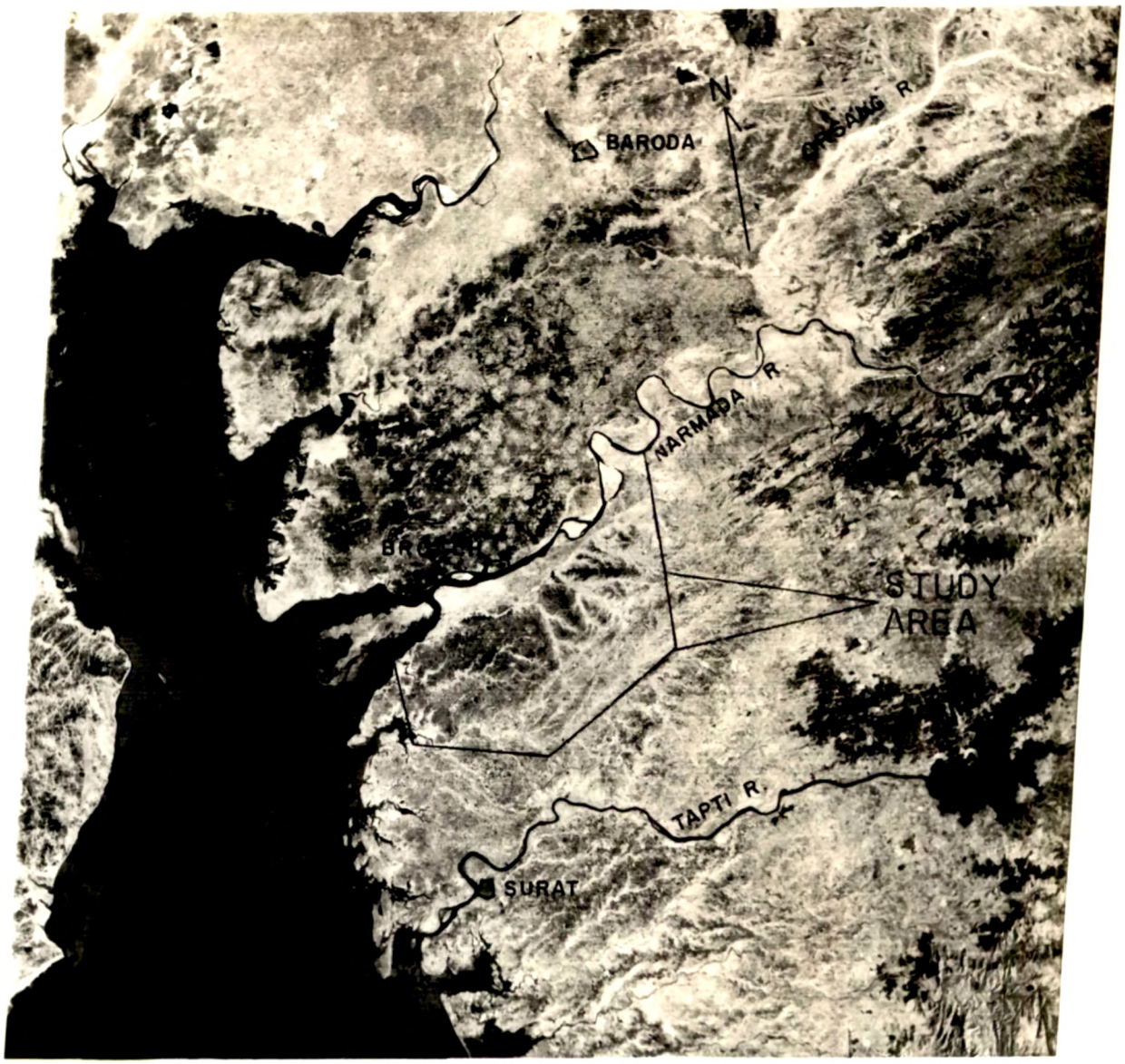
PLATE-I



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LANDSAT IMAGE OF PART OF GUJARAT
INCLUDING STUDY AREA

CHAPTER - I

I N T R O D U C T I O N

PURPOSE OF STUDY

In the course of oil exploration activities, the officers of the ONGC have, in recent years, contributed substantially towards the Tertiary geology of Western India in general and Gujarat in particular. The present author, having been associated with the geological activities of the ONGC had appropriate opportunity to get familiar with both surface and sub-surface Tertiary rocks of commonly referred to as 'Cambay Basin'. In the course of his investigations, he however, came across many interesting facts pertaining to the various geological events of the Tertiary period. What struck him most was the continuity of certain geological processes that were initiated with the advent of Tertiary, into the Quaternary

times. Although, the different parts of the terrain which now comprises the state of Gujarat, has been investigated geologically for the last 150 years or more, its Cenozoic rocks received practically no attention till petroleum was struck in Gujarat in the late fiftees. Thus, so far as the Tertiary and Quaternary rocks are concerned the last few decades have been very important in the history of the geological studies in Gujarat.

Obviously, quite a few features of Pleistocene and Holocene Epochs, as observed to-day, happen to reflect the Tertiary events. Realising that the Cenozoic history of Gujarat, now required a reappraisal, the author took up the present study. The result of his investigations, which have been presented in this thesis, not only throw new light on the Tertiaries of Gujarat, but they also reveal a close relationship existing between the Tertiary and Quaternary histories of the area. The strategy adopted by the author, therefore, included a thorough reinvestigation of all surface exposures of Tertiary and Quaternary, and a correlation of all observed geologic and geomorphic characteristics with the already available subsurface data. He has, to a considerable extent, succeeded in understanding the litho-stratigraphic changes both in time and space, effects of Tertiary and Quaternary tectonism, basin evolution and its control on sedimentation.

The author, in the thesis, has endeavoured to clearly bring out this continuity, specially of the cycles of tectonic activity affecting sedimentation and the structural interpretation

of the area with the help of tectonic and geomorphological investigations.

