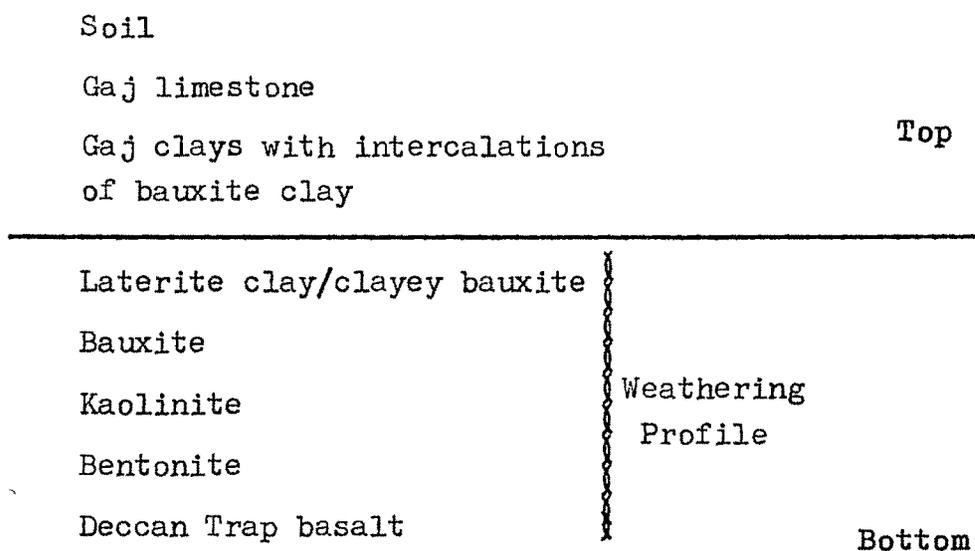


chapter iv

MODE OF OCCURRENCE

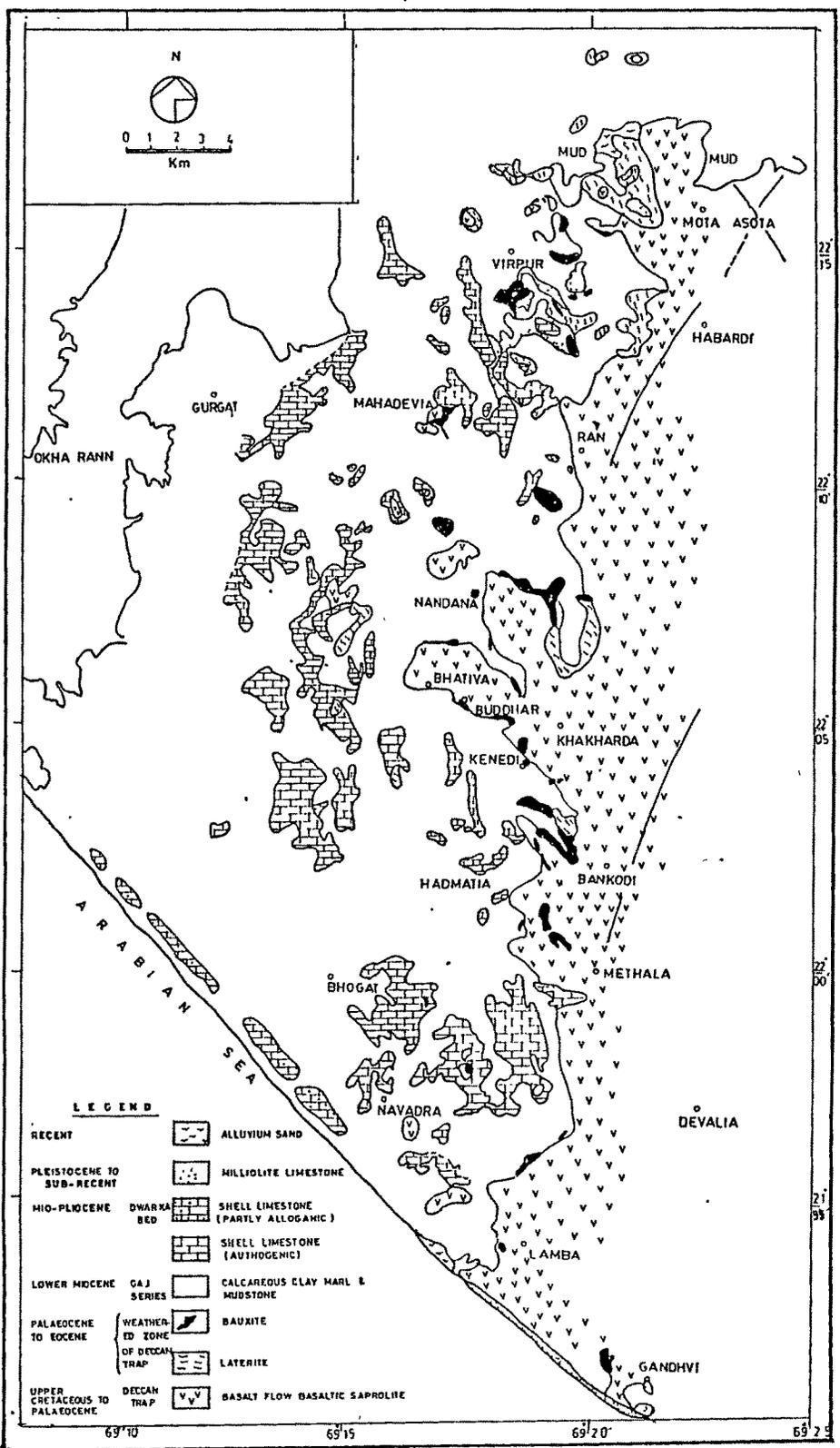
Bauxites of Jamnagar district are confined to a 50 km long narrow (1- 1.5 km wide) belt from Virpur in the north to Gandhvi in the south (Fig. 10).

The bauxite occurs in a single gradational, residual weathering profile of Paleocene to lower Miocene age developed over basalts of Cretaceous - Eocene age. This weathering profile consists of the following members :-



All these constitute, what is popularly known as an alteration blanket which occurs in the form of an elongate belt. Extensive exposures of bauxites are found in the northern part near Mahadevia, Ran and Mewasa. Each exposure was studied and the weathering profiles, wherever available, described as per the norms of The Soil Taxonomy of the U.S. Department

FIG.10
GEOLOGICAL MAP OF BAUXITE DEPOSITS, JAMNAGAR DISTRICT



(AFTER B.N. JAYARAM, A. MAJUMDAR, S.S. MUKUL, AHMED, M.S.G. RAO & S.K. GADHAKS. 1970-72)

of Agriculture (1965). Sampling of the sections was carried out only where complete weathering profiles were available. In this work, the bauxite has been considered to be part of an alteration blanket which was formed by in situ pedogenic processes leading to a vertical division into three major soil horizons :-

Horizon rich in oxides	Box (Fe, Al)
Horizon rich in Silicates	(B saprolite)
Horizon of fresh parent rock	C

Normally the soil sections are truncated with the A horizon always eroded. As per the Soil Taxonomy of the U.S. Department of Agriculture (1965), this type of bauxite belongs to the aquox sub-group in the group of oxisols which are soft during time of formation. During uplift above the ground water level, the Fe-rich parts form hard ferricretes, whereas the Al-rich parts become hard alucretes (Goudie, 1973).

Definition of Laterite Profile

Laterite must be studied in the context of the total weathering profile, with the residual soil horizon above, and the saprolite horizon as the typical laterite-saprolite weathering profile.

A "standard" or "normal" profile does not exist, as no two laterite or bauxite profiles are identical; however, the succession of horizons recurs world-wide, be it in highly variable thicknesses, absolute and relative, and with variable

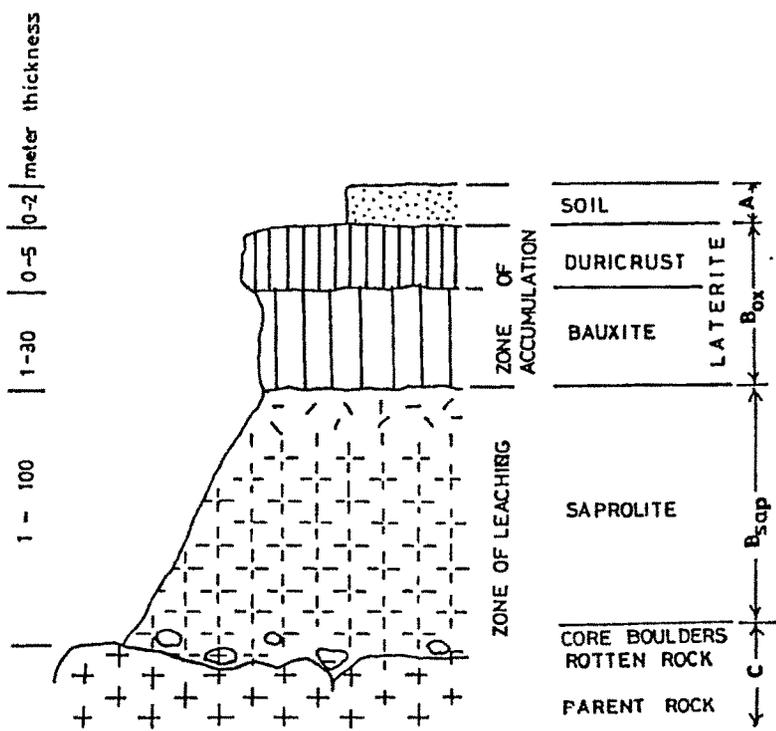
chemical as well as mineralogical composition (Bardossy & Aleva, 1990).

THE HORIZONS The complete profile is composed of four horizons, as shown in Fig. 11 for some horizons it can be advantageous to split them into two or more zones. In particular the bauxite horizon is frequently divided into several zones

(i) Residual soil horizon: it forms the uppermost horizon; it is composed of the mechanical and chemical weathering product of the underlying horizon, mixed with plant remains and humic matter. Its colour is related to that of the underlying horizon, but can also be either almost black through humic matter or iron oxide, or lighter as a result of its exposed position to leaching by rain and surface waters. Quartz may also occur in the soil horizon, even where the underlying horizon is free of quartz. An eolian derivation of this quartz seems acceptable, as sand and dust storms can transport quartz grains over large distances and deposit them at high topographic levels.

(ii) Duricrust horizon: it is the upper part and the main accumulation zone of the profile. Generally it is the hardest horizon of the profile due to new formation and recrystallization of iron minerals. In most profiles the duricrust is the horizon with the strongest colour, varying from brick red brown to blue black.

A TYPICAL LATERITE SAPROLITE WEATHERING PROFILE.



(after Bardossy & Aleva 1990)

FIG.11

(iii) Bauxite horizon: it represents the lower section of the lateritic parts of the total profile and is mainly differentiated from the upper duricrust by its lesser accumulation of iron minerals, and hence, its generally lesser hardness. The horizon can be homogeneous throughout, or composed of several horizontal zones with different structures, textures, composition or colour, or a combination of these attributes. In other places, the horizon is distinctly inhomogeneous, with respect to the same attributes, in a lateral direction, e.g., with abrupt changes of a massive texture into a columnar structure, or lateral changes in colour. In other places heterolithic textures dominate, with bauxite nodules or blocks embedded in a fine-grained to clayey matrix (bouldery texture). The colour of the bauxite horizon is highly variable from almost white through pinkish, yellowish and orange hues, to tan, orange and reddish brown to brown. Other colours of local occurrence are violet, yellow green, grey and black.

(iv) Saprolite horizon: it is composed of aluminium sheet silicate weathering products of the parent rock, mainly kaolinite (where the parent rock is not an ultrabasic or ultramafic rock) and minerals such as quartz, rutile, zircon, etc. that are highly weathering resistant in the saprolite environment. Less evolved weathering minerals, such as illite, nontronite, montmorillonite and mixed-layer structures of these minerals, may occur in the lower part of the horizon, but gradually disappear upwards over a short vertical distance.

In many places, the horizon consists of two zones, an upper and mostly thin zone without any relict textures and structures, and a lower and mostly thicker zone with relict textures and structures of the parent rock. The saprolite is usually lighter in colour than the overlying laterite or bauxite, with whitish, pinkish, tan, orange and reddish hues; also variegated and mottled colours may occur.

(v) Parent rock: so named as the weathering profile is derived from this rock, and its composition directly influences the nature of the weathering profile. In places, the composition of the parent rock cannot be established in the field because the total weathering profile may reach thicknesses of over 100 metres. It also may occur, particularly in bedded sedimentary parent rocks, that the parent rock has been completely weathered to the e.g., bauxite, and that the underlying rock is not the parent rock, but a subjacent rock of different lithology belonging to the same or another sedimentary succession (e.g., Onverdacht, Surinam; Weipa-Aurukun and Marchinbar Island, Australia).

As the formation of this bauxite belt is partly dependant upon the physiography, a brief account of this is included before the description of the individual bauxite exposures.

PHYSIOGRAPHY OF THE BAUXITE BEARING AREA:

The topography of the area where bauxite occurs in the Jamnagar district is characterised by a series of low ridges, (Plate 1) hillocks and isolated mounds ranging in altitude



Plate No. 1. Typical lowlying laterite ridges seen in the study area.



from 5-30 m above mean sea level. The area is dissected by a series of small nalas and streams. Towards the coast, the country side is even or smooth, extensively cultivated, and merging with the coastal plains (Plate 2), while further inland, the terrain becomes very rugged, with long and high ranges rising about 70-80 m above mean sea level.

