C H A P T E R-IV

FIELD STUDIES AND LITHOFACIES

As mentioned earlier, the lithostratigraphic sequence of Mainland is divided into four formations named as the Jhurio, Jumara, Jhuran and Bhuj Formations in ascending order. The Bhuj Formation is disconformably overlain by the basic flows of the Deccan trap Formation (Biswas et al., 1973) on the south while, the base of the Jhurio Formation is unexposed. The study area encompasses the entire Jhurio and Jumara Formations of the three domal structures of the Mainland of Kutch i.e. Jumara, Jhura and Habo from west to east.

As a pre-requisite for facies & microfacies analyses, geological field studies at Jumara, Jhura and Habo Domes were carried out. Systematic & close sampling of exposed carbonate sequences were made keeping in view the different facies criteria like lithology, rock colour,

bedding and lamination, sedimentary structures and textures, fossil content, stratigraphic relationship and geometric shapes of rocks. The dome wise details of the study has been given under two major headings i.e. Jhurio and Jumara Formations.

JHURIO FORMATION

The Jhurio Formation is exposed as inliers in these domal structures along the northern margin of the Mainland. The facies recognition in the Jhurio Formation is based solely on the lithological variations because sedimentary structures are rarely discernible. In this analysis, bioclasts have been utilized mostly as sedimentary particles; their identification has been extended only upto the level of phylum or class for gaining atleast a broad idea about the paleoenvironmental conditions.

JHURA DOME

Jhura Dome lying to the NNW of Bhuj is a huge hill in the middle of the Northern Range of the Mainland. The topography is apparently related to dome structure (Plate IV.1). The dome is in its early youth stage. Here the drainage is centrifugal to radial. The older rocks are exposed in deeply cut fault valleys whereas the younger beds form steep cuesta slopes. Due to the marginal flexure, the limestone beds have formed prominent hog-backs on the northern flank of the dome (Plate IV.2).

Plate IV.1 Photoplate of a portion of Jhura Dome

Plate IV.2 Photoplate of Hogback at the northern flank of Jhura Dome

The Jhura dome which is approximately 20 Km long and 6.5 Km wide has an egg shaped core. The roughly elliptical outline is defined by the Dhosa oolite band. The general trend of the major axis is S75°E - N78°W.

Both eastern and western parts of this ellipsoidal dome are elongated due to repetition of beds by innumerable transverse faults. The dome is dissected by a network of faults whose drag effects together with the effects of topography and the differential hardness of beds give peculiar shape to the outline of the dome. The ring like outcrop pattern of the beds within the dome shows a typical 'Onion shell' structure.

North limb of the dome is very steep; average dip being 45°-50° which becomes as steep as 75° at places. This steepness of the limb is due to the Kutch Mainland Fault which limits the northern margin of the fold.

The general form of the fold, the tensional faults and a greater upliftment at the central part of the fold probably indicate that the dome has been formed more by the vertical upliftment than by the flexing due to horizontal stress. The close association of the igneous intrusions and plugs in the peripheral region probably suggest the possibility of upliftment by the forces of igneous intrusion at depth. The dome might thus be sitting over a giant laccolith. This also explains the conspicuous shape of the

dome and the difference in the pattern of outlines between the inner and the outer closure.

In order to carry out systematic sampling of the exposed carbonate sequences in Jhura dome, a geological map prepared by Biswas et al (1977) was simplified and representative samples of different rock units were collected along the three traverses (**Fig.IV.1**).

In Jhura dome, the formation is exposed as circular inlier at the core. It is well exposed in the deep valleys. In fact the entire hill is made up of this formation only and hence, the formation is named after the hill (Biswas, 1977). The typical section is seen along a big stream that flows to the north from the center of the hill. The stream originates in the heart of the hill and flows out into the plain on the north to the south west of Badi.

This formation is readily identified in the field by its characteristic lithological association of limestone, shale and golden oolite rocks. This is the only formation in the Mainland where pure crystalline limestones are encountered. The country is recognizable from a distance by the high topographic relief and whitish appearance. The competent limestone bed on top of this formation forms the gentle arch of the dome structure of the hill. The older shaly beds ribbed with hard beds of golden oolite rock, are

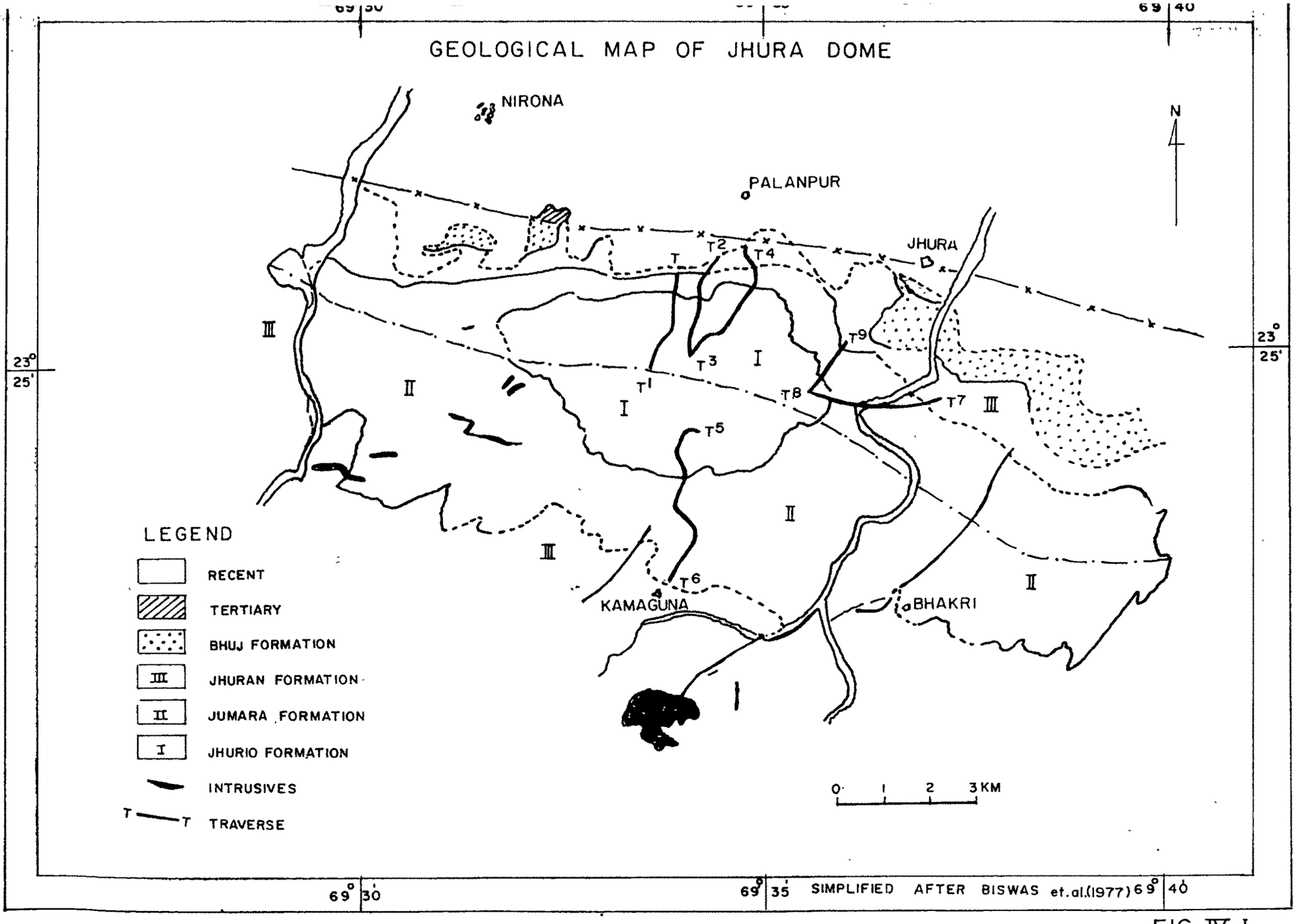

GEOLOGICAL MAP OF JHURA DOME
NIRONA
PALANPUR
JHURA
KAMAGUNA
BHAKRI
N
T1
T2
T3
T4
T5
T6
T7
T8
T9
I
II
III
23° 25'
69° 30'
69° 35'
69° 40'
LEGEND
RECENT
TERTIARY
BHUJ FORMATION
JHURAN FORMATION
JUMARA FORMATION
JHURIO FORMATION
INTRUSIVES
TRAVERSE
0 1 2 3 KM
SIMPLIFIED AFTER BISWAS et.al.(1977)

FIG-IV-I

exposed only in the deeply dissected fault valleys. Most of the members of the formation are, thus, exposed only in high and steep cliffs deep in the interior of the hill.

