

**GEOCHEMICAL, TEXTURAL AND  
MINERALOGICAL ANALYSIS OF AEOLIAN  
SEDIMENTS**

**Project Report submitted To Central University of Punjab**

**For the award of**

**Master of Science**

**In**

**Geology**

**By**

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**May, 2018**

# **Declaration**

I do hereby declare that the dissertation entitled “**Geochemical, textural and mineralogical analysis of aeolian sediments**” has been carried out under the guidance of Dr. Jitendra Kumar Pattanaik, Assistant professor, Department of Geography and Geology, Central University of Punjab, Bathinda, 151001. This dissertation has not been previously submitted for any degree or diploma to this or any University.

**Place: Bathinda**

**Date:**

**Ujjwala Rout**

## **Certificate**

This is to certify that the present work embodied in this dissertation entitled **“Geochemical, textural and mineralogical analysis of aeolian sediments”** carried under the supervision of Dr. Jitendra Kumar Pattanaik, Assistant professor, Department of Geography and Geology, Central University of Punjab, Bathinda. No part of the dissertation has not been submitted for award of any Degree or Diploma of this or any other University.

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Centre of Geography and Geology,

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Date-

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## Abstract

### **Geochemical, textural and mineralogical analysis of aeolian sediments**

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Key words: Stabilized sand dunes, Textural Analysis, XRD, percentage of carbonate phase

Geochemical characteristics of sediments of sand dune will control the quality of shallow ground water and soil type and its composition. In this study sediments from stabilized sand dunes found in in the area of Bathinda and Sikar Region were investigated. With time and change of climatic condition pedogenesis process will be active on the stabilized sand dunes. Aeolian sediments of stabilized sand dunes provides clue to understand the paleoclimate, paleo-vegetation, paleo-wind flow direction of these area. Grain Size Distribution and mineralogical analysis of the sediments helps to understand the depositional environment and energy condition of that area, degree physical and chemical weathering and transportation history. In the present study textural and mineralogical analysis of Aeolian sands was carried out to find out the chemical weathering intensity of that area and depositional environment of the sediments. The sediments of Bathinda and Sikar regions are texturally very fine sand. The Sikar regions are unimodal with fine grain size, whereas in Bathinda few samples shows bimodal. Based on various discrimination plots it is infer that the sediments are deposited in the quite aeolian environment with low active energy condition. Presence of calcrete and clay minerals indicate dunes were stabilized and pedogenesis process were active in the sand dunes. Maximum carbonate percentage is observed from the Loc S. Bulk geochemistry indicates the SiO<sub>2</sub> percentage varies from 58 to 64%. The maximum CIA value of 83 was observed in the Loc C samples. A-CN-K and A-CNK-FM ternary plot shows maximum samples are low to moderately weathered and trending towards Al<sub>2</sub>O<sub>3</sub> apex.

Name and Signature of Students

Name and Signature of Supervisor

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Place: Bathinda

**Ujjwala Rout**

Date:

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# CHAPTER -1

## INTRODUCTION

Geochemical characteristics of sediments of sand dune will control the quality of shallow ground water and soil type and its composition. With time and change of climatic condition pedogenesis process will be active on the stabilized sand dunes. Aeolian sediments of stabilized sand dunes provides clue to understand the paleoclimate, paleo-vegetation, paleo-wind flow direction of these area. Grain Size Distribution and mineralogical analysis of the sediments helps to understand the depositional environment and energy condition of that area, degree physical and chemical weathering and transportation history. In this study sediments from stabilized sand dunes found in in the area of Bathinda and Sikar Region were investigated.

### 1.1. What is Sand Dune:-

The accumulation of sands formed sand dunes, due to the wind action under the influence of gravity. These are mainly developed in arid regions as well as in coastal area. Dunes developed when it comes in contacts with obstacles or objects and the windblown sand grains settle down there uniformly and forms dunes. Sand dunes have two sides one side is called Wind ward face and another side is called Slip face. A wind ward face of sand dunes is that where wind start blowing and taking material up, which is also called as stoss sides, whereas slip face of sand dune is that where the materials deposited and there is no effects of winds in the slip face sides that side also called as lee sides. Generally the stoss sides are less smooth than the lee sides (figure-1)

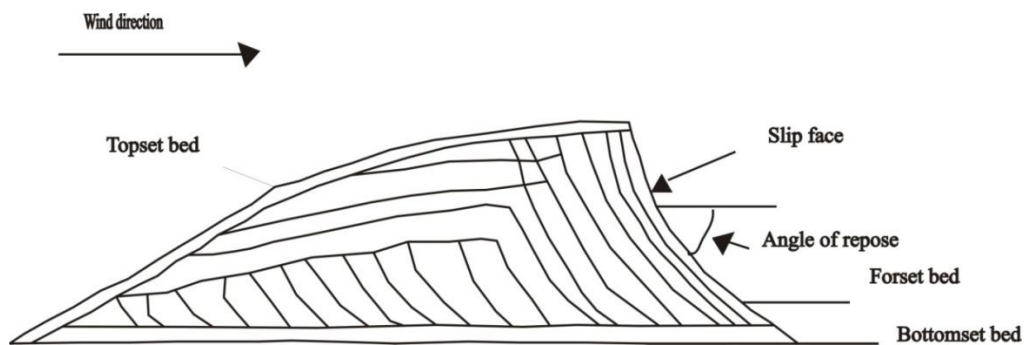


Fig1: Cross section of ideal sand dune.

## 1.2. How Sand Dunes are Formed:-

For the sand dune formation the following condition must require, such as

For the buildup the Sand dunes, Deposition of Sands must take place quicker than obstruction of material eroded.

Energy for movement should be strong winds so that it can transport sand particles.

An obstacle, for example, a piece of wood or a rock allow for the accumulation of. Many dune are formed where distribution of vegetation is high.

Dry climate: Due to the Moisture the sand grain size bond together. It also helps in plant growth. Plant growth in desert area or in Arid region helps in stabilization of the loose sediment and stops their movement.(<https://www.britannica.com/s>).Sand dunes are mainly formed due to the erosional and depositional forces. Due to the physical and chemical weathering process rocks are eroded into small sand size particles and these are accumulated to form sand dunes. The erosion leads to accumulation of sand. Strong winds pick up the sand and transport it (typically slightly above the ground) to another location. There they accumulated to form sand dunes. (<http://www.earthclips.com/geology/sand-dunes-formation-types.html>.)

## 1.3. Types of sand dunes

### (a)Barchans Dune:-

Due to the one direction of wind action this dunes are mainly formed (figure-2). These are Crescentic in shapes. It is also called as barchans or crescentic dunes. These dunes may occurs in separately or in groups.

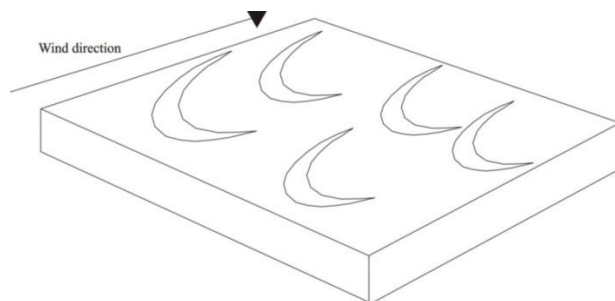


Fig 2: Barchans dune

**(b) Traverse Dune:**

These Dunes are perpendicular to wind direction and ridged like appears. Steep slip face present on these dunes at their back (figure-3). These Dunes mainly occurs in that area, where supply of sand is high and less plant life present. On beach areas traverse dunes are formed due to the strong winds, which originated from the ocean.(<http://www.earthclips.com/geology/sand-dunes-formation-types.html>.)

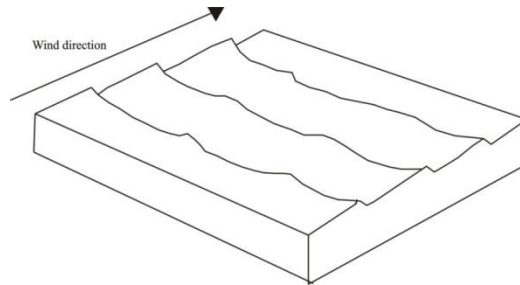


Fig:-3 Transverse dune

**(c) Blowout Dunes:-**

Blowout dunes are exactly opposite shape of the Barchans Dunes. In these dunes the Crescentic shaped and Slip faces away from the wind direction (figure-4). The Blown out Dunes are not formed with the help of the obstacles, but for the accumulation of sand over the years the vegetation forms a mold of leading to a stable dunes.(<http://www.earthclips.com/geology/sand-dunes-formation-types.html>.)

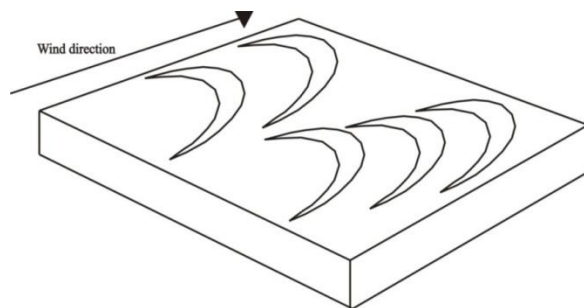


Fig4: Blownout Dune

**(d) Linear Dunes:-**

These Dunes are long and straight ridges, which are commonly parallel to the wind direction (figure-5) .These dunes can grow up to 100 m and extents to many kilometers. Geologist have found out that these Dunes are formed due to the action of wind ,that may travels from one direction in one season of the years, and later shift and travel from a separate direction during another season of the year.([http://www.earthclips.com/geology/sand dunes-formation -types .html.](http://www.earthclips.com/geology/sand%20dunes-formation%20types.html))

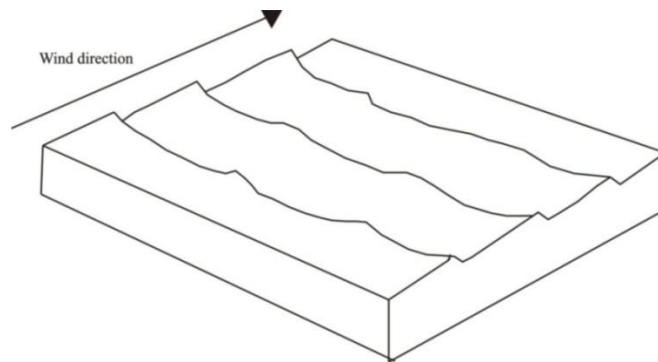


Fig 5: Linear dune

**(E) Star Dune:-**

These dunes radially symmetrical and have arms that radiated out from the high center of the pyramidal shaped Mound (figure-6) .They formed in the area where multi directional wind regimes. These dunes grow less in laterally and more in upward.([http://www.earthclips.com/geology/sand dunes-formation -types .html.](http://www.earthclips.com/geology/sand%20dunes-formation%20types.html))

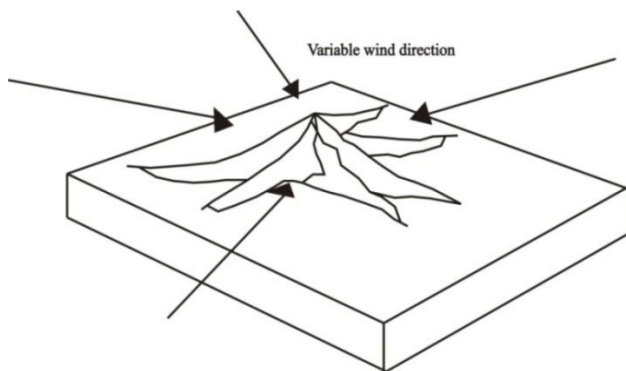


Fig 6: Star dunes

#### **(f) Composite Dunes:-**

These dunes mainly formed due to the combination of two or more kind of dunes. Composite dunes are generally very tall, large and very hilly, these types of dunes called Draas. These dunes are linear and traverse dunes that can accumulate up to 400 meters high. They reach finally into wide dune fields, which is known as Ergs. It can spread up to 500,000 km<sup>2</sup>. (<http://www.earthclips.com/geology/sand-dunes-formation-types.html>.)

#### **1.4. Stabilization of Sand Dunes**

Prerequisites for sand accumulation and dune building include wind velocity above a threshold that induces sand movement, availability of sand prone to erosion and presence of an obstruction around which moving sand tends to accumulate. (<https://www.britannica.com/s>)The formation of dunes may be prevented or slowed down by adopting measures like:

- (a) Reducing the velocity of wind by erecting barriers,
- (b) Restricting sand movement through chemical sprays, and
- (c) Encouraging the development of vegetation that binds sand.

Depending on the convenience and the availability of materials, dunes have been stabilized through use of water, chemicals and sealants, erection of physical barriers and through afforestation. Water is a fairly good stabilizer for short period. Frequent watering leads to formation of crust that can tolerate erosive force of average wind speed. This practice may be adopted in regions where water is available and the area to be stabilized is limited.

**I) Chemical Stabilization:** Sand dunes have been fixed through spraying of byproducts of petroleum on dune surface, use of chemical mulches and sealants. Ben Salem (1985) reviewed the techniques and the products available for sand dune stabilization.

**II) Byproducts Of Oil Industry:** In regions where oil is available, byproducts of oil industry have been used to stabilize the dunes. Products used include: (i) low gravity asphaltic oil (heavy oil), (ii) high gravity (light) waxy oil, and (iii) crude oil. The asphaltic oil forms a thin, non-sticky sheet over the dune surface, but is easily damaged by animals.

Repeated spray is often required. It is usually used near the roads where tree plantation is not possible. (Bhimaya *et al.*,1961).

**III) Other Chemicals:** Some chemicals are designed to facilitate growth of vegetation on unstable surfaces. The time for disintegration of these chemicals depends on the soil structure, slope, spraying techniques and concentration of the chemical. Most of these have been applied in Europe and America for -stabilization of slopes in road cuts or for fixation of coastal dunes with vegetation. (Mohammad,1988).

**IV) Physical Stabilization:** Locally available materials have been used to erect physical barriers to minimize the wind velocity and prevent sand movement. These usually include parts of locally available plants or other wastes like rail road sleepers, telephone poles, used oil drums, etc. When these materials are inserted vertically in the ground, called 'palisades', they act as micro wind breaks and when spread over the surface, called 'thatching', they act as mulching and prevent sand movement. (Kaul, 1985)

### **1.5. Soil Formation In Arid Region:**

In Arid region soils have no available of water for the mesophytic plants for the long periods. In this regions soils are deeper due to alluviation as well as colluvition ,also they often developed weakly,shallow and skeletal of A-R or A-C profiles except in the lower lands. In this regions the nearly absence or non –availability of water in these soils can have two reasons:-

The first one is the climatic reason linked to high evaporation and low precipitation, whereby little moisture is left for the soil processes like leaching and dissolution; and the second one is due to the presence of salts which retain and absorb water with such a strength that water is no more freely available in the soil, causing then an increase of soil solution osmotic pressure.

There are so many factors which affects for the formation of soils in the arid region like climate biological activity and vegetation are the major differentiating factors and therefore needs particular attention. Others like precipitation, wind action and evaporation etc. Dew is considered as secondary factor for the enhancement of the volumetric expansion and microbiological activity of salts.

**Rainfall and Moisture Supply:** In the arid regions the rain fall is characterized by irregular, low and unpredictable precipitation, often concentrated very less rainstorms. For

short periods of time over limited area it brings moisture in the soils. The moisture supplied to the soil from rain is offset by evaporation; the latter is enhanced by low air humidity, high solar radiation and high air temperature. Because of the irregular rainfall distribution mean precipitation values have little meaning in the (semi)-arid zone, if not also the range of variation is indicated. In arid soils the spatial as well as temporal variation have an impact on local difference in soil properties and soil process(Williams, 2008).

**Temperature:** In the arid zones the air temperatures are generally high and show variation in temperature between day and night, which under certain condition, it may attend 40°C or more. Variations of air temperature are well reflected at the soil surface, but rapidly disappear in depth. These high temperature gradients over short distance create important internal pressures because of the variable expansion of the different components inside the rock or the soil. This physical weathering process helps in the expansion of minerals present in the soils or rock materials (Jones, 2009).

**Wind:** On a arid region with very little or no protection from vegetation the effects of wind action may be important. Because of variations in atmospheric pressure winds are often very strong, especially during the day. Due to the wind action the transported material affects the chemical composition of the original products, which accumulated on top of the underlying rocks. Due to the wind action Medium-coarse particles are transported over relatively important distances of the order of a few 100 meters to more than 1000 km. the finest particles such as fine silt and clay carried out much larger distance. Hence, Aeolian deposits of silt-size material settle into a loess belt along desert fringes. (Jones, 2008).

**Dew:** Atmospheric dew is a very less important moisture source than the rainfall. It helps in improved of germination and early plant growth as a result of the major effect of this moisture source is linked to the development of microbiological activity and to the effects of salt hydration. Dew observations are rare, as low quantities registered per dew night and it difficult to measure them. Dew deposition is obviously influenced by site conditions, in particular topography and surface roughness. Dew, in contrast to rainfall, concentrates in a slow process on the soil surface during the night and early morning when evaporation is reduced to a minimum.

### 1.6. Pedogenic calcrete in Sand dune:

The soils of arid areas display a number of characteristic features such as: desert pavement, desert patina, vesicular layer and a prominent  $\text{CaCO}_3$  redistribution in the profile; the latter is expressed by the accumulation of secondary calcium carbonate under the form of individual nodules or of a continuous crust (caliche). When present, salts go into solution, redistribute and accumulate in the profile (Ref). For calcrete formation various mechanisms and models have been proposed. These are related to different geohydrological and hydrological settings, which can be classified as: surface water; soil-moisture zone; gravitational water zone; capillary fringe; and phreatic or groundwater zone.

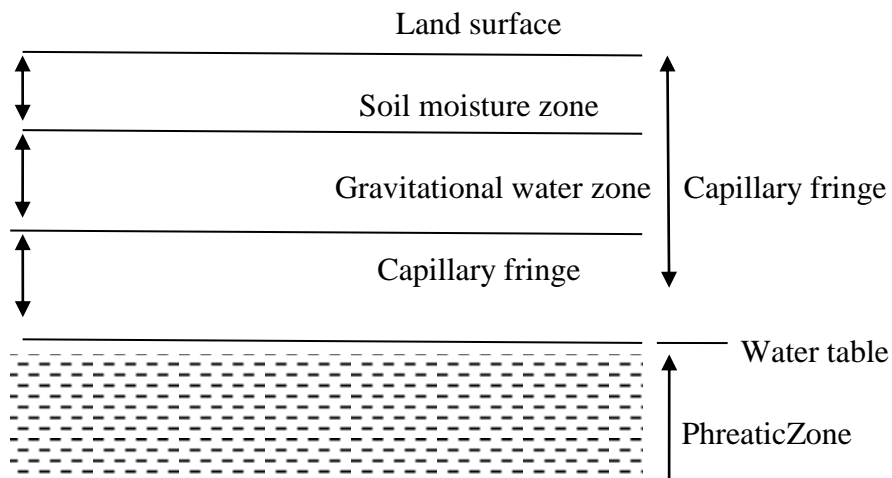


Fig 7: Geohydrological zones below the land surface

### 1.7. Research Problem and objectives:

Study of stabilized sand dunes present in the western India will help to understand the expansion and contraction of Thar Desert with time. Role of stabilized sand dune on shallow ground water quality, soil type and its composition in the semi-arid region of western India.

Sand dunes deposited in the arid region helps to determine the climate of that arid region, wind flow direction and energy, transportation history and tectonic activity of that region. Grain size distribution helps to understand the depositional environment, energy

condition of that windblown agent sand also the transportation history. from the mineralogical analysis of the sediments gives an idea about the abundance of the mineral components present in that area and also give information about the types of source sediment present in that area. Types of clay mineral present in the sediments provide information about the extent of chemical weathering and climate condition.

In the present study textural, mineralogical, carbonate percentage and its leaching were carried out on sand dune sediments collected from Bathinda (Punjab) and Sikar (Rajasthan) to achieve following objectives.

- To determine textural and mineralogical variation in the dune sediments using grain size distribution and XRD analysis.
- To estimate geochemical nature of the sediments using XRF analysis.
- To determine the percentage of calcrete for understanding the pedogenesis process active in the sand dune.
- To understand the mobility of elements during calcrete formation from carbonate fraction of the sediments using chemical leaching and subsequent ICP-MS analysis.

### **1.8. Review of Literature:**

Various Scientific published literatures were reviewed to acquire the background information for this project work. It also helped to design the project work plans and to correlate our work with the existing literature. Some of the reviews are discussed below.

Kasper-Zubillaga, et al., (2007) studied sediments of desert and coastal dunes of the Altar Desert, Sonora, Mexico to find out provenance using compositional, geochemical and sediment logical analysis.