Oval outcrops of laterite have, in many cases, given rise to locally radial drainage pattern. All these rivers are seasonal except the Rani nadi and Kalipat river, with water flowing only during the monsoon period. Many artificial small lakes have been created on these rivers by the construction of small dams across their channels to preserve water for irrigation purposes. The low ridges and hillocks of the laterite bearing area have escarpments towards the north-west (Plate 3) while gradual slopes are encountered to the south-east. The general topography of the area is practically flat with the only relief corresponding to the arcuate ridges of laterite and flat topped mounds.

The ridges are long, narrow and form parallel ranges, separated by shallow valleys, which are generally cultivated. At some places, the ridges are fairly broad and arcuate, forming numerous, broad, roughly circular valleys with several isolated mounds and hillocks. They present a panorama of vivid colours of red, pink, lavender, purple, yellow and white which contrast sharply with drab greys and browns of the surrounding country.



Plate No. 2. Intermittent lowlying land between laterite ridges.





Plate No. 3. Part of escarpment of laterite excavated for bauxite.

Description of the Individual Bauxite Deposits:

The bauxite exposures of Jamnagar district can be divided into 3 zones viz.

- (1) Mota - Asota, Virpur, Pindara.
- (2) Ran, Mahadevia, Mewasa, Khakharda, Nandana, Bhatiya, Kenedi, Bankodi.
- (3) Lamba, Gandhvi.

The generalised succession in a majority of the profile is as below

Soil				
Gaj limestones				
Gaj clays with intercalation of bauxite clay				
<hr/>				
Ferricrete				
Alucrete	{ Bauxitic clay	}	B _{ox} (Fe,Al)	Wea- thering Profile
	{ Bauxite	}		
Saprolite	{ Kaolinite	}	B(sap)	
	{ Bentonite	}		
Parent rock	Basalt			

Apart from the exposed profiles, fence diagrams drawn from bore-hole data (wherever available) are also given to present an overall picture of the deposition of horizons.

Mota - Asota Deposits

Bauxite pockets are seen in an E-W trending hill about 4 km SW of Mota Asota village where a complete profile has been exposed. At the slope of the hill, laterite/bauxite are exposed, and are capped by "Gaj" at higher elevations. Other exposures are seen in the chain of low-lying hills, situated to the north of the village. The lithological variation has been demarcated on the basis of existing mines which is as follows (Fig. 12).

Soil	A

Alucrete	B _{ox} (Al, Fe)

Base rock (basalt) was not exposed in the profile but the samples of the base rock has were taken from nearby well at the depth of 45.00 m.

Virpur Deposits

Laterite/bauxite are observed near the low lying hills, W and NW of Virpur village, close to the northern margin of laterite belt fringing the Gulf of Kutch. Isolated small humps of laterite/bauxite are seen capped by Gaj beds. The bauxite is ferruginous forming pockets along the lower slopes of the humps, and at places covered by soil. The rest of the sequence remains unexposed. The profile is as below (Fig. 13):

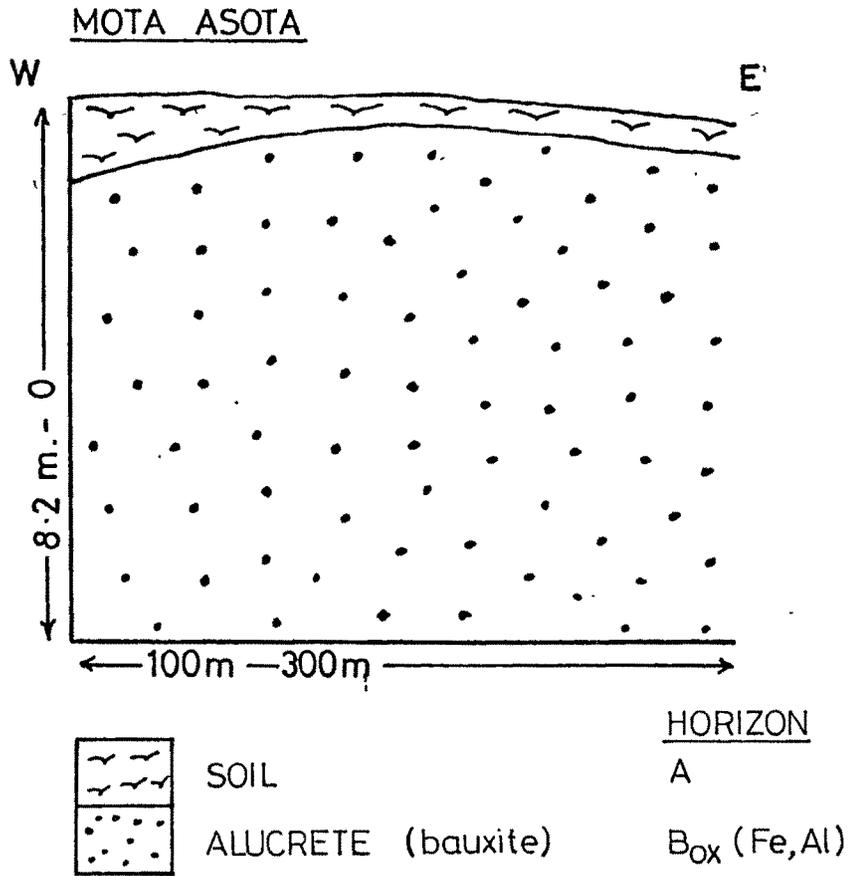


FIG. 12

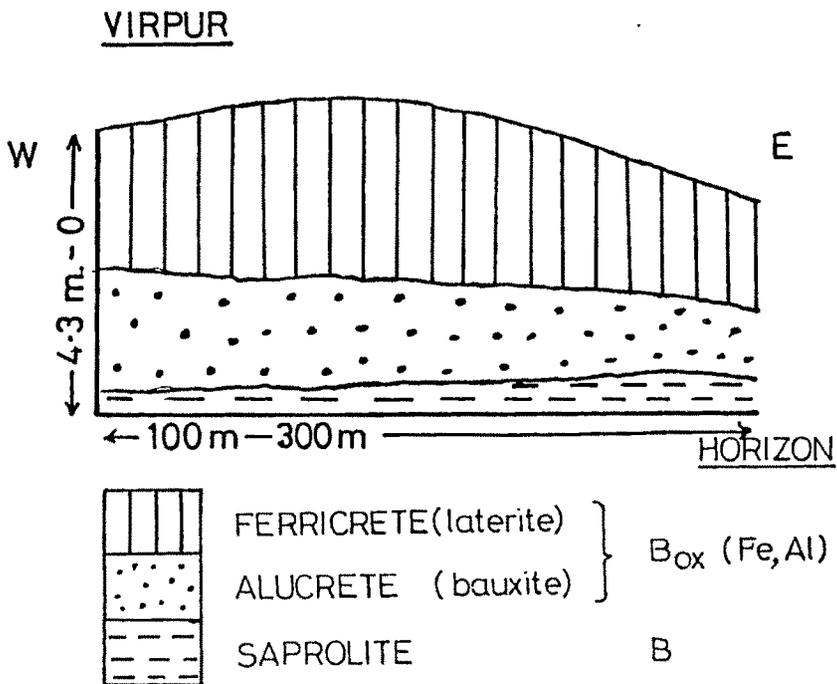
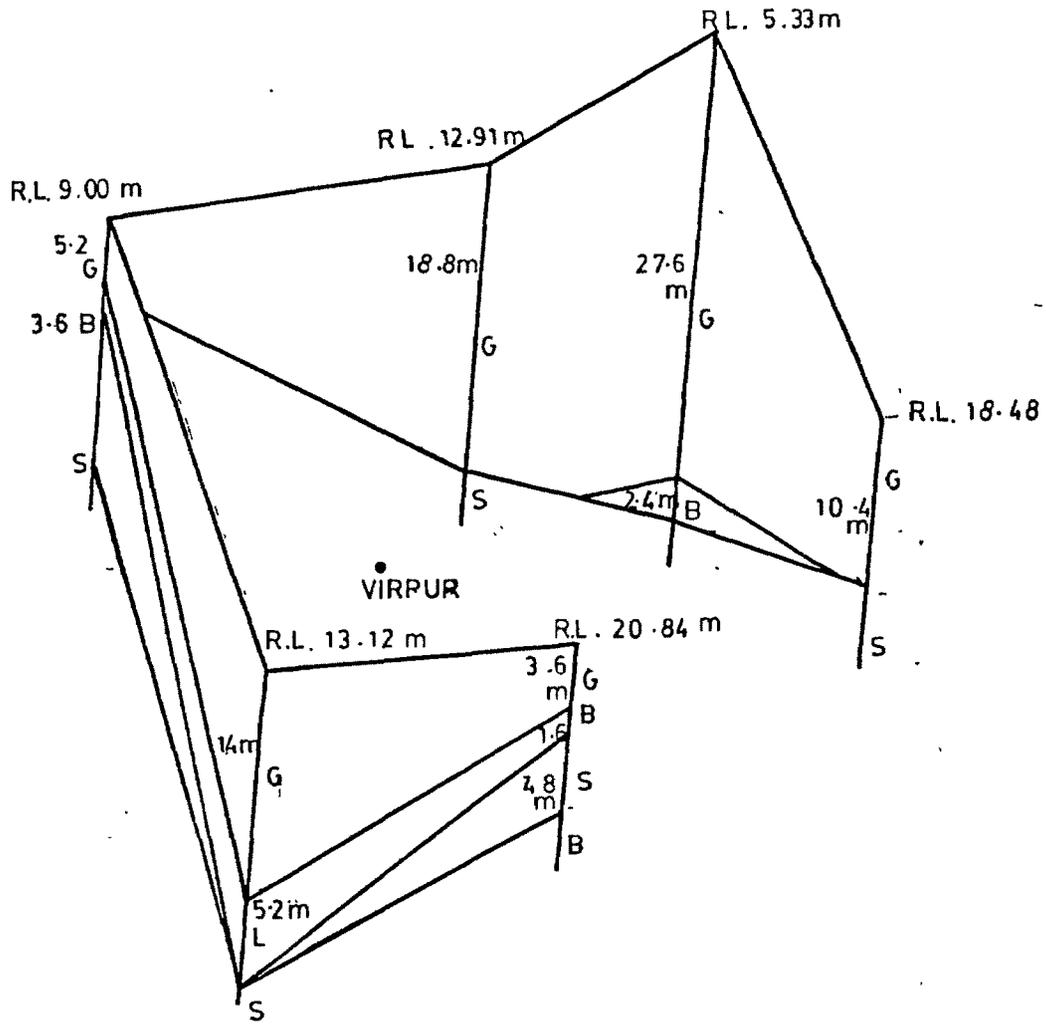


FIG. 13

FIG. 14

FENCE DIAGRAM OF THE AREA AROUND VIRPUR



Soil	SOIL
G	GAJ LIMESTONE
L	LIMESTONE
Box	BAUXITE
S	SAPROLITE
B	BASALT

Scale:
 V = 1cm = 4m.
 H = 1cm = 3m.



Ferricrete	(laterite)	
Alucrete	(bauxite)	B _{ox} (Fe, Al)

Saprolite	Clay	B(sap)

Base rock (basalt) was not exposed in the profile but the sample of the base rock has been taken from nearby well at the depth of 25.7 m.

From the fence diagram prepared from the bore-hole data (Fig. 14) the picture shows a lot of pinching and thinning of the individual members of the weathering profile. To the E and SE of Virpur, the bauxite is seen resting directly over the saprolite zone, while to the NW the bauxite is found overlain by laterite. Even the thickness of the top most Gaj beds is varying with extreme thickness to the E and NE, and lesser thickness to the NW, SW and SE.

Pindara Deposits

A small inlier of bauxite is noticed, one km NW of Pindara village, and is surrounded by Gaj beds. Here the bauxite appears more ferruginous but pisolitic in nature. The profile is given below (Fig. 15).