Detailed structural mapping and stratigraphic sequences worked out have delineated several anticlinal and synclinal features in the area. The trend of folds, plunges, trend of faults and their type have been precisely outlined. The significance of moderately tight structures in the north becoming gentler and subtle to the south has been understood. An appraisal of the close relationship existing between the drainage pattern and the structural features have enabled mapping of concealed subtle anticlinal and synclinal structures. The seismicity of the area, as revealed by various earthquakes including that of Broach of 1970, has been found to be related to the release of stresses generated by the periodic tectonic movement of the Broach, Anklesvar, Kosamba and Surat basement fault blocks.

The main emphasis of this pertains to the patch of the exposed Tertiary rocks and associated Quaternary sediments between Narmada and Kim rivers. The detailed geomorphological, stratigraphical and structural studies by the author have given answers to nearly all the related problems. Sub-surface geological data obtained through deep wells drilled by the O.N.G.C. in the area have also helped in the analysis. The high angle reverse faulting, identified during the study along the south-eastern limbs of anticlines, and south-westerly plunges, are indicative of differential pushing up of fault blocks and release

of stresses along the reverse faults by the relative pushing up of the northern part and the under riding of the southern part of each block. The abrupt change in the structural style of the Tertiary and Quaternary sequences in the areas to the north and south of the course of Narmada river in Gujarat is significant. The structural trends in the northern part are nearly north-south whereas they are north-north-east and south-south-east in the southern part. This could be attributed to a later phase of tectonic activity superimposed over the older trend, and affecting only the areas to the south of the Narmada river.

It is observed that from north to south, the folds tend to become gentler. The northern structures exhibit steeply dipping limbs forming a hilly area. That these structures are older in age are conclusively established as streams cut across them and are entrenched. The southern structures are gentle and the axial parts form gently undulating areas forming water-divides. The last structure to the south-east forms a very gentle high ground, and has an excellent geomorphic expression as well as a water divide. The morphology of various structures mapped indicates a decreasing effect of tectonic uplift from north to south.