Jones, et.al (2008) studied chrono sequences of soil development over 140 years at a temperate Atlantic UK dune system by the help of Aerial photographs, maps and optically stimulated luminescence dates. There soil formation had progressed for varying duration under different fluctuation in climate and nitrogen deposition regimes, for infer their relative influence on soil development compared with location-specific variables such as soil, slope, distance and pH to the sea. Results suggest that soil development followed a sigmoid curve. The soil increased with increasing nitrogen and temperature deposition in dry dunes and decreased with increasing summer gales. In wet dune habitats rates

increased with temperature and decreased with gales. These data suggest the importance of changing climate on soil development rates and highlight the contribution of biological N fixation in early successional systems.

Kaul (1996) studied sand dune stabilization program in the Thar desert of India is based on an understanding of the edaphic characteristics of the soil-water-plant relationships, as well as on the dune-interdune systems of the major dune types. From the last four decades, it has been found that the more lasting effects are achieved through a careful plantation of trees, shrubs and grasses at appropriate sites and using proven technologies.

MacDonald 2009 explained Harappan agriculture and urban water usage were likely sensitive to variations in Indian Summer Monsoon (ISM) rainfall. It shows negative correlations with central equatorial Pacific Ocean, with El Niño events and sea surface temperatures (SST's), in the eastern positively correlated with temperatures in the western equatorial Pacific. The disappearance, development and decline of Harappan civilization between 9000 and 3000 cal BP occurred against an environmental backdrop of decreasing northern hemisphere isolation, increasing frequency and amplitude of ENSO event and decreasing western equatorial Pacific SST's. The continued long-term trend towards greater aridity and inter annual variability during the Late Harappan Phase would have continued to present water resource challenges beyond the 4200 cal BP event and could have been a contributing factor to Harappan decline and ultimate disappearance.

Ball (1964) studied five test runs were performed to assess possible bias when performing the loss on ignition (LOI) method to estimate organic matter and carbonate content of lake sediments. An accurate and stable weight loss was achieved after 2 hours of burning pure CaCO<sub>3</sub> at 950 °C. Experiments with a standardized lake sediment revealed a strong initial weight loss at 550 °C, but samples continued to lose weight at a slow rate at exposure of up to 64 h, which was likely the effect of loss of volatile salts. A further test-run revealed that at 550 °C samples in the centre of the furnace lost more weight than marginal samples. At 950 °C this pattern was still apparent but the differences became negligible. Again, LOI was dependent on sample size. Factors such as exposure time, position of samples and sample size in the furnace and the laboratory measuring affected LOI results. Therefore, He recommend analysts to be consistent in the LOI method used in relation to the ignition

temperatures, the sample size, and exposure times and to include information on these three parameters when referring to the method.

Dhir and Singhvi (2002) Explained For long, widely divergent views based on isolated pieces of historical evidence or broad geological evolution of the subcontinent, notably the rise of the Himalayas in mid-late Miocene), had prevailed regarding origin and antiquity of the Thar Desert. Studies of the past few decades have since provided a wealth of new information on landform styles, palaeoclimate history and evolutionary processes with chronometric and isotopic constraints. Dunes and calcrete-bearing alluvial aggradations have been the focus of interest. This review synthesizes the multidisciplinary work to present the state of the Thar during the Quaternary period.

Joz. (2003). Studied Grain size distribution and heavy mineral content of beach and dune sediments from the Malindi Bay coast, Kenya were determined. By dry sieving sediments Grain sizes were determined; samples represent the upper 5 mm of the surficial sediments, collected from the four main Geomorphologic units (foredune, berm zone, dune field and beach), during three observation periods, covering the northeast and southeast monsoon seasons. Sediment samples were grouped according to their collection from the northern or southern sector of the Sabaki river. The heavy mineral content of several samples collected from the sand dunes, berm zone and beach was obtained by using separating funnels and tetra bromo methane to gain insight into the mineral distribution, the mineralogy and comment on the economic potential of prospecting for the heavy minerals. The petrographic parameters determined include the mineral composition of the heavy fractions and the heavy mineral weight percentages obtained using a petrographic microscope. The heavy mineral suite here is dominated by some red garnet and zircon as well as opaque iron-titanium minerals. The results demonstrate a good relationship between geomorphological elements and the corresponding the heavy mineral concentrations.

Gallet and Torii (1996) Explained Loess-soil sequences provide one of the most continuous and detailed records of the climate changes on land areas in the Quaternary. The Late Pleistocene loess section in Dankowice (Niemcza-Strzelin Hills) is one of the best recognized in SW Poland. For the investigation, 31 loess samples were tested in Dankowice. The chemical composition of loess is similar to the results presented in the world loess literature. Here the silica is high. The chemical composition of loess is

differentiated within the vertical sequence in Dankowice and confirm previous division of litho-pedostratigraphic units. So, the chemostratigraphic method used successfully as a one of lithostratigraphic methods. Decreasing values of the chemical weathering indicate that the material have been provided from the source areas of loess silt ,intense chemical weathering processes and less transformed by prolonged.

Roy and Pandey (2003) : Studied the great Indian desert in the eastern limit of the extensive hot desert region stretching from the western coast of Africa. The desert has been formed due to the absence of moist monsoon air and it's mechanisms over this region. The climatological hydrological, geomorphological, floristic, cultural and faunistics evidences of the past and present have been examined and discussed. From the discussion points in fevour as well as against expansion of the desert and possible causes for origin it emerges that the desert is neither expanding nor contracting but has been occupying essential the same position.

Madella and Fuller(2005) Explained Climatic change has often been cited as a determining factor in cultural changes in the context of the Harappan Civilization of northwestern South Asia, 2500–1900 BC. The main purpose is to assess the available evidence and published arguments and to provide a constructive working synthesis for the palaeo-environmental setting of northwestern South Asia for the mid- to late Holocene, especially ca 4000–1000 cal BC, and its possible connection to important cultural changes.

Bakliwal and Wadhawan (2002): Explained the frame work of quaternary litho-startigraphic classification has been established in different sectorss of thar desert. Fluvial and fluvio-lacustrine deposits formed the base for aeolian deposition and controlled the configuration and deposition of older aeolian deposits.Based on recorded the neotectonic evidences and correlative sub-surfaceand surface quaternary stratigraphic studies of the northely flowing,structurally controlled palaeo-drainage pattern for the early quarternary fluvial regime could be deduced.The present contribution attempts synthesis and elvaluation of the quarternary litho-stratigraphy and dune hierarchy in the sub-basins of arid thar.

Singh and Sharma(2013) Studied the Physical, chemical and morphological characteristics of soils developed on three physiographic units i.e sand dunes, alluvial terrace sand interdunal areas in the arid zone of Punjab(in Bathinda district) have been investigated.

The soils developed on sand dunes were lack subsurface diagnostic horizons, coarser in texture, do not show structural development and lack subsurface diagnostic horizons. On inter-dunal terraces Soils developed as yellowish brown in color in the surface and dark yellowish brown in lower horizons and were relatively fine textured along with the development of a structural of B horizon. The alluvial terrace soils were fine textured ,dark yellowish brown in colour throughout the profile and soil structure varies from weak fine sub- angular blocky to the massive. The fine textured alluvial terrace soils have highest cation exchange capacity followed by interdunal and sand dunal soils.

## **CHAPTER-2**

### **STUDY AREA**

Punjab is the part of alluvium expanse which is known as indo Gangetic plains. The length of this plain is 300km from north to south and about 280 km broad. The plain is extremely flat and it slopes from NE to SW. The height of the area between 180-330m above the sea level.

#### **2.1. Location and Extent:-**

Bathinda is the district of the southern west part of Punjab. It's geo coordinates  $29^{\circ} 33'$  to  $30^{\circ} 36'$  North latitude and  $74^{\circ} 38'$  to  $75^{\circ} 46'$  East longitude. It falls in Survey of India Topo sheets No. 44J, 44K, 44N, and 44O. It covers an area of 3367 Sq. Km. It is bounded by the state boundaries of Haryana and Rajasthan in the southern area, where as districts boundary of ferozpur in the west, Faridkkot in the north and also Sangrur in the east. Physiographically the area is gentle slope in NE to SW direction. It is the part of indo Gangetic alluvial plain, it comprises alternate bands of sand, clay and silt with pebbles. Sand dunes, sandy plains and topographical depressions are common in this region. Climatically the Himalaya in the north and the Thar desert in south and SW mainly influence the climatic condition. Rainfall in this area normally less than 400mm (Dinesh Tewari 2013).

In the eastern part of the Rajasthan the Sikar district is located and extends between the geo-coordinates of  $27^{\circ}07'00''$  &  $28^{\circ}12'34''$  N latitude and  $74^{\circ}41'21''$  and  $76^{\circ}05'14''$  E longitudes. The state mainly crescentic in shape and covers area of 7732 sq. km. It covered in the GSI degree sheet nos.45I,45M,54A,44Pand 44L.It bounded Churu and Jhunjhunu district on the northern side Of Rajasthan and on the east side Haryana state of Mahendragarh,on western side by Churu and Nagaur ,whereas on southern side Jaipur districts of Rajasthn state.

## **2.2. Geology:-**

Geologically, Punjab mainly composed of Siwalik and the Recent alluvium. The area of deposition belongs to Pleistocene to Recent periods and mainly consists of sand, silt, clays and gravels. Sand dunes and Sand plains are alluvial deposited due to the action of windblown sands in Bathinda districts near to that of the Rajasthan and Haryana state. The alluvium deposits forming the alluvial plains are locally known as Bhangar and Reh or Kallar. During the dry seasons the Reh covers the surface of the salt affected soils. Bathinda have semi –arid climates and due to the Thar desert of Rajasthan it shows topographical variation. Most of the sand dunes present in the area are stabilized; some of them are leveled and brought under cultivation. The sand dune areas are moderately sloping and the inter sand dunes areas level to gentle sloping. The elevation of the whole region about 220m in east and about 183m above the sea level(Tewari 2013).

The Alluvial and Aeolian sand layers are major part covered with in the districts of Sikar. The Aravali hill range occupied in the eastern part of the districts. The rock types of this area belong to Delhi Super Group of meta-sediments, whose exposures are seen in Neem ka Thana block in eastern part of the district. Alwar and Ajabgarh Groups are the parts of the Delhi super group, which found in the eastern part of the district and it characterized by slate, quartzite, schist, marble and phyllite . In eastern part of the district like Khandela, the Sri Madhopur and Neem ka Thana blocks Bhilwara Super Group is exposed. Sandmata complex is belongs to Bhilwara Super Group , which consist of gneiss, schist, migmatitic and dolomitic marble.(CGWB 2008).

## **2.3 Soil:-**

Two type of soils are mainly found in bathinda i.e desert soils and sandy soils. These soils developed in hot and arid climates and thin cover of bush or thorn vegetation. The soil is deficient and dry in humus. It is poor in potassium, phosphorus and nitrogen. Because of little rainfall and high evaporation, calcification is the soil forming processes, therefore the soils are predominately calcareous . There is no concentration of clay in any horizon.

The soils are light in color, ranging from yellow to light brown. Coarse texture are found in this area and these are mainly sandy loam, sandy or silty loams. The reaction is normal to alkaline and PH value ranges from 7.5 to 8.5.

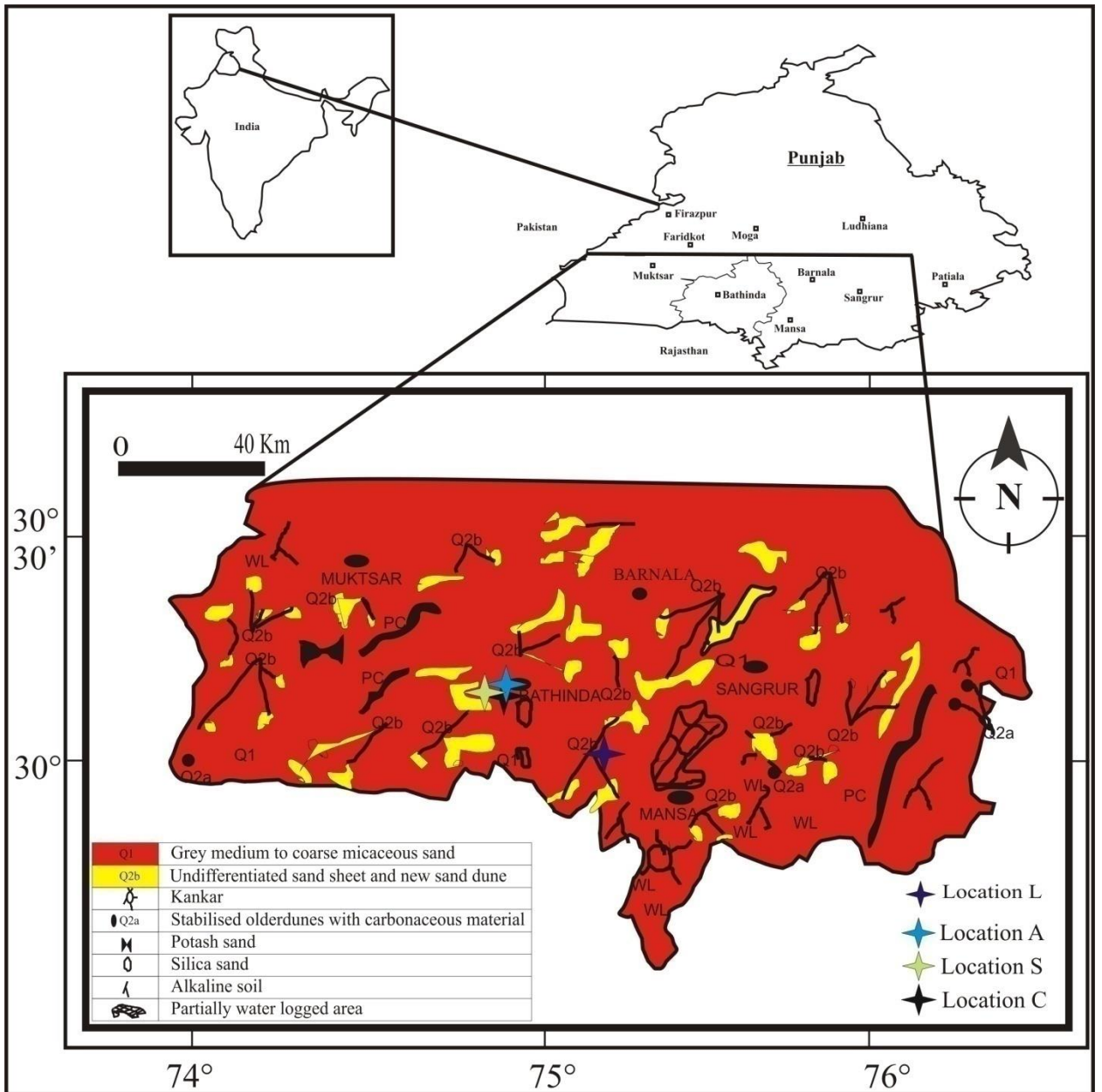
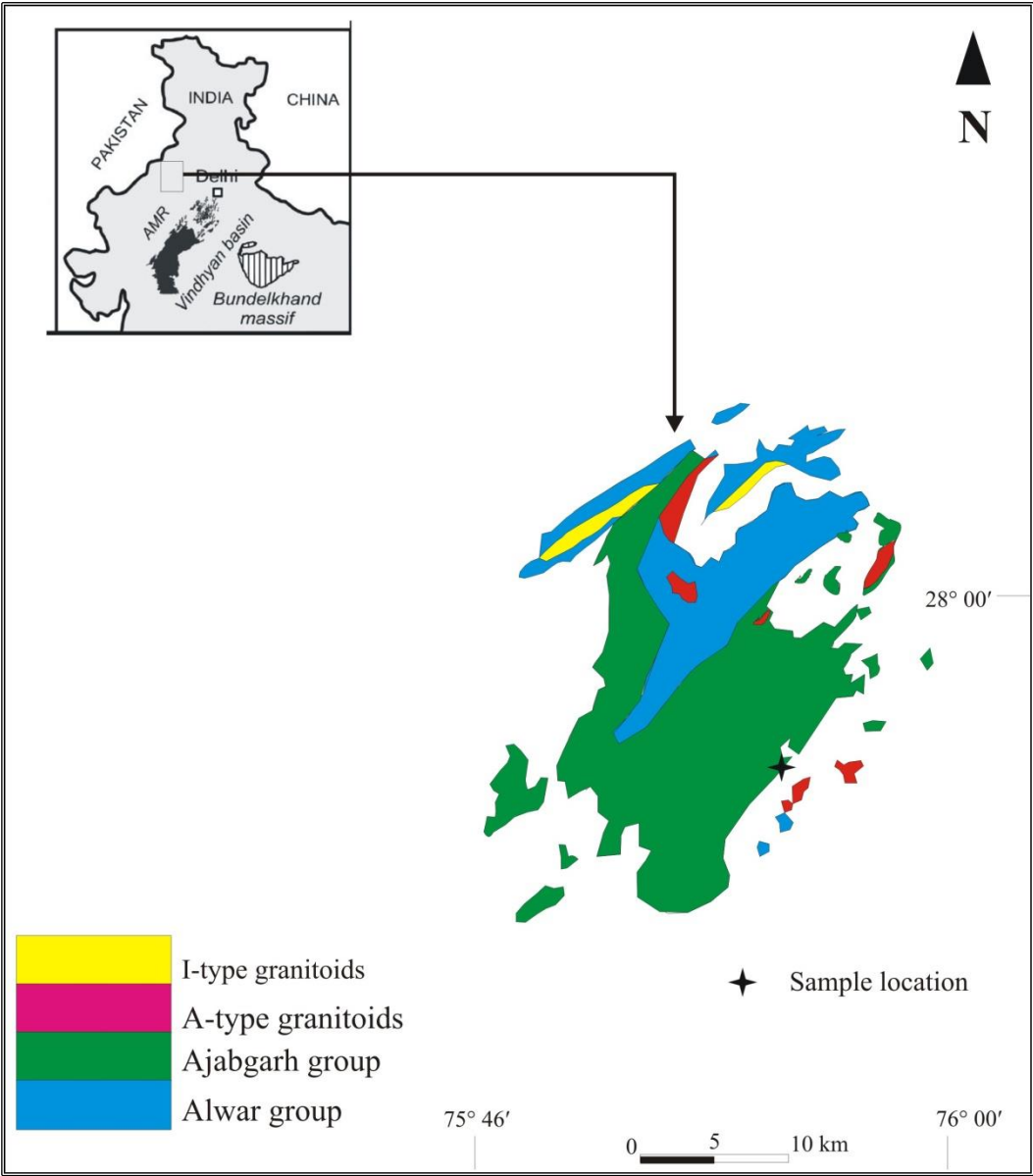


Fig 8: Study area map showing geology (part of Punjab) and sample location

Due to the human activities and the climate, soil suffers various degree of degradation ,particularly salinity and sodicity. In salinity soils, soulable salt content is high, for which it makes difficult to plant to absorb water from saline soil. Salinity soils have PH between 7.3 to 8.5 and the soils are neutral in reaction, where as the sodic soils have PH above 8.5 and strong in alkaline reaction. There are large tracts of slightly to moderately saline or sodic soils in Malwa plains due to aridity and depression like lower position in Bathinda district. , (A.K 2007).



**Fig9 :-Study area of Sikar Map**

The soils of the Sikar district have been broadly classified into: Desertic soil, Red desertic soil, Serozems, Saline soil, Lithosols, Regosols, Old alluvium

#### **2.4 Topography:**

The soils of the Bathinda districts are mainly sandy. The sandy plains have tendency to shift towards the eastern side and it is dotted with scattered sand dune (Fig 9). With the helps of machinery and technology the topography is undergoing a vast change with various aspects connected with green revolution.

Physiographically the Sikar district divided into two units one is sandy plain in W and E half and another one is hill range which trend in NE-SW. Kanti and Mendha are the two major river of the districts. Significant part of the district is that it falls within 'outside basin' which have no systematic drainage system. The topographical elevation of this district ranges between 375 to 500 m above the mean sea level. A minimum Elevation ranges from o 294m amsl in Fatehpur block which is situated in the NW part of the district to a maximum of 1,032m amsl in Piprali block in N part of the district.(CGWB, 2008).

#### **2.5.Climate:**

Climatically the districts have very hot in summer and frequently scorching heat is in full swing as the district located in the SW of the state, which is far away from Siwalik ranges in the northern state and also nearest to Thar desert of Rajasthan and faraway from the major rivers. The climate of Bathinda can be classified as Semi arid to Arid,tropical steppe and hot which is mainly dry except in the rainy months and characterized by cold in winter and intensely hot in summer from July to September three months are the seasons of monsoon, the moist air penetrate into the districts and high cloudness, humidity and good monsoon rainfall. Post monsoon season starts from October to November and cold season starts from December to February followed by the hot weather season or pre monsoon season upto the last week of June (Tewari, 2013).

The district is mainly semi arid region and it typically characterized by fairly good rain fall, hot summer and a chilly Winter season. The humidity levels of these regions are quite low, as a result dryness in air occurs but there are some brief monsoon

seasons when the humidity reaches upto 60% maximum. From march to June summer season starts, and at that time the temperature approaches 47° to 48°C, whereas in winter season extremely cold nights with temperature dropping to about 10°C. The average temperature is about 16 to 20 °C around the year. In this districts the average rainfall is about 363.7 mm , which received from SW monsoon in the months of July to September (CGWB 2008).