During field studies, the following major lithofacies have been identified and two litho-column have been made along major traverses and the sample positions were plotted (**Fig.IV.2 and IV.3**).

1. LIMESTONES AND SHALE FACIES (KJH-I)

The facies is partly exposed in the interior of the Jhura dome and can be approached only from the northern flank along the stream south of Badi. It corresponds to Member 'A' of Biswas (1977). The base of the facies is not exposed.

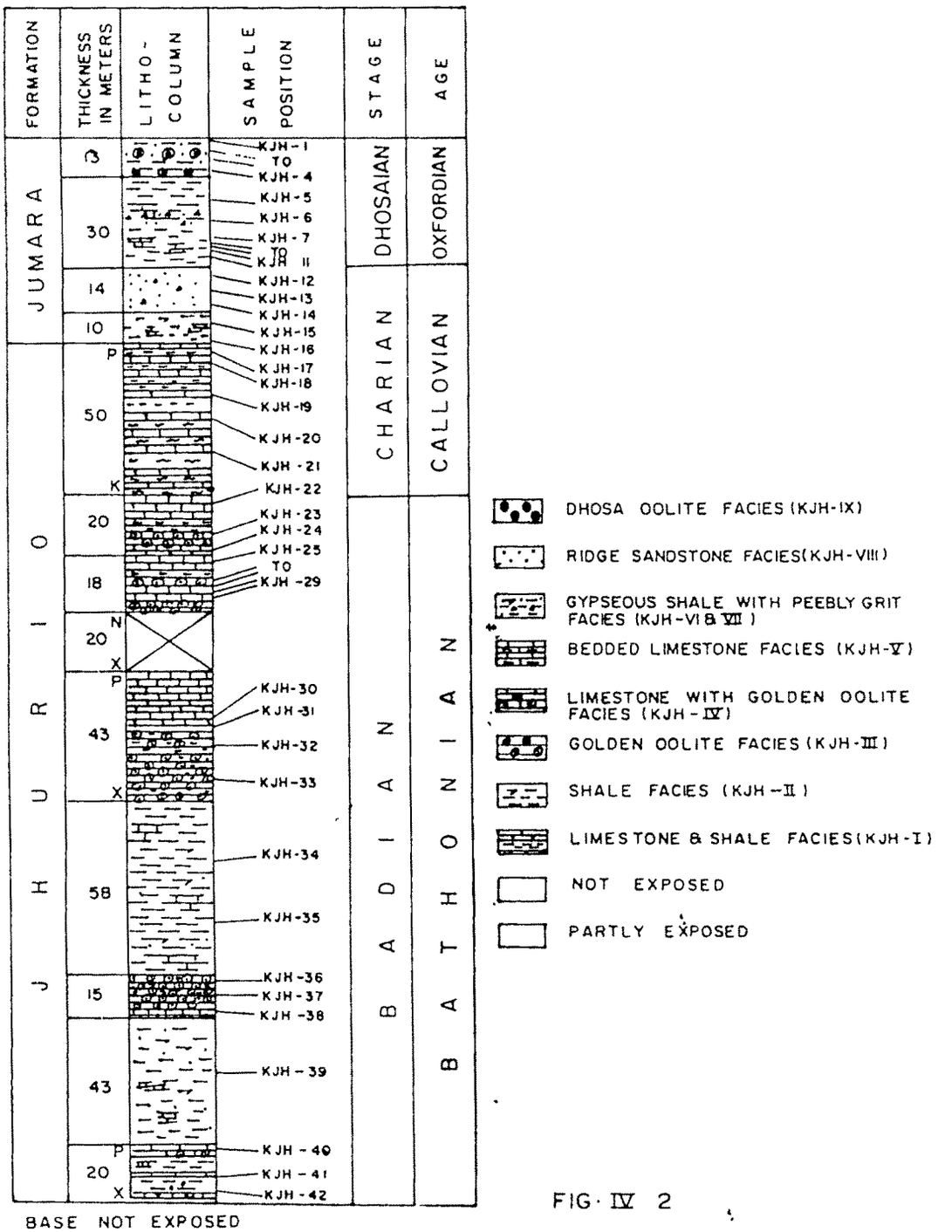
The facies is a lithological association of limestones and shales. The limestones are grey, and silty in nature. Some limestones contain streaks and lenticles of fine golden oolite aggregates. Localized limestone-pebble-conglomerate is also present within this facies. The shales are greenish grey in colour and massive and quartzose in nature.

2. SHALES FACIES (KJH-II)

The facies alternates with the two massive golden oolite beds. These are Khaki coloured laminated silty shales with calcareous bands. Based on the faunal assemblage of *Brotzenia Khawadensis* and *Epistomina ghoshi* within these

LITHOSTRATIGRAPHIC COLUMN ALONG TRAVERS T-T'

