Some Observations on the Quaternary of Western Maharashtra (India)

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with Pl. VIII–IX

Introduction

Quaternary formations in Western Maharashtra consist of variously consolidated, at places fossiliferous, alluvial silts and gravels interbedded locally with colluvial silts, gravels and sands. These fluvial deposits are restricted in extent, and are mostly of late Quaternary age. The sequence of sediments is one of aggradation repeatedly alternating with erosion. The writers believe that the Quaternary aggradations and erosions in the river valleys occurred both due to milder tectonic movements and to climatic changes. The tectonic changes were mostly of epirogenic type and the climatic changes include fluctuations in rainfall pattern. The rainfall probably departed from the present mean annual figures by 35 to 40 percent.

Location and Environment

The area examined by us[1] forms an integral part of the Deccan plateau of Peninsular India (Fig. 1). Its climate is of subtropical, monsoonic type with a mean annual temperature close to 26° C. The rainfall is restricted to about four months (June to October), the main contribution coming from the southwest monsoons. The distribution pattern is governed by the topographical features of the region. The source regions of most of the west-east flowing streams receive an annual rainfall of about 5000 mm and the plateau on the east (lying 50 to 70 km from the source) receives an annual rainfall of about 500 mm. The rainfall is very sporadic and at times heavy. The remaining 8 months of the year are characterized by a mild dry winter (November to February) and a hot dry summer from March to June. The minimum temperature in winter sometimes goes down to about 2° or 3° C. and the maximum temperature in summer reaches 40° to 42° C. Evaporation is high and most water courses are nearly dry for much of the year. Soils in the source region of the streams are heavily leached pedelfer type, while in the eastern part they are weakly leached and contain carbonate horizons in the subsoil portion. These pedocal types of soils are well known as "black cotton soils of India". The vegetation pattern closely follows that of the rainfall. In the high rainfall zone of the Western Ghats (i. e. in the source region) the vegetation is of semi-evergreen and wet deciduous type, while the eastern regions with low rainfall are covered by dry deciduous forests and thorn and scrub type of vegetation.

Physical features

The western portion of the region under consideration is flanked by a north-south running mountain range known as the Western Ghats, having an average elevation of about 1000–1300 m above sea level. The Western Ghats have a precipitous scarp on the western side, facing the Arabian Sea, and have a

[1] Dr. Gudrun Corvinus studied the Quaternary formations of the Pravara and Godavari valley in detail and discovered a factory site of Acheulian man at Chirki on Pravara. She has excavated the site of Chirki and a detailed report on it will be published soon. Dr. S. N. Rajaguru and Dr. G. G. Mujumdar have investigated the alluvia from the Krishna-Bhima valleys and carried out the laboratory tests on soils and sediments collected during the field work in western Maharashtra. The work has been carried out since 1964–65 and has been financed by the Deccan College, Poona, the Council of Scientific and Industrial Research. New-Delhi, the Wenner Gren Foundation, New York, and the Deutsche Forschungsgemeinschaft, Bonn.

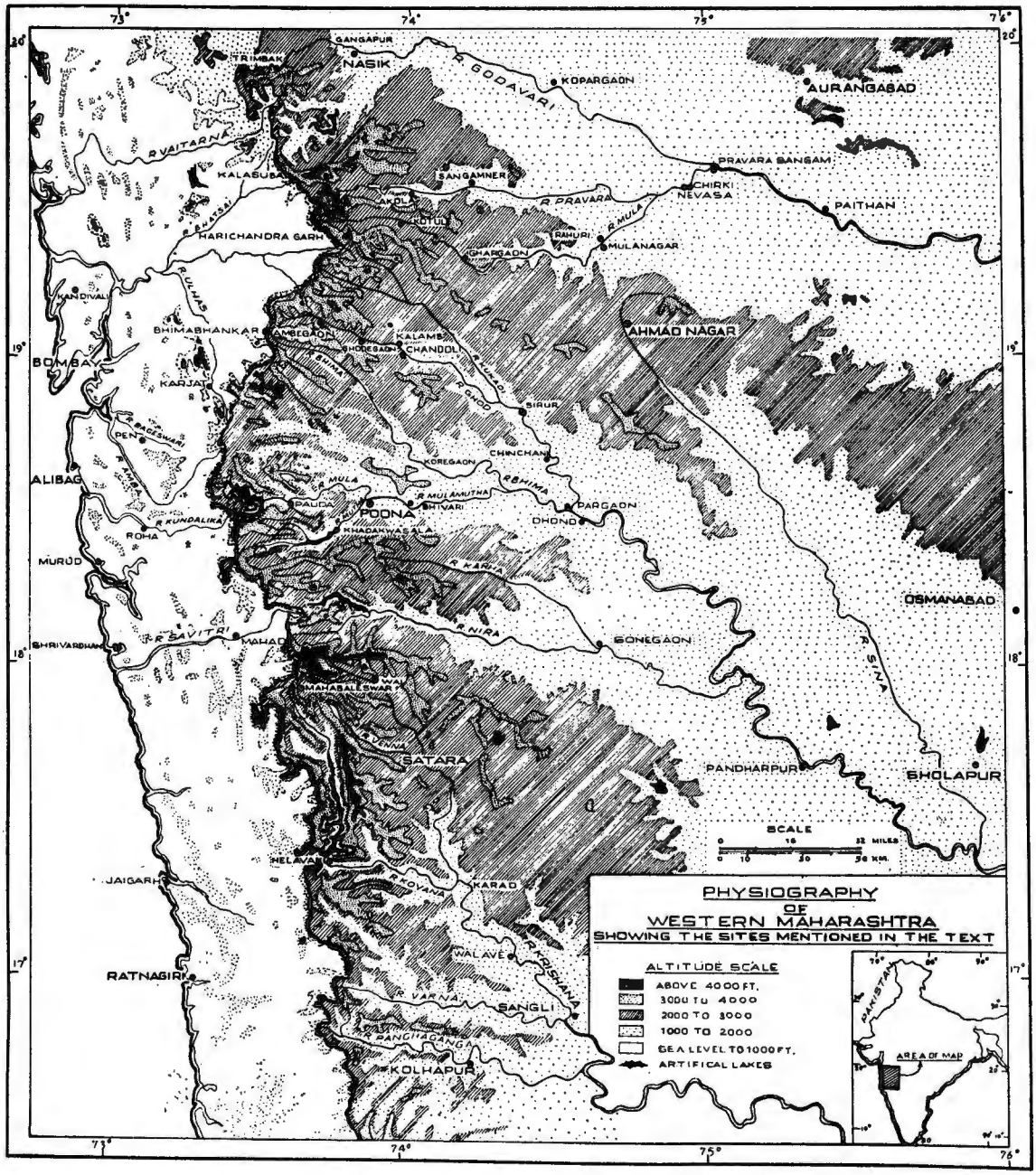


Fig. 1. Western Maharashtra.

gentle eastward tilt on the plateau side. The plateau portion of western Maharashtra has an average elevation of about 400 to 800 m above sea level and is drained by east to southeasterly flowing rivers like the Godavari, Pravara, Bhima and the Krishna. These rivers have their source in the Western Ghats, no more than 50–80 km from the west coast and flow eastwards through broad valleys for a distance of about 1000 km to meet the Bay of Bengal.

