MORPHOLOGY AND STRATIGRAPHY OF BEACH ROCK AT GUHAGAR, MAHARASHTRA

A DISSERTATION PRESENTED BY

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UNDER THE GUIDANCE OF

PRINCIPAL DR.TUSHAR SHITOLE

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF

MASTER OF PHILOSOPHY IN GEOGRAPHY

TO

DEPARTMENT OF EARTH SCIENCE

TILAK MAHARASHTRA VIDYAPEETH

GULTEKDI, PUNE

FEBRUARY 2016

DECLARATION

I hereby declare that the dissertation entitled**" Morphology and Stratigraphy of beach rock at Guhagar, Maharashtra"** completed and written by me has not previously formed the basis for the award of any Degree or other similar title upon me of this or any other vidyapeeth or examining body.

Tanaji Kharsinge
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Place: Pune
Date: 22nd February 2016

CERTIFICATE

This is to certify that the dissertation entitled **"Morphology and Stratigraphy of Beach rock at Guhagar, Maharashtra"** which is being submitted herewith for the award of the **Master of Philosophy (M.Phil.) in Geography** of Tilak Maharashtra Vidyapeeth, Pune is the result of original research work completed by Shri **Tanaji Dhondiram Kharsinge** under my supervision and guidance. To the best of my knowledge and belief the work incorporated in this dissertation has not formed the basis for the award of any Degree or similar title of this or any other University or examining body upon him.

Dr. Tushar Shitole
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ACKNOWLEDGEMENT

The completion of an academic work for the presentation of a dissertation requires considerable support and guidance. While working for my research, I have received the necessary support and help in all the stages of my work.

In the first place I would like to express my sincere gratitude towards my guide **Prin. Dr. Tushar Shitole** for his great support and sincere guidance till the final stages of my work and for his constant encouragement.

I am grateful thanks to Dr. Umesh Keskar, Registrar, Tilak Maharashtra Vidyapeeth, Dr. Shrikant Karlekar (Head of the Department), Dr. Bhagyashree Yargop and Prof. Ganesh Denage for their co-operation during the research work.

I am greatly indebted to Principal Dr. Nitin Ghorpade, Prof. Ramkrishna More Arts, Commerce and Science College, Akurdi and Principal Dr. Jayprakash Jadhav, Dr. D.Y.Patil ACS College for their co-operation, strong support and encouragement in the completion of this thesis.

I am enormously thankful to Dr. Savita Kulkarni, Prof. S.B. Shinde, Dr. Sanjay Jagtap, Dr. Manoj kumar Devne, Dr. Arun Magar, Dr. Ravindra Shinde, Dr. Suyog Kulkarni, Dr. Rahul Patil, Dr. Dinkar Chavan, Dr. Rajesh Birajdar, Prof. Shital Pasalkar, Prof. Anilkumar Jagtap, Mr. Ashok Parandwal, Mr. Balasaheb Lakhe and Mr. Onkar Tantarpale who have helped me in many ways. My friends Nilesh Mali and Shital Kavthekar made the field work easier and helped me in my field work. I would also like to extend my gratitude towards my friends Ravikant Koli, Abhijeet Shinde, Nilesh Kedar, Bandopant Pawar, Umesh Vachkal, Raviraj Thorat, Savita Shedbale, Anuradha Ovhal, Nilesh Indore, Sandip Shinde and Mahesh Kalshetti

for their help during my completion of the thesis. I am also thankful to Dhanaji the non-teaching staff of our department for their constant help to make facilities available at the earliest.

I have no words to express the support and co-operation given by my family. I would like to thanks my parents for their love and blessings, which made me strong for the completion of my work. Last but not the least I owe much to the support of my parents, my family, all of my friends and my students for their constant moral support and encouragement throughout my dissertation.I would once again like to express our gratitude to all those who were directly or indirectly involved in this project.

This work is an outcome of sincere help and cooperation from many other people. I express my deep sense of gratitude and sincere feelings to all of them.

Tanaji Kharsinge

(Research Student)

Place: Pune

Date: 22nd February 2016

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ABSTRACT

0.1) Introduction

The Sahyadri mountain range ("Western Ghats") forms the eastern boundary of the Konkan, and the Arabian sea marks the western boundary. Beach rocks are the common coastal formations, constructed through the lithification of beach sediments by carbonate cements. It is coarse grained beach sediment that has been cemented and preserved in the geological record. So it is one of the important geological feature along the coast to study the sea level changes (Pirazzoli 1991). On retreating coasts, outcrops of beach rock may be evident offshore where they may act as a barrier against coastal erosion. Mathur (2005) suggests high sea level of 1–4 m during middle and Late Holocene along the Indian coast which resulted in deposition of beach rock along the coastline. So the beach rock is a good indicator of the past sea levels, as it is considered to have been formed within the range of intertidal zone.

Beach rock is composed of beach sediments that have been chiefly cemented by calcium carbonate deposits. Beach rock is a friable to well cemented sedimentary rock that consist of a variable mixture of gravel, sand and silt sized sediment that is concerned with carbonate minerals and has formed along a shoreline. Beach rock typically forms within the intertidal zone within tropical or semitropical regions. Beach rock usually tends parallel to the beach. The beach rock is calcareous, sandy, shelly deposits dating back to 2400 to 2800 YBP. (Personal communication with Dr. S. N. Karlekar) Many coastal villages are situated on such fossil ridges. The beach rock has not been properly studied in India. The study of such beach rock is the main aim of this dissertation work.

From the konkan coast few morphological evidences have been recorded, beach rock is one of them indicates the high sea during the late Pleistocene. Occurrences of beach rock on Konkan coast of Maharashtra suggest a regressive sea level phase in Holocene.

The present work is aimed to study the morphology and stratigraphy of beach rock at Guhagar. In order to achieve this following objectives have been defined.

1) To study the morphology and evaluate the stratigraphy of beach rock
2) To ascertain the orientation and trend of development of beach rock in study area.
3) To study the characteristics of sediments of beach rock.
4) To understand the formation and cementation process of beach rock.
5) To reconstruct the earlier shoreline of Guhagar.

0.2) Study Area and Methodology

The study area is located on the west coast of Maharashtra popularly known as Konkan coast. Guhagar study area is a part of Ratnagiri District. Such a study area is a virgin sandy pocket beach. The latitudinal extent of the study area is 17^0 28' North to $17^0$30' North and longitudinal extent is $73^0$10' East to $73^0$11'East. The whole Guhagar beach is about 6.44 km long and the length of the study area is near about 5 kilometers from north to south as well as width is near about 300 meters east to west. Beach and coastal part of Guhagar is a well-known place for tourist attraction along the west coast of Maharashtra. Study area is bounded by northern and southern headlands. In the middle part between the headland beach rock is seen but towards the headland there is laterites found. The beach rock in the study area is formed by cementation of quaternary sediment deposits. Climate of the study area is west coast type of climate.

Beach rock exposures were found in inland of the study area and some patches are seen at the intertidal zone of beach. Various aspects of beach rock were surveyed and mapped in 2011 and 2012. Surveys were conducted to study the morphology and stratigraphy

of beach rock. Field observations are recorded photographically. To achieve the aim and objective of the study pre-field work, field work and post field work methodology adopted. In pre field work phase various beach rock images, articles, papers, books, thesis collected for the literature review. Fourteen wells were selected randomly in the study area to study the cementation, morphology, formation, compactness of beach rock. Out of 14 wells three wells were selected randomly to study the stratigraphy of beach rock and strata wise sampling were done. Samples collected in the field were analyzed by sieve analysis method that is mechanically sieving and determined the grain size parameters by a technique of "Folk and Ward" method. The calcium carbonate analysis was done to obtain the calcareous material in the beach rock. It indicates the compactness of beach rock.

0.3) Morphology and Sedimentology

Guhagar beach rocks are mostly found in the backshore zone. Most of them are found in the wells. The highest inland limit of beach rock in the study area is 335 meters and lowest is 185 meters away from the present day shoreline. The orientation of beach rock in the study area is north to south. Guhagar beach rock is discontinuous low, narrow ridges running almost parallel to the coastline. Guhagar beach rock are conceals by a layer of coastal alluvium. Textural group of Guhagar beach rock is sand. Grain size parameters of beach rock sediment sample like mean, sorting, skewness and kurtosis were estimated. After the analysis of sediment sample, the obtained mean sediment size in between dominantly medium sand and fine sand.

0.4) Stratigraphy of Beach Rock

In the study area three wells were selected randomly to study the litho-stratigraphy of beach rock. To identify the various facies of beach rock litho-section with the

help of properties of sediment such as texture, color, thickness, internal structure, bounding surface etc. The three beach rock litho-section shows variation. It means that variation is seen in the formation of beach rock. Well I (Northern well litho-section) show coarsening upward sequence. Well II (Middle well litho-section) shows fining upward sequence but the southern well litho-section that is dug well III does not show any particular sedimentary sequence.

To study the compactness of beach rock calcium carbonate analysis were done in the litho-section of beach rock. From such analysis the proportion of calcareous and non-calcareous material in the sediment sample was obtained.

0.5) Findings and Conclusions

In the study area, very few partly visible exposed beach rock was found in the backshore zone have north to south orientation. The gradient of beach rock in the study area is negligible and it is inclined towards the sea. On the basis of position of exposed beach rock and beach rock from dug well, the exposed beach rock is relatively modern and beach rock in dug wells is older. Beach rock found in dug well sections up to the 200 to 350 meters inland, thus almost shows a parallel ridge position to the shoreline. Hence it is the tentative earlier shoreline of Guhagar which is near about 200-350 meters away from the present day shoreline and the tentative elevation of earlier shoreline is near about 7 to 10 meters from mean sea level. The thickness of beach rock is more in the middle part of the study area and it decreases towards the both side that is northern and southern side. Most of the Guhagar settlement is situated on such beach rock. The occurrences of beach rock in the study area suggest that negative change in sea level along the beach has taken place and it also indicates that the Guhagar shore is retreated which is 200-300 meters from earlier shoreline. Composition of Guhagar beach rock is sand, silt, shells, titanium oxide, calcium carbonate and rock fragments. The nature of beach rock varies from north to south in the study area.

There is variation seen in the percentage of coarser, medium, fine and very fine sand in exposed beach rock sediment samples. It shows wave environment at the time of beach rock formation in study area.

Occurrence of beach rock in Guhagar coastal area indicates the favorable conditions for beach rock formation, such as availability of essential calcium on beach, gentle slope of the foreshore and ground water temperature. Exposed beach rock contains more calcareous material than the beach rock found in dug wells. It suggests that exposed beach rock is well cemented (cementation is intact) on the contrary dug well beach rock is poorly cemented. (Cementation is not intact) Little amount of calcareous material in dug well beach rock indicates that the weak formation and poor development. More amount of calcareous material in exposed beach rock indicates that the better formation and well development.

Northern dug well beach rock litho-section shows a particular sedimentary sequence that is coarsening upward sequence. Therefore it indicates that the energy level of the waves increases upward. Middle dug well beach rock litho-section shows a particular sedimentary sequence that is coarsening upward sequence. Therefore it indicates that the energy level of the waves increases upward. Middle dug well beach rock litho-section does not show any particular sedimentary facies sequence. It indicates that there is no occurrence of coarsening upward sequence or fining upward sequence. As go towards the northern side the variation is seen in the litho-sections of beach rock. In stratigrahy of beach rock there is variation in the amount of sediment load carried by the waves as well as variation in the texture that is in grain size, indicates energy of transporting process and waves. Natural or anthropogenic breaks was not found in litho-section of beach rock. The tentative earlier shoreline at the distance about 200-350 meters inland away from present day shoreline can be inferred from this study.

CHAPTER I

INTRODUCTION AND LITERATURE SURVEY

The occurrence of sediments in the coastal area is the aggregate process of erosion, transportation and deposition. These processes are carried out by oceanic waves, tides, wind, currents and tsunamis. Therefore, the coastal sediments have a complex history of marine transgressions and regressions. The history of sea level fluctuations, process of sedimentation leaves their record in the coastal sediments. (Deshwandikar A.1993). This work is an attempt to investigate morphology, formation, stratigraphy, depositional environment of beach rock found along the Guhagar coast.

1.1) Beach Rock

Earth's crust is made up of various types of rocks and rocks are aggregates of minerals. All rocks that are seen on the earth classified in to three types are as igneous or primary, sedimentary or secondary and metamorphic rocks. The classification was done according to their origin. Most rocks on the surface of the earth are sedimentary. The sedimentary rocks originate from detrital material and dissolved mineral matter produced due to decomposition of pre-exciting rocks and also from the degrading remains of plants and animals (R.Ravisankar et.al.2012). Beach rock is one of the sedimentary rocks that consist of variable mixture of sediments such as gravel, sand and silt that is cemented with carbonate minerals. These are the friable to well cemented sedimentary rock formed along a shoreline.

Beach rock is the hard coastal sedimentary formations consisting of various beach sediments lithified through the precipitation of carbonate cements (R.Ravisankar et.al.2012). Beach rock are normally defined as "any part of the shore oner with shore debris such as mud,

sand, shingle, pebbles or smooth stones are cemented and accumulated in a more or less continuous sheet. (Pimple 1983). Beach rock consisting of beach material such as calcareous debris, beach sand, mineral grains and rock fragments and it is cemented by calcium carbonate.

The characteristic types of beach rock are located on the low land coastal area (Pimple1983). The percentage of marine sediments is more accumulated on the beach rock. According to Dikshit (1976) the lower part of beach rock consist of rounded gravels and percentage of marine shells increases towards the top. The characteristic of intertidal beach rock are absence of the pebbles and shells. It is mainly available of the fine sand particles and calcareous material (Pimple1983).

The dune beach rock is developed on lower horizon of the dune of the west coast of India. The lithification is important but lithification is not perfect on the dune beach rock. Dune beach rock are found between the upper beaches and littoral terraces (Pimple 1983)

The presence of beach rock appears to affect beach morphodynamics by

1. 'Locking' the beach profile.

2. Modifying the near shore hydrodynamics.

3.Changing the porous character of the beach and thus it's response to wave forcing and differential bed erosion at the margins of the beach rock outcrops that can after significantly the long and particularly the coast shore sediment transport.

1.2) Position of Beach Rock

Beach rock is formed along a shoreline that means it is forms most commonly on beaches. Beach rock are more often found 30 to 40 meters inland from the shoreline as well as they are also found up to 1 km inland from the present day high water mark (Karlekar 1981). At this distance, they are discontinuous low, narrow ridges running almost parallel to the coastline with a height rarely exceeding 3-5 m. ASL. Beach rock forms at a definite

horizon in relation to the sea level, the occurrence of beach rock above this level is a good indication that emergence has taken place. These beach rocks are running almost parallel to the shoreline with their heights hardly exceeding above sea level. It's occurrence in variable settings create complications in using it as an evidence of recent sea level fluctuation, which can be studied with the help of beach rock formation.

Beach rock is located along the coastline in a parallel term and they are usually a few meters offshore. They are generally separated in several levels which may correspond to different generations of beach rock cementations. Thus, the older zones are located in the outer part of the formation when the younger ones are on the side of the beach, possibly under the unconsolidated sand. They also seem to have a general inclination to the sea (50-150). The result from this fact is an interruptible formation of separated blocks of beach rock, which may be of the same formation. The length of beach rock varies from few meters to kilometers; its width can reach up to 300 meters. With the help of position of beach rock one can draw a tentative sea level fluctuation curve in the study area.

Intertidal beach rock is found in foreshore zone. It is mainly observed low and high tidal mark on the lower horizon of the foreshore zone. The slope of intertidal beach rock is mainly seaward. The gradient of beach rock is negligible. The aragonite-cemented beach rock is intertidal in location and its cement is of marine origin. (Stoddart and Cann 1998).

1.3) Process of Beach Rock Formation

Beach rock formation is a global phenomenon. It is a sedimentary formation commonly appearing as layered deposit inclined towards the sea. World's most beaches are sandy. For the formation of beach rock sand is must. So it forms beast on sand beaches. Conglomeratic or shingle beach rock is less abundant. Sand moved out to the ocean by rivers, due to the erosion of cliffs sand produced and it is also picked up from the sea floor is moved

toward the shore by waves. Beach rock is a peculiar formation when compared to other types of rock formations. The beach rock is developed mainly due to the marine and submarine process. The natural factor of the beach, such as gentle slope of the foreshore, sufficient shell content and ground water temperature have also favored the formation of beach rocks (R.Ravisankar et.al.2012). For the development of beach rock ground water with enough calcium to provide cementing effect is essential. Beach rock is composed of calcareous shell and coral grains, but it can be also seen in beaches of quartz sand or other mineral composition.

Beach rock has almost the same general composition as the loose beach sand over which it lies. It takes the broad morphology of the intertidal zone of the beach in which it developed and it shows similar internal structure.

Beach sediment cementation (beach rock formation) is a sedimentary process that can transform significant sections of beaches into rock outcrops. (Michalis I. Vousdoukas et.al. 2009). These are forms where a layer of beach sand becomes consolidated by secondary deposition of calcium carbonate at about the level of the water table (Russell 1962). The cementing material is precipited from ground water in the zone between high and low tide level, which is subject to repeated wetting and drying as the water table rises and fall with the tide or during and after wet weather. Some believe that calcium carbonate precipitation is brought by the action of micro-organisms, such as bacteria, which inhabit the beach close to the water table. Often cementing material is aragonite, probably derived from sea water, rather than calcite, derived from ground water (Stoddart and Cann, 1965)

It is influenced by the effects of carbonate cement-magnesium calcite initially formed in the inter-tidal zone. Beach rock forms most commonly on beaches composed of calcareous shell and coral grains, but it can also develop in beaches of quartz sand or other mineral composition. The cementing material is precipitated from ground water in the zone between high and low tide level which is subject to repeated wetting and drying as the water

table rises and falls with the tide or during and after wet weather. Fresh water penetrates a beach from swamps behind it. If the beach undergoes erosion and thus retreats, the cemented strata become exposed and form beach rock. There are several appearances of beach rock formations which are characterized by multiple cracks and gaps.

Beach rock units' form under a thin cover of sediment and generally overlie unconsolidated sand. They typically consist of multiple units, representing multiple episodes of cementation and exposure. The main processes involved in the cementation are: supersaturation with $CaCO_3$ through direct evaporation of seawater (Scoffin, 1970), groundwater CO_2 degassing in the vadose zone (Hanor, 1978), mixing of marine and meteoric water fluxes (Schmalz, 1971) and precipitation of micritic calcium carbonate as a byproduct of microbiological activity (Neumeier, 1999).

The cementation of beach rock on a beach was affected directly by the texture and structure of the beach rock and wave energy varying along the beach. (Weiwang 1997)

The cement precipitation in the coastal environment is controlled by

1. The physiochemical conditions
2. The presence of organic compounds and microbes.
3. The magnitude and distribution of the wave energy along the coast.
4. The textural characteristics of the constituent sediments.

Most of the proposed theories on beach rock cementation have strong supporting evidence making it impossible to attribute all beach rock to a single process. All theories of beach rock formation have one important factor in common: cementation must take place within the intertidal zone. This is what separates 'true' beach rock from other lithfied beach deposits. Isotopic analysis and petrographic examination are the primary tools used to

determine the process of cementation and to recognize true beach rock. Radiocarbon dating is necessary to constrain the age of the deposit and of the lithification for the beach rock.

There have been numerous mechanisms proposed for beach rock cementation by calcium carbonate (Scholten, 1972)

1. Abiotic precipitation from evaporation of seawater (Emery et al. 1954)
2. Abiotic precipitation from ground water (Russell, 1962)
3. Abiotic precipitation in the salt water fresh water mixing zone (Schmalz, 1971)
4. CO_2 degassing from beach ground waters. (Hanor, 1978)

There are three stages of beach rock formation are as follows. (Figure 1.1)

1. In the first stage beach rock forms under the sand cover of a beach near the water table.
2. Once the covering sand has been stripped away, the beach rock formation hardens in to the rock and it will be visible on the beach. The exposed beach rock ledges indicate eroding shoreline.
3. As beaches continue to erode and retreat inland the beach rock ledges may be left out in the sea. Eventually these ledges of beach rock.

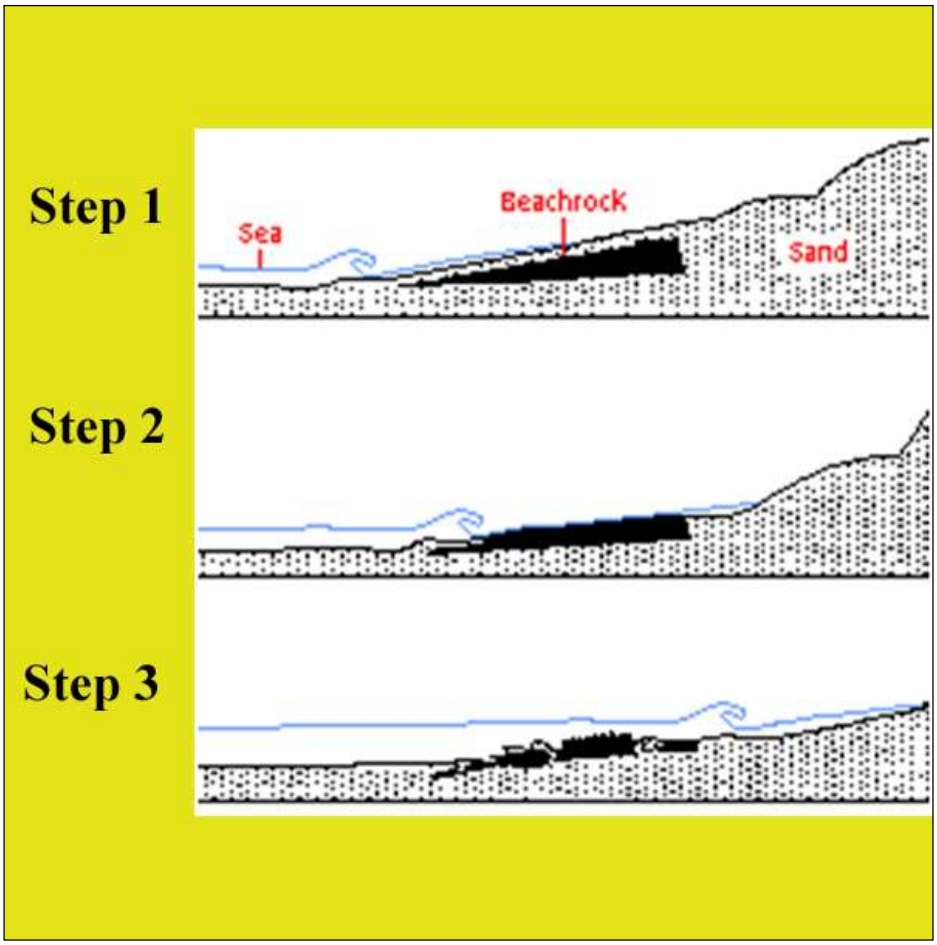

Figure 1.1: Stages of beach rock formation

Source – (www.vousdoukas.com, modified figure)

1.4) Worldwide Distribution of Beach Rock

Beach rock typically forms within the intertidal zone within tropical or semitropical regions. However, the quaternary beach rock is also found as far north and south as 60' latitude. Typical beach rock seems to have developed best along the sub-tropical and tropical coasts. (Figure 1.4) The great majority of beach rock is found in tropical / subtropical and low temperate latitude micro tidal coast as dug well as it widespread along the shores of the Mediterranean, Black, and Caspian seas. Beach rock has been also found on the shores of the Red sea, on the coasts of Brazil, South Africa and

Australia; it is commonly found on sand cays built up on reefs off tropical coast. It is reported from temperate regions but such occurrences are rare.