JHURA DOME



BASE NOT EXPOSED

FIG. IV 2

LITHOSTRATIGRAPHIC COLUMN ALONG TRAVERSE T^7 T^8

JHURA DOME

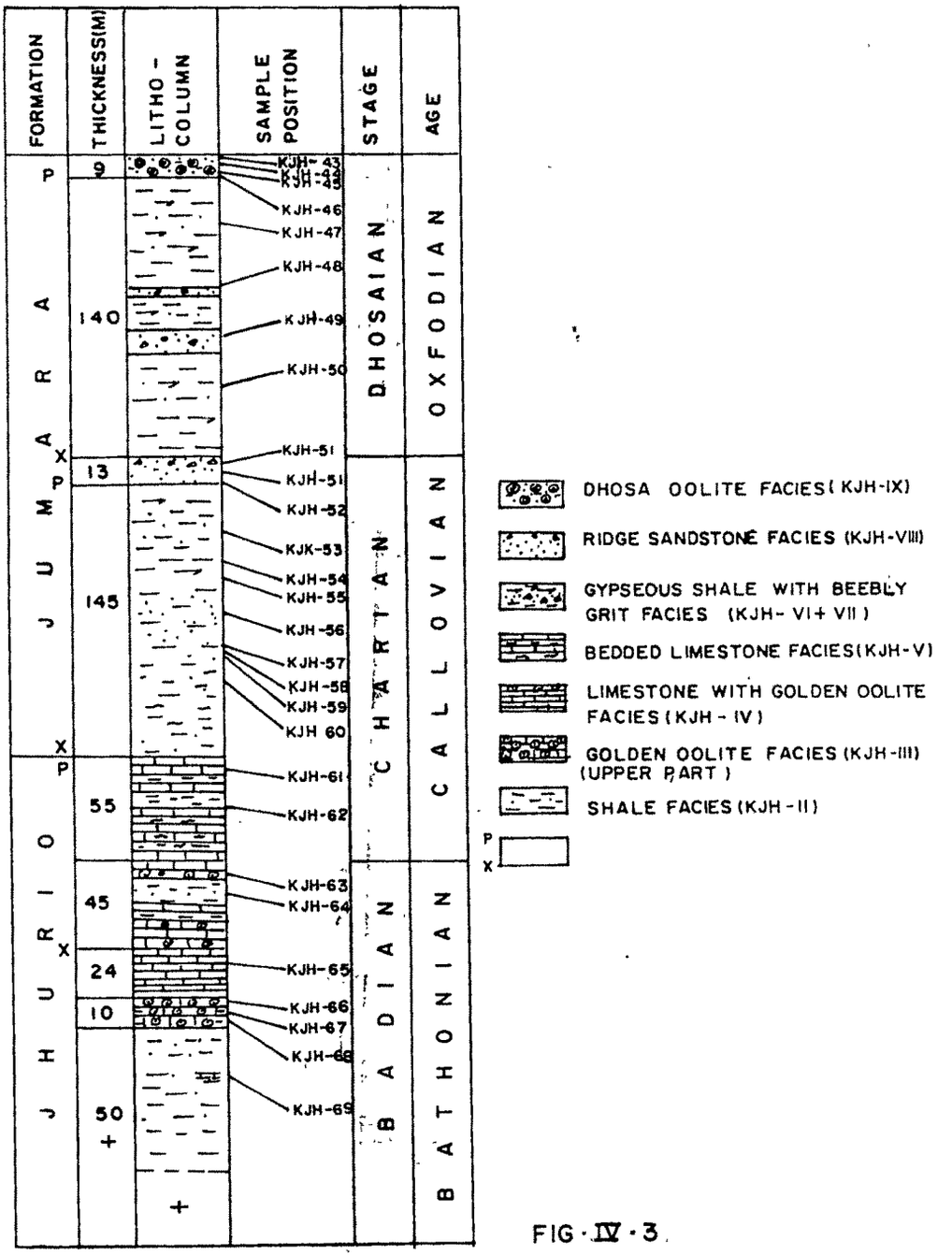


FIG · IV · 3

shales, Pandey and Dave (Paleontographica Indica, 1993) have assigned Badian stage corresponding to Bathonian age.

3. GOLDEN OOLITE FACIES (KJH-III)

Two bands of golden oolitic rocks have been identified which alternates with the Khaki laminated Shale Facies (KJH-II). The lower band is a massive bed of golden oolite rock with a thin bed of limestone at the base (**Plate IV.3**). On weathering the golden oolites of this member give a brick red colour. The bed corresponds to Member 'C' of Biswas (1977). The upper band consists of thick beds of golden oolites and stand out prominently as hard bands. The weathered surface gives a brownish black appearance typical of these rocks. The bed represents Member 'E' of Biswas (1977).

The rocks constituting the facies are made up of large ooids coated with golden iron oxide films on a calcareous matrix. At places, the golden oolite rocks are reddish brown coarse crystalline limestone full of large golden coloured ooids. These ooids are usually formed around fine rock particles. Often small pebbles are seen coated with golden yellow films forming the ooids. Pellets of green marl on the surface of golden oolite rocks are commonly seen. Ooids are rich in ferruginous matter. The concentric layers of the ooids are composed of chamosite which on oxidation gives the golden yellow colour. This is evident from the

Plate IV.3 Photoplate of lower band of Golden Oolite facies

Plate IV.4 Photoplate of ripple marks on top of localized conglomerate bed below upper golden oolite bed.

fact that a specimen of the same rock from the subsurface where there is no oxidation, show green colour instead of golden yellow (Biswas,1993).

These rocks are occasionally conglomeratic with pebbles of reddish brown ferrugenous rocks and more commonly subangular fragments of a greenish marly rock and show good ripple marks (**Plate IV.4**).

4. LIMESTONE WITH GOLDEN OOLITE FACIES (KJH-IV)

Here the golden oolites are interbedded with yellow, finely crystalline limestones which are at places silty in nature. At places the golden oolite bands show mega ripple marks. On top of this band occurs an olive green, coarsely crystalline saccharoidal limestone. The facies corresponds to the Member 'F' and lower part of Member 'G' of Biswas (1977).

5. BEDDED LIMESTONE FACIES (KJH-V)

The facies here is represented by well bedded limestone and corresponds to the upper part of Member 'G' of Biswas (1977). Based on the nature of limestone beds, the lithofacies can be divided into two subfacies;

A. **Chalky limestone subfacies (KJH-VA)**: The lower part of the facies is very distinctive for its chalky white appearance and brick like structures produced by the intersection of

Plate IV.5 Photoplate of nodular bedding in Chalky limestone subfacies, Jhurio formation, Jhura dome

Plate IV.6 Photoplate of Flaggy limestone subfacies, Jhurio formation, Jhura dome

bedding plane and closely spaced vertical joints. Here the limestone beds show nodular weathering and are separated by soft calcareous marly beds (**Plate IV.5**).

B.**Flaggy limestone subfacies (KJH-VB)**: The upper part of bedded limestone facies is flaggy in nature and is characterized by hard thinly bedded limestone of yellow to brownish yellow in colour. These limestones are separated by greenish shaly partings along the sharply defined smooth bedding planes (**Plate IV.6**).

JUMARA DOME

Jumara, a dome hill of the Northern Range of the Mainland, adjacent to the Rann, displays marked lithological variations and the formations are richly fossiliferous. The dome is maturely dissected and in its late youth stage. The core made up of shales has been eroded off giving rise to central depression, excepting at the center where the older limestone beds crop out. These limestone beds resisted erosion to form a low dome hill at the center (**Plate IV.7**).

To the north, steep limbs of the dome formed hogbacks of limestones (**Plate IV.8**). The limestone hill of the core is surrounded by annular valleys between cuestas. These cuesta girdles abruptly end up at the margin of the Rann due to the marginal faulting by the Kutch Mainland fault. Here the fracture zone of the fault has initiated

Plate IV.7 Photoplate of central part of Jumara Dome.

Plate IV.8 Photoplate of Hogbacks at Jumara Dome

erosion from the north and the dome hill has been opened up on that side. The central limestone core induces radial drainage which joins the annular ones draining out into the Rann.

The Jumara dome is an asymmetric anticline with gentle dips (10^{o} to 25^{o}) to the south and high dips (20^{o} to 50^{o}) to the north. Here part of Jhurio and the whole of Jumara Formation is exposed due to differential erosion in the form of inliers. The Jhurio Formation is exposed at the core of the dome as a circular outcrop forming the central hill. The Jumara Formation is best developed here. Any section radially across the dome from the central limestone (Jhurio Formation) exposes the formation with full details. However, a traverse from the tank about a thousand feet, west of the village of Jumara, towards the north presents an ideal section for study and can be considered as the type section as per Biswas, (1977). This section, therefore, has been taken as the type section of the Jumara Formation which is named after the dome hill popularly referred to as Jumara Dome.

In order to have a systematic and representative sampling from different carbonate sequences in Jumara dome, a broad geological mapping in the scale 4.2 cm = 1 km was carried out. The outcrop boundary of the Jurassic carbonates were traced with the younger siliciclastic Jhuran formation.

Boundary between the Jhurio and Jumara formations were also plotted (**Fig.IV.4**). The base of the formation is not exposed.

Two lithocolumns have been made along major traverses with sample positions plotted and shown in **Figure IV.5 and IV.6**. During field studies, three lithofacies have been identified within the Jhurio Formation.