The Western Ghats are the major continental divide between short (40–60 km long) westerly flowing streams of the coast and long easterly flowing streams of the plateau. Owing to favourable conditions for headward erosion, some of the westerly flowing streams, like the Ulhas and the Vaitarna, have encroached upon the headwater portions of the easterly rivers like the Indrayani and the Godavari respectively.

The easterly flowing Godavari, Bhima and Krishna are separated by west-east running divide ranges known as Balaghat and Mahadeo ranges respectively. These divides appear to be off-shoots of the Western Ghats and have preserved erosional surfaces of Tertiary age. The whole scenery of the plateau appears to be of polycyclic origin and has retained erosional surfaces at elevations of 1300, 850, 750 and 660 m (Dikshit, 1970).

The present courses of the rivers in the region generally show rejuvenated characters and have exposed 10 to 20 m high alluvial cliffs on their banks (Plate VIII, a). These rivers have broad box type or 'u' shaped valleys even in their source regions and valley pediments are quite common. These pediments imperceptibly merge into alluvial flats which are not more than 2 to 3 km in width (Fig. 2; s). The Quaternary formations are confined to these alluvial flats only. As opposed to these general valley morphological features, the Pravara valley in its source region has preserved different types of morphological features. There are waterfalls, about 50 m high, in the Pravara and its tributaries and deep gorges and entrenched meanders with a sinusity index of 1.9. Besides, the whole valley between Akola and Sangamner is filled with alluvium and gives an appearance of an infilled basin (Plate VIII, b).

In the following pages an attempt has been made to decipher the Quaternary history of the region in the light of field and laboratory studies of Quaternary formations and the associated valley morphological features observed in various streams and nalas[2].

Observations

The solid rock in which the valleys have been cut is the Cretaceous-Eocene basalt known as the Deccan Traps. At places they have been intruded by doleritic and basaltic dykes. These basalts have been capped by laterites, above 1000 m in the Krishna valley. The laterite cover is at places 20 to 30 m deep and shows a three layered structure at many places (i. e. ferruginous crust, lithomarge and weathered parent material). These plateau laterites in western Maharashtra appear to be of Tertiary age. The Quaternary formations mainly include following facies: –

A. Finer formations	a) Dark brown sandy silt
	b) Brownish sandy silt or silty sand, at times rich in calcareous nodules
	c) Yellowish brown sandy silt or silty sand, generally rich in calcareous nodules.
B. Coarser formations	a) Sandy pebbly gravels
	b) Bouldery gravels.

A. Finer formations

Colour

These silts are reddish brown (5 YR 4/4) or yellowish red (5 YR 4/6) in the source regions of most of the streams, especially in the Krishna and the Bhima valleys. They are light brown (7.5 YR 5/4) or yellowish brown (10 YR 5/4) in the major part of most of the valleys.

[2] Small streamlets draining directly or indirectly into the main stream are known as nalas, a native term, in India.

Texture and structure

The particle size determination[3] indicates that these silty deposits show considerable variation in grain size composition. They are commonly sandy silts or silty sands and at times clayey or silty and have a median value varying from 0.03 to 0.09 mm. The grading is poor and lamination is not uncommon. Alternations of sandy and silty layers in a vertical depth of about 6 m is very well seen in the cliff section exposed on the left bank of the Krishna near Sangli. The lenticular patches of sandy and sandy pebbly gravels intergrade with the silty deposits, especially in the lower parts. Such interfingering of coarser gravels with silts is more frequent in the Godavari and Pravara valleys than in the Bhima and Krishna valleys. Calcareous bands and calcareous nodules are quite common in these silts. They are sometimes tubular in form and appear to be casts of grasses and roots. At places, a deposit of 'fissured clay' is found to intercalate with these silty deposits. It is found to be best preserved in the Krishna valley around Wai and in the Pravara valley near Nevasa opposite Chirki. The fissured clay is non-calcareous, varies in thickness from 0.5 to 5 m and shows dark reddish brown colour (5 YR 3/4). Fissurred clay is probably a floodplain deposit with a good development of dessication cracks.

In addition to brownish and yellowish calcareous silts and coarser gravels, one also observes less calcareous dark brown (7.5 YR 4/2) silts and its associated finer gravels. These silts are at times well laminated and are found to rest against brownish calcareous silts.

Chemical and mineralogical composition

The silts in the source region of the streams with a present day rainfall of more than 2500 mm are slightly acidic with a pH of 5,6 to 5,9. Their percentage of aluminium oxide increases and that of silica decreases. They are rich in kaolinite and completely devoid of montmorillonite.

In the rest of the region with lesser rainfall the silts are distinctly alkaline with a pH varying from 7,4 to 8,8. The calcium carbonate varies from 3 to 12 per cent in the present day rainfall regime below 1000 mm and it is practically absent in areas receiving rainfall more than 1000 mm. Generally the yellowish brown silts are rich in calcium carbonate, up to 20 %. Organic matter is generally less than 1 %. Silica varies from 40 to 60 % and ferric oxide and aluminium oxide have percentages between 10 to 16 and 20 to 30 respectively. Mineralogically the silts are rich in montmorillonite, quartz, chalcedony, glass, illmenite and magnetite, while kaolinite, illite, goethite, plagioclase, felspar and pyroxene occur insignificant proportions. Plagioclase and pyroxene show obliterated optical characters due to weathering. Some of the yellowish brown silts, purely colluvial in origin, (e. g. near Poona, Wai and Sangamner) are, however, rich in fresh plagioclase and pyroxene in addition to normal resistant minerals. Surprisingly, the brownish silts near Poona and Wai contain considerable proportions of kaolinite.

Biological and cultural finds

The silts have so far yielded no animal or plant fossils nor Stone Age tools. Only at a few places such as Paithan, Nandur Madhmeshwar, in the Godavari valley and at Poona in the Mula-Mutha valley, fragmentary molluscan shells mostly of *Unio* type, have been collected from the silt. At Inamgaon a dark brown silty clay band, at 8 m depth from the surface of an old terrace has yielded a few pollens of *Accasia, Eugemia* and *Holopteria*[4].

