TEXTURE AND GEOCHEMISTRY OF SEDIMENTS FROM DELHI RIDGE ON THE THAR DESERT MARGIN

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CERTIFICATE

This is to certify that the research work embodied in this dissertation entitled **"Texture and geochemistry of sediments from Delhi ridge on the Thar desert margin"** has been carried out in the School of Environmental Sciences, Jawaharlal Nehru University, New Delhi. This work is original and has not been submitted in part or full for any other degree or diploma to any university or institute.s

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CHAPTER I

INTRODUCTION

Deserts or arid zones are one of the important components of the Earth's environment. They are fragile ecosystem where vegetation is absent or scarce as moisture is insufficient to support it. They are progeny of global climate system under the influence of large scale land-ocean–atmosphere-cryosphere interactions (Sikka, 1997). In addition to this human interaction has long been overlooked. The arid and seasonally arid regions of the world are the main source areas of windblown mineral dust (Prospero, 1981a; Pewe, 1981b; Coude-Gaussen, 1984).

Recently, there have been a great deal of interest in the study of dust and aerosols because of their importance in climate change problems (Broecker, 2000; Mikami, 2000), nutrient dynamics(Yaalon and Ganor, 1973; Drees et al., 1993 ; Reheis et al., 1995; Buseck and Posfai, 1999), atmospheric pollution and environmental health (Young et al., 1988 ; Pinnick et al., 1993 ; Ross et al., 1993; Wilson and Spengler, 1996; Prospero, 1999; Allen et al., 2001) and in the process of desertification (Lundholm, 1979; Intergovernmental Panel of Climate Change, 1995; Reynolds et al., 2001). Desertification is one of the greatest global environmental concerns which that transform productive or marginally productive land to deteriorated land and soil unable to support plants and animals (Merritts et al., 1997).

Aeolian deposits, such as loess, are studied extensively in earth sciences because they are the potential indicators of paleoclimatic change via preserved fossils, magnetic susceptibility or chemical compositions (e.g. Gallet et al., 1996; Jahn et al., 2001). There are human and economic benefits associated with dust deposition, notably the addition of airborne nutrients to soils (Yaloon and Ganor, 1973; Bromfield, 1974; Beavington and Cawse, 1979), stabilization of sand dunes and other mobile surfaces in arid regions by formation of a cohesive dust- rich crust (Tsoar and Moller, 1986) and the accumulation of fertile loess soils which are of a major agricultural importance (Chesworth, 1982). It has been estimated that 10% of the world's land surface area is covered by loess like deposits (Pecsi, 1968a). Loess regions in Central Asia and China were important centres for the development of early human cultures and civilizations (Ho Ping-ti, 1969, 1975; Ranov and Davis, 1979; Davis et al., 1980). In many countries loess has provided an important raw material for the brick and cement industries (Ginnzbourf, 1979), and in parts of China and North Africa houses are made from excavated loess.

The record of dust deposition preserved in thick loess profiles, marine sediments and ice caps provides some of the most complete and detailed information regarding the effects of Quaternary climatic changes on the continents (Parkin and Shackleton, 1973; Heller and Liu Tung-sheng, 1982; Thompson and Mosley-Thompson, 1981). Dust transport and deposition are also important on planets other than Earth, notably Mars and Venus, where they may be the dominant sediment transport processes (Sagan and Pollack, 1969; Zurek, 1982; Greeley and Iversen, 1985).

The north-western part of India witnesses frequent dust storms during the summer months (April- July) before the onset of the monsoon. These dust storms transport a large quantity of sediments in the arid to semi arid region (Pant, 1993). The famous Thar Desert of Rajasthan lies in the westernmost part of the India and the prevailing winds are strongly westerly during the summer months. There have been suggestions that the desert-forming processes in the Thar desert could have transported vast quantities of fine sediments to the desert fringe (Pant, 1993). Tripathi and Rajamani, (1999) suggested that the removal of silt from the Thar region by SW-W winds must have been responsible for the deposition of loess like sediments on the N-W margin of Thar desert and transfer of nutrient to the fertile land of western Uttar Pradesh, Haryana and Punjab. Prevailing S-W to W winds carry large amounts of dust particularly during the summer months possibly from the windward Thar desert in Rajasthan (Sikka, 1997). The origin of the Thar Desert and in particular the source of the desert sands are much debated topics of the Quaternary Geology of India (Singh, 1988; Pant, 1993). Archaeological evidence suggests that the region was once a flourishing green country-side with thick forest and a well-knit system of rivers of which Saraswati and the Yamuna were the largest (Sinha R. K., Ghial P., 1997). These ancient, but now extinct, rivers originating from the great Himalayan Mountains drained through the now desertified areas of Rajasthan (Valdiya, 1996a).

Epigraphic evidence by LANDSAT satellite Imagery confirms this (Sinha, 1997). The onslaught of man and his domestic animals on the local ecosystem changed the panaroma of the region from a land of plenty to a land of poverty in less than 5,000 years. The vestiges of Mohen-jo-daro and Harappa which stand in the barren desert tells the story of the effects biodiversity destruction and desertification can have on human civilization (Sinha, 1997).

The Delhi region has NE trending sub parallel ridges of quartzites and the entire area has a cover of consolidated sediments. The surrounding areas of the Delhi ridge, the bed rock are overlain by alluvial materials of the Yamuna River (Srivastava, 1988). Although the exposed sediments surrounding the ridge are predominantly flood plain alluvium of the Yamuna River (Thussu, 1995), those occurring within local depressions on the ridges are probably aeolian, as river inundation to the top of the ridges which are an average 100m above the adjoining river flood plain is less likely (Tripathi and Rajamani 1999).

The origin of most extensive loesses by aeolian transport by glacial outwash plains particularly during cold dry climate regimes of Pleistocene is well established (Tsoar and Pye, 1987). Penk (1930) considered loess as the product of different causes in which glaciers, rivers and wind, cold and arid climates work together. Many attempts have been made to understand chemical characteristic of aeolian sediments, especially loess (Taylor et al., 1983; Pye and Johnson, 1988; Clarke, 1995; Gallet et al., 1996; Winspear and Pye, 1996; Honda and Shimizu, 1998; Liu et al., 1999). Although a suggestion has been made that the Delhi ridge sediments could be loessic deposits of aeolian origin (Tripathi and Rajamani, 1999) none of the sampling sites were more than 2m deep. Any improvement to our knowledge of these ridge sediments requires a thorough sedimentological and geochemical study of a deeper profile up to the country rock. Because of the lack of primary data on the sediments in this semi arid region of India and also because of the regional and global importance of loessic sediments, I have undertaken a geochemical study of these loessic sediments in a 10.8m deep profile in the Delhi ridge region.

OBJECTIVES OF THIS STUDY:

1. To understand the nature of sediments geochemically, mineralogically and texturally
2. To understand variation in the processes during the deposition of 11m thick profile.
3. To understand the nature of source during the deposition and changes after the deposition.
4. To understand the implications of sedimentation processes on Delhi's environment.

Study Area

CHAPTER II

STUDY AREA

GEOLOGY OF DELHI REGION:

National Capital Territory of Delhi occupies 28 24’-28 53’N latitude and 76 50’-7720’ E longitude falling on the toposheets of 53 H/2 and 53 H/3. The south and south-eastern parts of Delhi are a plateau of 250-300meters height, rising about 100 meters above the surrounding area is known as the famous Delhi ridge. The area provides an interesting place to study the important surface geochemical processes because it occurs at the triple junction of Aravalli Mountain. Thar Desert and Indo-Gangetic plain and it has possible some subsurface connection with the Himalayas. The extension of the Delhi ridge to the base of Himalayas is known as Delhi-Haridwar ridge.

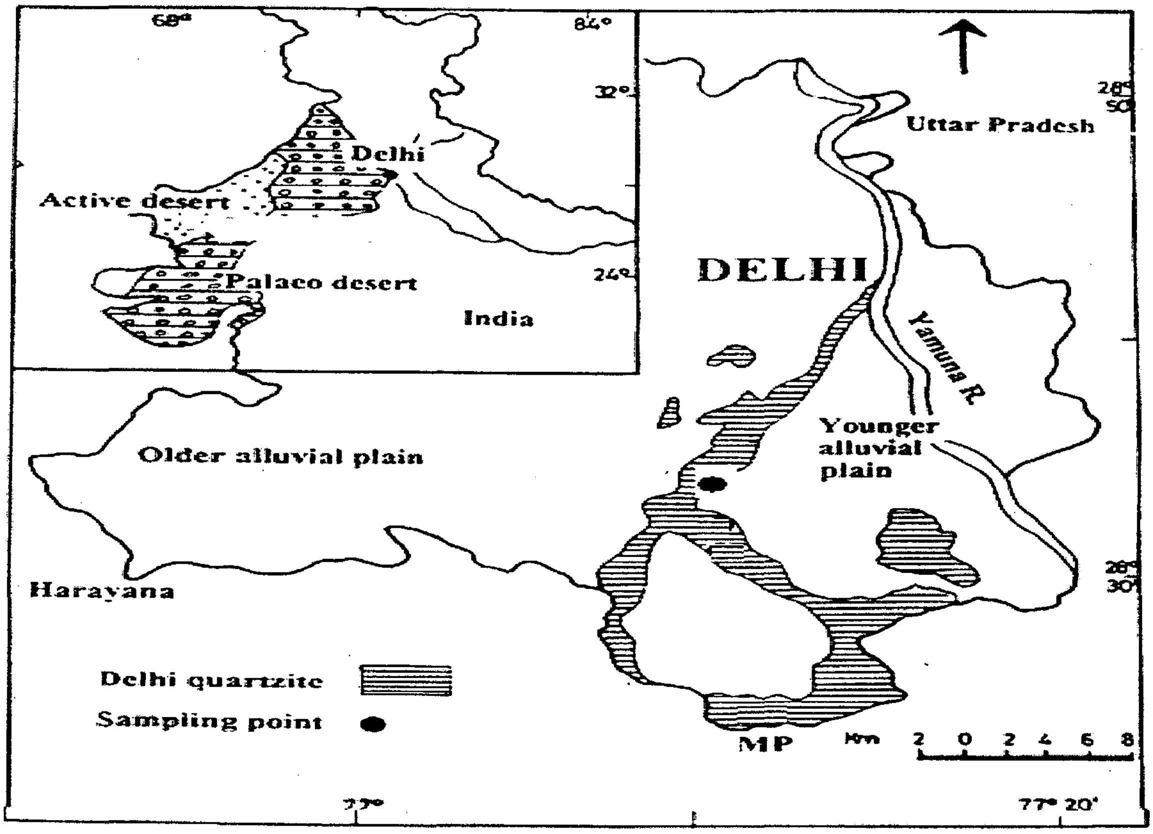

Fig.1: Geology of Delhi Region

PHYSIOGRAPHY AND SOIL:

Delhi ridge constitutes northernmost extension of the Aravalli range in the form of two ridges, i.e. Sohna ridge in Haryana, nearly 45km from Delhi, west of it is Harachandpur ridge also known as Delhi ridge, which has become famous for its environmental importance to this region. Physiographically the north western part of India covers deserts of Rajasthan and Haryana, Aravalli ranges and Indo-Gangetic alluvium. The Aravalli Mountains constitute remnant monuments of Precambrian times, whereas Thar Desert and alluvium are Quaternary features formed by aeolian and alluvial processes. Four major geomorphic landforms have been identified in this region (Thussu et al., 1992). These are (1) structural cum denudational hills and valleys (2) Rewari older alluvium surface (3) Aeolian sandy surface and (4) Yamuna flood plain surface. The structural cum denudational hills consists of linear ridges with rounded crest and wide valleys, isolated hillocks and inselberg. These extend southward from Delhi to Faridabad, Gurgaon, Mahendragarh and Bhiwani districts. Large numbers of ephemeral streams originate along the edges of these hills with piedmonts and hillwash deposits at the foot of the hill slopes. These streams are mostly controlled by joints.

Rewari older alluvial surface represents the surface formed by the earlier river system of the southern bank of Indo Gangetic basin. It is featureless plain with paleochannels, paleolakes and topographic depressions mostly used for cultivation. Aeolian sandy surface is well developed in the districts of Mahendragarh, Gurgaon and Hissar districts of Haryana, adjacent to Delhi. These are represented by ergs (dunal flat) and dunes. The Delhi- Harachandpur ridge makes abatement to the River Yamuna and thereafter submerges into the alluvium northward.

Soils of Delhi have been grouped into 15 series by Chibbar (1985). About 15% of this area is affected by salinity or alkalinity and about 64% of the total area is irrigated. Soils of Delhi are generally low in available nitrogen, low to medium in phosphorus, medium to high in potassium, adequate in calcium, magnesium and sulphur. Zinc deficiency has been noted in coarse textured soils. The soil type on Delhi ridge has been reported as sandy loam to loam (Chibber, 1985).

Climate

Delhi, like adjoining plains of Haryana, has a semi arid climate. Three different vegetational seasons are recognised, a dry hot summer from March to June, a wet monsoon from July to September and a dry cold winter from October to February. The summers are very hot with temperatures reaching as high as 43°C to 45°C. The winters are severe with minimum temperature varying from 6°C to 8.5°C occasionally dropping to near zero. The average rainfall of the Delhi is about 710mm, 80% of which is received during July to September.

Vegetation

Hardy evergreen and spinuous xerophytic trees and shrubs characteristic of arid climatic are most common vegetation of the ridge. They are *Propsopis spicigera* L., *Acacia Arabica* wild, *Balanites roxburghii, Butea monosperma, Anogeissus Pendula, Cassia fistula, Albizia lebbec* etc. *Capparis sepiaria* L. is common among larger thorny shrubs. Other shrubs are undershrubs are *Grevia tenax* and *Adhatoda vasica.*
In the alluvial plains, the only timber tree is *Dalbergia sisoo.* Other trees such as *Acacia Arabica, Ficus bengalensis, Prosopis juliflora,* and Eucalyptus sp. are planted along roadsides. In the soils of the recent alluvium trees like *Salvadora persica* and *Eruca sativa* and shrubs like *Calotropis procera* and grasses like *Erianthus ravennae* and *Saccharum spontaneum* are commonly observed.

