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SOME OBSERVATIONS ON THE LOESSIC DEPOSITS OF THE UPLAND MAHARASHTRA

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ABSTRACT: The paper identifies the occurrence, and gives the analysis, of some loessic silt deposits in the Mula, Nira and Karha valleys of Upland Maharashtra. The loessic origin of these deposits is corroborated by the granulometry of their sediments that produces a textural curve typical of a common loess with a high percentage of grains within the 0.016 — 0.063 mm range. Further, the paper gives the mineral and the chemical composition of the sediments, and inquires into the general problems related to loess deposits in the low latitudes.

Introduction

Loess deposits are not only of academic interest to understand the geomorphic processes, reconstruct paleoclimates or fix the archeological time scale, but they also play an important role in applied geomorphology and soil science since these deposits form the parent material of fertile soils. Charles Lyell's (1834) study of loess deposits in the Rhine valley introduced the local German word "loess", describing the "loose" or porous nature of the deposit, in English and opened a broad discussion on this enigmatic deposit. Lyell also established a resemblance between the Mississippi loam and the Rhinanian loess, but it is to the perceptive observation of Von Richthofen (1982) that we owe the global perspective of the loess phenomenon and the eolian hypothesis of its origin, notably that of China. While towards the end of last century the major loess regions of Europe, North and South America, and Asia (China, Mongolia, Persia) were recognized, a relative neglect of the loessic deposits of the Mediterranean and tropical semi-arid regions has, with a few exception, persisted.

In India research has seldom focussed on loess though described in a few locations like the Son (Clark, 1990) and the Kashmir valley. Loess-like silt deposits are found in the upper reaches of the major river valleys and their tributaries in Upland Maharashtra. Though their former extension has been considerably reduced by subsequent erosion, their study and analysis seem to hold a key to the understanding of the black or brown soil associated with them and to the reconstruction of the paleoenvironment.

Another important question related to the study of loess is the origin of the loessic deposits for which different hypotheses have been advanced. These include weathering, size reduction, translocation and transportation sequences, and point to a complex process interaction, thus bringing about large geographical variations in a deposit which at first glance appears relatively simple.

The present study describes some charateristic features of loess deposits in the upper part of Bhima valley, and also attempts to answer questions related to their granulometric, mineralogical and chemical composition.

Eolian sedimentation

In virtually all sediments eolian dust is present. With modern monitoring system, it is not only possible to determine the different rates of eolian sedimentation but also the likely area of the origin of the particles, as each dust-storm transports some silt of a particular grain size and mineralogical composition, e.g. four fallouts of Saharian dust were identified over a period of six months in the Nord Rhine Westfalia region (T. Littmann 1989). The percentage of the eolian component in a sediment depends on many factors. To name some: the general rate of sedimentation, since in an environment of slow sedimentation the eolian part will be higher, the material available, altitude and relief, proximity to deserts, atmospheric circulation and above all the climatic conditions. Thus, in certain bioclimatic environments, like the cold deserts, desert margins, areas with a pronounced seasonality of dry and wet seasons as the Gangetic plain and many parts of Western India, dust movement and dust storms have a greater frequency. It must, however, be admitted that the sedimentation is obliterated by the continuous agricultural land use in these areas.

Quaternary eolian sedimentation:

In the Quaternary, however, repeated rhexistasy with pronounced shifts in the complex bio-physical environment brought about periods of greater eolian deposition either in the form of dunes or loess deposits. The tropics with periods

LOCATION MAP

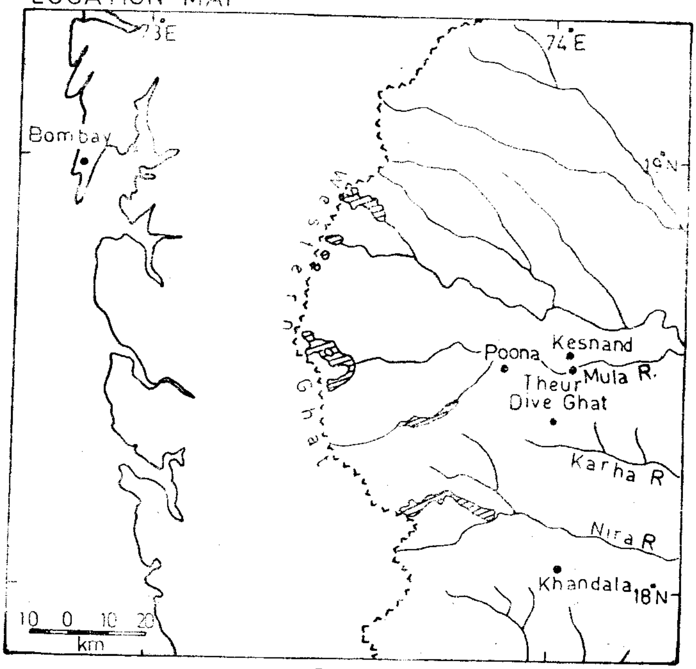


Fig 1a

of aridity and changed atmospheric circulation formed no exception. This can be easily recognized by the extensive eolinites or dune rocks along their coasts (millionites of Gujarat, silt dunes of the Andhra coast). The identification of loess deposits unlike sand dunes is beset with problems. First, the loess deposits may be relatively thin and cover relatively small areas. Secondly, one has to distinguish between the loess deposits as such and the loess that forms landforms. Von Richthofen (1882) already pointed out that a loess region, the gullied and highly dissected land, is the result of two climatic stages: 1) loess deposition during a period of increased aridity and 2) incision as a result of increased rainfall.

Some silt deposits of Upland Maharashtra :

In Upland Maharashtra silt deposits of pale brown to light yellow colour can be observed in the upper reaches of all rivers, from the Godavari valley near Nasik in the north to the Krishna valley in the south. They cover special facets of landscape. Though these deposits are more widespread, the present paper only attempts to study the deposits of some of the tributaries of the river Bhima. The following three sites may be distinguished (fig. 1).

i) Khandala in the southern Nira valley,

ii) Kesnand in the Mula valley,

iii) Dive Ghat on the Saswad plateau in the Karha valley.

A lower river terrace profile near Theur has also been analysed for the pupose of comparison. The deposit consists of 6 m dark brown loams.

