14

About 1 metre loose yellow colored coarse to fine grained sandstone occupying as overburden is easily excavable. Evidence of leaching is clearly observed on mine face. Leaching of ferruginous matter from overlying ferruginous sandstone has made ferruginous sandstone appear yellow and nodular fireclay appear red. Maximum thickness of fireclay is 6.2 to 8.2 m. Grey fireclay shows red nodules and flinty fractures at places. Nodular fireclay is seen in mine section (Plate IV.24).

Locality : Matel

Fireclay Mine 11 Babu Chakku Mine

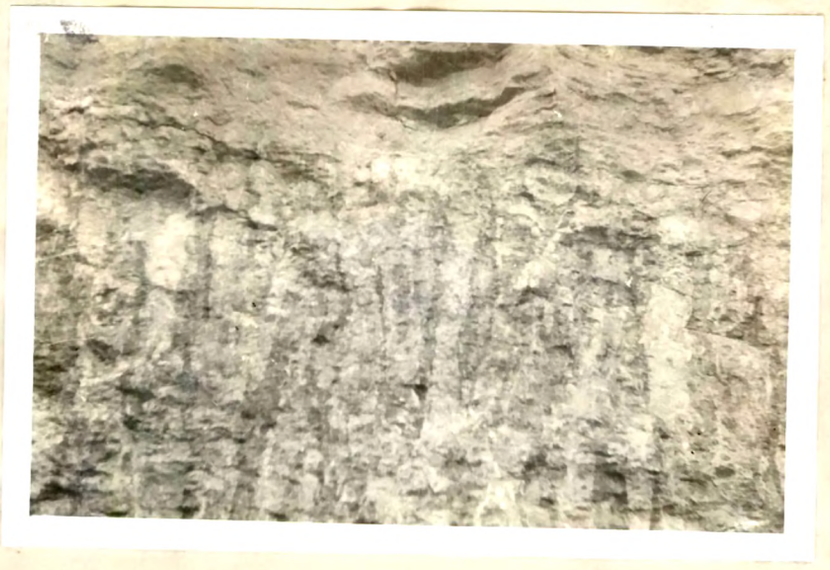
Matel is 16 kms north-east of Wankaner. Mines are located at the base of small hillock, 1 km from Matel. Profile of the fireclay mine (Fig. IV.5) near Matel, is as follows.

Mine 11	Thickness(m)
Sandstone	2.0 (varies)
Fireclay	1.5

Sandstone overburden varies as mine is located on a small hillock (Plate IV.25). Loose, yellow colored

PLATE NO. IV.24

SALTANPUR (10A)



Vertical face of mining pit showing nodular fireclay and evidences of leaching.

PLATE NO. IV.25

MATEL (11)

Fireclay mining pit showing increase in over-burden towards the hillock.

sandstone turns to red due to enrichment of ferruginous matter. Fireclay thickness also varies from 1.5 to 2m. It is grey colored with more siliceous matter. Plasticity is fair by hand feel.

Locality : Paneli

Fireclay Mine 12 Co-operative Sahakari Mandli Mine.

Paneli is 12 km south-east of Morvi. Profile of the fireclay mine (Fig. IV.5) near Paneli is as follows.

Mine 12	Thickness(m)
Soil	0.3 to 1
Fireclay	4.2 to 4.8

About two square km area is under mining operation (Plate IV.26). Fireclay is red in color due to addition of ferruginous material as a result of extensive leaching of ferruginous sandstone once overlying fireclay bed. There are number of open cast mining pits. Soil overburden varies from place to place but maximum soil cover is one meter thick. Fireclay are extensively mined in this area for its use in roofing tile factories located nearby.

PLATE NO. IV.26

PANELI (12)

Extensive mining for nodular fireclay.

Locality : Jambudia

Fireclay Mine 13 Bhadiad Pottery Works Mine.

Jambudia is 6 km south of Morvi. The profile of the fireclay mine (Fig. IV.5) 1 km from Jambudia is as follows.

Mine 13	Thickness (m)
Soil	1.0
Sandstone	1.0
Fireclay	6.4

Overburden is of soil and sandstone. Soil is about 1 m thick and loose sandstone also shows nearly same thickness. Fireclay is grey and semi-refractory because of the presence of siliceous matter. Occasionally ferruginous nodules made clay red in color at the some places. Fireclay is about 6.5 m thick.

Locality : Makansar

Fireclay Mine 14 Parshuram Pottery Works Mine.