Field Observations:

The Quaternary deposits in the Delhi have been grouped into sediments on the ridge (the pediments), older alluvium, newer recent alluvium and aeolian sediments (Chibbar, 1985; Thussu and Chopra, 1991). The sediments profiles on the Delhi ridge are well developed in local depressions on the ridge and also along the flanks of the ridge as pediplains and form a narrow strip before interceptibly merging with fluvial sediments of the Yamuna River (Thussu, 1995). Tripathi and Rajamani (1999) have described the Delhi ridge sediments as loessic in nature on the basis of sedimentology and geochemistry. The sampling site was a 10.8m (~33 feet) deep pit and also shows profile characteristics as seen by Tripathi and Rajamani (1999). The vertically standing sediment profiles neither show any stratification nor any cross bedding features that are common in alluvial deposits. The sediments are yellowish brown in colour from the base up to 13 feet after which the reddening of sediments appeared up to 22 feet. The sediments are yellowish to buff coloured, friable from 22 feet to the top of the vertical profile of sediments. Disseminated calcrete nodules are present throughout the sediment profile up to 10 feet. Also three calcrete horizons are present at 2, 5 and 13 feet from the base of the sediment profile. The sediments overlie the quartzites with sharp contact and many characteristics of sediment profile show that they are neither locally derived from quartzites nor a part of the alluvial plain, they are wind blown sediments deposited on Delhi ridge in Vasant Kunj area at the height of 216msl. I will discuss the loessic nature in detail in the discussion in Chapter No. IV.

Material & Methods

CHAPTER III

MATERIAL AND METHODS

ANALYTICAL TECHNIQUES AND METHODOLOGY

The research methodology adopted for this research work is categorised in four parts:

- Field studies and Sample collection,
- Particle Size Analysis,
- Mineralogical Analysis and
- Geochemical Analysis.

The field analysis involves surveillance of the sampling site, sample collection, primary observation of the samples like colour, texture etc. The Mineralogical study involves of mineralogical analysis using X-Ray Diffractometer. Geochemical study involves processing of sediment samples for geochemical analysis and quantitative determination of major and trace-elements by various wet chemical procedures adopted for the determination of elements. Distribution of different size particles i.e. sand, silt, and clay in sediments is determined by the sieve and sedimentation analysis.

FIELD STUDIES AND SAMPLE COLLECTION

Sediment samples were collected from 10.8m deep pit in Vasant Kunj area which lies on the Delhi ridge region. Field observations were carefully made and noted. Approximately 1 kg of sediments samples were collected in a plastic bag by channel scraping from the West wall of the pit at the interval of every 1 feet for grain size, mineralogical and geochemical study. Sediment samples were collected for the first 22 feet (Samples VKS1-22) from the west wall and then from Sample (VKS 22B-33) from the south wall. At 22 feet samples were collected both from west as well as south wall.

Particle size analysis:

Grain size distribution of clastic sediments constitutes basic data in sedimentology that helps in providing insights regarding hydrodynamics of flows and also about depositional conditions. A relation between sedimentary processes and textural responses is a powerful tool for interpreting the genesis of depositional environments (Visher, 1969).

The grain size distribution of the sediment is a function of the size range of available material, its accessibility for weathering, erosion and transportation, and the energy input into the sediments (Pandey et. al, 2002). The sediments can be classified on the basis of particle size, or the diameter of individual grain of sediments. This classification is based on φ logarithmic scale (which is Krumbein's modification of the Wentworth scale)

$$\Phi = -\log_2 D/D_0$$

Where Φ is the Krumbein phi scale, D is the diameter of the particle and Do is a reference diameter. Grain size analysis discloses the texture and composition of grains in a given sample. If the samples are having a great proportion of clay and clumps then deflocculation of the sample is done by two ways before proceeding for analysis.

***Carbonate Leaching*:** Around 100g of sample was taken in 500ml beaker and 1.3 N HCl acids were poured into it. The solution was stirred continuously and then left overnight (Gale and Hoare, 1991). The solution was then filtered with Whatman Filter and the sample was being washed with MilliQ until it gave the clear solution. The filter papers containing samples were then dried in oven at 40^0 and weighted for loss of carbonate.

Table 3.1: Sediment Classification based on particle size

SCALE	SIZE RANGE (metric)	SIZE RANGE (Approx. inches)	AGGREGATE NAME (Wentworth class)	OTHER NAMES
<-8	>256mm	>10.1in	Boulder	
-6 to 8	64-256mm	2.5-10.1in	Cobble	
-5 to 6	32-64mm	1.26-10.1in	Very core gravel	Pebble
-4 to 5	16-32mm	0.63-1.26in	Core gravel	Pebble
-3 to 4	8-16mm	0.31-0.63in	Medium gravel	Pebble
-2 to 3	4-8mm	0.157-0.31in	Fine gravel	Pebble
-1 to 2	2-4mm	0.079-0.157in	Very fine gravel	Granule
0 to 1	1-2mm	0.039-0.079in	Very coarse sand	
1 to 0	0.5-1mm	0.020-0.039in	Coarse sand	
2 to 1	0.25-0.5mm	0.010-0.020in	Medium sand	
3 to 2	125-250µm	0.0049-o.010in	Fine sand	
4 to 3	62.5-125µm	0.0025-0.0049in	Very fine sand	
8 to 4	3.90625-62.5µm	0.00015-0.0025in	Silt	Mud
>8	<3.90625µm	<0.00015in	Clay	Mud
>10	<1µm	<0.000039in	Colloid	Mud

***Sieve Analysis*:** The dry sieving method is used to fractionate a sediment/soil into its proportion of coarse sand, fine sand, very fine sand, silt and clay. For this analysis sieves of 0.5mm, 0.35mm, 0.25mm, 0.171mm, 0.125mm, 0.088mm, 0.063mm are used. A representative weighed (25g) sample is poured into the top sieve which has the largest screen openings. Each lower sieve in the column has smaller openings than the one above. At the base is a round pan, called the receiver. The column is typically placed in a mechanical shaker. The shaker shakes the column, usually for some fixed amount of time (usually 30mts but here for 1 hr because of clayey sample). After the shaking is complete the material on each sieve is weighed. The weight of the sample of each sieve is then divided by the total weight to give a percentage retained on each sieve.

Sedimentation/Pipette Method:

Sedimentation methods based on particle setting velocity are generally used to analyze sediment composed of silt and /or clay (less than 62µ size). The size parameter measured is related to settling velocity by Stokes's law, generally written as

$$w = \{(Ps-P)\ gd2\ \}/18\mu,$$

Where w= setting velocity, Ps=density of the particle, P=density of water, g = acceleration due to gravity, µ=dynamic viscosity of water and d= equivalent diameter of the particle.

After removing any sediment coarser than 62µ by sieving (wet sieving for silt and clay material), fines were transformed to 1000ml measuring cylinder. In this, a known amount of Calgon was added and then the sample was diluted to 1000ml. The suspension was well agitated using a stirring rod making long smooth strokes along the full length of the column. On removal of the stirring rod, timer was started, and at the twentieth second, the first 20ml of solution was withdrawn from a depth of 20cm using 20ml pipette. The withdrawn suspension contains silt, clay sized sediments. Successive aliquots were withdrawn from specific levels at specific time intervals (Galehouse, 1971; Mc Manus, 1988), placed in an evaporating dish or 50ml pre-weighed beakers and dried in an electric oven at 50°C. After drying, they were weighed again. Finally, cumulative weight and percentage of each size fraction were calculated and noted on data sheet.

The data were plotted on log probability curves following the procedures given by Visher (1969). Statistical analysis was done using the Gradistat programme. Probability ordinate scale was used for presentation of data and calculating grain size parameters, and the results were assigned to various descriptive classes.

MINERALOGICAL ANALYSIS:

X-ray diffraction method explains the geometry or shape of a crystalline materials using X-rays, and based on the elastic scattering of X-rays from structures that have long range order. The interaction of the incident rays with the sample produces constructive interference (and a diffracted ray) when conditions satisfy Bragg's Law ($n\lambda=2d \sin \theta$). This law relates the wavelength of electromagnetic radiation to the diffraction angle and the lattice spacing in a crystalline sample. These diffracted X-rays are then detected, processed and counted. Conversion of the diffraction peaks to d-spacing allows identification of the mineral because each mineral has a set of unique d-spacing. Typically, this is achieved by comparison of d-spacing with standard reference patterns. Mineralogy of samples was studied using Philips X'pert powder diffractometer with an accelerating voltage of 50 kV, a tube current of 40 mA and a scanning speed of 2 degrees 2θ per minute and with the following operating conditions.

Diffractometer type: PW3710 Based
Tube anode: Cu
Intensity ratio (alpha 2/alpha 1): 0.500
Divergence slit: 1°
Receiving slit: 0.1°
Scanned angle (2θ): 2° $^{\text{to}}$ 42° for bulk samples
Time per step(s): 0.200
Type per scan: continuous
Minimum and maximum peak tips width respectively: 0.00 to 1.00
Peak base width: 2.00
Minimum significance: 0.75

GEOCHEMICAL ANALYSIS:

Deducing valuable information from geochemical data requires accurate and precise determination of the concentration of the elements of interest in the sample under consideration. Therefore, maximum care was taken throughout the data acquisition process to obtain data with maximum precision.

Sample Processing:

About 1 Kg of sediments samples were crushed in hardened steel mortar to approx. 60 mesh size. The crushed sample was placed on a butter sheet and homogenized thoroughly by lifting alternate corners of the butter sheet for about 20 minutes and about half of the homogenized powder was collected by coning and quartering method and was ground to ~ 200 mesh sizes in an agate mortar.

This ~200 mesh size sample powder was stored in plastic vials and the same was used for X-ray analysis and preparation of the solution for geochemical analysis. Once the sample was ground to ~200 mesh sizes, the steel mortar and pestle and the agate mortar, the sieves, and other accessories, were washed with soap solution, dried up with the help of air blower and then cleaned with acetone before proceeding to next sample thereby limiting the inter-sample contamination.

The sample processing and dissolution procedures for the chemical analysis were kept the same as far as possible for both standards and sample solutions for any particular set of analysis. During the major and trace element analyses, International Rock Standards (IRS) and in-house rock standards were run as unknown after the calibration of the instrument, thereby checking precision of the given set of analysis.

Sample Dissolution

The samples are brought into solution for analysis by following the Shapiro and Brannock (1962), 'B' solution method.

***Solution 'B' Method*:** For the dissolution of sediment samples acid digestion method was used. In this method 0.5 g of ~200 mesh samples as well as standards were weighed and poured into Teflon crucibles. Few drops of MilliQ water was added in every sample to prevent spreading of samples while pouring the acids. The whole digestion is four step processes. In first step 1 ml HClO4 (Perchloric acid), 10 ml HF (hydrofluoric acid) and 5 ml of HNO3 (nitric acid) was added in each sample. Lid was kept over each crucible and the whole were placed on hot plate for 4-6 hrs. The samples were then left for few hours for cooling. The lids were removed carefully by dropping all the condensed vapours into the crucibles and samples were evaporated to dryness. In second step 5 ml of HF and 10 ml of HNO_3 was added in each sample and again kept on hot plate for evaporation to dryness. In third step only 10 ml of HNO_3 was added in each sample and evaporated to dryness. Fourth step involves addition of 25 ml 2N HCl in each sample and the samples were kept on hot plate for one hour with lids over them. Samples were cooled and transferred to 100 ml volumetric flask rinsing with 1N HCl and the volume was made up with MilliQ water. This solution was filtered with Whatman filter paper if required. Now this is 20 times diluted sample, used directly for analysis of trace elements. For the analysis of major elements 5 ml of these 200 times diluted sample was taken in 100 ml volumetric flask and volume was made upto 100 ml for 4000 times dilution (200x20). SiO_2 was analyzed by solution A method after Shapiro and Brannock (1962)

Sample Analysis

The precision and accuracy of analysis for major and trace elements were monitored using USGS rock standards (BHVO, STM and RGM) as well as in house rock and sediment standards and are generally to be better than 2% and 5%, respectively.

***Major and Trace elements analysis* on ICP-OES:** Inductively Coupled Plasma – Optical Emission Spectrometer, JY ULTIMA 2, ICP-OES was used for Al, Fe, Mn, Mg, Ti, Si, Ca, Na, and K.

Principle of ICP-OES:

ICP-OES makes use of the fact that the atoms of elements can take up energy from inductively coupled plasma, are thereby excited, and fall back into their ground state again emitting a characteristic radiation. The identification of this radiation permits the identification of the element. A quantitative determination takes place on the basis of the proportionality of radiation intensity and element concentration in calibration and analysis samples.

In ICP-OES analysis, the liquid sample is introduced into the inductively generated argon plasma through a nebulizer system and excited. The spectrum emitted is transferred into a spectrometer where it is decomposed into the individual wavelengths and evaluated. The intensities of the spectral lines are measured by CID semiconductor detectors. Calibration is effected with multi-element solutions mixed from standard solutions.

Instrument Mechanism: The ICP-OES is composed of two parts the ICP and the optical spectrometer. The ICP torch consists of 3 concentric quartz glass tubes. A water cooled coil of a radio frequency (RF) generator which surrounds part of the torch. Argon gas is typically used to create the plasma. When the torch is turned on, an intense magnetic field from the RF generator is turned on. The argon gas flowing through is ignited with a Tesla unit (typically a copper strip on the outside of the tube). The argon gas is ionized in this field and flows in a particular rotationally symmetrically pattern towards the magnetic field of the RF coil.

Stable, high temperature plasma of about 7000K is then generated as the result of the inelastic collisions created between the neutral argon atoms and the charged particles. A peristaltic pump delivers an aqueous or organic sample into a nebulizer where it is atomized and introduced directly inside the plasma flame. The sample immediately collides with the electrons and other charged ions in the plasma and is broken down into charged ions. The various molecules break up into their respective atoms which then lose electrons and recombine repeatedly in the plasma, giving off the characteristic wavelengths of the elements involved. A shear gas, typically nitrogen or dry compressed air is used to 'cut' the plasma flame at a specific spot. 1 or 2 transfer lenses are then used to focus the emitted light on a diffraction grating where it is separated into its component radiation in the optical spectrometer. The light intensity is then measured with a photomultiplier tube at the specific wavelength for each element line involved. The intensity of each line is then compared to previous measured intensities of known concentrations of the element and its concentration is then computed by extrapolation along the calibration.

Determination of Loss on ignition (LOI):

LOI was determined as suggested by Maxwell (1968). 1g of each sample of 200 meshes was taken into pre-weighed quartz crucibles of 50 ml volume. The Samples were kept in muffle furnace without lid and temperature was raised to 500°C stepwise. Once the temperature was attained the lids were kept on the crucibles and the temperature was increased in successive steps to 1000°C, at which it was heated for 30 minutes after stabilization. The furnace was switched off and left for free cooling. Once the temperature reduced to room temperature the samples were weighed and the difference in the weight from untreated to heat-treated one was made to percentage; it is the loss on ignition of a particular sample.

