LIST OF FIGURES

Chapter 1

Figure 1 1 Map showing major location and the extent of the study area	(3)
Figure 1 2 Shaded relief map of the Saurashtra peninsula	(4)
Figure 1 3 Map showing the rainfall and wind pattern on the Saurashtra peninsula	(5)
Figure 1.4 Drainage map of the Saurashtra peninsula showing radial drainage pattern	(5)
Figure 1 5 Offshore relief map of the Saurashtra showing major geomorphic features	(7)
Figure 1 6 Tectonic attributes surrounding the Saurashtra peninsula	(9)
Figure 1 7 Major lineaments on the Saurashtra peninsula	(9)
Figure 1 8 Gravity anomaly map of the Saurashtra peninsula	(11)
Figure 1 9 Geological set up of the Saurashtra peninsula	(12)

Chapter 2

Chapter 2	
Figure 2 1 A typical beach morphology	(23)
Figure 2 2 A typical beach ridge profile with associated landforms and depositional fa	icies (24)
Figure 2 3 A typical cliff profile showing shore platform and tidal notch	(27)
Figure 2 4 Variations in the morphology of the tidal notch profiles	(29)
Figure 2.5 coastal cliff near Jafrabad showing raised tidal notches and a rocky shore p	latform (31)
Figure 2 6 IRS 1D, LISS-III Geocoded satellite imagery of the Madhavpur area	(32)
Figure 2 7a Gravels & pebbles of Gaj & Dwarka limestones in the oldest	
Quaternary deposits near Mankhetra	(34)
Figure 2 7b Biomicrite showing the angular Quartz fragments along with the	
foraminfera in the limestone unit-1	(34)
Figure 2.8 Pedogenesis of the Unit-1 in the form of the palaeosol	(34)
Figure 2 9 Microsparitic infilling in the fractures of palaeosol	
as seen under the microscope	(34)
Figure 2 10 Recrystallized coarse grained, shell rich Unit-2 near Arena with	
gravels and pebbles of older limestone (unit-1)	(35)
Figure 2.11a Flattened and broken shell fragments indicating a fair degree of compact	tion
in unit-2.	(35)
Figure 2 11b Large crystals of neo-spartie with a very faint preservation of shell	
boundaries and morpholgogy of the first generation cement suggesting a	high
degree of limestone diagenesis	(35)
Figure 2 12 Type Miliolite showing high angle planar cross- laminations in the quarry	v cut face (36)
Figure 2 13 General textural and compositional characteristics of unit-3 miliolite	(36)

Figure 2 14 A noticeable presence of reworked lithoclasts of unit-1 showing angular quartz grains	(36)
Figure 2 15 Gently shore-ward dipping shell limestone forming the unit-4 near Okha.	(37)
Figure 2 16a A close up of unit-4 outcrop showing a predominant composition of shell fragments	(38)
Figure 2 16b Photomicrograph of unit-4 showing first generation rim of fibrous aragonite	
cement with a thin micrite substrate The intergranular pores are also infilled with	
aragonitic micrite	(38)
Figure 2 17 An outcrop of the unit -5 showing characteristic presence of coral fragments	
in reef limestone near Mangiol	(39)
Figure 2 17a A Close up of reef limestone containing molluscan shell fragments	(39)
Figure 2 17b Fragments of coralline algae Amphiroa Fragilissima as seen in the	
unit-5 under the microscope	(39)
Figure 2 18 A typical nature of unit-6 aeolianite (miliolites) showing a good presence of foraminife	era
belonging to Miliolidae family	(39)
Figure 2 19 Barren saline raised mud flat as seen along the southern Saurashtra coast	(40)
Figure 2 20 Skolithos ichnofacies in semi-consolidated beach sand occurring at 3m amsl on the	
Mangrol coast	(40)
Figure 2 21 A cut face of unit-9 showing in general homogenous nature of the	
stabilized dune sand near Mangrol	(41)