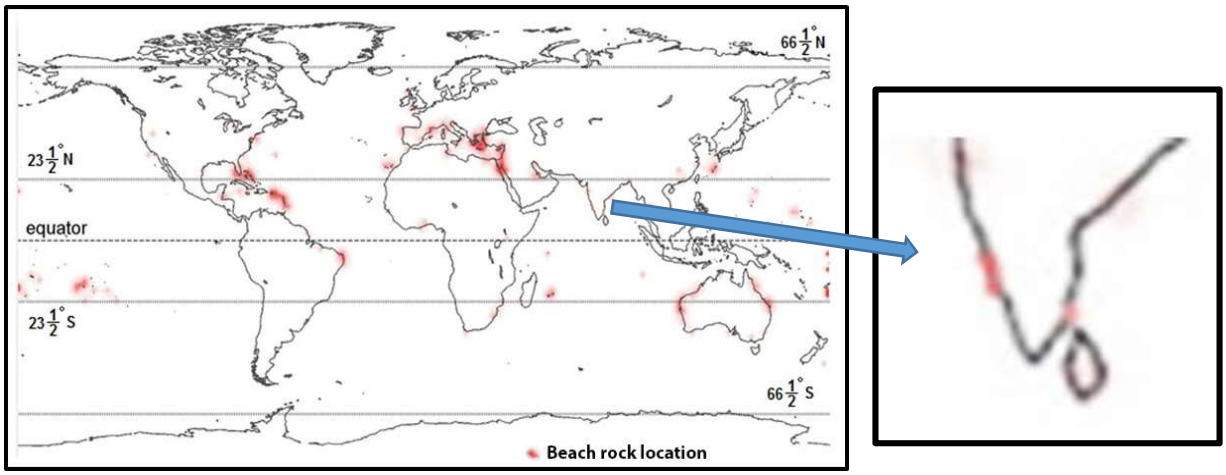

Figure 1.2: Worldwide distribution of beach rock

Source – (www.vousdoukas.com)

1.5) Beach Rock along the West Coast of India

Beach rock is found in many places in the world and few places in India. The dynamics of beaches occupied by outcropping or buried beach rocks. Its restriction to warm environments has been attributed to a requirement that interstitial water should have a temperature exceeding 20^{o} c for at least half the year in order to produce cementing of the beach sediment (Russell and McIntire, 1965b). The beach rock has not been properly studied in India. The study of such beach rock is the main aim of this work.

Geologically the region is occupied by the formation of different age's viz., Precambrian (granite and feldspathic gneisses), Cretaceous and Eocene (Deccan trap

basalts) and Tertiary and Quaternary (soils, sands, beach rock, shells and pebbles etc.) The major aspect of the West coast of India is the wide occurrence of beach rock. Along the central West coast of India several beach rock exposures have been observed in the inter tidal zone as dug well as 2-4 meters above the present day high water line (Wagle 1990). Stratigraphically these beach rocks are inferred to belong to recent formations, developed during later Holocene. The beach rock is most important on the West coast of India in inter tidal, dunel and creek beach rock. One such formation is noted on the south east coast of Tamilnadu.

The beach rock studied in course of the present work is from the beaches along West coast of India where the beaches are relatively wide. In these beaches occurrence of beach rock is the most important coastal feature. Beach rock formation on West coast of India at various distances in inland is an indicator of such fluctuation along the coast. The dune beach rocks are developed on lower horizon of the dune on the west coast of India.

1.6) Beach Rock along the Maharashtra Coast

The Sahyadri Mountain range ("Western Ghats") forms the eastern boundary of the Konkan, and the Arabian sea marks the western boundary. The fossil sediments of beach and dune are geomorphically significant along the Konkan coast. Occurrences of beach rock on Konkan coast of Maharashtra suggest a regressive sea level phase in Holocene. The beach rock along the konkan coast is calcareous, sandy, shelly deposits dating back to 2400 to 2800 YBP (Personal communication with Dr.S.N.Karlekar). These beach rock locally known as Karal are more or less parallel to the present day shoreline. Many coastal villages in the konkan are situated on such fossil ridges. Some descriptions are however certainly available and helpful (Pascoe 1964, Ahmed 1972, Setty and Wagle 1972, Dikshit 1978, Karlekar 1981, Karlekar et al 1998) they are based on field studies of limited areas. The present work is aimed

to study the morphology and stratigraphy of Guhagar beach rock and to collect the beach rock samples along the Guhagar and subjected to sediment analysis. The present contribution considers the dynamics of beaches occupied by outcropping/buried beach rocks.

1.7) Literature Review

Literature review is one of the most important stage of the study area where one tries to understand in-depth knowledge that is already in existence about the selected topic. Through literature review different components related to the study are explored. This may be directly or indirectly related to each other. Literature review helps to understand the basic concepts related to the topic and to know the methodologies adopted by various scholars in similar studies. Few research articles have been referred to understand morphology and stratigraphy of beach rock. These are as follows:

In the Robert Turners article entitled “The evolution of beach rock morphology and its influence on beach morphodynamics’’ he recognized that the impact of exposed beach rock on the event, seasonal and long term morphodynamics on a beach. The extent and morphology of exposed beach rock influence on beach processes. According to him the five distinct stages in the life cycle and morphological evolution of beach rock are identified based on research conducted on the coast of Puerto Rico.

The study of beach rocks from the south east coast of Tamilnadu, India has been done by R.Ravishankar et al.2012 by using spectroscopic techniques. The objectives of that study was to collect and review information on reported occurrences, characteristics and formation mechanism of beach rocks and applying the spectroscopic techniques for beach rock formation and evolution. Here the FT-IR and XRD technique is used to identify the constituent of minerals and cementing materials of the beach rocks.

CHAPTER II

STUDY AREA AND METHODOLOGY

2.1) Location of Study Area

The study area is located on the west coast of Maharashtra popularly known as Konkan and it is a part of Ratnagiri district of Maharashtra state. (Figure 2.1) Guhagar is well known for its virgin beach along the Maharashtra coast. Beach and coastal area of Guhagar is a well-known place of tourist attraction along the west coast of Maharashtra. The location of Guhagar is about 7 kilometers south of Dabhol. The nearest port is Jaigad about 20 kilometers to the south. It is easily approachable from Ratnagiri and Chiplun. Guhagar city has an average elevation of 10 meters (33 feet). Physiographically konkan region of Maharashtra is divided in to North konkan, Middle konkan and South konkan. The study area is the part of south konkan coast. The latitudinal extent of the study area is $17^0$28' North to $17^0$30' North and longitudinal extent is $73^0$10' East to $73^0$11' East. The length of the study area is near about 5 kilometers from north to south as well as width is near about 300 meters. The entire Guhagar is spread over narrow strip of land about 6 kilometers. Guhagar beach is near about 6.44 km long. Study area is bounded by northern and southern headlands. (Figure 2.2) Northern headland is characterized by cliff with broad rocky platform and southern headland with cliff and narrow rocky platforms is developed due to wave action. Tidal range of Guhagar is 2.5 km. (Karlekar 2009). The landward side of the beach is backed by dunes. The study area is divided in to two parts, northern in toposheet no.47G/2 and southern in 47G/3

Locally the Guhagar is divided in to three parts such as northern part known as Varchapaat, middle part is known as Devpaat and southern part is known as khalchapaat. The

study area is lies in between the two headlands. In the landward side of the beach some patches of beach rock are exposed and in the dug well larger extent of beach rock are seen.

In course of this study beach rock morphology and stratigraphy was studied at different places on Guhagar coast.

Location Map of the Study Area

(Guhagar, Maharashtra)

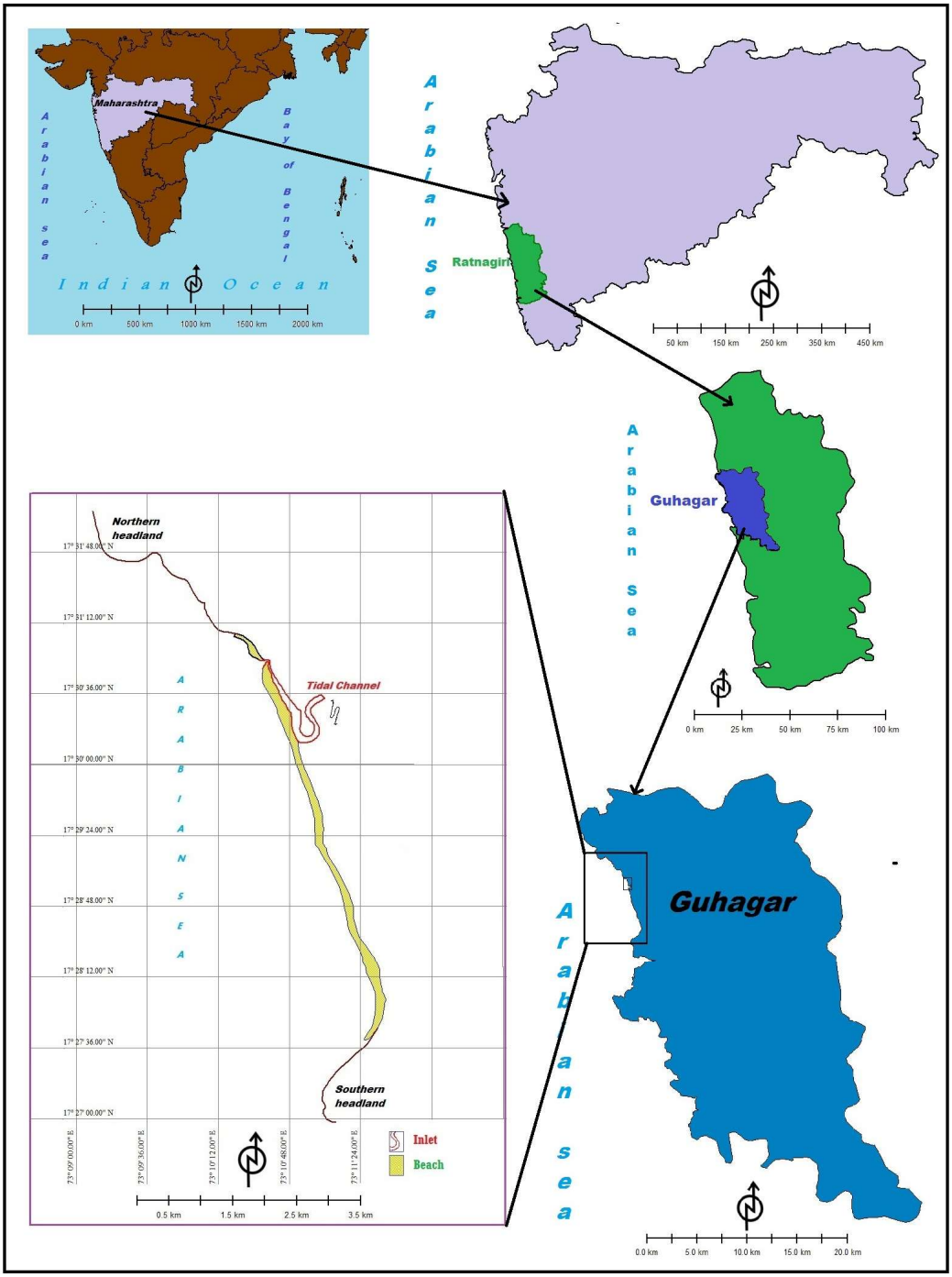

Figure 2.1: Location map of the study area

Toposheet 47G/2, 47G/3

Scale 1: 50,000

Google earth Image

23rd May 2013

Figure 2.2: Toposheet and google earth image of the study area

2.2) Climatic Condition

Climate of the study area is west coast type of climate. Indian climate is characterized by regular seasonal monsoon rainfall. Climatic condition of the study area is strongly influenced by its geographical conditions. The combine impact of Sahyadri mountain ranges and the proximity of Arabian sea is well reflected. The average annual rainfall at Guhagar is 2860 mm. The monsoon from June to September the monsoon rainfall is confined. October and November months receive late rainfall from returning monsoon. Due to the proximity of the sea the whole konkan plain is very humid.

From March, the temperature gradually rises and the humidity reaches saturation point. The summer is hot temperate and throughout the year humidity is high. Three distinct seasons can be identified as follows.

a. The summer from March to May.

b. South – West monsoon from June to September.

c. Winter season from December to February.

While October and November are climatically transitional month have average annual rainfall is about 220 millimeters and most of the rainfall is in monsoon season in which the June, July and August is the month of maximum rainfall. From October the rainfall decreases and it is very less in the month of December to April. (Figure 2.3)

The area does not show the seasonal temperature varies due to its coastal location. The annual temperature ranges from a high of 34^0c to a low of 19^0c. (Table 2.1) May is a month of maximum temperature; it is the hottest month 34^0c as well as subsequently November and December months are average high temperature. Average low temperature is more May which is 28^0c. Temperature falls down during the south west monsoon that is the month of July,

August and September. The January and February months are coldest month having average low temperature is 19^0c. (Figure 2.4)

Table 2.1: Climatic condition of the study area

Months	**Precipitation in mm**	**Temperature in ^{o} c**	
		Average high	**Average low**
January	0.8	32	19
February	1.2	32	19
March	3.3	32	22
April	5.1	32	25
May	68.6	34	28
June	801.6	30	25
July	872.2	29	25
August	650.8	29	24
September	368.0	30	24
October	128.4	32	23
November	32.4	34	22
December	6.0	33	20

(Source – Ratnagiri weather station)

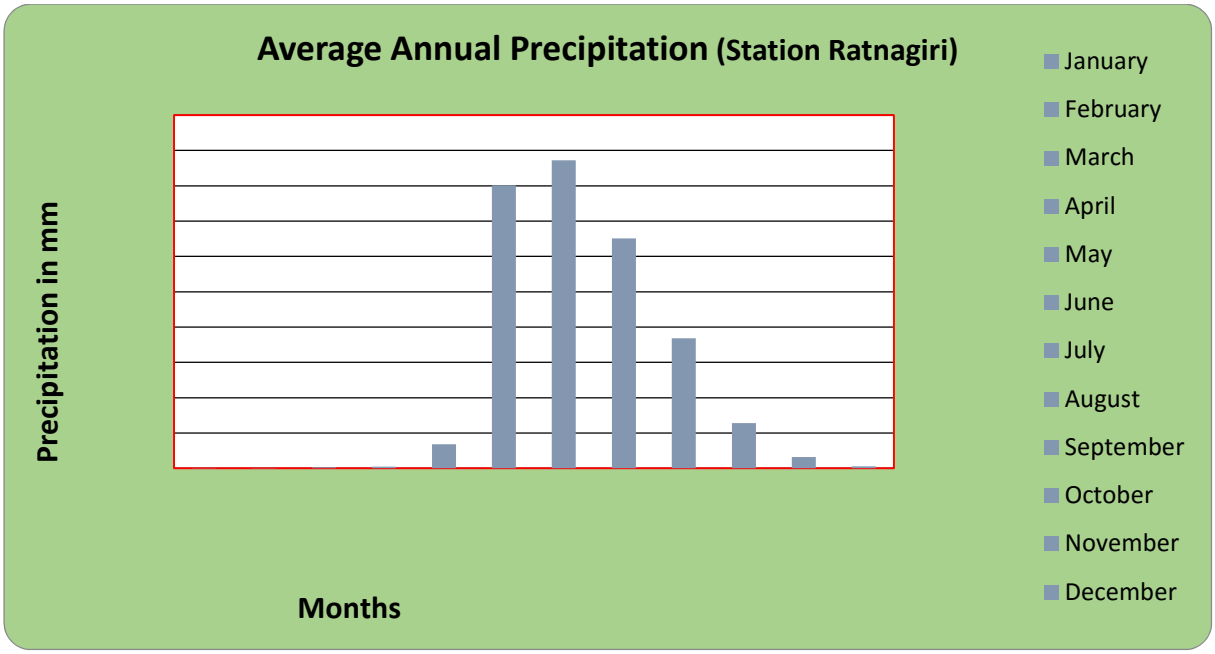

Figure 2.3: Distribution of average annual precipitation of the study area.

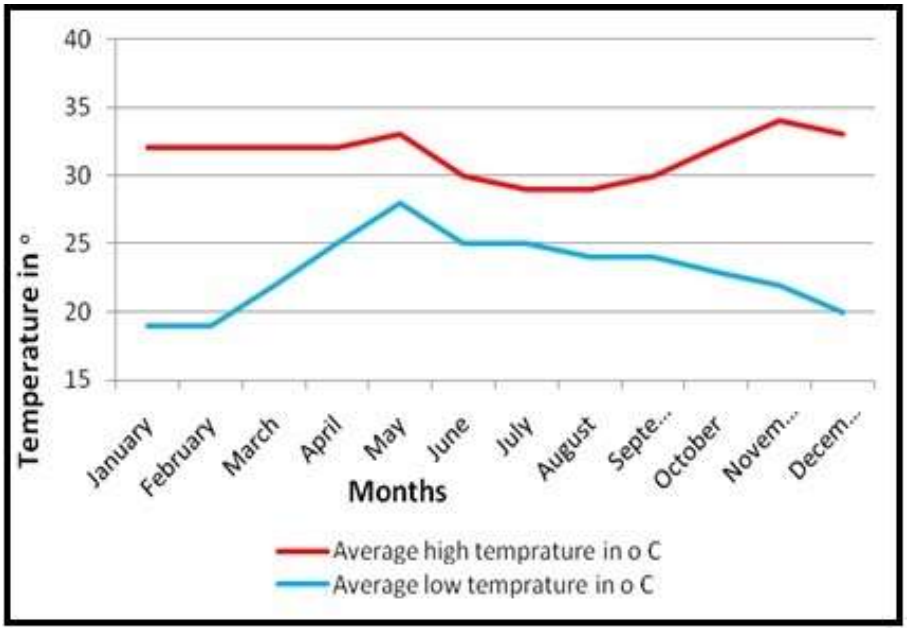

Figure 2.4: Annual distribution of average high and low temperature

(Source – Ratnagiri weather station)

2.3) Geology

The coastal area of Guhagar was covered by thick layer of laterite. As go towards the headland on both side of the study area laterites are seen. Northern headland is characterized by cliff with broad rocky platform and southern headland with cliff and narrow rocky platforms is developed due to the wave action. Only the middle part is occupied by beach rock. The studied beach rocks were formed by cementation of quaternary sediments deposited.

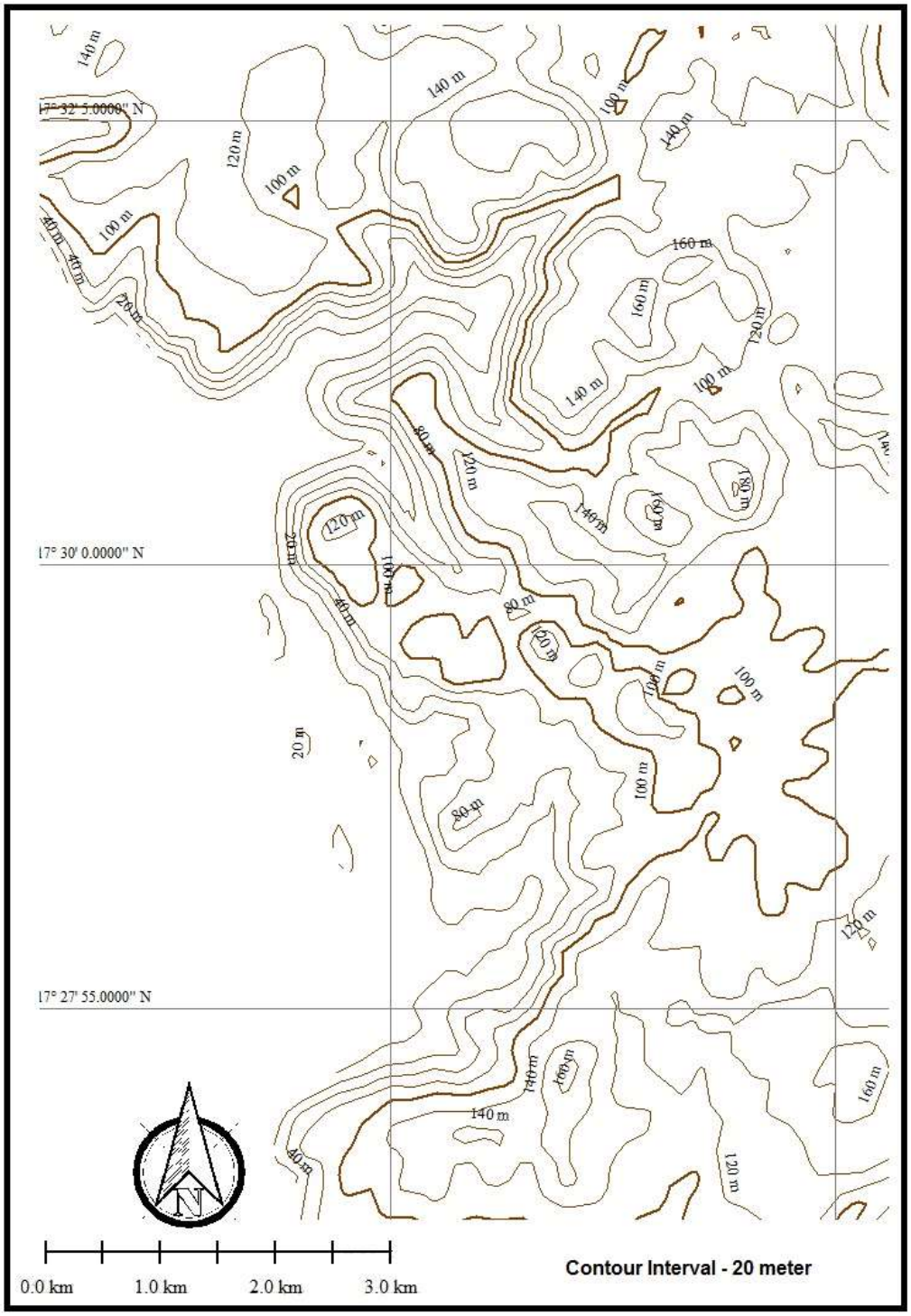

Figure 2.5: Contour map of the study area

Figure 2.5 shows the description of the contour map of the study area. With the help of contours elevation and slope was identified in the study area. The contours in the northern and southern part are close to each other so there is steep slope. Contour interval is 20 meters. Minimum contour line is 20 meters and maximum contour line is 160 meter. Northern and southern part of the study area indicates more elevated area. (Figure 2.5) In the field work beach is seen as bounded by headland in northern and southern sides. The central part shows less contours and which are not close to each other so it shows gentle slope and bay like structure with beach feature. For the formation of beach rock favorable condition is seen only at the middle part of the beach (bay like structure) that's why beach rock is mostly found in the middle part. Remaining part that is both the headland sides shows laterites.

