CHAPTER - V

S T R A T I G R A P H Y

GENERAL

The Tertiaries in Gujarat are exposed in, (i) the area between the Narmada and Tapti rivers, (ii) Bhavnagar area, and (iii) southern parts of Kutch mainland. Of these, the outcrops fringing the eastern margin of the Cambay basin, between the Narmada and Tapti rivers are best exposed, comprising two patches seperated by Kim river alluvium. The present study pertains to the northern part of these two exposures, lying between the Narmada and Kim rivers.

Occupying an area between the villages of Jhagadia in the

NE to Kosamba in the SW, the Tertiary exposures provide a fairly contrasting topographic expression from NE to SW. The outcrops near Jhagadia stand out as conspicuous hills against the low-lying south-western ground. The latter typically characterises a terrain made up of gentle hummocks and mounds. The aerial extent of the Tertiary rocks is approximately 60 percent, the remaining parts being covered by Quaternary sediments.

Good vertical sections are generally available along the river and stream sections, and good surface exposures occur where the dips are more than 20 degrees. In the low dipping areas, the outcrops are mostly confined to stream banks, nala cuttings, and even in canal cuttings exposures could be seen. In the central and northwestern hilly parts of study area, the exposures are comparatively scarce because of low dips and a residual soil cover.

The limestones in the southeastern part, resistant to weathering, form gentle undulating ground near Dinod and Dungri villages. The ferruginous sandstones and agate conglomerates of Babaguru formation occur prominently in the southeastern part of the area and can be easily recognised by the associated cherry red soil and loose agate pebbles

strewn all around the exposures forming gentle mounds. These conglomerates being hard and compact due to oxidation of ferruginous material in them, stand out prominently in the high dipping areas of Jhagadia anticline and could be easily band-traced on air photos. Similarly the hard and compact calcareous sandstones and conglomerates bands also stand out prominently on air photos in the high dipping areas of Jhagadia anticline to the northeast of study area.

The entire Tertiary sequence of the area ranges in age from Paleocene to Mio-Pliocene which is overlain by Quaternary sediments with a pronounced unconformity. The Jhagadia-Kosamba area not only represent the heart of Tertiary outcrops but also includes the various sedimentary features, structures, geomorphic features and megafaunal contents which obviously indicate the various events concerning its depositional history. The sequence is exposed along major tectonic features of the area of the Narmada tectonic belt evidenced through exploratory drilling and seismic surveys by ONGC (Agarwal,1983 and Sengupta, 1967).

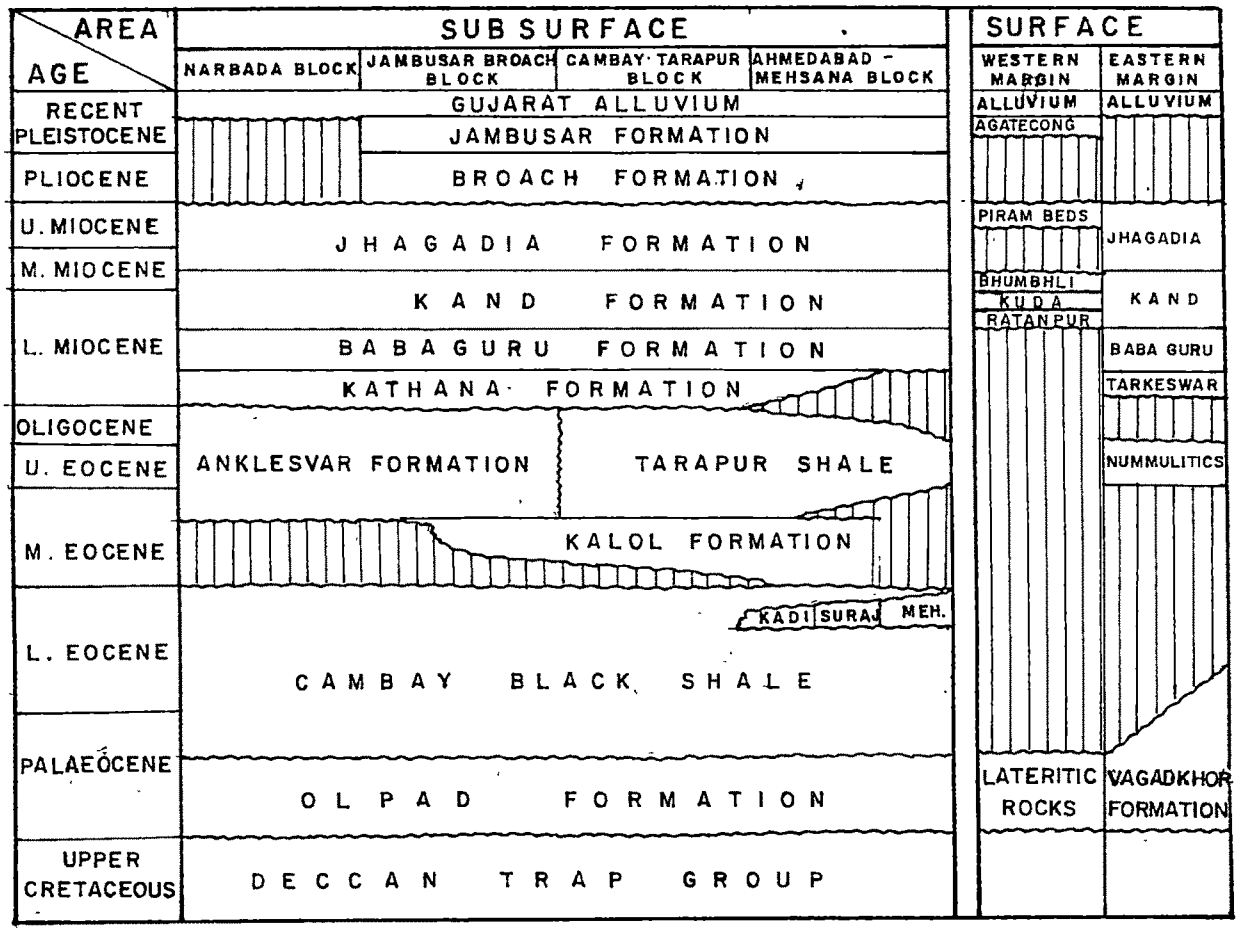
The rudaceous to calcareous facies and to highly ferruginous facies, cyclic sedimentation of calcareous sandstones and marls, calcareous clays, foraminiferal limestones and fossiliferous beds culminating into arenaceous facies, are some of the important features of the Tertiary sequence. The foramineferal limestone member becoming shale in the deeper