### 2.5.1 Rain fall:

In Bathinda districts the annual rain fall occurs 408mm in 20 days, which is unevenly distributed over the districts. In last week of June the southwest monsoons sets and withdraw towards end of September, contributes about 82% of annual rainfall. The rainiest months are July and August. Rainfall in the district increases from southwest to northeast (IMD).

#### Rainfall

Normal Annual Rainfall : 408 mm

Normal monsoon Rainfall : 335 mm

Normal Rain day : 20

#### Temperature

Mean Maximum : 42°C (May & June)

Mean Minimum : 3.9°C (January)

The rainfall data of the last 5 years of Bhatinda is given below (Source: IMD):

	2008	2009	2010	2011	2013
Annual rain fall (MM)	527.0	252.7	357.3	494.3	215.9

In sikar districts the annual rainfall is 463.0 mm (1971-2011), where as the normal rainfall is lower than the average rainfall and placed at 459.8. During the SW monsoon it received almost 95% of the total annual rainfall, which enters in the last week of June and withdraw in the middle of September. Neem Ka Thana, which is located in the south eastern part of the Sikar district has highest annual rainfall (536.6 mm) and at Fatehpur has lowest (407.8 mm), which lies near NW boundary of the Sikar district. (IMD)

Temperature:

Mean Maximum : 40°C (May & June)

Mean Minimum : 6°C (January)

## **2.6.Hydrology:**

The occurrence, movement and availability of ground water are mainly controlled by physical characteristics, structural features and the topographic features present in the geological formations. Indo-Gangetic alluvial plain is occupied within the Bathinda district by Quaternary age. The area has both confined and unconfined aquifers. The top aquifer ranges from 40 to 56 m. The depth of the top aquifer, in the East it is 38 m, in the south it is upto 58 m, in the west it is 40 m and in the North is upto 56 m. The fresh water granular zones exist upto 50 m in the Southwestern parts, upto 300 m in the North, upto 50 m in the Southwestern parts and upto 200 m in the Central of the district. The depth to water level in the district varies from 20.39 m bgl (western and southern part) to 16.50 m.bgl (Northern part) During the Pre -monsoon time. During the Post-monsoon, the pattern of the depth of water level is same as in pre-monsoon. The water level varies from 2.24 to 20.76 m.bgl. Seasonal fluctuation of the water level varies from 0.03 to 2.5 m. in this district the elevation of the water table ranges between 189.14 to 209.25 m amsl. The general slope of the water table is towards SW from North, NE, East and SE.(CGWB 2013)

In Sikar districts Ground water occurs under semi-confined to unconfined condition. The Quaternary sediments covering major part of the district like in central and western parts of the district, which are aquifer in nature and occupy about 75% of the districts area.

In Sikar basin, fine sand and silt form the main aquifer. The water level depth ranges in this area from > 2m to more than 75m. Depth range varies from 25 m to more than 45m in the western part, less than 10 m in central and eastern parts. During pre-monsoon and post monsoon the water level are ranges from 1.80 to 77.20 and 0.80 to 78.25 mbgl respectively. The general direction of flow of ground water is from SW to NE. The pH value of ground water is ranges from 7.02 to 9.00 indicating alkaline nature of ground water. (CGWB 2008).

### CHAPTER -3

#### SAMPLING AND ANALYTICAL METHOD

To find out the depositional environment, mineral composition, climate and energy of transportation history of Bathinda districts of Punjab and Sikar districts of Rajasthan and for comparing both the area, Dune samples collected from different places of that area.



**Fig10:-Sample Location, Bathinda: Google image of Sample location (2017 image)**

From Google image it shown that the Bathinda area how it gradually changes in the plantation or morphological characters. In 2004 image there is no developments of grass, plants or shrubs, where as in 2017 it shows the area is filled with plantation. which indicates that the stabilization of the inter sand dunes or dunes occurs and erosion portion is less or there is less movements or fluctuation of the dunes. so, the dunes are now well stabilized..

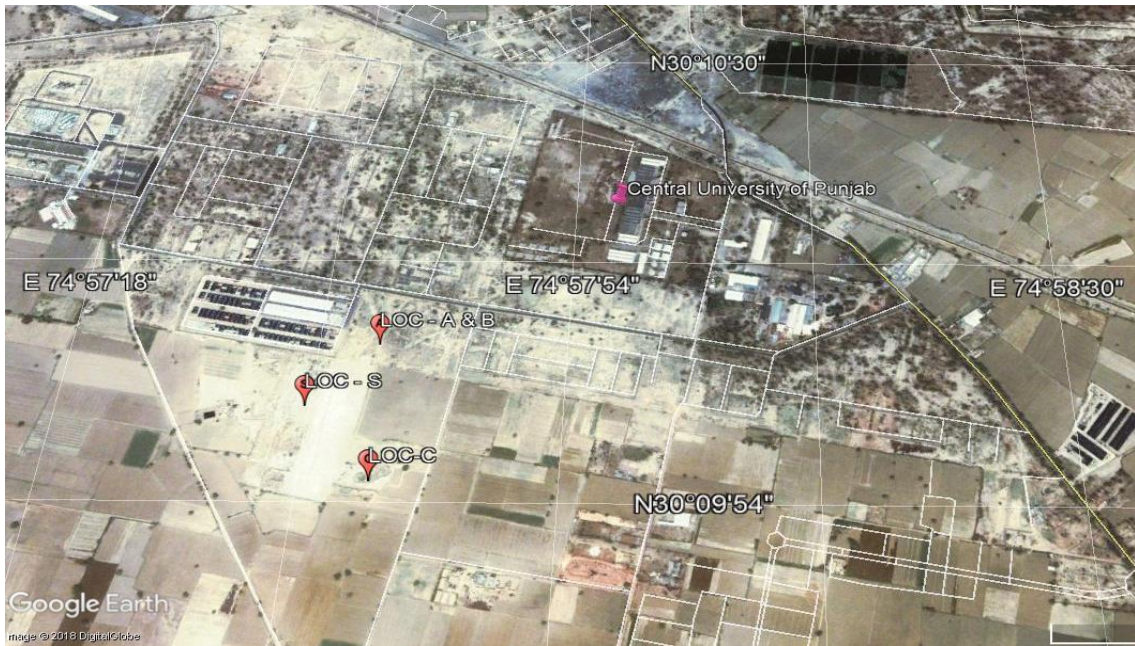


Fig 11: Sample Location, Bathinda: Google image of Sample location (2004 image)



Fig 12: Sample Location, Sikar: Google image of Sample location (2017 image)

### 3.1 SAMPLING:-

Total 23 samples were collected (table-1), out of which 19 samples collected from the Bathinda region and 4 samples are collected from Sikar of Rajasthan region. For this project work 3 sand dunes area are located near to that of the Cancer Institute of Bathinda, Mansa Road and 1 sand dunes location is identified in Sikar near to that of Awali veterinary college. Section of these sand dunes show variation in grain size from coarse sand to fine sand, clay, silt and from top to bottom calcrite percentage gradually increases. For this project work 2-2.5 kg of samples collected from both the areas. In the field During the sample collecting time sample location, geo-coordinates of that area, elevation and also the height of that area from where the samples collected and vegetation, surrounding of that area recorded in the diary. From that location to avoid the local mixing we collected samples from the inner part, then samples were packed in the polyethylene Zip lock and labeled and transported to lab for analysis work.

Table 1: Sample Location With Altitude And Pits Length, Breadth

Sample Name	Latitude	Longitude	Altitude(Meter)	Pits(Cm)	
				Length	Breadth
A0	N30 <sup>0</sup> 10'04"	E74 <sup>0</sup> 57'39.3"	208.43	19	9
A1	N30 <sup>0</sup> 10'04"	E74 <sup>0</sup> 57'39.3"	207.87	18.5	13
A2	N30 <sup>0</sup> 10'04"	E74 <sup>0</sup> 57'39.3"	207.37	16	9
A3	N30 <sup>0</sup> 10'04"	E74 <sup>0</sup> 57'39.3"	206.87	17	11.5
A4	N30 <sup>0</sup> 10'04"	E74 <sup>0</sup> 57'39.3"	206.37	17	10
A5	N30 <sup>0</sup> 10'04"	E74 <sup>0</sup> 57'39.3"	205.87	20	17
B0	N30 <sup>0</sup> 10'04"	E74 <sup>0</sup> 57'39.3"	204.47	10	20
B1	N30 <sup>0</sup> 10'04"	E74 <sup>0</sup> 57'39.3"	204.05	12	13
B2	N30 <sup>0</sup> 10'04"	E74 <sup>0</sup> 57'39.3"	203.55	13	11
B3	N30 <sup>0</sup> 10'04"	E74 <sup>0</sup> 57'39.3"	203.03	14	15
Ctop	N30 <sup>0</sup> 09'58.2"	E74 <sup>0</sup> 57'18"	204.82	19	12
C0	N30 <sup>0</sup> 09'58.2"	E74 <sup>0</sup> 57'18"	204.02	20	14
C1	N30 <sup>0</sup> 09'58.2"	E74 <sup>0</sup> 57'18"	203.02	22	13
C2	N30 <sup>0</sup> 09'58.2"	E74 <sup>0</sup> 57'18"	202.22	17	11
S0	N30 <sup>0</sup> 10'02.5"	E74 <sup>0</sup> 57'33.5"	206.35	16	12
S1	N30 <sup>0</sup> 10'02.5"	E74 <sup>0</sup> 57'33.5"	205.83	16	15
S2	N30 <sup>0</sup> 10'02.5"	E74 <sup>0</sup> 57'33.5"	205.19	18	11
S3	N30 <sup>0</sup> 10'02.5"	E74 <sup>0</sup> 57'33.5"	204.56	16	10
S4	N30 <sup>0</sup> 10'02.5"	E74 <sup>0</sup> 57'33.5"	203.96	21	12
T1	N27 <sup>0</sup> 44'48"	E75 <sup>0</sup> 52'48"	435.86	16	12

T3	N27 <sup>0</sup> 44'48"	E75 <sup>0</sup> 52'48"	435.47	13	10
T5	N27 <sup>0</sup> 44'48"	E75 <sup>0</sup> 52'48"	435.10	20	8
T7	N27 <sup>0</sup> 44'48"	E75 <sup>0</sup> 52'48"	434.73	14	12



Fig 13:Sampling Site of LOC – A & B (Bathinda)

In Bathinda Region three locations are marked as the Dunes are well stabilized, with great height and well developed. from the Location–A&B,11 samples collected namely(A0,A1,A2,A3,A4,A5,B0,B1,B2,B3) whose geo-coordinates and altitude are given in (table:-1) .In this first location the top of dunes are cover with grass and around that cultivation is also going on. The roots are also intruded to 50 or 60 cm below the surface. The sample A0 is situated 23 cm below that of the surface ,the second one A1 is located 56cm from that of the sample A0 .similarly 11 samples are collected with particular depth , whose depth distance from that previous sample is illustrated in the fig:13.The variable grain size with distance indicates the depositional environment.

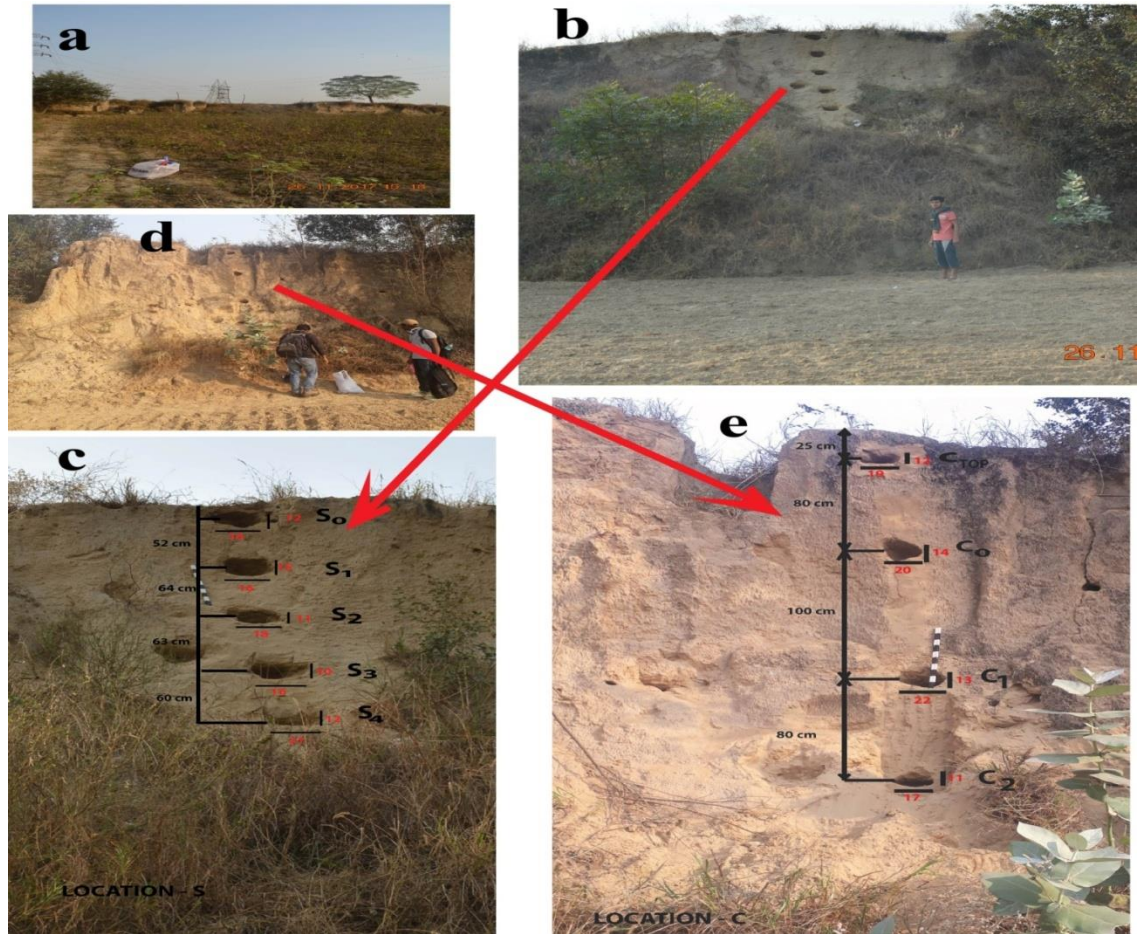


Fig 14: Sampling Site of Loc – C & S (Bathinda)

From Location-C four samples namely(Ctop,C0,C1 and C2) were collected ,which is situated at a distance of 500m from that location one. Also sampling site depth and pits dimension are illustrated in the fig 14.

Similarly in Location-S also five samples are collected, which is situated 300m from Location-A&B and 200m from location -C. The geordinates and altitude explains in (table 1) and the depth as well as pit dimension illustrated in fig14. The area is fully covered with grasses and roots are developed to very depth. very fine size particles are found in this location and very well developed calcrete found, and the percentages increases when we are going from top to bottom.

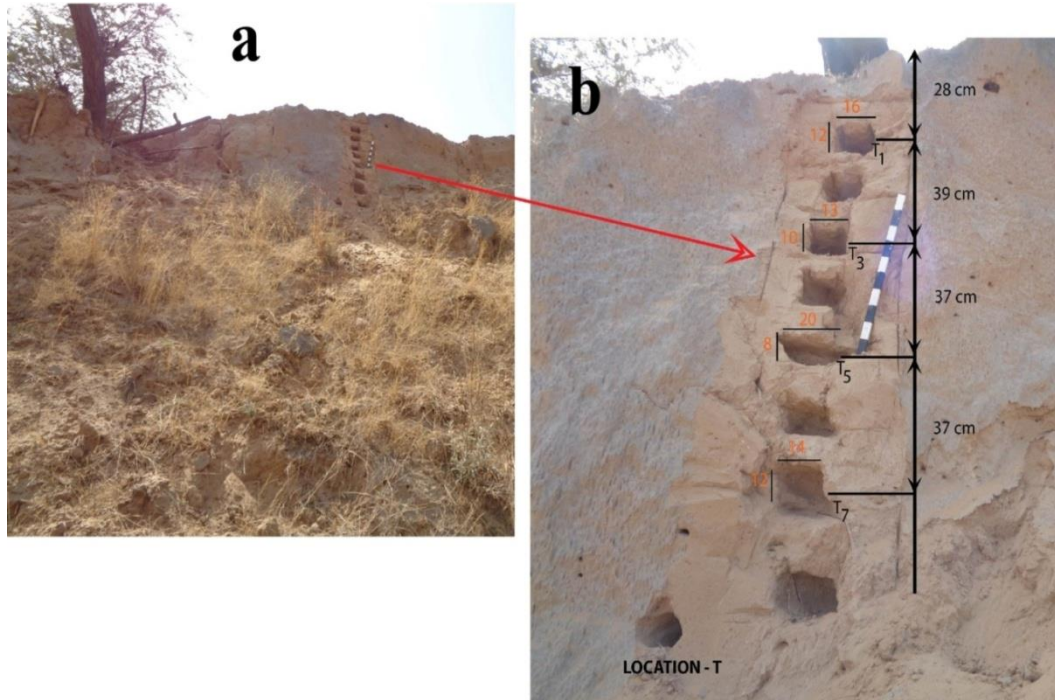


Fig15: Sampling Site of LOC – T (Sikar)

In the sikar districts of Rajasthan only one location is chosen from which 8 samples are collected. The geo coordinates and the altitude of that area was explained (table-1). The area is covered with grasses, root also developed and mountains are surrounded to that area. The depth of the samples from that top and the pit dimension are illustrated in fig:15. Very fine size particles of sand found in this location and very well developed calcrete are also found.

### 3.2 Analytical Methods:-

The 23 samples are sieved with 500 ( $\mu\text{m}$ ) to separate the calcrete from the samples. For the homogenizing of the samples, cone and quarters methods were followed. This cone and quarter method helps in well mixing of the samples and also helps to avoid biasness during the section of the sampling process.

In the cone and quarter methods the samples are well mixed and kept on the buttersheet papers. Then samples are poured into a uniform conical pile. Below that cone the butter sheet paper should be spread and that paper divided into four quardent. Then the

samples poured in the conical pile and collected in the center of the buttersheet paper like small mound range.

Then the samples are divided into quarters, from that the two opposite site of quarters are mixed and kept in the zip lock. The other two quarter followed the same rule like the previous one. Similarly the process going on till it reaches 20 to 15 gm.

Approximately 800gm to 600gm homogenized samples are kept for the grain size analysis, to 10gms for XRF, 4 to 7gms for XRD and 5 to 6gms for ICPMS analysis and 3 to 4gms for to know the % of  $\text{CaCO}_3$  present in the sample (table-2).

For the XRD, XRF, ICPMS analysis about 20 gm samples are grinded in the agate motter, till the size reduces to 20  $\mu\text{m}$  and it feels like talc powder. After grinding each samples are kept in the different small zip lock and labeled.

Table-2 wt of different samples used for different analysis.

Analysis	Sample wt. (g)	Nos. of samples
TEXTURAL ANALYSIS	600-800	23 samples
XRD	15 - 20 (3)	23 samples
XRF (major element)	15 – 20 (6)	10 samples
ICP-MS (Carbonate phase)	15 – 20 (1)	17 samples
Carbonate percentage	15 – 20 (1)	10 samples
For future analysis	800 - 1000	23 samples

### 3.3 Grain Size Analysis:-

From this analysis the percentages of different grain sizes are present in the sand dunes can be determined. For this the sieving sets are used to determine the distribution of fine sized particles. The distribution of grain size determines the type of depositional environment and wind flow direction and energy.

For the sieving method four sieve sets are arranged, whose meshes are i.e 500, 250, 125, 75  $\mu\text{m}$ . These sieve sets are arranged in increasing order from bottom to top

about 600 to 800 gm of samples are loaded in the sieve and kept for 1 hr each samples for sieving by using the electric shaker machine.

After sieving, the samples of different sizes segregated out and kept in the zip lock and labeled. Each sample weight in the wt machine available in lab and listed in (Table 3).

Table:-3 Weight of different grain sizes.