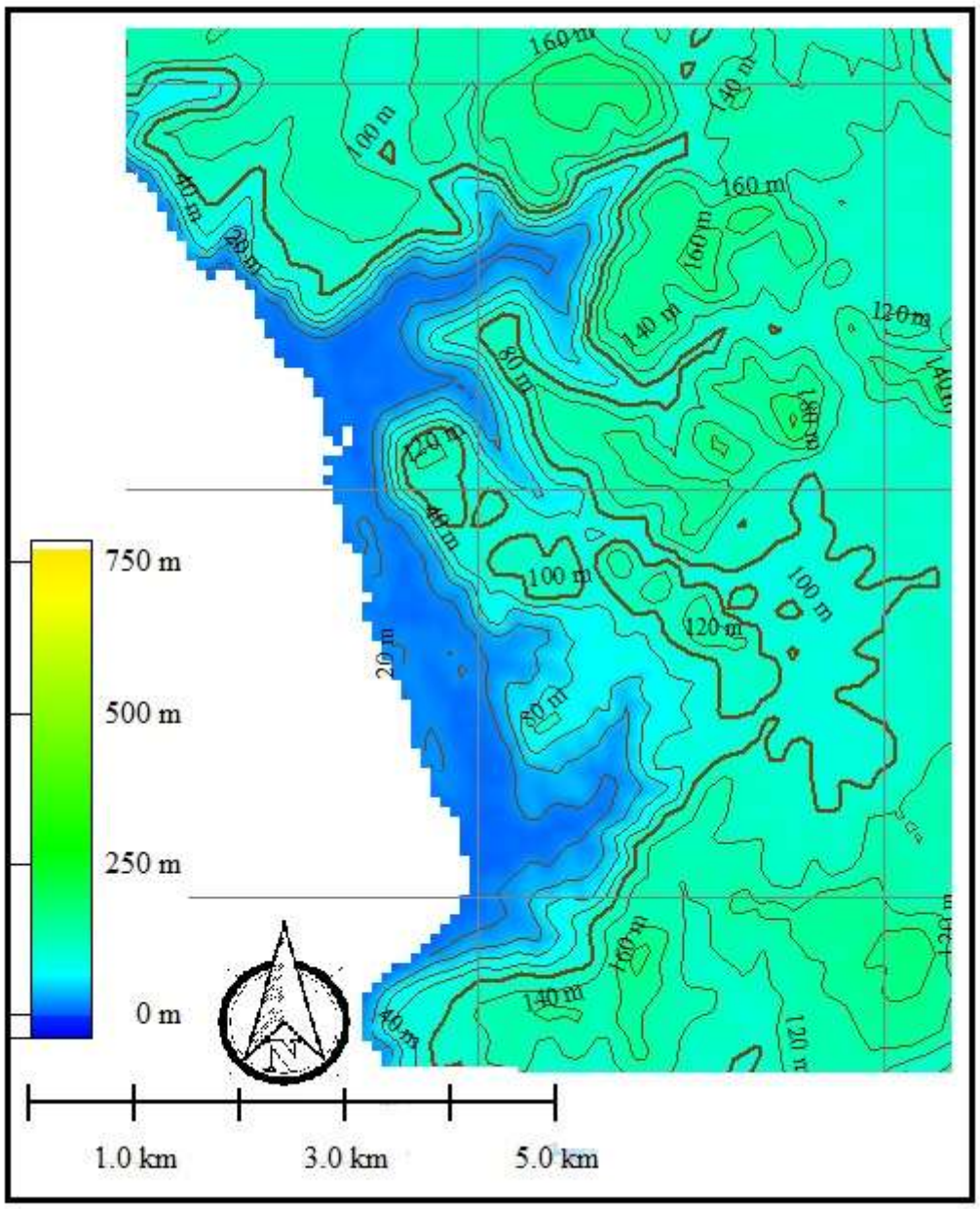

Figure 2.6: DEM of the study area

Digital elevation model is a matrix in which the elevations are given as different points equally paced in horizontal and vertical directions. To create digital elevation model of study area, in tiff format data collected from GLCF site. Index of the map shows elevation and the corresponding color used to show it.

2.4) Objectives of the Study

The main aim of the present work is geomorphic study of beach rock in Guhagar, Maharashtra. In order to achieve this following objectives have been defined.

1) To study the morphology and evaluate the stratigraphy of beach rock
2) To ascertain the orientation and trend of development of beach rock in study area.
3) To study the characteristics of sediments of beach rock.
4) To understand the formation and cementation process of beach rock.
5) To reconstruct the earlier shoreline of Guhagar.

2.5) Nature and Scope of the Problem

Large data and information is now available on the morphology of beach rock. Beach rock exposure sheets are found in inland part of Guhagar study area. (Photo 2.1) Some patches are seen at the intertidal zone of beach. The distance of beach rock from shoreline indicates the age of beach rock. The beach rock is a good indicator of the past sea levels. By using beach rock studies one can draw a tentative sea level fluctuation curve after the study of position of beach rock. In paleo- geography, stratigraphy, paleo-climatology and geomorphology the study of beach rock is of great importance. The research of beach rocks concentrated on the geomorphological action and indication of ancient sea level heights and coastal line locations as well as rock cementation processes.

Beach rock is old shore; it gives the idea about high tidal mark and low tidal mark at the time of their formation. Beach rock is very significant as they represent the former strandline and hence sea level variations. The usefulness of the beach rock residuals is that they record marked coastal retreat over a relatively short period of the late Holocene. Their

configuration provides information about the dynamic nature of retreating shore and allows a reconstruction of geomorphic history.

On retreating coasts, outcrops of beach rock may be evident offshore where they may act as a barrier against coastal erosion. Beach rock presence can also induce sediment deficiency in a beach and out-synch its wave regime. Because beach rock is lithified within the intertidal zone and because it commonly forms in a few years, its potential as an indicator of past sea level is important.

The study of beach rock is of very much help to geologist and geomorphologist because of their structure and peculiar location so geologically beach rock is most important. Beach rock influences on the barrier island developments. On retreating coasts, exposure of beach rock may be evident offshore where they may act as a barrier against development. Determining the age of beach rock is crucial to understanding the geographic location and preservation of the beach. In ancient period beach rock was used for construction of houses, they used beach rock as a brick. The evidences of that are seen in the Guhagar when primary data are obtained by interviewing the local people. Most of the settlement of Guhagar is situated on such beach rocks.

Beach rock as a keystone habitat for amphibious sea snakes. Snakes could not remain for long in the open (as a lethal body temperature was soon reached; <40 ◦C in snakes) during the day and the model cooled rapidly at night beach rock provided buffered thermal conditions. That's why it provides abundant refuges for sea snakes. (Bonnet et al 2009)

If the process of cementation continues, new beach rock would be formed in a new position in the intertidal zone. Successive phases of sea level change may result in sequential zones of beach rock. Study of the stratigraphy of beach rock gives idea about particular sedimentary sequence, process of deposition, wave energy, depositing environment, breaks in between the strata, and surface of contact between the two vertical neighboring strata.

Photo 2.1: Exposed beach rock near the creek located with shovel

2.6) Methodology

Methodology is one of the important part of analysis. Output or result of analysis is highly depending on the methodology used for the data processing or analysis purpose. Various aspects of beach rock were surveyed and mapped from 2011 to 2013. The surveys were conducted to understand the morphology and sedimentology of beach rock. Stratigraphical study were done to understand the variation in the beach rock litho-section as well as to identify sedimentary sequences.

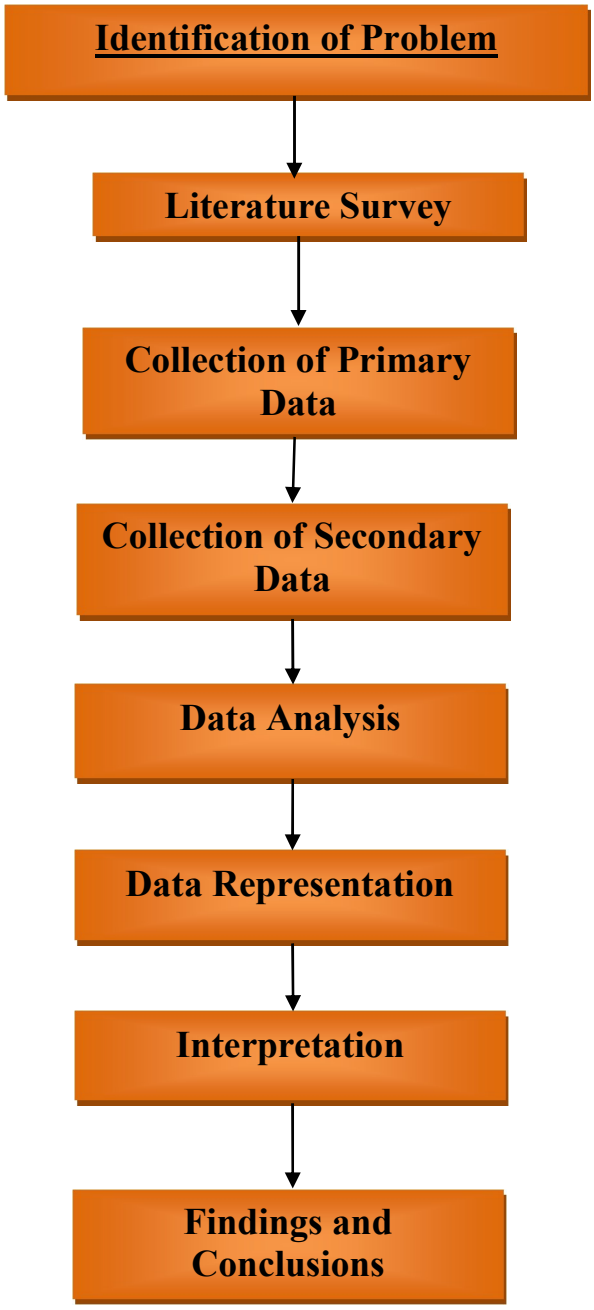

Figure 2.7: Methodology adopted for the present work.

In order to achieve the aim and objective of the study, methodology adopted is categorized in to the following stages.

- Pre-field work
- Field work
- Post field work

1) Pre Field Work Phase:

To identify the beach rock, various images of beach rock collected from various websites and books. Literature survey was done by using various research papers, books, articles, published/unpublished M. Phil, Ph.D. thesis etc. and then to plan for the field work. Obtained the toposheet and google maps of study area for the field work. The study area is divided into two parts, northern in toposheet number 47G/2 and southern in toposheet number 47G/3.

2) Field Work Phase:

Pilot field survey carried out to understand the area occupied by beach rock, nature and trend of development, morphology and stratigraphy of beach rock in the study area.

In order to study the morphology and stratigraphy of the beach rock in the field, analytical procedure were selected. The major part of the data and information of the work is collected directly in the field. This part of the study required instruments for measurements like measuring tape for the measuring length, width, depth, thickness etc. of the study area. GPS was used to obtain elevations and locations were demarcated. The shovel and hammer are also used, to collect the sediment samples. For the collection of primary data such as dug well depth, thickness of beach rock strata, water table, depth of beach rock etc. 14 dug wells with larger extent of beach rocks were selected and 6 exposed beach rocks are found in the study area. The locations of that exposed beach rock which is shown in the map. The samples were collected at 6 locations E1 to E6 using global positioning system (with accuracy up to 8m). In each location 200-300 grams bulk of beach rock samples were collected in a polythene bags to ascertain the properties of the beach rock. The measurements of the height, depth, thickness, were taken by the tape. (Table 3.1 and 3.2). In order to study the litho-stratigraphy of beach

rock at Guhagar three dug wells were selected randomly to represent the study area. First dug well is in the northern sector, second dug well is in the middle sector and third dug well is in the southern sector. Sediments facies with specified characteristics were identified on the basis of color, texture, internal structure, bounding surface and special characteristics. Thickness of each facie measured with the help measuring tape. The stratum wise sampling were done in the litho-sections of three dug wells. By using hammer and shovel the samples of 200-300 grams were collected in each stratum of litho-section to identify particular sedimentary sequence, process of deposition, wave energy, breaks in between the strata, surface of contact between the two vertical neighboring strata. Field observations are recorded photographically.

Photo 2.2: Collection of beach rock sediment samples from dug well

3) Post Field Work Phase

- Georeferencing of collected maps.
- Digitization of analogue data into digital format.
- Thematic maps
    1) Contour Map.
    2) Digital Elevation Model
- Laboratory analysis.

Collection of Elevation Data:

The data for DEM is collected from internet (ASTER GDEM site)

Table 2.2: Details of DEM data

Dataset	Acquisition year	Location
ASTER degree tiles	2010	Guhagar

DEM image is also georeferenced by above method; this image was used for creation of slope map.

- ## Laboratory Analysis

1) Sediment Analysis

The information thus obtained in the field was used for further analysis and mapping. To fulfill the object of understanding the sediment size and depositional process total 16 beach rock sediment samples were collected from the study area. 10 samples were collected from dug wells and 6 samples of exposed beach rock.

Samples thus collected in field were sieve mechanically to get the proportion of particles in different size group. A unit of 100 grams of each sample was passed through a set of 10 sieves such as 710, 600, 500, 355,300, 250,212, 150, 90 and 63 microns, the last pan collected sediment less than 63 microns select samples which had a higher percentage of sediment below 63 microns.

The data obtained through sediment analysis was used to determine major parameters like mean size, sorting index, skewness and kurtosis. This work was done by a technique of 'Folk and Ward'. Gradistat was used to obtain grain size parameters. It shows a textural group of the obtained sediment samples. The variation in the sediment distribution is plotted graphically. The mathematical and statistical techniques were also used whenever required. Pit was excavated 3-4 feet deep to identify and study the various strata in the beach rock profile.

Different software's were used for further analysis of data required during field work and laboratory component. A google image for the year 2010 was used for digital mapping. Arc GIS 9.3 version software was used and different parameters studied were depicted in cartographic maps using this software.

2) Calcium Carbonate Analysis

In order to study the compactness of beach rock calcium carbonate analysis method was used. It is useful to obtain the percentage of calcareous material in the sediment sample of beach rock. This method is used for the study of cementation of beach rock. For the calcium carbonate analysis concentrated hydrochloric acid was used which is 38% normality. Because calcium carbonate dissolved in HCL. If the acid is higher concentrated the reaction will be quicker so concentrated hydrochloric acid is used.

Calcium carbonate analysis method followed is given below.

10 grams of sediment sample was reacted with concentrated hydrochloric acid (HCL pure 38% normality) by using beaker. After the reaction of concentrated hydrochloric acid, the calcareous material is dissolved. The non calcareous material does not dissolve in the Hydrochloric acid. The materials after reaction was dried by using oven then weight the material and note the reading in notebook.

CHAPTER III

MORPHOLOGY AND SEDIMENTOLOGY

3.1) Morphological Characteristics of Beach Rock

There is every reason to believe that the beach rock in Guhagar is more a result of marine processes than the result of ground water fluctuation in coastal area. Mostly their formation is influenced by climate. The beach rock development has always got some influence of ground water seepage (Ressel and McInfire 1965) Climate control operates through warm sea water, saturated with calcium carbonate, high rate of evaporation and upward capillary movement have through the sand grains. The beach rocks are found mostly in the backshore of the study area in the dug wells. Very few partly visible exposed patches of beach rock are occurred in the backshore zone. These discontinuous low beach rock patches are parallel to the shoreline. The gradient of beach rock in the study area is negligible and it is inclined towards the sea.

The beach rocks are found on coasts where shore is retreating (Davis 1977). The fact which suggest the negative changes of sea level along the Guhagar coast. The lowest inland limit of the beach rock in the study area is 185 meters (exposed beach rock no.2), (Table and Figure 3.1) away from the present day shoreline as well as the highest inland limit of the beach rock in the study area is 335 meters (dug well beach rock no.12) (Table and Figure 3.2) away from the present day shoreline. Hence on the basis of position of exposed beach rock and beach rock from dug wells, the exposed beach rock is relatively modern and beach rock in dug wells is older. The length of study area is 4.5 km north to south and width is near about 300

meters from east to west. Dug wells in the study area are almost parallel to the shoreline. So the beach rock found in these dug well sections up to the 200 to 350 meters inland, thus almost shows a parallel ridge position to the shoreline. Hence it is the earlier shoreline of Guhagar which is near about 200-350 meters away from the present day shoreline and the elevation of earlier shoreline is near about 7 to 10 meters from mean sea level. The elevation of exposed beach rock of Guhagar from mean sea level is 6 to 9 meters (Table 3.1) and the beach rock which is found in dug wells at the elevation of 7-10 meters from mean sea level. (Table 3.2) Beach rock found in the study area is at the average depth of 3 meters and it found in the dug wells at the maximum depth of 6.30 meters. (Table 3.2) The thickness of beach rock is more in the middle part of the study area and it decreases towards the both side that is northern and southern side. Most of the Guhagar settlement is situated on such beach rock. The occurrences of beach rock in the study area suggest that negative change in sea level along the beach has taken place. It indicates that the Guhagar shore is retreated. The distance also indicates the age of beach rock. In Guhagar there is creek beach rock occurred which is found slightly inland from nearby the creek. Beach sediment cementation (beach rock formation) is a sedimentary process that transform the significant section of old Guhagar beach into the rock. The thickness of exposed beach rock in litho-section E1 is minimum 0.18 meters and maximum is 1.80 meters in Litho-section E5 (Table 3.1)

According to Wagle (1990), Guhagar beach rock is believed to have been formed in an intertidal environment during regressive phase of the sea. The beach rock in Guhagar is discontinuous low, narrow ridges running almost parallel to the coastline. The dug wells are found at certain distance in inland in a straight line indicates the earlier shoreline. The present beach rock under study was visited in the 5

times in 2011 and 2012. The structure of beach rock litho-section shows horizontal lamination with flaky and blocky structure. (Photo 3.1)

Photo 3.1: Litho-section of beach rock shows flaky structure with horizontal lamination

Table 3.1: Measurements of exposed beach rock

Exposed beach rock	Sample	Lat/Long	Elevation from mean sea level (m)	Thickness (m)
1	E-1	$17^0$29.180N $73^0$11.213E	09	0.18
2	E-2	$17^0$28.792N $73^0$11.354E	06	0.20
3	E-3	$17^0$28.780N $73^0$11.355E	07	0.50
4	E-4	$17^0$30.190N $73^0$10.917E	09	0.60
5	E-5	$17^0$30.194N $73^0$10.920E	08	1.80
6	E-6	$17^0$28.780N $73^0$11.355E	09	0.70

(Source – Fieldwork)

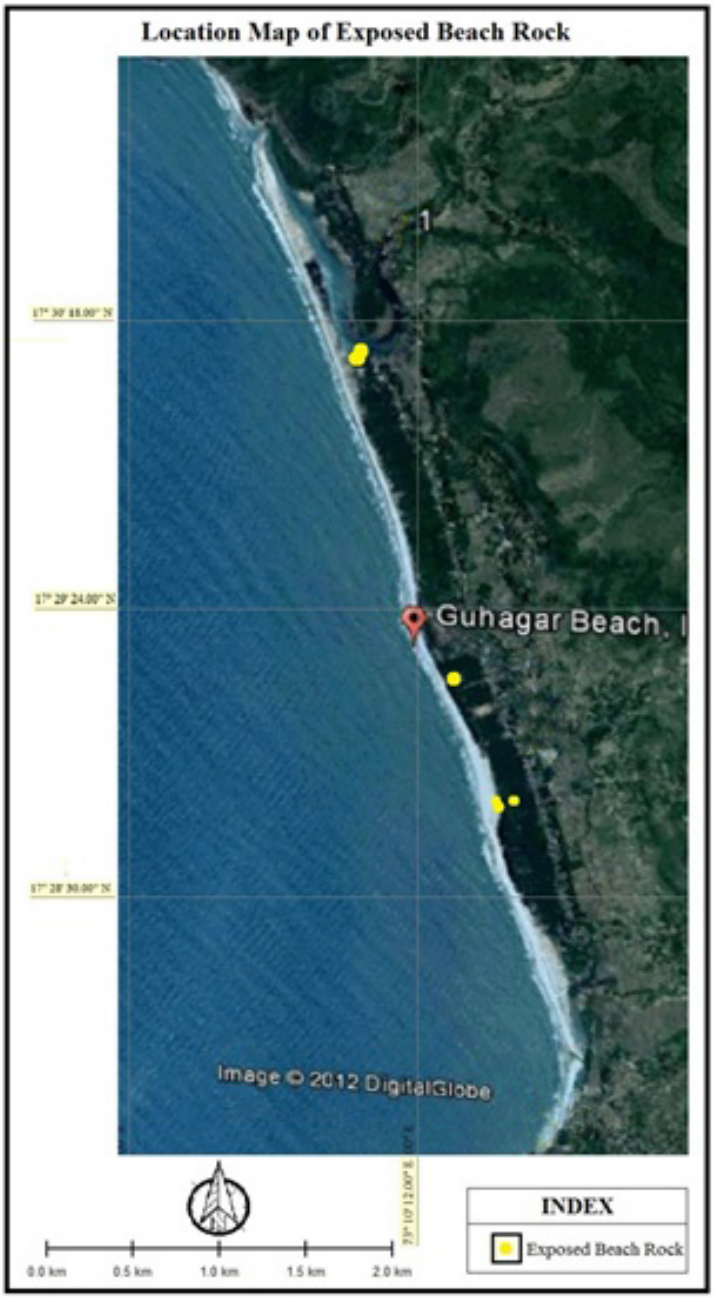

Figure 3.1: Exposed beach rock locations

Table 3.2: Measurements in dug wells

Dug well No.	Lat/Long	Elevation from mean sea level (meters)	Beach rock found in dug wells at the depth from (meters)	Beach rock found in dug wells at the depth up to (meters)	Water table (meters)
1	$17^0$28.997N $73^0$11.356E	09	4.30	5.40	3.30
2	$17^0$29.016N $73^0$11.345E	08	3.60	5.80	3.50
3	$17^0$29.033N $73^0$11.336E	09	4.40	6.10	4.50
4	$17^0$29.034N $73^0$11.338E	09	3.60	5.60	3.80
5	$17^0$29.057N $73^0$11.318E	08	4	6.10	5.20
6	$17^0$29.145N $73^0$11.275E	10	3.40	5.20	3.40
7	$17^0$29.180N $73^0$11.252E	09	3.10	5	4
8	$17^0$29.236N $73^0$11.225E	10	2.85	4.90	3.20
9	$17^0$28.776N $73^0$11.413E	08	5.40	5.90	3.70
10	$17^0$29.679N $73^0$11.149E	09	3.40	6.30	5.20
11	$17^0$29.918N $73^0$11.048E	09	3.20	5.10	4.50
12	$17^0$28.310N $73^0$11.609E	7	0	3.40	2.60
13	$17^0$29.662N $73^0$11.156E	09	0.60	5.20	3.60
14	$17^0$28.690N $73^0$11.443E	10	0.20	5.90	4