part of the basin, and the development of younger limestones in the deeper parts wedging out towards east and SE as revealed by sub-surface studies had posed problems to earlier workers while correlating them.

The lithostratigraphy of the Paleogene succession mainly from the subsurface geological data, was worked out by Rao (1969). He had divided the Eocene and Oligocene sequences of the Cambay basin into distinct mappable sub-crop formations encountered in different deep wells. The stratigraphic succession was divided by him into seven formations namely Olpad, Kosamba, Lower Anklesvar, Narmada shale, Upper Anklesvar, Dadhal, and Dhadhar. From the gross lithology and distribution pattern of individual lithounits of these formations generalised environment of deposition was indicated. The sands of Lower and Upper Anklesvar formations were considered to have been deposited under deltaic environment. The Lower Narmada, Narmada shale, Upper Anklesvar and Dadhal formations were considered equivalent in age to the exposed Nummulitic formation by him.

A review of the sedimentary sequence of the exposed and subsurface parts of the Cambay basin was carried out by Chandra & Chowdhary (1969) by studying the available data, and the following stratigraphic succession was presented (Table V.1).

TABLE V I



A total of 15 mappable rock units, and fourteen formations were recognised in the subsurface. Out of these 15 units, one group (Deccan Trap) and three formations (Babaguru, Kand and Jhagadia) were from the outcrop areas and these were continued in the subsurface. The remaining 11 units were recognised only in the subsurface. The authors had contended that the remaining 11 units of the subsurface were either absent or partly represented in different facies in the outcrop areas.

As more and more deep wells were drilled for the exploration of oil and gas additional subsurface geological information became available. This data was studied and correlated with the geology of the Tertiary outcrops of the area between the Narmada and Tapti rivers by Sudhakar & Basu (1973) and the following Paleogene stratigraphy of the southern Cambay basin was worked out by them (Table V.2).

TABLE-V.2

Age	Subsurface Area between Narmada river & Kosamba structure	Outcrop Area
Lower Miocene Upper Oligocene	Tarkeshwar formation (Inland Basin Facies)	
Lower Oligocene	Unconformity	
	Dadhar Formation Destructive Delta front Facies	Amravati Formation Marine Shelf
Upper Eocene ------	Angular unconformity ----------	
Middle Eocene	Anklesvar Fm. Delta Front	Ardol M.
----------	Unconformity ----------	
Lower Eocene	Cambay shale Lagoonal & paludal	Vagadkhol Fm.
Paleocene	Vagadkhol Formation Continental Facies	
----------	Unconformity ----------	
Upper Cretaceous	Deccan Trap	

The Vagadkhol formation, overlying with an unconformity over Deccan Traps, was indicated to be homotaxial with the

Cambay shale in the subsurface area. A thin section of Ardol member of Anklesvar formation occurs over Vagadkhol formation with an unconformity, and is in turn overlain by Amravati formation with an angular unconformity. This formation is of marine shelf facies and is overlain by Tarkeshwar formation with an unconformity in between. The age assigned to these formations by them has been indicated in the above Table. The Neogene sequence has not been described by them.

The area of Jhagadia and around Talodra, south of it, was studied by Gadekar (1975, 1980) and the following generalised stratigraphy was worked out by him (Table V.3).