[3] For particle size measurements the soil samples were treated with Sodium hexa meta phosphate during the dispersion process and the analysis was carried out by the International Pipette Method.

[4] A private communication from Dr. Vishnu Mittre of the Birbal Sahani Institute of Palaeobotany, Lucknow.

Mode of deposition of silts

These silts are purely fluvial in origin and not aeolian as thought by some of the earlier investigators. This is indicated by poor sorting, the presence of lenticular gravelly and sandy bodies almost throughout the vertical depth of the silt, the faint lamination and the similarity with the textural and mineralogical composition of modern flood silts. The field characters suggest that they are in most cases vertical accretion deposits. In some instances they occur as "channel plugs" and near channel deposits. The clayey bands observed at Inamgaon, Wai, Nevasa and at other places are only of local significance, indicating the presence of small stagnant pools during the aggradational phase. The local disconformities are indicated by cut and fill structures and by a few fossil soil horizons encountered in the silty deposit. The colluvial contribution into the alluvial formations can be easily distinguished in the field. They are dominantly yellowish brown in colour, contain higher proportion of calcareous nodules and the associated gravels are angular to subangular. Normally these colluvial silts are confined to the foot hill portions and thin out towards the valley plain. Sometimes they merge imperceptibly into alluvial sediments, the example of which is well seen in the Mula valley near Ghargaon and in the Pravara valley near Sangamner and Akola (Fig. 2 ; 2 & Plate VIII, b). At times colluvial silts sharply abut against alluvial formations, e. g. Dattawadi near Poona in the Mula-Mutha valley and Borkhal near Satara in the Krishna valley. At both these places the yellowish brown colour of the colluvial silt and the brownish colour of the alluvium are so different that their contacts can be clearly distinguished in the field. The colluvial silt sometimes reaches the present banks of the trunk stream. The most interesting example of this category is seen at Wai in the Krishna valley.

B. Coarser sediments

Bouldery gravels: These gravels generally occur in the lower portion of the alluvium normally 0 to 3 m above the present bed level. It is only at Paithan in the Godavari valley and at Nevasa that they occur at a level of about 20 m above the present bed level on the left banks (Fig. 2; 1). The gravels in the upper reaches of most of the rivers in western Maharashtra are distinctly bouldery, subrounded (ϱ 35 to 40 %), heterogeneous, polymodal, poorly sorted, crudely stratified, unimbricated and subjected to sliding with a sliding index varying from 32 to 40 %. Lithologically these gravels are dominated by compact basalts. Throughout the entire stretch of the Krishna valley the gravelly bodies contain about 35 % of well rounded laterite pebbles with a rounding index of 60–65 %. The gravels in the Krishna valley, as compared with those from the Bhima and Godavari valleys, are poor in the multi-coloured varieties of chert and jasper.

Rubble Gravels: These gravels are dominated by boulders and blocks derived from local outcrops of basalt. They are unstratified, ill sorted, angular to subangular (ϱ 10 to 20 %) and are cemented by calcium carbonate. The rubble gravels are common in the upper reaches of most of the streams. They are often associated with slope deposits, for example, at Wai in the Krishna valley and between Akola and Sangamner in the Pravara valley. At Chirki-on-Pravara near Nevasa, the rubble gravel was found to occur right on the bed rock basalt at an elevation of 5 m to 12 m above the present bed level of the Pravara (Fig. 3). The rubble exposure at Chirki covers an area of about 1 sq. km. It ist about 0.20 to 0.40 m thick and is confirmably overlain by sandy pebbly gravel, about 3 to 8 m thick. The whole site of Chirki has been thoroughly explored by Corvinus (1967, 1970, 1971).

Sandy pebbly gravels: They are fairly well sorted, stratified, subrounded to rounded (ϱ 40–60 %) and cross-bedded. The cross-bedding is generally of planar type and the dip of foreset rarely exceeds 30°. Clayey and silty intercalations are common. Lithologically the gravels contain a higher percentage of crypto-crystalline pebbles than the bouldery and rubble gravels. The degree of cementation is highly