The Khandala deposits represent the typical gullied loess features. They are situated 100 m above the main valley on a 2150 feet (655 m) planation surface. The Dive Ghat deposit too lies 100 m above the main valley near the mountain pass and retains steep walls on both sides of the road. The Kesnand deposits rest on the middle terrace but can only be observed in wells, as the stage of incision has yet not taken place. All the deposits

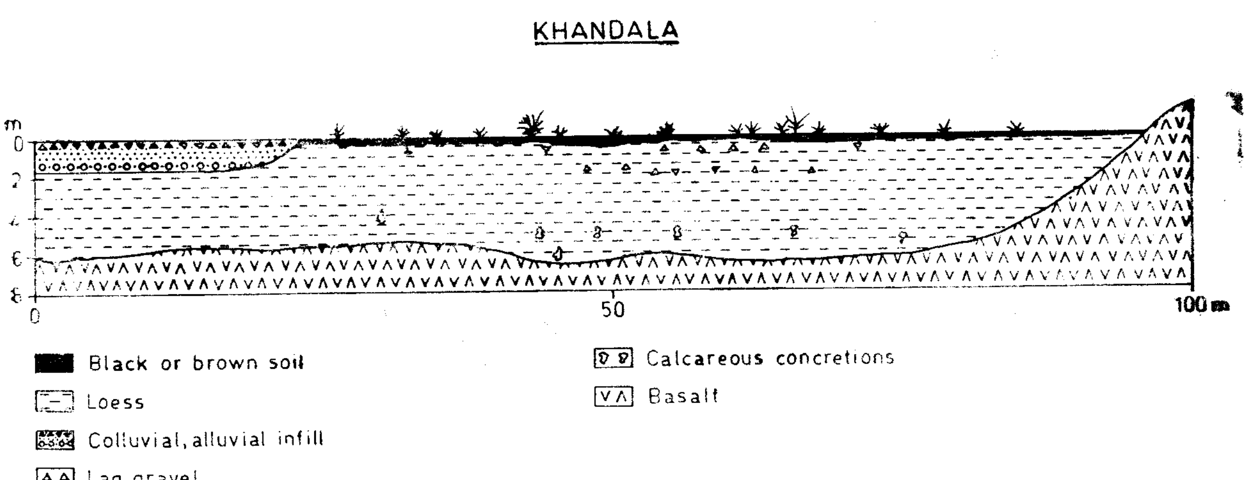


Fig. 1b

Profile of Khandala loess

rest on basalt or weathered basalt and against slightly higher relief features: rocky terraces or older planation surfaces. The deposits are overlain by soil, brown or black in colour

The Khandala deposits

The extensive deposits at Khandala form near vertical walls of 5 to 6 m height. They are formed by a relatively homogenous unstratified silt, but for the thin beds of lag gravel, mainly near the surface, which suggest occasional colluvial processes. The absence of stratification distinguished them from a later alluvial — colluvial infill with well stratified sand and gravel beds. The loess forms the parent material of the black to brown soil. The deposits are characterized

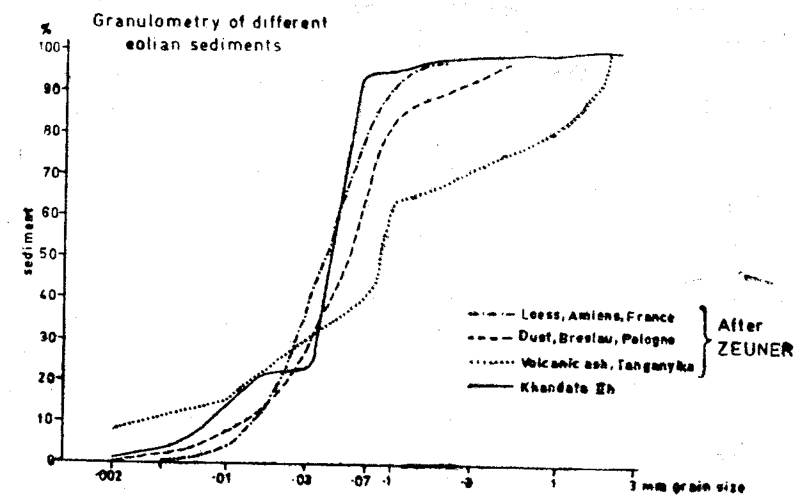


Fig. 2

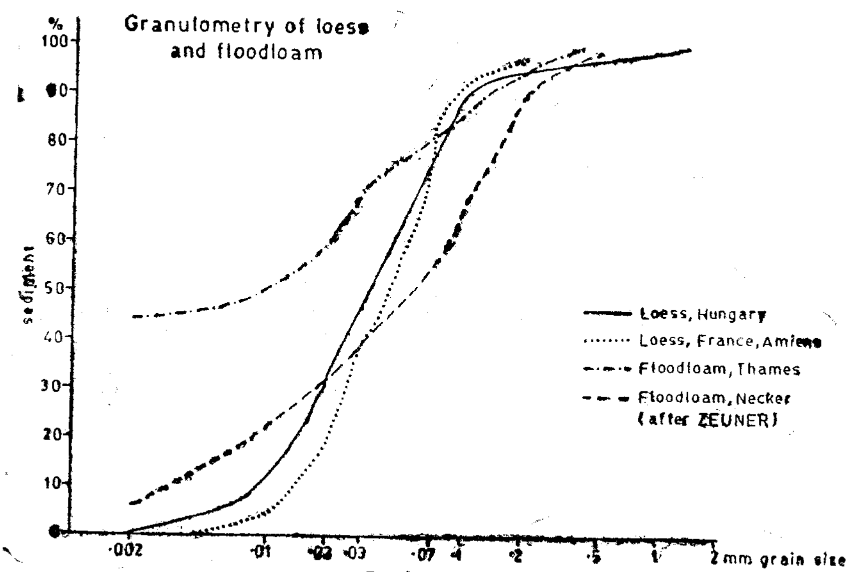


Fig. 3

by different degrees of calcareous formation, calcification along the mainly vertical roots, calcium nodules, white patches of calcareous material and calcareous concretions around the grains.