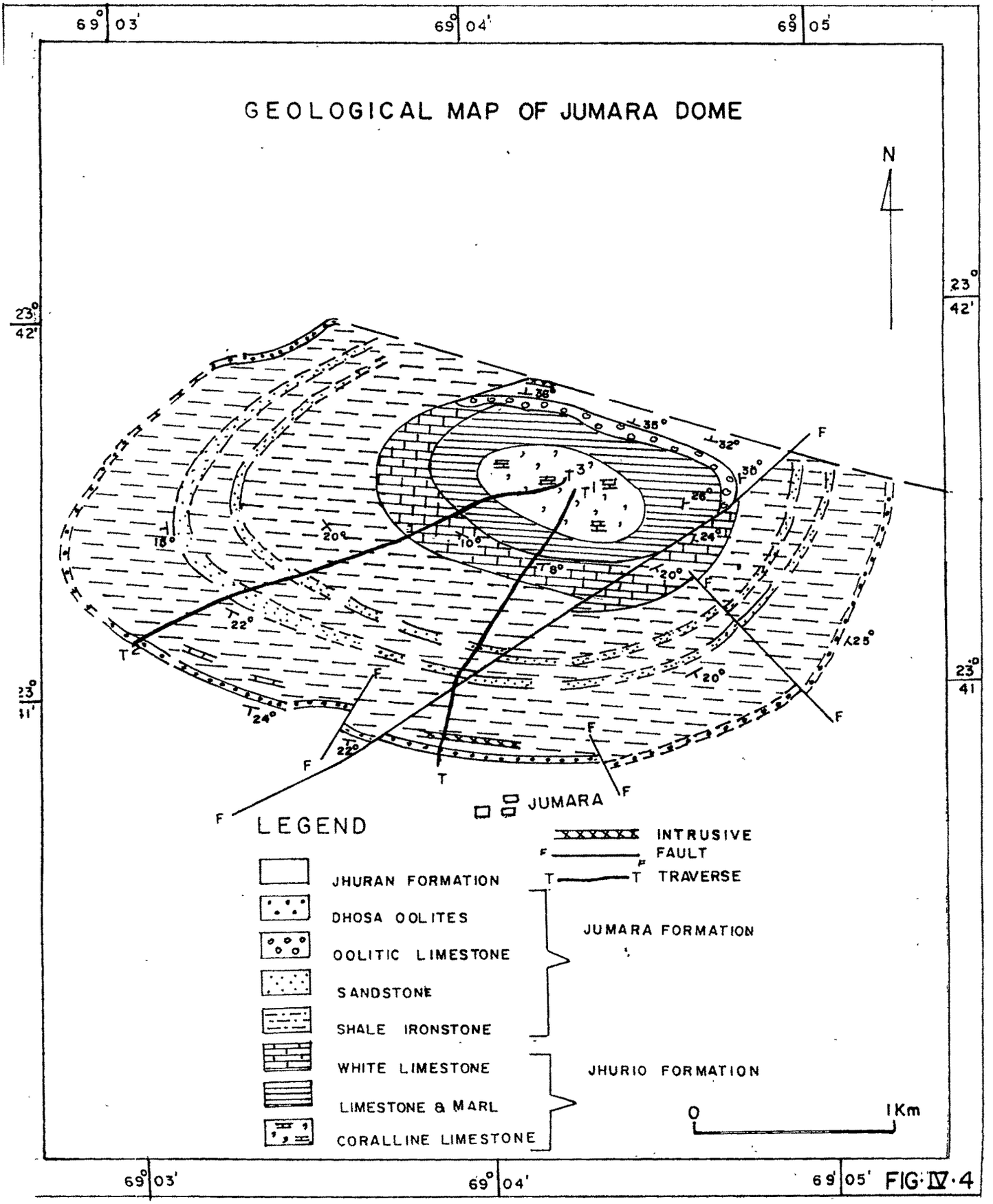
1. CORALLINE LIMESTONE FACIES (KJ-I)

The facies is exposed on top of the hill adjacent to the Rann and is easily approachable from the Rann side. It is more than 15 m thick and comprises greenish grey, gypseous, calcareous shales with bands of fine to medium grained coralline limestone which varies in thickness from 5 to 30 cms.

The distinctive characters of the facies are as follows:

- They are dominantly made up of fossil grains although mud may or may not infill the interstitial spaces between the grains.
- The fossils are largely intact far exceeding the sand size.
- Different communities of bioclasts dominate in different beds.

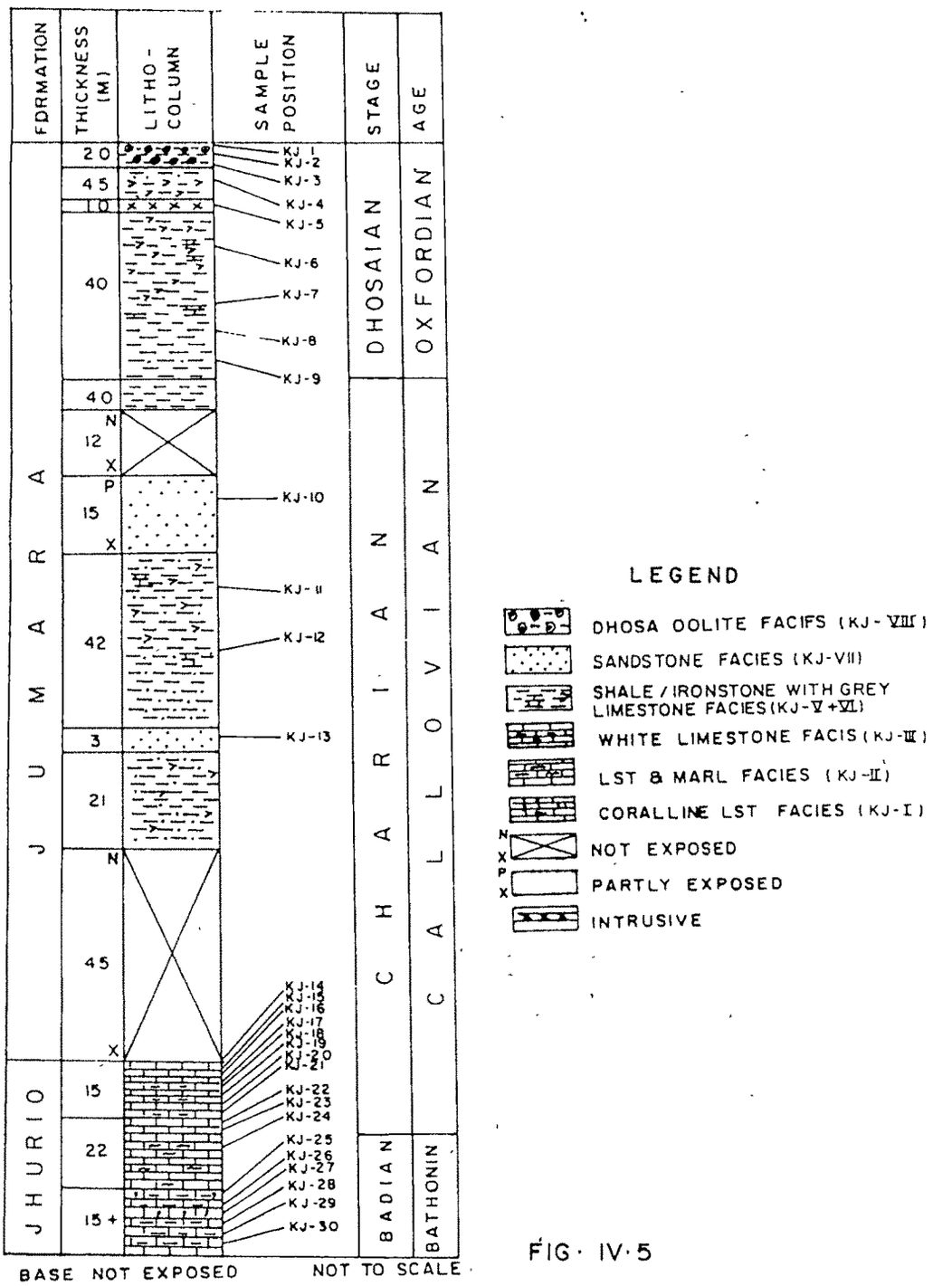
In field terms, the rocks can be named as Rudstone (Dunham, 1962). Mostly beds are dominated by large varieties