Determination of Chemical Index of Alteration (CIA)

Nesbitt and Young (1984) suggested a parameter called Chemical Index of Alteration (CIA) to be calculated from the chemical analysis of rocks and sediments. In the calculation, the molar proportion of the oxides of Al, Ca, Na, and k are used and the index is defined as:

$$CIA = Al_2O_3 / (Al_2O_3 + CaO^* + Na_2O + K_2O). 100$$

CaO^* represents the Ca in silicate form only. Here CaO was recalculated as suggested by Tripathi and Rajamani (1999)

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

Grain size Analysis

Grain size is a fundamental property of sediment particles, and influences their entrainment, transport and deposition. Therefore, grain size analysis provides important clues to the sediment provenance, transport history and depositional conditions (e.g. Folk and Ward, 1957; Friedman, 1979; Lindholm, 1987; Blott and Pye, 2001). Moreover it is a descriptive measure of sediment and is also commonly related to other properties (e.g. permeability), which have major economic implications (McManus, 1988; Tucker, 1991; Pell et al., 2000). Hence, grain size analysis is an important aspect of sedimentological studies (Pye and Tsoar, 1990; El Sayed, 1999).

Statistical Parameters:

Statistical parameters of grain size have been obtained using the Gradistat program. It is provided in Microsoft Excel format to allow both spreadsheet and graphical output. The program is best suited to analyse data obtained from sieve or laser granulometer analysis. The user is required to input the mass or percentage of sediment retained on sieves spaced at any intervals, or the percentage of sediment detected in each bin of a Laser Granulometer. The following sample statistics are then calculated using the Method of Moments in Microsoft Visual Basic programming language: mean, mode(s), sorting (standard deviation), skewness, kurtosis, D10, D50, D90, D90/D10, D90-D10, D75/D25 and D75-D25. Grain size parameters are calculated arithmetically and geometrically (in microns) and logarithmically (using the phi scale) (Krumbein and Pettijohn, 1938; Table 3.1). Linear interpolation is also used to calculate statistical parameters by the Folk and Ward (1957) graphical method and derive physical descriptions (such as "very coarse sand" and "moderately sorted"). The program also provides a physical description of the textural group which the sample belongs to and the sediment name (such as "fine gravely coarse sand") after Folk (1954). Also included is a table giving the percentage of grains falling into each size fraction, modified from Udden (1914) and Wentworth (1922) (see Table 4.1.). In terms of graphical output, the program provides graphs of the grain size distribution and cumulative distribution of the data in both metric and phi units, and displays the sample grain size on triangular diagrams. Samples may be analysed singularly, or up to 250 samples may be analysed together.

Systemic variation of mean grain size with environmental dynamics is normally detectable and systemic changes in standard deviation and skewness may also be detected in suitable areas. Within a local or regional context, recognizable patterns related to dynamics or supplied materials are not unexpected (Folk and Ward, 1957; Allen, 1971; Cook and Mayo, 1997; Mc Manus, 1988).

Passega (1957, 1964) recommended that sample point patterns representing the variations in a deposit of two parameters (C, an approximation of the maximum grain size, and M, the median) are characteristic of the depositional agent. The CM patterns have been used by workers for analyzing the deposition of recent sediments and to reconstruct the conditions of ancient sedimentary environments (Thussu et al., 1997). Therefore, the ratio of the C to M could be used as an indicator of the dynamics of the depositional mechanism, e.g. bedload, graded suspension, and uniform suspension.

Visher (1969) suggested that cumulative frequency curves could often be subdivided into two, three or four linear segments. Because log-normal distributions follow linear trends on the cumulative probability plot, he considered each segment to represent a separate sub-population whose character was determined by the dynamics of transport: traction, saltation and suspension.

Many of the sediments are composed not of one single grain size population but rather of a combination of sub-populations. Each sub-population may be defined by dynamic considerations or by supply characteristics. In the natural environment, individual sub-populations may be present in varying proportions from location to location. Thus, in related localities it may be possible to trace material from one specific source using its modal size and spread, noting the increases and decreases in its contribution to local materials.

Kurtosis or concentration of the distribution is not widely used, although frequently calculated by sedimentologists. This statistical parameter is related both to the sorting and the normality of the distribution.

For better understanding of the variability of grain size distributions histograms are used. Studying the histograms is useful for assessing the modality of the sediments. Cumulative frequency curves with probability scale were drawn for all the samples using gradistat. Such curves are useful for calculation of statistical parameters and recognition of the mechanisms of transportation (Visher, 1969). Statistical parameters were calculated for Mean, Sorting, Skewness and kurtosis using Graistat.

The data of Vasant Kunj samples shows a bimodal character and range with prominent size 3.8 Φ to 4.7 Φ in general the range of grain size is between 3.5 Φ to 5.5 Φ class intervals. The grain size distribution of the different samples of Delhi ridge sediments is similar in terms of statistical parameters. The percentage of sand is between 26.1 to 53.2 % with 44.5 to 71% silt and 0.8 to 6.3% clay. The mean grain size of the sediments ranges from 34.43 (μm) to 55.41 (μm) with an average of. The sediments indicate moderately to poorly sorted character. Standard deviation (sorting) of these sediments is 1.8 to 4.5 with an average of sediments in this area showing very fine skewed to coarse skewed character. The skewness ranges from -0.18 to -0.439. The sediments show mesokurtic to very leptokurtic values.

Table 4.1 Granulometric results of sediments samples of Delhi Ridge sediments

SAMPLE NAME	SAMPLE TYPE	TEXTURAL GROUP	SEDIMENT NAME
VKS1	Unimodal, Moderately Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt
VKS 2	Bimodal, Poorly Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt
VKS3	Unimodal, Poorly Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt
VKS4	Unimodal, Poorly Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt
VKS5	Unimodal, Poorly Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt
VKS 6	Unimodal, Poorly Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt
VKS 7	Unimodal, Poorly Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt
VKS 8	Unimodal, Poorly Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt
VKS 9	Bimodal, Poorly Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt
VKS10	Bimodal, Poorly Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt
VKS 11	Bimodal, Poorly Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt
VKS12	Bimodal, Poorly Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt
VKS13	Trimodal, Poorly Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt
VKS14	Bimodal, Poorly Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt
VKS15	Bimodal, Poorly Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt
VKS16	Bimodal, Poorly Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt
VKS17	Trimodal, Poorly Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt
VKS18	Bimodal, Poorly Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt
VKS19	Trimodal, Poorly Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt
VKS20	Bimodal, Poorly Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt
VKS21	Bimodal, Poorly Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt
VKS22	Bimodal, Poorly Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt
VKS22B	Bimodal, Poorly Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt
VKS23	Bimodal, Poorly Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt
VKS24	Bimodal, Poorly Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt
VKS25	Bimodal, Poorly Sorted	Muddy Sand	Very Coarse Silty Very Fine Sand
VKS26	Bimodal, Poorly Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt
VKS27	Unimodal, Poorly Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt
VKS30	Trimodal, Poorly Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt
VKS33	Trimodal, Very Poorly Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt