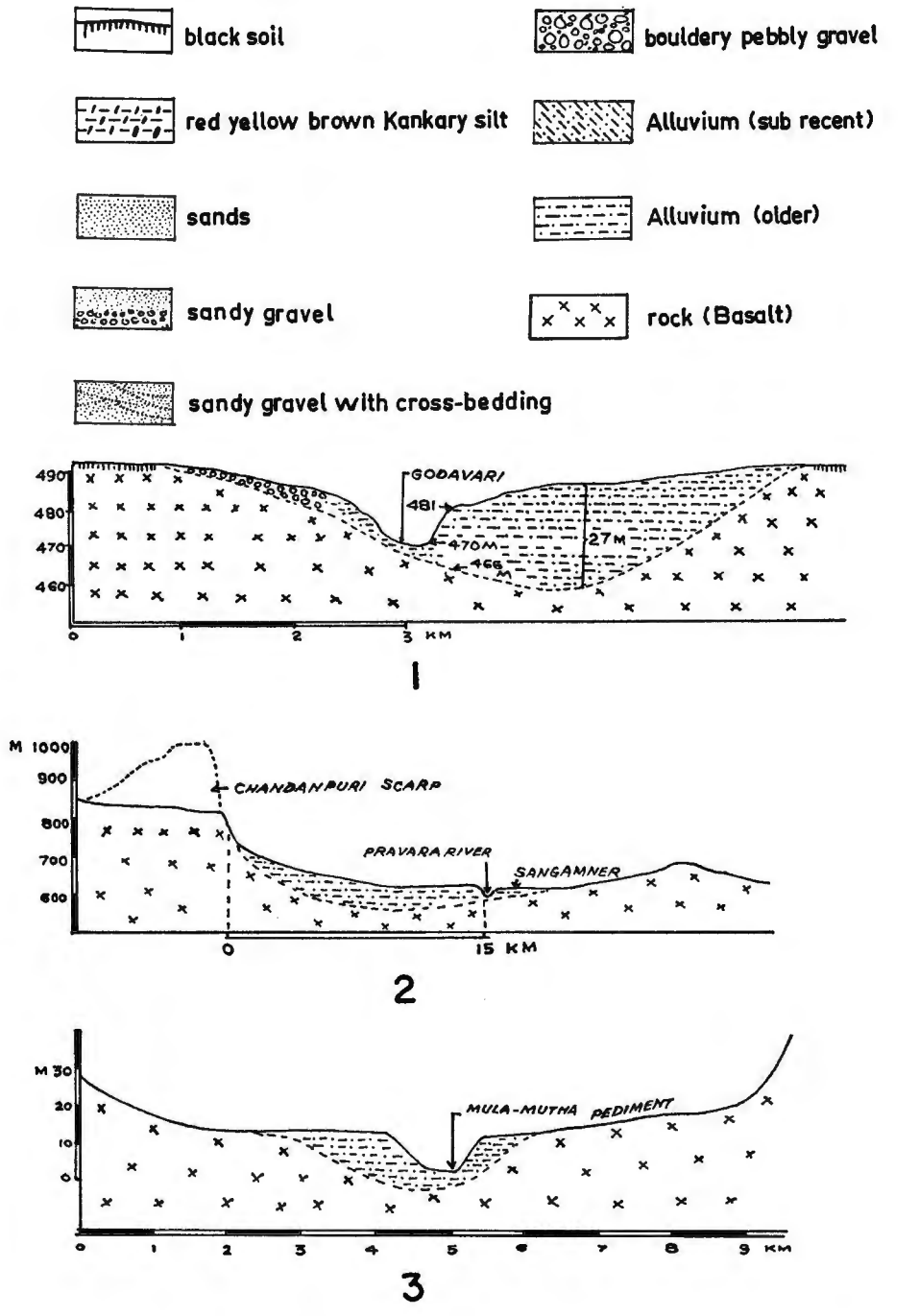


Fig. 2. 1: Cross section of the infilled valley of the Godavari river at the dam site of Paithan. (Partly based on bore-hole data.) 2: The Pravara valley alluvium near Sangamner. 3: Pediment and alluvium of the Mula-Mutha river near Poona.

variable and the cement is calcareous. The gravels occur as lenses almost throughout the depth of the exposed alluvium in most of the streams. The thickness of the gravels vary from 0.5 to 10 m.

Biological and cultural finds from the gravels

In the following table the location and position of important biological and cultural materials found in a stratified context is given.

Table No. 1

Sr. No.	River Valley	Site	Faunal/Floral material	Cultural material	Lithological[5] context
1	2	3	4	5	6
1	Godavari	Gangapur	*Bos namadicus* (Joshi 1967)	Early Stone Age tools	Sandy pebbly gravel + 2 m
2	Godavari	Nandur Madhmeshwar	*Unio* shells	–	Sandy pebbly gravel + 5 m
3	Godavari	Paithan	*Bos* sp.	Middle Stone Age tools	Sandy pebbly gravel – 3 to + 5 m
4	Pravara	Nevasa a.	*Bos namadicus, Unio, Dicotylo-*	Early Stone Age tools	Rubble gravel + 5 m to + 12 m
		Chirki Nevasa	*dons* (fossil wood) (Corvinus, 1971)	Middle Stone Age tools	Sandy pebbly gravel + 10 m
		b. Hathiwell Nevasa		Early Stone Age tools Middle Age tools	Bouldery gravel sandy pebbly grauel + 0.5 m to + 13 m
5	Mula	Mula-dam a. Main Cut-off trench (Fig. 3 ; 3)	*Bos namadicus, Bubalus bubalis, Terminalia wood* (Rajaguru, 1968)	–	Pebbly sandy gravel – 10 m
6	Mula	b. Spillway trench (Plate IX, a)	*Bos namadicus, Elephas* tusk	Middle Stone Age tools	Sandy pebbly gravel – 3 m
		c. Baregaon Nandur	–	Middle Stone Age tools	+ 3 m
7	Purna	Yeldari dam Pit at Power house	*Bos namadicus, Elephas hysudricus, Stegedon insignis, Elephas* sp.	–	Sandy pebbly gravel – 6 m

[5] The height of lithological units in reference to a find is given with respect to the modern bed level of the stream taken as a zero datum.

Sr. No.	River Valley	Site	Faunal/Floral material	Cultural material	Lithological[5] context
1	2	3	4	5	6
8	Bhima	Pandharpur	–	Early Stone Age tools	Sandy gravel + 1.5 m
9	Bhima	Dhond	*Bos* sp.	Middle Stone Age tools	Sandy pebbly gravel + 2 m to + 5 m
10	Ghod	Inamgaon	*Bos, Elephas* sp.	Middle Stone Age tools	Bouldery gravel + 1.5 m
			Unio shells		Pebbly gravel + 1 m to 6 m
11	Ghod	Kalamb	*Elephas*[6] *hysudricus*	–	Sandy pebbly gravel + 1 m
12	Krishna	a. Dhom Dam	*Unio* shells and *Elephas*-tusk		Bouldery gravel + 8 m
13	Krishna	b. Borkhal Dam (Fig. 3 ; 2)	*Elephas*-tusk	–	Sandy pebbly gravel + 10 m
14	Krishna	Asle near Wai	*Unio* shells	–	Sandy gravel + 3 m

Pieces of semi-carbonized wood from Mula-Dam and fresh water shells from Inamgaon, Dhom-Dam and Paithan were sent to the laboratory of the Tata Institute of Fundamental Research, Bombay for C^{14} dating. The following table gives the absolute dates as obtained by Agrawal (1971).

Table No. 2

Sr. No.	Site	Reference No.	C^{14} dates based on τ 1/2 = 5730 yrs. in years B. C.
1	Inamgaon	TF - 1003	19 775 + 630 — 585
2	Dhom-Dam	TF - 1004	37 640 + 9 200 — 4 250
3	Mula-Dam	TF - 345	30 030 + 5 715 — 4 245
		TF - 217	> 39 000
4	Paithan	TF - 891	17 075 ± 660

Mode of deposition of coarser gravels

These gravels are fluvial in origin and have been laid down as channel bar, channel lag and point bar deposits. The stream braiding and meandering have been mainly responsible for their deposition. The

[6] This fossil was discovered in company with Dr. Z. D. Ansari, Deccan College, Poona.

poor sorting and grading, the longer lengths of foreset beds, the crude stratification in bouldery gravels suggest their deposition by fast moving torrential streams. However, the rubble gravels, especially from Chirki on Pravara, seem to have been deposited mainly through colluvial processes.

The Quaternary formations in relation to valley morphology

For reconstructing the morphological history of the various streams in western Maharashtra, data were also collected on the total depth and lateral extent of the formations from various dam and bridge construction sites in the region, and have been given in the following table.