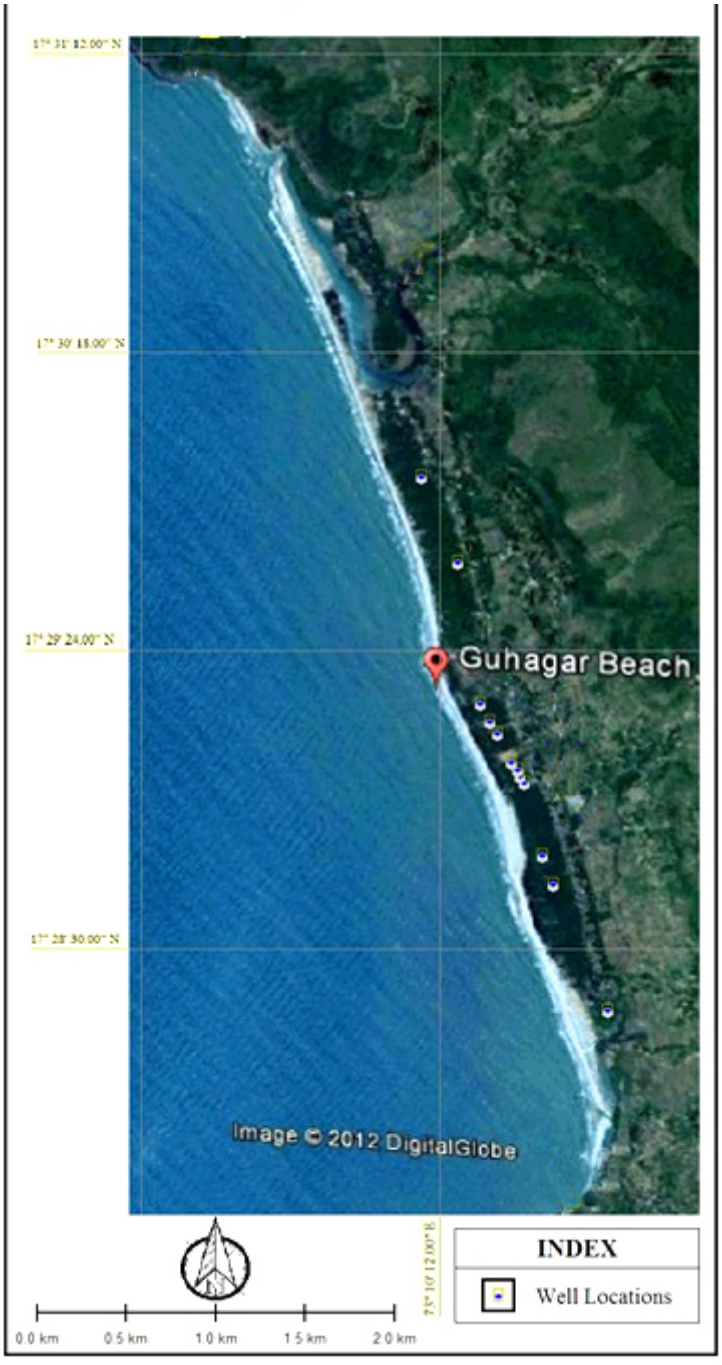

Figure 3.2: Dug well locations in the study area

3.2) Formation and Orientation of Beach Rock

The growth of calcareous material on coastal rock and calcium deposits after the recession of high tides. In this, tidal water is saturated with calcium carbonate. However, the amount of calcium carbonate is possibly not so much as to produce tide platform and beach rock. High temperature and higher capillary movement of water is responsible for the deposition of calcium on sand grains. Calcium carbonate is supplied to the beach by the shoreward transport of the shells and skeletons of marine organisms as well as corals. In the beach rocks calcium carbonate found in the form of calcite or aragonite. Formation of aragonite is favored by higher temperature and so aragonite rich sands are more common in lower latitudes, whereas calcite sands are more common at higher latitudes. Due to the higher temperature of Guhagar and location in lower latitudes aragonite is rich in beach rock. Occurrence of beach rock in Guhagar coastal area indicates the favorable conditions for beach rock formation, such as availability of essential calcium on beach, gentle slope of the foreshore and ground water temperature. Depending on location, the sediment that is cemented to form beach rock can consist of variable mixture of shell, coral fragments, rock fragments of different types, other materials. Beach rock in the study area have north to south orientation.

The progressive growth of precipited layer creates matrix of shells and sand grains successive wave attack partly removes the material in between the grains, but the tidal range being low, precipitation over rides the erosion and the beach rock is formed due to splashing of wave it gets craggy appearance. These rock are completely apposed when the sea receads. The sub aerial processes of erosion which then follows start destroying the rock. If the depositional processes in the near shore zone are more effective than the sub aerial erosion in the course of time, a thick layer of coastal

alluvium conceals the beach rock formations. In Guhagar, beach rock are conceals by a layer of coastal alluvium. It indicates on that points the heavy deposition in recent geologic period takes place.

Guhagar beach rock is sandy and sand is derived in Guhagar may be from three different sources: first source is sand moved out to the sea by Vasishthi, Shastri rivers and from some streams. Second source is sand produced by erosion of cliffs which are found in the northern and southern headlands. Third source is sand picked up from the sea floor and moved toward the shore by waves.

In Guhagar because of heavy rainfall the sediment material of coastal area is transported with water comes towards the ocean and from these material some of the deposited on the beach as well as when the high tide takes place then the water comes in the creek with marine sediment and which is responsible for the deposition of thick layer on beach rock.

3.3) Sediment Analysis of Exposed Beach Rock

In the sediment analysis of six exposed beach rock, the textural group of beach rock sediment sample is sand. It indicates that the main component of beach rock is sand. No pebbles or coarser material was found in sediment analysis. The beach rock is made by only sand and calcareous material. It suggests that Guhagar beach was sandy at the time of the formation of beach rock. In exposed beach rock sediment samples the percentage of silt is very low. Composition of Guhagar beach rock is sand, silt, shells, titanium oxide, calcium carbonate and rock fragments. The nature of beach rock varies from north to south in the study area. After the sediment

analysis of beach rock some sediment parameters were obtained such as mean, sorting, skewness and kurtosis which are as follows.

Table 3.3: Textural analysis of exposed beach rock sediment samples

Sediment sample	*Sample type*	*Textural group*	*Sediment name*	*Mean* (Φ)	*Des.*	Sorting (Φ)	*Des.*	Skewness	*Des.*	Kutosis	*Des.*
E - 1	***B.P.S.***	***sand***	***M.W.S.C.S***	***1.740***	***M.S.***	**1.058**	**P.S.**	**0.095**	**Symm.**	**1.055**	**M.K.**
E - 2	***T.P.S.***	***Sand***	***M.S.C.S.***	***2.360***	***F.S.***	**1.061**	**P.S.**	**-0.111**	**C.S.**	**0.846**	**P.K.**
E - 3	***T.P.S.***	***sand***	***P.S.C.S.***	***2.163***	***F.S.***	**1.241**	**P.S.**	**-0.235**	**C.S.**	**0.774**	**P.K.**
E - 4	***B.M.S.***	***Sand***	***M.S.C.S.***	***1.033***	***M.S.***	**0.935**	**MS**	**0.739**	**V.F.S.**	**1.309**	**L.K.**
E - 5	***T.P.S.***	***sand***	***M.S.C.S.***	***1.858***	***M.S.***	**1.209**	**P.S.**	**0.135**	**FS**	**1.013**	**M.K.**
E - 6	***T.M.S.***	***sand***	***P.S.C.S.***	***2.659***	***F.S.***	**0.893**	**MS**	**-0.336**	**V.C.S.**	**1.237**	**L.K.**

3.4) Sediment Parameters

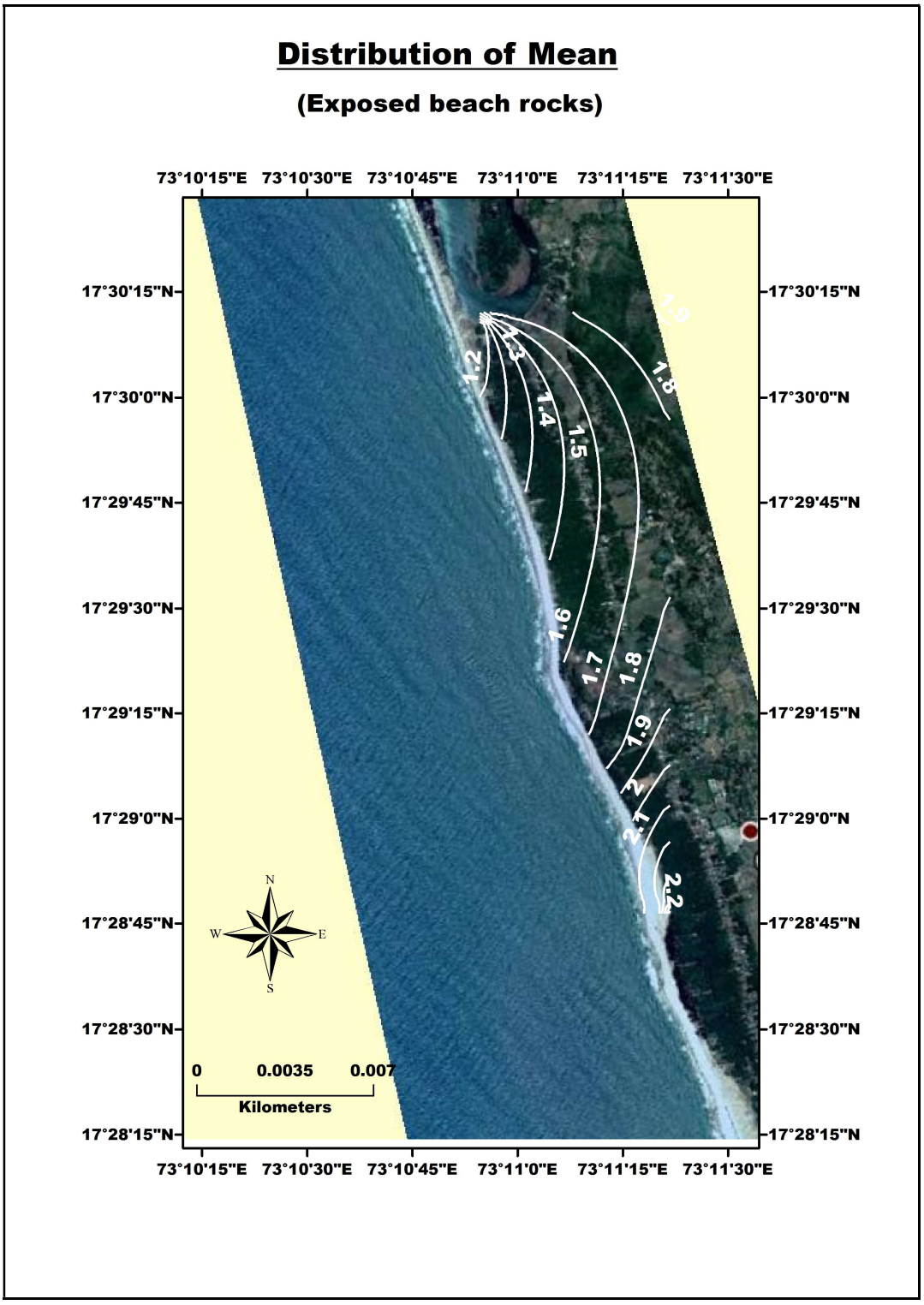

Figure 3.3: Distribution of mean

a) Distribution of Mean Sediment Size

It gives idea about average particle size. It is the best graphical measure for determining overall size of the particle in the sediment sample. The obtained value of mean sediment size ranges from 1.033 Φ to 2.659 Φ (Table 3.3). It is seen from the values that all the exposed beach rock mean sediment size ranges between medium sand and fine sand. It suggests that the overall size of the particle in the sediment samples of beach rock belong to medium and fine sand category. (Table 3.3) It reveals that condition of ancient beach.

Phi value of mean sediment size is less in the northern side so the amount of medium sand is more in northern side and the phi value of sediment size is more in the southern side indicates concentration of fine sand. (Figure 3.3)

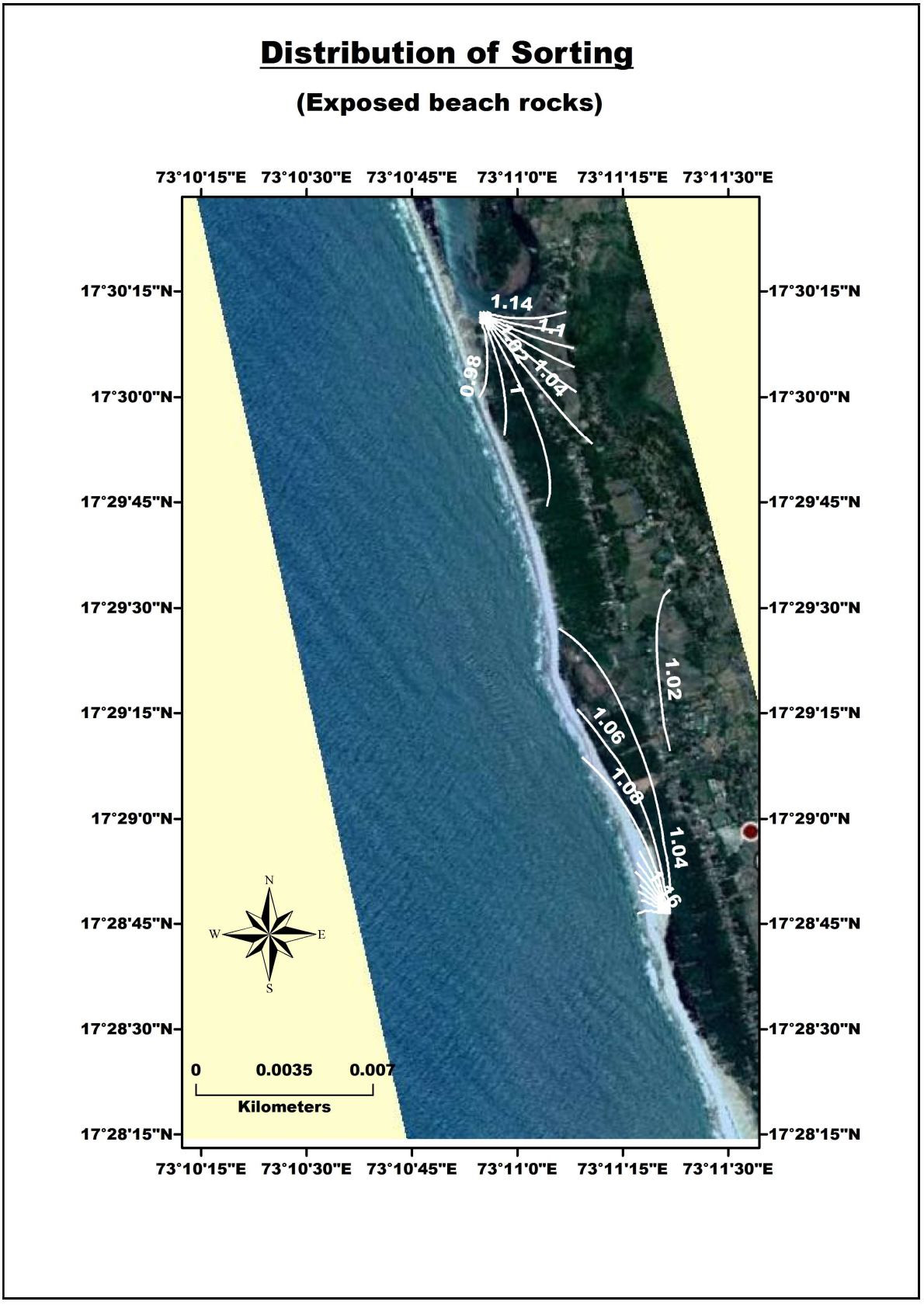

Figure 3.4: Distribution of sorting

b) Sorting index

It measures the sorting or uniformity of the particle size distribution within a sediment sample. The derived values of sorting index are varying between 0.893 Φ and 1.241 Φ. In the Guhagar beach rock sediment samples the E4 and E6 are moderately sorted it means there is moderate mixing of different size particles. Therefore, there is medium homogeneity in the size of particles. The calculated value of the remaining sediment samples E1, E2, E3 and E5 that is 1.058Φ, 1.061Φ, 1.241Φ and 1.209Φ respectively are poorly sorted. (Table 3.3) It means that there is mixing of different size particles. It indicates that there is no homogeneity or uniformity in the size of particles of beach rock sediments. In the northern side of the study area the value of sorting index increases landward and decreases seawards. It indicates that landward side sediments are poorly sorted and seaward side sediments are moderately sorted. On the contrary, southern side sorting values are increases seaward and decreases landward. (Figure 3.4) Sorting value in the southern side indicates the sediments are poorly sorted.

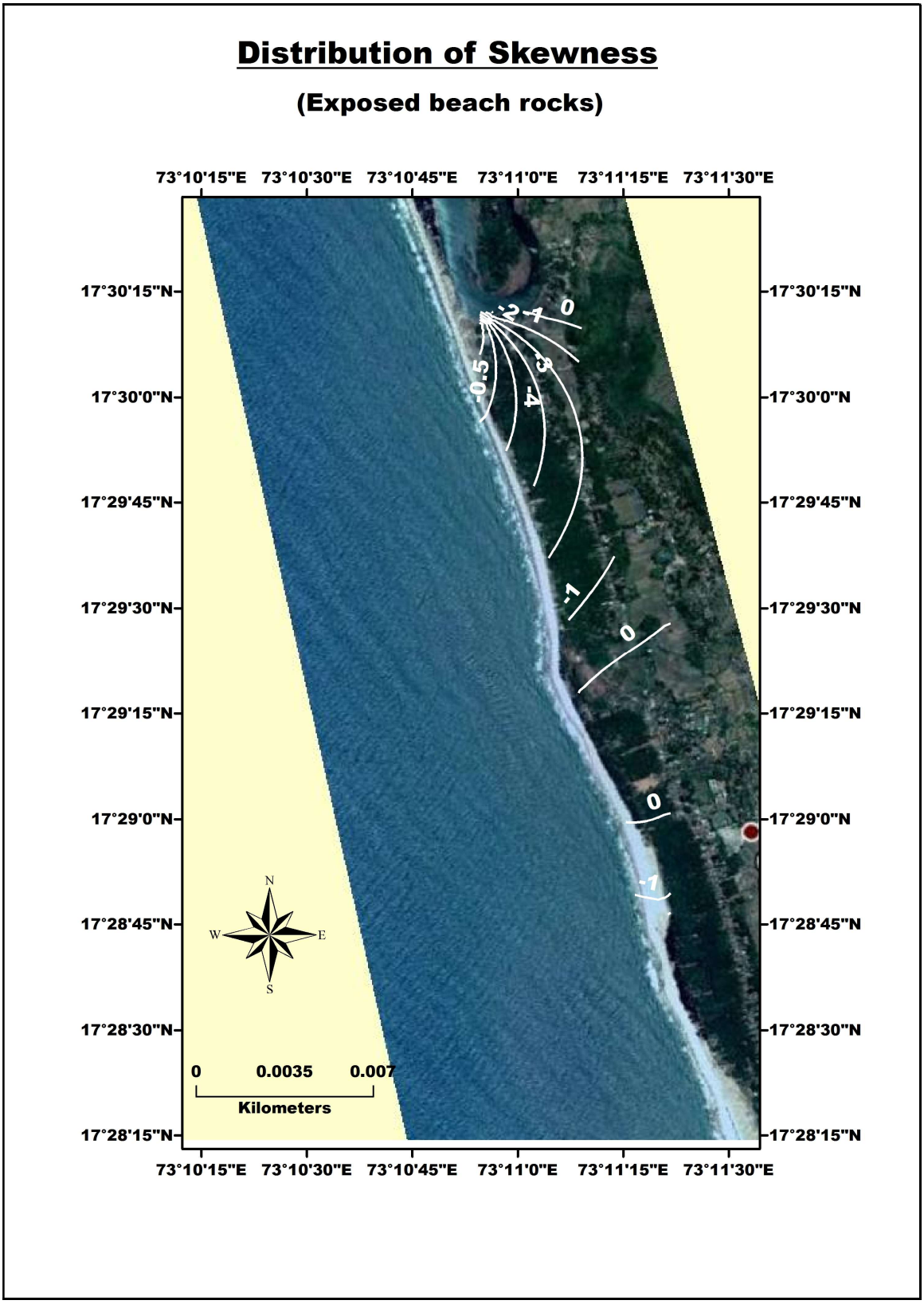

Figure 3.5: Distribution of skewness

c) Skewness

It is a measure of the asymmetry of the grain size distribution in sediment sample. If there is more presence of coarser material in the sediment sample, then the sample is coarse skewed that is negative skewed. If there is more presence of finer material in the sediment sample, then the sample is fine skewed that is positive skewed. Skewness is always expressed by positive (+) or negative (-) signs. The skewness value is pure number and should not be written with phi (**Φ**).

In all the exposed beach rock sediment samples, the variation is seen in the skewness value. Skewness value ranges between -0.336 to 0.739. E-1 sample is near symmetrical. E-2 and E-3 samples are coarse skewed it means there is more presence of coarser material. E-4 and E- 5 is very fine skewed and fine skewed respectively indicates abundance of fine material. E-6 has very coarse skewed that is negative skewed means more presence of coarser material. (Table 3.3)

In the northern side of the study area the concentration of coarser material is seen. The concentration is symmetrical in the middle side. Almost all the sediments are negatively skewed in the study area so the negative skewness is more in the study area. (Figure 3.5) It reveals that there is abundance of coarser particles in the beach rock sediment samples.