Figure 3.1 Map showing the major segments investigated in the study area	(42)
Figure 3 2 a. Physiographic and geomorphic map of the Okha-Dwarka area of segment-1	(44)
Figure 3.2 b Physiographic and geomorphic map of Bhogat-Miyani area of segment-1	(45)
Figure 3 2 c Physiographic and geomorphic map of Miyani-Porbandar area of segment-1	(45)
Figure 3 3 A satellite view of the northwestern Saurashtra	(46)
Figure 3.4 A sea cave the coastal cliff of Dwarka	(48)
Figure 3.5 Unconformable contact between the Dwarka limestone and the shell	
limestone belonging to the unit-4	(48)
Figure 3 6a Closer view showing larger shell fragments in a quarry near Dwarka	(49)
Figure 3 6bGraded bedding & wavy lamination in shell limestone.	(49)
Figure 3 7 Dead coral (Favia) in shell limestone unit at Gorinja	(50)
Figure 3.8 High angle dip in the limestone unit of Dwarka Formation at Kuranga.	(50)
Figure 3.9 Generalized Geological section along Navadra – Lamba segment.	(52)
Figure 3.10 A protosol layer separating two successive beach ridge of miliolite limestone	
near Miyani.	(53)
Figure 3 11 A palaeocliff in the miliolite limestone near Miyani	(54)
Figure 3 12 Biological borings & a layer of shell limestone at the base of palaeocliff at Miyani	(54)
Figure 3.13 A profile across the coast near Miyani showing the occurrence of abandoned cliff	(54)
Figure 3 14 Geomorphic set up of the Porbandar (Goasa) – Madhavpur area.	(57)

Figure 3.15 Mud cracks in the miliolite limestone of ancient beach ridge near Navibandar	(60)
Figure 3 16 Drifted blocks of limestone from the older beach ridge as seen in a shell	
limestone quarry near Balej.	(60)
Figure 3.17 Physiographic and geomorphic set up of the Madhavpur-Chorwad area of segment-2	(62)
Figure 3 18 Coastal cliffs and shore platform in the ancient miliolite ridge on the coast	
of Aantrolı-Lohej	(63)
Figure 3.19 The shell limestone of the second ancient beach ridge exposing tabular	
cross-stratifications with seaward dips near Shil	(63)
Figure 3.20. A dead coral reef as exposed on a quarry base near Mangrol Bandar	(66)
Figure 3 21 Stabilized dune sand resting over the ancient beach ridge made up of shell	
limestone at Mangrol Bandar	(66)
Figure 3.22 Cross-stratified and bio-turbated beach sand deposits at 3m amsl on Mangrol coast	(66)
Figure 3 23 Skolithos ichnofacies in semi-consolidated beach sand occurring at 3m amsl on the	
Mangrol coast	(66)
Figure 3 24 Abandoned quarry in the ancient beach ridge two of miliolite near Mangrol Bandar	(66)
Figure 3.25 Seaward dipping shell rich limestone with recrystallized top at Arean	(67)
Figure 3 26 Ball like concretions in the miliolite limestone at Sepa	(67)
Figure 3 27 A large coral fragment embedded in the shell limestone at Chorwad Holiday Camp	(68)
Figure 3 28 A stratigraphic correlation of various lithounits encountered in the dug well section of	
angroal – Shil area	(69)
Figure 3 29 Geological map of the Mangrol-Shil area and a schematic geological section	
along A-A' depicting the stratigraphic relationship between various lithounits	70)
Figure 3 30 Physiographic and geomorphic set up of the area between Chorwad-Chharaa	
of segment-2	(72)
Figure 3 31 Polygonal cracks as seen in the miliolite limestone on the top of a cliff near	
Vadodra coast	(73)
Figure 3.32 Abrasion furrows in the miliolite limestone on the top of a cliff at Adri coast	(73)
Figure 3.33 A biogenic encrustation on the roof of a palaeo sea cave at Adri coast	(73)
Figure 3 34 Prominent cross cutting joints in the litho unit-2 as seen on the Adri coast.	(73)
Figure 3 35 A generalized geological cross section of the Adri coast	(73)
Figure 3 36 Closer views of prominent joints developed in the litho unit-2 as seen on the	
shore platform at Veraval.	(74)
Figure 3.37 Geomorphic set up of the Diu-Jafrabad stretch of segment-3.	(77)
Figure 3 38 Landsat scene of the area between Diu and Mahuva of south Saurashtra coast.	(78)
Figure 3 39 A drift coral fragment embedded in the shell limestone of Kadwar coast.	(79)
Figure 3 40 A litholog exhibiting various facies as seen at the Kadwar coast	(79)
Figure 3 41 A sand quarry face near Vadodra-Zala exposing ancient beach sand, gravel	
and ash layer overlain by the stabilized aeolian sand	(81)