The drainage pattern of the area and its neighbouring terrain is marked by the existence of two river systems, viz. Narmada and Kim. Both the rivers flow due south-west and

debouch in the Gulf of Cambay. The water divide, and the pattern of their tributaries exhibit a control by various types of geological features (with related geomorphic expression) of Deccan Trap, Tertiary and Quaternary rocks. The occurrence of a major earthquake near Broach town on the bank of Narmada river in 1970 has indicated that the area is seismically active. The northward migration of the course of Narmada river, and the occurrence of Narmada river paleo-bank, about 5 kilometers to the south, points to the continued rise along the Anklesvar-Jhagadia structural trend, close to the southern course of Narmada river. This provides a good evidence of continued tectonic activity in the Quaternary times as well.

The main problems involved in the study area, and which were tackled, were as follows:

1. A revision of stratigraphy for finalising the limits of formations, recognising lithologic subdivisions and to standardise their nomenclature.

2. Biostratigraphy of the exposed fossiliferous sequence and dating of the sediments.

3. Interpretation of paleoecology and reconstructions of the events of the area in correlation with deeper parts of the basin in Anklesvar area to the north-west.

4. Structural highs, lows, and their trends, and associated faults in the area have been outlined and mapped.

5. Significance of drainage pattern and geomorphic features have been studied and explained.

6. Different tectonic phases which occured in the area of study and deformed the sediments have been identified and their causes determined.

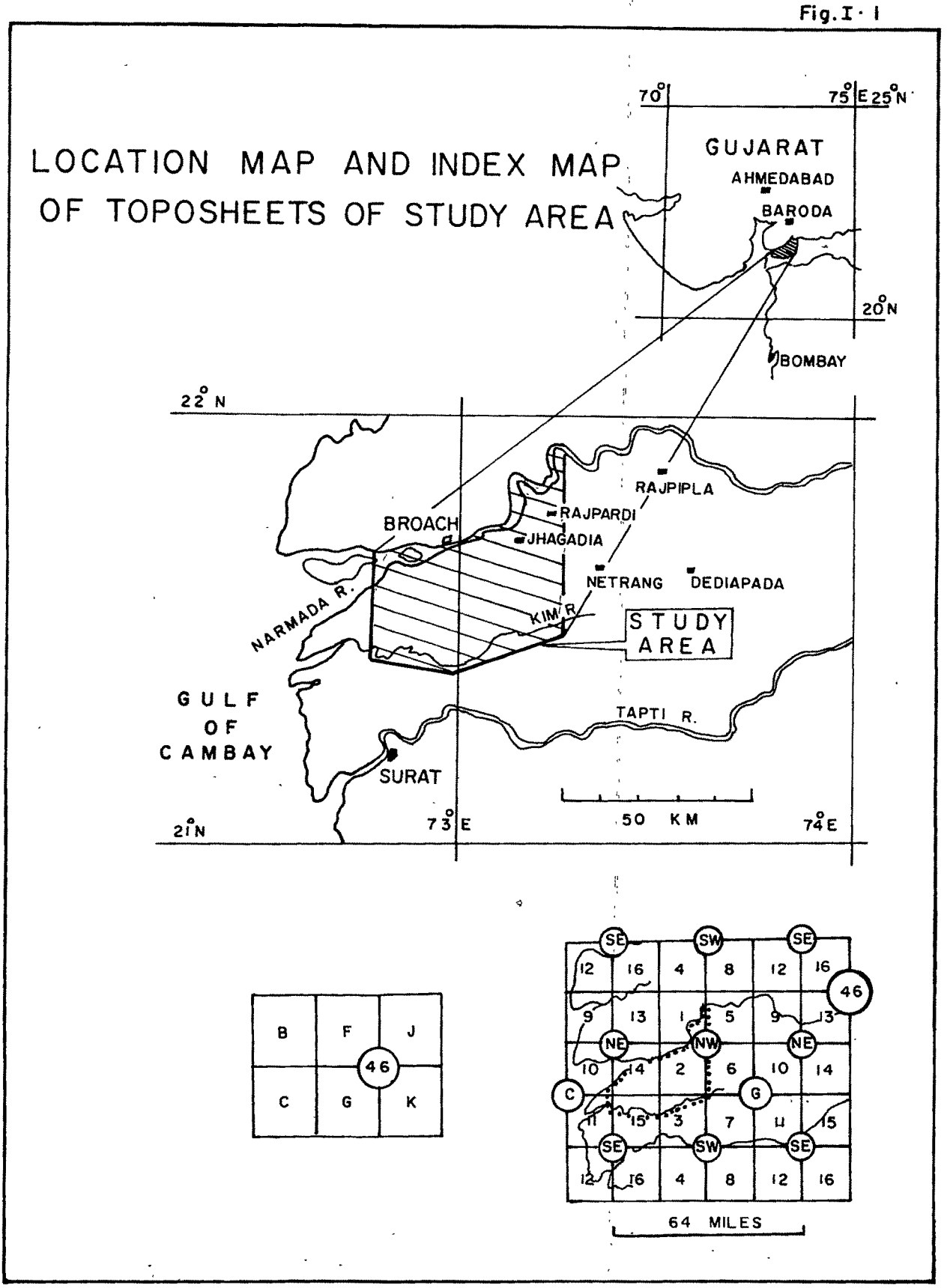
7. The Tertiary sediments are exposed between the Narmada and Tapti rivers, and are folded and faulted whereas they remain concealed north and south of these rivers. Field evidences have been collected to find a solution to this structural problem.