Grain size distribution in loess:

Loess definitions may vary with the approach of a scholar. The textural composition, however, is basic to most definitions. According to Russell, (1944) at least 50% must fall within the grain size fraction 0.01 to 0.05 mm to qualify a deposit as loess. This concentration of grains within the coarse silt fraction is expressed in the steep S-shaped granulometric curves of typical loess, or eolian dust loam, and distinguishes them from the more gradual curves of floadloam (fig. 2 and 3). The pronounced steep curve is not only charcteristic of loess but also recent dust deposits and, to a lesser degree, volcanic ash. The grain size dis-

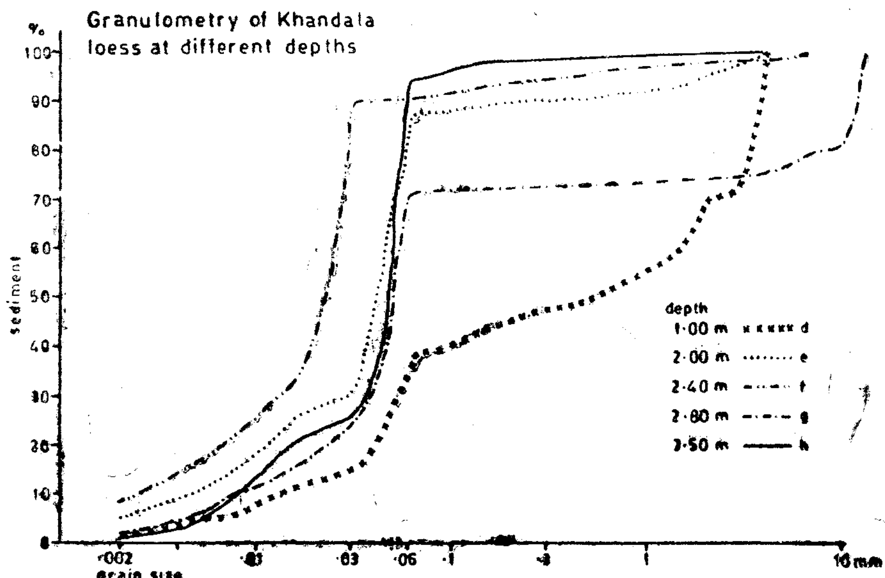


Fig. 4

tribution of the Khandala sediments conforms to the typical loess curve. (fig. 4) The majority of the Khandala samples analysed have more than 50% of the grains, by weight, within the coarse silt fraction of 0.016 mm to 0.063 mm. The highest value is observed at one metre depth in the first profile), 75, 95% of coarse silt, and at the lower section of the second profile, 72.83% of coarse silt (curve IIh). Samples that have a high amount of calcareous concretions and/or colluvial gravel have a lower percentage of coarse silt. (Table 1). This is the case in sample II d which has calcareous concretions of sand size and sample II g which has root concretions. The median of the grain size ranges between 0.024 mm and 0.048 mm (France sample 0.042 mm, Hungary 0.033).

In general the curves of the Khandala loess show a very steep section within the coarse silt fraction. The clay fraction is low to very low and the sand size fractions are nearly absent. The gravel

Table — 1: Grain size distribution of

Location	No.	Description	Depth in m	Clay 0.002 mm and below	Silt fine 0.002 to 0.0156 mm	Silt medium 0.0156 to 0.0625 mm
Khandala	Ia	brown soil with calcareous grains	0.00	3.05	29.05	53.97
	Ib	medium yellow, few gravels	0.25	2.78	14.44	36.77
	Ic	light yellow	0.85	0.92	11.23	75.95
Khandala	IIa	brown soil, calcareous grains	0.00	7.21	7.89	42.28
	IIb	light yellow	0.15	4.62	7.11	34.72
	IIc	medium yellow, concretions	0.40	1.10	9.97	45.99
	IId	light yellow, calcareous grains	1.00	0.87	8.85	22.92
	IIe	light yellow, few calcareous grains	2.00	5.66	20.11	54.68
	IIf	light yellow	2.40	8.25	25.56	56.13
	IIg	yellowish brown, root concretions	2.80	2.35	13.94	53.64
	IIh	medium yellow	3.50	1.48	18.86	72.83
Dive Ghat	b	medium yellow, few gravels	0.50	0.79	20.50	17.88
	c	light yellow	0.75	1.03	29.50	25.68
	d	medium yellow, root concretions	1.40	1.73	31.00	10.59
Kesnand	E3	pale brown	0.90	12.91	—	—
	E7	pinkish grey	2.10	8.54	—	—
	E12	pinkish grey	3.60	14.43	—	—
Theur	Fa	dark grey	0.00	34.05	—	—
	Fb	very dark grey	2.00	19.08	—	—
	Fc	dark brown	4.00	20.48	—	—
	Fd	very dark brown	6.00	20.93	—	—

natural sediment in percent

	Sand				Gravel	Sand and gravel	
total 0.002 to 0.0625 mm	fine 0.063 - 0.25 mm	medium 0.25-0.5 mm	coarse 0.5-2.0 mm	total 0.063-2.0 mm	above mm	above 0.063 mm	Total in %
83.02	4.79	1.11	6.89	12.79	1.14	13.93	100
51.21	8.26	2.73	16.70	27.69	18.32	46.01	100
87.18	4.42	0.88	3.28	8.58	3.32	11.90	100
49.17	5.50	1.72	9.11	16.33	27.29	43.62	100
41.83	12.68	4.11	20.79	37.58	15.97	53.55	100
55.96	6.43	0.90	3.98	11.31	31.63	42.88	100
13.77	9.83	3.30	22.11	35.24	32.12	67.36	100
74.79	8.82	0.71	5.00	14.53	5.02	19.55	100
81.69	3.38	0.53	2.63	6.54	3.54	10.08	100
67.58	2.05	0.42	2.11	4.58	25.49	30.07	100
91.69	5.14	0.29	0.86	6.29	0.59	6.88	100
38.38	—	—	—	—	—	60.83	100
55.18	—	—	—	—	—	43.79	100
41.59	—	—	—	—	—	56.63	100
44.48	18.35	0.89	4.96	24.20	18.41	42.61	100
48.36	20.43	2.47	3.74	26.64	16.46	43.10	100
61.94	14.04	1.94	1.45	17.43	6.20	23.63	100
35.26	6.10	2.04	8.19	16.33	14.36	30.69	100
35.07	29.87	4.93	2.96	37.76	8.09	45.85	100
55.73	22.67	0.78	0.34	23.79	0.00	23.79	100
44.40	29.70	3.92	0.99	34.61	0.06	34.67	100

fraction represents larger calcareous concretions and not actual gravel, except in sample IId where more than 50% of the grains are not concretions.

The Kesnand deposit is also characterized by a near absence of sand; a phenomenon which is neither observed in the younger nor older deposits of the same valley. The larger size diametres represent calcareous concretions.

The Dive Ghat with relatively thin beds of silt shows a different grain size distribution. However curve 'c' has a steep section which my reflect some eolian transport.

The alluvial deposits of Theur have a different grain size distribution, a higher percentage of clay (20 to 34%) and a higher percentage of fine sand.