TABLE-V.3

Geochronologic Unit	Lithostratigraphic Unit			Lithology
ERA PERIOD	FORMATION	MEMBER		
Quaternary	Holocene Pleistocene	-	-	Brown clays, Kankar and gravel
		Jhagadia		Grey calcareous volcarenites with rudites
	Miocene	Kand		Yellow gray flaggy biomicrudites
		Babaguru	Upper	Grey agate rudites
			Lower	Red brown volcarenites and micrites
		Tarkeshwar		Variegated Lutites
	Oligocene			
		Nummulitic (Bhilod)		Yellow brown clayey fossiliferous limestone
	Eocene	Vagadkhol		Grey volcrudites
	Paleocene	----------Unconformity----------		
Cretaceous	Deccan Trap			Basalt

The above author appears to have worked out the stratigraphy mainly on the basin of lithostratigraphic and the biostratigraphic aspects from the published literature. He had observed that the Vagadkhol formation increases in thickness from north to south, and the Nummulitic formation which was renamed by him as 'Bhilod formation' (Gadekar, 1980a) is developed only along Amravati river and that the Tarkeshwar formation becomes thinner both towards north and south in his area of study. The Babaguru formation shows thickness variation and occurs throughout the area. The sediments of Tarkeshwar formation were indicated to have been derived from the reworking of Upper Cretaceous Bagh beds exposed in Narmada valley. The red and brown volcarenites and agate rudites were indicated to have been derived from volcanic rocks from the near by areas. The Kand formation lithosome was observed to have an inter-tonguing relationship with the underlying Babaguru and overlying Jhagadia formations. The sediments of the Jhagadia formation were indicated to have lithic fragments derived from volcanic terrain and the heavy minerals from the Deccan Traps and reworked sediments of Bagh beds. The environment of deposition of the sediments of Broach Group was fluvial or deltaic except for the sediments of Kand and Nummulitic formations.

STRATIGRAPHY WORKED OUT BY THE PRESENT AUTHOR

The stratigraphic succession worked out by the present author substantially differs from those of the earlier workers

in many respects. Because he was able to evaluate the stratigraphic sequences of both surface as well as sub-surface occurrences, he could establish several lateral and vertical facies changes on the basis of lithological and faunal evidences from east to west i.e. towards deeper parts of the basin. His critical studies on the nature and pattern of sedimentation, have enabled him to work out a clear picture of the Tertiary transgressions and regressions. The most salient feature of his investigation happens to be the identification of numerous criteria pointing to the continuity of certain geological processes into Quaternary times. Accordingly, he has suggested the following revised stratigraphy (Table V.4).

The detailed lithology of each formation and their field relationship, fossil content and mineralogical characteristics are described below:

DECCAN TRAP

The rocks constituting the Deccan Traps comprise the basaltic lava flows. In the study area, they occur in the eastern part. The basalts of the Deccan Trap occur as numerous hillocks, two of which namely Sarisia near Rajpardi town and Ratanpur Reserved Forest, are quite prominent. To the south and southeast, they pass beneath the Tertiary and Quaternary sediments.

STRATIGRAPHY OF THE STUDY AREA

TABLE V.4

TIME			UNIT	ROCK UNIT (FM)		LITHOLOGY
ERA	PERIOD		EPOCH	ADJOINING AREA (Sub surface)	STUDY AREA (Out crop)	
CENOZOIC	QUATERNARY		HOLOCENE (Recent)	Gujarat Alluvium 60-100 m	NARMADA Angular unconf.	Sd., silt., cl. & gravels
			PLEISTOCENE	Jambusar 300 m.		
	TERTIARY	Neogene	PLIOCENE	Broach 300 m.		
				Jhagadia 200 m.	Jhagadia Plus 200 m.	sst., grit st., congl., br. cl. slt.
			MIOCENE	Kand 400 m	Kand 200-400 m	conglo., lst. fossil., calc., sst. & gr. cl.
				Babaguru 300 m	Babaguru 200-300 m.	conglo., sst., cl. cherry red & highly ferru.
		Paleogene	OLIGOCENE	Tarkeshwar 175 m. ?		
			EOCENE U	Ankleshwar 500 m.	Dinod 50 m.	lst. fossil., yel. br. & marls.
			EOCENE M	Cambay shale 430 m.		
			EOCENE L	Angular uncoformity		
				Vagadkhol 520 m.	Vagadkhol Plus 50 m.	congl., grit. sst., vari. cl. & silt st., occ. calc.
MESOZOIC		Cretaceous	Upper	Deccan Trap (Base not seen)	Deccan Trap (Base not seen)	Basalts, sometimes amygdaloidal and trachytic.