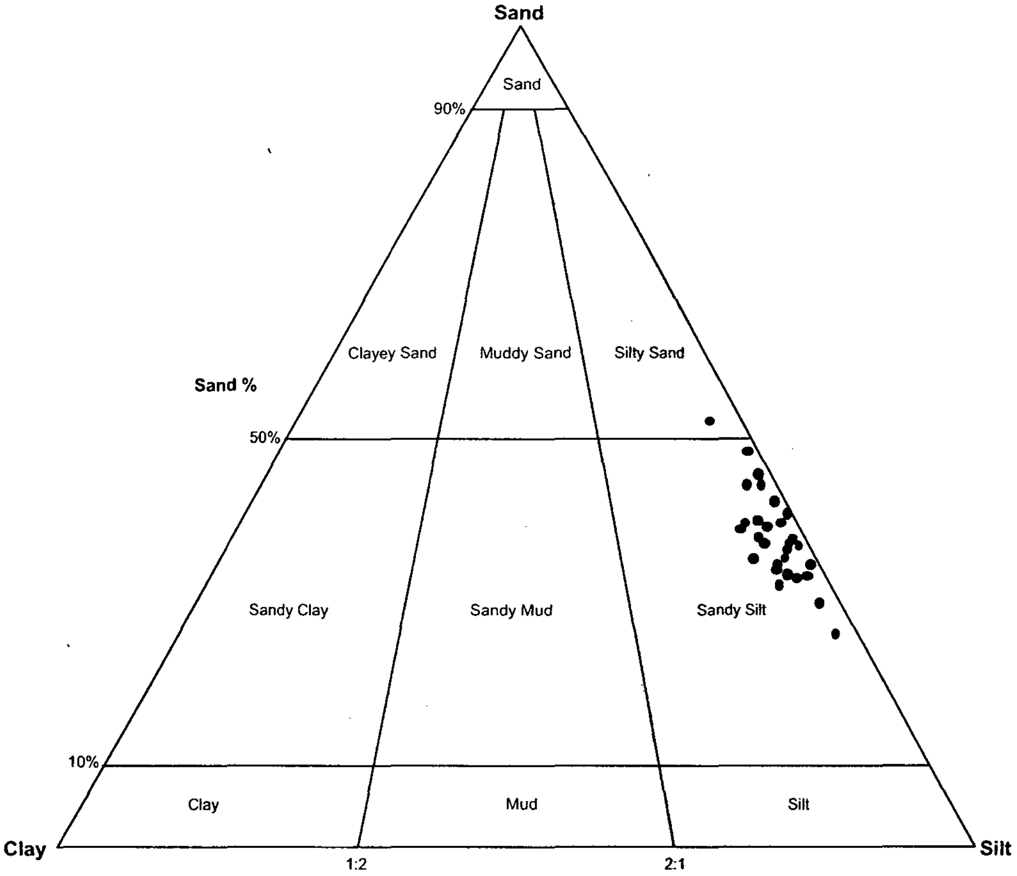

Fig. 4.1.Ternary Diagram of Sand-Silt-Clay for Delhi Ridge sediments

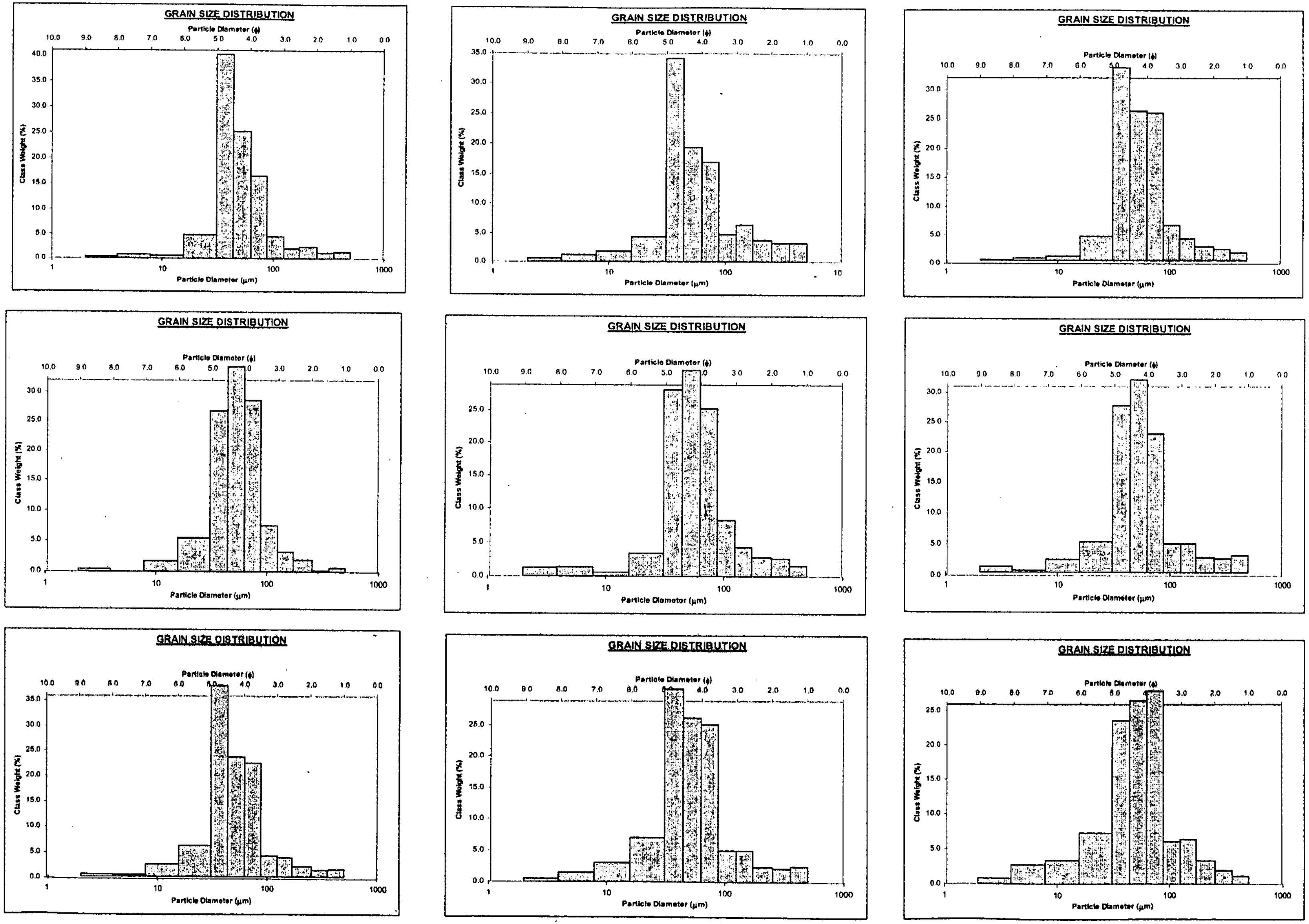

Fig.4.2. Grain size distribution of the Delhi Ridge sediments

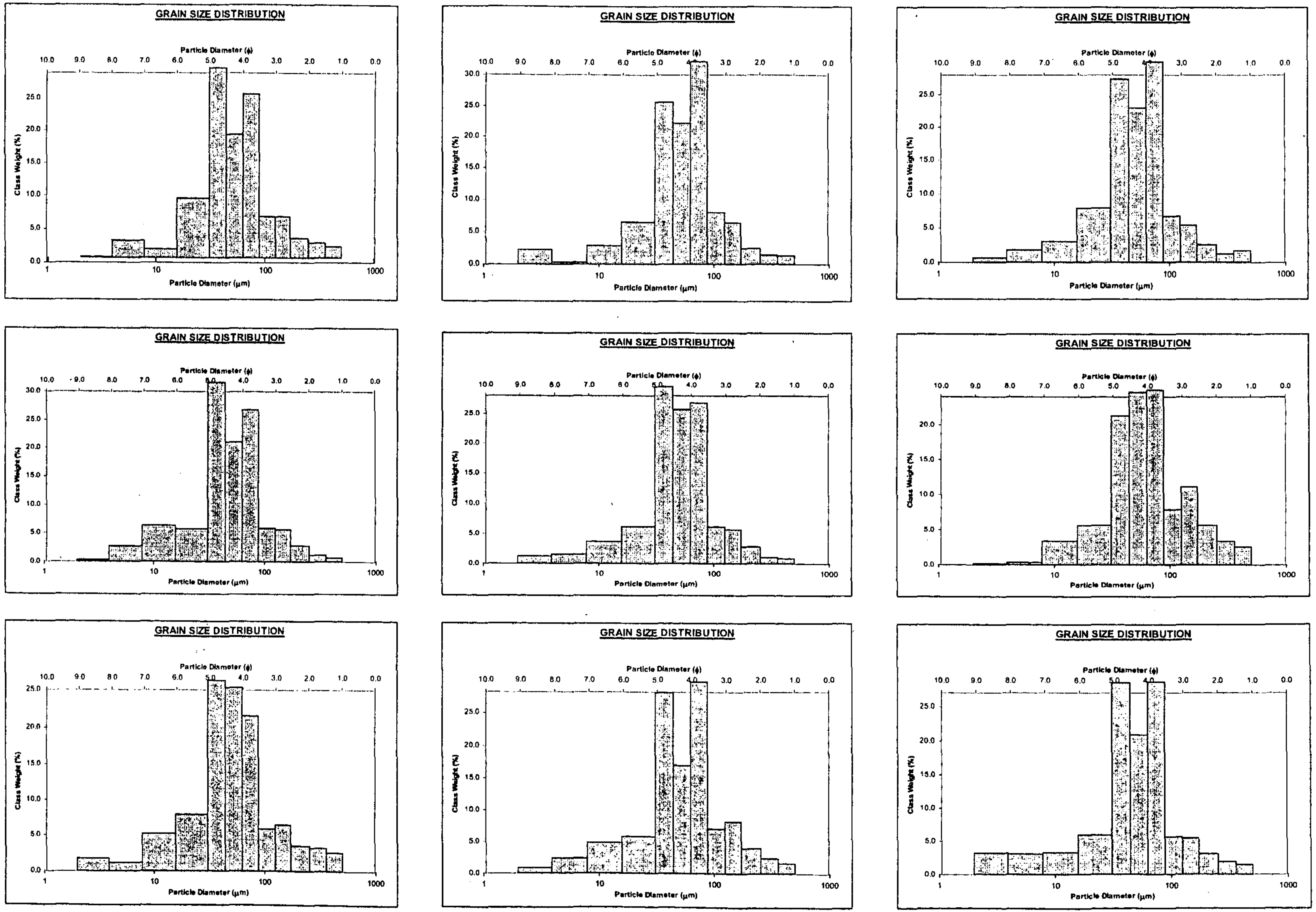

Fig.4.2. (Continued)

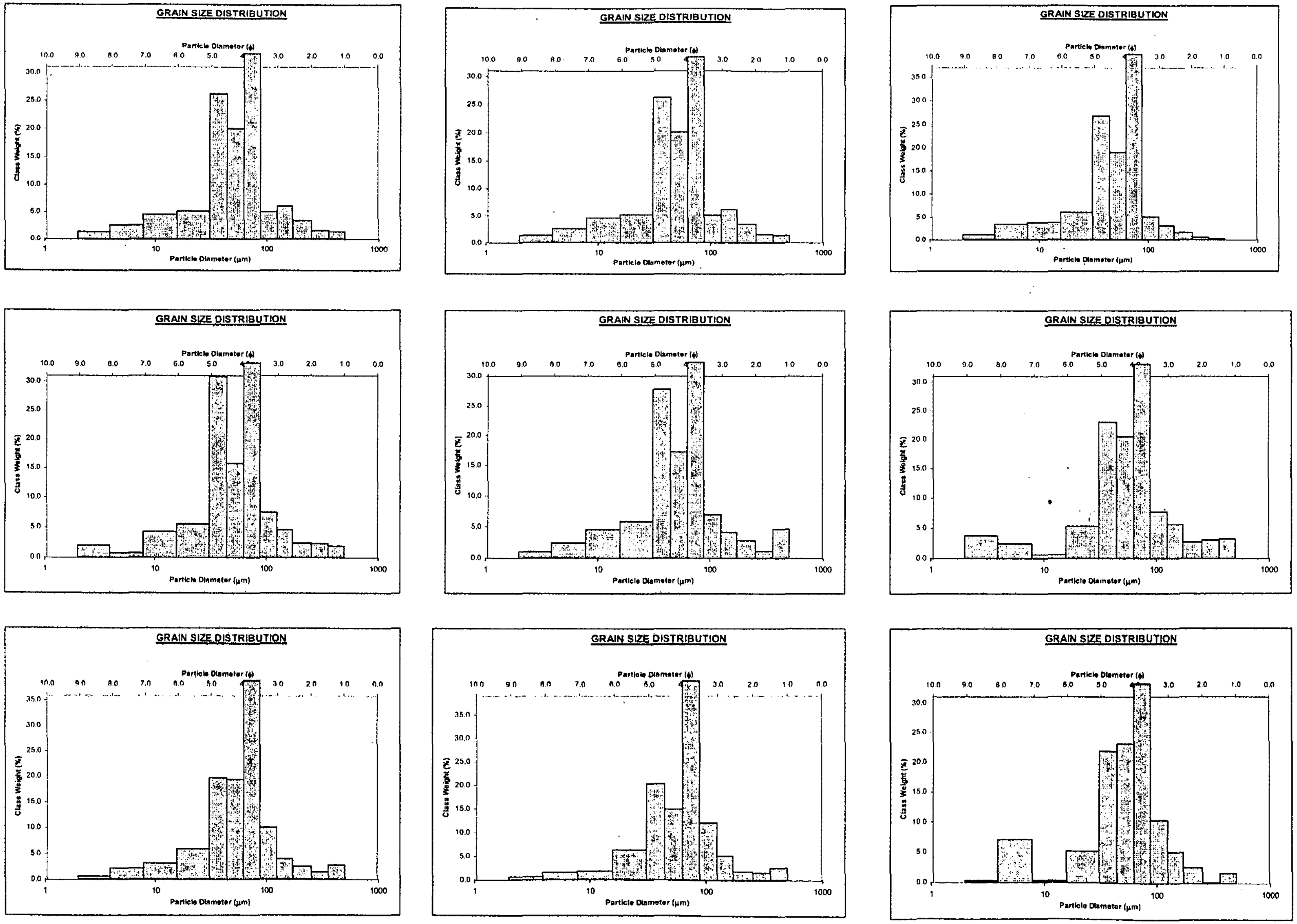

Fig.4.2. (Continued)

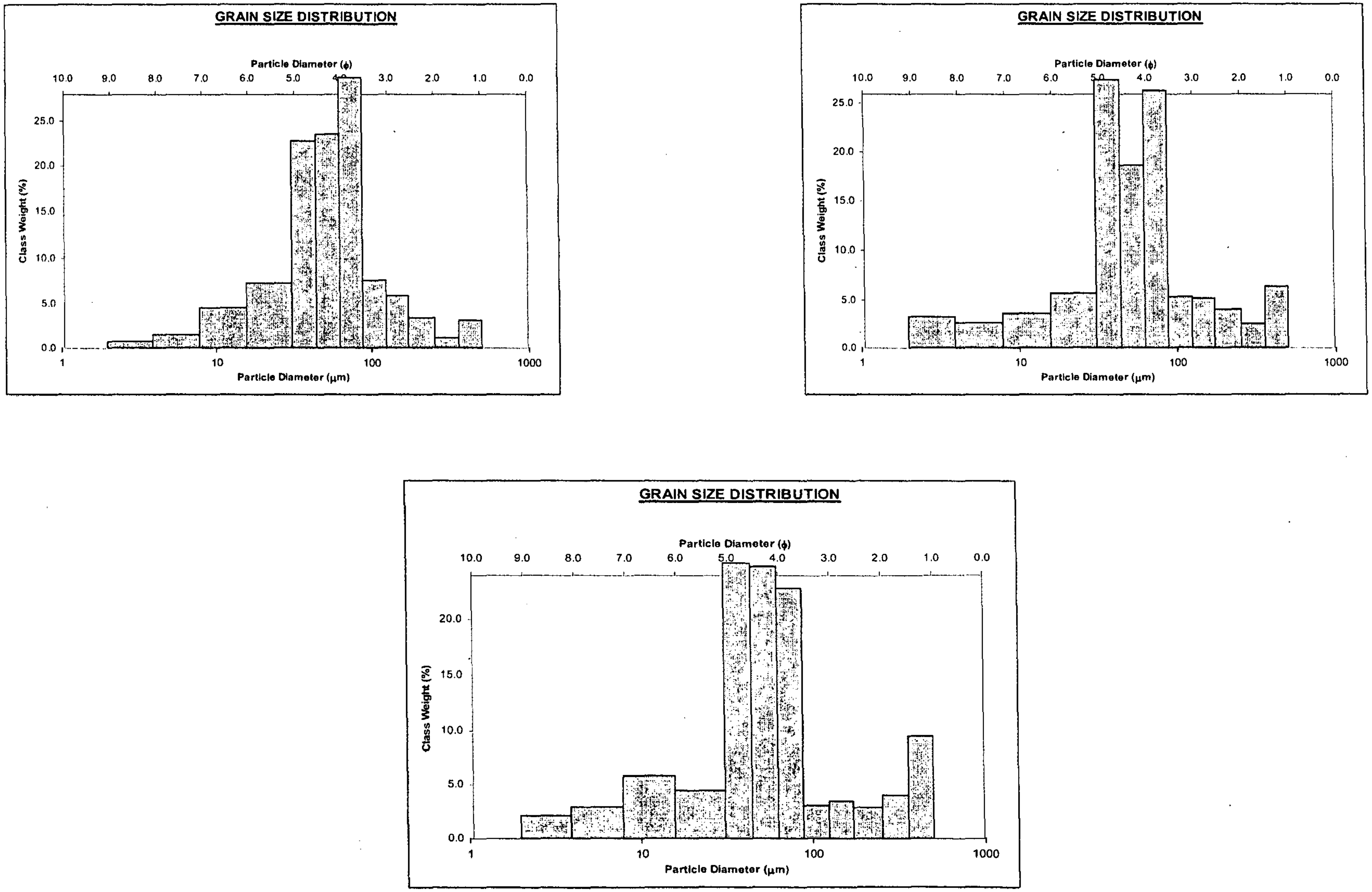

Fig.4.2. Grain size distribution of the Delhi Ridge sediments

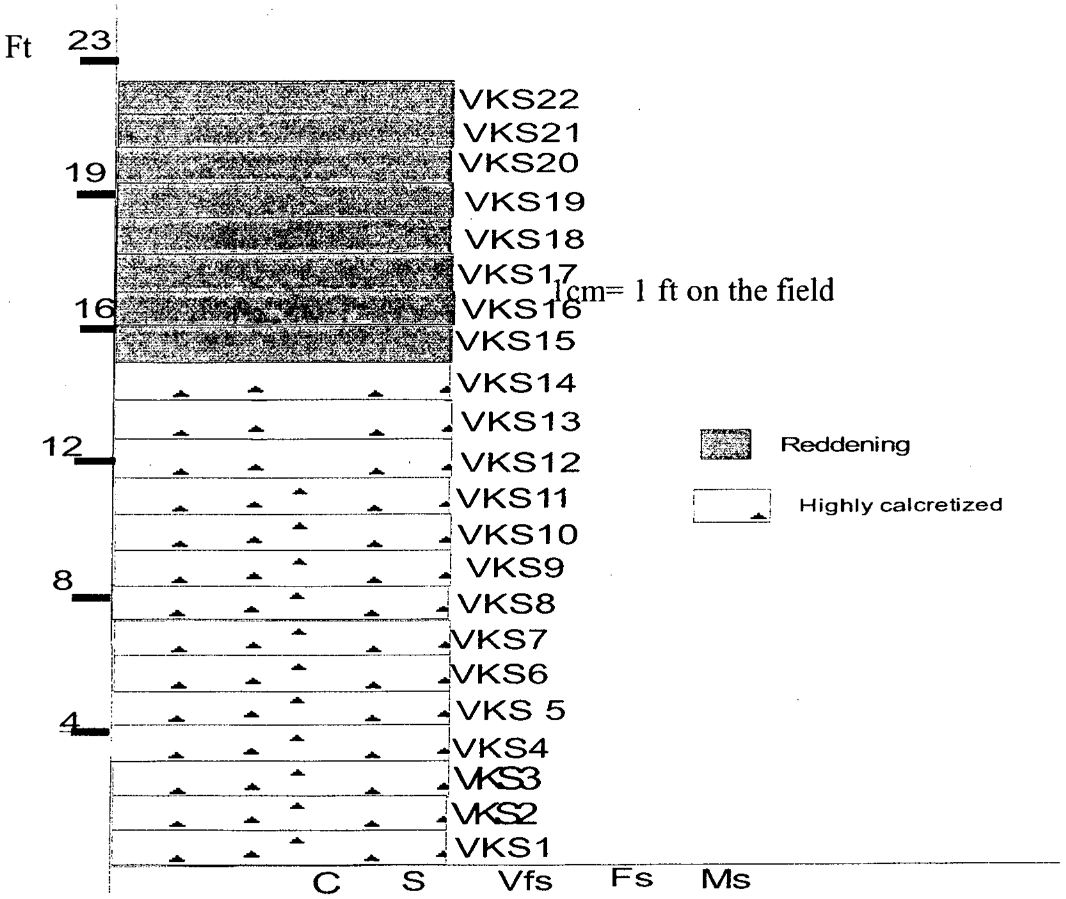

Fig. 4.3 (a). Litholog of West Wall

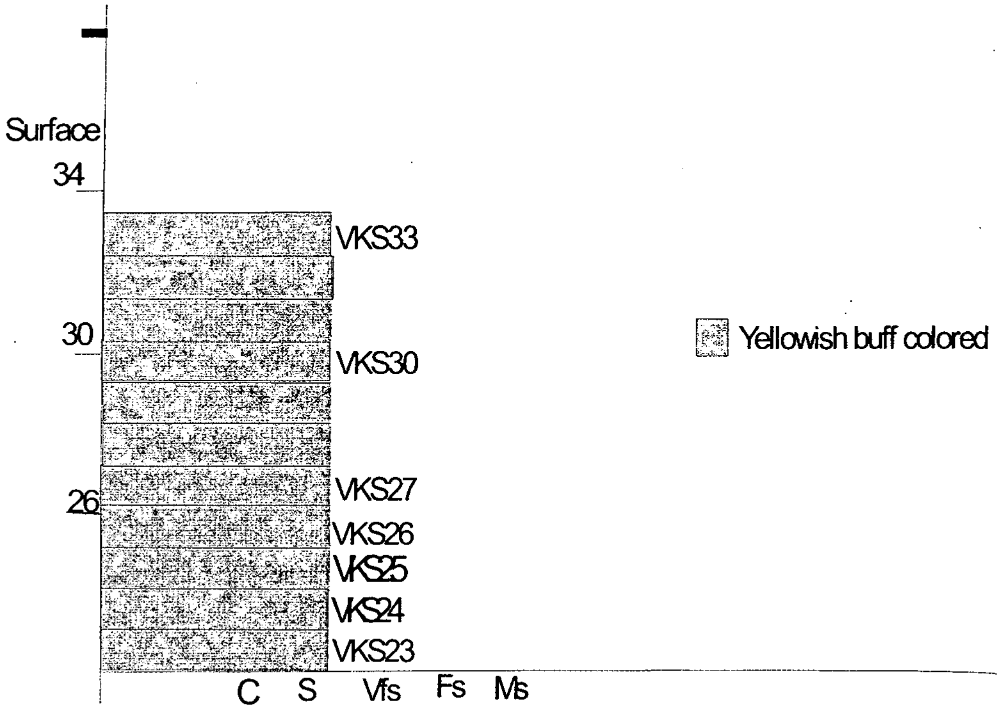

Fig. 4.3 (b) Litholog of South Wall

Mineralogy:

The average bulk of mineral composition of sediments estimated from XRD data shows that quartz is the dominant mineral in the sediments followed by feldspars (orthoclase), muscovite, biotite and chlorite. Sample No. VKS 5 and VKS 33 contain calcite along with the above mentioned minerals. Mineralogically all the sample have similar mineral composition and the sediments of Delhi ridge falls within the range indicated by Pye (1987) for loess sediments.