Ferricrete	(laterite)	
Alucrete	(bauxite)	B _{ox} (Fe, Al)

Saprolite	Clay	B(sap)

PINDARA

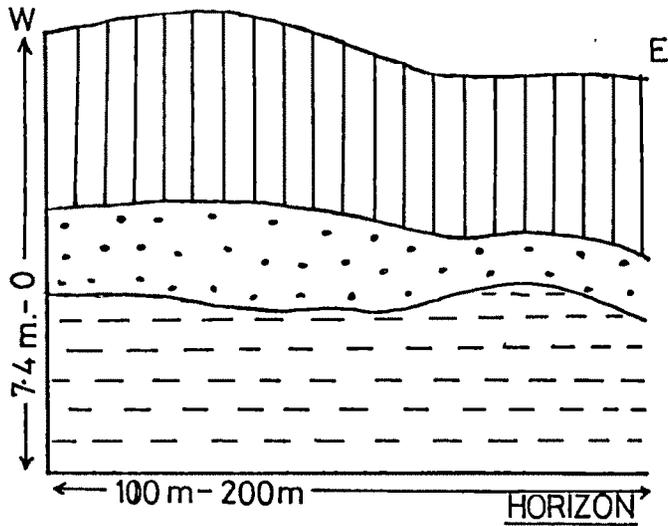


FIG. 15

	Ferricrete (laterite)	} B _{ox} (Fe, Al)
	Alucrete (bauxite)	
	Saprolite	B

RAN

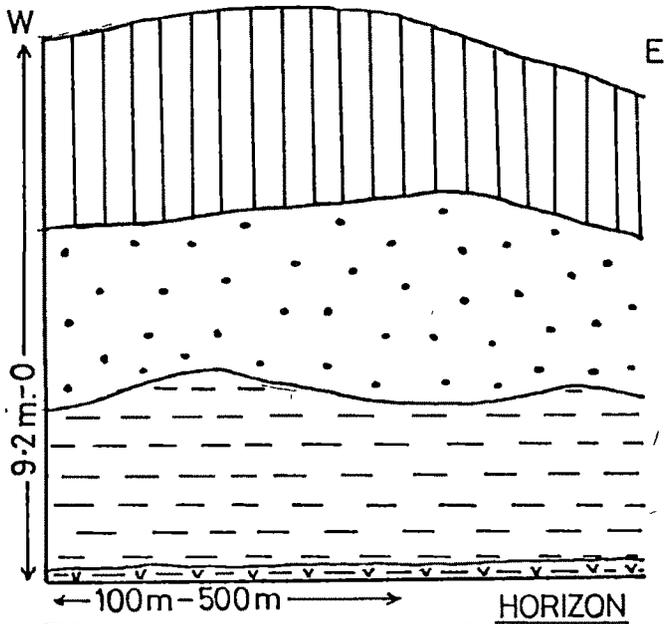


FIG. 17

	Ferricrete (laterite)	} B _{ox} (Fe Al)
	Alucrete (bauxite)	
	Saprolite	B
	Basalt	C

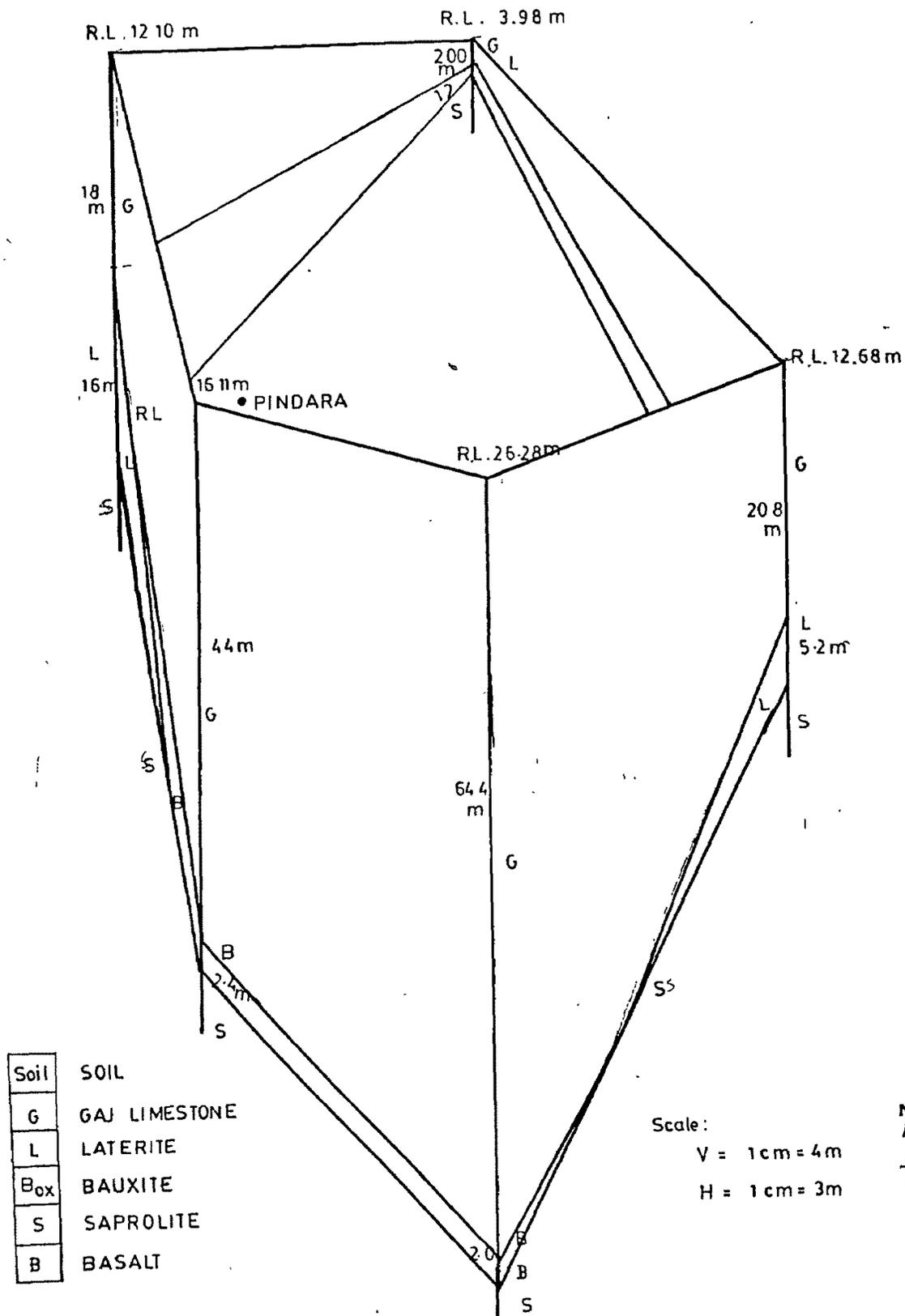
The bore-hole data reveals that there is extensive pinching and swelling of the individual members of the weathering profile (Fig. 16). The most conspicuous feature is the presence of laterite and absence of bauxite to the NW, NE and E of Pindara, while bauxite is present and laterite is absent to the SSW and SE. The thickness of Gaj beds is also more to the SSW and SE as compared to the other bore holes.

Ran Deposits

The exposures are seen one km west of the village Ran. A small pocket is also observed in a hillock called "Bodki dhar". An isolated hill NW of Ran also has bauxite deposits.

Four pockets are seen along the slope of the hills, 2 km south of Ran. Another pocket is seen in a nala, SSE of the hillock. Four other pockets occur in low-lying humps about 800 m west of Ran village. An exposure of bauxite is noticed in a small hillock about 1.6 km WSW of the village, and the thickness is 2.5 m. A small hillock, parallel to this and in the intervening low land, of a good bauxite deposit with an average thickness of about 2.2 m is seen. A small pocket further to the north with an average thickness of 2 m is exposed. Bauxite forming the top of the hill and covering the undulations reflects that the bauxite must have been eroded away before the overlying Gaj sediments were deposited,

FENCE DIAGRAM OF THE AREA AROUND PINDARA - FIG. 16



indicating a timelag between the two. The isolated hill NW of Ran village shows a good zone of bauxite.

A cluster of small low-lying hillocks situated about 2.2 km south of Ran, along with small isolated hillocks further to the south are covered by Gaj beds, where the bauxite is seen exposed along the slope of the hills.

Inliers of Deccan Traps are noticed to the north and south of hills. Bauxite covering the tops of the low hills and low saddles capped by Gaj beds clearly indicates that Gaj beds rest on the pre-existing undulatory topography. The profile is given below (Fig. 17).

Ferricrete	(laterite)	
Alucrete	(bauxite)	B _{ox} (Fe, Al)

Saprolite		B _(Sap)

Altered basalt		C

Base rock (basalt) was not exposed in the profile but the sample of the base rock has been taken from nearby well at the depth of 36 m.

Mahadevia Deposits

Good exposures/pockets of bauxite occur 1 km to the SW of Mahadevia village and immediately to the south of the tank

(Nagarwali). A small chain of low lying crags of inliers of laterite are surrounded by Gaj rocks. The laterite is comparatively more ferruginous with hematite pieces along joint planes and with pockets of bauxite. Clayey material is also seen along the joint planes. The section here is as follows. (Fig. 18).

Soil	A.
Ferricrete	laterite
Alucrete	bauxite $B_{ox} (Fe, Al)$
Saprolite	B(Sap).

Base rock (basalt) was not exposed in the profile but the sample of the base rock has been taken from nearby well at the depth of 47 m.

The fence diagram (Fig. 19) reveals the relationship of the existence of the bauxite horizon where there is an extensive thickness overlying Gaj beds (to the NNW, NNE, NNE, E and SW), while a thin Gaj horizon is associated with laterite but without bauxite.

Mewasa Deposits

1.6 km NE of Mewasa village, bauxite pockets are noticed along the northern slope of the hills. A small outlier of Gaj rock is noticed to the west of the hillock and the bauxite

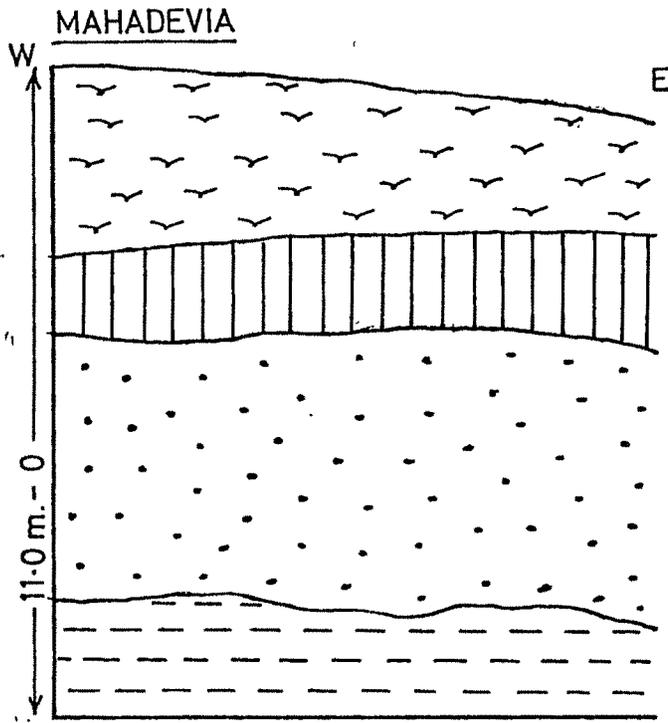


FIG. 18

		<u>HORIZON</u>
	Soil	A
	Ferricrete (laterite)	} B _{ox} (Fe,Al)
	Alucrete (bauxite)	
	Saproelite	B

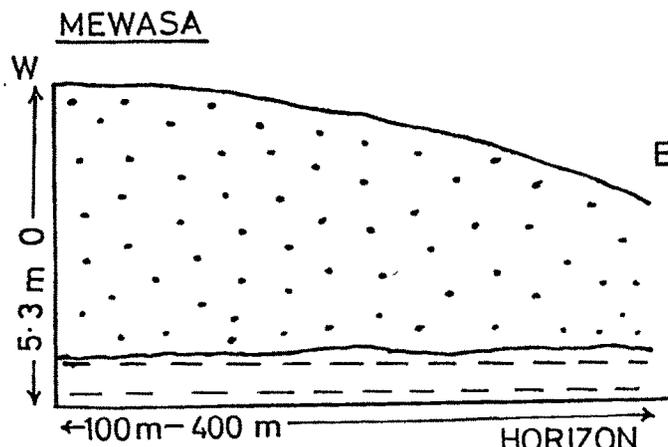
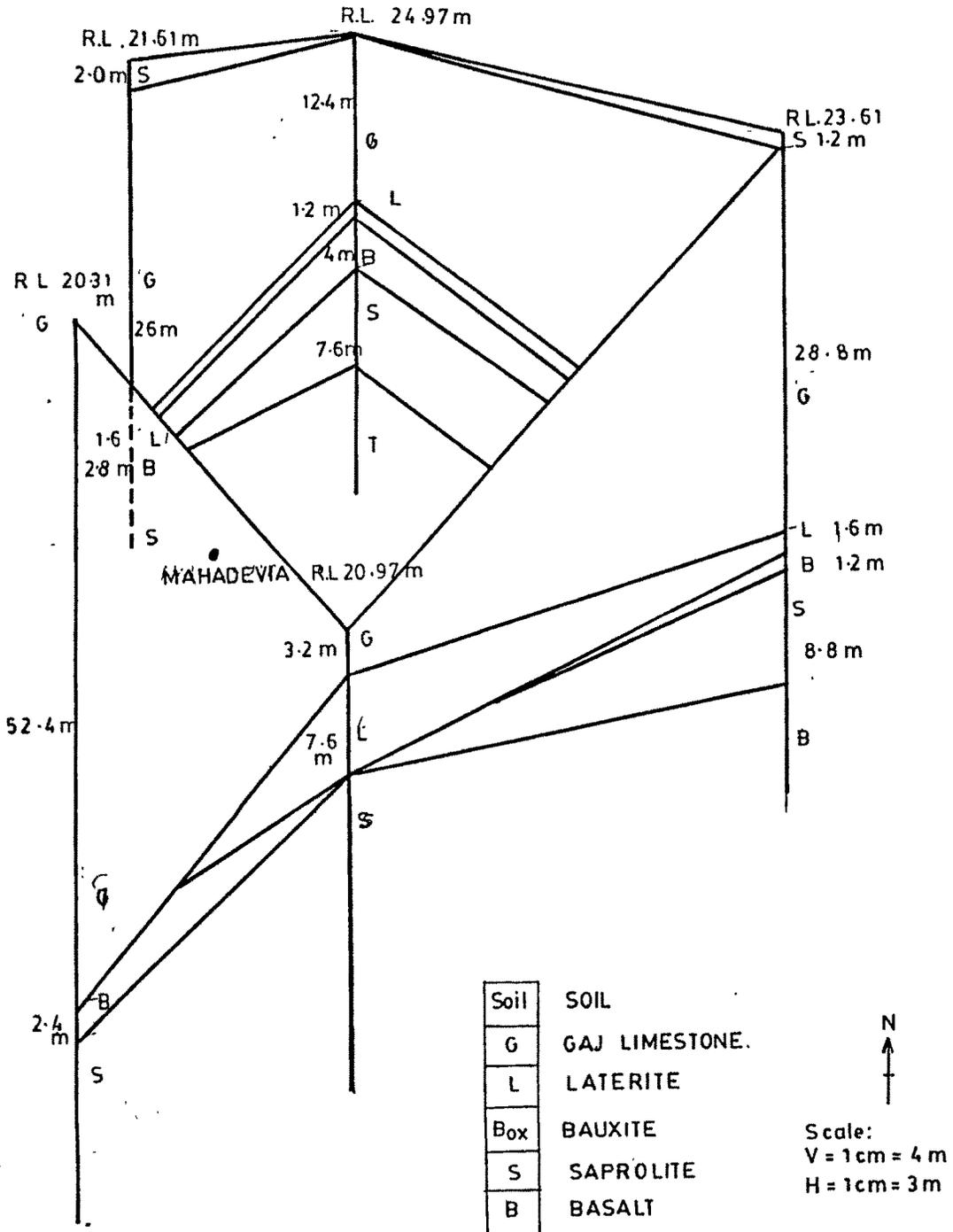