69° 03'
69° 04'
69° 05'
GEOLOGICAL MAP OF JUMARA DOME
N
23° 42'
23° 41'
JUMARA
LEGEND
JHURAN FORMATION
DHOSA OOLITES
OOLITIC LIMESTONE
SANDSTONE
SHALE IRONSTONE
WHITE LIMESTONE
LIMESTONE & MARL
CORALLINE LIMESTONE
JUMARA FORMATION
JHURIO FORMATION
INTRUSIVE
FAULT
TRAVERSE
0
1Km

FIG·IV·4

LITHOSTRATIGRAPHIC COLUMN ALONG TRAVERSE T-T'

JUMARA DOME



LEGEND

- DHOSA OOLITE FACIES (KJ-VIII)
- SANDSTONE FACIES (KJ-VII)
- SHALE / IRONSTONE WITH GREY LIMESTONE FACIES (KJ-V+VI)
- WHITE LIMESTONE FACIS (KJ-III)
- LST & MARL FACIES (KJ-II)
- CORALLINE LST FACIES (KJ-I)
- NOT EXPOSED
- PARTLY EXPOSED
- INTRUSIVE

FIG. IV.5

LITHOSTRATIGRAPHIC COLUMN ALONG TRAVERSE T^2-T^3

JUMARA DOME

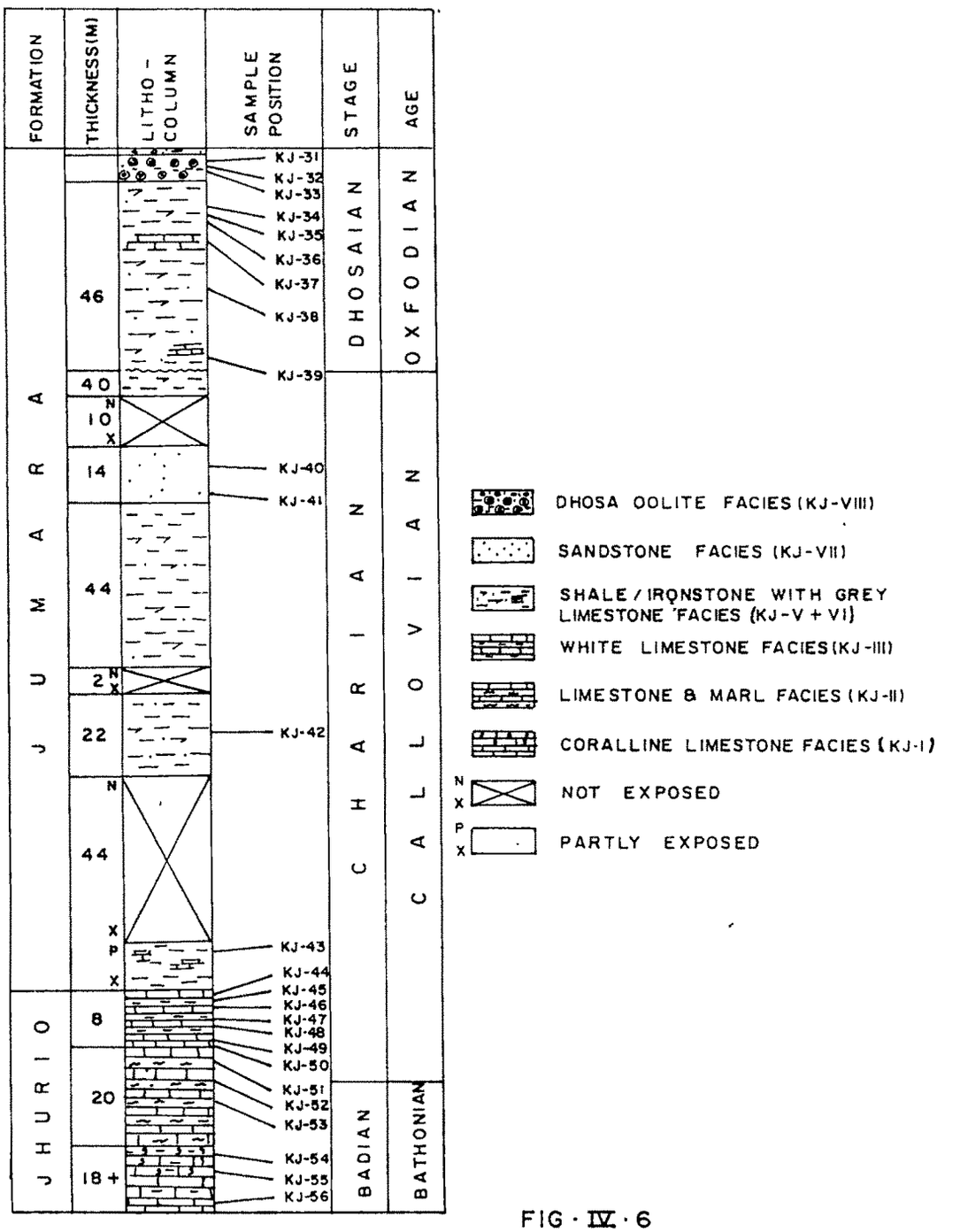


FIG · IV · 6

of corals scattered as loose fragments (**Plate IV.9**). The beds are essentially tabular in geometry. Except corals, other significant but subordinate components of these beds are sponges, echinoids and brachiopods. Brachiopods such as Terebratula are the dominant component.

2. LIMESTONE AND MARL FACIES (KJ-II)

The facies is apparently massive on weathered surfaces and looks homogeneous. In fresh vertical sections, however, its bedded nature is discernible (**Plate IV.10**). It forms the inner most cuesta girdle of the dome hill encircling the central hill. The facies, 22 m thick, consists of light grey to whitish, hard, nodular, fossiliferous lime and marl alternations. It weathers to soft drab yellow masses at places. Here the fossil fragments are sparsely scattered. The beds are broadly parallel sided but their upper and lower surfaces are slightly irregular. The beds lack internal laminations and their average thickness varies from 1 to 9 cm.

As far as field nomenclature is concerned, the rock can be named as a wackestone / floatstone depending on the size of the bioclasts present (Dunham, 1962). Few thin bands of packstone are also seen.

Plate IV.9 Photoplate of loose corals, in Coralline limestone facies of Jhurio formation, Jumara dome

Plate IV.10 Photoplate of Limestone and marl facies, Jhurio formation, Jumara dome

3. WHITE LIMESTONE FACIES (KJ-III)

The facies has the average thickness 15 m. No stratification is discernible within this facies. Here we are getting several shoaling up parasequences of mudstone and wackestone with shales forming plain eroded surfaces (**Plate IV.11**). These limestones occur on the southern limb of Jumara dome and are absent on the northern side. The comminuted shell fragments are sparsely present.

HABO DOME

Habo dome is named after the temple of Habay Mata at Habay village, situated on the southern flank of the dome. It is the biggest dome hill in Kutch and is in its immature stage of erosion. A prominent radially sloping cuesta is formed on the south side with high scarp facing plains of Rann on the north. This cuesta turns round on all sides but has been eroded off on the north becoming the central depression open towards the Rann side(**Plate IV.12**).

The Habo dome is dissected by small nalas which contains water during the monsoon season only. Kalajar is one such nala. The nala heads in the central part of the dome, taking a northerly zigzag course and disappears into the Rann of Kutch. Because the dome's northern flank is steep and the Kalajar nala cuts fairly deep, the entire sequence of the Jurassic rocks is well exposed within a comparatively small area.

Plate IV.11 Photoplate of white limestone alternating with eroded shales, Jhurio formation, Jumara dome

Plate IV.12 Photoplate of a portion of Habo dome overlooking the Rann of Kutch.