GEOGRAPHIC LIMITS

The area of study is bounded to the north and south by the Narmada and the Kim rivers (Plate-1), to the west by longitude 72°45'E, and to the east by longitude 73°17'E. Broach (Bharuch), the principal town is located on the right bank of Narmada river (Fig.I.1). The towns of Jhagadia, Rajpardi in the north-eastern part and Kosamba in the southern part of the area of study are the other semi-urban centres. The western boundary of the area runs close to the eastern side of the Gulf of Cambay. The study area measures 60 km in an E-W direction, and 30 km in a N-S direction encompassing an area of 1800 sq.km.

A large part of the area to the west, north-west and in the centre is covered by varying thicknesses of flood-plain

Fig. I · 1


LOCATION MAP AND INDEX MAP OF TOPOSHEETS OF STUDY AREA
70°
75° E 25° N
GUJARAT
AHMEDABAD
BARODA
20° N
BOMBAY
22° N
RAJPIPLA
RAJPARDI
BROACH
JHAGADIA
NETRANG
DEDIAPADA
NARMADA R.
KIM R.
STUDY AREA
GULF OF CAMBAY
TAPTI R.
SURAT
21° N
73° E
50 KM
74° E
B
F
J
46
C
G
K
SE
SW
SE
12
16
4
8
12
16
46
9
13
1
5
9
13
NE
NW
NE
10
14
2
6
10
14
C
G
11
15
3
7
11
15
SE
SW
SE
12
16
4
8
12
16
64 MILES

deposits, older alluvium and residual soils. These Quaternary sediments have been included in the study.

PHYSIOGRAPHY AND DRAINAGE

The area forms a gently rising ground east of the Gulf of Cambay. The ground elevation is from 20 to 50 metres above mean sea level. The higher values are towards the north-eastern part of the area. The hills of the Jhagadia-Rajpardi area rise to a height of 117 metres. The Sirsia rhyolite isolated hill, rising abruptly to 168 metres, lies close to the Tertiary rocks in the north-eastern part of the area. A number of streams traverse the area, and form the tributaries of Narmada river flowing west along the northern limit of the area. The Kim river in the south flows south-west marking the southern limit of the area. The water divide of the Narmada and Kim river drainage systems, has an almost south-west alignment passing along the Kosamba-Dinod geomorphological high.