Table No. 3

Sr. No.	River Valley	Site	Maximum depth of the alluvium from the terrace level (Fig. 4)	Maximum depth of the alluvium below the river bed level	The deepest position of the ancient channel, in relation to the present channel
1	Godavari	Gangapur-Dam	12 m	–	–
2	Paithan	Paithan Dam (Fig. 2; 1)	27 m	3 to 5 m	On the south
3	Pravara	Nevasa-Shrirampur Bridge	24 m	10 m	On the north
4	Mula	Mula-Dam (Fig. 3 ; 3)	40 m	20 m	On the south
5	Kukadi	Dam site near Narayangaon	24 m	10 m	On the north
6	Bhima	Ujani-Dam (Fig. 3 ; 1)	14 m	2 to 3 m	No change
7	Krishna	Dhom-Dam (near Wai)	35 m	7 m	No major change
8	Krishna	Takari Bridge (near Sangli)	35 m	11 m	On the north

The above table shows that the alluvium is usually not more than 50 m thick. The depth of the exposed alluvium varies from 10 m to 20 m and the lateral shift in the course of a stream is within a range of 5 to 6 km. The terraces are of cut and fill type. The older terrace, constituted by calcareous brownish silt and bouldery and pebbly gravels, is quite conspicuous in the region and occurs at an elevation between 10 to 20 m above the modern bed level. Another younger terrace is inset into the above terrace at a height of about 5 to 7 m and naturally has a limited spatial extent. The younger terrace is composed of dark brown silt and sandy gravels (Fig. 4).

At times the older alluvium is partically or completely replaced by the younger alluvium.

From these limited data on the total thickness of the alluvial fill it can not be said with confidence whether or not the upper reaches of the Godavari and Krishna are warped basins as hypothetically proposed by Vredenburg (1906). They only indicate that alluvial fills are deeper in the Godavari valley than in the Bhima valley. The Pravara in its source region between Akola and Sangamner has an extensive, 16 km long, alluvial fill (Fig. 2 ; 2). As stated earlier, the alluvium generally merges into val-

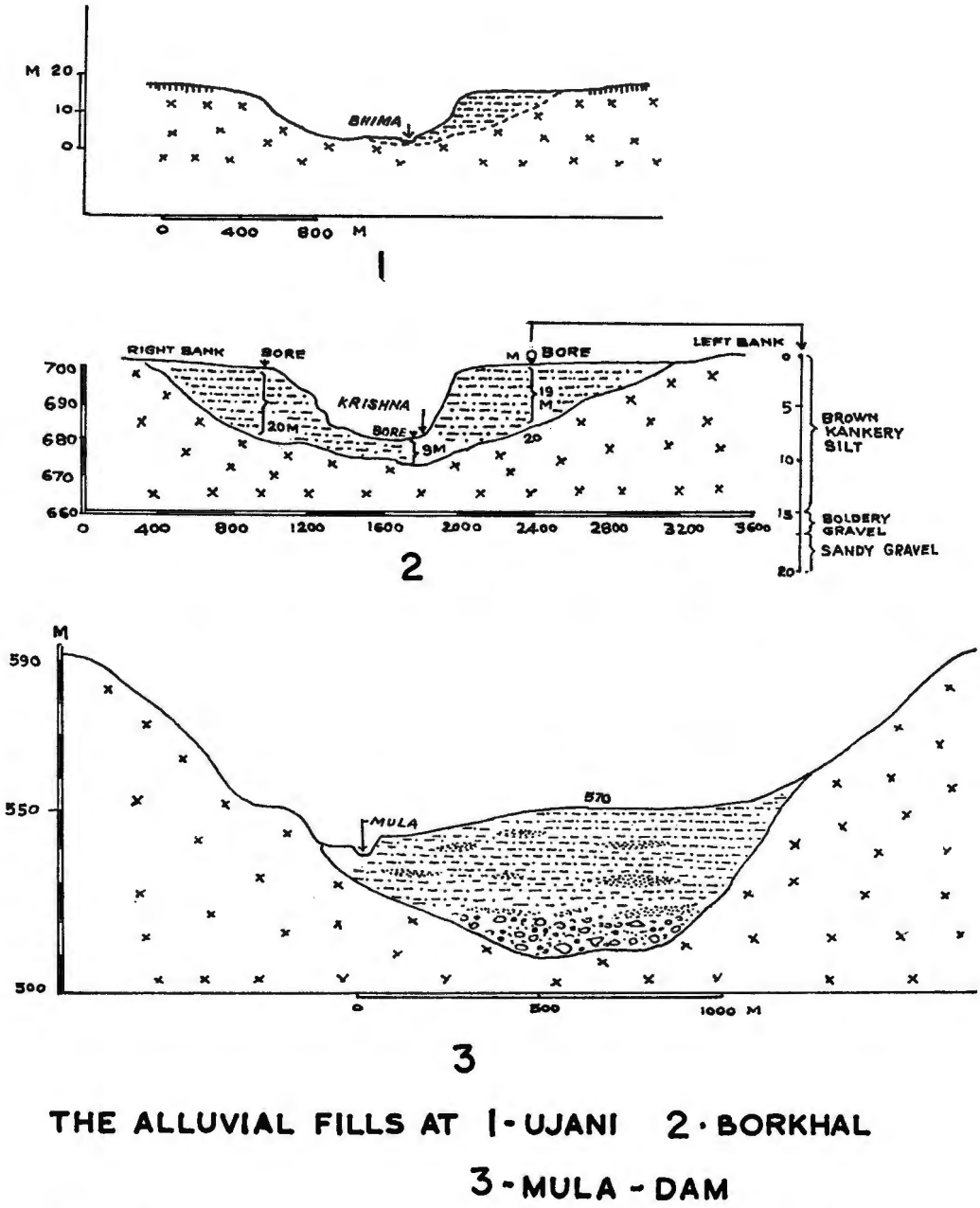


Fig. 3. 1: Section across the Bhima river at Ujani near Sholapur. 2: Section of the Krishna river a Borkhal dam near Satara. (Based on bore-hole data.) 3: Section at the dam site of the Mula river near Rahuri. (Based on excavation.)

ley pediments which further pass into concavo-convex slopes of the inter-fluves. The lateral extent of the alluvium is generally not more than 2 to 3 km on either bank of a stream. The valley between Akola and Sangamner, therefore, seems to have been a basin of accumulation of sediments in the late Quaternary. The question then arises as to why is it only in the Pravara valley that the alluvium is unusually extensive and lies direct against the scarp of the interfluve (Plate VIII, b). Such accumulations can occur when

a) there is unusually intense erosion in the source region of a river,
b) there is a rock-barrier such as a dyke,
c) a basin is formed by tectonic warping, a favourable place for the accumulation of sediments, and
d) when there is a decrease in the transportation capacity of a stream due to a river capture.

Careful examination of the Pravara valley below Sangamner has not revealed the presence of any large dyke or any geological formation and structure which could have acted as a barrier to the stream during the aggradational stage of the Pravara. The surficial geology and the environmental conditions in the catchment area of the Pravara valley are in no way different from the geology and environment in other valleys in western Maharashtra.

Further there is no evidence of capturing of the headwater portion of the Pravara in the post-Miocene period and hence the probability of reduction in transportation capacity of the stream due to stream piracy during the Quaternary is thin. Thus it appears that large scale factors such as tectonic movements and climatic changes have been responsible for the unusual geomorphic feature in the Pravara valley.