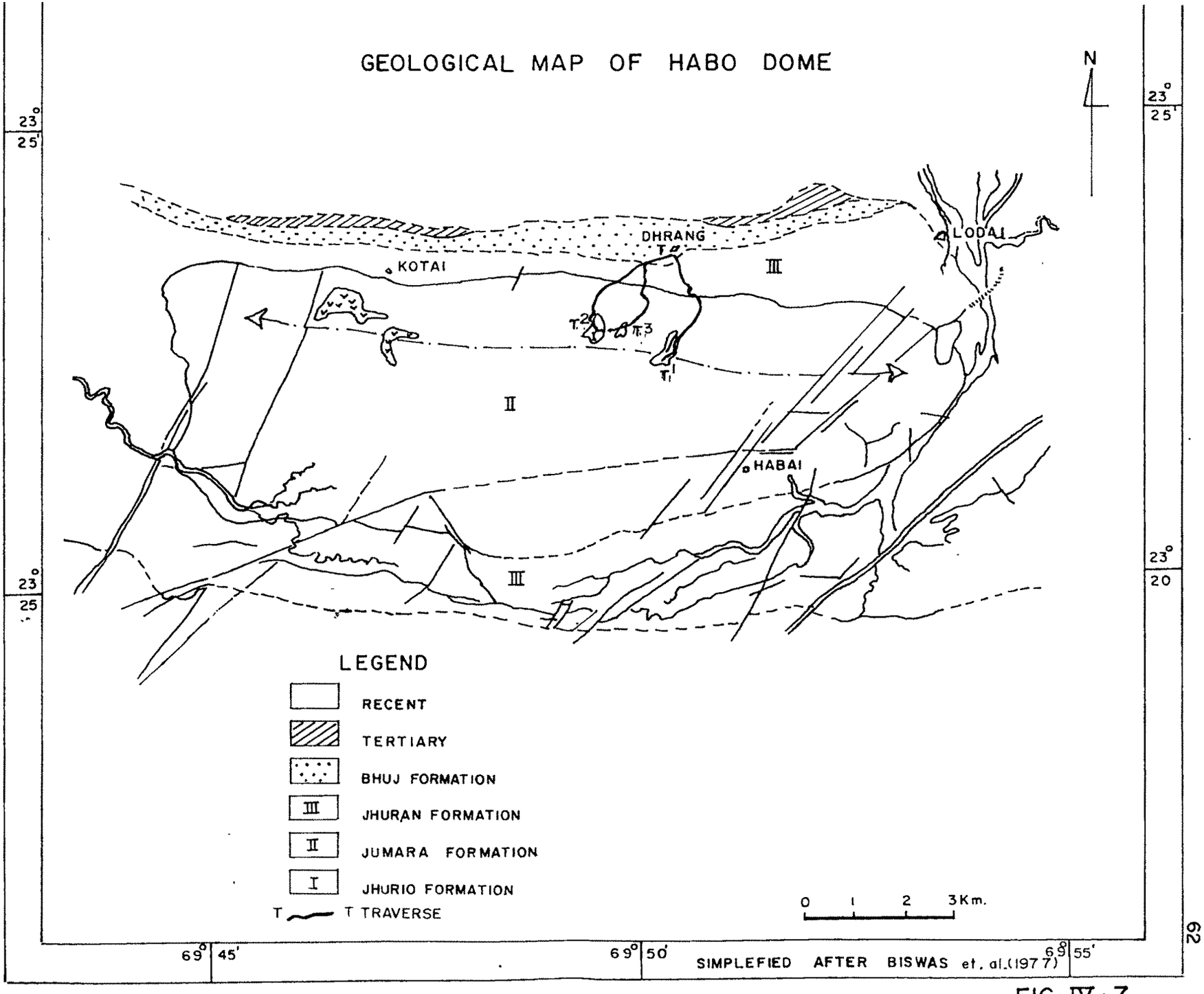
Habo dome, elliptical in outline is approximately 16 Km long and 7 Km wide and has egg shaped broader on the west. Like Jhura dome, here also the roughly elliptical outline is defined by the Dhosa oolite band. The general trend of the major axis is E-W.

A remarkable feature is the occurrence of a laccolith in the deeply dissected valleys and ravines i.e. to the south of Kotai, Dhrang and Fulae (**Plate IV.13**). The limestone beds of the Jhurio Formation have been domed up by this laccolith. Thin dykes and veins of basic rock are seen to extend from the laccolith into the limestone roof; some of them along small scale faults.

In the Kalajar nala section, the Jhurio, Jumara and Jhuran formations are present. Of the formations present, the Jumara Formation is the best developed and a complete sequence is exposed.

In order to carry out systematic and close sampling in Habo dome, the author has taken two major traverses covering almost all the exposures of different lithofacies under Jhurio and Jumara formations with the available geological map of Biswas et al (1977) in the scale of 1 inch = 1 mile. The major traverse was taken along the Kalajar nala (**Fig.IV.7**) and a litho-column has been made along this nala and the sample positions are plotted (**Fig.IV.8**).

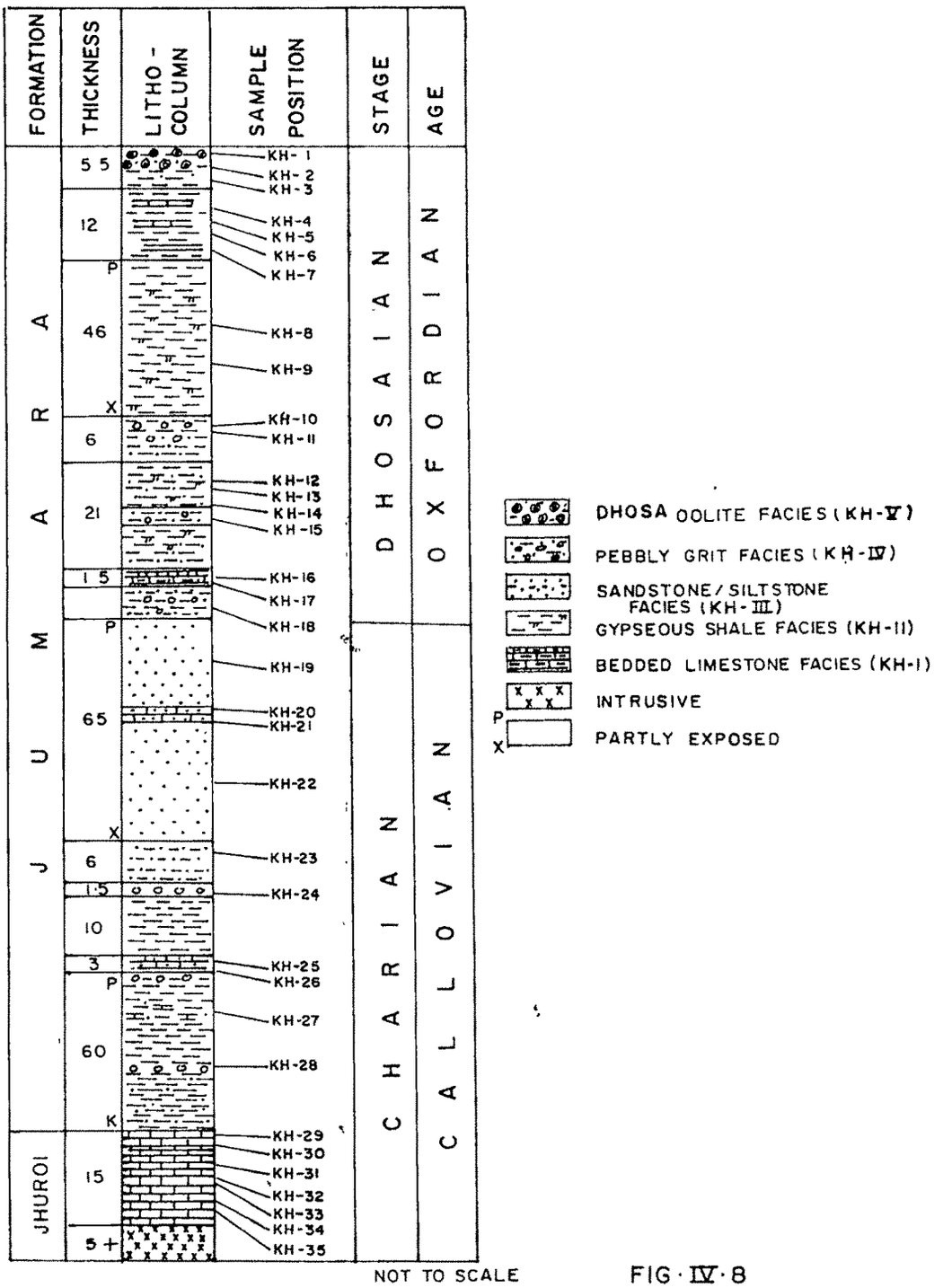
Plate IV.13 Photoplate of limestone of Jhurio formation on top of Laccolith in the core of Habo dome.