The main streams which are perennial from north to south are, (i) Narmada river, (ii) Hakran Nadi, (iii) Ratanpur-Ni-Nadi, (iv) Kaveri Nadi, (v) Amravati Nadi, (vi) Amla Khadi, (vii) Wand Khadi, and (viii) Kim river with its tributary, the Gondhawa Nadi.

The direction of flow of streams is controlled by the slope of the ground which is in turn related to the dip and strike of geological formations. At places streams flow along structural lows.

A significant topographic feature is observed along a line trending south-west connecting Rajpardi, Jhagadia and Anklesvar towns. North of it, the ground level is 3 to 10 metres lower. The course of the Narmada river lies 3 to 6 kilometres north of this line. The study of this feature has revealed that this line represents the earlier left-over bank of Narmada river. During the Quaternary times the Narmada river migrated northward.

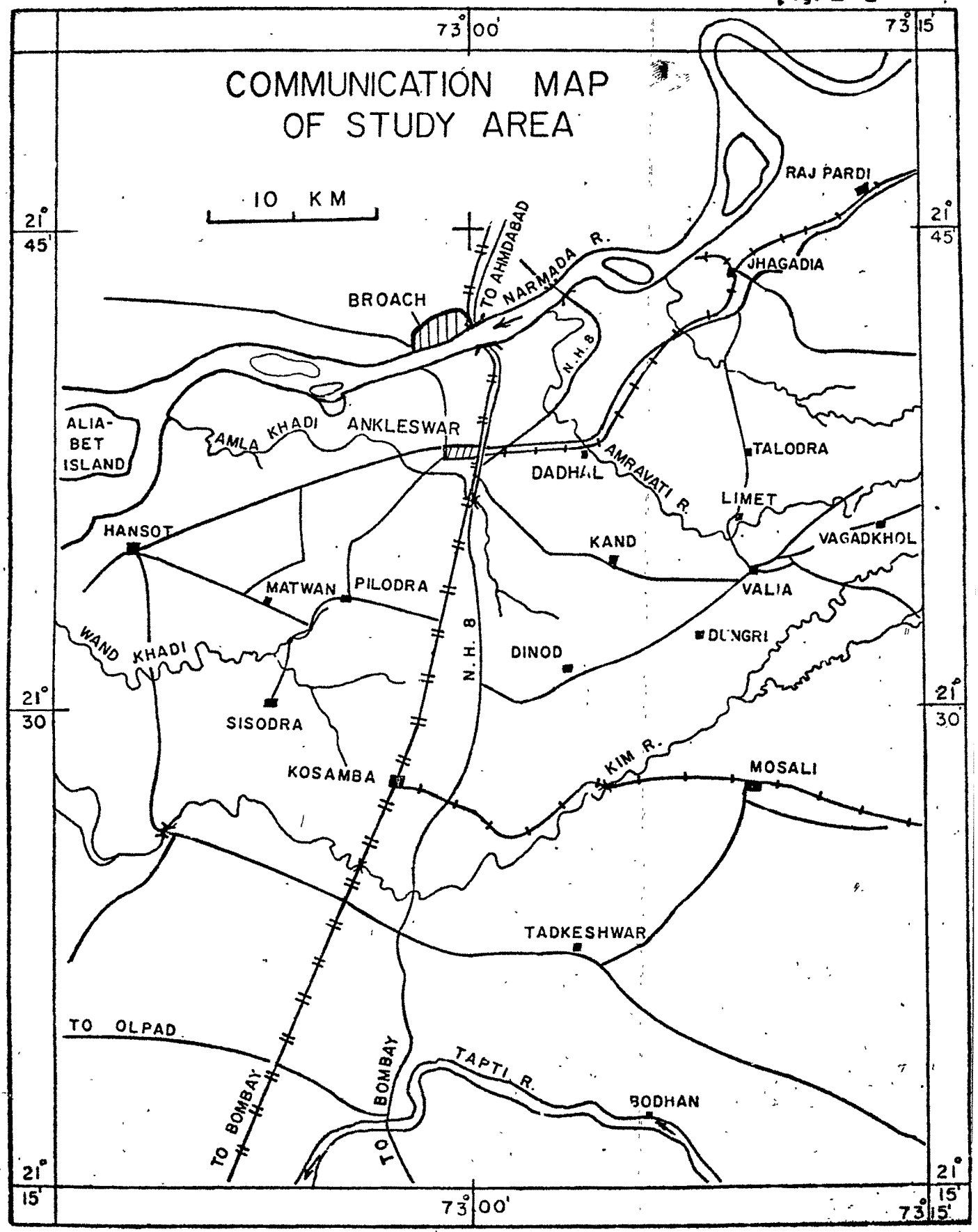
COMMUNICATION

Most of the area has a flat terrain covered by a thin veneer of soils and alluvium, and shows gently rolling topography. A good network of metalled and un-metalled roads criss-cross the area connecting various towns and villages (Fig.I.2). Several cart tracks in the area are motorable in dry season. The National Highway No.8 and the Delhi-Bombay railway line pass through Broach, Anklesvar and Kosamba towns. The State Transport buses ply on these roads. A new road-bridge on Narmada river has been constructed upstream of Broach town a few years back.

CLIMATE

The area experiences a dry and hot climate in general, and some rains between June to September months during the monsoon season. Mild winter is experienced after the rainy season till March followed by a rise in atmospheric temperature resulting in an uncomfortable weather due to hot winds and low humidity. The

Fig. I·2


COMMUNICATION MAP
OF STUDY AREA
10 KM
73° 00'
73° 15'
21° 45'
21° 30'
21° 15'
RAJ PARDI
JHAGADIA
TO AHMDABAD
NARMADA R.