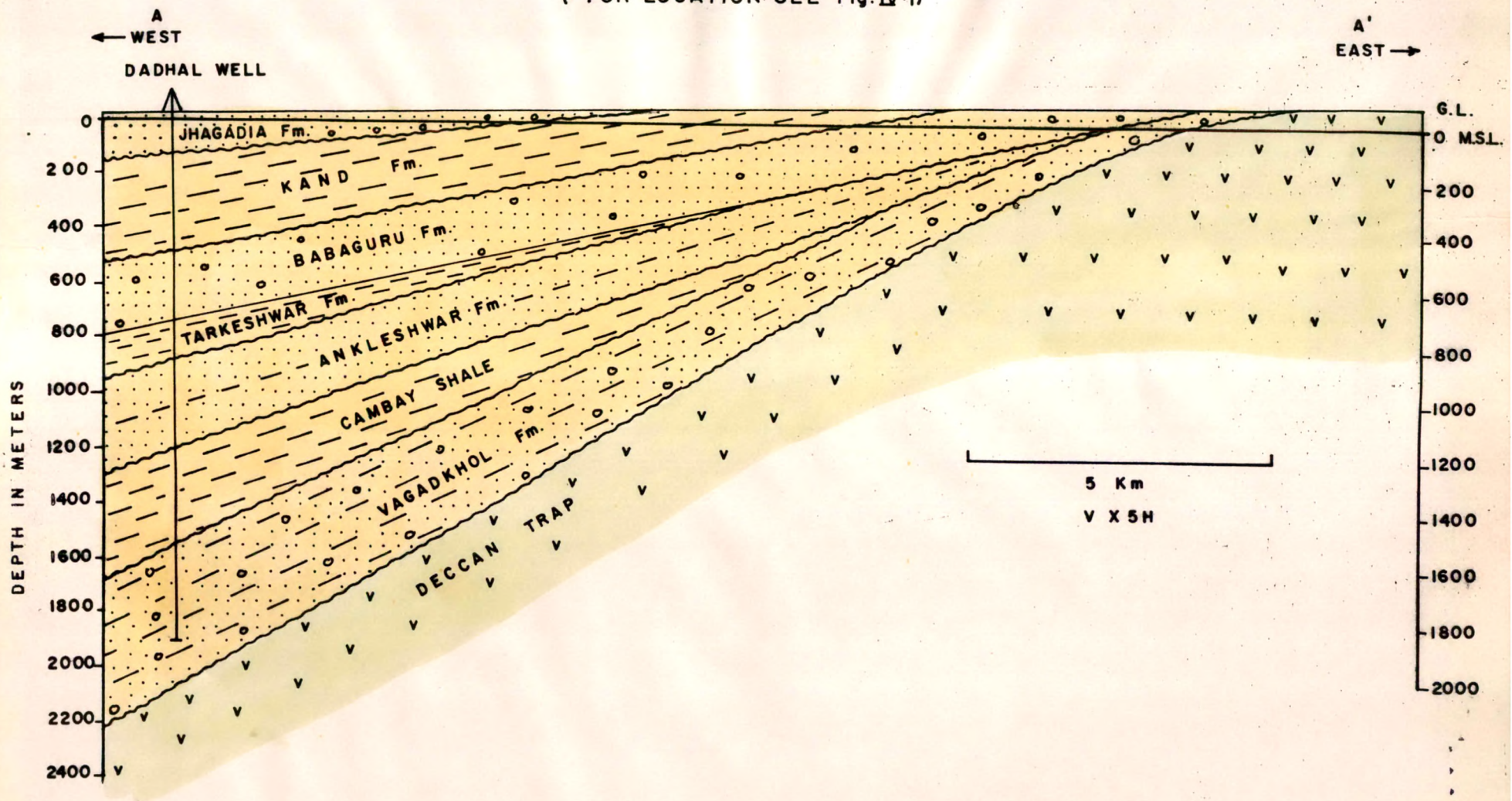
The constituent rocks consist of amygdaloidal as well as non-amygdaloidal massive basalts, and are frequently associated with andesite, trachyte and picrite. The trap has been encountered under the Tertiaries in deep wells in the adjoining areas of Dungri, Dinod, Kosamba and Anklesvar at varying depths.

VAGADKHOL FORMATION

The main constituents of Vagadkhol formation are conglomerates and variegated coloured clays. In the study area, it occurs along the eastern margin adjoining the Deccan Trap rocks (Fig.V.1). To the NW, at Dungri, Dinod, Kosamba and Motwan, in the subsurface, this sequence lies with an erosional unconformity over the basalts. Basically the formation consists of the material derived from the weathering of Deccan Trap basalts. The conglomerates consist of subangular pebbles and grits of basalts, claystones and agate in a matrix of highly ferruginous and calcareous matter. At times gritstones and sandstones are also present consisting of weathered basalt, claystone and agate material. They are also highly ferruginous. The clays are red, yellow, reddish brown and at times mottled, and occur in association with sandstones. Due to low dips of beds, the outcrops of variegated coloured clays occur as broad distinct patches in some areas near Vagadkhol village. The lithological characteristics are indicative of fluvial to shallow water