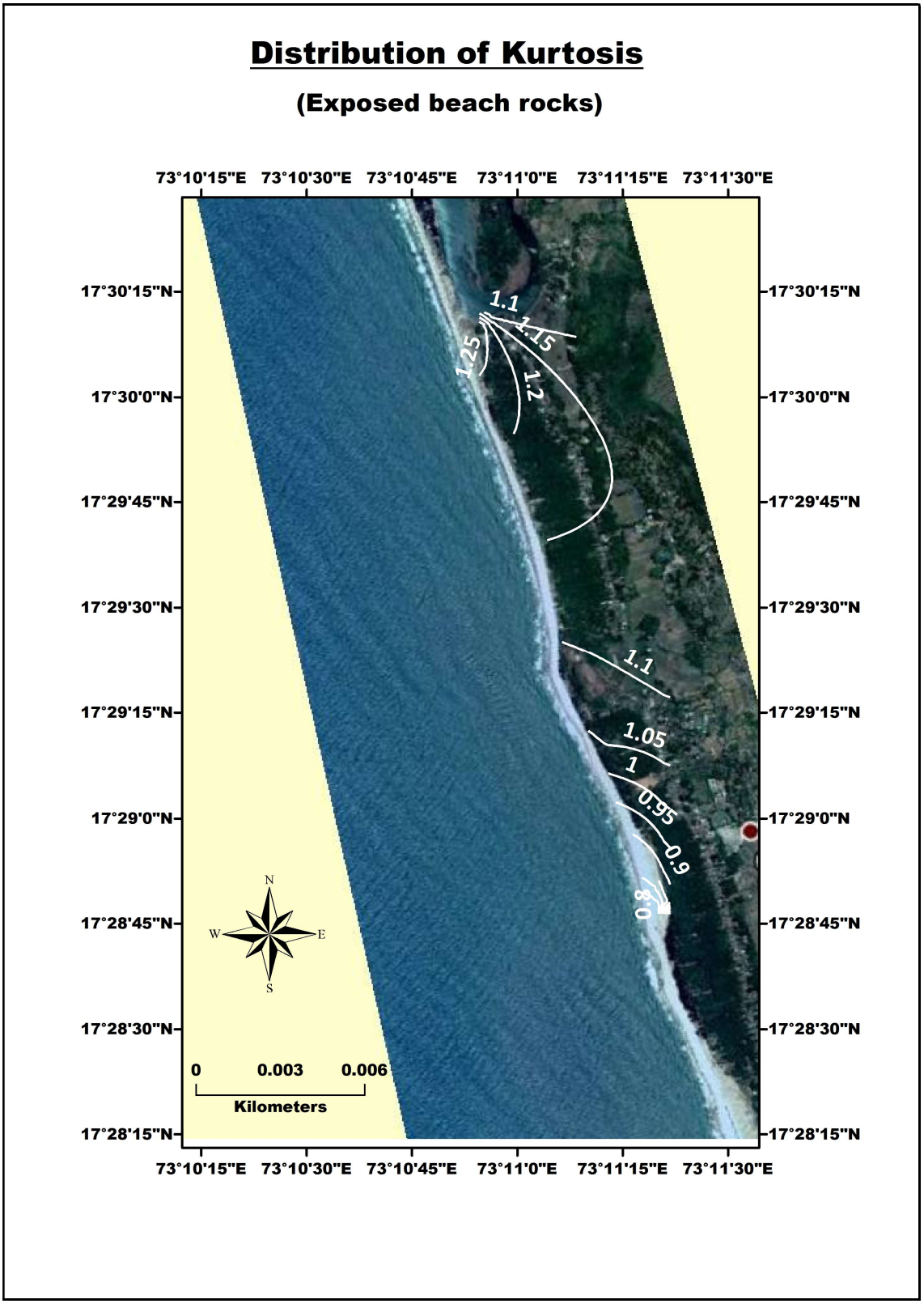

Figure 3.6: Distribution of kurtosis

d) Kurtosis

Kurtosis measures the ratio between the sorting in tails of the distribution and the sorting in the central portion of the distribution. It gives idea about degree of concentration of the grains to the central side. If the distribution is excessively peaked, then it is called leptokurtic. If it is flattened it is called platykurtic. If the distribution is medium peaked, then it is called mesokurtic.

In Guhagar study area the exposed beach rock sediment samples are leptokurtic, mesokurtic and platykurtic in nature. The kurtosis value is ranges between the 0.774 and 1.309 (Table 3.3). From southern to northern side value of kurtosis has been increases (Figure 3.6). Less value in the southern side indicates platykurtic nature of the sediments it means there is no concentration of grain size class. It suggest that all the sediment particles distributed throughout the sediment sample. Middle part indicates material is mesokurtic in nature. Northern part shows the material is in leptokurtic category. It means that there is concentration of particular grain size class means sediment particles are the uniform in size all over the beach rock.

3.5) Sediment Properties

Table 3.4: Grain size distribution of exposed beach rock sediment samples

Sediment sample	% of sand	% of coarser sand	% of medium sand	% of fine sand	% of very fine sand	% silt
E 1	97.9	21.2	37.6	27.1	12	2.1
E 2	95.8	13.7	24.1	31.5	26.5	4.2
E 3	96.3	20.7	20.6	25.3	29.7	3.7
E 4	96.9	63.9	19	9	5	3.1
E 5	95.2	23.8	30.5	25.9	14.9	4.8
E 6	98.9	7.5	11.2	42.4	37.8	1.1

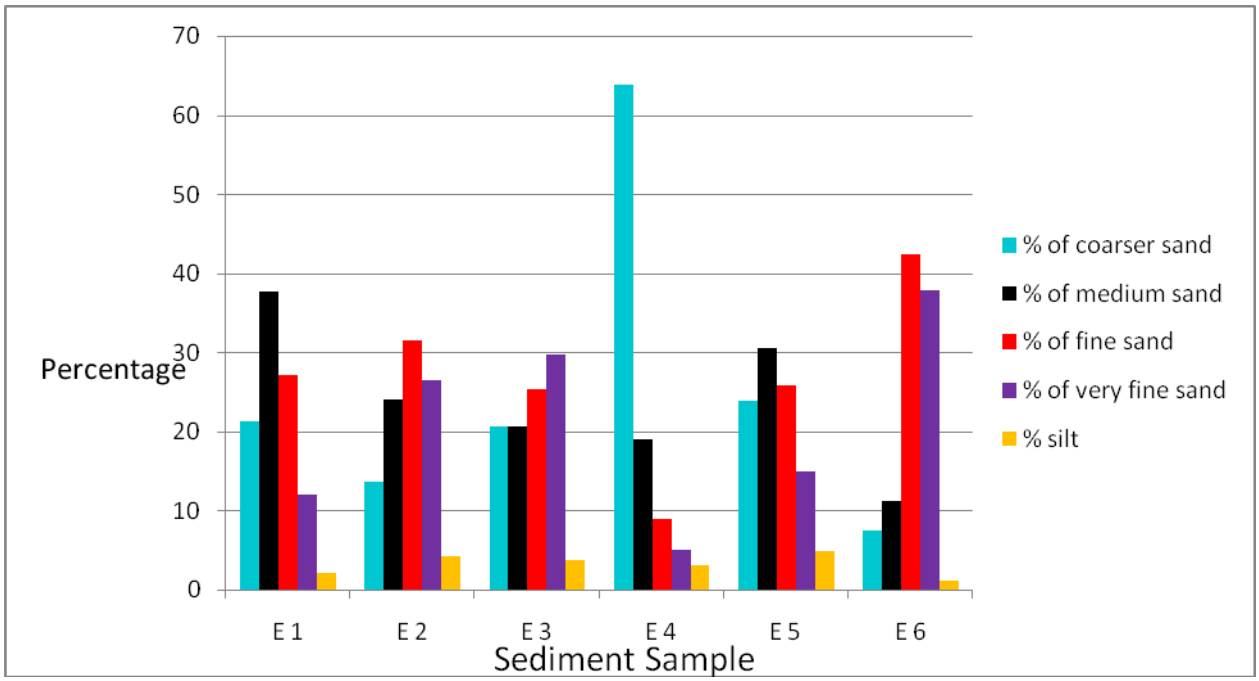

Figure 3.7: Grain size distribution of exposed beach rock sediment samples

For the formation of beach rock, sand is dominantly necessary. Here textural group of sediment sample is “sand”. Doornkamp (1974) the higher, medium grain sizes suggest more wave energy and the lower grain size suggest less wave energy. In the textural analysis of beach rock sediment samples the mean sediment size is ranges between dominantly medium and fine sand. Grain size distribution shows percentage of coarser, medium, fine sand and very fine sand. Percentage of coarser sand is more in E4 sediment sample which indicates more wave energy at the time of beach rock formation in that area. Percentage of silt is very less in all the exposed beach rock sediment samples. (Figure 3.7) There is variation seen in the percentage of coarser, medium, fine and very fine sand in exposed beach rock sediment samples. It shows wave environment at the time of beach rock formation in study area.

Location - Latitude – 17.51134 N **Elevation from msl -** 4 meters

Longitude- 073.18086 E

Beach rock found at the depth – 0.90 meters

Photo 3.2: Beach rock in the pit in inland area.

Table 3.5: Textural analysis of beach rock sediment samples in dug wells

Sediment sample	*Sample type*	*Textural group*	*Sediment name*	*Mean Φ*	*Des.*	Sorting Φ	*Des.*	Skewness	*Des.*	Kutosis	*Des.*
N 1	***T.P.S.***	***sand***	***P.S.C.S.***	***1.467***	***M.S.***	**1.134**	**P.S.**	**0.219**	**F.S.**	**0.592**	**V.P.K.**
N 2	***T.P.S.***	***Sand***	***P.S.F.S.***	***2.170***	***F.S.***	**1.064**	**P.S.**	**- 0.710**	**V.C.S.**	**0.751**	**P.K.**
N 3	***B.P.S.***	***sand***	***P.S.F.S.***	***1.924***	***M.S.***	**1.150**	**P.S.**	**- 0.463**	**V.C.S.**	**0.574**	**V.P.K.**
N 4	***T.P.S.***	***Sand***	***P.S.F.S.***	***1.853***	***M.S.***	**1.139**	**P.S.**	**- 0.323**	**V.C.S.**	**0.609**	**V.P.K.**
M 1	***T.P.S.***	***sand***	***P.S.F.S***	***1.927***	***M.S.***	**1.092**	**P.S.**	**- 0.334**	**V.C.S.**	**0.754**	**P.K.**
M 2	***B.M.S.***	***sand***	***P.S.F.S.***	***2.120***	***F.S.***	**1.122**	**P.S.**	**- 0.745**	**V.C.S.**	**0.707**	**P.K.**
M 3	**T.P.S.**	***sand***	***P.S.C.S.***	***1.659***	***M.S.***	**1.098**	**P.S.**	**-0.139**	**C.S.**	**0.636**	**V.P.K.**
S 1	***B.P.S.***	***sand***	***P.S.C.S***	***1.170***	**M.S.**	**1.167**	**P.S.**	**0.765**	**V.F.S.**	**0.504**	**V.P.K.**
S 2	**T.P.S.**	**sand**	**P.S.F.S.**	**1.808**	**M.S.**	**1.143**	**P.S.**	**-0.277**	**C.S.**	**0.560**	**V.P.K.**
S 3	**T.P.S.**	**sand**	***P.S.C.S***	**1.281**	**M.S.**	**1.128**	**P.S.**	**0.496**	**V.F.S.**	**0.667**	**V.P.K.**

Photo 3.3: Collection of beach rock sediment samples from dug well

Photo 3.4: Strata wise sediment sampling of beach rock litho-section in dug wells

Table 3.6: Grain size distribution of beach rock sediment samples in dug wells

Sediment sample	% of coarser sand	% of medium sand	% of fine sand	% of very fine sand
N 1	43.6	19.5	25.4	11.5
N 2	19.8	13.2	41.9	25.1
N 3	27.1	10.7	39.8	22.5
N 4	26	16.8	37	20.2
M 1	20.3	17.9	41.2	20.6
M 2	21.5	11	40.3	27.2
M 3	33	23.7	32.8	10.5
S 1	58.2	6.7	22.7	12.4
S 2	27.5	19.5	34.6	18.4
S 3	52.5	17.6	20.4	9.6

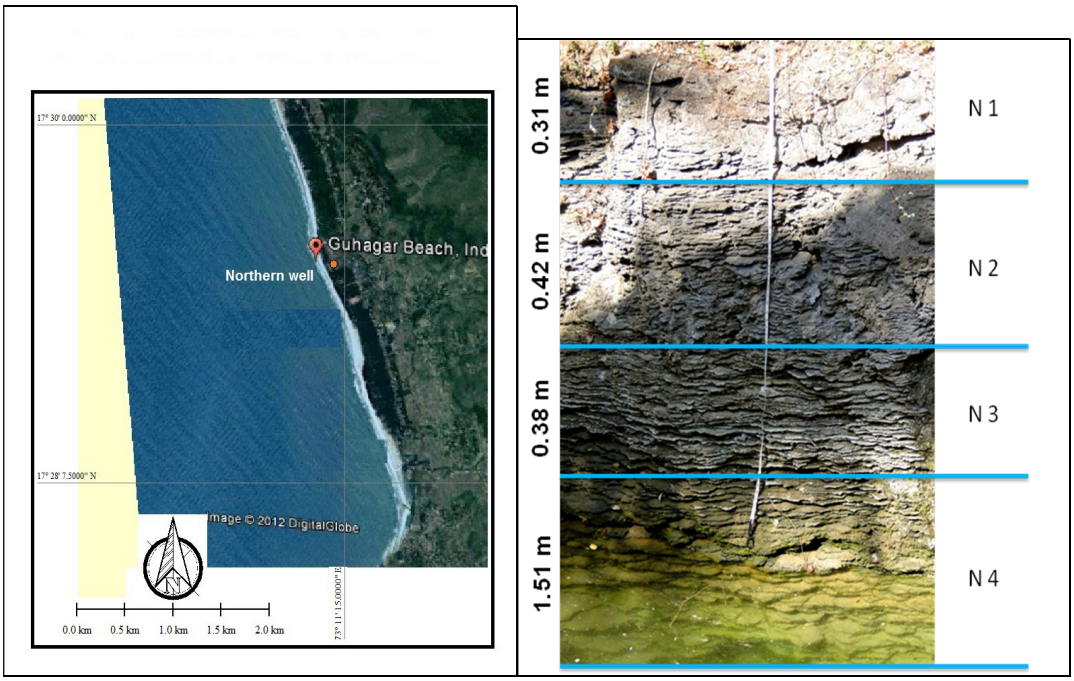

Figure 3.8: Location of northern dug well and litho-section of beach rock

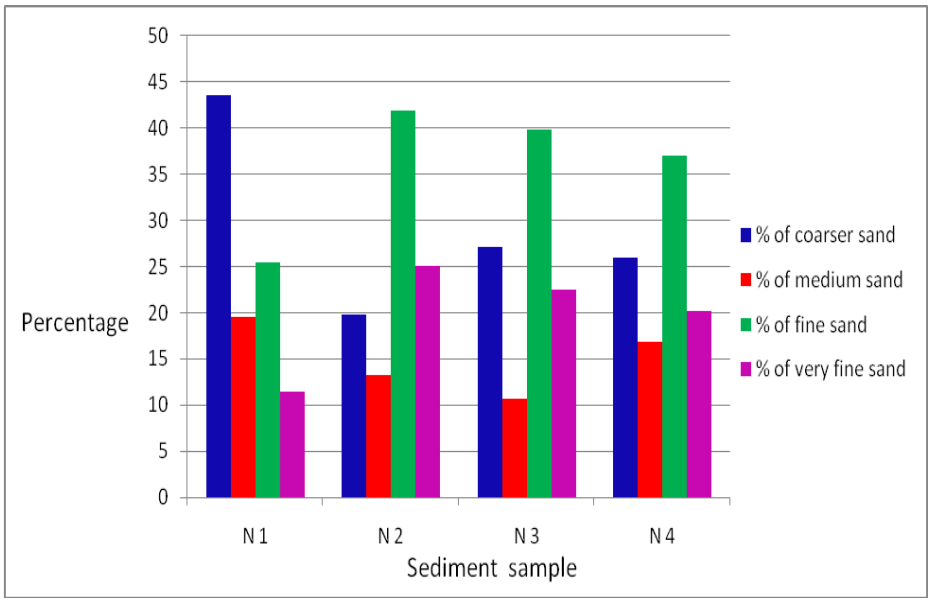

Figure 3.9: Grain size distribution of beach rock sediment samples in northern dug well litho -section

In the grain size distribution of northern dug well litho-section it indicates that the proportion of fine sand is more and percentage of medium sand is less as compared to other grain size in the sediment samples. (Figure 3.9) In the first facie the proportion of coarser sand is more indicates more wave energy and the percentage of very fine sand is less. Second, third and fourth layer that is N2, N3 and N4 proportion of fine sand is more indicates less wave energy environment at the time of formation beach rock. Percentage of medium sand is less in these stratums. (Table 3.6)

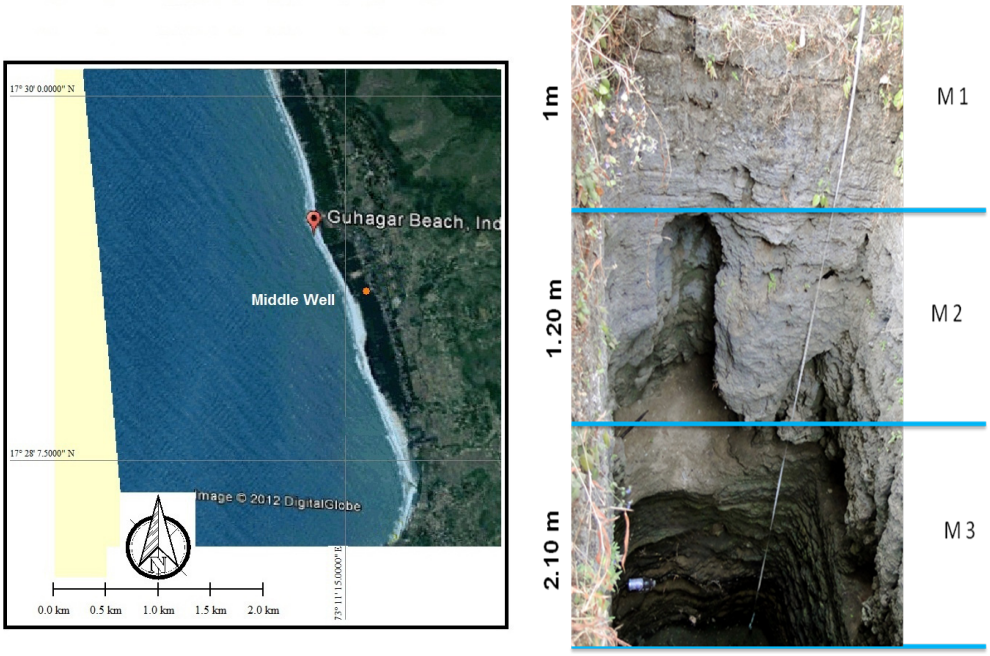

Figure 3.10: Location of middle dug well and litho-section of beach rock

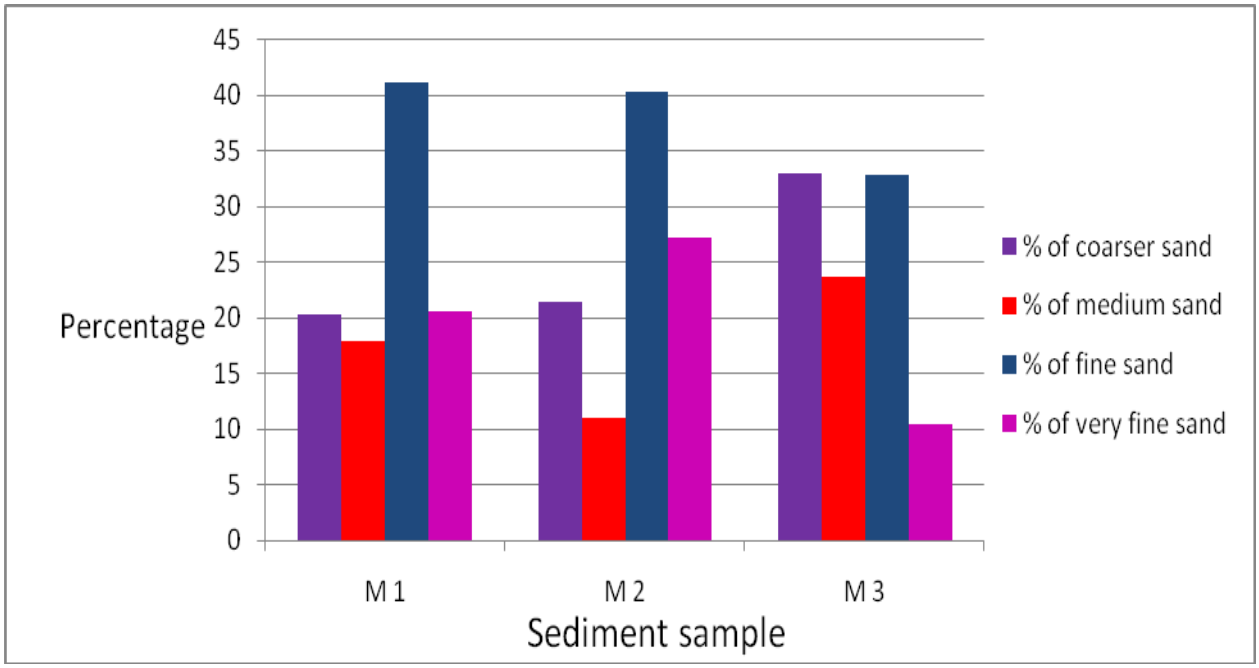

Figure 3.11: Grain size distribution of beach rock sediment samples in middle dug well litho-section

In the grain size distribution of beach rock sediment samples in middle dug well litho-section the proportion of fine sand is more in the entire sediment sample and the percentage of medium sand is less as compared to other grain size (Figure 3.11). More amount of fine sand in the entire litho-section indicates less wave energy eviroment at the time of formation of beach rock. In the first and second facie the proportion of fine sand is more and the percentage of medium sand is less. Third layer that is M3 proportion of coarser sand is more and the amount of very fine sand is less. **(**Table 3.6)