FIG. 20

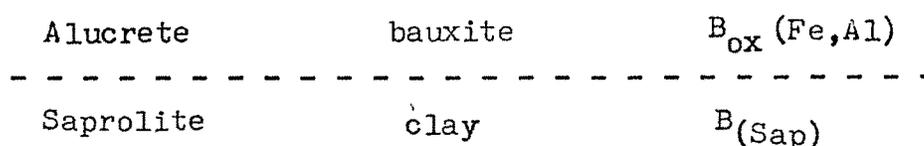
		<u>HORIZON</u>
	Alucrete (bauxite)	B _{ox} (Fe,Al)
	Saproelite	B

FIG. 19
FENCE DIAGRAM OF THE AREA AROUND MAHADEVIA



exposures occur to the SE and NE of the outlier with a difference in elevation of 4 to 5 m. This clearly shows that the Gaj sediments were deposited on an eroded undulatory surface of the laterite. Here the bauxite shows fawn grey pisolites in a pinkish clayey matrix passing downwards to reddish brown small nodules and dense massive boulders of grey bauxite.

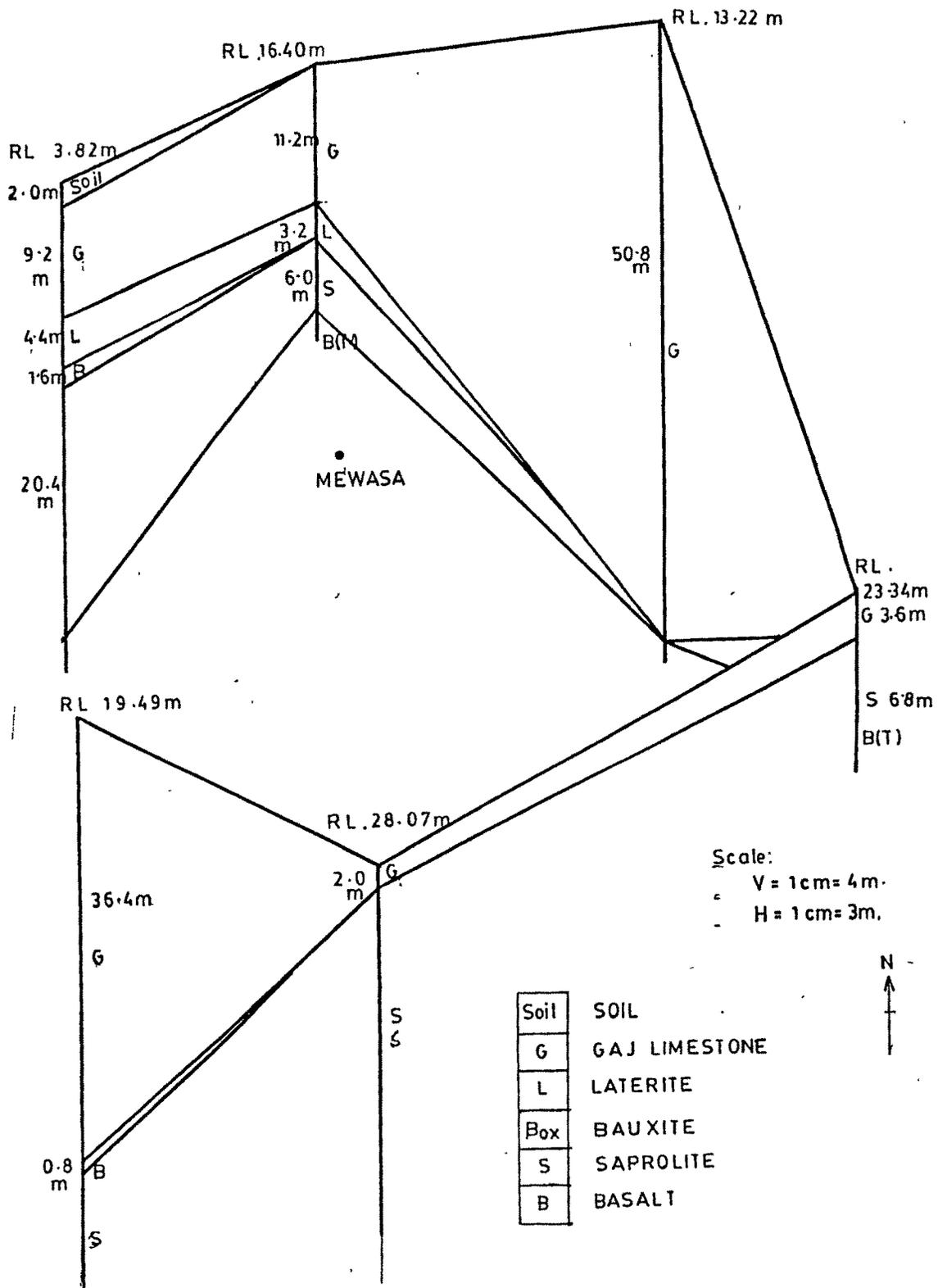
Another good section of bauxite is noticed in the nala section about 600 m NE on the border of Mewasa village. Here the bauxite is earthy, light grey in colour with pink and brownish nodules and boulders surrounded by light grey clayey material at places. Lithomargic clays are seen occupying the bottom of the bauxite profile. The section is given below (Fig. 20):



Base rock (basalt) was not exposed in the profile but the sample of the base rock has been taken from nearby well at the depth of 38.1 m.

Bore hole data (Fig. 21) reveals that the bauxite is associated with a good thickness of Gaj beds, except the NW of Mewasa, where both laterite and bauxite are seen with a minimal thickness of Gaj.

FENCE DIAGRAM OF THE AREA AROUND MEWASA FIG.21



Khakharda Deposits

The bauxite deposits are located about 4 km to the NW of Khakharda village. The deposits are situated on both sides of the railway line between Bhatiya and Bhopalka stations. Here monotonous plains are seen interspersed with isolated small humps of massive grey bauxite. The section is as below (Fig. 22)

Ferricrete	(Laterite)	B _{ox} (Fe,Al)

Saprolite		B _(Sap)

Altered basalt/ Fresh basalt		C

Nandana Deposits

Three pockets of bauxite occur NW of Nandana village. Another exposure is seen 2 km to the NW of Nandana village (in the nala, flowing E-W). A large pocket is also seen 1/2 km to the E of the village. A continuous strip of laterite/bauxite intervening in between Deccan Trap and Gaj beds is seen. A small inlier of Deccan Trap is observed between Nandana and Bhatiya. Three inliers of Trap are also noticed to the NW. Good bauxite outcrops are seen along the eastern margins of the Trap. Small saddles of bauxite in between the humps are seen exposed. The section is given below. (Fig. 23)

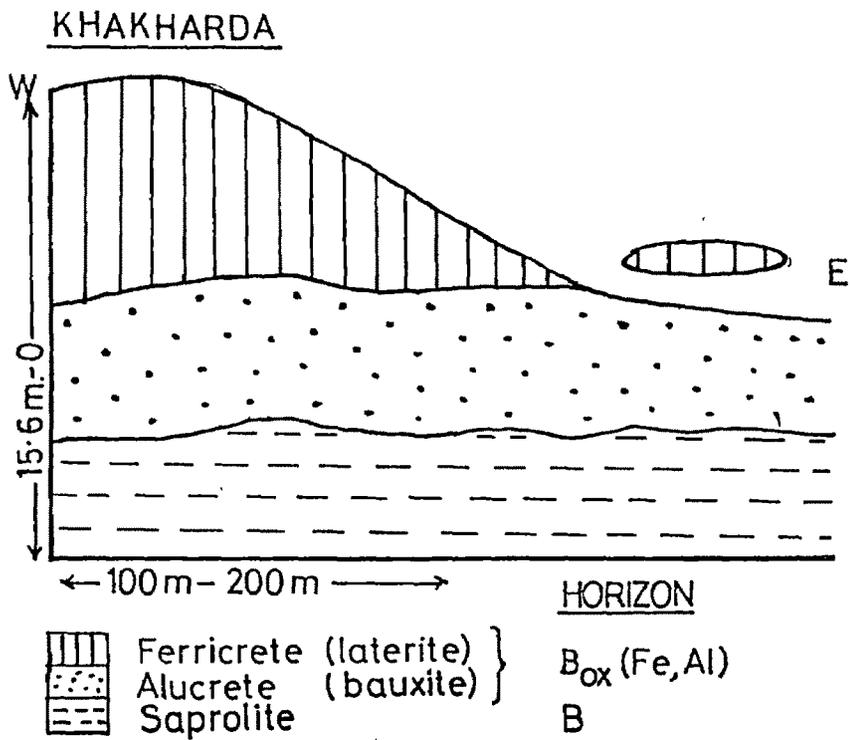


FIG. 22

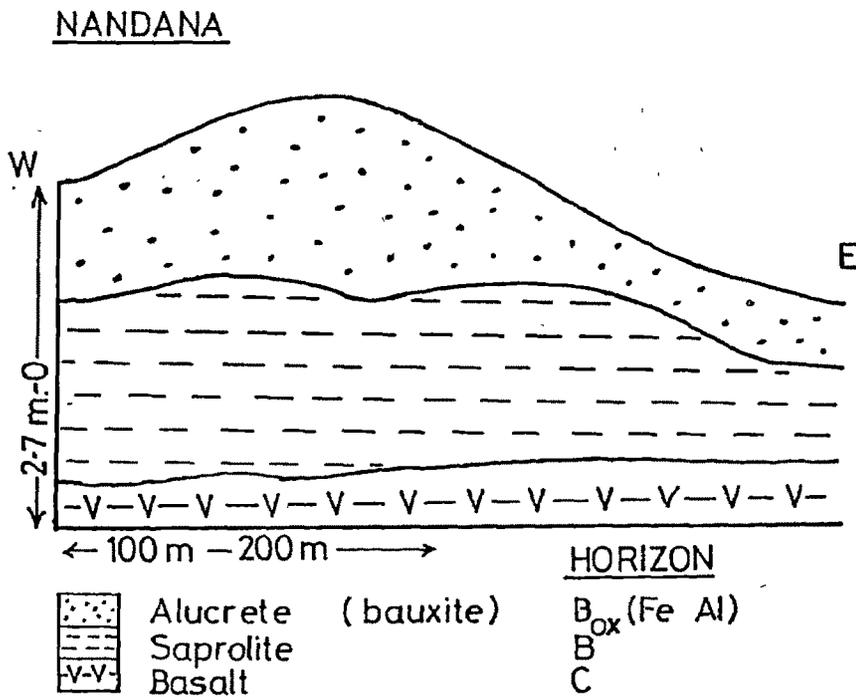
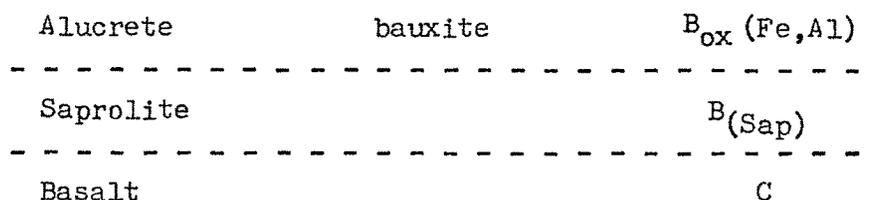


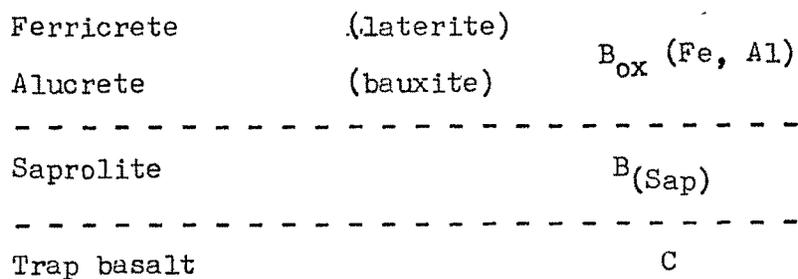
FIG. 23.