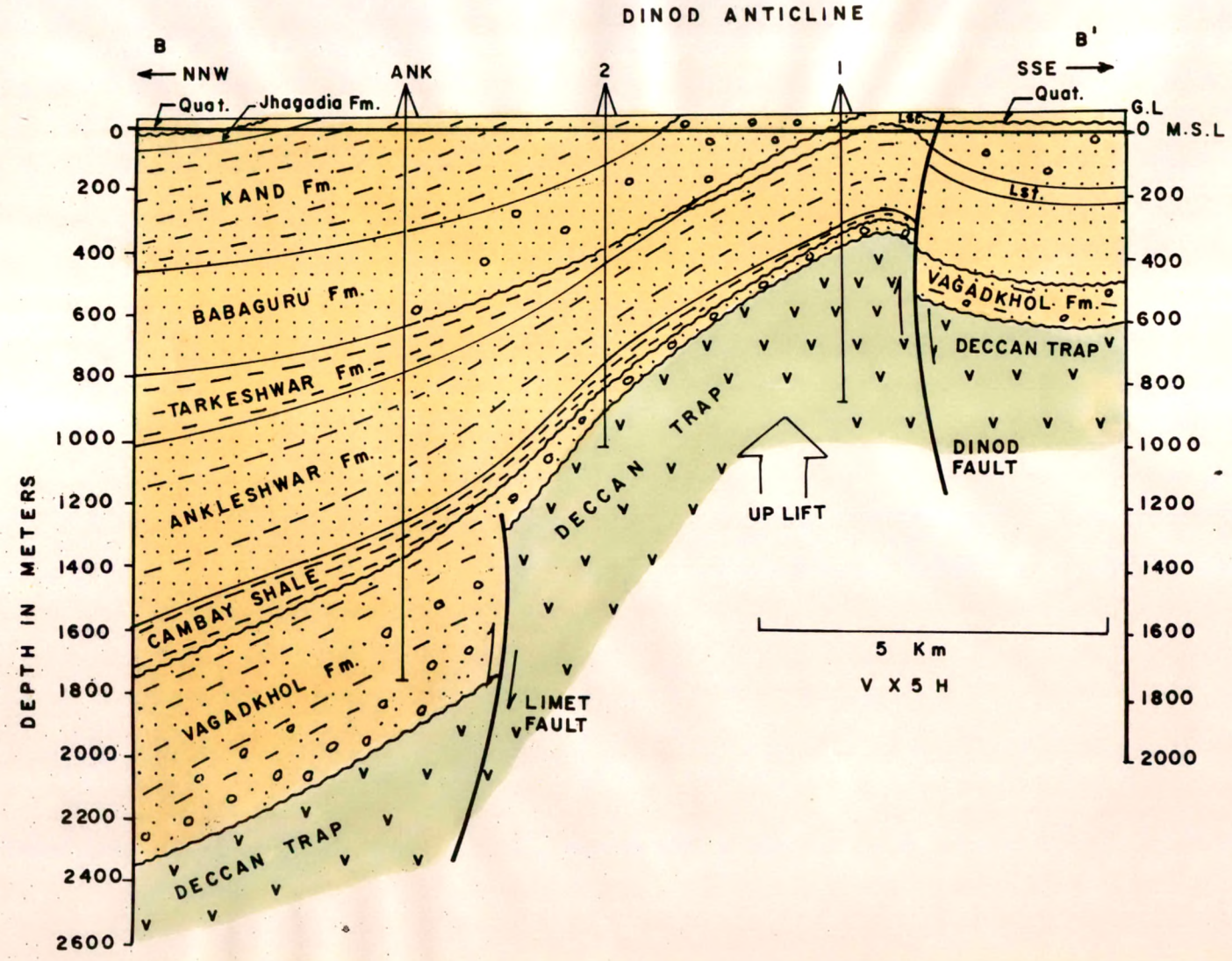
GEOLOGICAL SECTION ACROSS NORTHERN PART

(FOR LOCATION SEE Fig. IV·1)



GEOLOGICAL SECTION ACROSS DINOD ANTICLINE

(FOR LOCATION SEE Fig. IV · 1)



environment under oxidising conditions and rapid deposition accompanied with a short transportation. The formation is unfossilliferous. The age of the formation is tentatively shown as Paleocene to Lower Eocene from its general stratigraphic position.

DINOD FORMATION

The fossiliferous limestones of Dinod formation occur as gentle high grounds in the areas of Nandev (Plate-V.1.C), Dinod and Dungri villages. Near Dinod and Dungri, the yellowish brown limestone is quarried and used as road metal locally. The quarries thus provide good exposures for study (Plate-V.1.A,B). The outcrops of Dinod formation are found along anticlinal axes of Nandev, Dinod and Dungri structures. These structural features are very gentle and low dipping. The limestone outcrops of Dinod anticline are found all along the area of the doubly plunging structure. At places the limestone is coquinoidal and has macro foraminifera (Plate-V.2.A,B). The outcrops occur along a gentle high of Dungri anticline and throughout the exposure coquinoidal limestone is observed. The limestones are hard and compact massive and yellow in colour. At times they are argillaceous and soil hands with yellow colour. Brown tints observed occasionally in limestones are due to weathering of minor ferruginous matter present in the rock. The fossil assemblage of the limestones has been investigated in detail. The limestone samples collected from

PLATE-V·1

A

B

C

PLATE - V · 2

A

B

C

different outcrops have yielded a rich but poorly diversified foraminiferal assemblage which includes Discocyclina dispensa (Sowerby), Discocyclina Sella D' Archiac, Discocyclina sp., Nummulites fabianii (Prever) and shell fragments. The Discocyclines of mostly megalospheric generation of Nummulites seems to be absent in the assemblage. On the contrary, the large microspheric forms are frequent. The general ratio of foraminiferal tests as compared to matrix portion is high. The above species have been illustrated in Plates V.3 & 4 alongwith their explanation.

The above assemblage does not specify a precise age to the sediments due to the absence of short ranged foraminifera. However, the association of Discocyclina sella and Nummulites fabianii has helped in defining the age. Such assemblage had been recorded in subsurface sections in south and north Cambay basin (Pandey & Nath, 1974 and Singh et al. 1980). Development of fossiliferous limestone is noticed in the well sections (Unpub.report of SP-1 & SP-2 ONGC, 1977) of Anklesvar area, where only Nummulites fabianii dominates the assemblage. This has been assigned Early Oligocene age by Raju (1971), Datta (1974), Pandey & Nath (1974), Guha (1980) and Singh & Koshal (1978). The subsurface biostratigraphy of Cambay basin was worked out by Guha & Singh (1980), and reported the presence of larger foraminifera of Late Eocene age from different subsurface well sections.