Mine is located 8 km south of Morvi and two to three km north of Makansar. The profile of the fireclay

PLATE NO. IV.27

MAKANSAR (14)

Wedge shaped purple clay between fine grained compact sandstone above and fireclay below.

mine (Fig. IV.5) near Makansar is as follows.

Mine 14	Thickness(m)
Sandstone	1.4
Purple Clay	0.6
Saggerclay	1.1
Siliceous Whiteclay	1.1
Fireclay	1.6

About one sq. km are is mined extensively. It shows wedge shaped purple clay (Plate IV.27) and fireclay Hard, fine grained yellowish white sandstone is sometimes removed by blasting. It is underlain by purple clay which is not at all used. Below this clay, inferior quality 1.1 m thick fireclay occurs which is also not used. It is underlain by siliceous white clay of 1.1 m thick. Below this 1.6m thick, fireclay occurs.

The present author has carried out field observations of fireclay mines from 15 localities in Surendranagar and Rajkot districts, and has made an attempt to classify these fireclays into 3 groups on the basis of characteristics in raw state i.e., plasticity by hand feel, slacking nature, type of fracture and presence of nodule.

The 3 groups are as follows :

1. Plastic fireclays
2. Semi-flint and flint fireclays
3. Nodular, flint fireclays.

Plastic Fireclays

In most of the mines in Surendranagar district, plastic fireclays occur as 1.5 to 4 m thick underclays.

Plastic fireclay occurs in bedded form and shows fair plasticity by hand feel. It contains more organic matter and less of silica and mica. The particle size is much finer.

Semi-flint and Flint Clays

Most of the plastic clays are overlain by thin layers of semi-flint clays (locally called sagger clays).

They are less plastic than underlying underclays. Thickness is not uniform. Sometimes they show good plasticity when ground finely and mixed with water. They contain less organic matter and more mica flakes and silica.

They are dense and hard with flintly fractures. Maximum thickness is upto 4.5 m at 5B.

Flintclays occur at 7B and 3C. At 3C maximum thickness is 9 m. They are hard, dense with waxy luster and break with concoidal (flinty) fracture. The flint clay is more refractory and hence is the most valuable of all fireclays to the refractory manufactures. At 3C flint clays contain the harmful constituent, mainly pyrite. After firing these pyritic material forms a hard mass in the refractory body. Hence it is very necessary to remove pyrite from such clays.

Nodular Fire Clays

Nodular fireclays which occur at 10A, 12 and 13 contain nodules of iron oxide (red in color), gibbsite and other hydrous aluminium oxides. Iron oxide nodules are formed due to the addition of iron oxide leached from overlying ferruginous sandstone. Mine face at 10A shows evidences of leaching.

STRUCTURE

Joints

Fireclay shows vertical, horizontal as well as oblique joints at most of its localities. Vertical and oblique joints are observed on mine face at Ratidevali (Plate IV. 20), and Tarnetar. These vertical and oblique joints provided channel for the ferruginous matter leached out from the overlying sandstone. Horizontal joints which are partings in bedding planes are prominant where fireclay occurs as underclay. Vertical and oblique joints are caused due to the weight of the overburden. In sandstone beds also vertical and oblique joints are common (Plate IV.28).

Slickenside

At Ritidevali, slickenside surfaces on fireclays observed, show distinct colouration (Plate IV.29). At Tarnetar and Palasa slickenside surfaces are also observed on fireclays but due to their dark grey to black color they are not so distinct. These features are more common in flint fireclay lying below sandstone

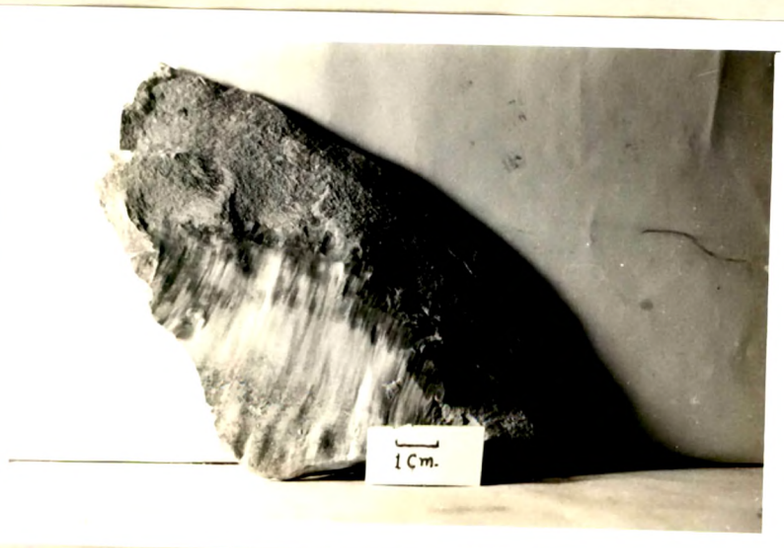
PLATE NO. IV.28

MAKANSAR

Jointing and color bands in horizontally bedded sandstone with silt stone band.