The bore-hole data (Fig. 24) reveals that again a good thickness of Gaj beds is associated with bauxite, especially to the N and S of Nandana. Laterite is nowhere encountered.

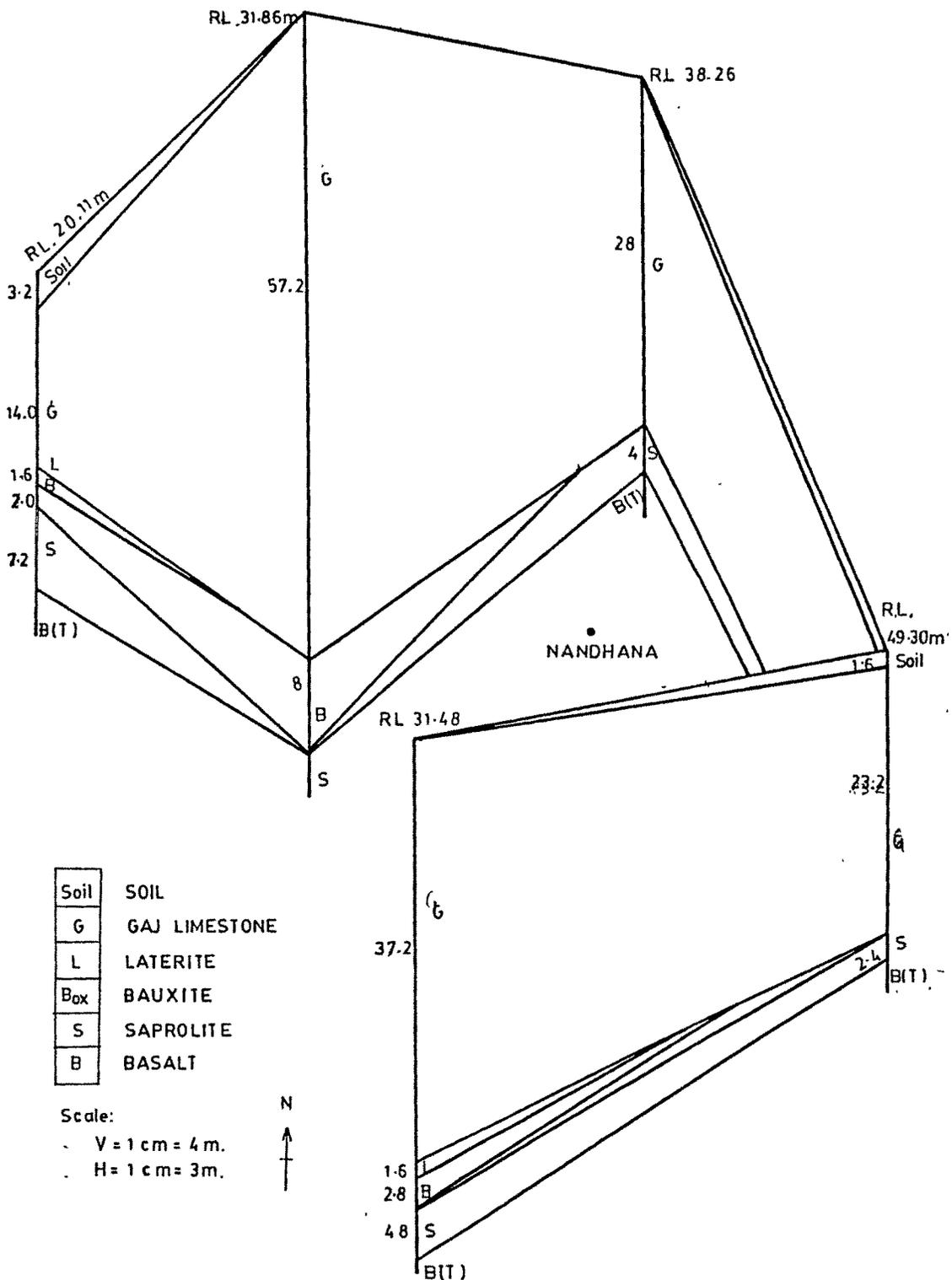
Bhatiya Deposits

Two pockets of bauxite occur about 1 km to the NE of Bhatiya village. The area is covered by soil (black) except a few isolated outcrops of Gaj limestones. A small strip of laterite separated from the main laterite belt occurs N and NE of Bhatiya village. Bauxite is exposed along the eastern slopes. The exposed profile is as below (Fig. 25):



The fence diagram (Fig. 26) shows the same standard Gaj/bauxite relationship.

FENCE DIAGRAM OF THE AREA AROUND NANDANA · FIG. 24



BHATIYA

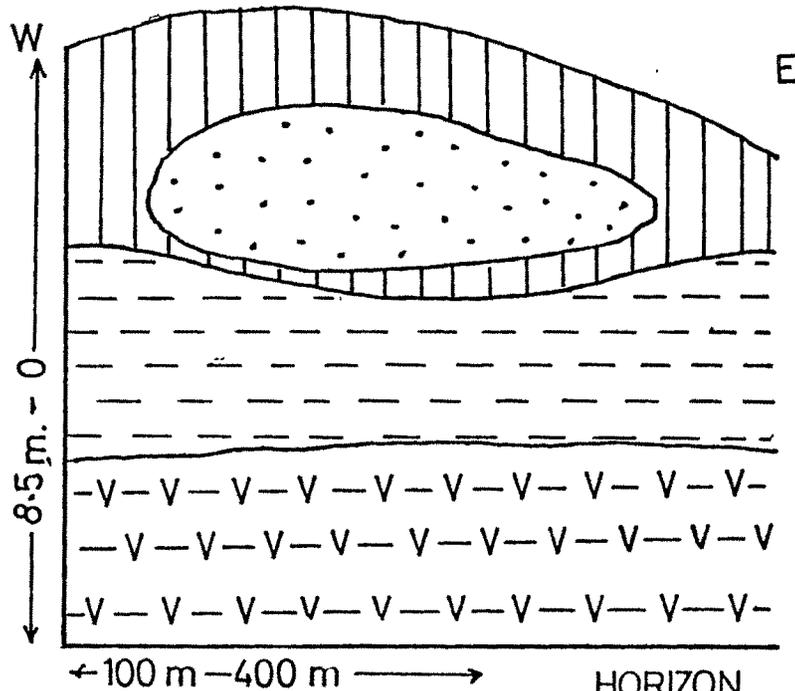


FIG. 25

		<u>HORIZON</u>
	Ferricrete (laterite)	} $B_{ox}(Fe, Al)$
	Alucrite (bauxite)	
	Saprolite	B
	Basalt	C

KENEDI

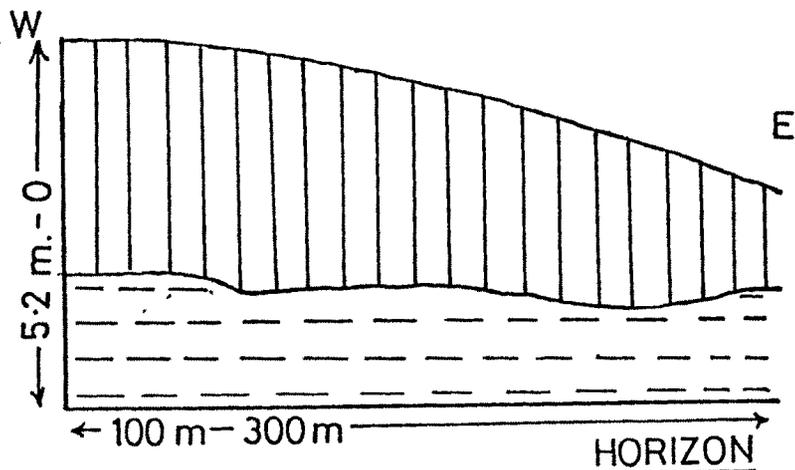
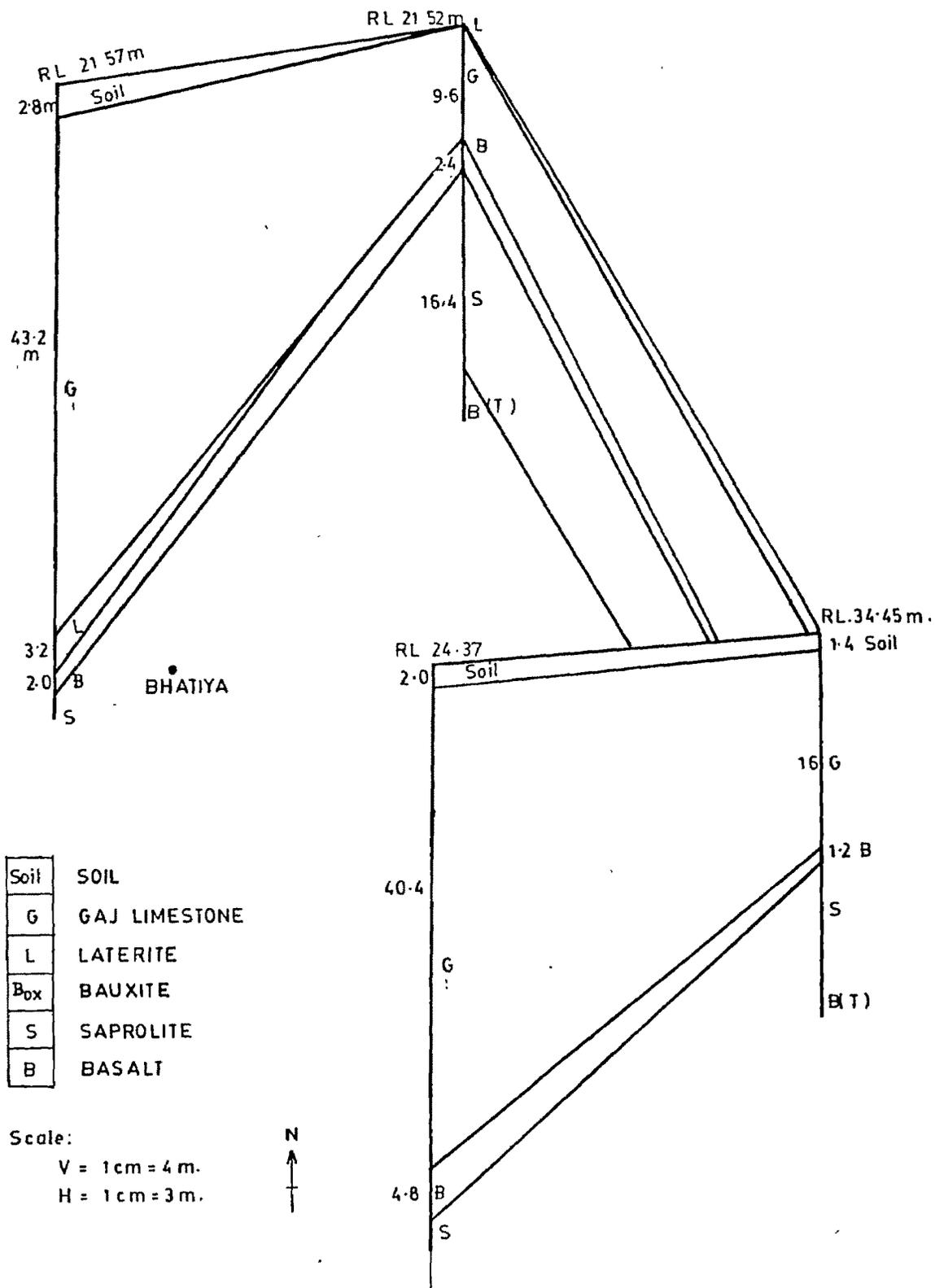


FIG. 27

		<u>HORIZON</u>
	Ferricrete (laterite)	} $B_{ox}(Fe, Al)$
	Saprolite	
		B

FENCE DIAGRAM OF THE AREA AROUND BHATIYA FIG. 26



Kenedi Deposits

Several exposures occur around Kenedi village. The bauxite deposits are close to Bhatiya-Kalyanpur road. Marshy plains around the village are mostly soil covered, exposing isolated outcrops of grey bauxite. The plains are occasionally covered by Gaj beds forming mounds NW and SE of the village, while hills to the NE and SW are capped by Deccan Trap. The generalised profile is given below (Fig. 27):

Ferricrete	Laterite	B _{ox} (Fe,Al)

Saprolite		B(Sap)

Base rock (basalt) was not exposed in the profile but the sample of the base rock has been taken from nearby well at the depth of 22.20 m.

Bankodi Deposits

Seven pockets of bauxite occur 1 km to the west, and three pockets 1 km to the SW of Bankodi village. Laterite/bauxite occurs in the saddles of the 3 m high humps, below a 3 m thick over burden consisting of Gaj limestone.