GEOLOGICAL MAP OF HABO DOME
N
23° 25'
23° 20'
69° 45'
69° 50'
69° 55'
DHRANG
T0
LODAI
KOTAI
III
T2
T3
T1
II
HABAI
III
LEGEND
RECENT
TERTIARY
BHUJ FORMATION
III JHURAN FORMATION
II JUMARA FORMATION
I JHURIO FORMATION
T T TRAVERSE
0 1 2 3Km.
SIMPLEFIED AFTER BISWAS et. al.(1977)

FIG·IV·7

LITHOSTRATIGRAPHIC COLUMN ALONG TRAVRESE T - T'

HABO DOME



NOT TO SCALE

FIG · IV · 8

The Jhurio formation is exposed in Habo hill to the south of Dhrang and Fulae. At three places it occurs in deep ravines in the interior of the hill. Only one major lithofacies has been identified during field studies.

1. BEDDED LIMESTONE FACIES (KH-I)

The core of the Habo dome is represented by almost horizontal beds of grey coloured limestone and thinly laminated light grey coloured calcareous shaly partings. The observed maximum thickness of the facies exposed is 15 m and the average thickness of the limestone bed varies from 2 to 40 cms.

The facies can be divided into two parts. The lower part is represented by alternate bands of white and black coloured limestones. At places the facies is intruded by large intrusive laccoliths. This limestone at the core of Habo dome has been referred to Patcham in earlier works. However, the same has been contradicted by Pandey & Dave (1993) after a systematic study of foraminifers. According to them the limestone at the core of Habo dome is of Charian stage corresponding to Callovian age.

At places the lower part of the facies shows a chalky white appearance and brick like structure produced by the intersection of bedding plane and closely spaced vertical joints (**Plate IV.14**). A pale green coloured highly altered

Plate IV.14 Photoplate of brick like structure produced by the intersection of bedding plane and vertical joint planes in the lower part of bedded limestone facies, Habo dome.

Plate IV.15 Photoplate of beautiful banding of limestone and thinly bedded calcareous marly beds, Jhurio formation, Habo dome

tuffaceous rock with secondary calcite is also intercalated between the limestone partings and is due to the igneous intrusion.

The upper portion of the facies is represented by beautiful banding of limestones and thinly bedded calcareous marly beds and is exposed in the Kalajar nala about 2 Km south east of Dhrang (**Plate IV.15**).

JUMARA FORMATION

The Jumara formation crops out as two chains of inliers along the Northern Range and Charwar Hills (Biswas 1977) and are restricted within the eroded domes, brachy anticlines and anticlines which form the two hill ranges of the Mainland. The uplift and the erosion of the dome hills were responsible for exposing this formation. In the Northern Range it is exposed in Jara, Jumara, Manjal, Keera, Jhura, Habo and Kas Hill regions. The base of the formation is exposed. The study is based on three sections namely Jumara, Jhura and Habo where outcrops are fairly well exposed and also readily accessible. Comparisons have been drawn from the studied sections.

The rocks constituting the Jumara Formation can be divided in several lithofacies in accordance with their distinctive lithologies, associations and internal structures where preserved. Nevertheless, the nature of constituent sediments as well as associations provide valuable clues for

understanding the genetic significance of the facies.

JUMARA DOME

As mentioned earlier, the Jumara Formation is best developed in Jumara dome. Here, a bean shaped east-west elongated asymmetrical outcrop of limestone in the core of the dome dip to the north and south of a small rivulet running due west through shales of the core. To the south of this rivulet are exposed, three low south dipping limestone bands corresponding to three lithofacies of Jhurio Formation. On the northern side of the rivulet i.e. on the northern limb of the dome, formations are somewhat steeply dipping to the north and expose only two lower limestone bands. The third limestone is missing. Instead, there is a Oolitic limestone facies (Calcareous oolitic sandstone, Pandey & Dave, 1993) with unconformable relation, suggesting an event of erosion **(Plate IV.16)**.

Based on micropalaeontological evidences, Pandey & Dave (1993) have suggested that the Oolitic limestone facies (Bed no. 22 of Rajnath) is nothing but a northerly extension of the Dhosa oolite in the southern limb. Here the author has verified the above conclusion after field studies. However, the unit has been taken as a separate lithofacies in view of its lithological dissimilarity with the Dhosa oolite facies especially in the upper eroded portion. Hence, in the present study, five lithofacies have been identified in Jumara dome:

Plate IV.16 Photoplate of Dhosaian / Charian unconformity at Jumara Dome

1. **OOLITIC LIMESTONE FACIES (KJ-IV)**

A 10 m bed of thinly bedded, sporadically oolitic, rustly brown limestone (fresh surface patchy green) occurs on top of limestone and marl facies. These are exposed only in the northern side of the dome and dip steeply to the north.

2. **SHALE/IRONSTONE FACIES (KJ-V)**

This facies is characterized by repeated alternations of green grey shales/ironstone and white limestone. At places it alternates with yellow grey multistoreyed sandstone. The shales are gypseous and variably calcareous. The rock is rich in mud sized terrigenous grains. Clay minerals of indeterminate nature dominate, however, fine grains of mica and quartz are also present sometimes in fairly good amount. Ironstones are associated with the shales and are found scattered loosely on the top of shale beds. These are calcareous brick red coloured concretions with high concentration of bioclastic fragments.

3. **GREY LIMESTONE FACIES (KJ-VI)**

The soft and grey limestones within the shale/ironstone facies are patchy and are restricted to the southwestern flank of the dome. At places, these are interrupted by intrusive bodies.

4. **CALCAREOUS SANDSTONE FACIES (KJ-VII)**

The scattered outcrops of calcareous sandstones are commonly multistoreyed. Being heavily encrusted with

ferruginous matter, these beds seem to be massive. The geometry of the beds is sheet-like. Evidence of bioturbation is completely lacking within these beds. The sandstones are yellowish grey in colour and are medium to very fine grained. Sedimentary structures are not discernible due to limited exposure conditions.

5. DHOSA OOILITE FACIES (KJ-VIII)

This heterolithic facies represents repeated alternations between oolitic limestones and grey shales, and occur immediately below terrigenous Jhuran Formation. The thickness of the facies varies widely from 1 m to 4 m. While the limestone beds are about 15 cm thick, the shale beds are on an average 65 cm. The shales are faintly laminated whereas the limestones look completely massive (**Plate IV.17**). The limestone bands within the heterolithic facies at the top of Jumara Formation are regionally persistent and are better known as Dhosa oolite.

The topmost part of the sequence of Jumara Formation has a distinct subfacies, which is conglomeratic in nature (**Plate IV.18**). The thickness of the subfacies varies from 35 to 60 cm. The composition of the clasts/pebbles and that of the groundmass are essentially similar. Both are oolitic wackestones. Small scale synsedimentary deformational structures, like microfaults and open flexures are fairly common within this conglomeratic subfacies.

Plate IV.17 Photoplate of Dhosa Oolite facies, Jumara formation, Jumara dome.