PLATE - V·3

105 A

105 C

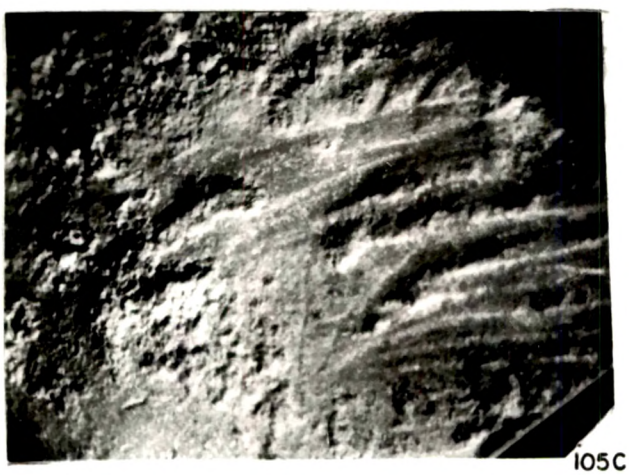
105 B (B)

105 B (D)

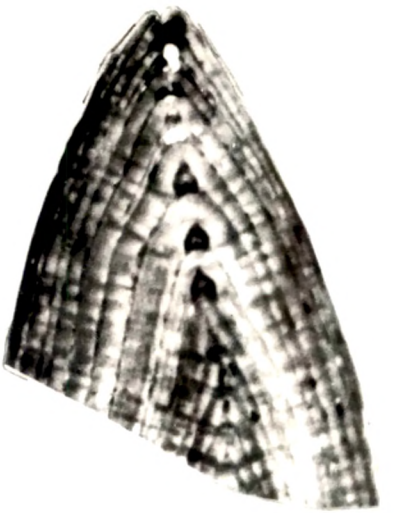
PLATE - V · 4

105A

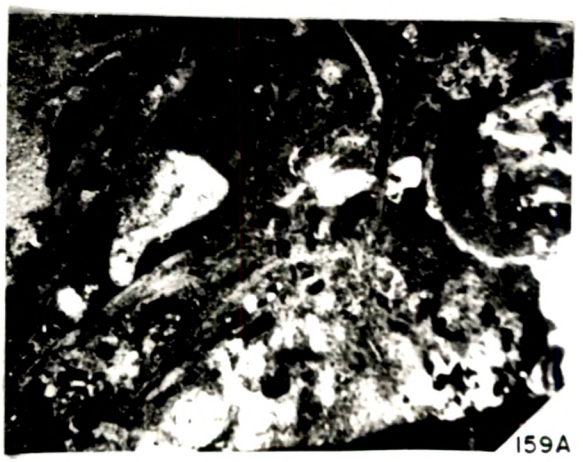
105B



105C



105D



159A

159B

The occurrence of Discocyclina dispansa and D.sella with Nummulites fabianii indicates that the sediments were deposited during the Late Eocene epoch. The flooding of larger foraminifera with fewer species indicates that during the Late Eocene itself a regressive phase had set-in. The bathymetry of these areas, as evidenced from the above assemblage, seems to have fluctuated between 20 to 50 metres. It appears that the Oligocene sea was confined more or less to the central part of the basin with its northern limit extending upto Jotana area (Singh & Koshal,1978), and it did not encroach upon the basin-margin areas. The study area falls in the eastern basin margin area.

On correlation of the surface and subsurface sections, the Late Eocene assemblage bearing coquinoidal-limestone of Dinod formation is seen to change over laterally to shale in subsurface areas. The two limestone beds, encountered in Motwan-1 well, 20 km to the WNW direction and deposited during Late Oligocene, do not show their continuity in basin margin areas due to nondeposition/regression. However, the stratigraphers had so far correlated these subsurface Late Oligocene limestone beds with the exposed Late Eocene limestone on the basis of a general lithological similarity. The present study has, however, clearly demonstrated that the two are of different ages, and the exposed Dinod Limestone of Late Eocene changes over to a shale facies in subsurface of Motwan-Anklesvar area to the northwest (Fig.V.1). The present study has further brought out clearly

that the marine Oligocene sediments including the limestones present in the subcrop in Anklesvar area, do not extend SE in the area of study. The exposed fossiliferous limestones are definitely of Late Eocene age. Further the occurrence of Discocyclina sella in the exposed coquinoidal limestone of the area is being reported by the present author for the first time. The study has also led to a re-designation of Late Eocene rocks as, "Dinod Formation" which were earlier referred as Nummulitics, Amravati and Bhilod Formations by previous workers.

The contact of the limestones of Dinod formation with the underlying conglomerates of the Vagadkhol formation is not seen in the field. In the southern part of the study area the limestones are covered beneath the black cotton alluvial soil of Kim river. The limestones extend to northeast upto Dungri outcrop, and obviously, they were not deposited northeast of Dungri.

The Dinod formation is seen unconformably overlain by the highly ferruginous sandstones and agate conglomerates of Babaguru formation. Thus, after the deposition of Dinod formation there had been a long period of non-deposition due to regression.

BABAGURU FORMATION

The sedimentary sequence of the Babaguru formation consists of cherry-red sandstones and highly ferruginous agate conglomerates. The formation is underlain by the foraminiferal limestones of the Dinod formation and is in turn overlain by the calcareous sandstones, marls and fossiliferous limestone bands of Kand formation. The typical outcrops of the Babaguru formation occur near Babaguru Dongri hill where agate had been mined since a long time.