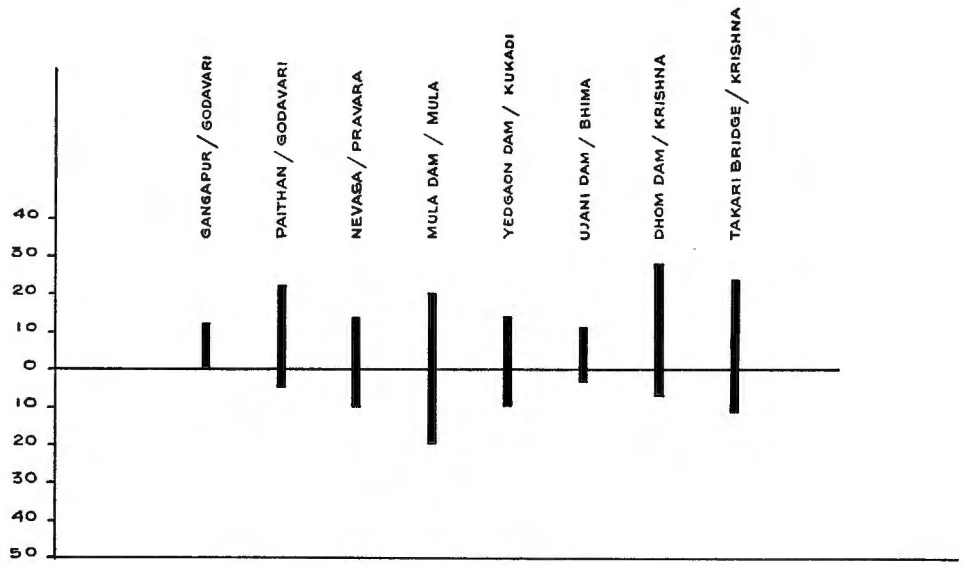


Fig. 4. Thickness of the older alluvium in Western Maharashtra.

The Quaternary chronology, tectonics, and climatic changes

a) Chronology:

The Older[7] alluvial formations can be correlated by means of faunal, cultural and lithological methods. The absolute dates obtained by radiometric methods are extremely useful for correlation. In practice these methods overlap to a considerable extent.

1) Faunal material: The following extinct species of Bovids and Proboscids have been discovered by us (Rajaguru, 1968).

[7] The term "Older Alluvium" was initially proposed by earlier geologists (Pascoe, 1964) to differentiate the Pleistocene alluvium from the recent alluvium (Younger Alluvium) found in various river valleys in Peninsular India and in the Indo-Gangetic plain.

Bos namadicus, Elephas hysudricus, Stegedon insignis and *Bubalus bubalis.* In addition to these, earlier investigators had found the following mammalian species in the older alluvial formations of the Godavari and the Pravara (Pilgrim 1905, and Tripathi 1967):

Hippopotamus palaeindicus, Rhinoceros unicornis, Elephas namadicus, Stegedon insignis ganesa, Cervus duvaucelli, and *Equus namadicus.*

Most of the molluscs found by us and by other scholars are of *Unio* and *Corbicula* types. A few examples of *Planorbis* and *Lymnaea* have also been found. All these molluscan species are identical to their modern counterparts and hence are of very little use in stratigraphy.

More or less similar type of mammalian fossils have been recovered from the Older alluvium of the Central Narmada, Ganges and its tributaries, from the Boulder Conglomerate stage of the Upper Siwaliks, and from the Arkosic sand-stones of Sayamalai, Tamilnadu. On the basis of faunal characteristics Tripathi (1970) has dated these formations to the Middle Pleistocene.

The dating of the Older alluvium to the Middle Pleistocene may not be entirely correct, at least in the Central Narmada and in the Godavari. In recent years it has been observed that the Middle Pleistocene Species occur in association with the Middle Stone Age tools and with the carbonized wood at Mula-Dam which has been dated to about 30,000 years B. P. (Rajaguru, 1970). So far, it has not been possible to detect any difference in the evolutionary stages of the different forms recovered from the Older alluvia of the region under consideration. It appears that the early forms of the Pleistocene fauna persisted almost till the end of the Pleistocene in this region and hence the palaeontological material cannot be relied upon for the precise dating of the Quaternary formations of western Maharashtra. It should be emphasised that more detailed palaeontological studies are necessary if we want to use faunal evidence for dating alluvial deposits and the associated cultural materials. Dating based on stray finds of fossils should be avoided.

2) Cultural material: The greater part of the Older alluvium in the region has mostly yielded Middle Stone Age tools. It is only at a few places like Gangapur near Nasik in the Godavari valley and at Chirki on Pravara that we get Early Stone Age tools in a stratified context. At Chirki (Fig. 3) Early Stone Age tools have been found in the basal rubble horizon. Supekar (1968) found, however, Middle Stone Age tools in association with Early Stone Age tools in the basal Boulder conglomerate of the central Narmada at Mahadeo-Piparia (District Narsinghpur, M. P.). These two examples clearly indicate how difficult it is to form a chronological framework based merely on cultural units. It should be remembered that terms like Early, Middle and Late Stone Ages are lables for cultural stages with appreciable spatial and chronological overlaps and they do not in any way denote even a relative time.

3) Lithological units and geomorphological events: The following features of the alluvial deposits and of the morphology are commonly observed in western Maharashtra.

I) A pre-aggradational cutting phase.

II) A major aggradational phase as represented by a conspicuous alluvial terrace occuring at elevations varying from 7 m to 20 m from the modern bed level. The Older alluvial deposits are characterised by coarser gravels in the lower parts and by brownish calcareous silts in the upper parts. Interfingering of gravels and silts is quite common and the disconformable contacts are produced mainly due to the cut-and-fill phenomena.

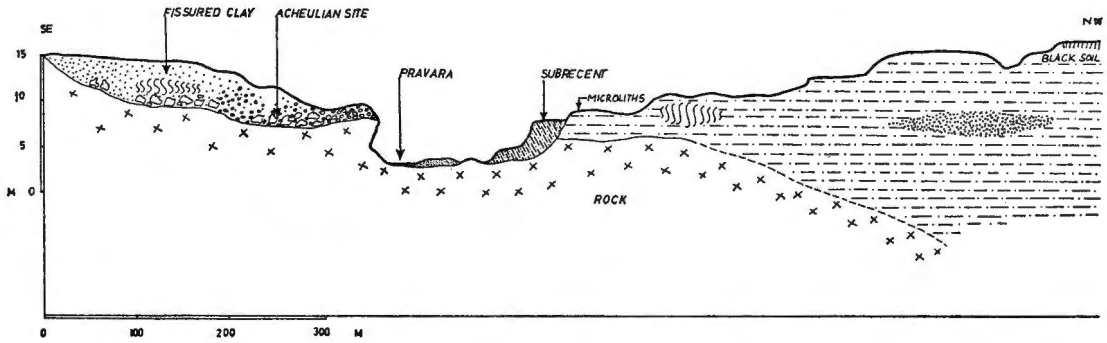
III) A major cutting phase of the Holocene with a minor aggradational phase represented by the dark-brown, and less calcareous, finely laminated silt. These deposits have formed an inset type of terrace, at an elevation of 5 to 7 m from the modern bed level.