As the sediments are calcareous, the silt and clay analysis has also been done on the decalcified samples. Curves of these samples show steep sections in the coarse silt fraction, and often a shift towards finer grains. (fig. 5)

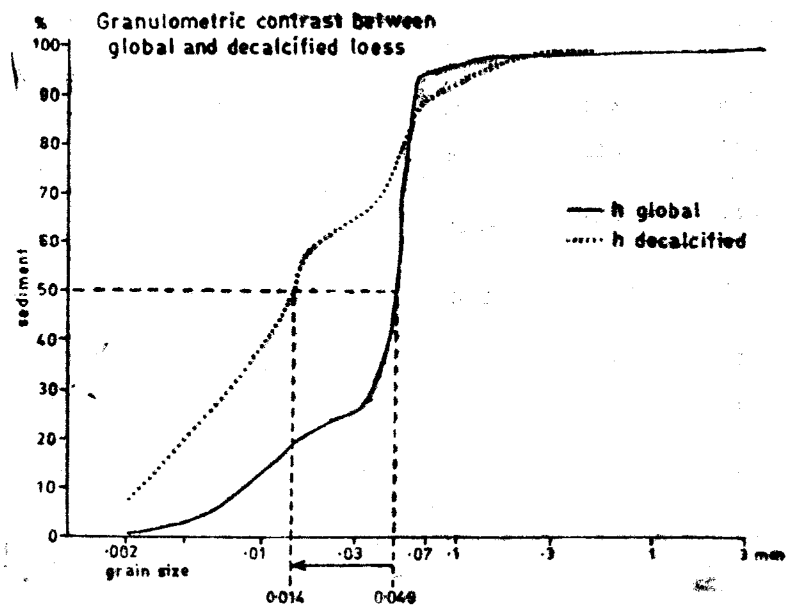


Fig.5

Mineral Composition:

Different grain sizes of different samples have been examined under the microscope. Larger grain fractions of 1 mm and 0.5 mm diameter are dominated by calcareous concretions. In the lower grain sizes (0.090 and 0.053 mm) the concretions account for maximal 18 percent and consequently the mineral composition can be observed more clearly. The mineral composition of the grains indicate their basaltic origin. Basaltic rock fragments as such are absent in the lower grain sizes as all the rock constituting minerals have been separated by earlier weathering and selective transport processes.

The following types of visually classified grains can be distinguished: Transparent grains — mainly represented by zeolite and plagioclase as quartz is rare, usually around one percent; white and