The outcrops of the formation are prominently seen along the topographic high area between Kosamba to Valia towns. The lower part of the formation consisting of cherry red sandstones, generally friable and devoid of agate pebbles, are seen to outcrop along the NW flank of the Dungri anticline. The upper part of the formation consisting of cherry-red lateritic type of sandy rock with agate pebbles outcrops over a large area.

Along the road from Anklesvar to Valia town, beyond Kand (Kondh) village, cherry-red to reddish brown sandstone and conglomerate exposures and soil is conspicuously observed belonging to the Babaguru formation. The released pebbles of agate from the conglomerate are seen strewn all around. Due to the concretionary, highly ferruginous and lateritic type

of soil the vegetation is sparse and almost a barren topography is represented by the area of Babaguru formation (Plate V.5.A). Good exposures of cherry-red sandstones and agate conglomerate, north of Limet village, form a gentle topographic high. Further north of Limet village cherry red sandstones cover a large area near Talodra village. Good exposures of agate conglomerates are seen along a low lying hillock east of the road near Talodra.

Agate conglomerates of Babaguru formation are well exposed in the axial part of the Jhagadia anticline along the Ratanpur-Ni Nadi section. The pebbles are embedded in a highly ferruginous matrix and weathering to iron oxides have imparted compactness and hardness to the rocks (Plate V.5.B). The outcrops of the Babaguru formation, along the Hakran Nadi section, are represented by conglomerates with pebble to cobble size agate and quartz. The matrix is highly ferruginous and renders the rock hard and compact due to oxidation. The conglomerates are underlain by ferruginous sandstones which are at times friable and are with occasional hard and compact beds whenever the ferruginous matter is more.

The agate pebbles derived from the weathering products of Deccan trap and cavity filled agates from the nearby area, were deposited with the wash out from the lateritic surface of the basalts. As a result of this the sediments deposited

PLATE-V·5

A

B

consisted essentially of lateritic rock intermixed with occasional quartz sands and agate pebbles embedded in them. On weathering the lateritic rock becomes hard and compact, and by erosional processes the pebbles loosen and come out of the exposed surface imparting a larger size honey comb like appearance to the exposed rock face in the field. Many a times the freed pebbles are seen strewn all over the flat surface of the outcrops giving a typical look to the outcrop. At times after the removal of pebbles from the rock and oxidation of ferruginous matter the appearance of rock is like a laterite, and suggests that the weathered product of basalt had been transported and deposited close to the Deccan Trap outcrops. The basin margin, therefore, during the deposition of the Babaguru formation was close to the provenance and the deposition took place in a fluviatile oxidising environment.

No fossils were found in the sequence, and its precise age is therefore not known. However, from the underlying Dinod formation consisting of foraminiferal limestones of Late Eocene age and the overlying Kand formation consisting of fossiliferous limestone beds of Early Miocene age, the approximate age of the Babaguru formation may be Lower Miocene.

KAND FORMATION

The calcareous sandstones, clays, marls and thin fossiliferous limestone bands constitute the Kand formation.

It overlies the Babaguru formation with an unconformity. Its fossiliferous limestones with microfossils easily visible in the outcrops are seen around the Kand (Kondh) village. The limestone bands are at times as thick as one meter, hard and compact, and occur as mounds (Plate V.6.B). The clays are generally grey to light grey in colour and are highly calcareous. At places marls occur with argillaceous matter in varying percentage. The sandstones are light grey in colour with white patches and are fine grained to gritty. All the sandstones and clays of the Kand formation are highly calcareous, and the boundary with the overlying Jhagadia formation is marked by the absence of calcareous matrix in the sandstones, clays and conglomerates of the Jhagadia formation.

The presence of indurated cherry-red sandstone pebbles in the conglomerate beds of the Kand formation at a number of places clearly indicates that in the provenance area the cherry-red sandstones of the older Babaguru formation were exposed and the sandstones had become hard and compact before erosion took place. Thus there must have been a longer time gap after the deposition of the Babaguru formation and the commencement of the deposition of the Kand formation.

The outcrops of the conglomerate beds of the Kand formation where pebbles of cherry-red and reddish-brown sandstones of Babaguru formation have been observed in the field are at Sunikhud village along the metalled road in

PLATE - V·6

A

B

C

the westernmost part of the study area, at Bhadi village in a small stream section; under a road bridge on a tributary of Amravati Nadi near village Batariya and at other several outcrops. A good exposure of ferruginous sandstone with a large number of cherry-red sandstone pebbles and cobbles is seen in the bed of a stream section near a road bridge between Kosamba town and Mahuvej village. This outcrop also clearly shows that during deposition the cherry-red sandstones of the Babaguru formation were exposed and were also contributing to the sedimentation of Kand formation.

The fossils contained in the limestone bands (Plate V.7, A,C) include species of Lamellibranchs, Gastropods, Echinoids, Cirripedia, doubtful fish teeth, calcified fossilwood and leaf impressions. The Lamellibranchs include the fossils of Ostrea, Pecten, Cardita and other unidentified genera. The Gastropod fossils consist of Turritella, Conus and several unidentified genera. The Echinoids are represented by the fossils of spines and the Cirripedia by Balanus. On the basis of these fossils and the presence of Lepidocyclina, Miogypsina, and Austrotrillina howehini (Narayana Rao, 1956) Burdigalian (Lower Miocene) age has been assigned to the Kand formation.