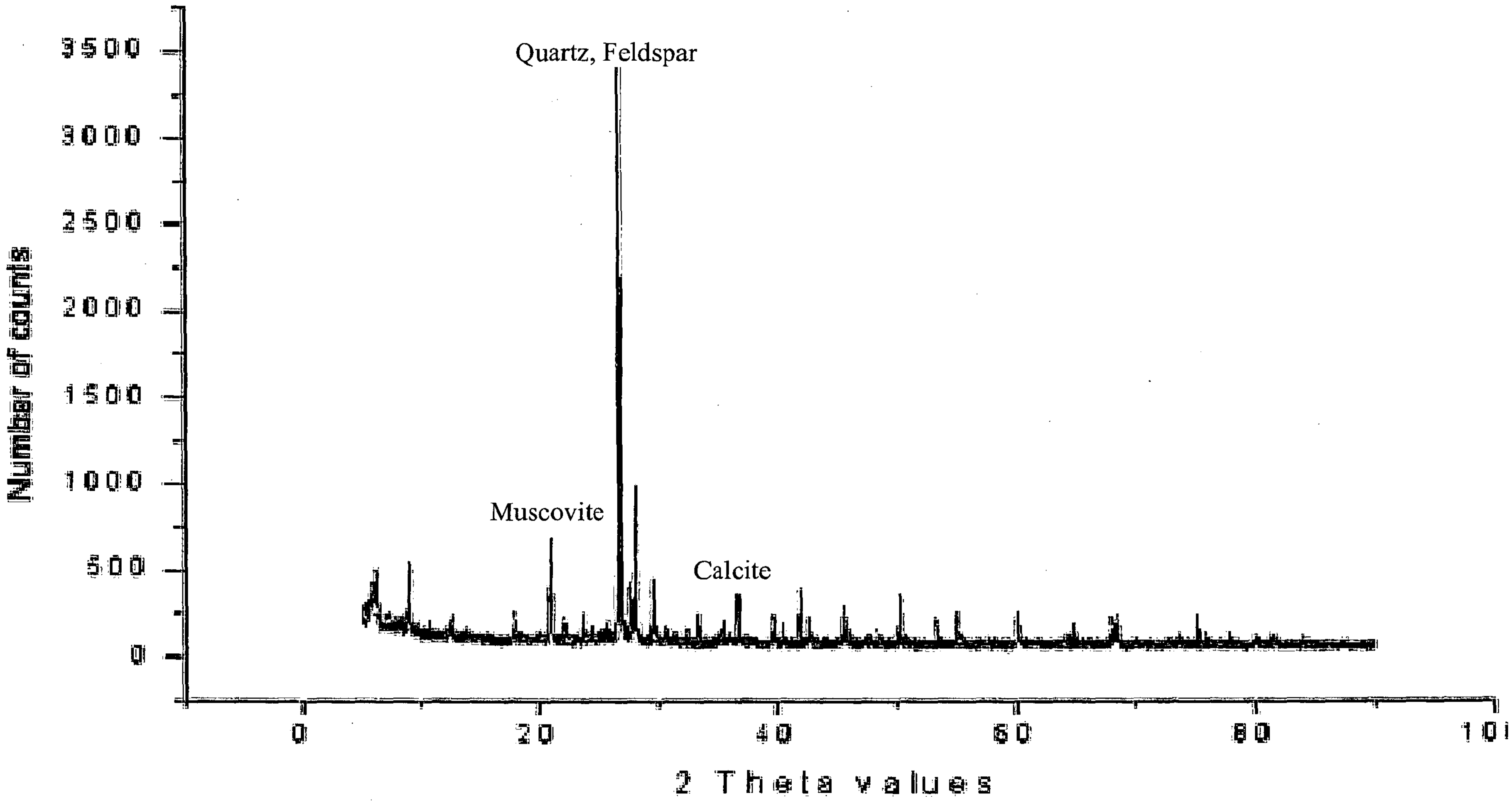

Fig 4.4. X-ray diffractogram of sediments from Delhi Ridge Area

Geochemistry

Geochemical studies of modern and ancient siliciclastic sediments for determining the provenance have been carried out extensively (McLennan et al. 1983:1992; Crischton and Condie, 1993; Van De Kamp and Leake, 1994; Graver and Scott 1995; Fedo et al. 1996; Winspear and Pye, 1996; Nesbitt et al., 1996; Holail and Moghazi, 1998; McCann, 1998; Di Leo et al., 1999; Singh and Rajamani, 2001). Chemical composition of sediments is a function of geological, climatic and biotic factors affecting the weathering of source rocks and their conversion to sediments and soils (Suttnet et al., 1981; McLennan, 1989; Berner, 1992; Johnson, 1993; Whitw and Blum, 1995; Nesbitt and Young, 1996; Millot et al., 1999; Liu et al., 1999; White et al., 1999; Sharma and Rajamani, 2001). The character and intensity of source rock weathering, physical sorting during transportation and sedimentary deposition and diagenesis exert important control on sediment geochemistry (Fralick and Kronberg, 1977; Taylor and McLennan, 1985; Nesbitt and Young, 1996; Honda and Shimizu, 1998). Tectonic activities exert significant primary controls on sediment geochemistry (Ingersoll, 1978; Dickinson and Villoni, 1980; Bhatia, 1983; Roser and Korch, 1988; Kasper-Zubillage et al., 1999).

Major element chemistry

The analytical data were recalculated on an anhydrous basis to 100 % (Table 4.2). The sample show high silica values (68.7% to 77.03%), attributed to the high quartz proportions. Among the major oxides only CaO (in bulk analysis) shows a large variation (0.98% to 8.06%) possibly due to the presence of variable amount of secondary carbonates.

To evaluate the nature of the sediments, their provenance and the chemical behaviour of various elements during the formation of the sediments, concentrations of various elements in the Delhi ridge sediments are plotted against those of average Upper Continental Crust (Taylor and McLennan 1985) (Figure 4.5). Concentrations of Al, Fe and K approach near equiline; those of Na and Calcium are slightly depleted and those for Si and Ti are enriched. High Silica over that of UCC possibly be due to

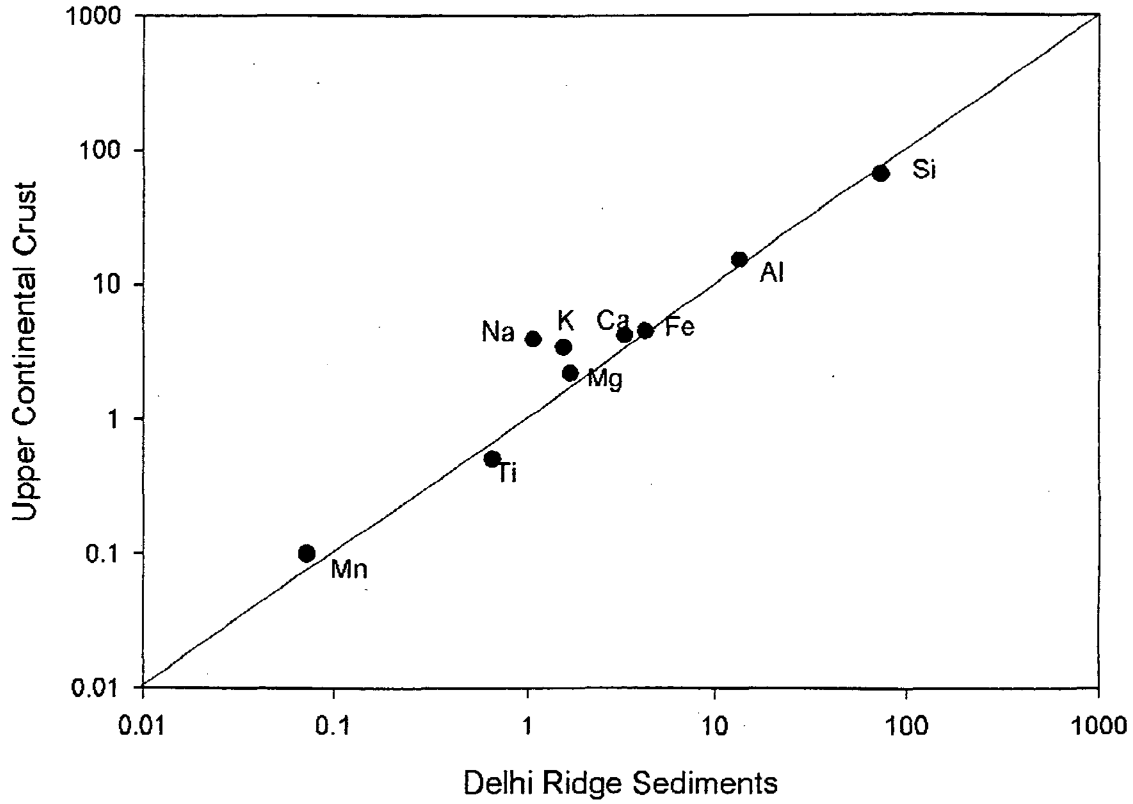

Fig.4.5. Comparison diagram of Delhi ridge sediments with upper continental crust

concentration of quartz in silt fraction and minor quartz addition from local quartzite. Excess Silica and carbonate in the sediment could have some diluting effect on all the elements. The chemistry of Delhi Ridge sediments is strikingly similar to that of average Upper Crust just as other loess deposits reported by Taylor et al. (1983).

To quantify the extent of weathering undergone in the rocks of the provenance area of the sediments CIA has been calculated for Delhi ridge sediments. Soils and sediments derived from intensively weathered rocks and containing residual minerals such as Kaolinite and/or Gibbsite have CIA value approaching to 100, and totally unweathered UCC has a CIA value of 50. CIA values for world loesses range from 55 to 70. Delhi ridge sediments have CIA values of 69±1.98 which is well below the CIA's of shale (70-75). The molar proportions of Al_2O_3, CaO + Na_2O and K_2O and Al_2O_3, CaO +Na_2O+ K_2O and FeO + MgO are plotted on triangular plots separately (Nesbitt and Young, 1984, 1989) (Figure 4.6a, 4.6b & 4.6c). The CIA values and plots of Delhi Ridge sediments onto the triangular diagram near rocks of UCC show that they were formed from a source which had suffered relatively a small extent of chemical weathering.

	VKS 1	VKS 2	VKS 3	VKS 4	VKS 5	VKS 6	VKS 7	VKS 8	VKS 9	VKS 10
SiO2	76.5	71.1	72.5	71.9	68.8	75.7	75.9	75.6	75.0	75.3
TiO2	0.6	0.6	0.6	0.5	0.5	0.6	0.6	0.6	0.7	0.6
Al2O3	13.2	14.0	12.9	12.1	13.3	12.9	14.0	13.5	12.3	12.9
FeO	3.9	4.7	4.8	4.7	5.3	4.1	3.7	4.7	4.8	4.4
MgO	1.7	1.7	1.5	1.6	1.6	1.8	1.7	1.8	1.8	1.8
MnO	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
CaO	1.3	5.4	5.2	6.5	7.8	1.8	1.4	1.1	2.8	2.3
Na2O	1.2	1.1	1.1	1.2	1.2	1.1	1.1	1.1	1.0	1.1
K2O	1.6	1.4	1.4	1.5	1.4	1.7	1.5	1.6	1.4	1.6
CIA	70.67	72.89	71.09	69.05	71.16	69.92	72.61	71.49	71.06	70.84

	VKS 11	VKS 12	VKS 13	VKS 14	VKS 15	VKS 16	VKS 17	VKS 18	VKS 19	VKS 20
SiO2	73.9	72.3	75.8	75.3	75.1	73.4	74.1	73.7	73.7	75.4
TiO2	12.8	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Al2O3	3.4	13.8	12.6	14.1	13.9	14.5	14.7	13.0	13.6	14.1
FeO	1.5	3.8	3.8	3.9	4.1	3.9	3.7	3.8	3.9	3.9
MgO	0.1	1.6	1.7	1.7	1.8	1.7	1.4	1.6	1.6	1.6
MnO	5.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
CaO	1.0	5.3	2.8	1.7	1.7	3.3	2.8	4.8	4.0	2.0
Na2O	1.8	1.1	1.1	1.1	1.1	1.1	1.1	1.0	1.0	0.9
K2O	0.6	1.4	1.5	1.5	1.6	1.5	1.5	1.4	1.5	1.5
CIA	71.22	73.24	70.90	73.30	72.25	73.62	73.94	73.31	74.00	75.42

	VKS 21	VKS 22	VKS 22 B	VKS 23	VKS 24	VKS 25	VKS 26	VKS 27	VKS 30	VKS 33
SiO2	68.8	73.5	74.3	77.0	76.3	75.8	76.1	73.5	73.4	69.0
TiO2	1.1	0.7	0.7	0.6	0.7	0.7	0.7	0.7	0.7	0.5
Al2O3	13.8	14.6	14.0	11.6	13.6	14.0	13.0	13.2	13.0	11.4
FeO	6.5	4.3	4.1	3.9	3.9	3.9	4.0	4.4	4.3	3.3
MgO	2.6	1.5	1.6	1.5	1.4	1.5	1.6	1.8	1.7	1.3
MnO	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
CaO	3.5	2.9	3.0	3.0	1.6	1.7	1.9	3.6	4.3	8.1
Na2O	1.2	1.0	0.9	0.9	1.0	1.0	1.1	1.2	1.0	0.9
K2O	2.4	1.5	1.5	1.4	1.5	1.5	1.5	1.5	1.5	5.3
CIA	67.71	74.90	76.00	72.49	74.02	74.14	70.82	70.65	72.66	56.26

Table 4.2. Major element chemistry of Delhi Ridge sediments

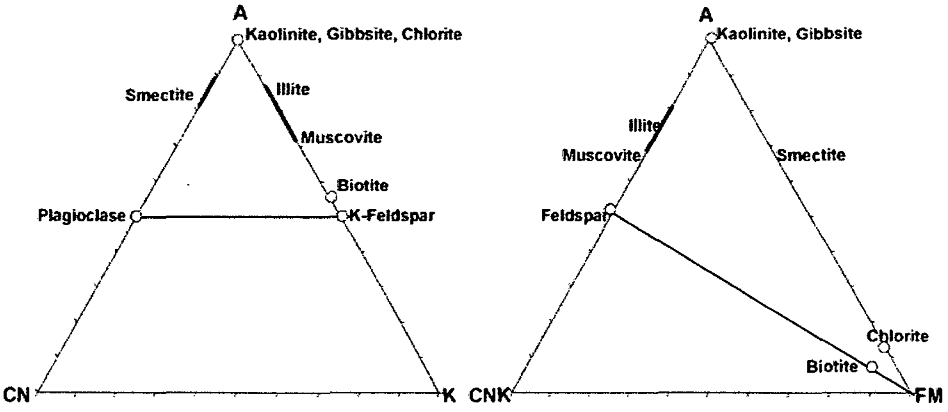

Fig. 4.6a Plots of different primary silicate minerals and their weathering product minerals in the A-CN-K and A-CNK-FM diagrams.