Lamba Deposits

A majority of the deposits are located near Lamba-Bhatiya road. Several pockets occur west and SW of Lamba. The bauxite prospects are within the laterite exposed in the hills rising

20 m from the ground level. They fringe the western margin of the Deccan Trap outcrop trending N-S for a length of 6.5 km near Lamba.

Other pockets occur about 1 km WNW of the village, NNW of Asapura temple. Exposures are also observed along the northern slope of the two hills to the SE of the Movaria talav, and several small pockets are noticed to the east of the talav. Scattered pockets are noticed in the hillocks along the coast, $1\frac{1}{2}$ km west of Lamba.

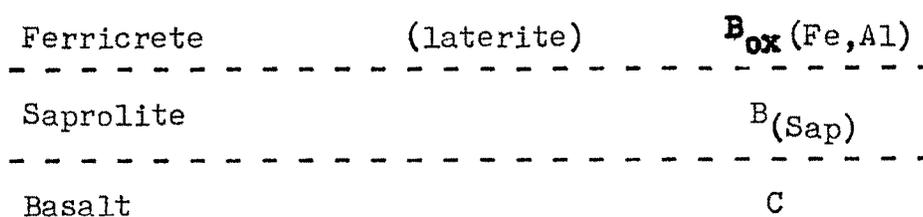
Isolated pockets are also seen in the laterite hills along the coast. Small isolated outcrops of Gaj beds cap the laterite and bauxite at many places, and the over burden is almost negligible as the Gaj beds have been eroded.

Small patches of laterite capped by Gaj limestone are noticed NNW of Asapura temple, 1 km NW of Lamba. Although small exposures of bauxite are scattered at the foot of hillock, a continuous bauxite horizon is not exposed. A close study of several sections reveals that the Gaj sediments rest on the eroded and gently undulating surface of bauxite.

A good pocket of bauxite is observed 400 m NW of Lamba and Satapar, with an average thickness of 2 m, with no over burden.

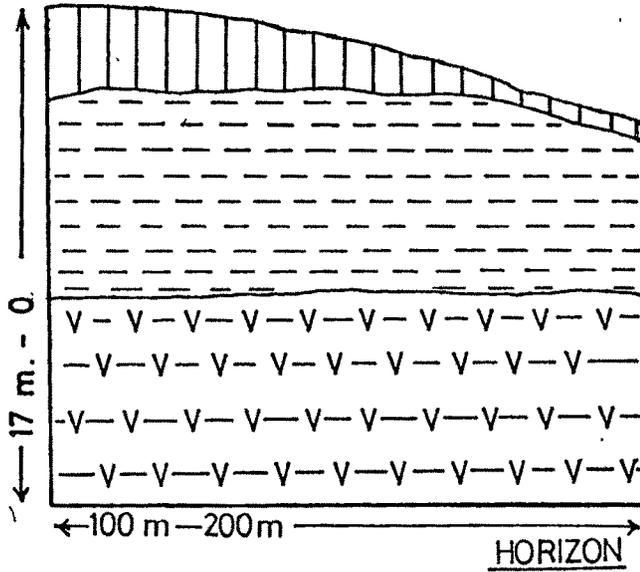
Several small scattered pockets of bauxite are noticed in the hillocks along the coast about 4 km west of Lamba. The slope of these hillocks are covered by talus of the Gaj limestone.

Several isolated hills rising 10-20 m above the ground and having bauxite are exposed towards the NW and S of the Lamba village. The upper portion of the hills are covered by Gaj limestone. Outcrops of fossiliferous beds capping the laterite /bauxite are also observed at many places. Here the bauxite is hard and compact with vesicular cavities simulating those of Deccan Trap basalts. The upper part of the bauxite profile is pisolitic and nodular, succeeded by bouldary and massive bauxite. Both these varieties, at places, are surrounded by comparatively loose clayey material. A nodular bauxite is inferred to have been derived from the upper part of the bauxite profile intermittantly exposed due to the erosion of the thin capping of the Gaj limestone. The generalised section is given below (Fig. 28)



The fence diagram (Fig. 29) shows the same standard Gaj/ bauxite relationship.

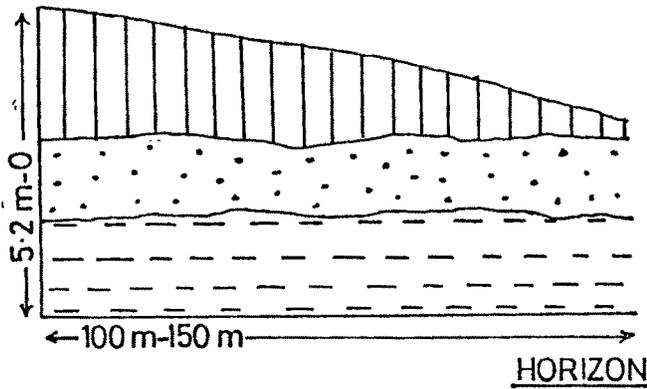
LAMBA



	Ferricrete (laterite)	$B_{ox}(Fe, Al)$
	Saprolite	B
	Basalt	C

FIG. 28

GANDHVI

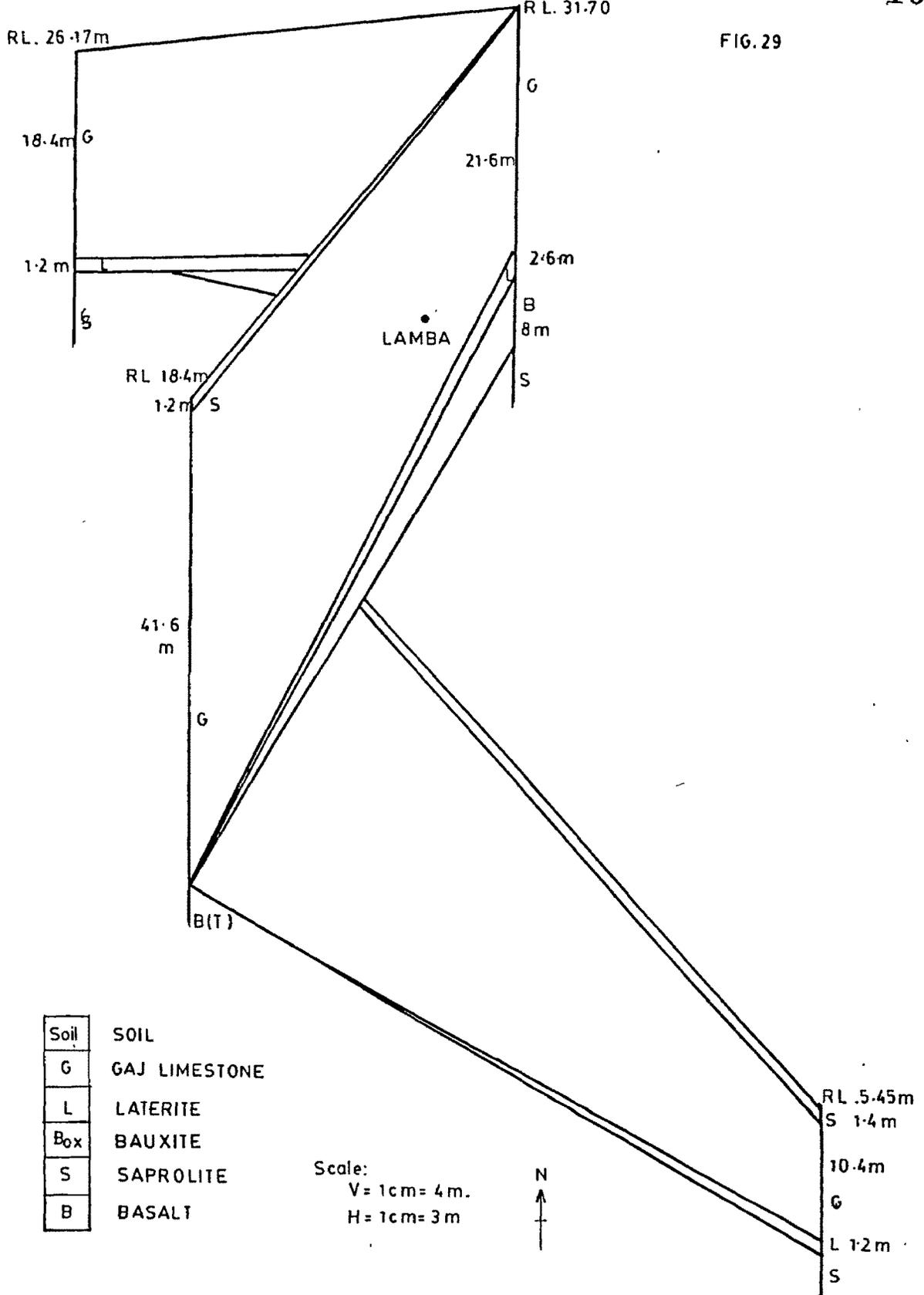


	Ferricrete (laterite)	$B_{ox}(Fe, Al)$
	Alucrite (bauxite)	
	Saprolite	B

FIG. 30

FENCE DIAGRAM OF THE AREA AROUND LAMBA

FIG. 29



Gandhvi Deposits

A L-shaped bauxite pocket is 1 km to the NW of Gandhvi village. Here there is no over burden.

Several isolated small hillocks with yellowish fossiliferous Gaj limestone are noticed along the coast between Lamba and Gandhvi. Bauxite crops out along the NE slope, 400 m NW of Gandhvi village. The bauxite is whitish grey, soft, spongy and clayey in nature. The profile is as below (Fig. 30)

Ferricrete	(laterite)	
Alucrete	(bauxite)	B_{ox} (Fe, Al)

Saprolite		B _(sap)

Salient field characters of bauxite occurrences in

Jamnagar district

- (1) The bauxite occurrences are confined to a narrow 1-1.5 km wide elongate Paleocene belt which runs in a north-south direction. Over a length of 50 km. Parallel to Gaj beds. This belt is sandwiched between the Cretaceous-Eocene basalts and the subsequent Tertiary sequence.
- (2) Physiographically, this belt constitutes a plain having low-lying elongated laterite ridges separated by broad, intermittent valleys. Deeply incised valleys are absent.
- (3) The generalised section in the bauxite bearing areas is as follows:

	Soil	
	Gaj limestone	
	Gaj clays	
	Laterite	} Horizon rich in oxides B_{ox} (Fe,Al)
	Bauxite	
Weathering sequence	Kaolinite	} Horizon rich in silicates B _(sap)
	Bentonite	
	Basalt	Horizon of fresh parent rock C.

This weathering sequence (Plate 4) is continuous, gradational residual in nature, with no signs of sedimentary reworking.

This lateritic/bauxitic sequence constitutes what is popularly known as an alteration blanket with the generally speaking, A horizon eroded.

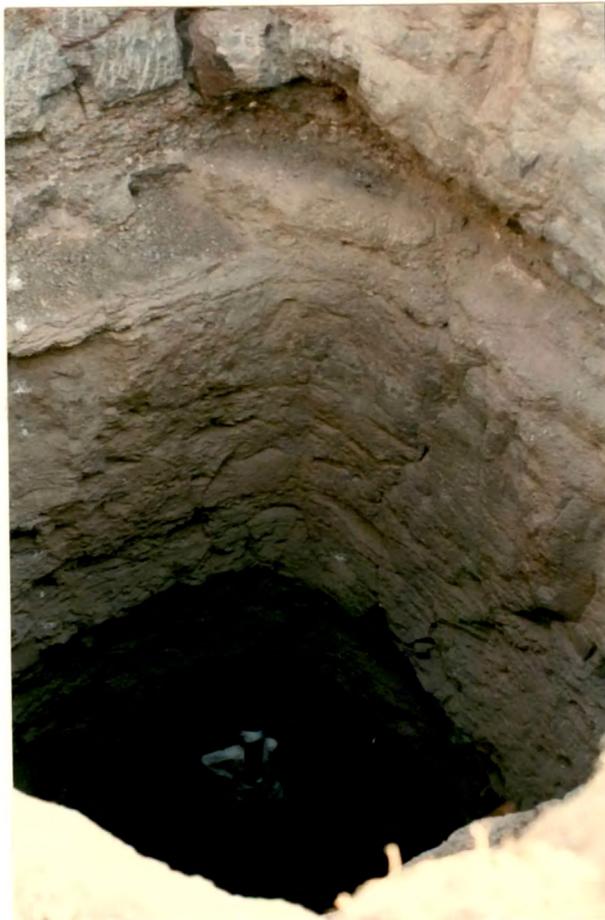
- (4) The lower most member of this weathering sequence is the zone of fresh parent rock viz., Deccan Trap basalt. Surficial exposures of basalt are very restricted, and are usually found at the bottom of the weathering profile or can be traced in well sections (Plate 5). One such 15 m deep well at Khakharda was studied in detail and it was found that fresh basalt was encountered at 1 m from the bottom of the well. This was followed upwards by a 14 m clayey weathered zone constituting of sticky bentonitic clays in the lower parts, followed upwards by Kaolinitic and lateritic clays respectively.



Plate No. 4. Typical bauxite mine section showing Gaj limestone at the top, followed by Gaj clays, underlain by bauxite, followed by bauxitic clay.



Plate No. 5. Basalt exposed in a well section at Khakharda.



The basaltic zone, whether found in well sections or exposed surficially, has conspicuous jointing and most conspicuous around Mahadevia, Mewasa and to the north of Virpur.