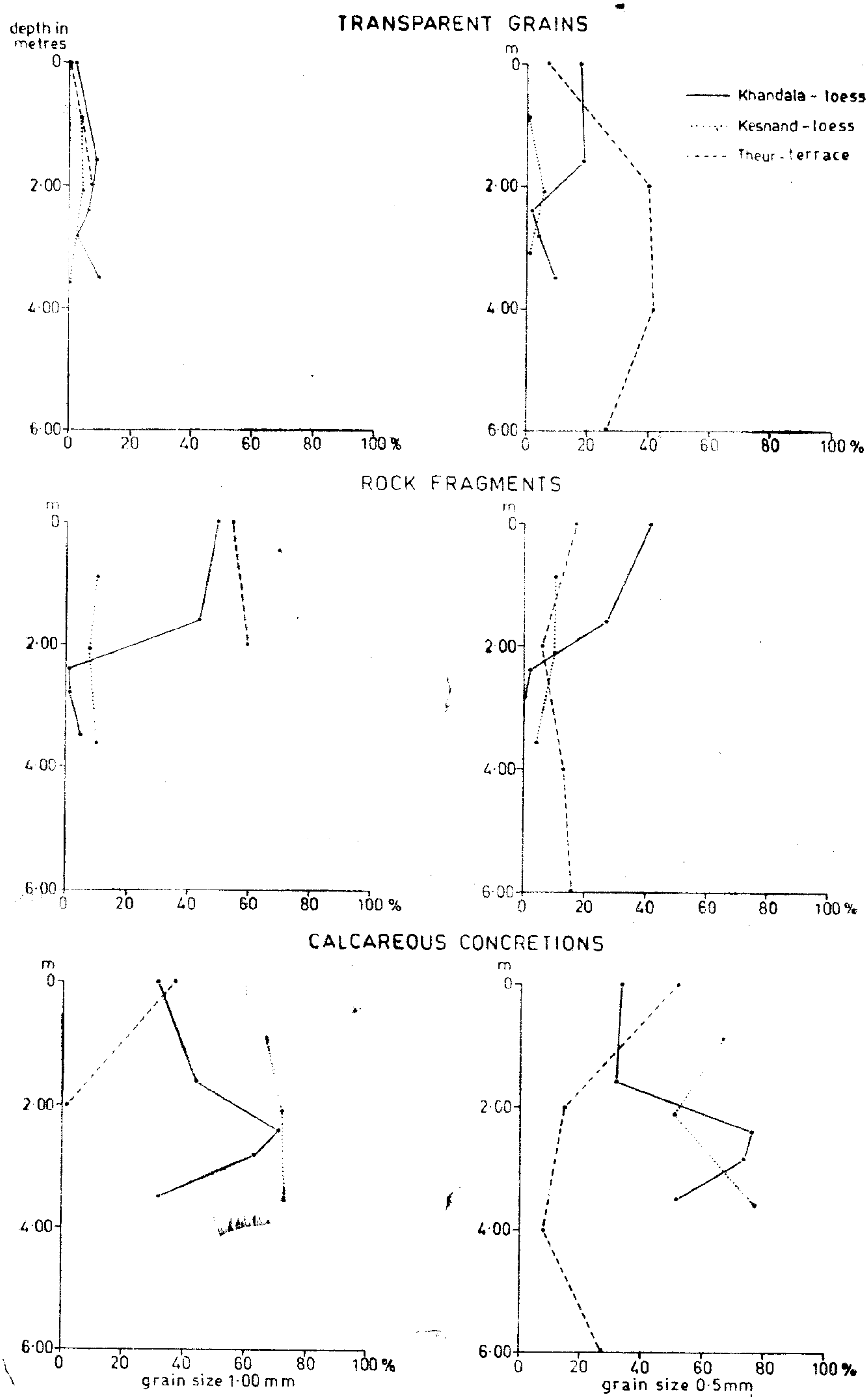


Fig. 6

Percentage of different kinds of grains in loess and terrace sediments

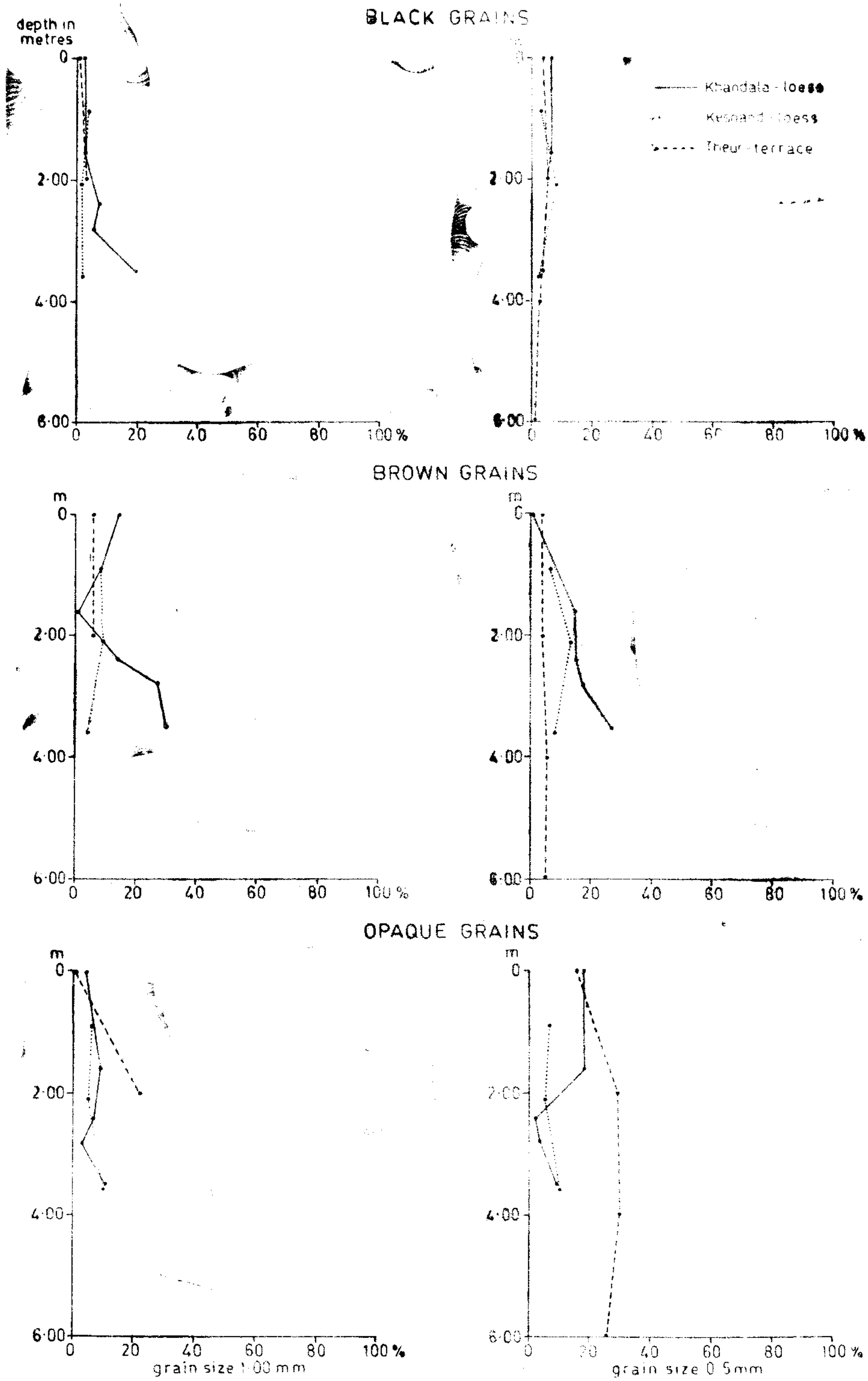


Fig 7

Percentage of different kinds of grains in loess and terrace sediments opaque grains — plagioclase and chert; brown grains — volcanic glass; black grains — pyroxene or iron oxides as ilmenite and magnetite.

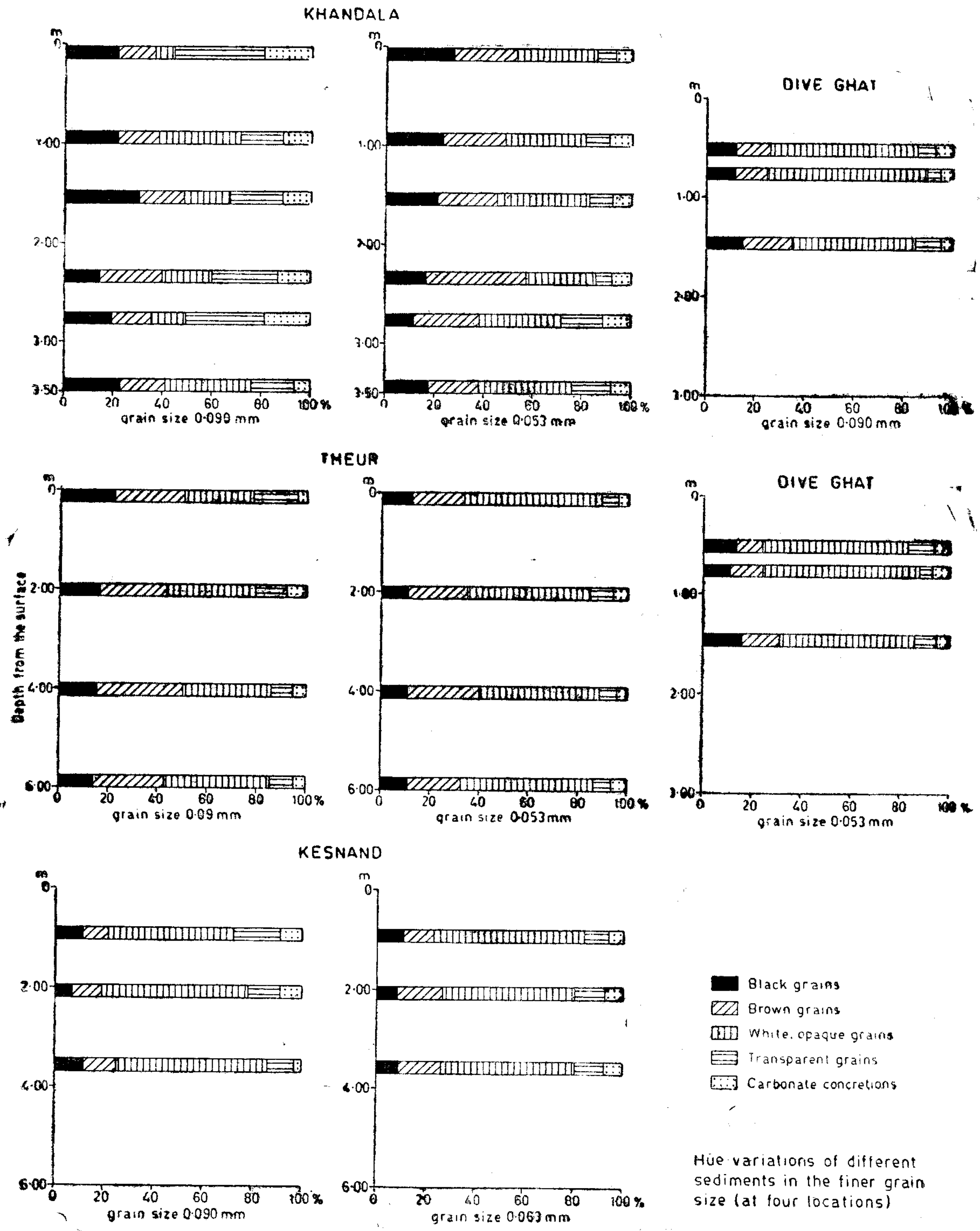
Larger grain sizes: In detail the following observations could be made on the mineral composition of the larger grain size fractions (1.0 and 0.5 mm) (fig. 6 and 7). Calcareous concretions dominate in the Khandala and Kesnand samples ranging from 30 to 80 percent. Within the profile, the Kesnand samples do not show pronounced differences in their mineral composition. In the Khandala profile, however, two samples, one at the surface and one at 1.60 m depth differ in their composition from the remaining samples of the same profile. The difference consists in a higher percentage of basaltic rock fragments, opaque and transparent grains and a consequently lower percentage of calcareous concretions (30 to 40 percent). As these two samples represent slightly gravelly beds, the differences may relate to the intermittent wash processes.