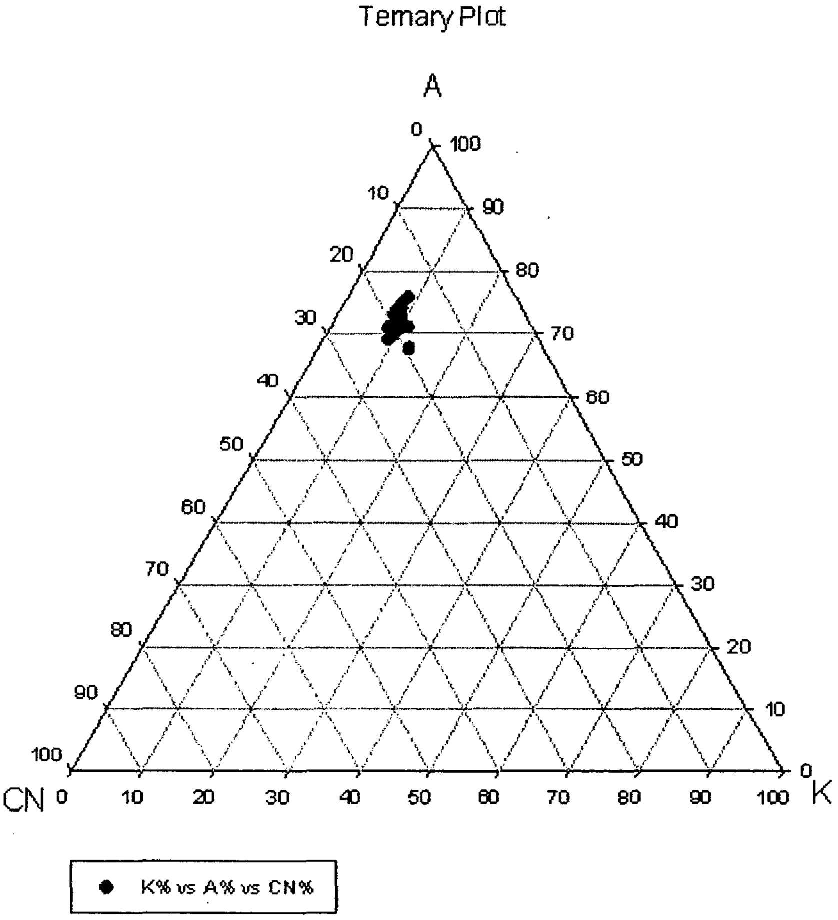

Fig.4.6b. Temary plot of A-CN-K (molar proportions) of the analysed samples of Delhi Ridge Area

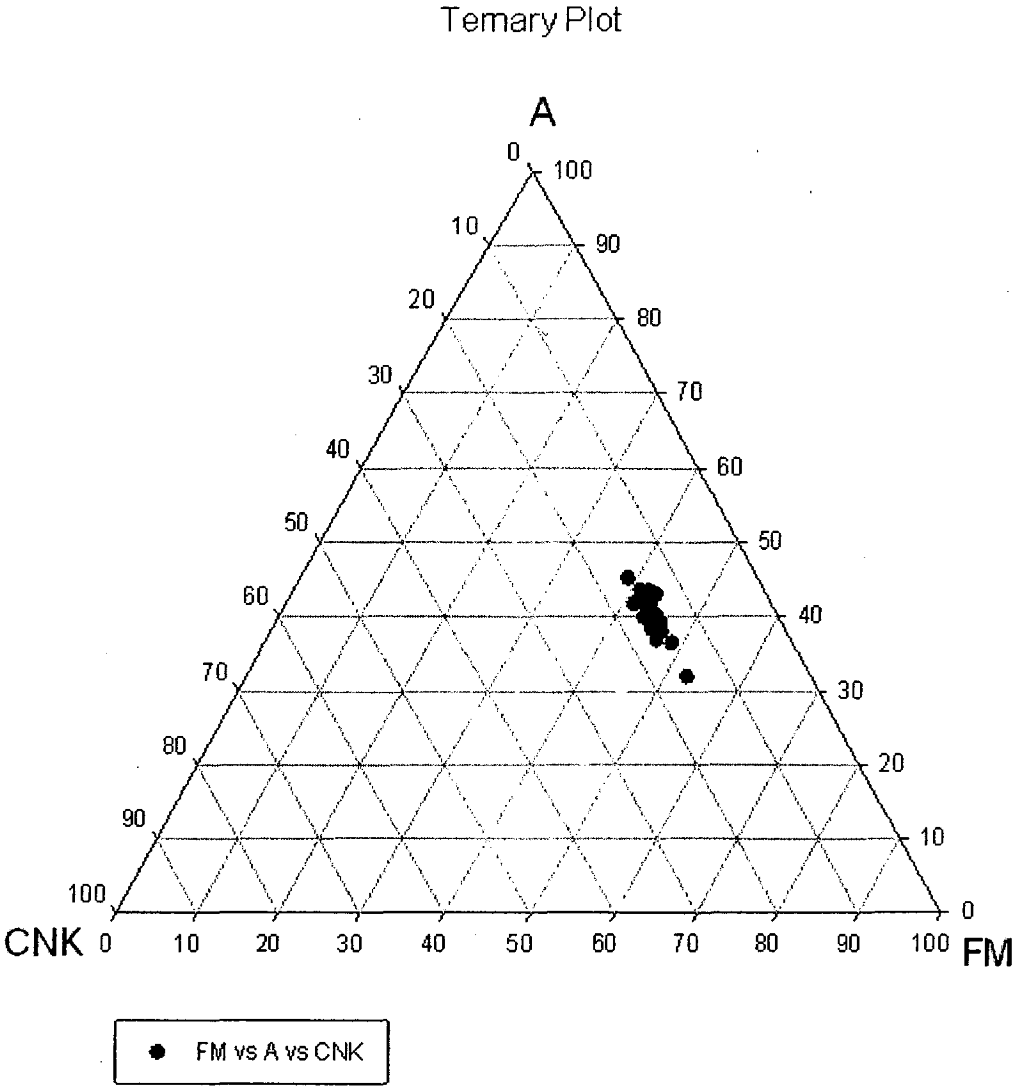

Fig.4.6c. Ternary plot of A-CNK-FM (molar proportions) of the analysed samples of Delhi Ridge Area

DISCUSSION:

In texture, mineralogy and chemistry Delhi ridge sediments are similar to loess deposits (Taylor et al. 1983; Pye 1987). Delhi ridge sediments have high silica which is a characteristic feature of loesses (Taylor et al 1983). Similarly reduction of grain size of quartz to silt range from common felsic igneous rocks requires grinding of the rocks or a very long transport, so the presence of higher proportions of silt size quartz in the sediments but with a composition similar to that of UCC would require source consisting of mechanically ground rocks. Movement of glaciers is the most effective way of producing rock flour for subsequent sedimentary redistribution processes.

In the A-CNK-FM diagram the Delhi ridge sediments samples fall within the region of least to moderately weathering stage. Geochemically the Delhi ridge sediments are very similar to average UCC (Figure 4.7). from the geochemical data and from its uniformity in the whole profile studied we could infer (1) aeolian processes seem to be effective in homogenizing sediment composition internally and in the process making the sediments compositionally similar to that of the exposed upper crustal rocks, (2) a large sampling area must have been available for selective sampling of silt fraction by the winds, (3) the sampling area must have had mechanically ground up rocks, (4) neither the sediments nor the source sediments/rocks had undergone extensive chemical weathering.

The physico-chemical nature of Delhi ridge sediments and the inferred sedimentary processes involved in their generation seem to suggest a possible genetic connection between the sediment formation, Himalayan orogeny and Pleistocene glaciation. Such a connection between loess forming processes and Pleistocene glaciation in the young orogenic region have been suggested by Taylor et al (1983). The major phase of Himalayan uplift is thought to be 1.7-1.6 my ago (Valdia, 1996). The Pleistocene glaciation in the Himalayan Mountains must have produced vast alluvial outwash plains possibly by now extinct Himalayan rivers (Misra,1995,Kar,1995). This rock flour of the outwash plain could potentially constitute the sampling area for loess forming processes.

The sediment profiles in Delhi area include hard concrete nodules which appear to be similar to the calcretes present in the late Pleistocene sandy plains of the Thar Desert (Dhir, 1995; H.Achyuthan, press.comm, 1996). If the calcrete nodules in the sandy plains of Thar desert and that in the Delhi ridge sediments were formed contemporaneously then it raises the interesting possibility of a genetic link between the sandy plains of Thar and the silty cation rich loess sediments of Delhi and other areas. If the aeolian processes selectively sampled silt sized particles from the rock flour of glacial outwash plains, it would leave behind infertile sandy residue. The loess forming processes associated with the Himalayan orogeny and the Pleistocene glaciation in the process of redistributing the rock flour of glacial outwash plains could have caused a geochemical differentiation. This resulted in the build up of fertile agricultural land in the leeward direction of the wind (Westerly to South westerly) and infertile sandy desert in the source area. The importance of this loess forming process in the desertification of Thar Desert needs a detailed study.

Mode of deposition:

In his classic paper Richthofen (1988) discussed that whenever the dust is carried away by wind from a dry place and deposited on a spot which is covered by vegetation, it finds a resting place, and may be washed off and carried further away by the next rain, if the ground is sloping, or it may be joined to the soil if the ground is flat or slightly inclined. If these depositions are repeated, the soil will gradually grow. In the region where the rains are equally distributed through out the years, little dust is formed and the rate of growth of the soil covered with vegetation will be exceedingly small. But the dry season alternate with rainy season, the amount of dust which is put in motion is distributed through the atmospheric agency can reach enormous proportions as seen by the dust storms. When this dust falls on barren ground, it is carried away by the next wind, but when it falls on vegetation, its migration is stopped

Frequent dust storms are encountered in the Thar Desert and its peripheral region. Dust storms are often accompanied by thunderstorms (dry and wet). The annual number of thunderstorm is about ten over western Rajasthan and increases to about 4040 over east Rajasthan (Sikka, 1997). Generally the winds near the surface have westerly component during major part of the year. They are stronger over the western Rajasthan than over the eastern Rajasthan. Strong winds raise dust from loose sandy soils of the region and the dust is transported eastward over the peripheral region (Sikka, 1997; Naegamvala, 1971; Siddhu, 1977). It has been reported that Gurgaon and Mahendragarh districts of Haryana occurring in the southwest of Delhi are severely affected by wind erosion (Chibbar, 1985).

Dust from the Southeast region of Delhi is mainly transported in the form of silt and clay size particles in suspension. Pye and Tsoar (1987) suggested that silt particles larger than 50 micrometer are unlikely to be transported more than 60 km from source and most will be deposited about 30km; particles corresponding to the typical model size of loess (20-30micrometer) are likely to be transported thousand of kms. Deposition of these suspended dusts occurs if (1) there is a reduction in wind velocity (2) the particles are washed out in rains or (3) the particles are trapped by surface roughness elements (Tsoar & Pye, 1987).

The decreasing wind velocity towards the semi-arid region of Delhi must be important to the dust deposition. The entrapped dust on the rugged surface of the ridge and thin vegetation (Mitra, 1990) are washed down into the small valleys by the monsoon rains which occur subsequent to dusty summers (March to June). These deposits occurring as pockets in the small valleys on Delhi ridge could not achieve great thickness as of the other loess deposits of the world (e.g. Chinese). It could be due to its association with arid deserts of Holocene origin (Bowler, 1978), whereas the source sediments of these deposits are Pleistocene glacio-fluvial in origin.

Environmental impact of dust deposition:

Elements such as Ca, Mg, K are essential nutrients for plants. It has been found that their levels in soils of forest of the world have dropped (Hedin and Liken, 1996). Hedin and liken suggested similar losses in the other regions and declined in forest is due to the precipitous loss of the base cations. It has been found that this is because they do not receive enough base cations from the atmosphere. It can be suggested that the dust supply in the north western India would have played an important role in maintaining the soil fertility by replenishing the base cations in the agricultural lands, which has been extensively cultivated at least since the decline of Harrapan Civilization. Thus the present day dust storms must be creating a great loss to the desertifying regions of Rajasthan and Haryana but simultaneously it is a gift to the region occupying the periphery of the Thar Desert. The loss of fertile soil has been a major cause of decline of Harrapan culture from the Thar region (Mishra, 1995). Probably the silt and clays of fertile land have been eroded away by the desert forming processes and deposited in the peripheral region.

Dust particles may serve one another important role by neutralizing acid rains. Delhi has been a highly polluted city and fossil fuel burning produces a SO_2 and NO_2. This causes acid rain in the region, but in the air, dust particles can neutralize acid rains. Neutralization in the atmosphere takes place as dust particles dissolve into acidic cloud – water droplets or combine directly with acidic gases (Hedin and Likens, 1996). Saxena et al. (1996) also reported that the alkaline nature of rain water over Agra city,also occurring in the adjacent part of Thar desert, is due to its acidity being neutralized by soil components. In addition to lowering the acidity of precipitation, base cations of the dust also neutralizes the acid once they reach the ground, although the chemistry is a bit different than in atmosphere (Likens et al, 1996). Small particles of clay and humus in soil bear a negative charge and thus attract positively charged cations and as a result soil contain a natural store of basic cations. As acidic rain water drains into the ground the base cations give up their places to the positively charged hydrogen ions. As long as the soil has an abundance supply of base cations, this buffering effect, known as cation exchange protects the vegetation and soil from the harmful effects of acidic ions.