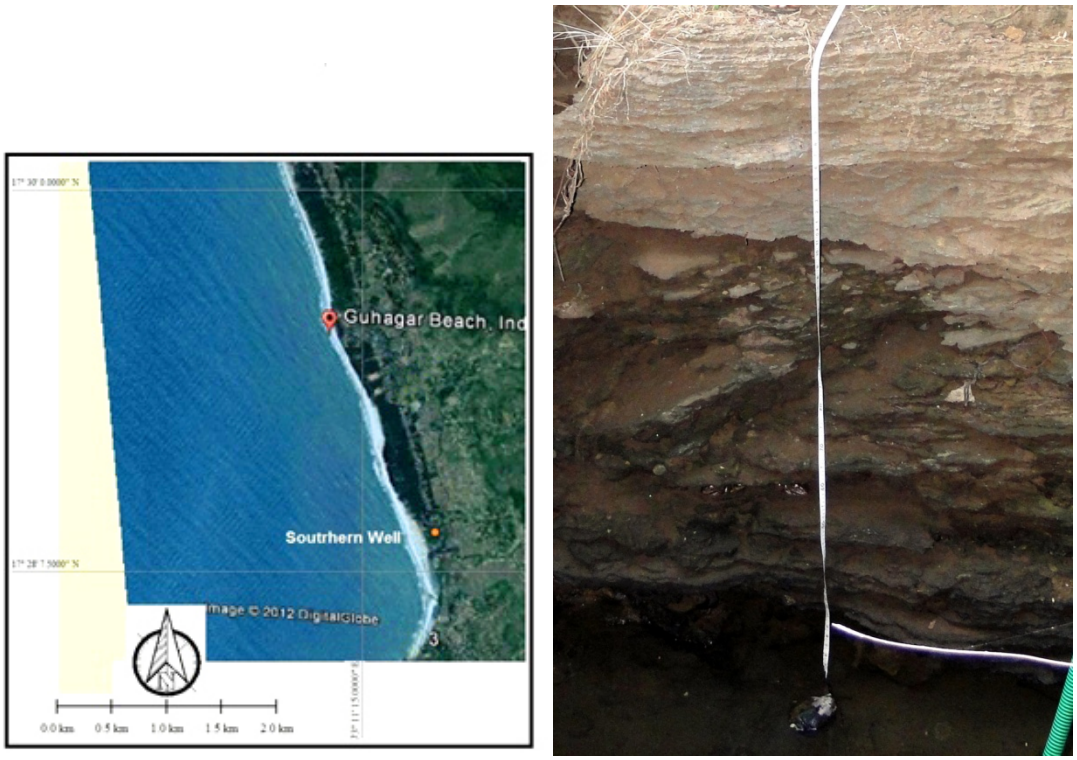

Figure 3.12: Location of southern dug well and litho-section of beach rock

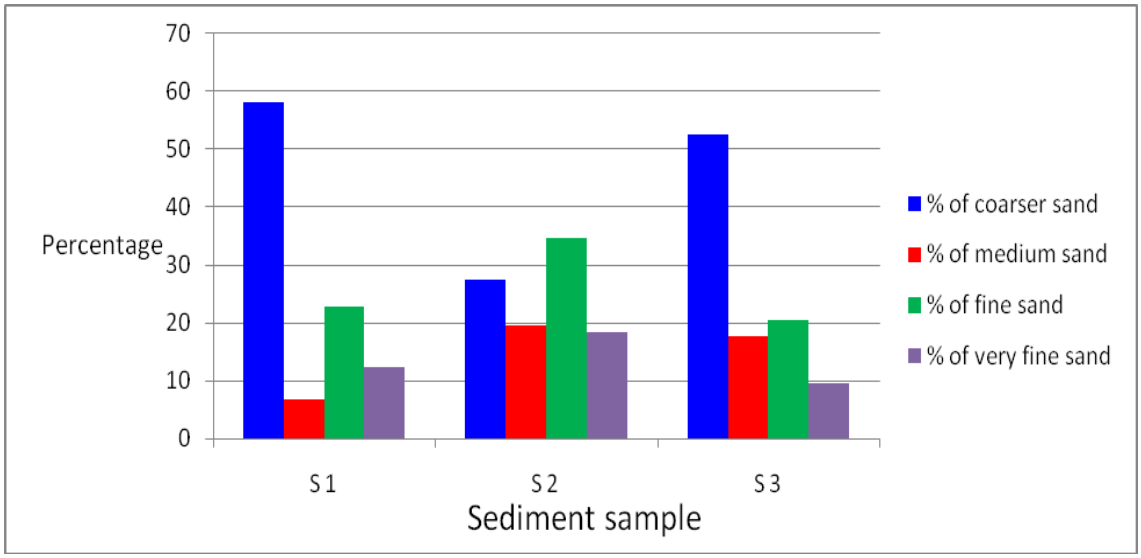

Figure 3.13: Grain size distribution of beach rock sediment samples in southern dug well litho-section

In the grain size distribution of southern dug well litho-section indicates that the proportion of coarser sand is more and proportion of very fine sand is less. (Figure 3.13) It reveals that more wave energy environment at the time of beach rock formation. In the first facie the proportion of coarser sand is more and the proportion of medium sand is very less. In the second layer that is S2 proportion of fine sand is more and very fine sand is less. Third layer has high proportion of coarser sand and less proportion of very fine sand. **(**Table 3.6)

From the above grain size distribution in all the three beach rock litho-sections in dug wells shows that the proportion of coarser material is more in southern part shows more wave energy at the time of beach rock formation. But in middle and northern side the occurrence of fine sand is more in beach rock sediment samples of litho-sections suggest that the wave energy decreases in middle and southern part of study area. It reveals the wave environment at the time of beach rock formation.

3.6) Calcium Carbonate Analysis of Exposed Beach Rock

In the calcium carbonate analysis of exposed beach sediment samples E1 and E3 sediment samples has more presence of calcareous material as compared to other exposed beach rock sediment samples, so these two exposed beach rock have better formation and well cementation as compared to other exposed beach rock sediment samples. E6 exposed beach rock sediment sample has less presence of calcareous material as compared to other exposed beach rock sample. So it has weak formation and poor cementation. E2, E4 and E5 exposed beach rock sediment samples has medium cementation (Figure 3.14) Cementation variation is seen in entire exposed beach rocks.

Table 3.7: Calcium carbonate analysis of exposed beach rock samples

Sediment sample	Weight of sample (gms)	Weight of non calcareous material (gms)	Weight of calcareous material (gms)	% of non calcareous material	% of calcareous material
E 1	10	6.48	3.52	64.8	35.2
E 2	10	7.21	2.79	72.1	27.9
E 3	10	6.10	3.90	61	39
E 4	10	7.58	2.42	75.8	24.2
E 5	10	7.63	2.37	76.3	23.7
E 6	10	8.06	1.94	80.6	19.4

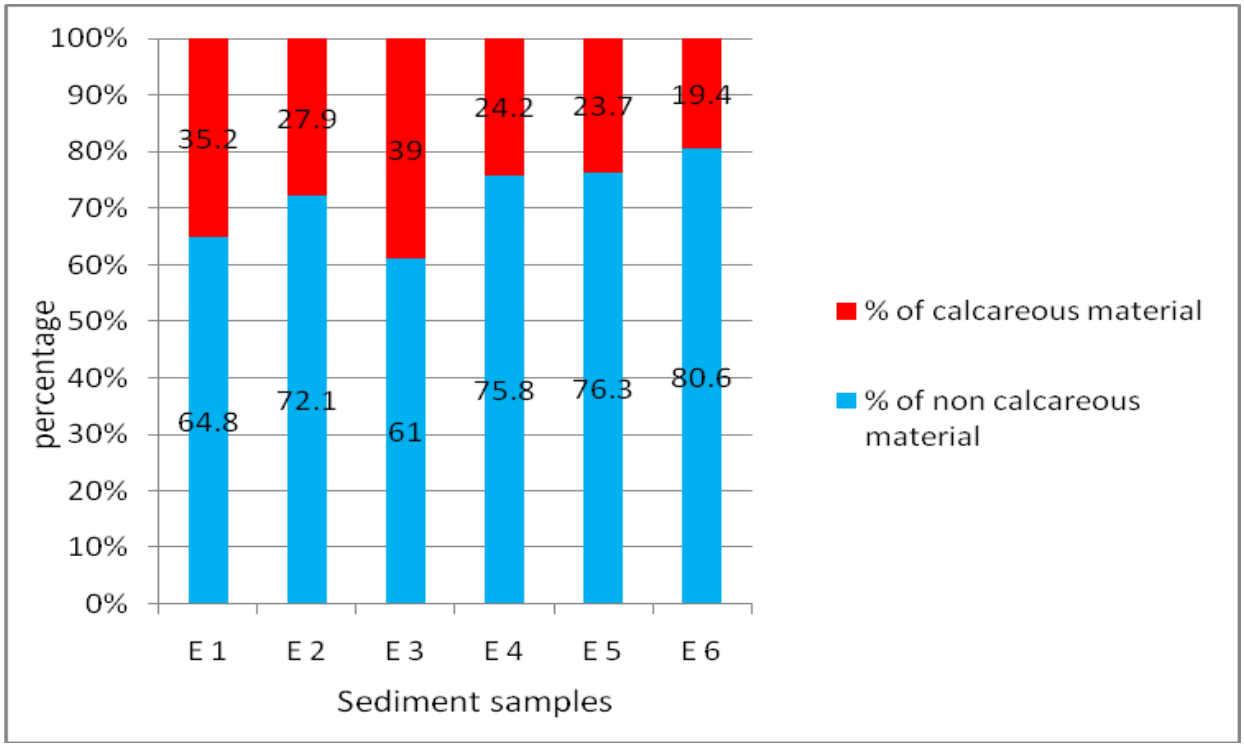

Figure 3.14: Proportion of calcareous and non calcareous material in the exposed beach rock sediment samples

CHAPTER IV

STRATIGRAPHY OF BEACH ROCK

Stratigraphy is the analysis of different rock formation through time and changing environments. Usually it is associated with sedimentary rocks because they follow predictable rules as they are deposited. It built on the concept that the present is the key to understanding the past. The same processes that create the rocks today were operation in the past. Stratigraphy is the basis of interpreting what happened in the past. Here beach rock facies used to interpret the depositional environments. Changes in facies both vertically and horizontally allow to interpret changes in ancient landscapes and processes. Stratigraphically these beach rocks are inferred to belong to recent formations, developed during later Holocene. Sediment of beach rock represent ancient sedimentary deposition. Beach rock sedimentary deposits indicates action of old waves and environments.

According to Nicholas Steno in 1669 proposed that there are three basic principles of sediment accumulation are as follows.

1. Principle of Original Horizontality –

If sediments accumulate in a large basin, the laws of gravity will deposit the beds, horizontal to the surface of the earth.

2. Principle of Superposition -

This principle states that in a sequence of sedimentary rock layers, the bottom layers are older than the top layers. The top layers were deposited first. One can determine which stratum is younger or older, just by the position of the strata.

3. Principle of Original Continuity –

It states that the beds can be traced over a long interval if the basins were open.

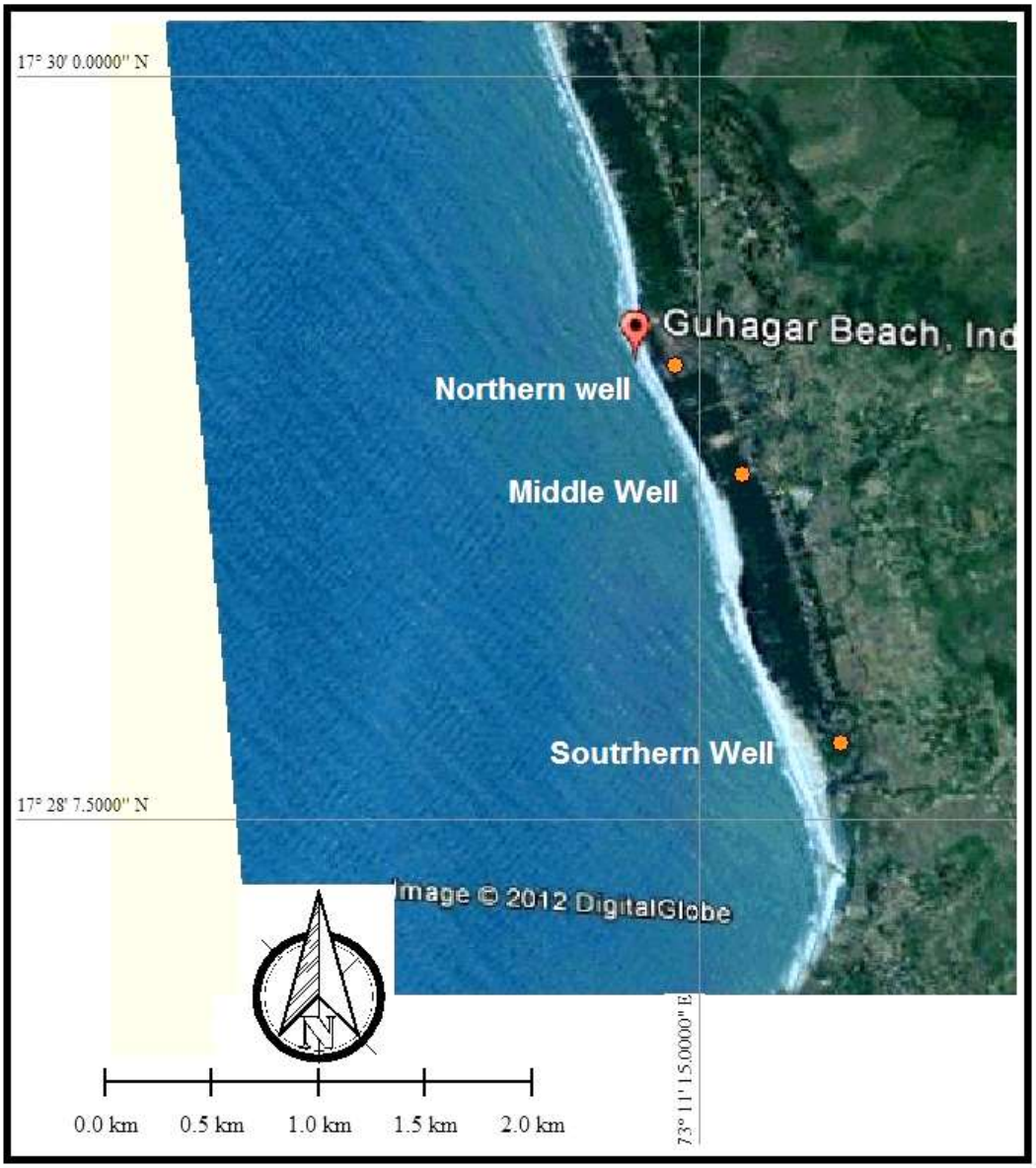

Figure 4.1: Location map of dug wells selected for the study of stratigraphy of beach rock litho-section

4.1) Litho Stratigraphy of Beach Rock

The study of stratigraphy of beach rock litho-sections in all dug wells in the study area is not possible because the dug wells are inaccessible in nature. Therefore, in order to study the litho-stratigraphy of beach rock at Guhagar there are three dug wells were selected randomly to represent the study area. (Figure 4.1) With the help of properties of sediment such as texture, color, thickness, internal structure, bounding surface and special characteristics the various layers with different characteristics in the litho-section of beach rock was observed. In the southern dug well litho-section and middle dug well litho-section there were three layers found but the variation is seen in northern dug well litho-section here four layers were observed with different characteristics. As go towards the northern side the variation is seen in the litho-section of beach rock. It suggests that there is variation in formation of beach rock in study area. There is variation in the amount of sediment load carried by the waves. Variation in the texture that is in grain size, indicates energy of transporting process and waves. Internal structure is concerned with pattern or structure of grains seen inside the deposited sediment. There is relationship between pattern of grains and wave velocity. Horizontal laminations in coarser sand may indicate a planar bed that is near critical flow regime. Cross bedding indicates a lower regime flow.

Dug well I (Northern dug well litho-section)

Location - Latitude– $17^{0}29.268$'N
Longitude- $73^{0}11.189$' E

Elevation from msl - 3 meters

Dug well depth – 4.30 meters

Water table –3 meters

Total thickness of beach rock layers- 2.62 meters

Total layers found – 4

Beach rock found at the depth – 1.68 meters

Table 4.1: Stratigraphy of beach rock litho- section in dug well I

Zone/facie	Sample	Thickness (meter)	Texture	Color	Internal structure	Bounding surface	Special characteristics
1	N 1	0.31	Coarser sand	Reddish brown	Blocky	Gradual	Upper layer
2	N 2	0.42	Fine sand	Grayish Black tint	Horizontal lamination , flaky	Sharp	Titanium oxide (Ti O)
3	N 3	0.38	Fine sand	Brown	Horizontal lamination ,flaky	Sharp	
4	N4	1.51	Fine sand	Light Brown	Horizontal lamination ,flaky	Sharp	Bottom layer

(Source – Fieldwork)

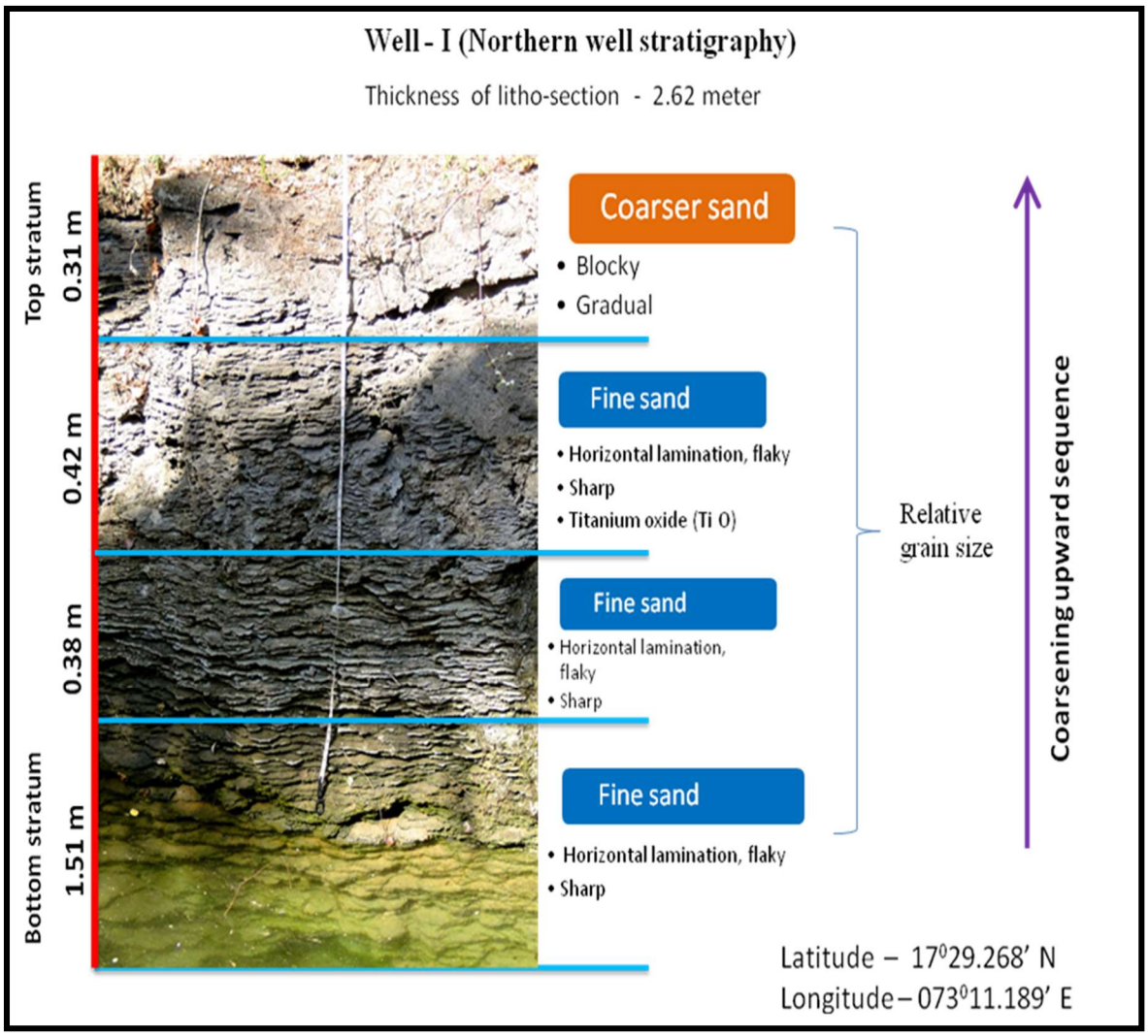

Figure 4.2: Stratigraphy of beach rock litho-section in northern dug well

The first dug well selected in the northern sector of the study area. The latitudinal location of the dug well is $17^0$29.268' North and longitudinal location is $073^0$11.189' East. The elevation of dug well from mean sea level is 3 meters. Depth of well is 4.30 meters and the water table is seen at the depth of 3 meters. (Table 4.1) In the first dug well the beach rock found at the depth of 1.68 meters and which is found at the depth up to 4.30 meters. The total thickness of beach rock layer is 2.62 meters. This litho-section consists of four layers with different characteristics. First layer was very thin as compared to other layers so first layer indicates low sediment load by the waves. Last layer was very thick so this layer indicates high sediment load by the waves therefore it indicates wave environment. Texture of first layer is coarser sand and remaining is fine sand. The size of the sedimentary particles gradually increases from the bottom to the top of sedimentary section. So the section shows a particular sedimentary sequence that is coarsening upward sequence. (Figure 4.2) Therefore it indicates that the energy level of the waves increases upward. The color of first layer is reddish brown indicates the presence of iron. The color of second layer is grayish blackish tint and fine sand texture indicates that the material is titanium oxide (Ti O) which is shown in special characteristics. Third and fourth stratum color is brown and light brown respectively. Internal structure of uppermost layer is blocky and remaining layers are flaky with horizontal laminations. First facies was bound to other neighboring facies with irregular bounding surface. Remaining three facies has regular bounding surface. (Figure 4.2)

Dug well II (Middle dug well litho-section)

Location - Latitude – $17^0$28.994' N
Longitude- $73^0$11.357' E

Elevation from msl – 5 meters

Dug well depth – 4.90 meters

Water table – 4 meters

Total thickness of beach rock layers - 4.30 meters

Total layers found – 3

Beach rock found at the depth – 0.60 meters

Table 4.2: Stratigraphy of beach rock litho- section in dug well II

Zone/ facie	**Sample**	**Thickness** (meter)	**Texture**	**Color**	**Internal structure**	**Bounding surface**	**Special characteristics**
1	M 1	1	Fine sand	Grayish	Blocky	Gradual	Upper layer
2	M 2	1.20	Fine sand	Grayish black	Blocky	Sharp	
3	M 3	2.10	Coarse sand	Brownish	Horizontal lamination, flaky	Sharp	Bottom layer

(Source – Fieldwork)