The mineral composition of the river deposit near Theur differs considerably from that of Kesnand and Khandala. Calcareous concretions are present in a much lower percentage. The highest percentage is found near the surface of the deposit. Further, the concretions have a rounded appearance indicating a certain transport. The terrace deposits contain more rock fragments and a much higher percentage of transparent and opaque grains. The 6 m deep terrace deposit has a relatively homogenous composition but for the surface sample.

Smaller grain sizes: The mineral composition of the 0.090 and 0.053 mm grain sizes is represented in columns (fig. 8). The left side of the column shows the heaviest mineral, pyroxene with a density of 3.25-3.55. The lightest mineral is zeolite with a density of 2.2-2.3; the density of plagioclase is around 2.6.

A comparison of the mineral comsition of the Khandala and Dive Ghat profiles shows that the Khandala profile has undergone more changes due to transport. The lighter transparent grains, mainly zeolite, are over represented especially in the 0.090 mm grain size. Feldspar and volcanic glass increase in the 0.053 mm grain size. At a given wind speed it may be easier to pick up larger grains of zeolite than those of glass or feldspar. In the Mula valley where the loessic deposits have a larger percentage of zeolite in the larger grain size (0.090 mm) than the adjacent river deposits, one may think of deflation of alluvial sediments and the deposition of loess in favourable locations as related processes.

Dominant grains in loess: Quartz grains are considered to be the major component of loess sediments and have often been included in the loess definition. Much scientific discussion focusses on the likely origin of the quartz particles in the silt size (Kuenen, 1969, etc.). The extensive Argentine loess, however, has a very different mineralogical composition with a predominance of volcanic minerals which are derived from basaltic rocks. The coarse silt fraction (0.031-0.062 mm grain size) of the Argentine loess has usually 30 to 40 percent glass shards and the medium silt fraction (0.011 to 0.032 mm) more than 60 percent volcanic glass shards (Teruggi, 1957). The mineral composition of the Maharashtrian loess is comparable to the Argentine loess. The availability of silt sized particles is related to the disintegration of the fine grained basaltic rock.



Hue variations of different sediments in the finer grain size (at four locations)

Fig 8

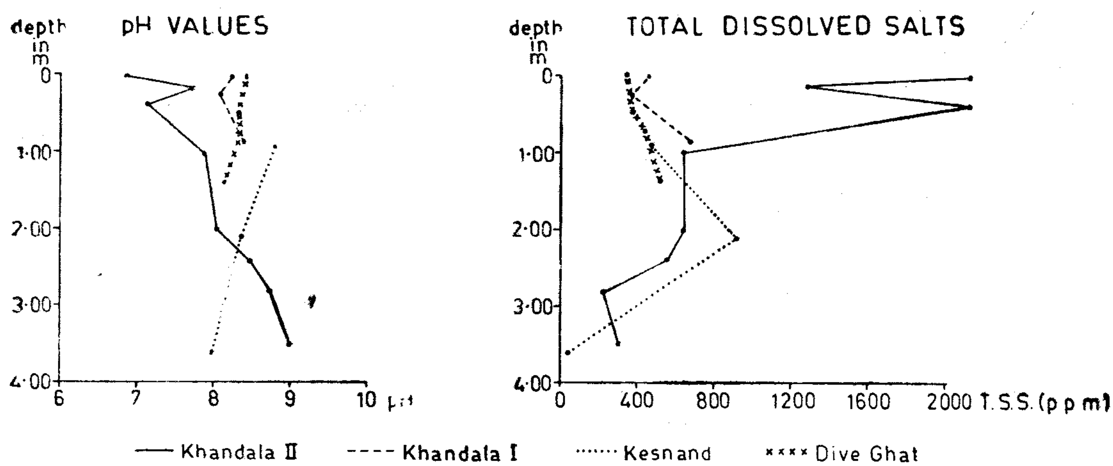
Chemical analysis:

Samples were analysed for the following chemical properties: pH value, total soluble salts, loss on ignition, and determination of alumina as Al_2O_3, silica as SiO_2 and carbonates ($CaCO_3$ and $MgCO_3$). The determination of iron oxides etc. could not be done.

The pH values show moderately alkaline (pH 7.6 to 8.3) to strongly alkaline (8.4 to 9.0) values. Only the upper horizons of the second Khandala profile have nearly neutral values, especially the surface sample having a pH of 6.85. This can be explained by the vegetation cover and the presence of shrubs. The lower section of the same profile is strongly alkaline while the upper one is moderately alkaline (fig. 9).