Figure 3.42 A closer view of the clayey sand unit consisting of shells, bones and pottery fragments. (81)

Figure 3 43 An ancient anthropogenic structure in the sand quarry of Vadodra-Zala	
The continuation of ash layer can also be seen	(81)
Figure 3 44a Raised shore platform at Madhvad light house.	(82)
Figure 3 44b Closer view showing <i>lithophaga</i> borings at same location	(82)
Figure 3 45 Geological and geomorphic set up of the Diu Island	(83)
Figure 3 46 Inliers of Shell limestone in the backshore dune sand at Banakwara	(85)
Figure 3.47 Landward dipping younger miliolite unit overlying the seaward dipping older	
unit near Nagwa	(85)
Figure 3 48 A layer of prominent luthophaga borings on the raised notch near Nagwa	(85)
Figure 3 49 Sea wards dipping sheets of shell limestone at Nagwa	(85)
Figure 3 50 A quarry face in younger miliolite showing herringbone cross-stratification near	
Phudam	(86)
Figure 3 51 Oysters embedded in the algal mat in Rupen river bed near Chikhali.	(87)
Figure 3 52 A raised shore platform as seen at the Lheriya Mahadev near Khada Bandar.	(88)
Figure 3 53 Convolute laminations in the younger sequence of miliolite limestone at Khada Bandar	(88)
Figure 3 54 A Coastal cliff at Dhara Bandar showing a prominent raised shore platform and notch	(89)
Figure 3 55 A raised tidal notch in the younger miliolite sequence at Sarkeshwar near Balana	
in front of it the beach and dune sand can also be seen	(90)
Figure 3 56 A closer view of the notch roof showing leafy pattern of biological encrustation.	(90)
Figure 3 57 An abandoned cliff showing a network of <i>lithophaga</i> borings.	(90)
Figure 3 58 A raised marine terrace/tidal notch as seen on the Babarkot coast	(90)

Figure 4.1 Important drainage basins of the southwestern Saurashtra peninsula ((95)
Figure 4 2 (a) Map showing the Bhadar river through out its course ((97)
Figure 4 3 (b) Detailed map of the Bhadar river basin showing its tributaries & major locations ((97)
Figure 4 3 Photograph showing palaeosol facies (P1) and (P2) at in Bhadar river basin ((98)
Figure 4 4 Normal grading in the foresets of the (Gt1) facies at Panchpipla ((99)
Figure 4 5 Gt2 facies underlain by palaeosol (P2) near Jetpur railway bridge ((99)
Figure 4.6 A closer view of Gh facies in Bhadar river near Thepda.	(100)
Figure 4 7 Typical Sp facies marked by gentle planar cross-stratification in Survo river	
near Jetpur.	(100)
Figure 4.8 Planar cross-stratified sand facies (Sp) with a lensoid form of locally occurring	
scour fill (Ss facies)	(101)
Figure 4 9 Bioclastic carbonate sand dominating massive sand (Sm) facies in Bhadar	
river near Panchpipla.	(101)
Figure 4 10 Biogenic structures in the Sm facies suggestive of its near shore deposition at Thepda ((102)

Figure 4.11 Lithologs starting from the upstream of the Bhadar river basin showing hithofacies. (103)