These three stages are observed not only in western Maharashtra but also in almost the whole of Peninsular India. The causes responsible for such features must, therefore, be operating on a regional scale.

They could be either tectonic or climatic. Eustatic changes are not likely to have controlled the behaviour of streams under consideration as they are far off from their mouths about 1000 to 1500 km.

The main problem is whether it is possible to build up time stratigraphic units on the basis of lithological characters alone in the major aggradational phase.

The alluvial facies mainly include bouldery gravels, pebbly gravels, sandy gravels, brownish silts, and yellowish brown silts. As stated earlier these deposits are governed by the local environmental factors to great extent for example, bouldery gravels are common only in the upper reaches of most of the streams, and reddish brown or brownish silts are more uniform and finer in texture in the Krishna valley than the yellowish brown silts of the Godavari – Pravara valleys. The rubble gravel of Chirki-on-Pravara and the reddish brown silt occuring below the Early Stone Age tool bearing gravel at Gangapur near Nasik are of local occurrence only. As the vertical range of the fluctuation of the channel of a stream is restricted here to less than 50 m and as the lateral shifting of a stream is also of a limited range of not more than 6 km, the alluvial formations seem to have been subjected to considerable erosion, reworking and redeposition in the period under consideration. The erosional disconformities, in the form of cut and fill structures, are common, but it has not yet been possible to estimate the time lapse represented by them.



CROSS SECTION AT CHIRKI ON PRAVARA

Fig. 5. Cross section through the Pravara valley at the Acheulian site of Chirki-on-Pravara.

By the modern concept of stratigraphic geology, most of the Older alluvial formations in western Maharashtra, can be classed as 'rock units' as distinct entities having physically recognizable boundaries, but their use as 'time stratigraphic units of rock' is not possible because of the paucity of good palaeontological materials and the near absence of radiometric dates for the Older alluvium.

If the four C^{14} dates obtained from the region are accepted then the greater part of the Older alluvium does not appear to be older than 50,000 years. Therefore, the older alluvium of western Maharashtra could be dated to the late Quaternary period.

b) The Quaternary Tectonics:

The main geomorphological features suggesting that Quaternary tectonic movements have taken place in western Maharashtra are:

1. The Western Ghats
2. The entrenched meanders of the Pravara between Rajur and Akola
3. The water falls on some rivers like Godavari and the Pravara and
4. The in-filled nature of the Pravara between Akola and Sangamner.

1. The Western Ghats: They form a peculiar continental divide extending in a NNW–SSE direction for a distance of over 1200 km lying between latitudes 8° and 21° N and longitude 73° and 78° E approximately. The scarp on the western side of the Ghats is maintained on horizontal basalt, inclined schists and gneisses and massive charnockites. The geophysical evidence shows very high negative gravity anomaly figures below the Western Ghats and an immediate positive gravity anomaly zone in the coastal part. This evidence therefore suggests that the Western Ghats are an upraised and disrupted continental block very similar to the Drakensberg scarp of South Africa (Radhakrishna, 1967). The geological studies carried out so far have failed to detect any direct evidence of faulting or folding in the Western Ghats of Maharashtra. Only shear zones have been reported at some places.

The Ghat seems to have originated not earlier than the early Miocene as there are no marine sediments earlier than Miocene on the West coast of India (Radhakrishna, 1967). The absence of any major river captures on the crestline of the Ghats where situations for such a phenomenon is extremely favourable, and the fresh, youthful look of the scarp face suggests a late date, Pliocene or early Pleistocene (Spate, 1952). The geomorphic features thus indicate that the western margin of western Maharashtra was tectonically unstable till the Miocene or even possibly up to the early Pleistocene.

2. The entrenched meanders of the Pravara: They may be either due to the rejuvenation of the valley floor or by the expansion of meanders during the process of downcutting unrelated to the rejuvenation. Entrenched meanders formed by rejuvenation, show symmetrical valley profiles, while those formed by a simple process of down cutting are asymmetrical in transverse profile (Easterbrook, 1969, p. 193). In the present case the valley profiles are more or less symmetrical and therefore the meanders have been formed by rejuvenation. The rejuvenation belongs to the period prior to the late Pleistocene aggradational phase. The other streams in this region do not show entrenched meanders and therefore a rejuvenation of such very localized nature in the Pravara valley is probably due to tectonic movements and not to climatic changes.

3. The waterfalls: Most of the waterfalls are in the source regions of the streams and they are either the normal cap-rock type (e. g. near Wai in the Krishna valley) or occur as a major knick point between the contact of two erosional surfaces (e. g. near Gangapur in the Godavari valley). But the waterfalls on the Pravara, Adula (Plate IX, b), Venna etc. do not appear to fall in these categories. King (1962, p. 327) postulates a late Cenozoic warping of the marginal coasts and an uplift of the interior plateau of the Peninsula. He regards the waterfall on the Venna as a knick point of Quaternary age that has advanced as a fall almost across the whole breadth of the Peninsula. In the Pravara valley, the falls occur in a roughly WNW-ESW orientation and at an approximate elevation of 700 m above sea level. The falls and their gorges are older than the late Pleistocene aggradation because the late Pleistocene alluvium is found to be resting against the walls of the gorge in the Pravara valley.

4. The infilled valley of the Pravara between Akola and Sangamner: It has already been shown earlier that the infilled valley in this region is really an unusual geomorphic feature in western Maharashtra and therefore it appears that this part of the Pravara valley is likely to have been involved in vertical movements affecting its longitudinal profile. The presence here of entrenched meanders, the waterfalls at similar levels both in the Pravara and its tributary valleys, and the existence of the highest peaks of the Western Ghats in the source region possibly support the tectonic hypothesis. As detailed geological data are lacking, no definite statement can be made about any tectonic movements in the Pravara valley. Burrard's geophysical work (Krishnaswami, 1954) possibly indicates the possibility of vertical movements in the source region of the Pravara. Further, the tectonic instability of the region is also indicated by a strong earthquake of December 11, 1967 in the Koyna valley.