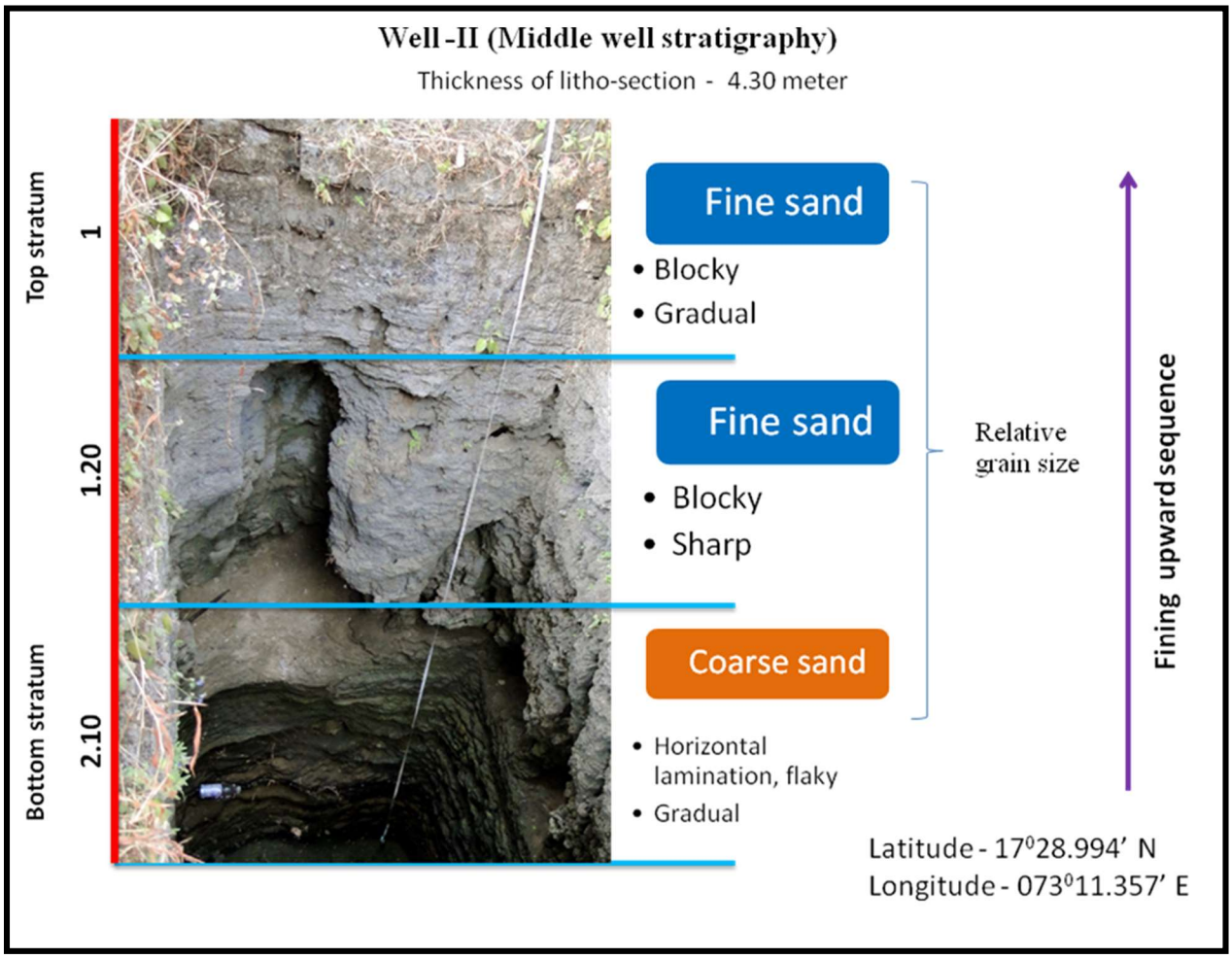

Figure 4.3: Stratigraphy of beach rock litho-section in middle dug well

The second dug well was selected in the middle sector of the study area that is in devpaat. The latitudinal and longitudinal location of dug well is 17^{0}28.994' North and 073^{0}11.357' East respectively. The elevation of dug well from mean sea level is 5 meters. Depth of dug well is 4.90 meters and the water table is seen at the depth of 4 meters. (Table 4.2)

In the second dug well the beach rock was found at the depth of 0.60 meters and which is found at the depth up to 4.90 meters. The total thickness of beach rock layer is 4.30 meters. This litho-section consists of three layers with different characteristics. First layer was very thin as compared to other layers so first layer indicates low sediment load by the waves and last layer was very thick so this layer indicates high sediment load by the waves and overall it shows wave environment at the time of beach rock formation. Texture of first two layers are fine sand and bottom layer indicates coarser sand. The size of the sedimentary particles gradually decreases from the bottom to the top of sedimentary section. So the section shows a particular sedimentary sequence that is fining upward sequence. (Figure 4.3) Therefore, fining upward sequence suggests that the energy level of waves decreases upward at the time of beach rock formation. The color of all three layers is different that is grayish, grayish black and brownish respectively. Internal structure of first two layers is blocky and third layer is horizontal lamination flaky. First facies was bound to other neighboring facies with irregular bounding surface. Remaining two layers has regular bounding surface. (Table 4.2)

Dug well III (Southern dug well litho-section)

Location - Latitude – $17^0$28.316' N **Elevation from msl -** 3 meters

Longitude- $73^0$11.606' E

Dug well depth – 2.50 meters **Water table –** 2 meters

Total thickness of beach rock layers -2.30 meters **Total layers found – 3**

Beach rock found at the depth – 0.20 meters

Table 4.3: Stratigraphy of beach rock litho- section in dug well III

Zone/ facie	**Sample**	**Thickness** (meter)	**Texture**	**Color**	**Internal structure**	**Bounding surface**	**Special characteristics**
1	S 1	0.60	Coarser sand	Reddish brown	Horizontal lamination	Sharp	Rootlets, Upper layer
2	S 2	0.50	Fine sand	Grayish brown	Horizontal lamination	Gradual	
3	S 3	1.20	Pebbly coarser sand	Blackish tint	Horizontal lamination, flaky	Gradual	Bottom layer

(Source – Fieldwork)

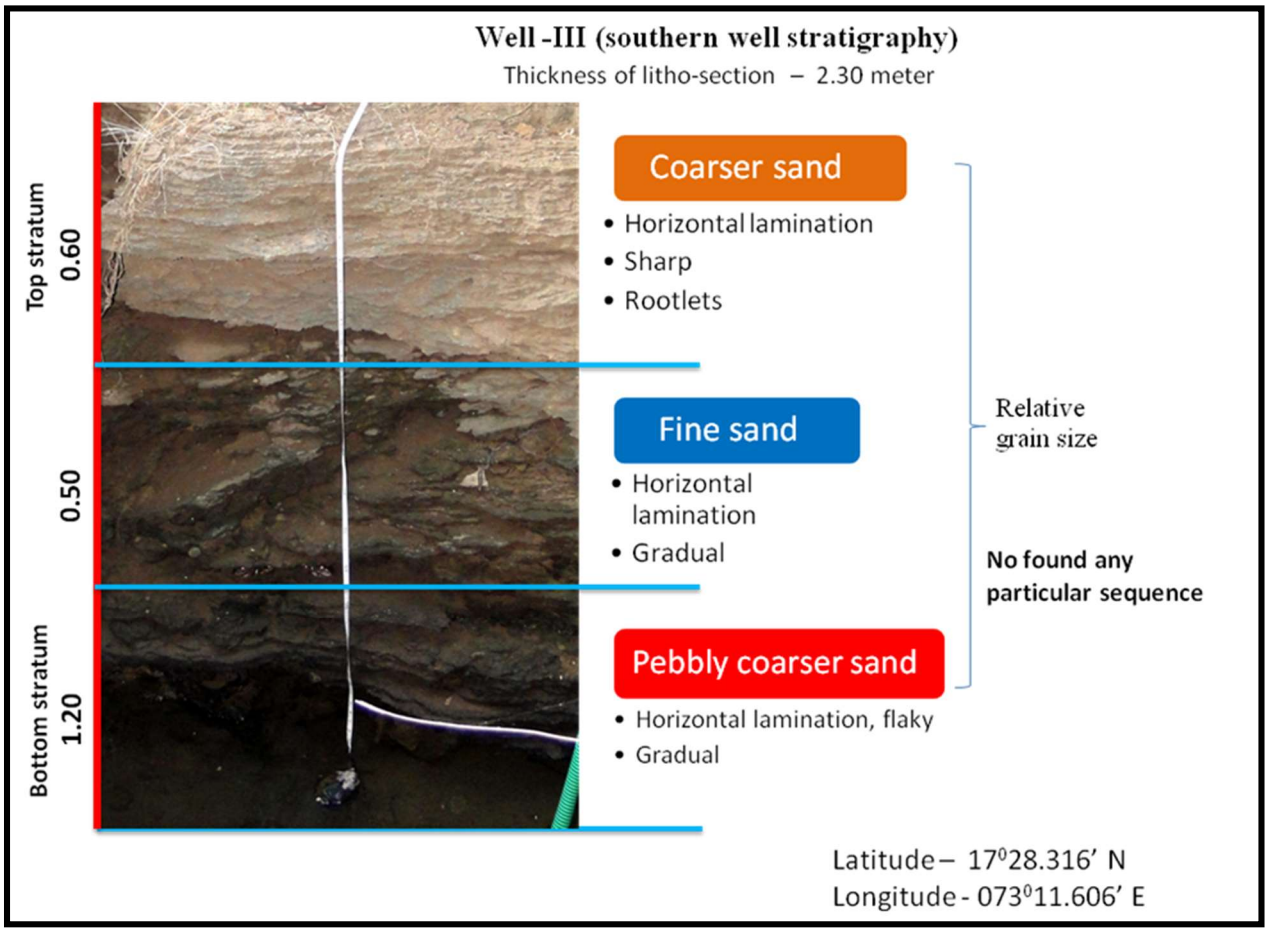

Figure 4.4: Stratigraphy of beach rock litho-section in southern dug well

The third dug well was selected in the southern part of the study area that is in khalchapat. The latitudinal and longitudinal location of that dug well is $17^0$28.316' North and $073^0$11.606' East respectively. The elevation of dug well from mean sea level is 3 meters. Depth of dug well is 2.50 meters and the water table is seen at the depth of 2 meters. (Table 4.3)

In the third dug well the beach rock was found at the depth of 0.20 meters and which is found at the depth up to 2.50 meters. The total thickness of beach rock layer is 2.30 meters. Three layers with different characteristics were found in this litho-section. Here second layer was thin as compared to other layers so first layer indicates low sediment load by the waves and last layer was very thick so this layer indicates high sediment load by the waves. Therefore it shows all about wave environment. Variation is seen in the texture of sediments of all three layers (Table 4.3). The texture of first layer is coarser sand. In second layer founds mostly fine sand. Third layer consisted most of coarse sand and some pebbles are seen that is resulting from storm deposits. In this litho-section variation is seen in the grain size. This section does not show any particular sedimentary facies sequence (Figure 4.4). It means that there is no occurrence of coarsening upward sequence or fining upward sequence. The color of first layer is reddish brown indicates the presence of iron. Second layer is grayish brown and the third layer is blackish tint. Internal structure of first two layers is horizontal laminations and third layer is flaky with horizontal lamination. From the top first layer is bound to other neighboring layer with sharply. Remaining two layers has gradual bounding surface. Rootlets are seen in the upper layer. (Table 4.3 and Figure 4.4)

In these three beach rock litho-sections there is no found any post depositional changes i.e. disturbances. Bottom layer of all three dug wells are thick. It indicates uniform wave

environment. Internal structure of all litho-sections of beach rock is same that is horizontal lamination but some facies are flaky and some are blocky in structure. Bounding surface of the facies to the neighboring facies is sharp as well as gradual it indicates in the litho-sections some facies are bounded to other facies with regular bounding surface and some are with irregular bounding surface. Natural or anthropogenic breaks was not found.

Photo 4.1: Thickness measurement of beach rock stratums in northern dug well litho-section

4.2) Stratigraphic Calcium Carbonate Analysis of Beach rock

In order to study the cementation of beach rock litho-section in dug wells in the study area, stratigraphic calcium carbonate analysis was done in three dug wells litho-sections are as follows. Formation the formation and cementation of beach rock calcium carbonate is essential. To understand the formation, cementation and compactness of beach rock calcium carbonate analysis method was done. This analysis gives the percentage of calcareous and non-calcareous material in the beach rock sediment samples in the stratums of litho-sections.

Table 4.4: Calcium carbonate analysis of beach rock in dug well I (Northern dug well litho-section)

Sample	Weight of Sample (gms)	Weight of non-calcareous material (gms)	Weight of calcareous material (gms)	% of non calcareous material	% of calcareous material
N 1	10	8	2	80	20
N 2	10	8.61	1.39	86.1	13.9
N 3	10	7.71	2.29	77.1	22.9
N4	10	8.68	1.32	86.8	13.2

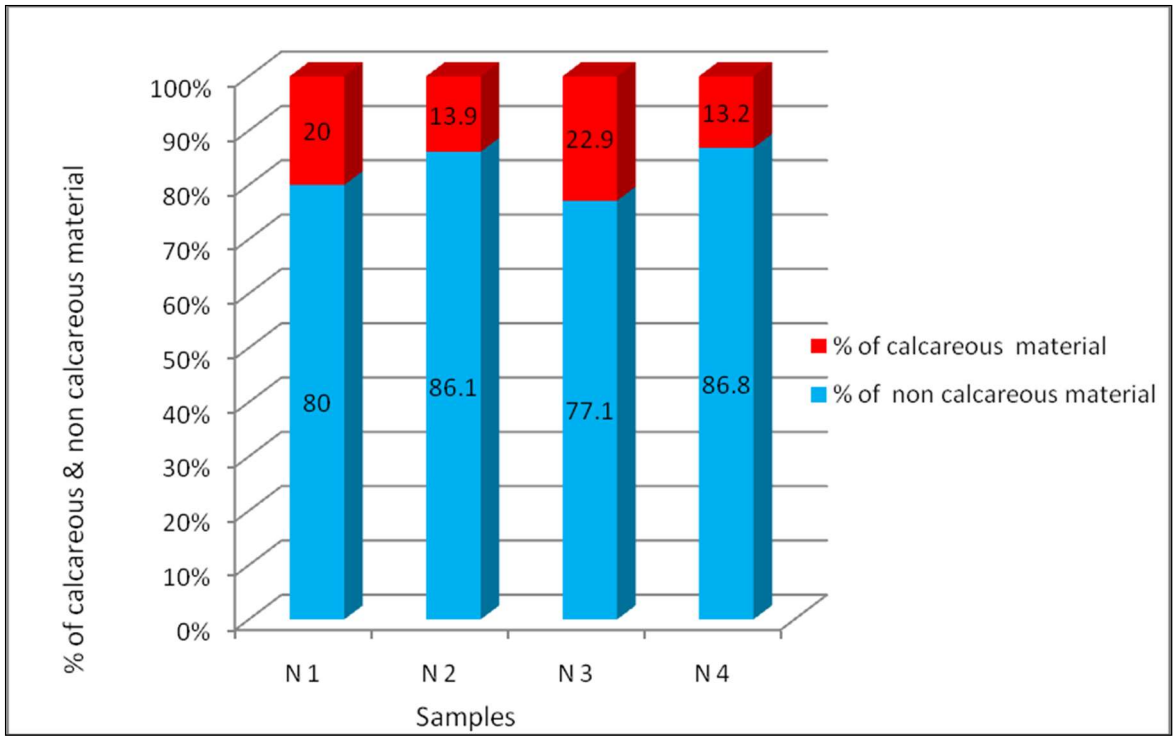

Figure 4.5: Proportion of calcareous and non-calcareous material in beach rock sediment samples of northern dug well litho-section

In the stratawise calcium carbonate analysis of northern dug well litho-section section the upper stratum N1 has 20% calcareous material and the remaining 80% is non calcareous material. N2 stratum has 13.9 % calcareous material and the remaining 86.1% is non-calcareous material. N3 and N4 stratums has 22.9 % and 13.2% calcareous material and the remaining 77.1% and 86.8% is non-calcareous material respectively.(Table 4.4) N1 and N3 stratums has more presence of calcareous material as compared to other stratums so the N1 and N3 beach rock stratum have better formation and well cementation. N2 and bottom layer that is N4 has less presence of calcareous material suggests that the weak formation and poor cementation. (Figure 4.5) It indicates that variation in the formation of beach rock litho-section.

Table 4.5: Calcium carbonate analysis of beach rock in dug well II (Middle dug well litho-section)

Sample	Weight of Sample (gms)	Weight of non-calcareous material (gms)	Weight of calcareous material (gms)	% of non calcareous material	% of calcareous material
M 1	10	8.09	1.91	80.9	19.1
M 2	10	8.66	1.34	86.6	13.4
M 3	10	7.18	2.82	71.8	28.2

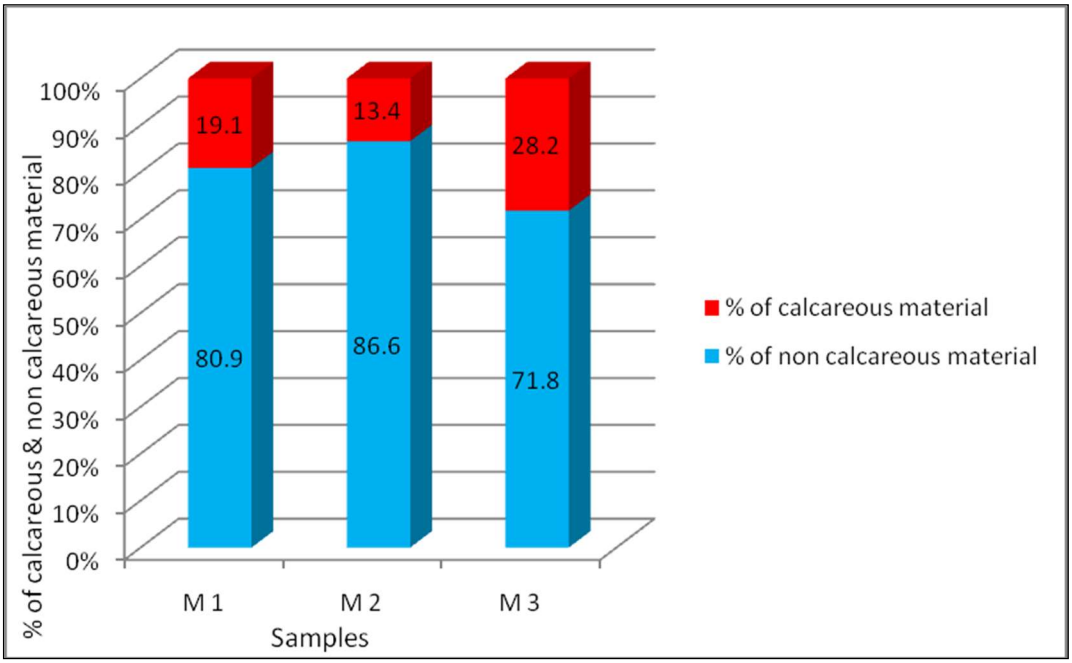

Figure 4.6: Proportion of calcareous and non-calcareous material in beach rock sediment samples of middle dug well litho-section

In the middle dug well litho-section the stratigraphic calcium carbonate analysis shows that upper stratum has 19.1% calcareous material and 80.9% non-calcareous material. Middle stratum M2 has 13.4% calcareous material and the remaining 86.6% is non-calcareous material. Bottom stratum that is M3 has 28.2% and 71.8% calcareous and non-calcareous material respectively. (Table 4.5) Middle strata has less presence of calcareous material as compared to other layers. So this layer has weak formation and poor cementation. First and third stratum of beach rock has more presence of calcareous material indicates better formation and well cementation. (Figure 4.6) It suggest that the variation in the formation of beach rock litho-section.

Table 4.6: Calcium carbonate analysis of beach rock in dug well III (Southern dug well litho-section)

Sample	Weight of Sample (gms)	Weight of non-calcareous material (gms)	Weight of calcareous material (gms)	% of non calcareous material	% of calcareous material
S 1	10	8.73	1.27	87.3	12.7
S 2	10	7.64	2.36	76.4	23.6
S 3	10	7.14	2.86	71.4	28.6

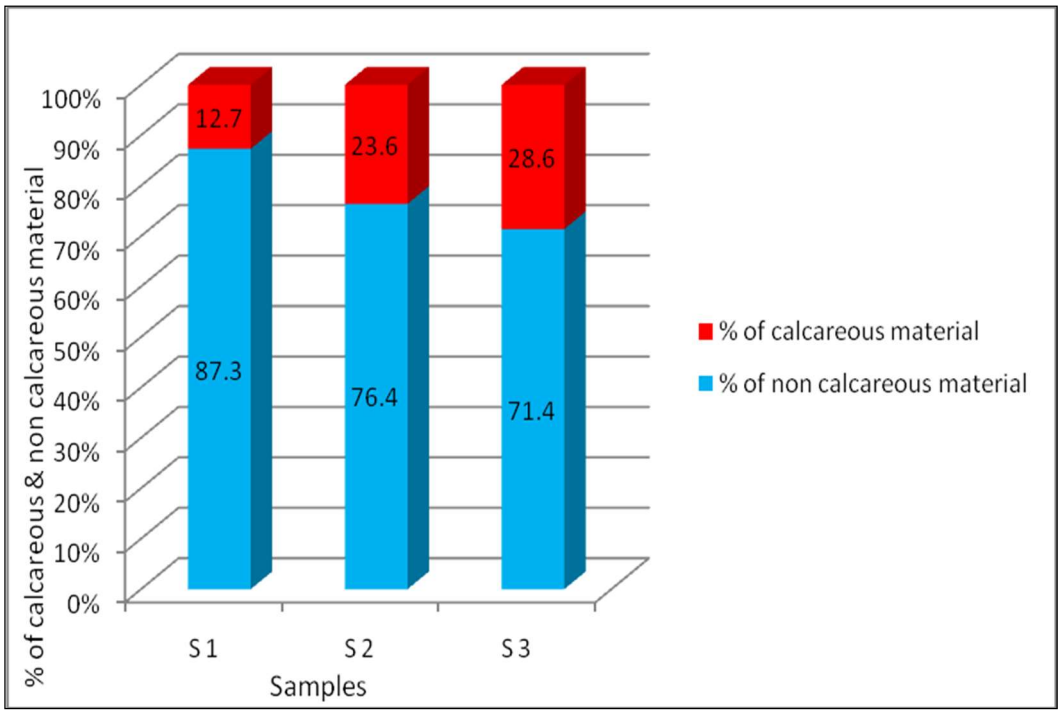

Figure 4.7: Percentage of calcareous and non calcareous material of southern dug well litho-section

In the southern dug well litho-section the stratigraphic calcium carbonate analysis indicates that the upper stratum S1 has 12.7% calcareous material and the remaining 87.3% is non calcareous material. Stratums S2 and S3 has 23.6% and 28.6% calcareous material respectively and remaining 76.4% and 71.4% is the non-calcareous material respectively. (Table 4.6)Upper stratum has less presence of calcareous material as compared to other stratums so the upper stratum has weak formation and poor cementation. Second and third layer has more presence of calcareous material indicates such beach rock stratums has better formation and well cementation. (Figure 4.7) It suggest that the variation in the formation of beach rock litho-section.

From this analysis in all the three litho-sections of beach rock third stratum has more calcareous material indicates that better formation and well cementation of beach rock in third stratum.

Exposed beach rock contains more calcareous material than the beach rock found in dug wells. (Figure 3.14) It suggests that exposed beach rock is well cemented (Cementation is intact) on the contrary dug well beach rock is poorly cemented. (Cementation is not intact) Little amount of calcareous material in well beach rock indicates that the weak formation and poor development. (Figure 4.5, 4.6 and 4.7) More amount of calcareous material in exposed beach rock indicates that the better formation and well development.