Sample Name	>250 $\mu$ m	>125 $\mu$ m	>75 $\mu$ m	<75 $\mu$ m	total wt(g)
A0	42	464	173	161	840
A1	37	338	362	243	980
A2	29	376	221	282	908
A3	31	262	253	361	907
A4	30	624	300	273	1227
A5	18	273	379	238	908
B0	17	160	320	300	797
B1	24	158	144	241	567
B2	28	247	296	240	811
B3	7	264	269	249	789
CTOP	9	172	282	292	755
C0	18	224	279	306	827
C1	6	106	402	315	829
C2	6	96	238	326	666
S0	3	57	402	258	720
S1	3	73	359	363	798
S2	6	58	552	275	891
S3	2	53	364	349	768
S4	5	62	307	285	659
T1	2	113	668	103	886
T3	4	42	665	119	830
T5	3	74	420	154	651

To calculate the grain size, statistic and logarithmic analysis GRADISTAT excel sheet with macro enabled used. The grain size data used to calculate the graphical mean ( $M_z$ ), standard deviation ( $\sigma_1$ ), Kurtosis ( $K_G$ ), skewness ( $S_K$ ) and sorting based on Folk and Ward given method. This excel sheet was given by Simon Blott (october 2000)

### 3.4 Statistical Formula Used in the calculation of grain size parameters:-

f-is the frequency in percent, m-is the midpoint of each class interval in metric(mm) or phi( $m\phi$ ) units,  $P_x$  and  $\phi_x$  are grain diameters in metric or phi units respectively at cumulative percentile value of x. The grain size used for statistic calculation, grain size

and scheme of categorization of sediments based on their distribution and other calculated parameter are given in table 4-9.(Source: Blott And Pye June 2001)

Table:-4 Arithmetic method of movements

Mean	Standard Deviation	Skewness	Kurtosis
$\bar{X}_a = \frac{\sum F M_m}{100}$	$\sigma_a = \sqrt{\frac{\sum F (M_m - \bar{X}_a)^2}{100}}$	$SK_a = \frac{\sum F (M_m - \bar{X}_a)^3}{100 \sigma^3}$	$K_a = \frac{\sum F (M_m - \bar{X}_a)^4}{100 \sigma^4}$

Source: Blott And Pye (June 2001)

Table 5:Geometric Method Of Movements

Mean	Standard Deviation	Skewness	Kurtosis
$\bar{X}_g = \exp \frac{\sum F \ln M_m}{100}$	$\sigma_g = \sqrt{\frac{\sum F (\ln M_m - \ln \bar{X}_g)^2}{100}}$	$SK_g = \frac{\sum F (\ln M_m - \ln \bar{X}_g)^3}{100 \ln \sigma^3}$	$K_g = \frac{\sum F (\ln M_m - \ln \bar{X}_g)^4}{100 \ln \sigma^4}$

Mean $X_g$		Skewness $SK_g$	Kurtosis $K_g$
Very well sorted	<1.27	Very fine skewed <1.30	Very platykurtic <1.70
Well sorted	1.27-1.41	Fine skewed 1.30-.43	Platykurtic 1.70-2.55
Moderately well sorted	1.41-1.62	Symmetrical 0.43-0.43	Mesokurtic 2.55-3.70
Moderately sorted	1.62-2.00	Coarse skewed 0.43-1.30	Leptokurtic 3.70-7.40
Poorly sorted	2.00-4.00	Very coarseskewed >1.30	Very leptokurtic >7.40
Very poorly sorted	4.00-16.00		
Extremely poorly sorted	>16.00		

Source:- Blott And Pye (June 2001)

Table:-6 Logarithmic Methods Of Movements

Mean	Standard Deviation	Skewness	Kurtosis
$\bar{X}_\phi = \frac{\sum F M_\phi}{100}$	$\sigma_\phi = \sqrt{\frac{\sum F (M_\phi - \bar{X}_\phi)^2}{100}}$	$SK_\phi = \frac{\sum F (M_\phi - \bar{X}_\phi)^3}{100 \sigma_\phi^3}$	$K_\phi = \frac{\sum F (M_\phi - \bar{X}_\phi)^4}{100 \sigma_\phi^4}$

Standard Deviation $\sigma_\phi$	Skewness $SK_\phi$	Kurtosis $K_\phi$
Very well sorted <0.35	Very fine skewed >1.30	Very platykurtic <1.70
Well sorted 0.35-0.50	Fine skewed .43 - 1.30	Platykurtic 1.70-2.55
Moderately well sorted 0.50-0.70	Symmetrical .43-.43	Mesokurtic 2.55-3.70
Moderately sorted 0.70-1.00	Coarse skewed .43-1.30	Leptokurtic 3.70-7.40
Poorly sorted 1.00-2.00	Verycoarseskewed <1.30	Very leptokurtic >7.40
Very poorly sorted 2.00-4.00		
Extremely poorly sorted >4.00		

Source Blott And Pye (June 2001)

Table:7 Logarithmic (original) Folk and Ward (1957) Graphical measures

Mean	Standard Deviation	Skewness	Kurtosis
$M_z = \frac{\Phi_{16} + \Phi_{50} + \Phi_{84}}{3}$	$\sigma_i = \frac{\Phi_{84} - \Phi_{16}}{4} + \frac{\Phi_{95} - \Phi_5}{6.6}$	$SK_i = \frac{\Phi_{16} + \Phi_{84} - 2\Phi_{50}}{2(\Phi_{84} - \Phi_{16})} + \frac{\Phi_5 + \Phi_{95} - 2\Phi_{50}}{2(\Phi_{95} - \Phi_5)}$	$K_G = \frac{\Phi_{95} - \Phi_5}{2.44(\Phi_{75} - \Phi_{25})}$
Mean $M_z$	Skewness $SK_i$	Kurtosis $K_G$	
Verywellsorted <0.35	Very fine skewed 0.3-1.0	Very platykurtic <0.67	
Well sorted 0.35-0.50	Fine skewed 0.1-0.3	Platykurtic 0.67-.90	
Moderately well sorted 0.50-0.70	Symmetrical 0.1-0.1	Mesokurtic 0.90-1.11	
Moderately sorted 0.70-1.00	Coarse skewed 0.1-0.3	Leptokurtic 1.11-1.50	
Poorly sorted 1.00-2.00	Very coarse skewed 0.3-1.0	Very leptokurtic 1.50-3.00	
Very poorly sorted 2.00-4.00		Extremelyleptokurtic>3.00	
Extremelypoorly sorted >4.00			

Source Blott And Pye (June 2001)

Table:-8 Geometric Folk And Word (1957) Graphical Measure

Mean $M_G$	Standard Deviation $\sigma_G$
$M_G = \exp\left(\frac{\ln P_{16} + \ln P_{50} + \ln P_{84}}{3}\right)$	$\sigma_G = \exp\left(\frac{\ln P_{16} - \ln P_{84}}{4} + \frac{\ln P_{5} - \ln P_{95}}{6.6}\right)$
Skewness	Kurtosis
$SK_G = \frac{\ln P_{16} + \ln P_{84} - 2(\ln P_{50})}{2(\ln P_{84} - \ln P_{16})} + \frac{\ln P_{5} + \ln P_{95} - 2(\ln P_{50})}{2(\ln P_{25} - \ln P_{5})}$	$K_G = \frac{\ln P_{5} - \ln P_{95}}{2.44(\ln P_{25} - \ln P_{75})}$

Source Blott And Pye (June 2001)

Sorting	Skewness $SK_G$	Kurtosis $K_G$
Very well sorted <1.27	Very fine skewed 0.3-1.0	Very platykurtic <0.67
Well sorted 1.27-1.41	Fine skewed 0.1-0.3	Platykurtic 0.67-0.90
Moderately well sorted 1.41-1.62	Symmetrical 0.1-0.1	Mesokurtic 0.90-1.11
Moderately sorted 1.62-2.00	Coarse skewed 0.1-0.3	Leptokurtic 1.11-1.50
Poorly sorted 2.00-4.00	Very coarse skew 0.3-1.0	Very leptokurtic 1.50-3.00
Very poorly sorted 4.00-16.00		Extremely leptokurtic >3.00
Extremely poorly sorted >16.00		

Table:-9 Udden-Wentworth Grain size scale for siliclastic sediments (Wentworth, 1992)

MILIMETER	$\mu M$	Phi( $\Phi$ )	Wentworth Size Class
		-20	
4096		-12	
1024		-10	
256		-8	Boulder
64		-6	Pebble(-6 To -8 $\phi$ )
16		-4	
4		-2	Pebble(-2 To -6 $\Phi$ )
3.36		-1.75	
2.83		-1.50	
2.38		-1.25	
2.00		-1.00	Gravel
1.68		-0.75	
1.41		-0.50	
1.19		-0.25	

	1.00		-0.00	Very Coarse Sand	
	.84		0.25		
	0.71		0.50		
	0.59		0.75		
1/2	0.50	500	1.00	Coarse Sand	
	0.42	420	1.25		
	0.35	350	1.50		
	0.30	300	1.75		
1/4	0.25	250	2.00	Medium Sand	
	0.21	210	2.25		
	0.177	177	2.50		
	0.149	149	2.75		
1/8	0.125	125	3.00	Fine Sand	
	0.105	105	3.25		
	0.088	88	3.50		Sand
	0.074	74	3.75		
1/16	0.0625	63	4.00	Very Fine Sand	
	0.0530	53	4.25		
	0.0440	44	4.50		
	0.0370	37	4.75		
1/32	0.0310	31	5	Coarse Silt	
1/64	0.0156	15.6	6	Medium Silt	
1/128	0.0078	7.8	7	Fine Silt	
1/256	0.0039	3.9	8	Very Fine Silt	
	0.0020	2.0	9		
	0.00098	0.98	10		
	0.00049	0.49	11		Mud
	0.00024	0.24	12		
	0.00012	0.12	13		
	0.00006	0.06	14	Clay	

### 3.2 X-Ray Diffraction (Xrd):-

X-ray powder diffraction (XRD) is a rapid analytical technique primarily used to provide information on unit cell dimensions and for phase identification of a crystalline material. Used for the study of crystal structure and identification of fine-grained minerals such as mixed layer of clay sand clays. Max von Laue was the first conducted the experiment in 1912. He discovered that crystalline substances act as three-dimensional diffraction gratings for X-ray wavelengths

similar to the spacing of planes in a crystal lattice. (source: [https://serc.carleton.edu/research\\_education/geochemsheets/techniques/XRD.html](https://serc.carleton.edu/research_education/geochemsheets/techniques/XRD.html)).

X-ray diffractometers consist of three basic elements: a sample holder, an X-ray tube, and an X-ray detector. By heating the filaments of the cathode ray tube it generates X-rays to produce electrons. Then it is filtered to produce monochromatic radiation, directed towards the sample. The samples and constructive interferences produced by samples get interact with each other and satisfy the Bragg's law ( $n\lambda=2d \sin\theta$ ). The law relates the spacing of planes in a crystal lattice and diffraction angle of electromagnetic radiation of the wave. The sample was scanned at an angle of  $2\theta$  and all possible diffraction directions of the lattice should be obtained due to random orientation of powdered materials. (source [https://serc.carleton.edu/research\\_education/geochemsheets/techniques/XRD.html](https://serc.carleton.edu/research_education/geochemsheets/techniques/XRD.html)). Powdered sediment sent to inter university Accelerator Centre (IUAC), New-delhi. By using the Panalytical instrument we got the Xrd data in the format of \*.Xrdml. The data analyzed by using X-Pert high score software, where selected peaks were matched with spectrum of reference minerals listed in the library. Mineral phase identifications were carried out mainly by the stick pattern match whereas semi-quantifications were carried out using relative intensity ratio (RIR) value of the standard minerals.

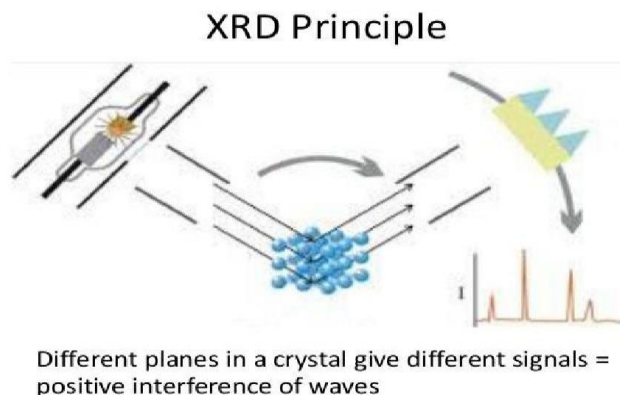
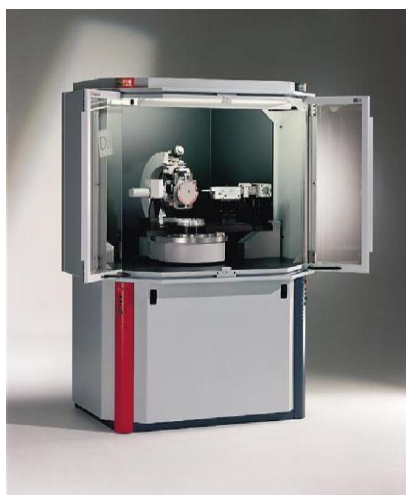


Figure19: Image of XRD instrument (left) and XRD principle (right) source ([https://serc.carleton.edu/research\\_education/geochemsheets/techniques/XRD.html](https://serc.carleton.edu/research_education/geochemsheets/techniques/XRD.html))

### **3.3 Percentage Of Carbonate**

For measuring the calcium carbonate ( $\text{CaCO}_3$ ) in soils. There are two procedure, the first one procedure is (Method I), the  $\text{CaCO}_3$  content is calculated from the weight of  $\text{CO}_2$  lost after treating a sample with excess hydrochloric acid. In another procedure is, the  $\text{CaCO}_3$  content was calculated from the pH of a suspension of the soil in dilute acetic acid (Method II). source John Ashworth (1997).

For this measurement we followed the first procedure, for this taking nearly 1 gm of sample and put it in the centrifuge tube with known weight. After that the sample added with the 1N of 5ml dilute HCl with the help of 1ml of pipette and get mixed with the help of vortex machine. After mixing with the samples, the tube kept open for some time so that the  $\text{CO}_2$  can evaporate out then closed that tube. After one hour, again the sample get mixed with dilute normal HCl with the help of vortex machine. Similarly the process continued for 6 to 7 times, till the evaporation of  $\text{CO}_2$  decreased. Then the samples get centrifuged with the help of Tanco machine with RPM 7000 kept for 15 mins. The solution removed from the centrifuged tube and 5 ml of MQ grade water (type -1 water) is added to the solution then mixed that samples with the vortex machine, then it again centrifuged with Tanco with RPM 7000 for 10 mins. After that the sample moved to a Petri dish glass and kept in the oven at temperature below  $50^\circ\text{C}$ . The dry sample get weighted with the help of the fractional weight machine (Mettler Toledo JB 1603-c/FACT). Now the dry sample weight and initial weight of the sample known, from that the weight loss of  $\text{CaCO}_3$  calculated (table 8).

### **3.4 Identification Of Mineral Under Stereo Zoom Microscope:**

From every location very few quantity of samples taken on the glass Petri dish. Glass petri dish kept under the high resolution microscope (Leica Sapo) to find out the mineral composition of that area, the grain size of the minerals, the shape of the minerals, and the amount of minerals are present can be determined with the help of the point counting methods. There are some minerals which are identified in lab with the help of microscope which are given below figures-17.

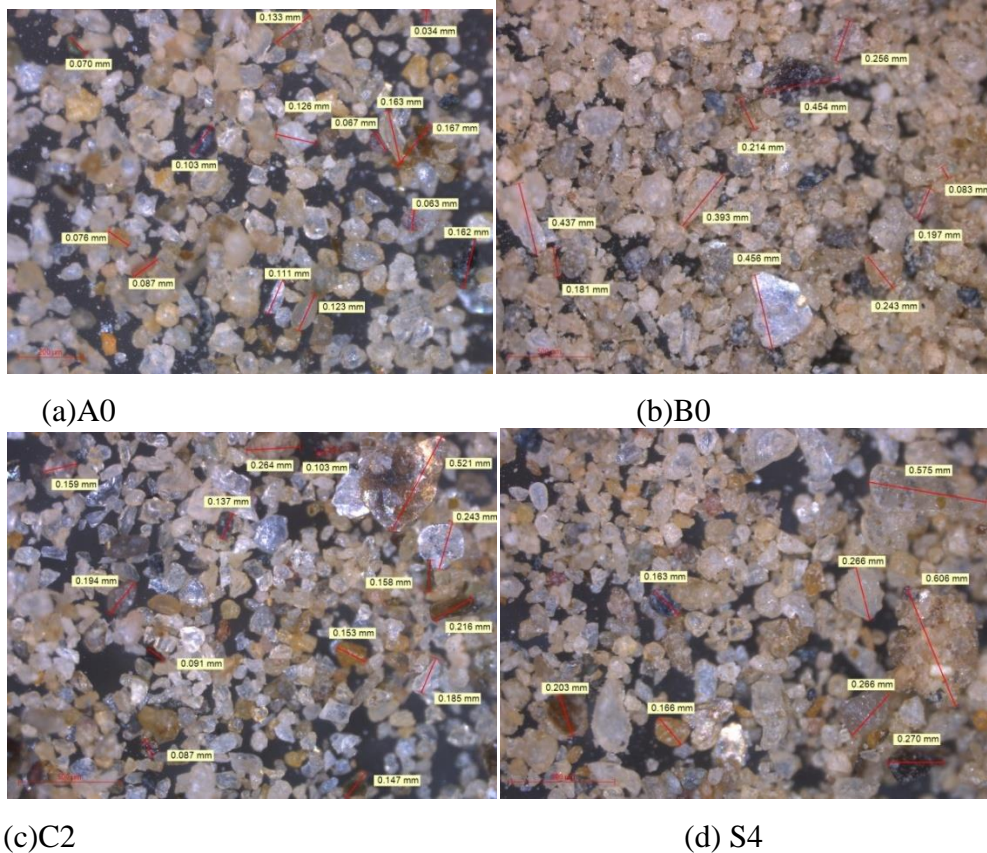


Fig17:-image of minerals under the microscope

### 3.5 X-Ray Fluorescence (XRF):-

X-ray fluorescence (XRF) is a powerful quantitative and qualitative analytical tool for elemental analysis of materials. It is ideally suited to the measurement of film thickness and composition, determination of elemental concentration by weight of solids and solutions, and identification of specific and trace elements in complex sample matrices. The method is fast, accurate, non-destructive, and usually requires only minimal sample preparation.(Source:<https://www.xos.com/XRF>)

When elements in a sample are exposed to a source of high-intensity X-rays, fluorescent X-rays will be emitted from the sample at energy levels unique to those elements. The basic concept for all XRF spectrometers is a source, a sample, and a detection system. The source irradiates the sample and a detector measures the fluorescence radiation emitted from the sample. In most cases for XRF, the source is an X-ray tube.(Source:<https://www.xos.com/XRF>)

The analysis of major and trace elements in geological materials by XRF is made possible by the behavior of atoms when they interact with X-radiation. An XRF spectrometer works because if a sample is illuminated by an intense X-ray beam, known as the incident beam, some of the energy is scattered, but some are also absorbed within the sample in a manner that depends on its chemistry. When this primary X-ray beam illuminates the sample, it is said to be excited. The excited sample, in turn, emits X-rays along a spectrum of wavelengths characteristic of the types of atoms present in the sample.



Fig 18:-An XRF spectrometer, with the sample port on top, and a set of samples in silver metallic holders in the sample changer in front. (Source [https://serc.carleton.edu/research\\_education/geochemsheets/techniques/XRF.html](https://serc.carleton.edu/research_education/geochemsheets/techniques/XRF.html))

If a sample has many elements present, as is typical for most minerals and rocks, the use of a Wavelength Dispersive Spectrometer much like that in an EPMA allows the separation of a complex emitted X-ray spectrum into characteristic wavelengths for each element present. Various types of detectors (gas flow proportional and scintillation) are used to measure the intensity of the emitted beam. The scintillation detector is commonly used to analyze shorter wavelengths in the X-ray spectrum (K spectra of an element from Nb to I; L spectra of Th and U). X-rays of intermediate wavelength (K spectra produced from Zn to Zr and L spectra from Ba and the rare earth elements) are generally measured by using both detectors in tandem. The intensity of the energy measured by these detectors is proportional to the abundance of the element in the sample. (Source: [https://serc.carleton.edu/research\\_education/geochemsheets/techniques/XRF.html](https://serc.carleton.edu/research_education/geochemsheets/techniques/XRF.html))

Powered sediment sent to Indian Institute of Science Education and Research, Kolkata .By using the instrument we got the XRF data in form of percentage. Then oxide elements are converted into molar weight and CIA, A-CN-K,A-CNK-FM and Al/Si with Fe/Sicalculated.

$$CIA = \frac{Al_2O_3}{Al_2O_3 + CaO + Na_2O + K_2O} * 100$$

### 3.6 Carbonate Phase Leaching:-

Scientists have shown that significant trace metal concentrations can be associated with sediment carbonates; this fraction would be susceptible to changes of pH. The original was leached at room temperature with 8 ml of 1 M NaOAc adjusted to pH 5.0 with acetic acid. Continuous agitation 5 hours in temperature 25°C was maintained and the time necessary for complete extraction was evaluated. Some workers have demonstrated that the lower pH values lead to a partial attack of Fe and Mn oxides. The time required for carbonate dissolution will depend upon such factor as particle size,percentage,and type of carbonates present. The extraction time is likely to be sufficient for more samples of finely divided suspended solids.However,for coarse bottom sediments with high carbonate contents, longer leaching times and frequent pH adjustment necessary.(Tessier et .al.1979)

The centrifuge tube was taken with the mark of the sample name, it washed with 0.5% N of HNO<sub>3</sub>, Elix(type-2 water)and finally with MQ grade water. After dry of that tube 1gm of samples poured in the tube and 8 ml of NaOAc mixed with the samples after that just check the PH value ,if the solution grater than 5 PH then add HoAc(acetic acid) till it reaches 5PH ,then mix that samples with the help vertex machine,keep the samples 5 hrs in the tube sand before doing centrifuge one more time egitate that samples. Then the samples centrifuge with the help of the machine Tanco7000 RPM kept for 15 mins . Now the samples get settled and the liquids are removed from the tube and kept in the another tube with the marking of the sample name. Thesample settled in the tube and mixed with 5 ml of mQ grade water for two times,then the sample mixed by vertex machine and centrifuged for 10 mins with same7000RPM. The MQ grade water poured outside and the sample put in the petri disk for dry,kept in the oven and keeping temperature below 50°C. For removing the impurity present in the solution, it poured on the filterpaper. Then solution of NoAC get dry on the hot plate machine available in Lab. Till the solution

converted into solids it kept on the hot plate. After dried the liquid mix with the 5ml of HNO<sub>3</sub> and kept in the tube for ICPMS study. The sample was diluted 10 times (10x) for ICP-MS (Thermoscientific) and analysis was done in central instrumentation laboratory (CIL) ,CUPB,Bathinda. The dry sample weight with the fractional weight machine and loss of the sample weight calculated and tabulated below.