BROACH
N.H.8
ALIA-
BET
ISLAND
AMLA KHADI
ANKLESWAR
DADHAL
AMRAVATI R.
TALODRA
LIMET
HANSOT
KAND
VAGADKHOL
MATWAN
PILODRA
VALIA
WAND KHADI
DINOD
DUNGRI
SISODRA
KOSAMBA
KIM R.
MOSALI
TADKESHWAR
TO OLPAD
TO BOMBAY
TAPTI R.
BODHAN

maximum and minimum day temperature experienced during the year range between 45°C to 25°C in the months of May and January respectively.

FLOODS

The Narmada river, flowing westward along the northern flank of the area, floods its banks during the monsoon season. Due to its long and fairly wide catchment area and absence of any big dam on its way, enormous quantity of flood water flows along the Narmada river inundating low lying areas, mainly its left bank. Now a dam is under construction across the Narmada river near Navagam village. It will not only arrest floods but will irrigate a large part of Gujarat and generate electricity.

FLORA

The hilly terrain south of Jhagadia and Rajpardi towns, located in the north-eastern part of the area fall within the Ratanpur Reserved Forest forming the western most part of the Satpura hills. The Narmada river forms the northern boundary of this forest area. Due to the sandstones and conglomerates exposed in the hills, the moisture content in the soil is low, and as such only small trees grow. In the remaining part of the area shrubs and occasional trees near the water sources are seen. The tropical dry deciduous type of forest of Ratanpur R.F. comprises the dominant species of teak (Tectona grandis, Shorea

robusta, Terminalia tomentosa), sisum (Dalbergia latifolia, Dalbergia Sissoo), Khair (Acacia catechu), dhawada (Anogeissus Latifolia), banyan (Ficus bengalensis), pipal (Acacia arabica), neem (Azadirachta indica), tamarind (Tamarindus indica) and Eucalyptus species.

Along the river banks the fauna consists of Babamadendron mukul, Cressa cretica, Evolvulus alsioides and species of Lycium, Aristida, Cenchrus, Lunea and Heylandia as described by Toor (1958).