CHAPTER V

FINDINGS AND CONCLUSIONS

This work is an attempt to investigate morphology, formation, stratigraphy, depositional environment of beach rock found along the Guhagar coast. The observations and conclusions are based on the beach rock studies of Guhagar on the west coast of India.

In the field investigation of the study area, very few partly visible exposed beach rock was found in the backshore zone have north to south orientation. These discontinuous low beach rock patches are parallel to the shoreline. Beach sediment cementation (beach rock formation) is a sedimentary process that can transform significant sections of beaches into rock. The gradient of beach rock in the study area is negligible and it is inclined towards the sea. The lowest inland limit of beach rock is 185 meters (sample E-2) (Figure 3.1) and highest is 335 meters (sample W-12) (Figure 3.2) away from the present day shoreline. Hence on the basis of position of exposed beach rock and beach rock from dug well, the exposed beach rock is relatively modern and beach rock in dug wells is older.

The elevation of exposed beach rock is in between 6 to 9 meters from mean sea level (Table 3.1) and the beach rock in dug wells is in between 7 to 10 meters from mean sea level.(Table 3.2) Dug wells in the study area are almost parallel to the shoreline. So the beach rock found in these dug well sections up to the 200 to 350 meters inland, thus almost shows a parallel ridge position to the shoreline. Hence it is the tentative earlier shoreline of Guhagar which is near about 200-350 meters away from the present day shoreline and the tentative elevation of earlier shoreline is near about 7 to 10 meters from mean sea level. Beach rock found in the study area is at the average depth of 3 meters and it found in the dug wells at the maximum depth of 6.30 meters. (Table 3.2) The thickness of beach rock is more in the middle part of the study area and it decreases towards the both side that is northern and southern side.

Most of the Guhagar settlement is situated on such beach rock. The occurrences of beach rock in the study area suggest that negative change in sea level along the beach has taken place and it also indicates that the Guhagar shore is retreated which is 200-300 meters from earlier shoreline. The thickness of exposed beach rock in litho-section E1 is minimum 0.18 meters and maximum is 1.80 meters in Litho-section E5 (Table 3.1)

Textural group of exposed beach rock sediment samples is sand so the overall grain size of sediment belongs to sand category. Medium and fine sand is dominant in this region. It suggests the overall size of particle in sediment samples of beach rock belong to medium and fine sand category. It reveals that condition of the ancient beach. Sand is derived in Guhagar may be from three different sources: first source is sand moved out to the sea in Guhagar by rivers such as Vasishthi, Shastri rivers and from some streams. Second source of sand is produced by erosion of cliffs which are found in the northern and southern headlands. Third source is sand picked up from the off shore region and moved towards the shore by waves. In exposed beach rock the percentage of silt is very low. Composition of Guhagar beach rock is sand, silt, shells, titanium oxide, calcium carbonate and rock fragments. The nature of beach rock varies from north to south in the study area.

The obtained value of mean sediment size ranges from 1.033 **Φ** to 2.659 **Φ** (Table 3.3). It is seen from the values that all the exposed beach rock mean sediment size ranges between medium sand and fine sand. It suggests that the overall size of the particle in the sediment samples of beach rock belong to medium and fine sand category. (Table 3.3) It reveals that condition of ancient beach. Phi value of mean sediment size is less in the northern side so the amount of medium sand is more in northern side and the phi value of sediment size is more in the southern side indicates concentration of fine sand. (Figure 3.3)

The derived values of sorting index are varying between 0.893 **Φ** and 1.241 **Φ**. In the Guhagar beach rock sediment samples the E4 and E6 are moderately sorted it means there is

moderate mixing of different size particles. Therefore, there is medium homogeneity in the size of particles. The calculated value of the remaining sediment samples E1, E2, E3 and E5 that is 1.058Φ, 1.061Φ, 1.241Φ and 1.209Φ respectively are poorly sorted. (Table 3.3) It means that there is mixing of different size particles. It indicates that there is no homogeneity or uniformity in the size of particles of beach rock sediments. In the northern side of the study area the value of sorting index increases landward and decreases seawards. It indicates that landward side sediments are poorly sorted and seaward side sediments are moderately sorted. On the contrary, southern side sorting values are increases seaward and decreases landward. (Figure 3.4) Sorting value in the southern side indicates the sediments are poorly sorted.

In all the exposed beach rock sediment samples, the variation is seen in the skewness value. Skewness value ranges between -0.336 to 0.739. E-1 sample is near symmetrical. E-2 and E-3 samples are coarse skewed it means there is more presence of coarser material. E-4 and E- 5 is very fine skewed and fine skewed respectively indicates abundance of fine material. E-6 has very coarse skewed that is negative skewed means more presence of coarser material. (Table 3.3)

In the northern side of the study area the concentration of coarser material is seen. The concentration is symmetrical in the middle side. Almost all the sediments are negatively skewed in the study area so the negative skewness is more in the study area. (Figure 3.5) It reveals that there is abundance of coarser particles in the beach rock sediment samples.

In Guhagar study area the exposed beach rock sediment samples are leptokurtic, mesokurtic and platykurtic in nature. The kurtosis value is ranges between the 0.774 and 1.309 (Table 3.3). From southern to northern side value of kurtosis has been increases (Figure 3.6). Less value in the southern side indicates platykurtic nature of the sediments it means there is no concentration of grain size class. It suggest that all the sediment particles distributed throughout the sediment sample. Middle part indicates material is mesokurtic in nature.

Northern part shows the material is in leptokurtic category. It means that there is concentration of particular grain size class means sediment particles are the uniform in size all over the beach rock.

Beach rock sediments represent ancient sedimentary deposition. Percentage of silt is very less in all the exposed beach rock sediment samples. (Figure 3.7) There is variation seen in the percentage of coarser, medium, fine and very fine sand in exposed beach rock sediment samples. It shows wave environment at the time of beach rock formation in study area.

Grain size distribution in all the three beach rock litho-sections in dug wells shows that the proportion of coarser material is more in southern part shows more wave energy at the time of beach rock formation. But in middle and northern side the occurrence of fine sand is more in beach rock sediment samples of litho-sections suggest that the wave energy decreases in middle and southern part of study area. It reveals the wave energy environment at the time of beach rock formation.

Occurrence of beach rock in Guhagar coastal area indicates the favorable conditions for beach rock formation, such as availability of essential calcium on beach, gentle slope of the foreshore and ground water temperature. Exposed beach rock contains more calcareous material than the beach rock found in dug wells. (Figure 3.14) It suggests that exposed beach rock is well cemented (cementation is intact) on the contrary dug well beach rock is poorly cemented. (Cementation is not intact) Little amount of calcareous material in dug well beach rock indicates that the weak formation and poor development. (Figure 4.5, 4.6 and 4.7) More amount of calcareous material in exposed beach rock indicates that the better formation and well development.

Beach rock sedimentary deposits indicate action of old waves and environments. In order to study the litho-stratigraphy of beach rock at Guhagar there are three dug wells were selected randomly to represent the study area. (Figure 4.1) First dug well is in the northern side,

second in the middle part and third in the southern side. With the help of properties of sediment such as texture, color, thickness, internal structure, bounding surface and special characteristics, various layers with different characteristics in the litho-section of beach rock are observed. In Northern dug well litho-section i.e. dug well I the size of the sedimentary particles gradually increases from bottom to the top of sedimentary section. (Figure 4.2) So the section shows a particular sedimentary sequence that is coarsening upward sequence. The litho-section consists of four layers with different characteristics. First layer was very thin as compared to other layers and last layer was very thick so it indicates wave environment. First facies was bound to other neighboring facies with irregular bounding surface. Remaining three facies has regular bounding surface. (Figure 4.2) In middle dug well litho-section the size of the sedimentary particles gradually decreases from bottom to the top of sedimentary section. So the section shows a particular sedimentary sequence that is fining upward sequence. (Figure 4.3) Fining upward sequence suggests that the energy level of waves decreases at the time of formation of beach rock. First layer was bound to other neighboring layers with irregular bounding surface. Remaining two layers has regular bounding surface. (Table 4.2) In southern dug well litho-section there is no any particular sedimentary facies sequence. Three layers with different characteristics were found in this litho-section. In that litho-section, the second layer was thin as compared to other layers and last layer was very thick indicates wave environment.

In these three beach rock litho-sections there is no found any post depositional changes i.e. disturbances. Bottom layer of all three dug wells are thick. It indicates uniform wave environment. Internal structure of all litho-sections of beach rock is same that is horizontal lamination but some facies are flaky and some are blocky in structure. Bounding surface of the facies to the neighboring facies is sharp as well as gradual it indicates in the litho-sections some facies are bounded to other facies with regular bounding surface and some are with irregular bounding surface. Natural or anthropogenic breaks was not found.

In the litho-section of beach rock first dug well (Northern dug well) stratigraphic calcium carbonate analysis indicates N1 and N3 stratums has more presence of calcareous material as compared to other stratums so the N1 and N3 beach rock stratum has better formation and well cementation. N2 and bottom layer that is N4 has less presence of calcareous material suggests that the weak formation and poor cementation. (Figure 4.5) It indicates that variation in the formation of beach rock litho-section. In the middle dug well litho-section the stratigraphic calcium carbonate analysis shows that middle strata has less presence of calcareous material as compared to other layers. So this layer has weak formation and poor cementation. First and third stratum of beach rock has more presence of calcareous material indicates better formation and well cementation. (Figure 4.6) It suggest that the variation in the formation of beach rock litho-section. Third litho-section that is southern dug well litho-section shows upper stratum has less presence of calcareous material as compared to other stratums so the upper stratum has weak formation and poor cementation. Second and third layer has more presence of calcareous material indicates such beach rock stratums has better formation and well cementation. (Figure 4.7) It suggest that the variation in the formation of beach rock litho-section. As go towards the northern side the variation is seen in the litho-sections of beach rock. In Stratigrahy of beach rock there is variation in the amount of sediment load carried by the waves as well as variation in the texture that is in grain size, indicates energy of transporting process and waves.

From the calcium carbonate analysis in all the three litho-sections of beach rock third stratum has more calcareous material. It indicates that better formation and well cementation of beach rock in third stratum. (Cementation is intact)

The tentative earlier shoreline at the distance about 200-350 meters inland away from present day shoreline can be inferred from this study. This inferred shoreline shown by yellow color. (Figure 5.1) By the sedimentary process of beach rock formation (beach sediment

cementation) a large significant section of old beach at Guhagar was transformed into beach rock and most of the settlement of Guhagar is situated on such beach rock.

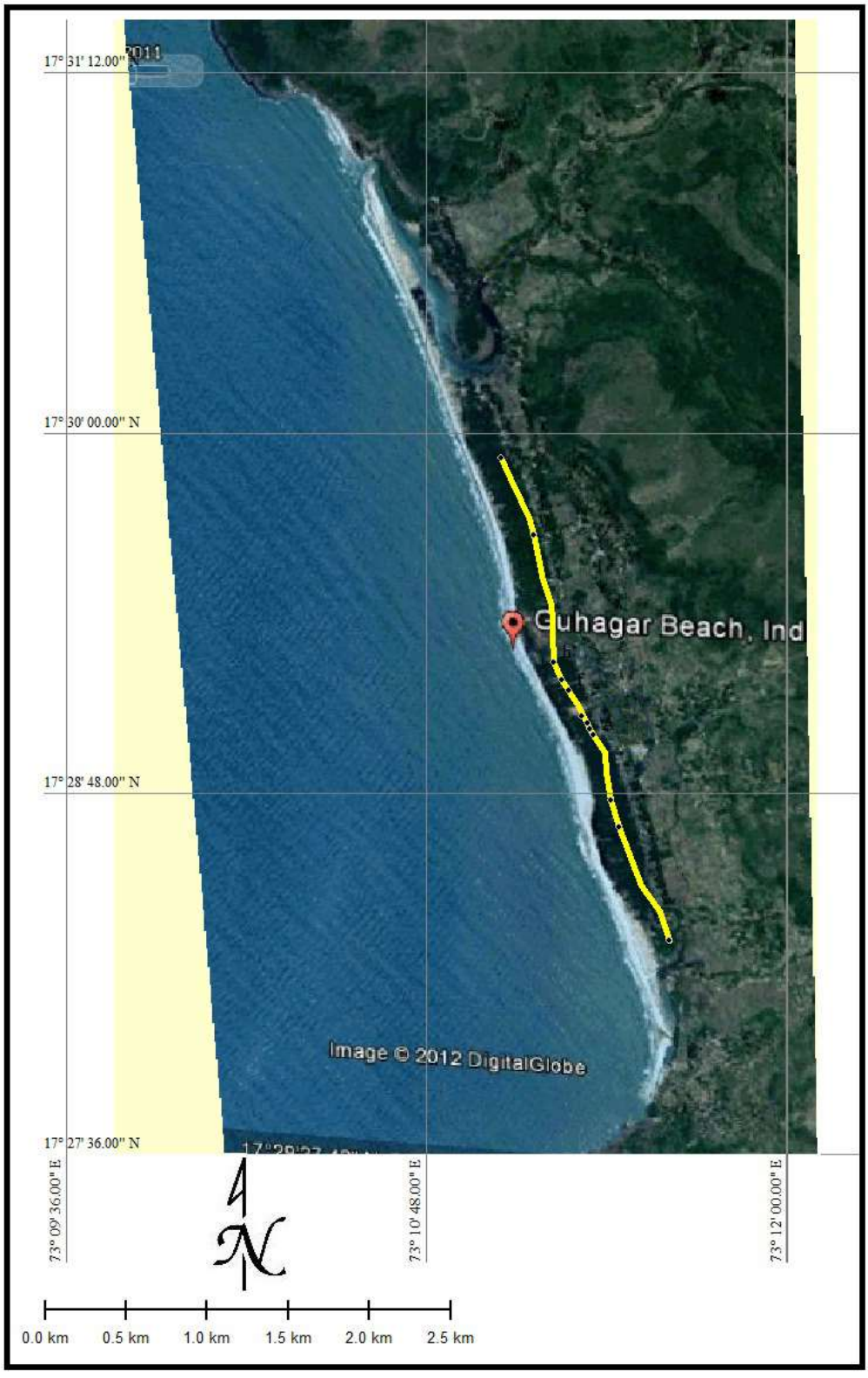

Figure 5.1: Tentative earlier shoreline in study area

BIBLIOGRAPHY

- **Deshwandikar Abhay (1993):** "Nearshore Sediments, Sedimentary Features and Tidal Basins Along Diveagar-Aravi-Valvati Coast of Maharashtra", Unpublished Ph.D. Thesis, University of Pune.
- **El-Shater A. and Abou Auf M.A. (1995):** Beach rock in South Jeddah, The Red Sea Coast of Saudi Arabia, Faculty of Marine Science, King Abdulaziz University, Jeddah, Saudi Arabia.
- **Kale Vishwas and Gupta Avijit (2001):** Introduction to Geomorphology, University Press Hyderabad India.
- **Karlekar Shrikant (1993):** Coastal Geomorphology of Konkan, Aparna Publication Pune.
- **Karlekar Shrikant (2009):** Coastal Processes and Landforms, Diamond Publication Pune.
- **Kharsinge Tanaji (2010):** The Beach rock of Narpad and Umbergaon, unpublished M.A. dissertation thesis, University of Pune.
- **Knight Jasper (2007):** Beach rock Reconsidered. Discussion of: Kelletet, D., 2006.Beach rock as Sea-Level Indicator? Remarks from a Geomorphological Point of View. Journal of Coastal Research.
- **Nubia C. Guerra, Chang H. Kiang and Alcides N. Sial (2004):** Carbonate Cements in Contemporaneous Beach rocks, Jaguaribe Beach, Itamaraca Island, Northeastern Brazil: Petrographic, Geochemical and Isotopic Aspects.

- **Omoto Kunio:** Radiocarbon Ages of Beach rocks and Late Holocene Sea-level Changes in the Southern Part of the Nansei Islands, Southwest of Japan Department of Geography, College of Humanities and Sciences, Nihon University Tokyo Japan.
- **Pethic John (1984):** Introduction to Coastal Geomorphology, Arnold Heinemann publication London.
- **Ravisankar R. et.al. (2012):** Beach rocks from the South East Coast of Tamilnadu, India: A Spectroscopic study.
- **Ravisankar R. et.al. (2011):** Mineral Analysis in Beach rocks of Andaman Island, India by Spectroscopic Techniques.
- **Sanjeeva Rao P.C. (2001):** A text Book of Geology, Discovery Publishing House New Delhi.
- **Schwartz Maurice L.:** Encyclopedia of Coastal Science, Springer Publication.
- **Setty M.G.Anantha Padmanabha and Wagle B.G. (1971):** Beach rock from Goa coast, National Institute of Oceanography, Panjim, Goa.
- **T.Ahmet Ertek and A.Evren Erginal (2003):** Physical properties of beach rocks on the coast of Gelibolu Peninsula and their contribution to the Quaternary sea level changes, Istanbul University, Geography department , Turkey.
- **Umrikar Bhavna N. and Devi Nowbuth Manta (2011):** Groundwater Quality Assessment for Guhagar Coastal Area Maharashtra, India. Journal of Environmental Research and Development.
- **Vousdoukas M.I., Velegrakis A.F. and Karambas, T.V. (2009):** Morphology and Sedimentology of a Microtidal Beach with Beach rocks: Vatera, Lesbos, NE Mediterranean. Continental Shelf Research.

- **Wagle B.G. (1990):** Beach rocks of the Central West Coast of India, National Institute of Oceanography. Dona Paula, Goa.
- **Wang Wei (1998)**: Beach rocks and Storm Deposits on the Beaches of Hong kong. Science in China, series D Volume 41 No. 4
- **Woodroffe (2002):** Coast: Form, Process and Evolution, Cambridge University press.

APPENDICES

A 1) Textural Analysis of Beach Rock Sediments Samples

a) Sieve analysis procedure

1. Beach rock sediment samples collected at some intervals in the field using global positioning system. (accuracy up to 10 m)
2. In each location 1 sample of 300-400 grams was collected, sealed and marked in the zip lock polythene bags.
3. The samples of beach rock are already dried, the clumps of beach rock crushed in to small pieces using porcelain pestle and mortal.
4. Enough force applied to separate the grains.
5. A unit of 100 gm of each sample was passed through a set of sieve which is710, 600, 500, 355, 300, 250, 150, 90 and 63 microns. The last pan collected sediments are less than 63 microns.
6. Sieving is carried out carefully.
7. Empty the sieve on to a large sheet of paper.
8. To remove the sand particles from the rim of the sieve with either the hand or by using a toothbrush along the general direction of diagonal of the wire mesh.
9. Sediment from each sieve weighted and taken the reading.
10. Keep them aside in the zip log bags.

b) Calculations of graphic measures

By using 'Gradistat' software the grain size parameters such as mean, sorting, skewness and kurtosis were derived and these parameters are checked by cumulative weights of grain size were plotted on the probability graph paper. The following formulae proposed by Folk and Ward in 1957, were used to calculate the statistical parameters of grain size.

Mean size = (ϕ 16 + ϕ 50 + ϕ 84) / 3

Sorting index = (ϕ 84 – ϕ 16) / 4 + (ϕ 95 – ϕ 5) / 6.6

Skewness =

{(ϕ 16 + ϕ 84 – 2 ϕ 50)/2 (ϕ 84 – ϕ 16)} + {(ϕ5 + 95-2 ϕ50)/2 (ϕ95 – ϕ5)}

Kurtosis = (ϕ 95 – ϕ5) / 2.44 (ϕ 75 – ϕ 25)

A 2) Procedure of Calcium Carbonate Analysis

To obtain the proportion of calcareous and non calcareous material in the sediment sample of beach rock we used this method. The detailed description of procedure is as follows.

a) Apparatus used

For the study of calcium carbonate analysis there are 7-8 apparatus was used such as 100 ml beakers, conical flask, measuring cylinder, funnel, pipette and filter paper.

b) Reagents used

Hydrochloric acid (HCL) pure (38 % N) concentrated.

c) Procedure

1) Place 10 gms of sediment sample of beach rock in 100 ml beaker.
2) Add 10 ml of reagent concentrated hydrochloric acid (HCL) by means of a pipette and measuring flask (cylinder) in that beaker and keep the beakers for 15 minutes to react with the mixture.
3) After the reaction of concentrated hydrochloric acid, the calcareous material is dissolved in HCL and non calcareous material does not dissolved in HCL.
4) When the bubbles stopped and the non calcareous sediment material is settling down in the bed of beaker, then by using funnel and conical flask and filter paper the HCL were removed slowly.
5) The dissolved calcareous material in HCL is goes in conical flask and the remaining non calcareous material was trapped in filter paper as dug well as in beaker.
6) The trapped non calcareous material on filter paper and in beaker was dried by using oven.
7) Firstly, taken the reading of empty 100 ml beaker as dug well as blank filter paper. Secondly weighted dried filter paper and dried beaker. Then subtract the reading of blank filter paper and empty beaker from the dried filter paper and dried beaker respectively. Eventually we get the weight of non calcareous material in the sediment sample.
8) Subtract the weight of non calcareous material from the weight of 10 grams then we get the amount of calcareous material. After the calculation we obtained the percentage of calcareous and non calcareous material in the sediment sample.

d) Reaction –

Calcium carbonate ($CaCO_3$) is reacted with hydrochloric acid (HCl) the products are Calcium chloride ($CaCl_2$), water (H2O) and the gas would therefore be carbon dioxide (CO_2) which is released.

$$\mathbf{CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2 \Uparrow}$$

A 3) Abbreviations Used

Abbreviation	Description	Abbreviation	Description
MSL	Mean sea level	M.K.	Mesokurtic
M.S.	Medium sand	L.K.	Leptokurtic
F.S.	Fine sand	V.L.K.	Very leptokurtic
P.S.	Poorly sorted	B.P.S.	Bimodal poorly sorted
MS	Moderately sorted	T.P.S.	Trimodal poorly sorted
Symm.	Symmetrical	B.M.S.	Bimodal moderately sorted
C.S.	Coarser skewed	T.M.S.	Trimodal moderately sorted
FS	Fine skewed	M.S.C.S.	moderately sorted coarser sand
V.F.S.	Very fine skewed	P.S.C.S.	Poorly sorted coarser sand
V.C.S.	Very coarser skewed	M.S.M.S.	Moderately sorted medium sand
P.K.	Platy kurtic	P.S.F.S.	Poorly sorted fine sand
M.W.S.C.S.	Moderately well sorted coarser sand	Φ	Phi
E	Exposed beach rock	W	Well beach rock
N	Northern well	S	Southern Well
M	Middle Well	Des.	Description
Gms.	Grams	Fig.	Figure

WEBLIOGRAPHY

Sr.No.	Websites
1	www.wikipedia.com
2	www.pelagiareseachlibrary.com
3	www.scholarsresearchlibrary.com
4	*Michalis I. Vousdoukas, Personal scientific website*
5	*www.academia.edu.in*