Table 10. Carbonate Wt % after leaching

sample name	wt. of tube (g)	sample wt(g)	Wt of Dry Sample(g)	net wt of sample(g)	wt .%
A0	6.795	1.002	0.937	0.065	6.48
A2	6.801	1.005	0.939	0.066	6.56
A4	6.775	1.06	1.032	0.028	2.64
B0	6.802	1.07	0.989	0.081	7.57
B2	6.783	1.096	1.062	0.034	2.82
Ctop	6.78	1.015	0.931	0.084	8.27
C2	6.815	1.053	1.02	0.033	3.13
S0	6.782	1.013	0.943	0.07	6.19
S2	6.797	1.017	0.959	0.058	5.7
S4	6.794	1.024	0.978	0.046	4.49
T1	6.807	1.035	0.716	0.319	30.08
T3	6.782	1.103	0.931	0.172	15.59
T5	6.77	1.035	0.992	0.043	4.15

## CHAPTER-4

### RESULTS AND DISCUSSION

#### 4.1 Grain Size Analysis:-

The result of the textural analysis listed in the table 13. From Bathinda region in location - 1, 10 samples collected, the sample A0, A1,2, A3, A4 , B1, B2, B3 are bimodal and moderately well sorted innature, where as A5 and B0 are bimodal and well sorted. The textural group of all these samples belongs to Sand groups. The sediment names for the sample A0 is very fine sand, where as for other samples (A1, A2, A3, A4, A5, B0, B1, B2, and B3), it named as very fine sand. The sample A0 shows fine skewness and A4 shows very fine skewness, whereas all other samples A1, A2, A3, A5, B0, B1, B2 and B3 shows very coarse skewness. Sample A0 is platykurtic in nature and B0 is very leptokurtic whereas A1, A2, A3, A4, A5, B1, B2and B3 samples are very Platykurtic in nature. In location-2 Sample, C0 is Bimodal moderately sorted, very coarse skewed and very platykurtic in nature and it belongs to sand and very fine sand. The sample C1and C2 are Unimodal, very well sorted and very leptokurtic in nature and it belongs to Sand and very fine sand but the skewness of the sample C1 is coarse skewed and C2 is very coarse skewed. The sample Stop is Bimodal, well sorted, very coarse skewed and very leptokurtic in nature and it belongs to sand and very fine sand. In location -3 the Samples S0, S1, S2, S3, S4 are Unimodal and very well sorted, very leptokurtic and coarse skewed in nature except for the S1 which shows very coarse skewness in nature. And it belongs to Sand and very fine Sand.

In Sikar region of the Rajasthan districts 4 samples were collected, which are T1, T3, T5, T7 and it shows unimodal, very well sorted, coarse skewed and very leptokurtic in nature and it belongs to Sand and very fine sand. Results of Textural analysis of samples on Arithmetic, Logarithmic of Folk and Ward method in metric is listed in the table -11. Similarly, results of textural analysis of samples based on logarithmic and Folk and Ward method in phi is listed in table-12. The grain size distribution and Stastic such as mode, D10, D50, D90,(D90/D10),(D90-D10),(D75/D25) and (D75-D25) both in metric ( $\mu\text{m}$ ) and this listed in the table-13.

Table11 : Textural Analysis (descriptive) of sediment samples collected from Bathinda and Sikar region

SAMPLE NAME	SAMPLE TYPE	TEXTURAL GROUP	SEDIMENT NAME	FOLK AND WARD METHODS(DESCRIPTION)			
				MEAN	SORTING	SKEWNESS	KURTOSIS
<b>A0</b>	Bimodal, Moderately Well Sorted	Sand	Moderately Well Sorted Fine Sand	Very Fine Sand	Moderately Well Sorted	Fine Skewed	Platykurtic
<b>A1</b>	Bimodal, Moderately Well Sorted	Sand	Moderately Well Sorted Very Fine Sand	Very Fine Sand	Moderately Well Sorted	Very Coarse Skewed	Very Platykurtic
<b>A2</b>	Bimodal, Moderately Well Sorted	Sand	Moderately Well Sorted Very Fine Sand	Very Fine Sand	Moderately Well Sorted	Very Coarse Skewed	Very Platykurtic
<b>A3</b>	Bimodal, Moderately Well Sorted	Sand	Moderately Well Sorted Very Fine Sand	Very Fine Sand	Moderately Well Sorted	Very Coarse Skewed	Very Platykurtic
<b>A4</b>	Bimodal, Moderately Well Sorted	Sand	Moderately Well Sorted Fine Sand	Very Fine Sand	Moderately Well Sorted	Very Fine Skewed	Very Platykurtic
<b>A5</b>	Bimodal, Well Sorted	Sand	Well Sorted Very Fine Sand	Very Fine Sand	Well Sorted	Very Coarse Skewed	Very Platykurtic
<b>B0</b>	Bimodal, Well Sorted	Sand	Well Sorted Very Fine Sand	Very Fine Sand	Well Sorted	Very Coarse Skewed	Very Leptokurtic
<b>B1</b>	Bimodal, Moderately Well Sorted	Sand	Moderately Well Sorted Very Fine Sand	Very Fine Sand	Moderately Well Sorted	Very Coarse Skewed	Very Platykurtic
<b>B2</b>	Bimodal, Moderately Well Sorted	Sand	Moderately Well Sorted Very Fine Sand	Very Fine Sand	Moderately Well Sorted	Very Coarse Skewed	Very Platykurtic
<b>B 3</b>	Bimodal, Moderately Well Sorted	Sand	Moderately Well Sorted Very Fine Sand	Very Fine Sand	Moderately Well Sorted	Very Coarse Skewed	Very Platykurtic
<b>Ctop</b>	Bimodal, Well Sorted	Sand	Well Sorted Very Fine Sand	Very Fine Sand	Well Sorted	Very Coarse Skewed	Very Leptokurtic
<b>C0</b>	Bimodal, Moderately Well Sorted	Sand	Moderately Well Sorted Very Fine Sand	Very Fine Sand	Moderately Well Sorted	Very Coarse Skewed	Very Platykurtic

<b>C1</b>	Unimodal, Very Well Sorted	Sand	Very Well Sorted Very Fine Sand	Very Fine Sand	Very Well Sorted	Coarse Skewed	Very Leptokurtic
<b>C2</b>	Unimodal, Very Well Sorted	Sand	Very Well Sorted Very Fine Sand	Very Fine Sand	Very Well Sorted	Very Coarse Skewed	Very Leptokurtic
<b>S0</b>	Unimodal, Very Well Sorted	Sand	Very Well Sorted Very Fine Sand	Very Fine Sand	Very Well Sorted	Coarse Skewed	Very Leptokurtic
<b>S1</b>	Unimodal, Very Well Sorted	Sand	Very Well Sorted Very Fine Sand	Very Fine Sand	Very Well Sorted	Very Coarse Skewed	Very Leptokurtic
<b>S2</b>	Unimodal, Very Well Sorted	Sand	Very Well Sorted Very Fine Sand	Very Fine Sand	Very Well Sorted	Coarse Skewed	Very Leptokurtic
<b>S3</b>	Unimodal, Very Well Sorted	Sand	Very Well Sorted Very Fine Sand	Very Fine Sand	Very Well Sorted	Coarse Skewed	Very Leptokurtic
<b>S4</b>	Unimodal, Very Well Sorted	Sand	Very Well Sorted Very Fine Sand	Very Fine Sand	Very Well Sorted	Coarse Skewed	Very Leptokurtic
<b>T1</b>	Unimodal,ver y well sorted	sand	Very well sorted very fine sand	Very fine sand	Very well sorted	Coarse skewed	Very leptokurtic
<b>T3</b>	Unimodal very well sorted	sand	Very well sorted very fine sand	Very fine sand	Very well sorted	Coarse skewed	Very leptokurtic
<b>T5</b>	Unimodal very well sorted	sand	Very well sorted very fine sand	Very fine sand	Very well sorted	Coarse skewed	Very leptokurtic
<b>T7</b>	Unimodal very well sorted	sand	Very well sorted very fine sand	Very fine sand	Very well sorted	Coarse skewed	Very leptokurtic

Table12:Statistical Analysis (Arithmetic, Geometric and Folk & Ward, in  $\mu\text{m}$ ) of sediment samples of Sikar and Bathinda.

Sample Name	METHOD OF MOMENTS Arithmetic ( $\mu\text{m}$ )				METHOD OF MOMENTS Geometric ( $\mu\text{m}$ )				FOLK AND WARD METHOD ( $\mu\text{m}$ )			
	MEAN	SORTING	SKEWNESS	KURTOSIS	MEAN	SORTING	SKEWNESS	KURTOSIS	MEAN	SORTING	SKEWNESS	KURTOSIS
A0	129.6	54.27	1.258	5.586	118.1	1.487	0.112	2.353	117.7	1.507	-0.261	0.790
A1	111.6	52.11	1.823	7.076	101.6	1.474	0.843	2.872	98.2	1.424	0.506	0.632
A2	114.3	51.18	1.486	6.195	103.9	1.48	0.522	2.276	98.58	1.439	0.446	0.575
A3	104.9	51.40	2.015	7.788	95.16	1.478	1.066	3.224	94.05	1.430	0.574	0.619
A4	120.5	47.68	1.111	5.696	110.7	1.460	0.139	2.012	114.3	1.429	-0.380	0.587
A5	104.4	44.75	1.917	8.149	96.39	1.423	0.969	3.046	96.03	1.408	0.528	0.665
B0	96.16	43.57	2.597	11.36	89.11	1.401	1.544	4.792	90.98	1.389	0.571	1.750
B1	105.6	54.40	2.038	7.519	95.12	1.498	1.121	3.329	93.66	1.436	0.601	0.618
B2	107.4	50.95	1.979	7.721	97.87	1.466	1.005	3.175	96.21	1.424	0.528	0.637
B3	103.6	41.00	1.344	5.775	96.08	1.417	0.691	2.160	95.45	1.415	0.517	0.617
Ctop	95.85	39.82	2.190	9.666	89.32	1.388	1.286	3.744	91.35	1.393	0.573	1.657
C0	101.3	45.79	2.075	8.649	93.11	1.435	1.118	3.356	93.48	1.415	0.562	0.648
C1	87.91	31.89	3.187	17.04	83.70	1.303	2.011	6.961	77.99	1.228	0.250	1.866
C2	87.96	34.67	2.984	14.99	83.07	1.333	1.902	6.176	76.69	1.239	0.411	1.743
S0	84.12	25.54	4.050	26.39	81.27	1.242	2.529	10.61	77.72	1.205	0.196	1.848
S1	83.59	26.68	3.578	21.15	80.43	1.260	2.335	8.809	76.55	1.216	0.307	1.751
S2	84.37	26.41	4.849	34.24	81.57	1.235	2.959	14.22	78.29	1.195	0.157	1.959
S3	81.77	23.38	4.030	26.52	79.24	1.229	2.593	10.89	76.33	1.201	0.279	1.664
S4	84.92	30.02	3.898	23.39	81.28	1.278	2.445	9.672	76.93	1.219	0.285	1.793
T1	90.35	26.34	2.773	13.51	87.15	1.251	2.038	6.599	82.29	1.183	0.271	2.842
T3	85.17	22.37	5.747	47.17	83.08	1.192	3.613	20.25	81.34	1.149	0.207	2.390
T5	88.28	28.1	3.316	18.71	84.85	1.265	2.146	7.812	79.87	1.207	0.179	2.516
T7	91.16	31.86	3.643	20.56	87.20	1.280	2.340	8.903	82.02	1.190	0.266	2.830

Table 13: Statistical Analysis (Logarithmic and Folk and Ward, in  $\phi(\square)$ ) of Sediment samples of Sikar and Bathinda.

Sample Name	Method Of Moments Logarithmic ( $\Phi$ )				Folk And Ward Method ( $\Phi$ )			
	Mean	Sorting	Skewness	Kurtosis	Mean	Sorting	Skewness	Kurtosis
A0	3.082	0.573	-0.112	2.353	3.087	0.591	0.261	0.79
A1	3.300	0.560	-0.843	2.872	3.348	0.510	-0.506	0.632
A2	3.266	0.573	-0.522	2.276	3.343	0.525	-0.446	0.575

A3	3.393	0.563	-1.066	3.224	3.410	0.516	-0.574	0.619
A5	3.375	0.509	-0.969	3.046	3.380	0.493	-0.528	0.665
B0	3.488	0.486	-1.544	4.792	3.458	0.474	-0.571	1.750
B1	3.394	0.583	-1.121	3.329	3.416	0.522	-0.601	0.618
B2	3.353	0.552	-1.005	3.175	3.378	0.509	-0.528	0.637
B3	3.380	0.503	-0.691	2.160	3.389	0.501	-0.517	0.617
Ctop	3.485	0.473	-1.286	3.744	3.453	0.478	-0.573	1.657
C0	3.425	0.521	-1.118	3.356	3.419	0.500	-0.562	0.648
C1	3.579	0.382	-2.011	6.961	3.681	0.297	-0.25	1.866
C2	3.589	0.415	-1.902	6.176	3.705	0.310	-0.411	1.743
S0	3.621	0.312	-2.529	10.61	3.685	0.270	-0.196	1.848
S1	3.636	0.333	-2.335	8.809	3.707	0.282	-0.307	1.751
S2	3.61	0.304	-2.959	14.22	3.675	0.257	-0.157	1.959
S3	3.658	0.297	-2.593	10.89	3.712	0.265	-0.279	1.664
S4	3.621	0.354	-2.445	9.672	3.700	0.286	-0.285	1.793
T1	3.52	0.323	-2.038	6.599	3.603	0.243	-0.271	2.842
T3	3.589	0.253	-3.613	20.25	3.620	0.201	-0.207	2.390
T5	3.599	0.339	-2.146	7.812	3.646	0.271	-0.179	2.51
T7	3.519	0.356	-2.340	8.903	3.608	0.251	-0.266	2.830

	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	Ctop	C0	C1	C2	S0	S1	S2	S3	S4
MODE 1 ( $\mu\text{m}$ ):	152.5	82.50	69.00	69.00	152.5	82.50	82.50	69.00	82.50	82.50	69.00	69.00	82.50	69.00	82.50	69.00	82.50	69.00	82.50
MODE 2 ( $\mu\text{m}$ ):	82.50	152.5	152.5	152.5	82.50	152.5	152.5	152.5	152.5	152.5	152.5	152.5							
MODE 1 ( $\phi$ ):	2.737	3.605	3.863	3.863	2.737	3.605	3.605	3.863	3.605	3.605	3.863	3.863	3.605	3.863	3.605	3.863	3.605	3.863	3.605
MODE 2 ( $\phi$ ):	3.605	2.737	2.737	2.737	3.605	2.737	2.737	2.737	2.737	2.737	2.737	2.737							
D <sub>10</sub> ( $\mu\text{m}$ ):	69.00	67.59	66.64	65.82	68.14	67.33	65.99	65.64	66.82	66.58	65.91	66.04	65.96	65.28	66.14	65.46	66.66	65.46	65.59
D <sub>50</sub> ( $\mu\text{m}$ ):	133.7	84.94	86.43	80.17	128.0	83.21	79.33	79.15	83.05	82.77	79.26	80.46	78.46	75.40	78.55	76.38	79.34	76.33	77.01
D <sub>90</sub> ( $\mu\text{m}$ ):	174.2	168.5	169.5	165.6	170.5	163.3	156.0	166.9	166.4	163.0	156.3	162.0	138.2	143.0	89.51	89.83	89.26	89.02	125.8
(D <sub>90</sub> / D <sub>10</sub> ) ( $\mu\text{m}$ ):	2.524	2.494	2.544	2.517	2.502	2.426	2.365	2.543	2.491	2.448	2.372	2.453	2.095	2.190	1.353	1.372	1.339	1.360	1.918
(D <sub>90</sub> - D <sub>10</sub> ) ( $\mu\text{m}$ ):	105.2	100.9	102.9	99.83	102.4	95.99	90.05	101.3	99.61	96.40	90.43	95.97	72.20	77.71	23.37	24.36	22.60	23.56	60.22
(D <sub>75</sub> / D <sub>25</sub> ) ( $\mu\text{m}$ ):	1.997	1.916	2.049	1.950	2.000	1.830	1.256	1.965	1.905	1.913	1.270	1.868	1.220	1.244	1.198	1.219	1.177	1.212	1.219
(D <sub>75</sub> - D <sub>25</sub> ) ( $\mu\text{m}$ ):	78.76	68.74	76.06	66.78	76.57	61.76	18.13	67.36	66.07	66.07	19.03	61.51	15.54	16.79	14.08	15.19	12.85	14.69	15.24
D <sub>10</sub> ( $\phi$ ):	2.522	2.569	2.560	2.594	2.552	2.614	2.680	2.583	2.587	2.617	2.677	2.626	2.856	2.806	3.482	3.477	3.486	3.490	2.991
D <sub>50</sub> ( $\phi$ ):	2.902	3.557	3.532	3.641	2.966	3.587	3.656	3.659	3.590	3.595	3.657	3.636	3.672	3.729	3.670	3.711	3.656	3.712	3.699
D <sub>90</sub> ( $\phi$ ):	3.857	3.887	3.908	3.925	3.875	3.893	3.922	3.929	3.904	3.909	3.923	3.921	3.922	3.937	3.918	3.933	3.907	3.933	3.930
(D <sub>90</sub> / D <sub>10</sub> )( $\phi$ ):	1.530	1.513	1.526	1.513	1.519	1.489	1.463	1.521	1.509	1.494	1.465	1.493	1.374	1.403	1.125	1.131	1.121	1.127	1.314
(D <sub>90</sub> - D <sub>10</sub> ) ( $\phi$ ):	1.336	1.318	1.347	1.332	1.323	1.278	1.242	1.347	1.316	1.292	1.246	1.295	1.067	1.131	0.437	0.456	.421	0.443	0.940
(D <sub>75</sub> / D <sub>25</sub> ) ( $\phi$ ):	1.375	1.335	1.376	1.336	1.369	1.303	1.094	1.340	1.327	1.328	1.099	1.309	1.081	1.089	1.073	1.080	1.066	1.078	1.080

(D <sub>75</sub> - D <sub>25</sub> ) (φ):	0.998	0.938	1.035	0.964	1.000	0.872	0.329	0.975	0.930	0.936	0.345	0.901	0.287	0.315	0.261	0.286	0.235	0.277	0.285
% MEDIUM SAND:	5.0%	3.8%	3.2%	3.4%	2.4%	2.0%	2.1%	4.2%	3.5%	0.9%	1.2%	2.2%	0.7%	0.9%	0.4%	0.4%			
% FINE SAND:	55.2%	34.5%	41.4%	28.9%	50.9%	30.1%	20.1%	27.9%	30.5%	33.5%	22.8%	27.1%	12.8%	14.4%	7.9%	9.1%			
% V FINE SAND:	39.8%	61.7%	55.4%	67.7%	46.7%	68.0%	77.8%	67.9%	66.1%	65.7%	76.0%	70.7%	86.5%	84.7%	91.7%	90.5%			

Table 14: Textural and statistical analysis of Aeolian sediments of Bathinda & Sikar regions

SAMPLE	MODE 1 (μm):	MODE 1 (φ):	D <sub>10</sub> (μm):	D <sub>50</sub> (μm):	D <sub>90</sub> (μm):	(D <sub>90</sub> / D <sub>10</sub> ) (μm):	(D <sub>90</sub> - D <sub>10</sub> ) (μm):	(D <sub>75</sub> / D <sub>25</sub> ) (μm):	(D <sub>75</sub> - D <sub>25</sub> ) (μm):	D <sub>10</sub> (φ):	D <sub>50</sub> (φ):	D <sub>90</sub> (φ):	D <sub>90</sub> / D <sub>10</sub> (φ):	(D <sub>90</sub> - D <sub>10</sub> ) (φ):	(D <sub>75</sub> / D <sub>25</sub> ) (φ):	(D <sub>75</sub> - D <sub>25</sub> ) (φ):	% Sand:	% Medium Sand:	% Fine Sand	% V Fine Sand
T1	82.5	3.605	73.19	82.29	136.1	1.860	62.92	1.129	9.956	2.877	3.603	3.772	1.311	0.895	1.05	.174	100%	.2%	12.8%	87%
T3	82.5	3.605	71.15	81.34	89.09	1.252	17.95	1.121	9.260	3.489	3.620	3.813	1.093	.324	1.04	.164	100%	.5%	5.1%	94.5%
T5	82.5	3.605	67.82	80.8	132.5	1.954	64.73	1.152	11.43	2.915	3.630	3.882	1.332	.967	1.058	.204	100%	.5%	11.4%	88.2%
T7	82.5	3.605	71.09	82.02	137.1	1.928	66.0	1.134	10.32	2.867	3.608	3.814	1.33	.947	1.052	.181	100%	.1%	12.1%	86.9%

## 4.2 Grain Size Distribution:

### 4.2.1 Textural Analysis-Bathinda

In fig19(a)-Mean grain size vs. depth plot shows that sample A0 and A4 have higher mean grain size as compare to the others samples .This may be due to the energy condition ,during that time energy condition was high compare to the other samples . Textural analysis shows (fig 19(b)) that in Loc A, majority of the samples shows bimodal distribution, whereas LOC-B shows unimodal distribution. The unimodal or Bimodal distribution mainly depends upon the grain size, enery transportation of material . This may occurs due to the Rain water percolation might have transported the fine sediments to a depth or may be due to the Abundance of coarser particle can also indicate high wind energy condition prevailed during deposition.