PLATE NO. IV.29

RATIDEVALI (7B)



Slickensided surface of fireclay.

strata. As these slickenside surfaces are restricted upto certain depth, they might have been caused by overburden of sandstone. They indicate presence of minor faults in this area.

Fault

At Ratidevali several small (minor) faults in fireclay are observed (Plate IV.30). These faults have not affected the overlying sandstone strata. At Ratidevali, fireclay shows different color banding, hence it becomes easy to recognize faults. Where fireclay is compact and of uniform color these minor faults are difficult to recognized.

The present author has observed two faults in the fireclay opencast mines located at the base of the small hillock hear Songadh (1D). Dragging of beds are clearly seen on mine face. Faculting has affected both overlying sandstone and underlying fireclay beds which are horizontal (Plate IV. 31).

The down throw side is towards west and the amount of down throw is 1.2 to 1.4 m. Due to this normal fault, thickness of overburden increases on down throw side.

PLATE NO. IV.30

RATIDEVALI (7B)

Minor fault in fireclay.

PLATE NO. IV.31

SONGADH (1D)

Normal fault in Lower Dhrangadhra Formation.

About 8 m west of this fault the present author has noted another fault of which down throw is more than 5 m. Fireclay bed has gone down and the amount of overburden has increased. It has become practically impossible to excavate fireclay from this place. Due to the presence of such faults in this area, miners are facing difficulties because the fireclay bed may disappear or may occur at greater depths. These faults must have also played a major role in the formation of small hillocks in the central part of Dhrangadhra Formation.

Cross Bedding

Dhrangadhra Formation having obscure bedding shows tabular type of cross bedding. The forests of these units have gentle curvature, tangential to the base with concavity upwards. Generally serval cross bedded units occur one above the other in vertical succession. It is best observed in the sandstone quarry of Digvijay Cement Company near Makansar. These solitary units, showing cross bedding are commonly underlain and overlain by normal bedding planes. Most of the cross

beddings may be termed as planer tabular cross bedding because lower bounding surfaces of most of the cross-bedded units are plane. A major cross bedding is observed at mine 1A (Plate IV.32).

Graded Bedding

Graded beddings are most commonly observed in mine sections. Sandstones showing graded bedding are loose and poorly cemented. Repeatition of graded beddings are observed in sandstone quarries. Fireclay mine faces where sandstone overlies fireclay, graded beeding is observed most commonly. Coarse grained sandstones grade to fine grained sandstones and sometimes even to silt and clays. At Makansar Digvijay sandstone quarry, gradation of conglomerate, grit, coarse grained sandstone to fine silt stone is observed . Graded bedding is observed in loose sandstone (Plate IV.33).

Parallel Lamination

Parallel lamination is a simple structure consisting of the parallel and alternating laminae less than 2 cm thick. The laminations show difference in either grain

PLATE NO. IV.32

SONGADH (1A)

Cross bedding in lower Dhrangadhra Formation.

PLATE NO. IV.33

RATIDEVALI (7A)

Graded bedding in sandstone overlying fireclay.

size or colors. The difference in grain size is due to the segregation of particles by differential setting resulting from change in current velocity. Difference in color is due to change in the water chemistry. Parallel laminations are commonly observed in fireclay beds (Plate IV.34), and sandstone beds (Plate IV.35).

Wavy Lamination

It is also formed by difference in grain size or color resulting due to weak currents, irregular depositional surfaces or obstractions on the surface.

Lenticular Laminations

In lenticular laminations, lense shaped bodies upto 10 cm in length and consisting of sand and silt particles are arranged in a line. They represent current ripples formed on the bottom of fireclays and later filled by coarse material due to oscillatory movement of the waves. The lenses are further blanketed by an influx of fine grained sediments (Plate IV.36).

Cross Lamination

Laminæ deposited at an oblique angle to the

PLATE NO. IV.34

SADALA (4C)

Parallel lamination in Fireclay.