Basalt

Basalt which forms the oldest rock unit in the area is greenish to greyish in colour, splintery, exfoliated, jointed, porphyritic and quite frequently with amygdules of zeolites, calcite and various soft and soapy secondary vesicle fillings. Onion-skin spheroidal exfoliation (Plate 6) is a common feature in basalt. At places, the exfoliation spheroids superficially resemble pillow structure. But the absence of both a glassy skin and radial cracks in them rules out the possibility of their being pillow structures. Sub-vertical pipe amygdules are observed in basalt 1 km WNW of Habardi.

At many places, however, basalt exposed within the oval outcrops of the laterite is found to be in various degrees of decomposition. The state of decomposition of basalt varies sharply across the flow rather than along it.

Gabbro

A gabbro boss intrusive, into the basalt flows, occurs west of Gandhvi at southern end of the area. The western boundary of the gabbro boss is chilled and occurs at about 50 m above



Plate No. 6 Remnants of spheroidal weathering preserved in the B(Sap) zone underlying bauxite.



ground level. The old Harsad temple is situated on it (187' spot height). The western flank of the boss is gently sloping westwards.

Dolerite dyke

Dolerite grading to basalt occurs as dykes trending NNE and NNW. They are greenish to black, hard, massive, often amygdular but much less altered than basalt flows and range from a few cm to 50 m in thickness. In the northern part, just near Ran village, a 30 m wide dolerite dyke runs for about 1 km with a N25°E alignment, and further to the NNE, a fine to medium-grained basalt-dolerite dyke is exposed west of Habardi and east of Mota Asota, with a N30°E trend. About 1 km west of Harbadi, a dyke wall forms a 4 m high vertical bank of a nala. Just 50 m north of it, the dyke branches out into thinner veinlets of 3 cm width. A close examination reveals that a major sub-vertical branch of the dyke becomes a sub-horizontal flow within a distance of 50 m, east of the nala.

The second major dyke of the area also runs from north of Maletha towards the NNE via east of Bankodi. It has an average width of 30 m and its trend ranges from N 15°E to N 20°E. Just SE of Bankodi, it is disconnected or concealed by a lava flow for a length of 1 km. About 2 km north of Kenedi, a small dyke of basalt of 1.3 km length and 20 m

width runs N 16°E and then disappears into the surrounding terrain of basalt flows. The third basalt dyke occurs at a distance of 1.6 km east of Mota Asota and trends N 20° W - S 20° E.

- (5) The next horizon above the basaltic zone, is the highly altered clayey zone, consisting of extremely sticky and wet clays having various colour shades ranging from chocolate brown to white and dirty grey.

Chocolate brown clay and purple clay

A well defined zone of chocolate and brown colored ferruginous and purple bentonitic clay occurs above the basalt flow, especially where the laterite-bauxite zone is well developed. These clays are usually exposed at the base of steep scarp sections of laterite-bauxite zone (Plate-7). In some cases, as in Bhopamadhi (Virpur area), these clays overlying the basalts are exposed within the central depressions of the laterite-bauxite ovals. Although, the chocolate brown soapy clay underlies the purple clay horizon, both of these may be found to be intermixed at their contact zone, and gradually passing downward, into less and less altered basalt. This horizon ranges from 2 m to 8 m thickness. The clays have a soapy feel with abundant greyish to greenish white clay patches.

Purple clay is sometimes found to occur directly, above basalt without any development of the chocolate brown clay.



Plate No. 7. Typical chocolate brown clay zone found at the bottom of weathering profiles bereft of bauxite.

The purple clay is soft, extremely moist and sticky, powdery in nature and characterised by small patches of greyish white clayey laths (altered phenocrysts?) rounded to ellipsoidal patches of white and greenish clayey material (after amygdules of secondary minerals?). The gross appearance of the clay (Plate 8) because of its fine grain size and powdery nature, may resemble that of a tuff bed. But, (i) the presence of the criss-cross arrangement of numerous needles and laths of white clay akin to that of the crystalline intergranular texture of basalt, (ii) a definite absence of volcano-clastic texture and (iii) the presence of horizontally elongated clay (Plate 8) patches representing most probably the elongated, decomposed amygdules suggest that it was originally a lava flow rather than a pyroclastic tuff bed. Although, in a much altered state, the chocolate brown and purple clays resemble structurally, decomposed lava flows possibly of basaltic composition.

Relict spheroidal and exfoliation features are preserved in this zone, though being completely altered to clay. The amygdaloidal texture of basalt is also seen preserved, though the secondary minerals have been altered to clay. Calcite and gypsum veins and encrustations are seen in this horizon. Therefore, they have been clubbed together under the general term 'saprolite'. The term 'saprolite' is defined as a "a rotten rock, which has been geochemically weathered in-situ dominantly into clays of different composition, with little



Plate No. 8. Horizontally elongated reddish clay zones.

or no volume change or movement of the alteration products, but which has retained the original structure, so that the parent rock may be recognised from it". The purple clay at number of places shows laminations which are defined by color bands of light yellow ochre, bright violet, red and never by any grain size variation.

Lithomarge-Laterite - Bauxite

The purple clay horizon gradually passes upwards into the lithomarge-laterite-bauxite zone. Lithomarge occurs as imper-sistent lenticular horizon of variegated clays rich in kaolinite and ferric oxides and hydroxides often showing secondary laminations and concretionary structures. It occurs below the laterite-bauxite horizon (Plate 9) and has developed especially where the bauxite deposits have been well developed. Sporadic occurrence of pisolites and nodules of bauxite are observed within this lithomarge. It is a part and parcel of the laterite-bauxite weathering profile.

The laterite-bauxite horizon ranges from 0.4 m to 8 m in thickness (Plate 10) and is extremely inhomogeneous in both physical and chemical properties. It consists broadly of three parts, viz., mottled laterite, bauxite deposits and ferruginous mottled laterite. The light colored materials developed with a sub-horizontal extension with a deep brownish red lateritic background, have imparted a pseudostratification to the rock. Differential erosion has removed the softer clay

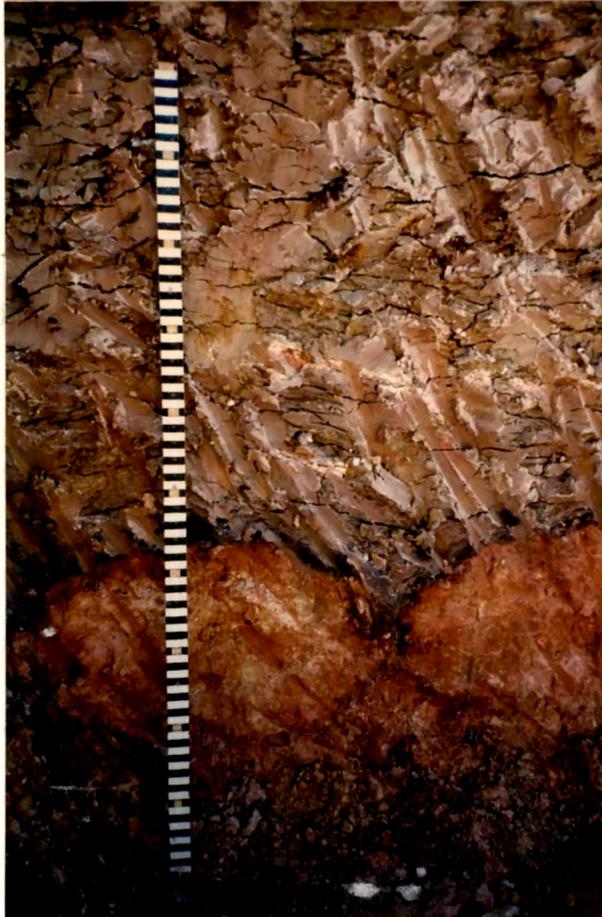


Plate No. 9. Part of lateritic bauxite horizon exhibiting relict amygdaloidal texture.



Plate No. 10. Boulders of laterite below a lateritic ridge.

portions in many places leaving behind a relatively hard ferruginous rock with numerous cavities (Plate 11) and these are noticeable on the scarp sections of mottled laterite. Differential erosion of the softer clayey portion in many cases has undercut the scarp to such an extent that the relatively harder ferruginous crust of the laterite at the top is left overhanging. Thus, round to ellipsoidal voids or caves have commonly developed in the escarpments of laterite. Black ferric and manganese minerals may occur in laterite. The mottled laterite, at many places, might have laterally to lenticular bodies of bauxite. In such cases, an irregular thin zone of mottled laterite may occur to some extent above the bauxite deposits, which, in turn grade downwards into the lithomarge (Plate 12). Bauxite show a color variation from cement grey, grey, creamy, yellow, brown, light pink and occasionally violet grey.

The mottled laterite zone with or without bauxite deposits has a deep brown to brownish hard ferruginous cap frequently with large concretionary structures. Smaller colloform structures and occasionally pisolites may also be seen. The laterite-bauxite horizon is exposed in numerous isolated oval outcrops, to the north of Bhatiya, especially around Mahadevia, Ran, Mewasa and Virpur.

Bauxitic clay

Bauxitic clay is invariably associated with white Kaolinitic



Plate No. 11. Boulders of laterite below a lateritic ridge.



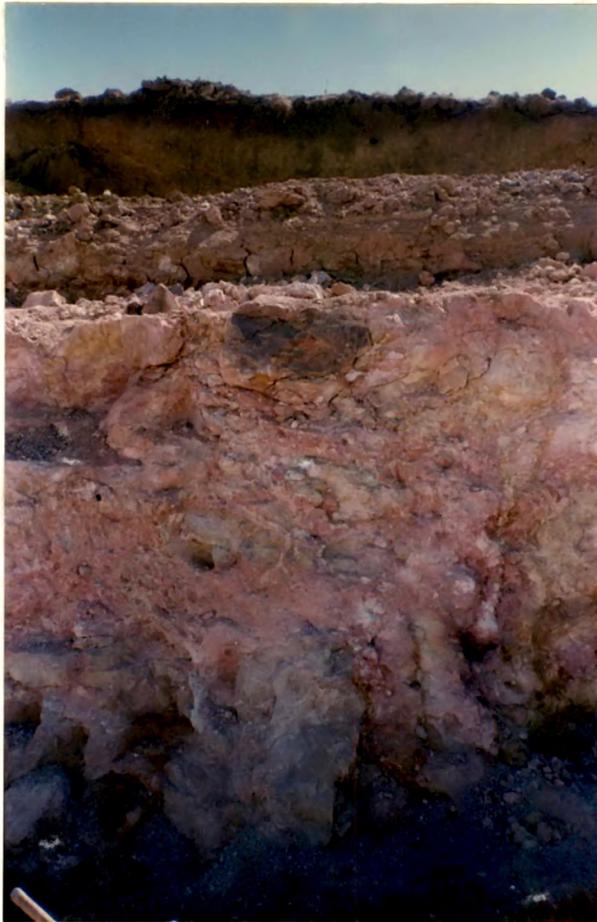


Plate No. 12. Mottled lateritic clay zone underlain by bauxite followed downwards by lithomargic clay.

and occasionally with purple montmorillonitic rich clays (Plate 13). Bauxitic clay is identified by its typical cement grey color, rough and non-soapy feel and its common association with kaolinite which can be easily identified by its bright white color, soft soapy feel and powdery nature.

Gaj series and its lowest surface

As described earlier, the laterite-bauxite horizon is overlain unconformably by a sedimentary succession - the Gaj series (Plate 14). The sedimentary succession consists principally of three main facies viz. carbonaceous, argillaceous and calcareous facies from bottom to top. However, there are all gradations and repetitions to some extent of the different facies. Argillaceous compact sediments occurring as lenticular bodies, overlie laterite-bauxite zone.

Transported bauxite

Transported bauxite is occasionally encountered above the zone of mixed clay. Its transported character is clear from the association of the arrangements of high grade hard and compact bauxite (Plate 15) within a matrix of arenaceous mudstone and mixed clay. The unsorted nature of such bauxite deposits indicate their transportation over a short distance from the the nearby in-situ deposit.



Plate 13. Purplish montmorillonite clay overlain by light coloured kaolinitic clay.



Plate No. 14. The Gaj succession overlying bauxite, consisting of calcareous and argillaceous clays followed upward by Gaj limestone



Plate No. 15. Boulders of reworked bauxite in a clayey matrix exposed in a river section.



Mixed clay

Mixed clay which includes fragments of pyritiferous black shale in a matrix of variegated, argillaceous and reddish ferruginous clays. The fragmentary nature and widespread ferruginous material within this zone may imply a local intraformational stratigraphic break.

Mudstone, calcareous clay and marl

Mudstone occurs above the mixed clay and gradually passes up into bright yellow calcareous clay which is occasionally fossiliferous. Further upwards, yellowish calcareous clay is gradually mixed with argillaceous clay and thus grades into marl.

Gypseous mudstone and marl

With impoverishment and absence of the calcareous component, marl grades up into mudstone. Gypseous mudstone is frequently non-laminated. It occurs both as translucent greyish white lumps and as transparent selenite type. Gypsum plates are deposited parallel to the bedding planes of the mudstone. Therefore, gypsum is syngenetic with the mudstone. North of Bhatiya, occurrence of gypsum is practically restricted to the mudstone. Mudstone whether gypseous or not, always occurs as lenticular bodies.