Plate IV.18 Photoplate of Conglomerate on top of Dhosa oolite bed, Jumara dome

JHURA DOME

In Jhura dome, this formation is well exposed in the north eastern part, south west of Jhura village. The rocks of this formation occupy the central part of the Jhura dome encircling the core of the Jhurio Formation.

The upper boundary of Jumara formation describes the outer closure of the dome. In the northern, eastern and south eastern parts of Jhura dome, it occupies an area of high relief while on other parts the relief is not much. Hard bands form prominent dip slopes and strike ridges while the softer shales form plains and valleys between the ridges.

Here the formation comprises chiefly of shales, sandstones, conglomerates, pebbly grit and oolitic limestone. The following lithofacies have been identified:

1.GYPSEOUS SHALE FACIES (KJH-VI)

The facies is mainly composed of grey to khaki gypseous shales with several intercalations of brownish hard flaggy calcareous sandstone and marls. The shales are clayey at places. The facies alternates with the Ridge sandstone facies. The calcareous sandstone forms the thin sheets and hence it is used as building stones in nearby villages. No megafossils are seen, although the marks of trace fossils are seen on the bedding planes (**Plate IV.19**). Poorly defined ripple marks are also observed. Small scale current bedding

Plate IV.19 Photoplate showing ichnogenous *Cochlichnus* (W.52) and *Plunolites* (W.95) on Calcareous sandstone, Jumara formation, Jhura dome.

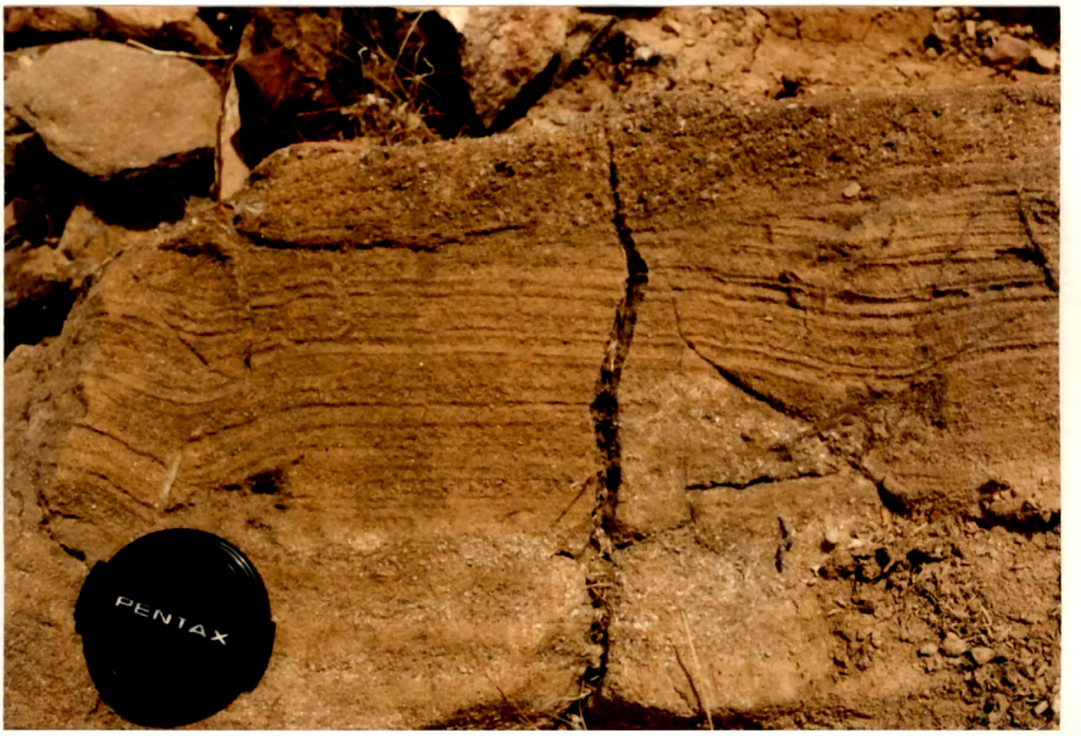


Plate IV.20 Photoplate of current bedding with slump structures on sandstone of Jumara formation, Jhura dome.

besides slump structures are seen in many thin sandstone bands.(Plate IV.20)

2.CALCAREOUS PEBBLY GRIT FACIES (KJH-VII)

Two orange to brick red hard calcareous pebbly grit beds with intervening gypseous shales form this facies (**Plate IV.21**). The facies is well exposed in the eastern part and partly in the western part of Jhurio dome.

3.RIDGE SANDSTONE FACIES (KJH-VIII)

This facies of hard rocks form high ridges with well developed dip slopes and consequently named as Ridge sandstone bed. This bed forms a conspicuous steep and high wall around the base of Jhura hill (**Plate IV.22**).

The thickness of the facies is about 13 m. The sandstone is brown, hard, bedded, coarse grained, poorly sorted and calcareous. Bands of intraformational conglomerate with rounded to subrounded limestone and marl pebbles occur within this bed. Top of the bed is conglomeratic.

4.DHOSA OOLITE FACIES (KJH-IX)

The facies is a distinct marker horizon occurring throughout the Kutch Mainland. It is defined by the presence of iron ooids and a thick ferruginous crust at or near its top and is best developed and attains its maximum thickness here. About 9 m of shales and oolitic limestone bands occur towards the top of the formation. Five well developed oolitic

Plate IV.21 Photoplate showing calcareous Pebbly grit bed of KJH-VII facies, Jhura dome.

Plate IV.22 Photoplate of Ridge sandstone facies (KJH-VI), Jhura dome

bands are seen alternating with shales in the eastern part of the dome. The top band contains green ooids while all the other bands have brown ooids only. At places the bands are devoid of ooids. The top of the facies is locally conglomeratic and similar to the band in Jumara section.

HABO DOME

The Jhurio, Jumara and Jhuran Formations are exposed in Kalajar nala section. Of all these, the Jumara is best developed and shows a complete sequence. While the thickness of the formation here is about 310 m, individual shale and sandstone beds, however, show varying thickness from section to section depending upon the thinning or thickening of the shale beds.

The following lithofacies have been identified:

1. GYPSEOUS SHALE FACIES (KH-II)

The facies is mainly composed of buff, light brown with yellowish tinge, gypseous, friable, soft, weathered shale associated with limestone, siltstone and pebbly grit beds. The associated carbonates are 2 to 2.5 m in thickness and are yellowish white in colour. These carbonates are brown, sandy, compact, hard, fossiliferous and full of coral colonies (**Plate IV.23**).

2. SANDSTONE/SILTSTONE FACIES (KH-III)

The facies occupies the maximum thickness within

Plate IV.23 Photoplate of coral colonies, Jumara formation, Habo dome

Plate IV.24 Photoplate of current bedding on sandstone of Jumara formation, Habo dome

Jumara formation in Habo dome. It is associated with the facies KH-II and KH-IV. The sandstones are white, yellowish to reddish brown in colour and partly ferruginous. They are fine to medium grained, compact, hard and highly cross bedded (**Plate IV.24**). The associated siltstones are yellowish grey, calcareous, compact, hard, sometimes thinly bedded, showing ripple marks at places and having intercalations of shale.

3. **PEBBLY GRIT FACIES (KH-IV)**

In field terms, the rock constituting the facies can be termed as Rudstone. It is red, yellow and variegated in colour, compact, hard and consisting mostly of jasper pebbles. At places, the lower part of the bed grades into sandstone. Fossil fragments are present.

4. **DHOSA OOLITE FACIES (KH-V)**

The Dhosa oolite facies is well lithified and forms a prominent ridge which can be easily picked up in the field. The facies are exposed in patches and are subjected to erosion. The fossils are scattered but concentrated in a shale bed to the top.

All the above described lithofacies, constituting the Jhurio and Jumara Formations are characterized by several microfacies. These microfacies bear signatures of various depositional and diagenetic processes and are discussed in detail in the subsequent chapter.