PLATE-V·7

A

B

C

JHAGADIA FORMATION

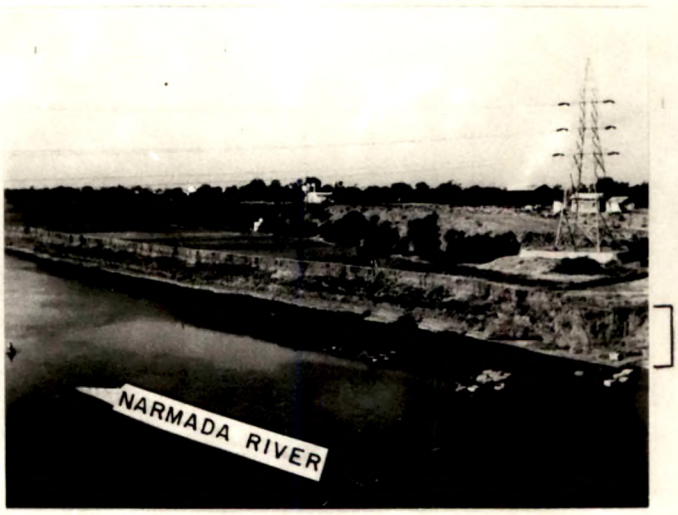
The sedimentary sequence of the Upper Tertiary constitute the Jhagadia formation, and consist of sandstones, gritstones and pebble to cobble conglomerates (Plate V.8.A). They are generally soft, friable and massive with calcareous bands. The rocks are light grey in colour and exhibit a 'salt and pepper' appearance. The conglomerates contain pebbles of marls, sandstones, claystones, agate and occasionally of weathered basalt. At times, white encrustation of salt is observed over the rock faces. In the lower part of the Jhagadia formation, grey to brown clays which are occasionally silty are present. These clay beds are only a few meters thick. The sandstones exhibit cross bedding, and the foresets show distinct banding due to the differential concentration of ferruginous minerals.

In the northeastern part of the study area, the beds show unusually high dips, as much as 60°, and the southwesterly striking beds are seen abruptly terminated against the Quaternary sediments of the Narmada river. In the northwestern part of the area, the dips are low ranging from 5° to 10°, and the beds are overlain by Quaternary sediments. The sediments of Jhagadia formation are devoid of fossils, and considering its place in the order of superposition, a Middle Miocene to Lower Pliocene age is assigned. The lithostratigraphic characteristics of Jhagadia formation point to a continental fluviatile depositional condition.

PLATE-V-8

A

B



C

NARMADA FORMATION

The unconsolidated sands, silts, gravels and clays constitute the Narmada formation. They occur with a pronounced unconformity with the Tertiaries, all over the area, excepting the hilly areas and the mounds where Tertiaries and Deccan Traps are exposed. They are typically marked by an uncompacted nature and lack of sorting. The deposits of the Narmada formation have been divided into following three members, on the basis of lithological characteristics and mode of occurrence : The members are (a) Residual soil, (b) Black soil, and (c) Flood Plain Deposits.

The residual soil is obviously the oldest member of the Narmada formation, and occupies the largest area in the central and western parts of the study area. It overlies various formations of the Tertiary sequence with a pronounced unconformity. It consists of sands and silts and occasionally gravels. The entire sequence is generally ferruginous, loose and friable and shows a crude layering. The dips of the residual soil is immeasurably low but a general northwesterly inclination is observed at places. A maximum thickness of two meters of these soils has been observed in the Amravati river section. These sediments have been derived mainly from the weathering of the underlying/nearby Tertiary sequences exposed in the eastern and the southeastern parts.

They occur either 'in situ' or have been transported locally during floods. It is most interesting to record that the present day streams meandering through the soil covered terrain, have entrenched the Tertiaries. This phenomenon typically suggests a gradual uplift during the Pleistocene and Holocene. This neotectonic activity has imparted a very gentle inclination to these sediments in the central part of the area.

The Black Soil member is mostly restricted to the low-lying areas of the southeastern part of the study area. It is essentially the weathered product of the basalts, brought down by the Kim river and its tributaries from the eastern uplands. The Kim river and its tributaries flow southwest along the depressions which are in fact geomorphic expressions of structural lows, and point to the deposition of the sediments by rivers during floods. Sections exposed along the banks cut by the Kim river provide good profiles of these deposits and it is observed that the constituent material is a silt with occasional sandy, pebbly or gravel beds.

The Flood Plain deposits, which are the third member of the Narmada formation, occur all along the area adjoining the Narmada river to the northwest of the study area. The banks of Narmada river, specially the right bank with vertical scarps and cliffs provide good sections of the flood plain

deposits. To the left of Narmada river, a well defined paleo-bank occurs at a distance of 1 to 6 kilometers away from the present river bank, and this also provides good sections. The sequence consists of silts and clays with occasional sandstones and pebble beds. The silts are light brown to light grey in colour. At places, crude layering is also observed. Good profiles of these sediments can be seen on the east side of the road across the new bridge on Narmada river near village Jhadeshwar on the left Narmada river paleo-bank, and on the east side of the old iron bridge on Narmada river near Broach town. These deposits are obviously the material brought by the Narmada river and laid-down on the plains after emerging out of the hilly areas east of Rajpipla.