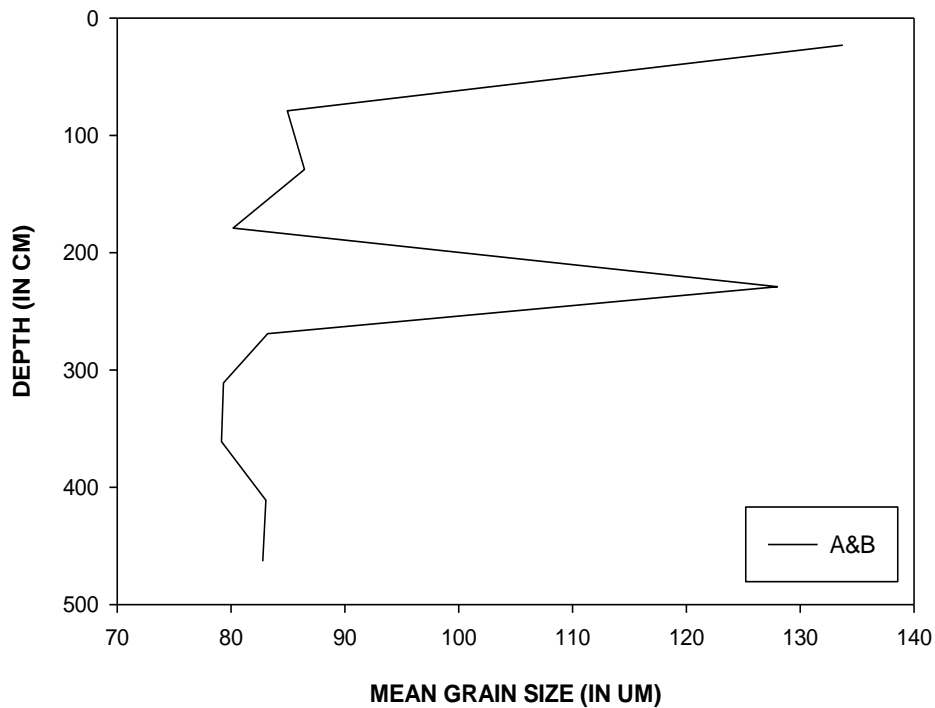


Fig 19: (a) Mean Grain size (( $\mu\text{m}$ ):) vs.depth (cm) plot of Loc -A and B (Bathinda)

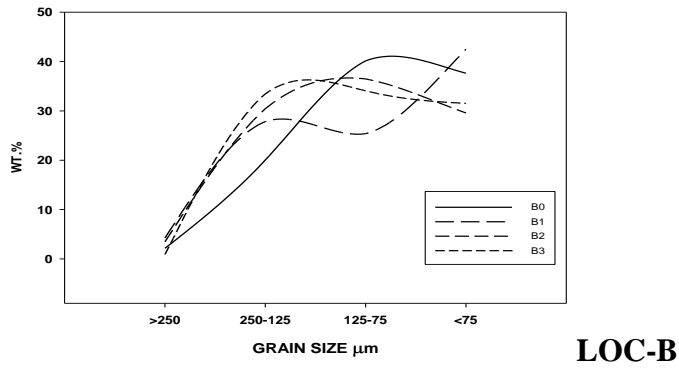
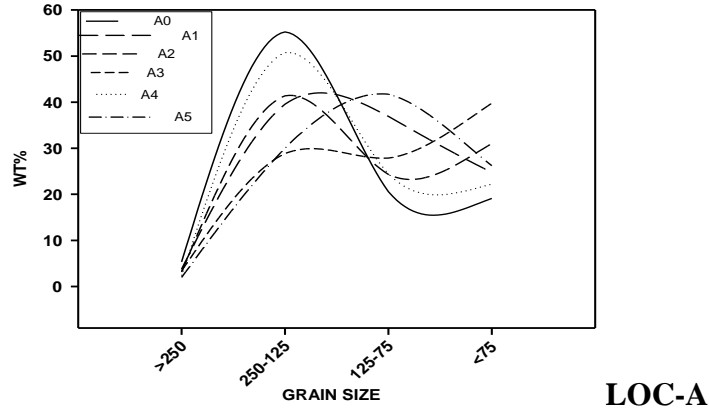


Fig 19:(b)Grain size ( $\mu\text{m}$ ) vs. Wt % plot of Loc –A and B (Bathinda)

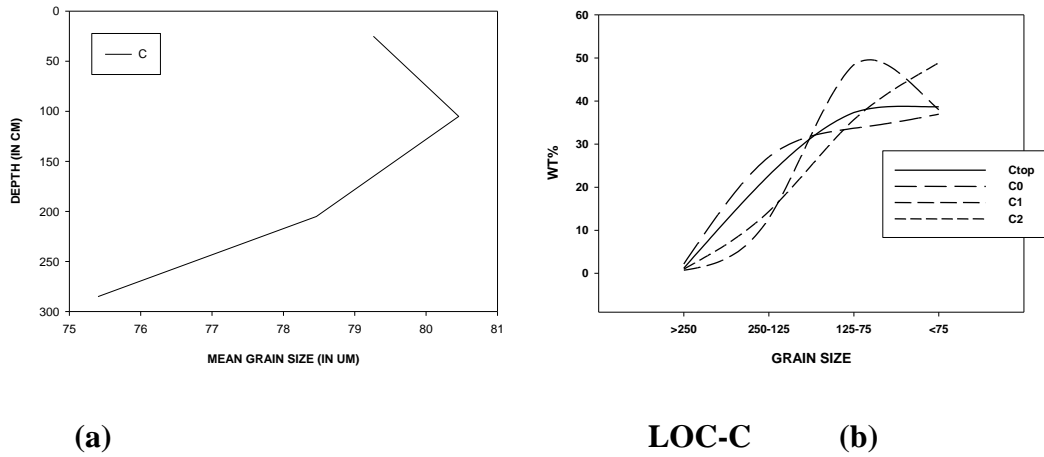


Fig 20 :(a) Mean Grain size ( $\mu\text{m}$ )vs.depth (cm) plot , (b) Grain size ( $\mu\text{m}$ ) vs. Wt % plot of Loc-C

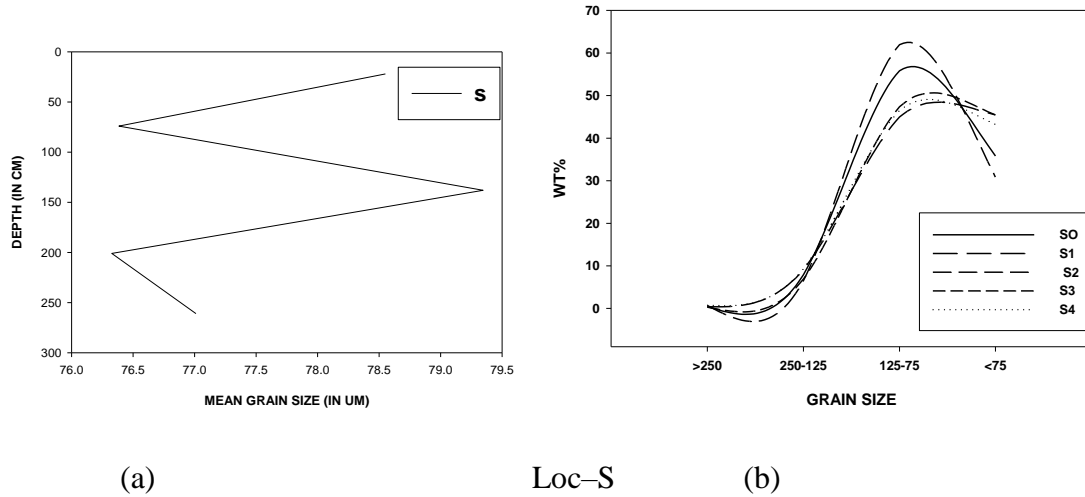


Fig 21: (a) Mean Grain size ( $\mu\text{m}$ ) vs. depth (cm) plot, (b) Grain size ( $\mu\text{m}$ ) vs. Wt % plot of Loc-S

#### 4.2.2 Textural Analysis: Sikar -Rajasthan

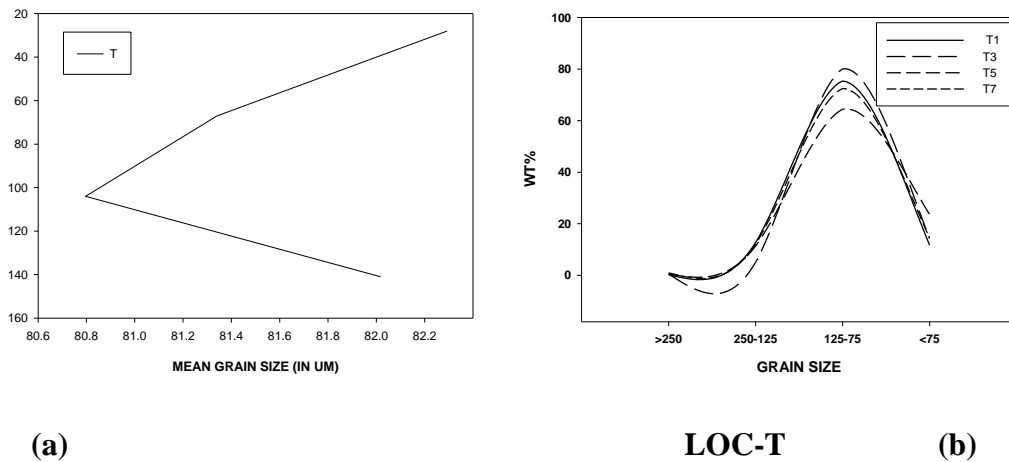


Fig 22: (a) Mean Grain size ( $\mu\text{m}$ ) vs. depth (cm) plot, (b) Grain size ( $\mu\text{m}$ ) vs. Wt % plot of Loc-T

In fig 20(a), 21(a) and 22(a) the mean grain size ( $\mu\text{m}$ ) vs. depth (cm) show very less variation in their grain size between 2-5 ( $\mu\text{m}$ ), whereas in Loc C and Loc S fig 20(b) and 21(b) shows unimodal distribution. The Loc B, C and S have very fine mean grain size distribution compared to Loc A. All the samples in Loc T fig 22(b) shows unimodal

distribution with fine grain size distribution .Similar grain size distribution and less variation in mean grain size in the area shows highly homogenized (texturally) sand distribution. Similar result can be seen in Loc S collected from Bathinda area .

#### **4.3.DEPOSITIONAL ENVIRONMENT :-**

Various discrimination plots were used for identification of the depositional environment of the Sediments based on the grain size distribution and statistical analysis. Using data from various observations from different depositional environments and deposits these discrimination plots and their fields were developed. Three important discrimination plots were used here for inferring the depositional environment of the sediments. Skewness vs. Kurtosis plot(fig-23) of all the samples indicates the passive environments or low energy depositional environment. (source: techniques in Sdimentology by Maurice Tucker, pg no. -80) .In this plot all the samples are plotted in the X and Y quadrant, which indicates it formed in low energy environment.

All the sand dune samples are plotted along with Sikar and Bathinda region in the Median vs. Deviation plot (fig-24). This plot used to distinguished the depositional environment like river deposits, wave dominated, quite water deposits and Aeolian deposits. River and wave deposits are generally plotted towards the lower value of both X and Y axis where as quite water slow deposits plot towards the higher value, and the Aeolian deposits occurs above the River and Wave deposits and below that of quite water slow deposits. Here all the samples are plotted in between the Aeolian deposits and Quite water slow. This bivariante discrimination plot is being used science 1958 (Stewart ,1958).

Another bivariant plot was done in between the quartile Deviation (mm) vs. Median(mm) (Fig-25). It mainly used to differentiate various depositional environments. In this plot quite water, flowing water and Aeolian deposits can be identified. Here all the samples are plotted in between the Aeolian depositional environment except two samples A2 and B2 which are plotted outside of the environment. (source: techniques in sedimentology by maurice tucker, pg no. -80)

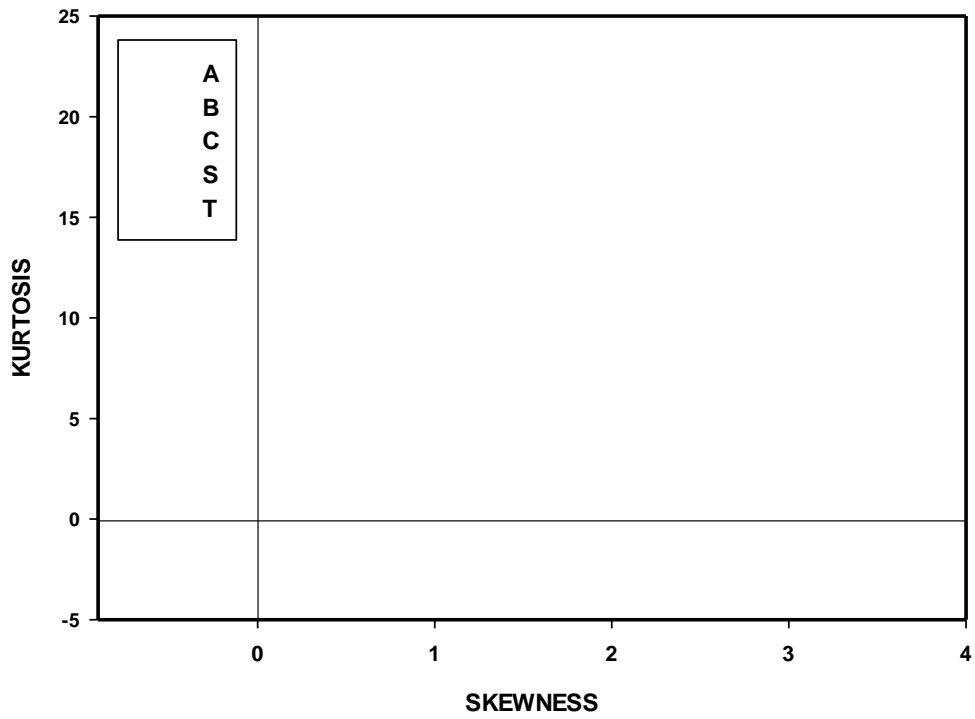


Fig 23: Skewness Vs Kurtosis Plot Of Bathinda And Sikar Region.

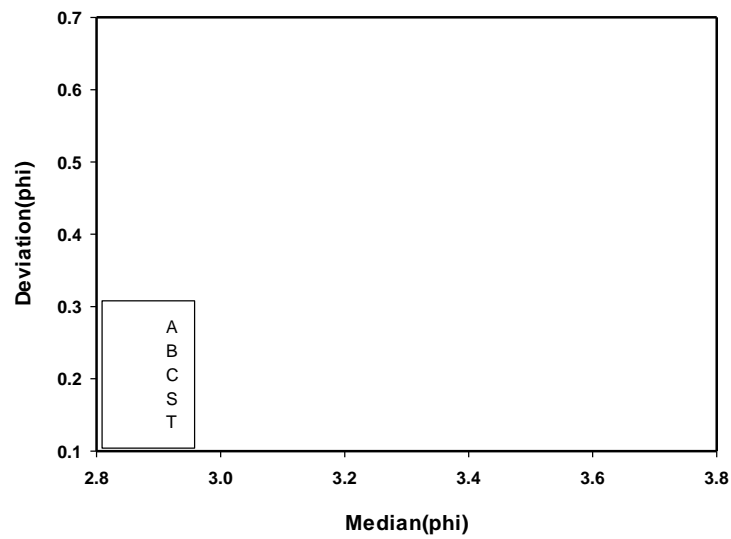


Fig 24: Median(Phi) Vs. Deviation(Phi) Plot Of Bathinda Vs Sikar Region.

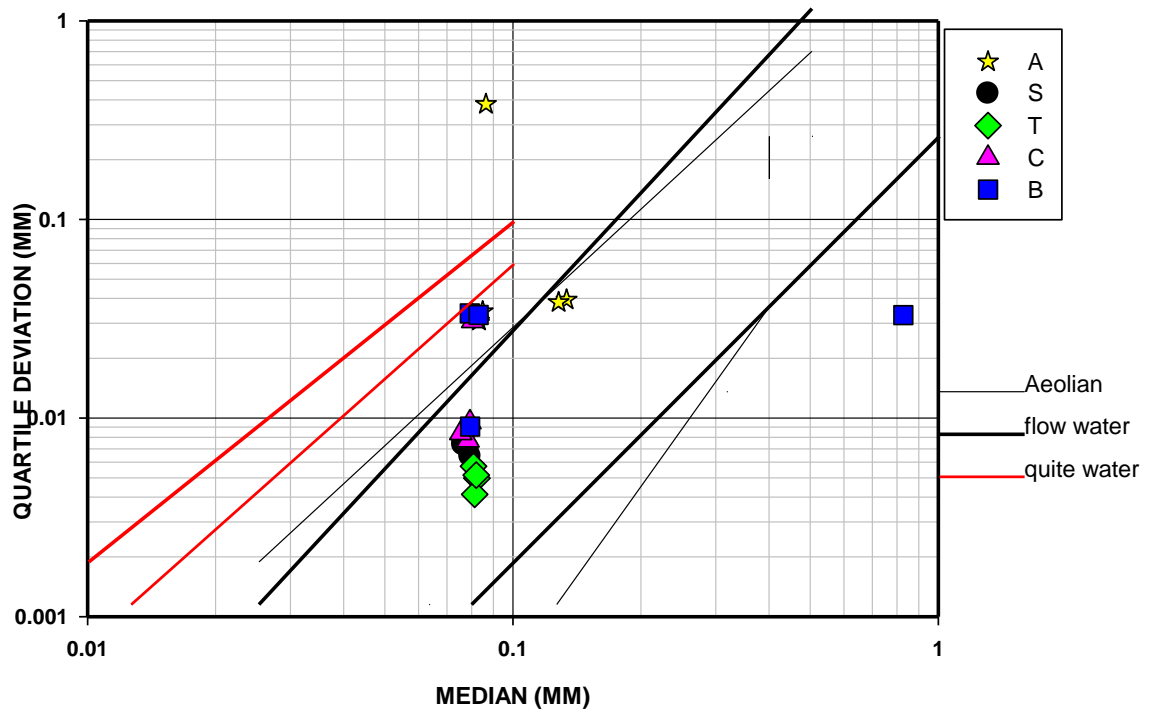


Fig25: Median (mm) Vs. Quartile Deviation (mm) plot to discriminate the depositional environments of different sand dune samples.

#### 4.4 X-RAY DIFFRACTION (XRD):-

Homogenized powdered sediment samples were analysed as per details given in the methodological section. Using X'pert high score software XRD spectra were analyzed to semi-quantify and to identify different mineral phases present in the samples. Using this method precise quantification is not possible but it provides an estimate about minerals present in the sediments. The important and abundant elements present in the sediments are listed in the table no-14. The percentage of individual mineral phases are also listed in the table no-15. Different mineral peaks are shown in a typical XRD spectrum. The spectra of each sediment are compared (fig 27 to 31) to see the variation in mineralogical composition.