FAUNA

The hilly areas of Ratanpur Reserved Forest and grasslands in the low lying areas specially east of Dinod village have a variety of wild fauna. The footprints of tigers (Felis Tigris) were observed by the author in the river beds. Other fauna reported include panther (Felis pardus), fox (Vulbus bengalensis), black faced monkey (Presbytis entellus), and Cobra (Naja naja) Chital or deer (Cervus axis), Barking deer (Cervulus muntjac), and Sambar (Cervus unicolor). The most common poisonous snakes found are Cobra (Naja naja), Krait (Bungarus caeruleus and Russell's Viper (Vipera russeli).

CROPS

Agriculture is the main occupation in the area and provides means of livelihood to 71.2 per cent of the total population. The

soil in the central and northern banks consists of the erosional products of the Tertiary rocks and patches of black cotton soil occur along the streams that pass through the Deccan Trap country to the east. The Kharif season is from middle of June to middle of October, and the main crops grown are paddy, bajri, jowar, kodra, maize, gram, math, mag etc. All along the Kim river and south of it, in the black cotton soil are grown jowar (Sorghum), cotton, and pulses (tuvar, udad and moong). The relationship of the type of soil and crop is indicated below:

Black soil - Highly retentive of moisture and crops grown are jowar (both rabi and kharif), wheat, paddy, lang, tuvar, gram, peas, and cotton.

Gorat soil - In the western part of Hansot the soil is relatively shallow and contains more sand. Crops grown are paddy, bajra, kodra, tuvar, mag, math and groundnut.

Bhatha soil - Rich alluvial silt deposited by rivers, found in the bank of the river Narmada. Crops grown are jowar, tobacco and vegetables.

Kyari soil - Richest soil growing paddy, wheat and gram.

HISTORY

Jhagadia town, located in the north-eastern part of the area near Narmada river, is a place of historical and

archaeological importance. Bawaghor was an Ethiopian merchant who started the mining of semi-precious stones in the Sixteenth Century from the Babaguru hills near Ratanpur town (Pascoe 1965). The local people visit his tomb located on the hills. The agate mines in the area have supported the famous agate industry of Cambay (Gujarat) for the last several centuries. The hillock, Kadia Dungar, near Pandwania village is of archaeological importance due to the presence of a number of caves which are believed to have been inhabited by Jain monks in the early Medieval period (Mehta 1972).

POPULATION

The population of the Jhagadia Taluka is about 87,000 as per the 1961 census. About 45 per cent of these, belong to schedule castes and tribes. The religions followed by the people are Hinduism, Islam, Christianity and Jainism. The tribal people follow their own religion and social customs.

OBJECT AND SCOPE OF WORK

The Tertiary and Quaternary rocks of the area between Rajpardi and Kosamba towns in the southern part of the state of Gujarat have been investigated with a special emphasis on the structural style and geomorphological expressions. The geological mapping of the area has been carried-out on a

scale of 1:25,000 with the help of aerial photographs, and has made a systematic collection of rock samples, measured representative stratigraphic sections and constructed various types of geological sections. The structures and their surface expressions have been mapped in detail. Other problems studied and assessed in greater detail for finding various geological solutions include the litho-stratigraphic changes both in time and space, effect of tectonic processes on the basin evolution and its control on sedimentation, cycles of tectonic activity affecting sedimentation and the structural interpretation of the area with the help of neotectonic and geomorphological investigations.

The published subsurface geophysical and geological data of deep wells drilled in the area has enabled in working out the vertical and spatial variation in the litho-stratigraphy, thickness and structural details.

SALIENT FEATURES OF THE FINDINGS

The present author has been able to make a substantial contribution to the existing knowledge on the geology of the area, and has considerably modified its stratigraphy. Based on detailed and careful field investigations coupled with photo-geology and laboratory studies, the present author has

prepared elaborate geological and structural maps(Fig. IV.1) He has clearly brought out the fact that there exists a marked difference in the structural grain on the two sides of the Narmada river. A fair answer to the reasons of differing structural grain has been brought out.

Based on his own field mapping, as well as taking into account the relevant earlier works, the author has suggested the following modified stratigraphic succession for the study area (Table I.1).