The knowledge about the neotectonics in western Maharashtra is still very inadequate. The precise dating of various tectonic events is not possible at this stage. It can only be surmised that the region under

consideration was tectonically active till Miocene, Pliocene or even early Pleistocene and the effects of these crustal movements may have influenced the landscape development during the whole of Pleistocene.

c) The Quaternary climatic changes:

In the absence of a sound knowledge of the neo-tectonic history of western Maharashtra discussions of the late Quarternary climate in the following paragraphs is bound to remain a working hypothesis only. The focus of attention in these studies is mainly on the rainfall changes, the other facets of climate such as temperature, and pressure have not been dealt with. In the absence of a good number of pollens, microfossils and climatically sensitive vertebrate and invertebrate fossils in the late Quaternary alluvium, the palaeoclimatic conditions have to be inferred from the geological evidence alone.

Climate wetter than that of to-day is indicated by the following features:

1. The Pravara and the Godavari had a greater competence during the late Quaternary than in the modern times. This is indicated by the coarser older gravels at Nevasa and Paithan where the modern bed material is comparatively fine.
2. The large scale general deposition of mature silty alluvium indicate a higher rate of chemical decomposition as opposed to the present day dominance of physical disintegration in the semi-arid parts of the region.
3 The Older silts at Poona and Wai contain higher proportion of kaolinite. The modern flood silts are dominated by montmorillonite. Thus, the greater leaching of soils suggests more moisture during the late Quaternary. The rise in mean annual rainfall corresponds to about 25 percent.
4. The present "Misfit" situation of most of the streams in their late Quaternary broad floodplains also inidicates more rainfall.

A climate drier than that of to-day is only indicated by some of the heavily calcified alluvia in the area where present mean annual rainfall is about 1000 mm. Flint (1963) considers these secondary carbonates as indicative of a dry climate and they seem to form best under conditions of about 450 to 500 mm of rainfall per annum.

The sedimentological features described above suggest that the climatic changes have not been of sufficient magnitude to alter significantly the present day climatogeomorphic pattern. Climatic changes of the late Quaternary were of degree only and not of kind. Intensification and slackening of phenomena might have taken place. The present monsoonic climate and the rainfall distribution from west to east essentially remained more or less the same in the late Quaternary. The present evidence is too meagre to establish the occurrence of distinct "climatic cycles" in this region. We are, therefore, of the opinion that earlier attempts to construct a chronological framework for the Quaternary solely on the evidence of climatically induced gravel-silt sequences are not convincing.

Thus, our study of Quaternary formations from various river valleys in western Maharashtra has clearly shown that the problems of valley morphology, stratigraphy and paleoclimatology are exceedingly complex. Some of the geomorphological and palaeoclimatic interpretations may, therefore, require modification as our knowledge regarding modern fluvial processes in monsoonic climates, the mechanism of the monsoon itself and the neotectonic activity in this region advances in future. The conclusions drawn here have, therefore, to be taken as a part of a working hypothesis and may serve as a basis for further work.

Abstract

The Quaternary formations from western Maharashtra are confined to various river valleys only and are of fluvial origin. Their thickness is not more than 50 m. Their late Quaternary age is indicated by

the presence of fossil species such as *Elephas namadicus* FALC. & CAUTL. and *Bos namadicus* FALC. As per a few C^{14}-dates of carbonized pieces of wood and fresh water mollusks the major portion of the exposed alluvial formations do not appear to be older than 40,000 years B. P. The various cut and fill sequences observed in these alluvial formations are mainly due tomilder tectonic changes and less due to climatic changes. The morphological features such as infilled valleys, entrenched meanders and waterfalls suggest the existence of tectonic movements of epirogenic type. That the climate was slightly wetter than today is indicated by higher competence of streams and by higher leaching of soils. Early as well as Middle Stone Age man was occupying this region throughout the Quaternary. (The terms Early and Middle Stone Age are according to African terminology.)

Zusammenfassung

Pleistozäne Sedimente sind in Maharashtra sehr begrenzt und nur an die Täler der nach Osten fließenden Ströme gebunden. Sie sind fluviatilen Ursprungs. Die Mächtigkeiten übersteigen nicht 50 m. Ihr jüngeres pleistozänes Alter wird durch die Anwesenheit von Fossilien wie *Elephas namadicus* FALC. & CAUTL. und *Bos namadicus* FALC. gekennzeichnet. Einige C^{14}-Daten (von Holz und Süßwasser-Mollusken) weisen auf ein Alter von nicht mehr als 40 000 Jahren für die untersuchten Sedimente hin. Die Serien verschiedener Erosions- und Aggradationsphasen im Alluvium sind durch tektonische Bewegungen und weniger durch klimatische Fluktuationen erklärbar. Geomorphologische Erscheinungen wie Wasserfälle, tief eingeschnittene Mäander und Sedimentfüllungen von Tälern weisen auf tektonische Bewegungen epirogenen Charakters hin. Das Klima war zwar etwas feuchter als heute, da die Ströme höhere Wasserkapazität hatten und die Böden tiefer ausgelaugt wurden, jedoch handelte es sich weder um Pluviale noch um größere Schwankungen, sondern nur um leichte Fluktuationen innerhalb des monsunalen Klimas.

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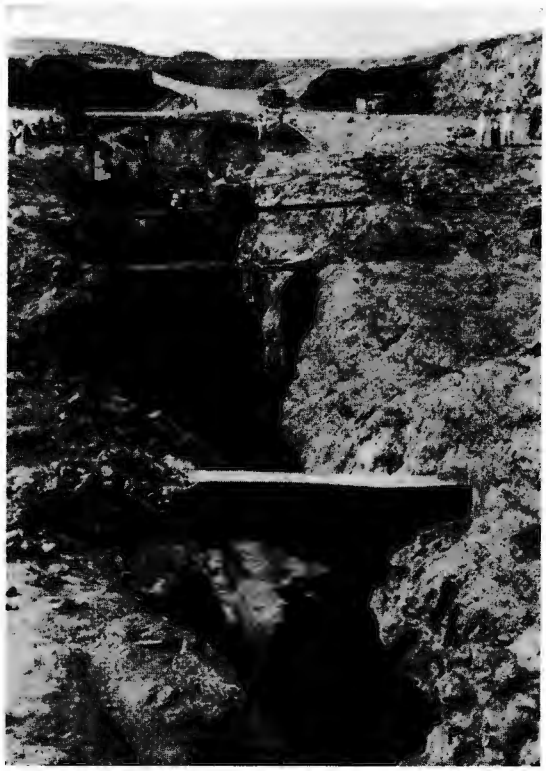
a: Rejuvenation with alluvial cliffs, Adula river, a tributary of the Pravara river.

b: Infilled basin of the Pravara at Sangamner.



a: Spillway cut-off trench, Mula dam.

b: Waterfall in the Adula valley.