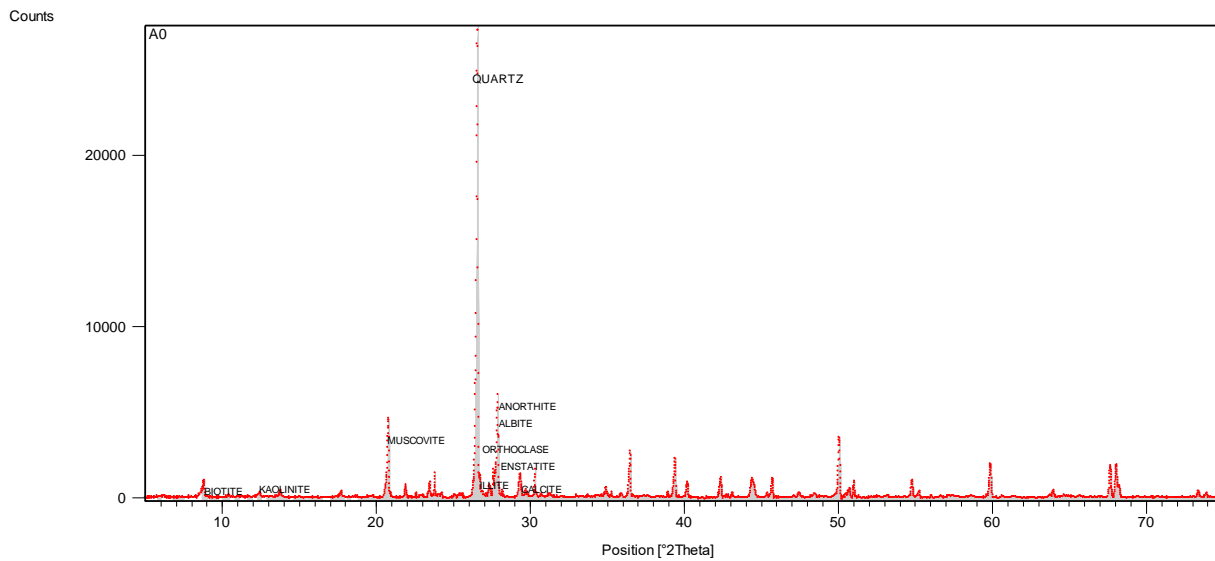


Fig 26: Spectrum showing different mineral peaks.

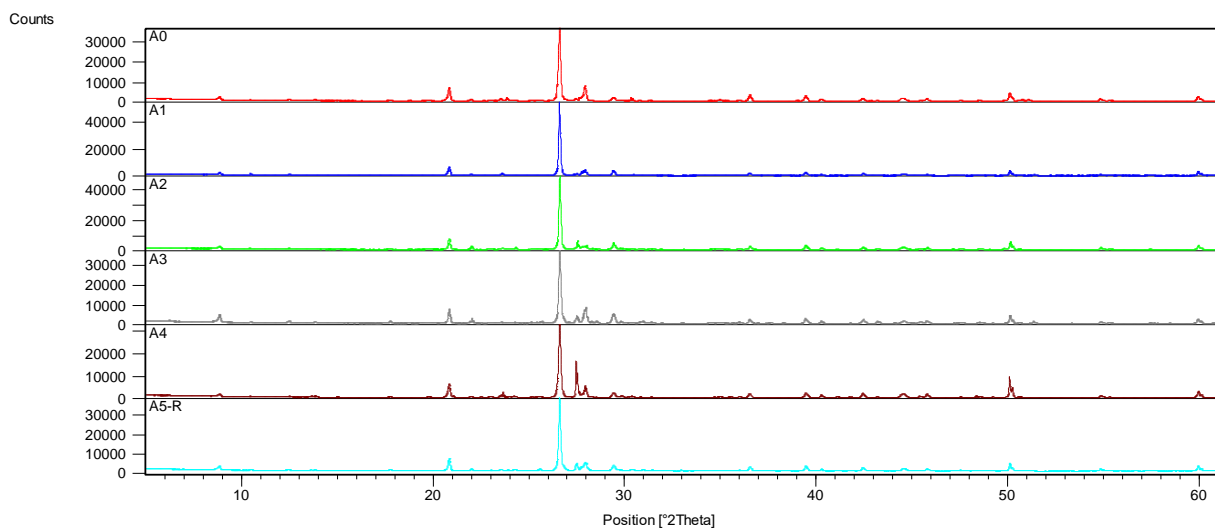


Fig27: XRD spectrum of different samples of Loc-A

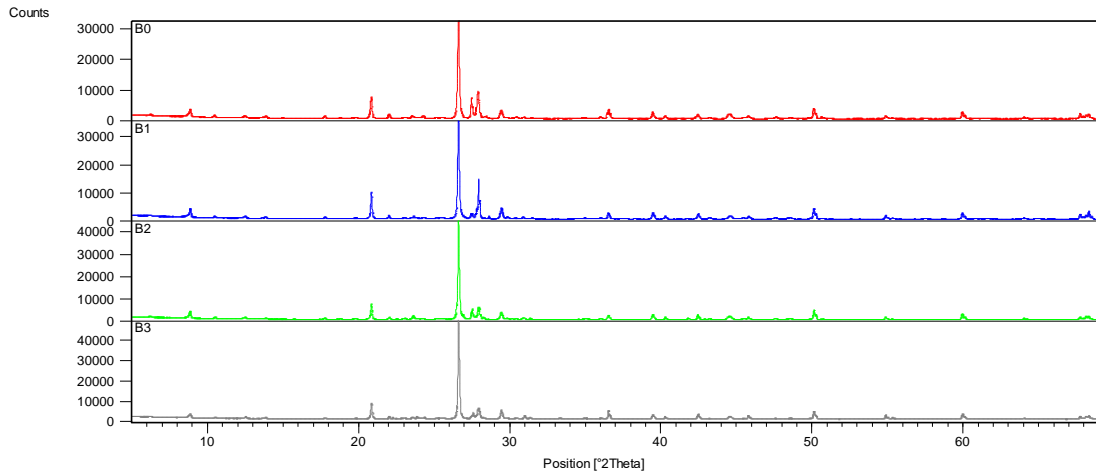


Fig 28: XRD spectrum of different samples of Loc-B

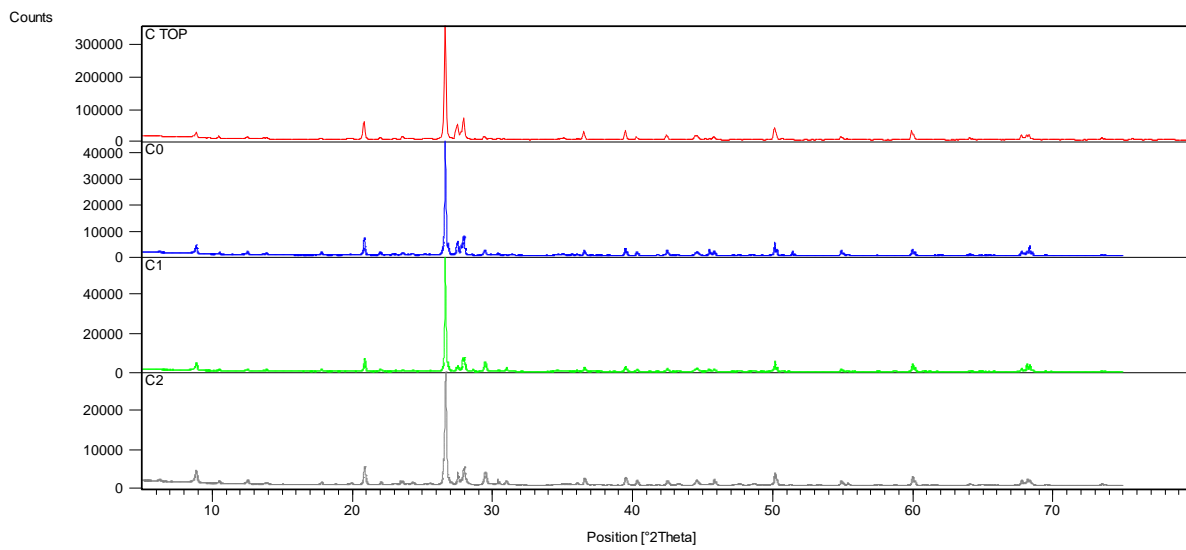


Fig 29: XRD spectrum of different samples of Loc-C

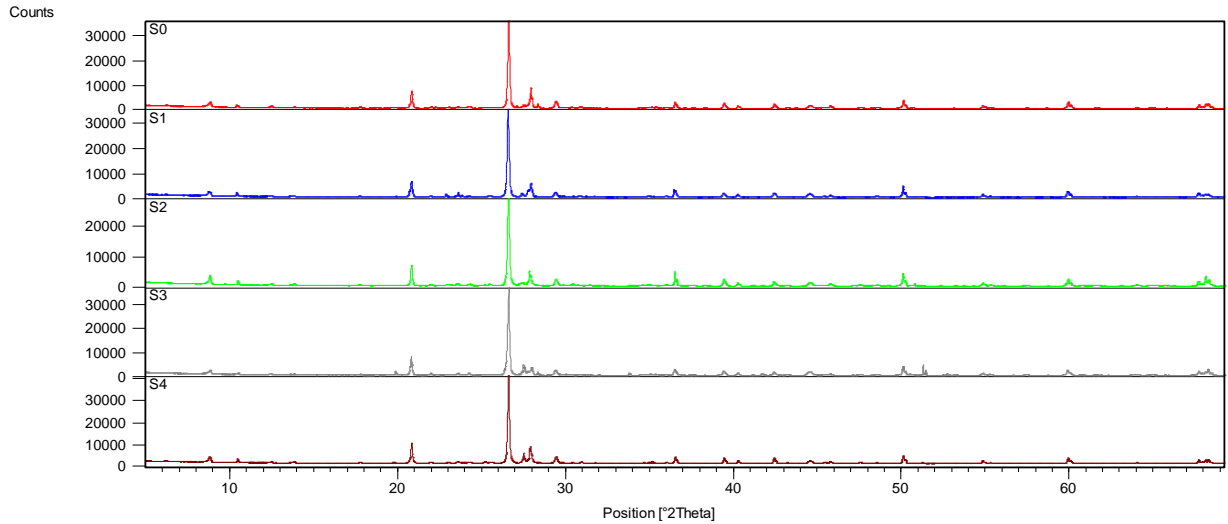


Fig 30:- XRD spectrum of different samples of Loc-S

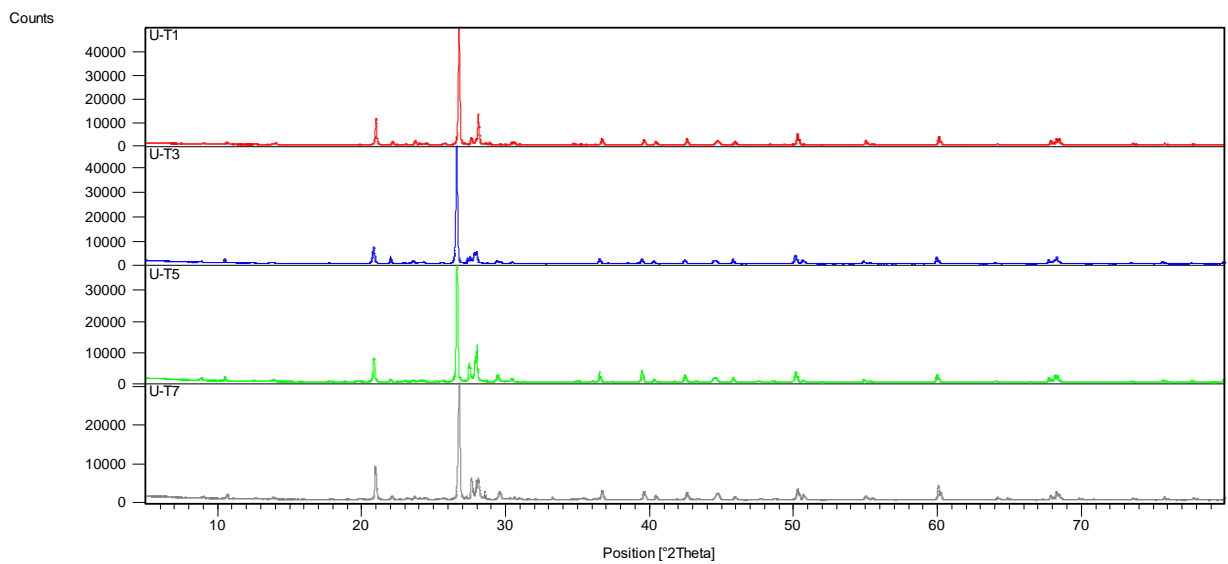


Fig 31:- XRD spectrum of different samples of Loc-T

Here the samples are compared with in the same profile of bathinda and Sikar regions. In all the sediment sample quartz at 26.64 2theta value is the prominent peak. Albite and Anorthite also another peak which is distinct form the all other spectrum. In Loc-A sample A0 and A4 shows high peak of Albite, Anorthite, Enstatite and Biotite as Compared to the other three Samples. Semi quantity of mica was high in A2 & A5 Compared to other samples. Sample A4 show one extra peak having 1.81 Å<sup>0</sup> and D-spacing 50.39 which is known as Nasonite (fig-30). Albite, Anorthite, Enstatite and

Muscovite shows high peak (3.18-3.20) in sample B0 & B1, as compared to others two . In the B1 sample 3.18 peak is prominent and all the samples shows similar pattern with varying intensity (fig- 31). In B3 sample mica concentration is high and clay concentration is low compared to other samples (table-15). In sample C0 Albite, Anorthite, Enstatite (3.18-3.20) peak is less as compared to other samples, where as sample C1 & C2 shows high peak of calcite(3.03) compared to others (fig-29). Sample S0 shows higher peak of albite (3.18 )as compared to the other samples.orthoclase and illite shows high peak(3.31-3.33)in sample S3 and S4 as compared to others.and all other sample shows similar peak for different minerals (fig-30).S3 shows less semi quantification (6)value compared to the other samples (table-16). Sample T3 shows less Albite, Anorthite,(3.18) peak compared to other samples, where as muscovite shows high peak(4.29) compare to other samples.(fig-32).

Table 15:shows semi –quantification of different minerals present in different samples.

SAMPLE NAME	QUARTZ	PLAGIOCLASE	K-FELDSPAR	MICA	CLAY	CALCITE	ENSTATITE	OTHERS
A0	13	36	3	9	7	2	26	4
A1	40	16	2	23	9	3	4	3
A2	35	13	6	34	6	4	7	2
A3	17	20	3	28	12	3	17	0
A4	23	29	4	20	10	1	13	0
A5	17	27	4	34	12	3	4	0
B0	15	29	2	18	30	2	4	0
B1	17	17	2	22	36	2	4	
B2	17	13	3	13	36	1	11	5
B3	25	10	7	38	12	3	3	0
CTOP	13	18	2	22	38	1	6	
C0	26	26	4	27	8	1	0	6
C1	30	22	3	30	8	2	4	2
C2	20	15	4	22	25	2	7	4
S0	21	21	1	27	5	2	21	2
S1	21	19	1	17	34	1	3	2
S2	16	18	2	20	38	2	3	2
S3	28	21	3	31	6	2	4	3
S4	18	14	3	22	37	2	2	3
T1	11	13	9	30	7	0	28	2
T3	14	18	2	15	39	1	11	0
T5	19	23	0	16	34	1	4	2
T7	12	20	17	30	10	1	6	3

In loc-A Sample A0 and A4 shows high concentration of plagioclase,A3 & A5 shows high concentration of mica , sample A1 show high concentration of Quartz compared to all other minerals , where as all other sample shows same mineralogical characteristics. In Loc-B sample B0 has high concentration of plagioclase , sample B3 have high concentration of K-feldspar and Mica. Enstatite Concentration is high in sample B2 compared to all other samples. In Loc-c sample C1 has high concentration of quartz, ctop has high concentration of clay and gradually the calcite concentration gradually increases with depth. In Loc-S sample S3 Shows Low Concentration of clay and S0 shows high concentration of Enstatite, where as all other mineral shows similar mineralogical characteristic. In Loc-T sample T7 shows high concentration of k-feldspar and all other mineral shows similar mineralogical characteristics (table-15).

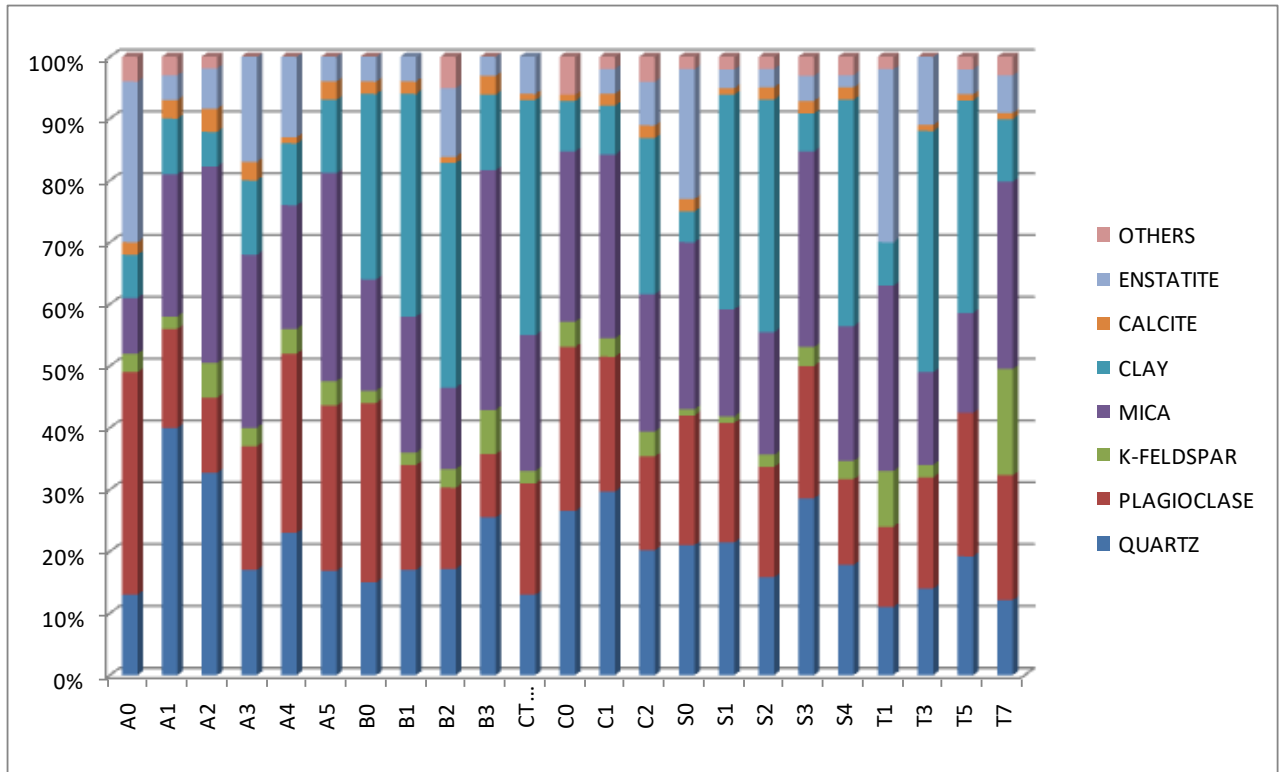


Fig 32: Semi-quantification of different minerals present.

The important minerals such as Quartz, K-feldspar, Na & Ca plagioclase, Calcite, Muscovite, Biotite, Phlogopite, Pyroxene, Hornblende and Clay minerals such as Kaolinite, Illite, Smectite, Vermiculite are identified from sediment samples. Graphical representation

to estimate mineral percentages are given in the bar diagram (fig 35). During weathering least resistant minerals are weathered and stable minerals are enriched in that dunes. In that area some minerals like Plagioclase and Pyroxene(Enstatite) are found ,which indicates the lesser amount of chemical weathering took place during the sedimentation Production. The difference in mineralogical composition and clay minerals contents infers that during deposition the prevailing climate of the area was different than the present days. From XRD analysiswe can find out the climatic fluctuation and extends of chemical weathering during sediment production. Clay minerals study of these area give more information about Palaeo climatic environments of that area.

#### 4.5PERCENTAGE OF CARBONATE :-

In Loc- A percentage of carbonate in sample A2 is high compared to the all other samples, the percentage varies between 12.33 to 17.50 (table --16) ,where as in Loc-B there is very little percentage of change in carbonate shown. In Loc-C carbonate percentage is high in sample S2,compared to top portion .In Loc-S the carbonate percentage is low in S2 as compared to other two samples,the percentage varies between (14.3 to 18.10). In Sikar region carbonate percentage is high in top portion compared to the other two samples. The carbonate percentage with depth plot is given,it shows how the percentage of carbonate varies with depth is explained(fig-33).