Table I.1 : STRATIGRAPHIC SEQUENCE OF STUDY AREA

AGE	FORMATION	LITHOLOGY
Quaternary to Recent	Narmada	Sands, silts, clays and gravels
----------	Unconformity	----------
Upper Miocene to Pliocene	Jhagadia	Sandstones, grits, conglomerates & clays
----------	Unconformity in NE part	----------
Lower Miocene to Mid.Miocene	Kand	Limestone bands, pebbly (fossiliferous), calcareous sandstones and clays, and marls
----------	Unconformity in NE part	----------
Lower Miocene	Babaguru	Ferruginous sandstones and clays, agate conglomerates, and silts.
----------	Unconformity	----------
Late Eocene	Dinod	Limestones(fossiliferous)and marls
----------	Unconformity	----------
Early Eocene	Vagadkhod	Conglomerates, sandstones, and pink, red and yellow coloured clays
----------	Unconformity	----------
Late Cretaceous to Paleocene(?)	Deccan Trap	Basalts

Base unknown in the area of study

The Vagadkhol formation unconformably overlies the Deccan Trap basalts, and consists of agate and basalt pebble - conglomerates, clays of pink, red and yellow colour, and gritty sandstones. The rocks of this sequence are exposed as detached outcrops in the eastern part of the study area. After a long hiatus a marine transgression took place in the area, from the south-west, and deposited fossiliferous limestones, and at times coquina beds of Dinod formation. These limestones outcrop in the southern part of the area but their contact with the underlying Vagadkhol formation is not seen exposed in the area. The limestones of the Dinod formation have been found to be absent to the north-east, and the overlying Babaguru formation rests directly over the Vagadkhol formation with an unconformity in that part of the area. The Babaguru formation overlying the Dinod limestones, with an unconformity in the southern part, was deposited following the regression of the sea. There had not been any sedimentation during Oligocene in the study area. The cherry red and ironstone like sandstones and agate conglomerates of Babaguru formation are very conspicuous in the field, and form high ground due to their compactness. The Kand formation, overlying the Babaguru formation unconformably, was deposited in a transgressive phase and a near shore environment. There was a marked change in the provenance and the drainage system, which had deposited quartz arenites in the area. With a further regression fluvial environment prevailed and deposition of a thick sequence of sandstones, conglomerates and occasional clays of Jhagadia

formation occurred, occupying a major part of the area. These rocks were in turn, overlain unconformably by the Quaternary to Recent sediments of Narmada formation.

The present studies have found a most probable answer to the significant events of the upliftment accompanied by folding, faulting and partial erosion of the Tertiaries in relation to the undisturbed sequences adjoining the study area. The Tertiaries of the study area lie folded along NE-SW trend where as the general structural grain of the Cambay basin is N-S. Eleven anticlinal features have been mapped in the area. The linear anticlinal folds are generally assymmetric and invariably faulted by reverse type of faults along their steeper SE limbs, cutting across the entire sequences and extending in depth through Deccan Trap and Mesozoic sequence. The deformation has been found to be due to the differential vertical movement of basement fault blocks from time to time. The re-activation of faults, from the earlier normal faults to reverse faults, was possibly related to the collision of the Indian plate with the Asian plate thereby narrowing the Narmada basin gap within which the study area falls on crossing the Cambay basin. The Narmada geofracture had divided the Indian plate into two parts, the northern and the southern subplates. The convergence of the two subplates during the Late Cenozoic final welding of the Indian plate with the Asian plate had caused the basement fault-block movement, push of the blocks

one against the other and the deformation of rocks resulting in their folding and reverse faulting.

A number of Quaternary geomorphological features have been mapped, and they point to the occurrence of neotectonic movements in the study area. Drainage analysis have specially been of great help in outlining geomorphic features. Good evidences have been found which point to the northward migration of the Narmada river during Quaternary times.

Lineaments corraborating regional faults in the study area extending in the Deccan Trap country to the NE suggest the faulting of Deccan Traps as well during the Late Cenozoic tectonic activity.