The values for the total dissolved salts range in general between 200 and 600 ppm. However, the three uppermost

Fig 9a pH values and total dissolved salts in the loess of upland Maharashtra



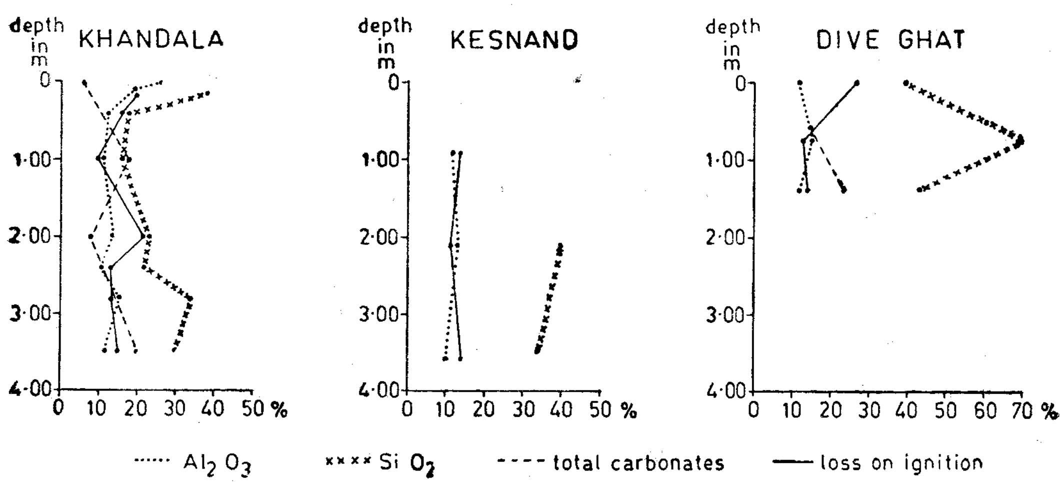


Fig 9b Content of Al_2O_3, SiO_2, total carbonates and loss on ignition varying with depth

samples of the second Khandala profile which had lower pH values show a much higher amount of total dissolved salts (1200 p.pm. and above) most probably related to the presence of humus. The amount of total dissolved salts decreases with depth (below 2 m) while the pH values increase or remain unchanged.

The concretionary nature of the deposists is indicated by a higher percentage of total carbonates, often more than 20% in the lower horizons. The lime content of the terrace deposit near Theur is usually below 2 percent. The presence of carbonates has been used as an important criterion in loess definitions (Russell, 1944 etc) but as the carbonate contents vary greatly wth the environmental processes, Cegla (1972) would like to exclude carbonates from the definition of "typical" loess. They can, however, serve as a valuable index on the loess formation.

While the amount of aluminium sesquioxides present in the different profiles does not show much variation with the exception of the surface sample in Khandala, the amount of SiO_2 shows wide locational and intraprofile variations.. The Dive Ghat samples have a high percentage of SiO_2 ranging from 40 to 60 percent. The Kesnand loess has 33,8 percent $Si\ 0_2$ at the base and 40 percent in the middle portion of the profile. The lowest values are observed in the Khandala profile more than half of the number of samples show values between 16 and 23 percent. In the two lowermost samples of this profile the percentage of $Si\ 0_2$ increases (IIg 34.5%, IIh 30.1 %). The interprofile differences may be associated with the mode of sediment transport or subsequent leaching processes.

The environment of loess deposition:
General considerations:

The deposition of any sediment **will** be governed, among other factors, by the pre-existing relief and a particular bioclimatic environment. Loess deposition forms no exeption. In this context it is worth emphasizing two important contributions to the loess question by Von Richthofen (1882).

The first one applies to the definition of loess. 'Loess', according to him, is the deposit of the steppe environment, as the grass vegetation helps to trap the wind blown dust. Thus, the typical vertical cleavages of the loess are explained by the vertical roots and rootlets of the grasses and the absence of stratification". The second point is more geographical as he distinguished between two classes of loess though a series of gradation may exist between them. There are "1) The loess of the central regions of the continents with endorheic drainage, and 2) the loess of the "wide grass-covered plains which are known by the names of prairies, savannas, llanos, pampas and steppes of Southern Russia and Siberia". The difference between the two classes lies in the aridity of the climate, the loess of the grass covered plains being characterized by alternating dry and wet seasons where periods of luxuriant grass cover are followed by periods of dried up vegetation cover and exorheic drainage. Von Richthofen (1882) wrote: "The rate at which the growth of the soil takes place will depend upon the character of the adjoining regions from which the wind prevailing in the dry season removes the loose soil. It can no longer be doubted that the "black earth" of Southern Russia is growing in this way and I am inclined to hold the same opinion with with regard to the "Regur" in India".

He has the following profile in mind: black colour soil in the uppermost layer only, brown colour of loess with its structure in the deeper portions. This "prairie" or "savanna" loess is, so he states, subjected to greater teaching processes than that of the central continental regions.

The above statements may serve as a deductive framework to the actual observations in the field which have been made without the prior acquaintance of Von Richthofens more than hundred years old paper but were provoked by discussions with Dikshit more than twenty years ago.

The map on the world distribution of loess (Scheiding, 1934) included besides the lower Ganga loess region also probable loess region in Western Rajasthan, the Gangetic plain and South-east Peninsula India. Ginzbourg and Yaalon (1963), Brunnacker (1969), I. J. Smalley and C. Vita-Finzi (1968) and others advanced the discussion on "desert loess". More recently G. Coude'-Gaussen (1980) introduced the concept of the "Pleitocene peridesertic loess". The mineralogical analysis of calcretes in the Anti-Atlas region and Patagonia (Thea Vogt 1989) and loess-like deposits in north-western Nambia (Bluemel 1989) could identify the eolian component and area of origin of the deposits.

Origin of eolian dust and site of deposition:

River sediments and terraces, and loess deposits are closely associated. This does not only apply to the Rhine, Rhone or Mississippi valleys but also to the desert loess. Yaalon (1969) postulated that the ultimate source of the extensive loess of the Be'er Sheva basin are the wadi floors and fans. Silt and clay layers deposited during occasional large floods dry, crack, and disappear within a few months as they are blown out of the desert. In Upland Maharashtra river terraces and loessic deposits also exist side by side and in a complex interrelationship.

Cegla (1969) views the association of loess wth the grass vegetation differently. He sees the major role of the vegetation in the preservation of loess and attributes a decisive role in the accumulation of the same to capillary forces. The process is initiated by dust particles which settle down on rocky surfaces wetted by capillary water. The capillary forces then prevent the particles from being blown away. The process is self-promoting as the wetted dust layer will bind more dust particles on its surface. The capillary forces for the grain size of of loess are very high (more than 20 m) and thus deposits of considerable depth may accumulate. The concept of capillary forces in the accumulation of loess explains their occurence on initially bare rock surfaces as in the case of Khandala or Kesnand. This would also explain the occurrence of loess in isolated patches.