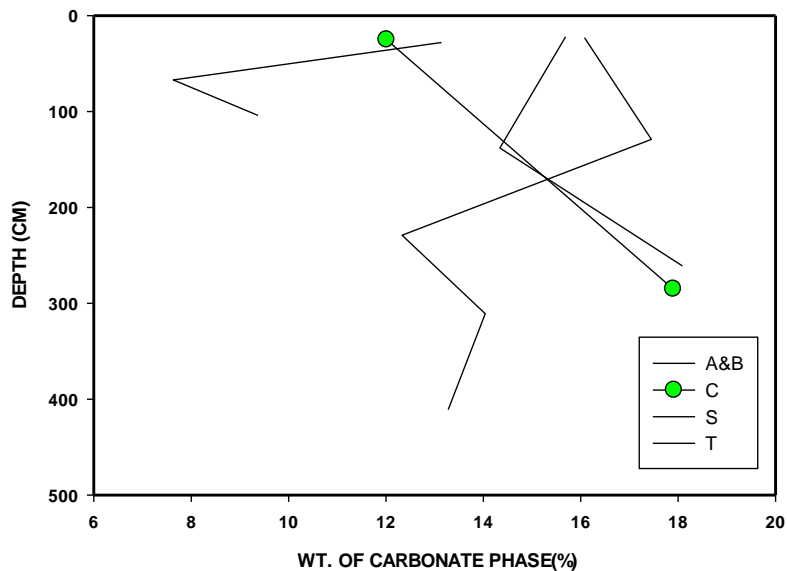


Fig33: Depth vs.percentage of carbonate of different minerals

Table 16: wt% of CaCO<sub>3</sub> in different samples.

Sample no	Wt. of tube with cap (gm)	Vol. of 1N HCl (ml)	Wt. of sample	Wt. of sample after dry	Loss of sample wt. in (mg)	% OF Carbonate
A0	6.796	4	1.001	0.84	0.161	16.08
A2	6.801	4	0.991	0.818	0.173	17.45
A4	6.775	4	0.989	0.867	0.122	12.33
B0	6.802	4	0.997	0.857	0.14	14.04
B2	6.783	4	1.031	0.894	0.137	13.28
Ctop	6.78	4	0.999	0.879	0.12	12.01
C2	6.815	4	1	0.821	0.179	17.9
S0	6.782	4	0.981	0.827	0.154	15.69
S2	6.797	4	1.018	0.872	0.146	14.34
S4	6.794	4	1.028	0.842	0.186	18.09
T1	6.807	4	0.966	0.839	0.127	13.14
T3	6.782	4	1.008	0.931	0.007	7.63
T5	6.77	4	1.045	0.947	0.098	9.37

#### 4.6 X-Ray Fluorescence (XRF):-

The XRF data of different oxide minerals we got in percentage (table--18) ,then that percentage value converted into molar proportion by dividing the molecular weight percentage to molecular weight (table-19).Here as the calcrite percentage is high the actual weight of CaO (CaO\*) calculated as molecular weight of CaO to the molecular weight of CaCO<sub>3</sub>.then the actual weight percentage of CaO is (CaO\*) equal to wt.% CaO multiple by 0.56.

CaO\* = CaO% - CaO (from sequential leaching)

From this molar value the CIA can calculated.

$$CIA = \frac{Al_2O_3}{Al_2O_3 + CaO + K_2O + Na_2O} * 100$$

Table 17:Oxide percentage of different minerals

sample name	SiO2 (%)	Al2O3 (%)	Fe2O3 (%)	MnO (%)	MgO (%)	CaO (%)	CaO*(%)	Na2O (%)	K2O (%)
A0	63.826	8.393	3.171	0.02	1.905	5.561	1.9322	1.081	2.014
A3	58.911	8.472	3.772	0.02	2.954	8.69	5.0164	0.969	2.082
A3 rpt	59.837	8.767	3.79	0.02	3.087	8.775	5.1014	1	2.101
A5	62.942	8.531	3.495	0.02	2.729	7.029	2.7898	1.158	2.001
B1	59.546	8.692	3.884	0.03	3.221	7.571	5.8182	0.987	2.095
B3	63.545	8.753	3.413	0.02	2.731	6.696	3.504	1.177	2.098
CTOP	63.702	9.951	3.61	0.03	2.258	3.432	-1.1992	1.02	2.248
C2	60.02	8.676	3.635	0.02	3.026	7.599	5.8462	1.08	2.089
S0	59.669	8.795	3.821	0.03	3.125	7.409	3.9426	1.048	2.12
S2	60.036	8.705	3.724	0.03	3.065	6.917	3.725	1.129	2.09
S4	60.432	8.778	3.81	0.03	3.166	7.063	4.5486	1.162	2.09

Table 18: Molar proportion of major oxides. In(M)for molar weight

sample	SiO2	Al2O3	Fe2O3	MnO	MgO	CaO*	Na2O	K2O	CIA*
A0	1.0624	0.0823	0.0199	2.82E-04	0.0473	0.0345	0.0174	0.0214	52.9046
A3	0.9805	0.0831	0.0236	2.82E-04	0.0733	0.0895	0.0156	0.0221	39.5141
A3 rpt	0.996	0.086	0.0237	2.82E-04	0.0766	0.091	0.0161	0.0223	39.9198
A5	1.0476	0.0837	0.0219	2.82E-04	0.0677	0.0497	0.0187	0.0212	48.2679
B1	0.9911	0.0852	0.0243	4.23E-04	0.0799	0.1038	0.0159	0.0222	37.5271
B3	1.0577	0.0858	0.0214	2.82E-04	0.0678	0.0625	0.019	0.0223	45.2794
CTOP	1.0603	0.0976	0.0226	4.23E-04	0.056	-0.0214	0.0165	0.0239	83.7499
C2	0.999	0.0851	0.0228	2.82E-04	0.0751	0.1043	0.0174	0.0222	37.1669
S0	0.9932	0.0863	0.0239	4.23E-04	0.0775	0.0703	0.0169	0.0225	44.0143
S2	0.9993	0.0854	0.0233	4.23E-04	0.076	0.0664	0.0182	0.0222	44.4194
S4	1.0059	0.0861	0.0239	4.23E-04	0.0786	0.0811	0.0187	0.0222	41.3626

Table 19: Different oxide minerals in Normalized ternary data.

sample name	K <sub>2</sub> O(M)	Al <sub>2</sub> O <sub>3</sub> (M)	CaO+Na <sub>2</sub> O +K <sub>2</sub> O( M)	Fe <sub>2</sub> O <sub>3</sub> +MgO( M)	Al <sub>2</sub> O <sub>3</sub> (M)	C <sub>A</sub> O+Na <sub>2</sub> O +K <sub>2</sub> O (M)
A0	13.7532	36.939	32.8995	30.1616	29.3091	26.104
A3	10.5088	27.0508	41.4063	31.543	18.7754	28.7393
A3 RPT	10.3528	27.2411	40.9883	31.7707	19.0308	28.6347
A5	12.2331	31.8372	34.0814	34.0814	25.2641	27.045
B1	9.7754	25.7169	42.8313	31.4519	17.434	29.0362
B3	11.7616	30.7747	37.231	31.9943	22.8861	27.6874
CTOP	20.4974	50	9.7336	40.2664	74.6748	14.5371
C2	9.6943	26.0324	44.0196	29.948	17.2058	29.0942
S0	11.4796	29.0182	36.8863	34.0955	21.9649	27.9206
S2	11.5505	29.2967	36.6381	34.0652	22.2628	27.8415
S4	10.6679	27.7205	39.2788	33.0006	20.0279	28.3787

It indicates the minerals are in highly weathered form or in less weathered form. If it falls above that of 50 then the minerals are in weathered form. Only two samples A0 & Ctop show higher value >50, where all other value shows less than 50 which are less weathered (table-18) (source-Nesbitt and Young,1982,1984). This may occur due to the high percentage of calcite present in these areas.

In the A-CN-K plot all the samples except two A0 & Ctop which lie above the 50% of ternary diagram (FIG-34). From the plot of A-CN-K it indicates that most of the samples are rich in Ca and Na and less in K<sub>2</sub>O and Fe<sub>2</sub>O<sub>3</sub>. As these areas are rich in calcite all the samples are moving towards the CaO & Na<sub>2</sub>O site. The Loc-A samples are less rich as compared to the Loc-C & S. The Loc-C have high percentage of calcite as compared to the others two. All the samples lie within the range of 35-55 molar weight.

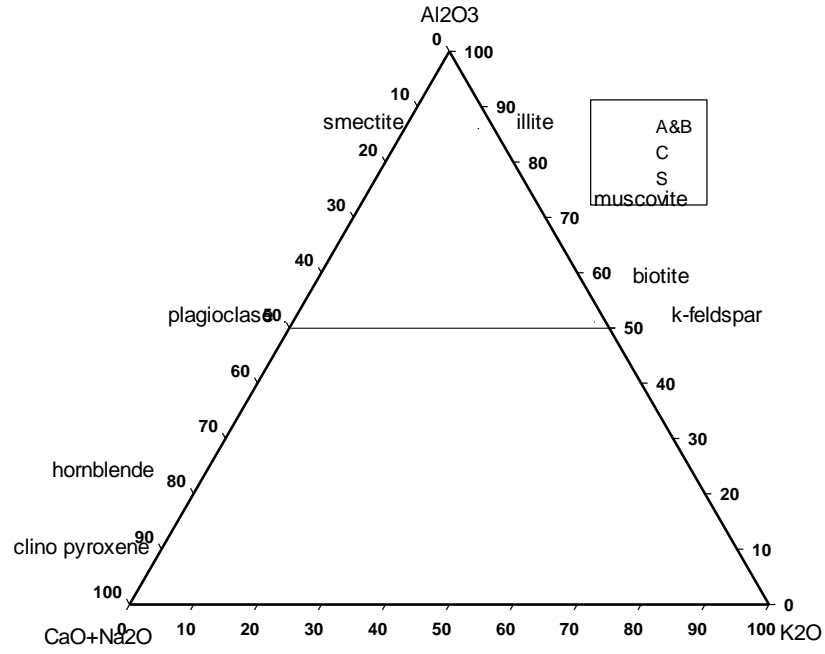


Fig 33: Ternary plot of A-CN-K of different samples

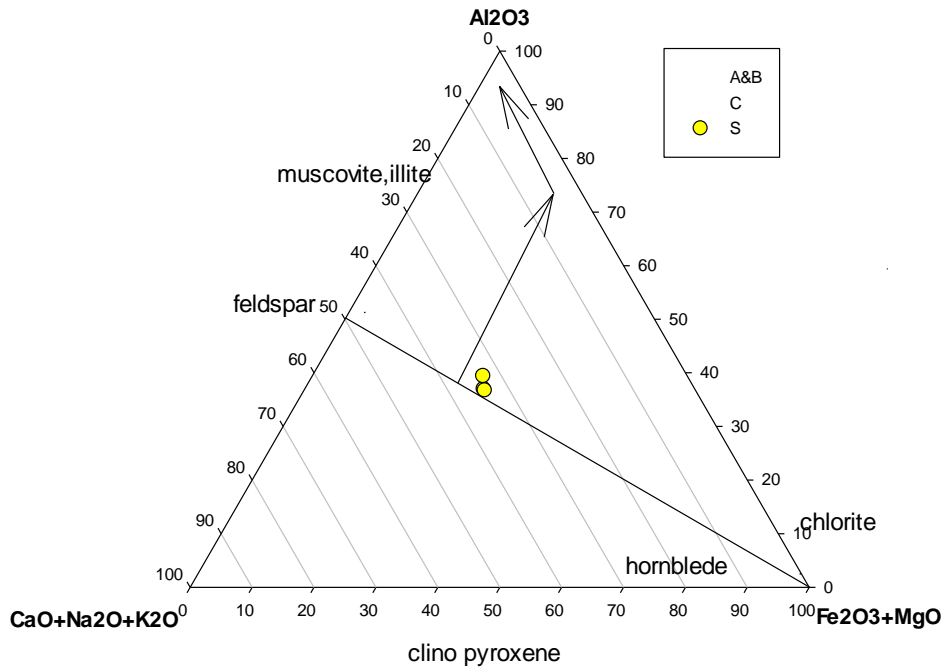


fig 34: Ternary plot of A-CNK-FM of different samples

In the plot of A-CNK-FM plot most of the samples are plot in between the 40 to 55% range .This diagram generally show the movements of elements towards the  $Al_2O_3$ . The most of the samples are lies in between smectite and andesite and gradually it started moves towards the Kaolinite or Gibbsite Regions ( $Al_2O_3$ ). Here most of the minerals lie within the Felsic Regions, but Felsic minerals will take much more time to weather as compaired to the Mafic minerals.(Fig-34)

Al/Si and Fe/Si are directly correlated to the bulk sediment grain-size and are a proxy of mineral sorting (Bouchez et al., 2011a; Lupker et al., 2011). In this plot we can able to know wheter elements are enriched of quartz, clay or muscovite or in Biotite. If the Quartz rich (low Al/Si and Fe/Si) bottom sediments and Clay rich (high Al/Si and Fe/Si) surface Sedimentsand for Biotite their should be riched in Fe/Si and for Muscovite riched in Al/Si . Also from this plot we can able to know that weather the samples are weathered or less weathered. In this plot most of the samples are plotted in the Biotite area i.e high in Fe/Si , some of them lies in the Quartz zone while only one sample Ctop lies near to the Muscovite regions. This indicates that the samples of this area is less weathered ,because if the weathering percentage is high then the minerals are plotted in the Clay region i.e the top of the diagram (fig-35)

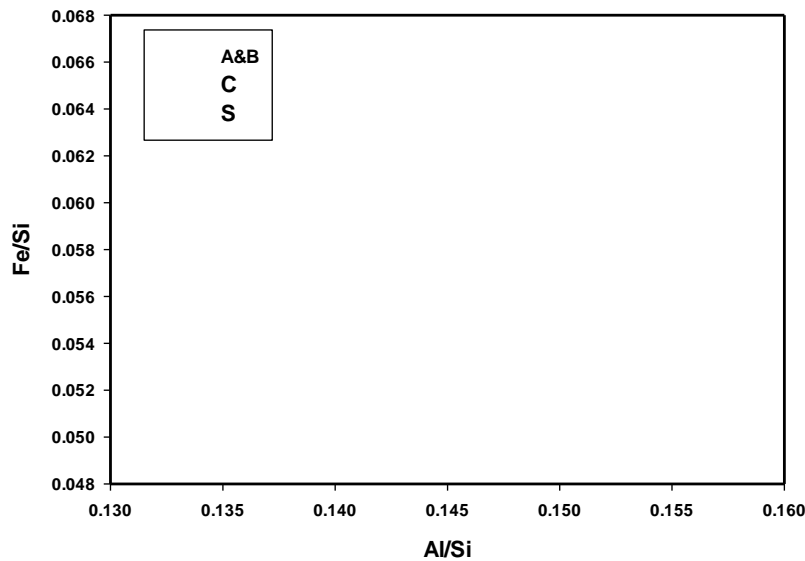


fig 35: Fe/Si & Al/Si plot of different samples

#### 4.7 Carbonate Phase Leaching :-

Different elements are correlated with each other, some of them show nearly correlated to each other while some of the element does not show good correlation. Some elements like As and Th show good correlation and also Cu & Th also shows good correlation. The percentage of carbonate was well correlated with the Th & U, Cu & As, Th & U, and As & U shows good correlation in between them. (table-20 in ppm), where as in ppb only few elements Mn & Sr as well as percentage of carbonate vs. Sr show good correlation in between them (table-21 in ppb).

The plot between percentage of carbonate vs. elements are plotted and it shows how the elements are correlated or vary with the carbonate percentage.

Table-20:- correlation between different of different samples in ppm

	wt.% (HNO3)	% CaO	K	Mn	Fe	Sr
wt.% (HNO3)	1.00					
% OF CaO	-0.29	1.00				
K	0.09	-0.13	1.00			
Mn	-0.50	0.39	0.21	1.00		
Fe	0.18	-0.02	0.38	-0.09	1.00	
Sr	-0.59	0.37	-0.08	0.68	-0.18	1.00

Table-21:- correlation between different of different samples in ppb

	wt.% (HNO3)	% OF CaO	Co	Ni	Cu	As	Sr	Th	U
wt.% (HNO3)	1.00								
% OF CaO	-0.29	1.00							
Co	0.10	0.04	1.00						
Ni	-0.01	0.10	0.82	1.00					
Cu	0.09	0.60	0.35	0.27	1.00				
As	0.24	-0.59	0.30	-0.05	-0.74	1.00			
Sr	-0.59	0.37	0.04	0.23	0.27	-0.29	1.00		
Th	0.92	-0.60	0.11	-0.27	-0.98	0.99	-0.62	1.00	
U	0.72	-0.27	0.61	0.30	-0.66	0.72	0.08	0.70	1.00

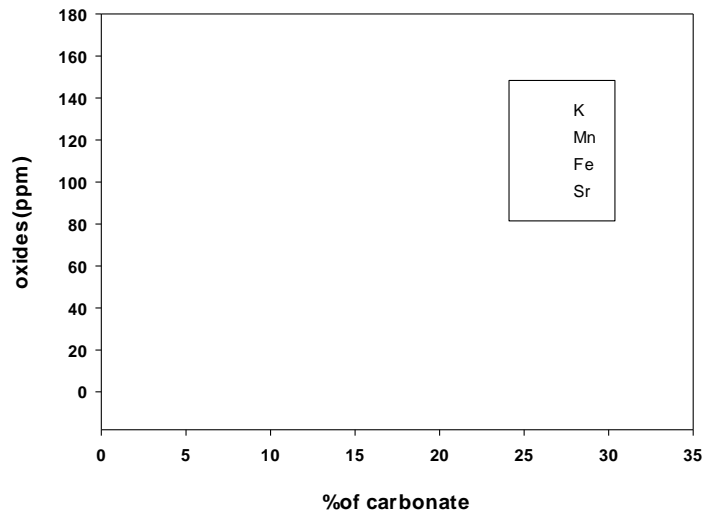


Fig36: Carbonate percentage vs. different elements (ppm) of differentsamples.

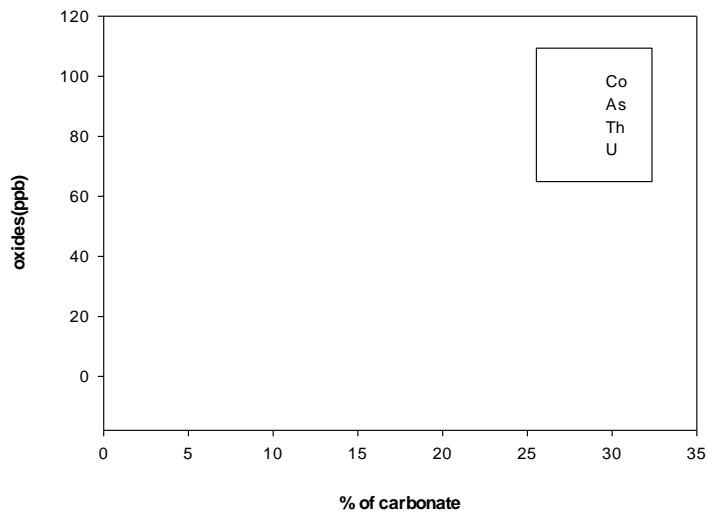


Fig 37: different elements vs. percentage of carbonate of different samples in ppb

## CHAPTER-5

### CONCLUSION

In this study sediments were collected from different horizons of stabilized sand dunes found in the Bathinda regions of Punjab and Sikar regions of Rajasthan. Textural, bulk mineralogy, geochemistry and carbonate phase geochemical analysis were carried out on selected samples. Following conclusions were drawn from the results.

Textural analysis of the sediment shows grain size distribution is bi modal in Loc A and B sand dune whereas other location including Sikar shows Unimodal distribution. Possible explanation for bimodal distribution is change in source, energy condition during deposition of the sands. Mean grain size of all the sediments are very fine sand and shows moderately to very well sort. Statistical analysis of grain size and from various discrimination plot indicating quite depositional environment and plot in the field of aeolian field of quartile deviation and median plot.

Mineralogical phase analysis shows the sediments are rich in quartz, feldspar, calcite and clay minerals. Presence of calcrete and clay minerals indicate dunes were stabilized and pedogenesis process were active in the sand dunes. Maximum carbonate percentage is observed from the Loc S.

Bulk geochemistry indicates the  $\text{SiO}_2$  percentage varies from 58 to 64%. The maximum CIA value of 83 was observed in the Loc C samples. A-CN-K and A-CN-K-FM ternary plot shows maximum samples are low to moderately weathered and trending towards  $\text{Al}_2\text{O}_3$  apex. Overall composition is felsic in nature.

**Future work:** Detailed geochemical work is required to understand the provenance and pedogenesis process acting on the stabilized sand dunes.

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