PLATE NO. IV.35

SONGADH (1C)

Parallel lamination in Sandstone Overlying fireclay.

PLATE NO. IV.36

RATIDEVALI

Lenticular laminations in sandstone.

general bedding or the bounding surface has given rise to 3 types of cross laminations depending on the nature of the lower bounding plane. The lower bounding surface if simple and non-erosional, straight and erosional or curved and erosional, form the simple, planer or trough type cross laminations respectively. In sandstones planer and through-cross laminations are present. These cross laminations are formed by the ripples resulting from varying current velocities. These cross laminations indicate south-westerly current direction.

Ripple Drift Lamination

Changing current directions, current velocities and gradual drifting of the sediments climbing on the stoss side of the ripple give rise to ripple drift laminations (climbing ripple).

Distorted Lamination

Distorted laminations are laminations distorted by slumping of the sediments deposited on river beds. In Dhrangadhra Formation, distorted laminations are similar to small scale intraformational recumbent folds.

They are formed by over-riding silt laden currents over slow moving saturated sediments on a slightly inclined plane. Distorted laminations suggest the deposition of sediments between the lower part of river valley and deltaic region (Plate IV.37).

Iron Concretions

Iron concretions larger than 2 cm are observed in both sandstone and fireclay. They indicate that the sediments must have been exposed to the oxidising conditions.

Iron Concretion in the Fireclay (Plate IV.38)
Iron Concretion in the Sandstone (Plate IV.39)

Load Marks

Irregular convulant load marks are formed due to the deposition of sand over the fireclays.

Prospecting and Mining

The resistivity method of geophysical prospecting can be employed with advantage where the nature of rock

PLATE NO. IV.37

RATIDEVALI (7B)

Distorted lamination in fireclay.

PLATE NO. IV.38

RATIDEVALI (7B)

Iron concretions in fireclay (flint clay)

PLATE NO. IV.39

TARNETAR

Iron concretions in ferruginous sandstone
of Upper Dhrangadhra Formation

associated with fireclay is such that it gives a distinctive variation in resistivity values. But due to low cost of fireclays, prospecting by open pit method is very satisfactory and predominantly used. It is advantageous to do prospecting by open pit method of fireclay in Saurashtra because overburden consists of 0.5 to 1.8 m loose sandstone. Where overburden is 3 to 6 m thick, auger bore is recommended, provided the strata to be penetrated is not very hard.

Fireclay mining in Saurashtra is carried out by open cast mining methods for 2 reasons. Firstly, the overburden is not so thick and hard. Secondly, the fireclay is of such a low market value that it cannot justify the higher costs of underground mining.

At most of the places, as the overburden is not very thick, it is removed by pick and shovel method. If the overburden consists of hard sandstone, it is blasted and the loose debris is removed manually.

After the removal of the overburden, the pits are dug using picks and shovels. Fireclay is removed from the pit manually. Stacking of the fireclay at the mine site is carried out for allowing it to dry before transporting

it by trucks to the factories. The quality of fireclay is controlled by hand sorting and mixing.

Fireclay mining in Saurashtra is carried out in most unsystematic and unscientific mannter (Plate IV.10) Pits are dug without any benches. There is no scope for lateral extension of the pits. After reaching a certain depth, fireclay is mined laterally. The upper pit wall which becomes overhang, collapses. After the daily mining operation is over under cutting of mine face by unauthorized persons to remove coal results in the collaps of overhand upper pit wall. Such accidents sometimes do result in loss of human life. Hence systematic mining with proper benching has been adopted at many places e.g. at Parmar Minerals Mine, Palasa (Plate IV.15) and at Parshuram Pottery Works Mine, Makansar. According to some mine owners, the "method" they follow is the most practical and economic one, although it does not conform to any code of mining.

The occurrence of fireclay as pockets or lenticular bodies does not justify mechanized mining, such as stripping with bulldozers etc., as the cost of mining operations may exceed the price of fireclay produced.

There are plenty of instances in Saurashtra where pits have been abandoned just because a little inferior quality of fireclay was met with. Upto now, all the miners in this area have produced only the best quality of fireclay leaving aside fireclay which is only little inferior in quality. This has resulted in the depletion or exhaustion of nearly all the good quality fireclay deposits. Hence it is suggested that future entrepreneurs should produce and make use of all grades of fireclays.

As all the mining operations are carried out manually daily production of fireclay entirely depends on the availability of labour.