Thus the dust storms in Delhi region are beneficial in two ways: (1) it replenishes the agricultural land in base cations (2) it neutralizes acid rain as well as acid soils of the region.

Conclusion

CHAPTER V

CONCLUSION

Quartzite ridges in the Delhi region include in their local depressions thick pile of unconsolidated, unhorizonated yellowish brown sediments. These Delhi ridge sediments have textural, mineralogical and geochemical characteristics similar to those of loess sediments. The chemical index of alteration, calculated from the carbonate free basis chemical data after Nesbitt and Young, (1984, 1989) and other chemical parameters suggest a provenance of chemically least weathered ground up rocks. The last phase of upliftment of the Himalayas, accompanied by Pleistocene glaciation could have provided a vast plain of glacial outwash deposits and the prevailing aeolian processes seem to have selectively transported fertile silt materials leaving behind infertile desert sands.

Based on the above observation we suggest that (1) sediments in Delhi ridge have all the characteristics of loess deposits, (2) its formation requires an initial stage of chemically least weathered ground rock flour and a second stage of selective physical sorting by wind, (3) physical sorting has lead to a high degree of chemical homogenization although the mechanism of this processes is not adequately understood, (4) the loess forming processes is likely to be related to Pleistocene Himalayan orogeny and glaciation, (5) the loess forming process possibly could have lead to augmenting the fertility of alluvial soils of lee-side of the Thar Desert, (6) at present, the dust supply to Delhi, one of the most polluted city of the world, must be important for the acid rain neutralization.

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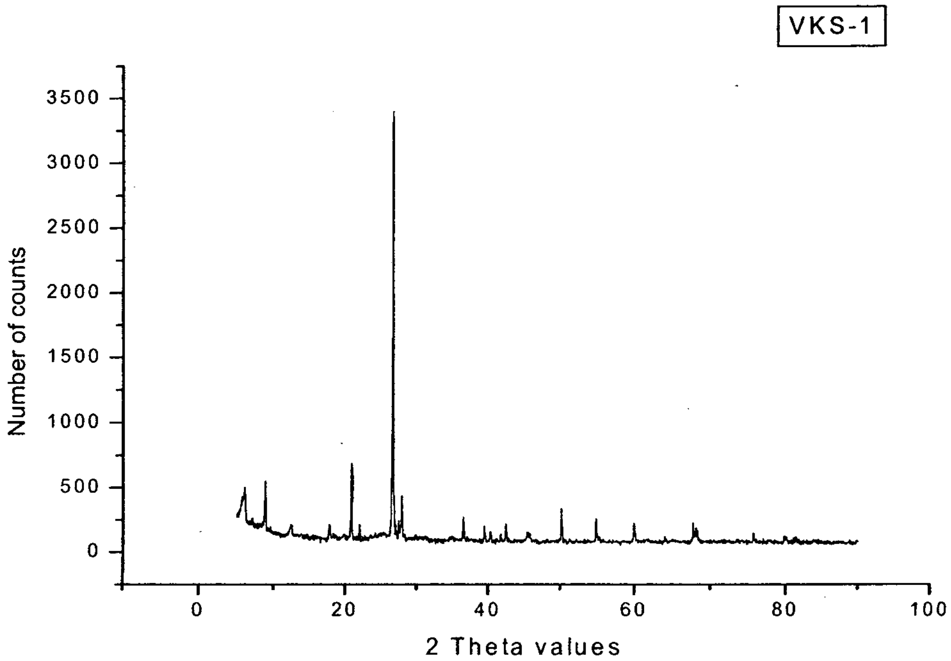
Appendix