Past and present climatic considerations:

Under the present climate Upland Maharashtra, left in undisturbed natural state would have been a savanna with many more trees than we find in the actual landscape. The banks of the rivers would have been marked by a gallery forest leaving little chance for deflation of dust particles from river sediments. In fact the dry summer fields of the agricultural landscape promote more eolian movement than the natural landscape would. An increased eolian activity under natural conditions would presume a climatic shift towards greater aridity causing the destruction of the gallery

Table — 2 : Wind Speed, Frequency of Dust Storms and Rainfall Data of Selected

Station	Annual Mean Rainfall in mm	Mean No. of Rainy Days	Total Rainfall in Driest Year in mm	Wind Speed Km/h Annual Mean
RAJASTHAN				
Phalodi	242.0	14.8	39.9 (1889)	15.3
Bikaner	304.7	18.4	29.0 (1899)	7.7
Jodhpur	380.1	21.4	24.4 (1899)	10.9
Barmer	310.3	17.4	128.8 (1938)	9.5
Jaipur	648.1	37.4	128.1 (1905)	12.4
Ajmer	557.4	31.5	149.3 (1918)	7.4
UPLAND MAHARASHTRA				
Jalgaon	840.4	48.3	205.7 (1878)	11.7
Malegaon	579.5	35.6	205.0 (1899)	8.4
Ahmednagar	677.3	38.2	287.3 (1912)	7.9
Pune	714.7	50.1	268.5 (1918)	5.3
Sholapur	742.0	46.5	325.4 (1920)	9.8
Aurangabad	792.1	50.1	266.5 (1920)	12.8

(Source: India Meteorological Department)

forest by a fall in the water table and/or erosion followed by deposition. These relatively unprotected river sediments would be open to the winnowing and selective movement of dust particles. The observations of actual dune forming processes by Shukla (1988) in the river bed of the Tapi show that microclimatic conditions of temperature and pressure gradient can create air movement and turbidities to build well sorted sand dunes.

The sight of whirlwinds and dust flurrys which suddenly rise and spin through the landscape lifting a lot of sand, dust and dry leaves are not rare in summer. Actual dust storms also occur. A few facts about the eolian environment emerge while comparing some relevant climatic data of Upland Maharashtra and Rajasthan (table 2). In Upland Maharashtra, Aurangabad and Solapur have a higher frequency of dust storms (three per year) than Jalgaon, Pune or Ahmadnagar. In Rajasthan the frequency is highest in Bikaner, with eight dust storms per year, followed by Jaipur with 6, Jodhpur with 6, Phalodi having five dust storms. The frequency

Stations in Rajasthan and Upland Maharashtra

Month with Highest Mean Wind Speed				No. of days with wind speed of Km/h				Dust Storms
Month	Km/h	Mean Rainfall in mm	No. of Rainy Days	62 or More	20-61	1-19	Calm	Mean No. of Days
June	25.6	23.3	1.5	0	87	249	29	5
June	13.3	27.0	2.1	0	15	306	44	8
June	18.5	30.9	2.1	1	55	260	49	6
June	14.2	21.5	1.3	0	13	302	50	3
June	17.8	54.0	4.1	0	25	276	64	6
June	14.6	66.5	3.4	0	29	223	113	1.6
May	21.5	12.5	1.0	0	61	270	34	6.1
June/July	13.2	109.5	6.3	0	28	280	57	1.3
July	11.5	101.9	7.0	0	26	280	59	0.3
July	9.2	186.8	13.9	0	13	231	121	0.2
July	13.0	127.7	9.2	0	22	304	38	3
June	19.2	141.2	8.0	0	73	265	27	3

of dust storms in Barmer is the same as in Solapur and Aurangabad. If we compare the wind data of Jalgaon which has the lowest dust storm frequency and Bikaner showing the highest frequency, it becomes clear that Jalgaon has a higher mean annual wind velocity (11.7 km/h) than Bikaner (7.7 km/h). This paradox applies also to the wind velocity of the month with the highest wind speed (21.5 km/h and 13.2 km/h respectively). In Jalgaon the number of days with wind speed of 20 to 61 km/h is four times as high (61 days) as in Bikaner (15 days), the days of calm are fewer in Jalgaon than in Bikaner. The eolian processes in Rajasthan are thus not a function of particular high wind velocities and frequencies but of their combination with aridity and the resultant space vegetation cover. Low mean annual rainfall, a fewer number of rainy days, high rainfall variability, extreme droughts characterize the climate of the stations like Phalodi, Bikaner, Barmer in Western Rajasthan. It may be added that in Rajasthan the month of the highest wind speed is the dry and hot month of June, but in Western Maharashtra with the exception of Jalgaon, it is the cooler and rainy month of July where wet soil and vegettion cover are likely to resist deflation.

From the above data we may conclude that a considerable decrease in the amount of precipitation alone could tilt the balance of geomorphic forces towards eolian processes in Upland Maharashtra. The climatic consequences of the cold periods, however, do not limit themselves to changes in the annual water budget but apply also to changes in temperature, relative height above sea-level, distance from the sea, and global circulation pattern, changes which might have lead to inceased wind strength and activity in Upland Maharashtra. In this context it should be mentioned that aerosols are supposed to have increased world wide by 5 to 30 times during the maxima of the cold periods (1989 T. Vogt). The tributaries of the upper Bhima river form broad valleys flanked by high divides and the nearly insurmountable margin of the Western Ghats. It is, therefore, inferred that the transport of silt particles by the wind was confined to the valleys and especially the lower facets of the relief. There is no indication that the loess is not local in its origin though calcareous dust particles may have travelled longer distances from the exposed shelf. The word "local", however has its own problems as the Deccan basalt covers large areas, and a movement of dust from the drier eastern parts of the valley towards the stretches further west cannot be excluded.

The process of eolian dust accumulation was not a continuous one, as intraprofile differences (Khandala profile) show; nor can wash processes be excluded. In a later, more humid stage, loess has undergone soil forming processes, erosion and deposition.

Conclusions:

Based on the above empirical and theoretical observations the following points emerge. Loess deposits exist in Upland Maharashtra. The best example are the deposits of Khandala which have a grain size distribution comparable to the European loess and satisfy loess definitions in many other aspects: colour, verticals walls, origin of grains in silt size, calcareous concretions. As the tributaries of the Upper Bhima have different valley forms, developmental stage and process dynamics, the loessic deposits reflect these differences. Though the deposits of the Dive Ghat must be classified as slope deposits an eolian component in some horizons cannot be excluded.

Much more detailed research is required to assess the distribution, environment, facies and later erosion of loessic deposits. However, it must be emphazised that one cannot speak of past dry climates without considering eolian processes.

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