Concretionary Limestone

Above the gypseous mudstone appears the calcareous clay with foraminiferal concretionary limestone. It is generally yellowish to greyish white in color, over a major part of the area, north of Lamba, brownish yellow calcareous clay is exposed.

Shell Limestone

Further upwards, brownish yellow, hard and massive limestone occurs frequently. It forms number of flat topped elongate table lands. There are several such ridges of shell limestone in between Mahadevia and Mewasa, east of Pindara, north of Ran, west and south of Bhatiya, around Hadmatia and in between Navadara and Lamba. The structural and textural features of the rock suggest that the rock is authigenic.

Dwarka beds

Dwarka beds consisting essentially of fossil rich limestone and marl overlie the shell limestone of the Gaj? With a disconformity. Dwarka limestone is less compact.

Structurally it may be distinguished by its detrital character, frequent current bedding, and coarse unassorted clastic texture, which are uncommon in the Gaj limestone. All around the base of the ridges the bright yellow calcareous clay horizon of the Gaj series is found. Immediately overlying this clay bed, a

a conglomerate bed occurs, consisting of fragments of yellow massive Gaj shell limestone and ferruginous concretions embedded within the Dwarka bed. The conglomerate bed, therefore, bears testimony to the stratigraphic hiatus between Gaj and the Dwarka. The conglomerate horizon is overlain by Dwarka limestone.

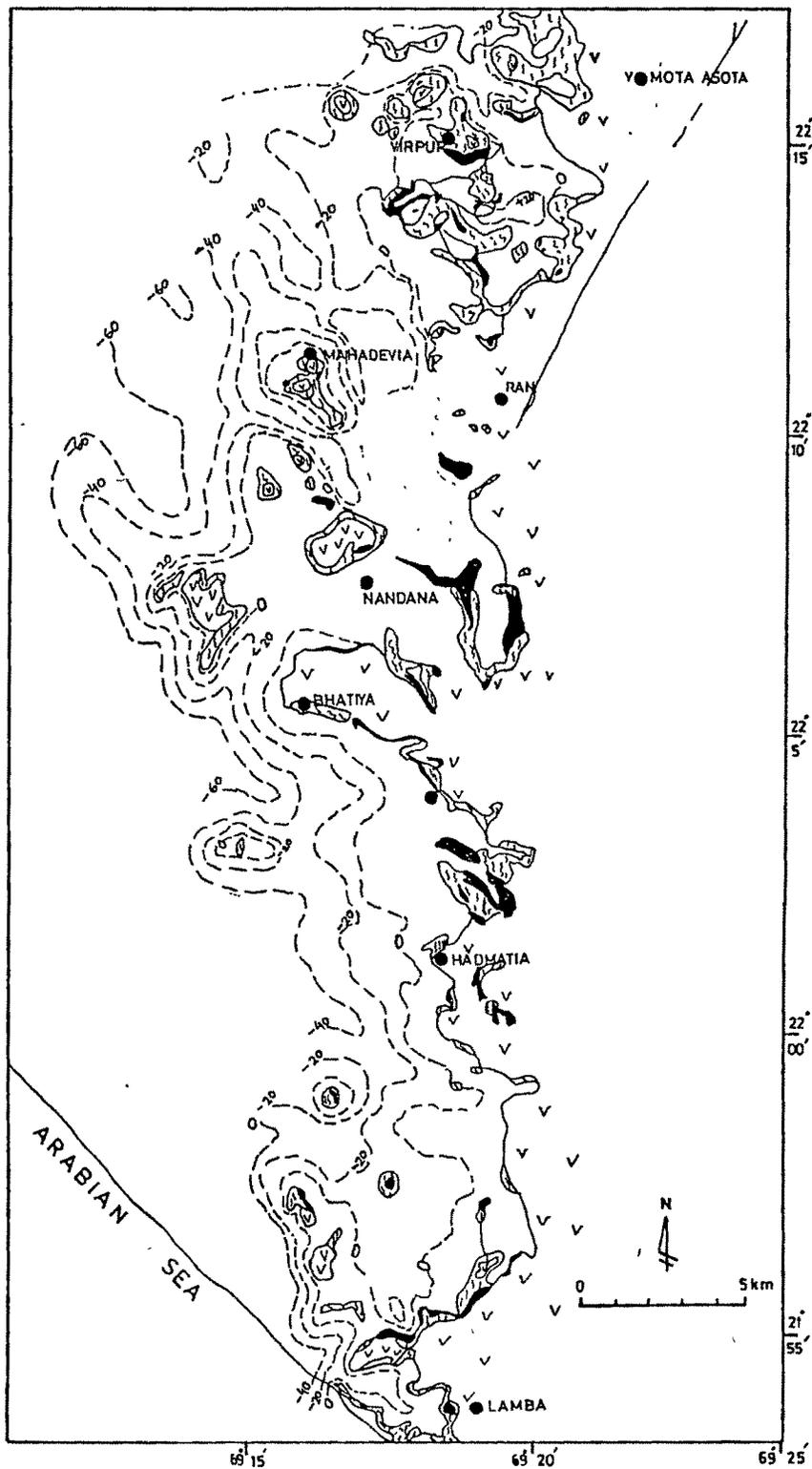
Miliolite limestone

Miliolite limestone is the youngest rock unit in the area. It occurs in patches, overlapping the flanks of the limestone and laterite ridges and typically along the nala courses. The rock is generally milky white, well bedded, medium to coarse grained with cross beddings. On the slopes of the ridges of laterite, Gaj and Dwarka limestone, miliolite limestone generally thin, includes pebbles and fragments of the underlying rocks. The best outcrops of miliolite limestone in the area are seen near the Dhand river section. 1.4 km SW of Mewasa village Bedding planes on both the banks of river, dip at 10° to 15° towards the river bed. At a distance of 2.4 km NW of Bhatiya a NS trending flat topped ridge of Gaj limestone is rimmed by miliolite limestone which dip at 10° to 15° away from the ridge all around.

Comparative study of the pre-Gaj and present day drainage system of the area

In order to prepare a pre-Gaj topographic map (Fig. 31), the thickness of the Gaj sediments above the Deccan Trap, as

FIG. 31
PRE-GAJ TOPOGRAPHY SHOWING DISPOSITION OF BAUXITE
DEPOSITS. (PREPARED FROM BORE HOLE DATA GEOL. SUR. INDIA)



obtained in the bore holes drilled by the Geological Survey of India has been deducted from the reduced level (R.L.) of the bore-hole points. The results give height or depth with respect to the mean sea level of the pre-Gaj surface below that point. Contouring all these heights of depth for all the bore-holes that penetrated upto the Deccan Trap, the pre-Gaj topographic map was prepared. From the study of this map, the pre-Gaj drainage of the area could be separated into two distinct groups. 1. on the northern part, from Nandana to Virpur, the area is well dissected with valleys and spurs - all sloping towards the NNW and merging with the Gulf of Kutch, indicating (a) the general slope in the part of the area was towards NNW and (b) well developed drainage conditions, 2. in the southern part, from Nandana to Gandhvi, the pre-Gaj valleys and spurs were broad, less frequent and all were gently sloping towards the west, signifying that (a) the general pre-Gaj ground slope was westerly, and (b) the area was poorly drained.

Drainage conditions of the pre-Gaj period is more or less still reflected in the present day drainage pattern of the area. The major water-divide separating the two different pre-Gaj drainage still forms an ENE-WSW trending water divide running through (Bhatiya) for the present drainage system. However, the valleys in the north central part (north of Mahadevia) of the northern drainage are now filled up by a

thick pile of the Tertiary sediments (Gaj sediments). In the southern area, on the other hand, calcareous clay of the Gaj series has developed all along the broad and shallow pre-Gaj valleys and gently sloping spurs. The only major river, Kalipat, shows a westward course upto Kenedi. But from Kenedi to the south of Hadmatia, towards the SW, the river takes a SW trend, cutting across the trend of the pre-Gaj valley slopes. This trend is again followed further downstream by a westerly direction of the river flow.

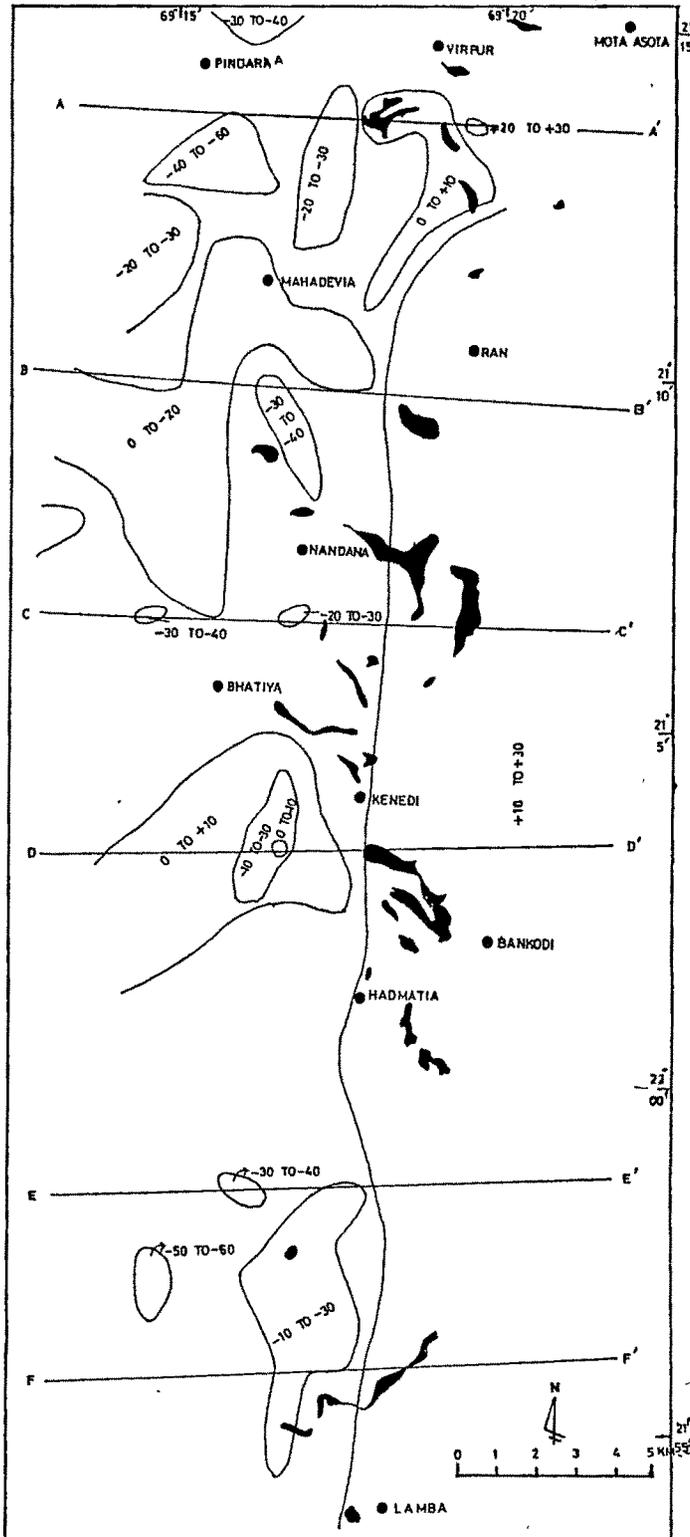
The salient inference that can be drawn from the above comparative study of the present day and pre-Gaj drainage pattern are:

1. the water divide that separates both the pre-Gaj and present day drainage into two major parts - NNW in the northern part and west to SW in the southern part - represent more or less, the high linear ENE-WSW trending surface of the Deccan Trap basalts before the deposition of the Gaj sediments.
2. the approximate occurrence of the present day river courses with the pre-Gaj ground slopes, suggest that there has not been any appreciable large scale tilting of the crust in this area since the lower Miocene time.
3. the change in the course of the Kalipat river from EW to SSE from Kenedi to south of Hadmatia could be due to local tilting of the block.

In order to get a picture of the, depth of weathering (i.e., Saprolite formation), the depth to fresh rock (i.e. Deccan Trap basalt) was subtracted from the reduced levels of the various bore holes drilled by the Geological Survey of India and a map was prepared (Fig. 32). Some very interesting points came to light:

- i) there is an arbitrary N-S line which separates the entire study area. Major bauxite deposits are located to the east of this line, while to the west, scattered small pockets are found;
- ii) the reduced levels of basalt encountered to the east of this line are all above mean sea level, while basalt is encountered below mean sea level to the west;
- iii) numerous E-W profiles drawn across the entire (Fig. 33), show that the occurrence of bauxite is usually along crests, and upper slopes of elevated areas, but rarely along valley bottoms,
- iv) bauxitic pockets are usually associated with an underlying saprolitic horizon, though at some places bauxite is found resting directly over the basalt.

CONTOUR MAP SHOWING DEPTH OF FRESH ROCK. DARK COLOURED FIG. 32
 AREAS SHOW BAUXITE DEPOSITS OCCURRING ABOVE M.S.L.
 (PREPARED FROM BORE HOLE DATA GEOL. SUR INDIA)



CROSS SECTION ACROSS THE STUDY AREA FIG. 33
(SEE FIG. 32 FOR EXACT LOCATION OF PROFILES)