APPENDIX I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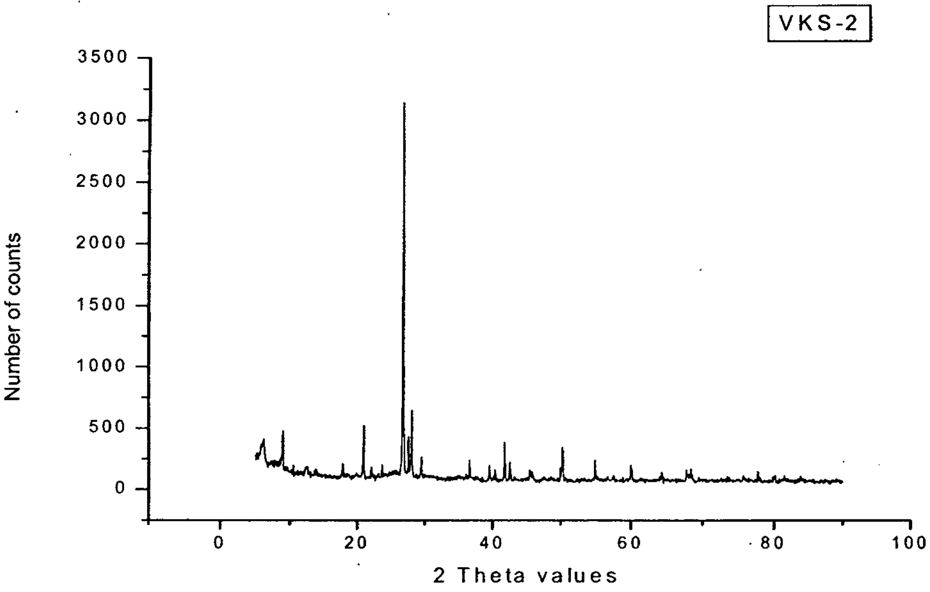
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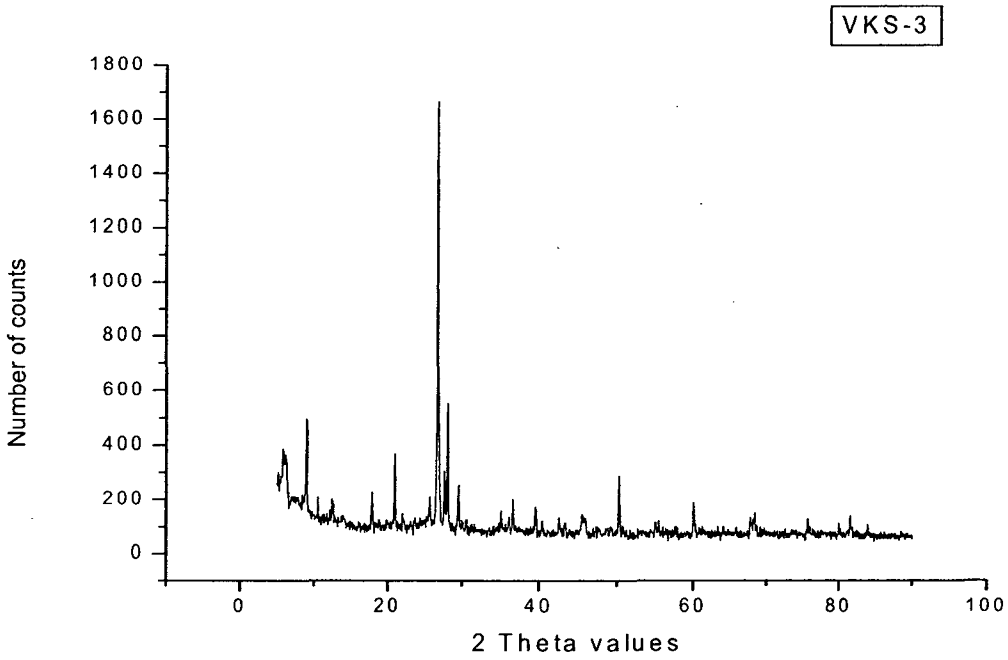
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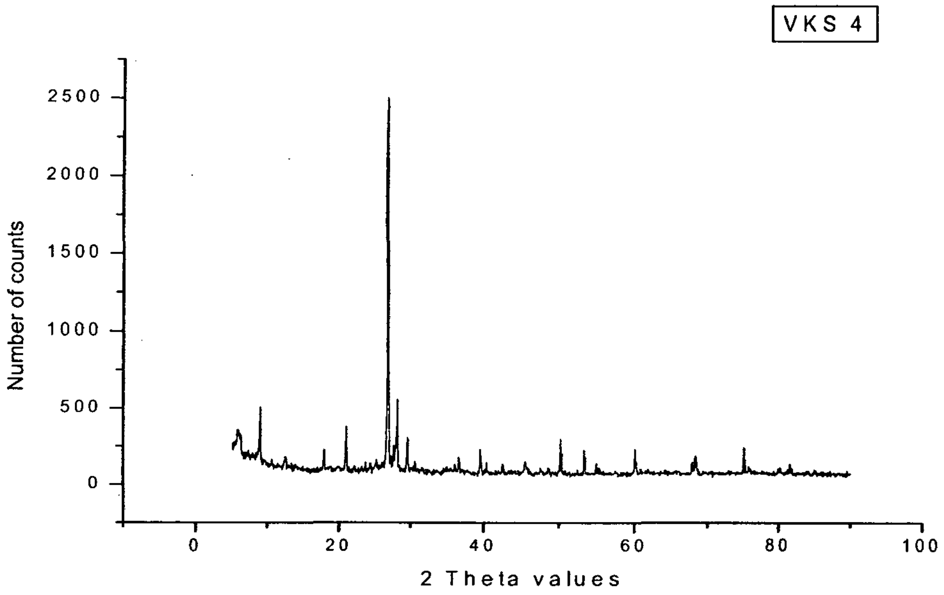
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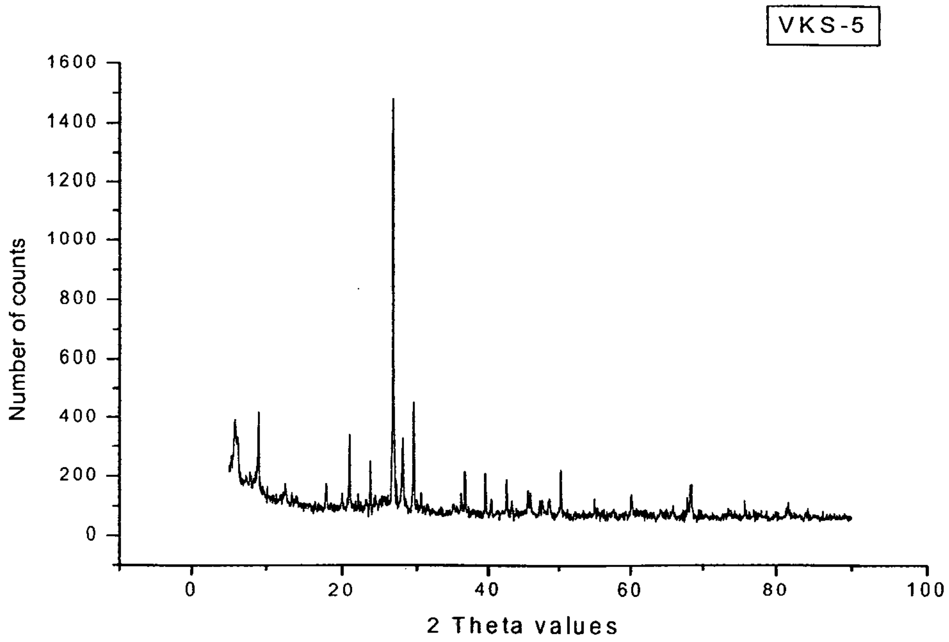
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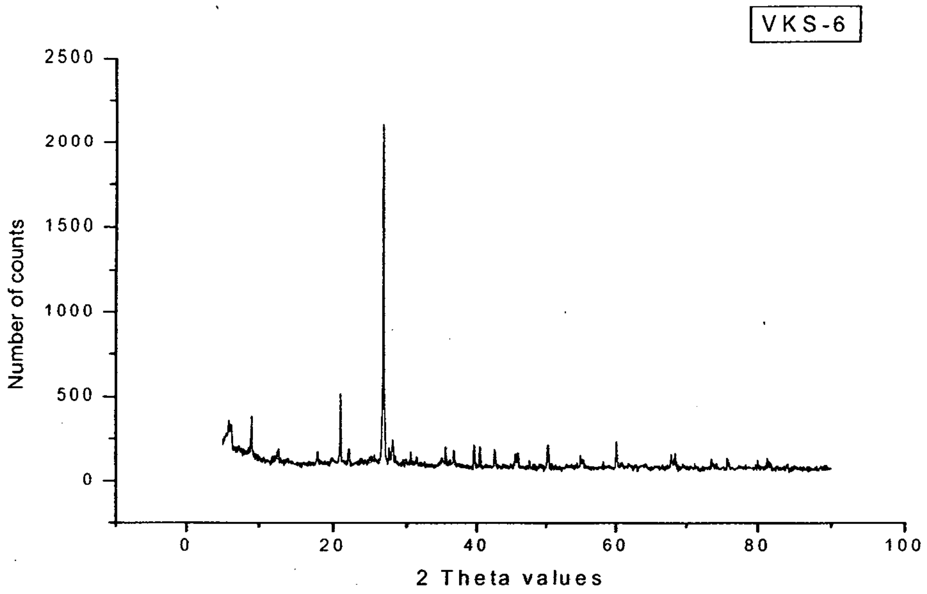
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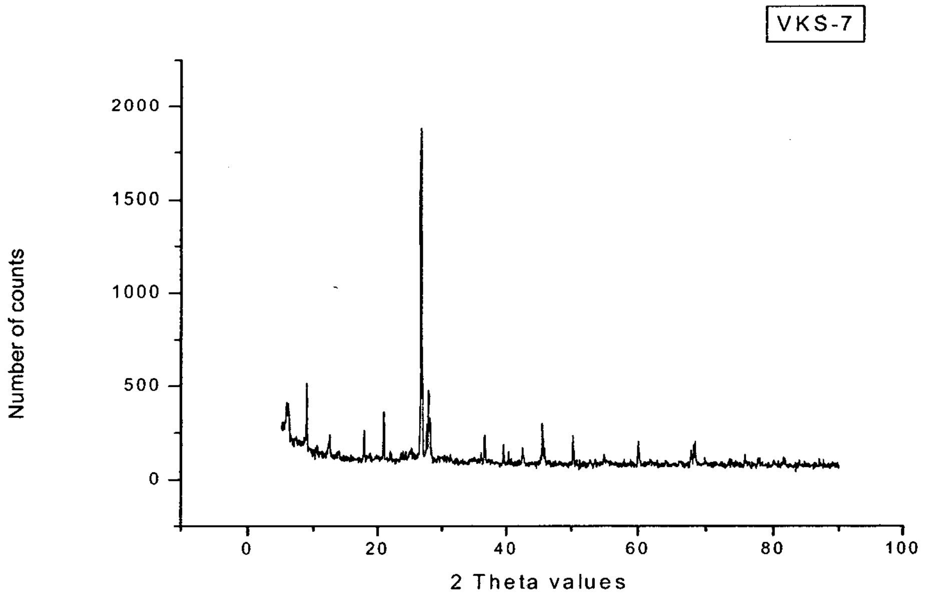
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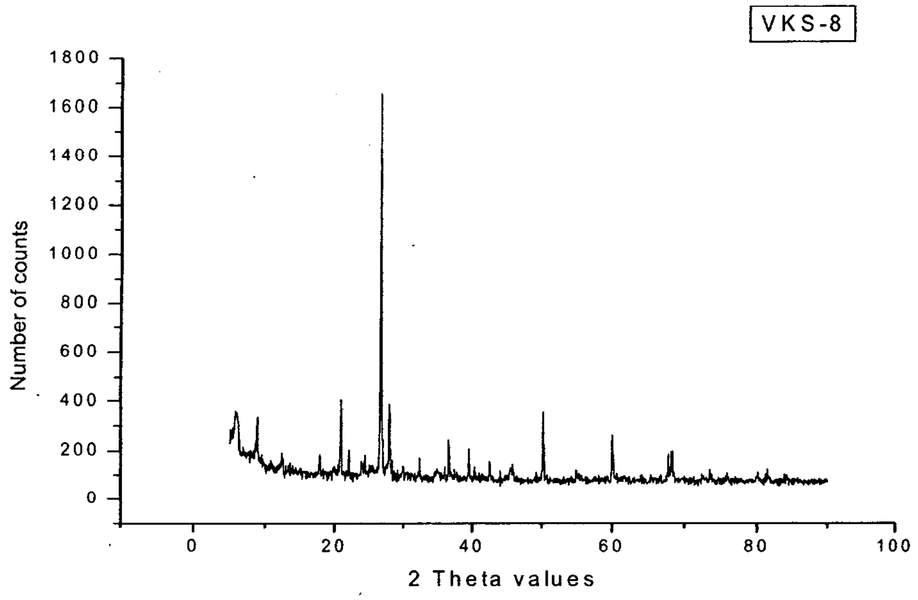
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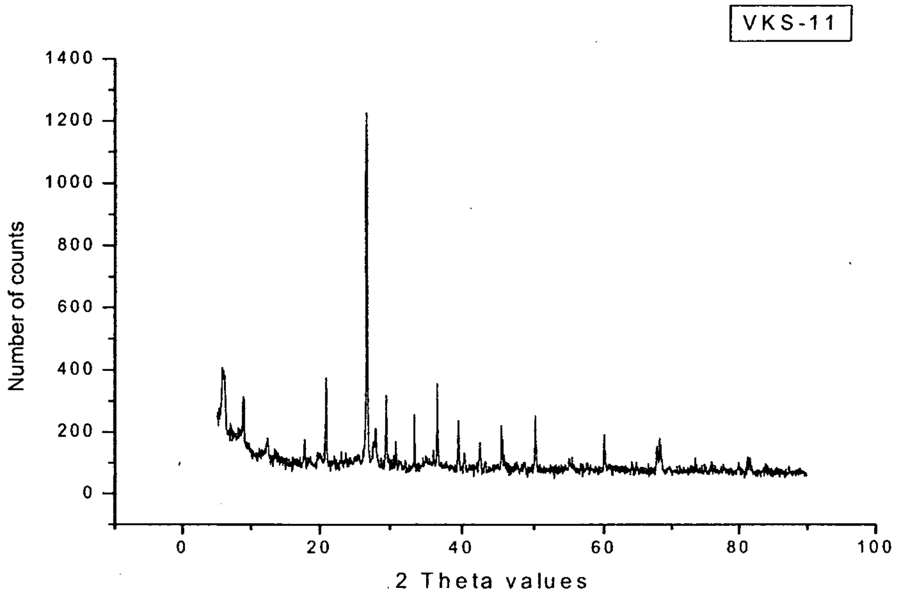
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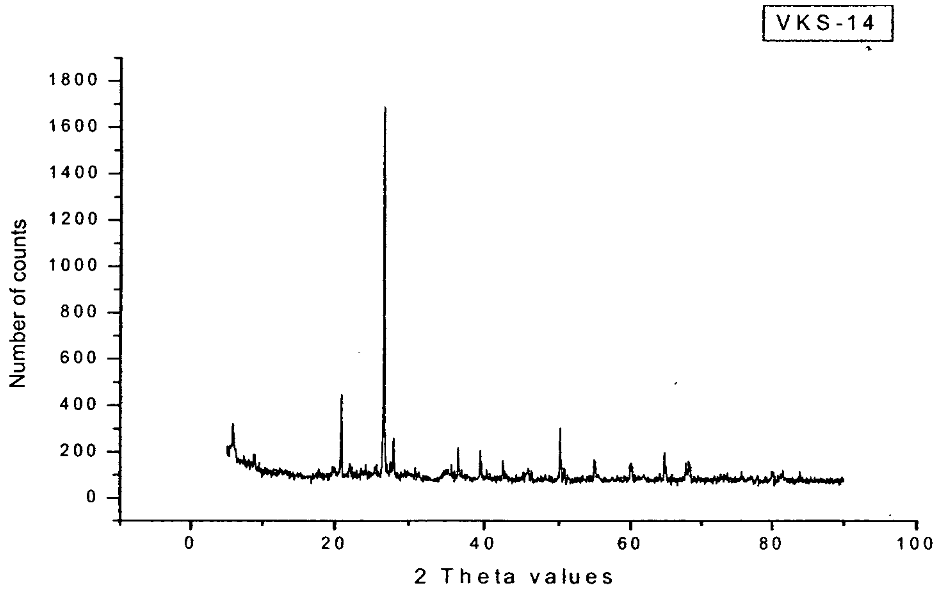
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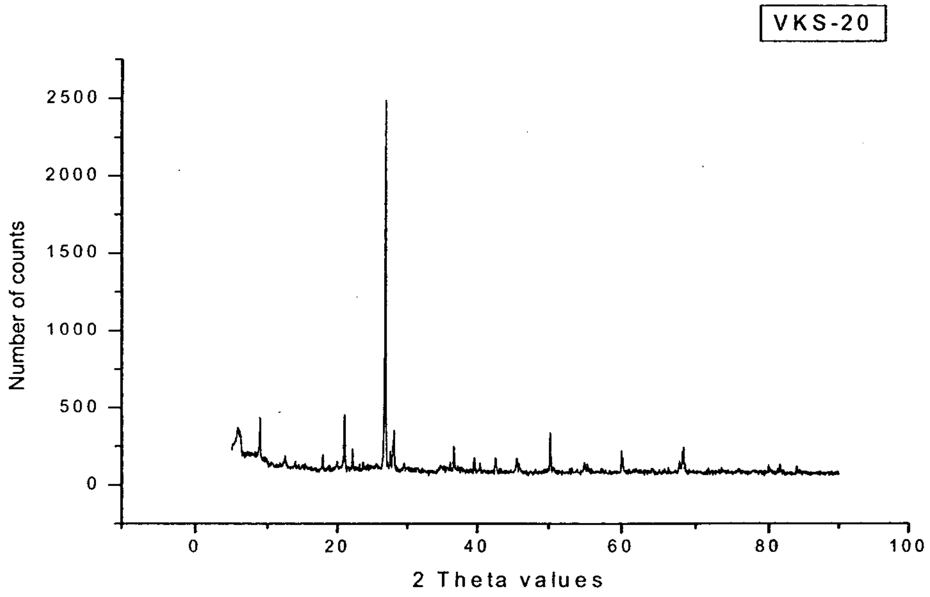
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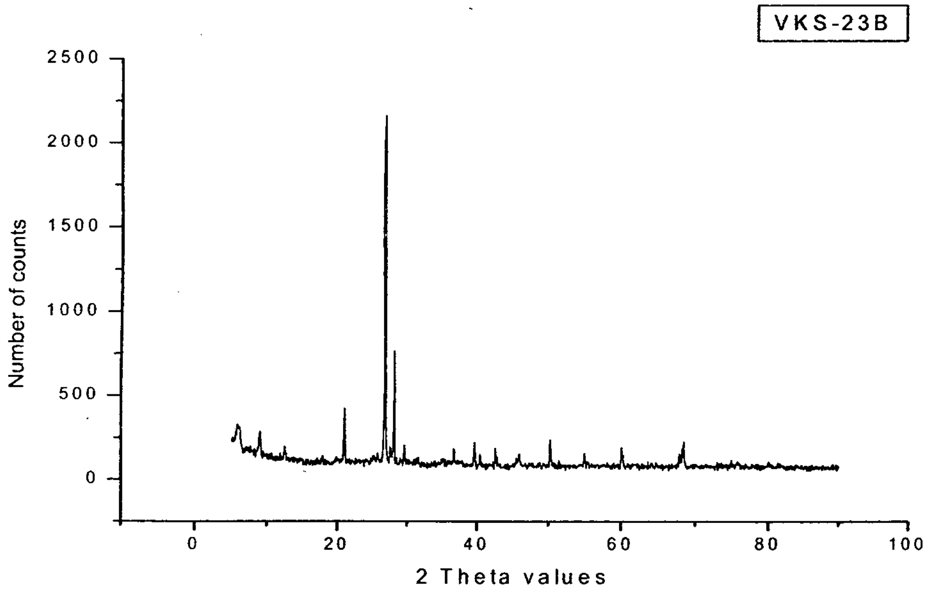
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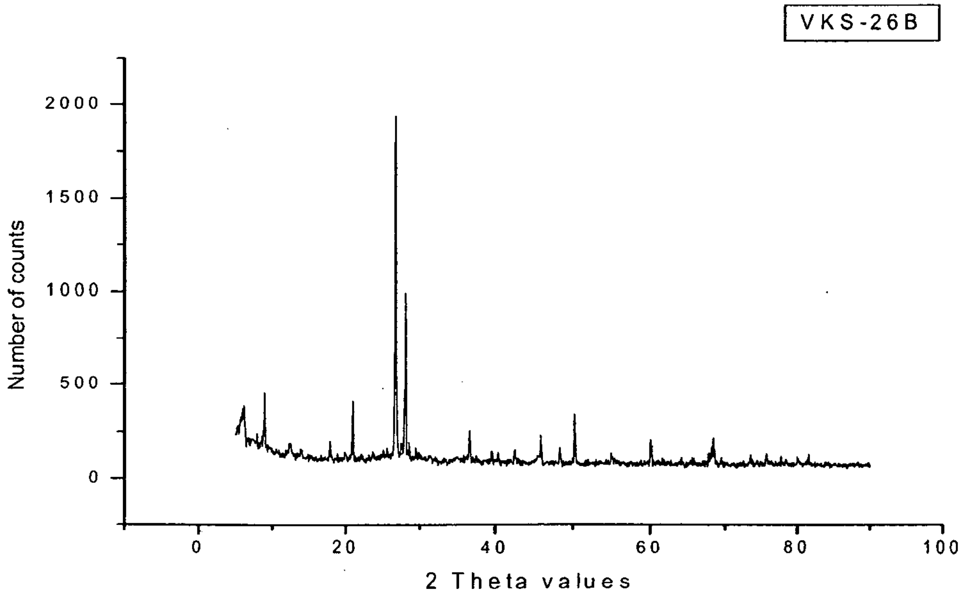
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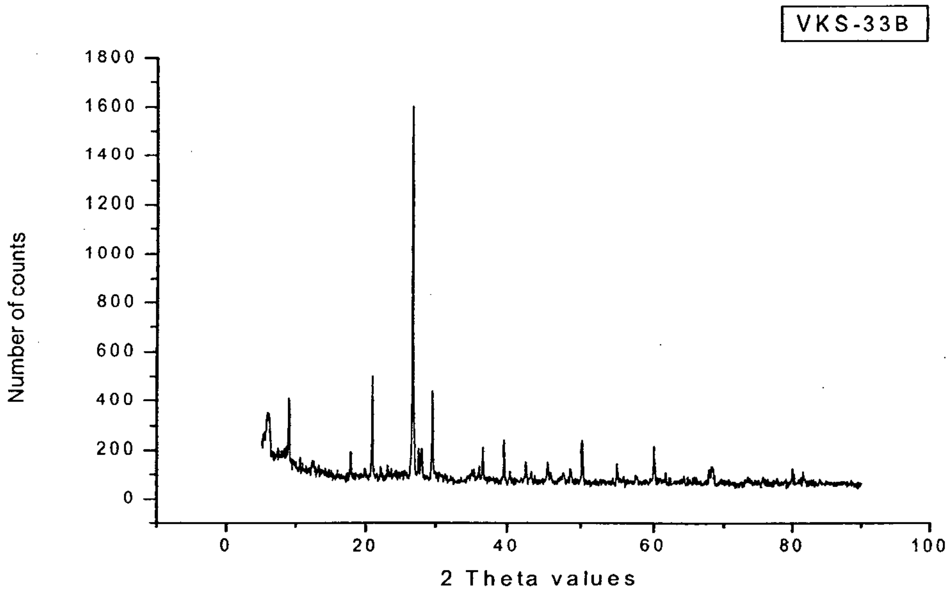
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Field Photographs

Plate A

Plate B

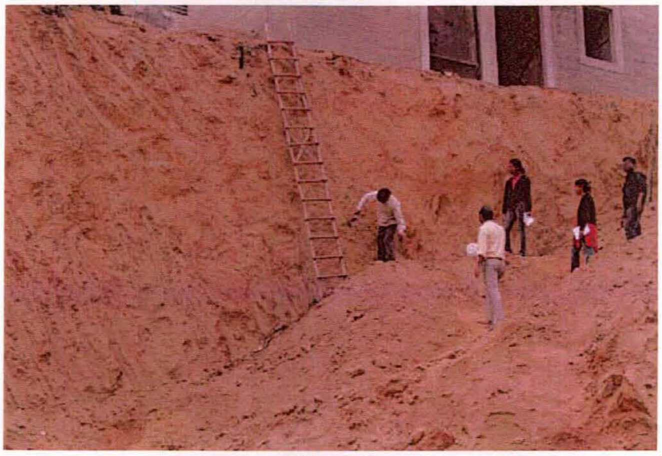

Plate C

Plate A & B showing typical vertical profile of the sediments, characteristics of loesses, on the West wall of pit in Delhi Ridge Area in Vasant Kunj.

Plate C showing typical vertical profile of the sediments, characteristics of loesses, on the south wall of pit in Delhi Ridge Area in Vasant Kunj