Figure 4 12 A part of Landsat image showing conspicuous valley width and abandoned	
sediment lobe of the Ojat river basin	(105)
Figure 4 13 A typical Gt facies of Ojat river resting on an undulatory surface characterizin	ng
its typical channel fill nature near Anandpur.	(105)
Figure 4 14 A part of the Gt facies showing alternation with thin sand layers in Ojat river	
near Anadnpur	(105)
Figure 4.15 Rhizocretion in the basal unit of fluvial sequence exposed in Ojat river near A	nandpur (107)
Figure 4.16 Alternating carbonate sand and sandy clay units in the upper part of the fluvia	l
sequence of Ojat river near Anandpur	(107)
Figure 4.17 Gt facies in Ojat river near Sukhpur The overlying palaeosol and Sm facies c	
an be seen in the background	(107)
Figure 4 18 Figure 4.18 Lithologs showing various facies in the Ojat river basin	(108)
Figure 4.19 Lithologs of the other rivers of the southwestern Saurashtra	(109)
Figure 4 20 Compact tidal clay unit underlain by a prominent pedogenised Gh facies as se	en
in Noli river at Kamnath	(110)
Figure 4 21 Horiozontally bedded bioclastic carbonate rich sandy unit (Sh facies) underla	in
by poorly sorted gravelly (Gh facies) unit	(112)
Figure 4 22 A palaeosol unit (P1 facies) developed over the basalt showing	
a typical vertisolic character	(112)

Figure 5 1 Map showing the distribution of the major earthquake epicenters in Gujarat	(119)
Figure 5 2 Orthogonal joints in the miliolite limestone in Rupen river bed near Chikhali	(120)
Figure 5 3 An open antiformal structure in miliolite near Chikhali in Rupen river	(120)
Figure 5 4 a A general view of an outcrop showing convolute bedding in miliolite limestone unit of	overlain
by a horizontally bedded unit in Noli river south of Mangrol	(121)
Figure 5 4 b A part of the above outcrop exhibiting a complex pattern of bedding deformation	(121)
Figure 5 4 c A closer view of deformation in the miliolite beddings	(121)
Figure 5 5 River bank cliff near Chhachar outcropping the fossiliferous clay unit	(122)
Figure 5 6 Prominent two sets of joints in a relatively finer grained shell limestone unit	(123)
Figure 5.7 Orthogonal joints in the slightly recrystallized In miliolite limestone unit.	(123)
Figure 5 8 NE-SW oriented joints on the Bararkot shore platform.	(124)
Figure 5 9 Rose diagram exhibiting the prominent frequencies of joints encountered	
in the Quaternary sequences of the study area.	(125)
Figure 5 10 A drainage lineament map of the southwestern Saurashtra coast.	(127)
Figure 5.11 Rose diagram prepared using the drainage lineaments studied in the	
southwest Saurashtra	(128)
Figure 512 A generalized longitudinal profile of a river.	(129)
Figuure 5.13 Longitudinal profiles of the major drainages of southwestern Saurashtra coast.	(131)

3

Figure 5.14 Longitudinal profiles of the minor coastal streams of the southwestern Saurashtra.	(132)
Figure 5 15 Plot of Gradient Indices against distance on longitudinal profile	
of various rivers studied	(134)

Figure 6 1 Marine oxygen isotope curve after Imbrie et al , (1984) showing	
various isotope stages, A proxy record of sea level high and low stands	(139)
Figure 6 2 Profiles of various cliffs and associated tidal notches exhibiting formal	
sea levels along south Saurashtra coast	(144)
Figure 6.3 Plots of litho units encountered in the coastal carbonate sequences of the study	
area on the sea level curve of Kindler & Hearty (1995)	(146)
Figure 6.4 The available geochronological data shown in Table VI.1 are plotted on the sea level	
curve after Shackleton (1987)	(147)

,

LIST OF TABLES

-

Table I 1	Lithostratigraphic framework of the Saurashtra region	(13)
Table IV 1	Summary of the lithofactes of fluvial sequences of south Saurashtra	(113)
Table V 1	Major occurrences of earthquakes in Saurashtra region	(118)
Table V.2	Summary of major faults and lineaments of Saurashtra peninsula.	(119)
Table V 3	Summary of Gradient and gradient indices of the rivers of the SW Saurashtra	(133)
Table V.4	PHI values calculated for the longitudinal Profiles of the SW Saurashtra rivers	(136)
Table VI 1	Summary of the available radiometric dates of the bioclastic carbonate deposits	
	of Saurashtra	
Table VI 2	Summary of the lithofacies of fluvial sequences of south Saurashtra.	(149)
Table VI 3	Sequential stages of geomorphic evolution of the southwestern Saurashtra coast.	(155)