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Quaternary History of a Part of the North Eastern Fringe of the Thar Desert, India

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Abstract An attempt has been made to establish the Quaternary stratigraphic sequence of the north-eastern fringe of the Thar desert, based on the lithological character, physical order of superposition, artefacts and organic/pottery remains. Semi- quantitative study of detrital qartz grains under SEM, and X-ray analysis of minerals have been utilised to reconstruct the environmental evolutionary history.

The studies reveal three sedimentary cycles in the area. Each cycle commenced with a fluvial phase and through a transitional playa stage culminated in an aeolian phase. The dunes of each aeolian phase have their own characteristic features. Oldest dunes are mostly modified, the second phase of dunes are parabolic and obstacle, and the youngest ones are mainly of obstacle, parabolic, longitudinal and barchanoid types. The last mentioned dunes have derived sand from the reactivation of older dunes.

Key words Quaternary geology, Quaternary history, Paleoenvironment, Thar desert

Vast area to the east of the Jaipur upland and around the north- eastern part of the Aravalli hill gaps is covered by Quaternary lithological units which are product of aeolian, fluvial and lacustrine playa environments.

Verstappen (1970), Sinha (1977), Roy (1978), Wasson et al. (1983) and Raghav (1986) attempted to interpret the geomorphology and palaeoclimate of the adjoining desert terrain. The purpose of this study was to reconstruct the Quaternary evolutionary history of the region and to study geomorphological features of the terrain for assessing the environment. The study area covers 10,000 km^2. of the north-eastern part of the Aravalli hills and is bounded by N longitudes 74^o 45' : 75^o 50' and E latitudes 26^o 40' : 27^o 46'. The area is drained by the Kantli, Sobawati, Mendha and Rupangarh internal ephemeral rivers and the Bandi ephemeral river which is a tributary of the Yamuna.

Materials and Methods

Borehole, augerhole and dugwell logs, and deeply dissected river and gully sections were examined to reconstruct the lithostratigraphic sequence. Besides the sediments characteristics, pedogenised surface, artefacts, pottery, vertebrate and invertebrate remains were also studied.

Fifty two samples of silt, sand and clay (in < 95 mu fraction) collected from different environments (Table 1) were subjected to X-ray diffraction analysis.

Detrital quartz grains of sand samples (-1.25 and + 3 mesh size) were examined under Scaning Electron Microscope (SEM) following the procedure prescribed by Krinsley and Doornkamp (1973).

Results and Discussion

Quaternary Geology

Physical order of superposition of the quaternary sediments and various pedogenised surfaces (Fig. 1) reveal that the area witnessed three sedimentary cycles during the Quaternary period. Each cycle is characterised by following.

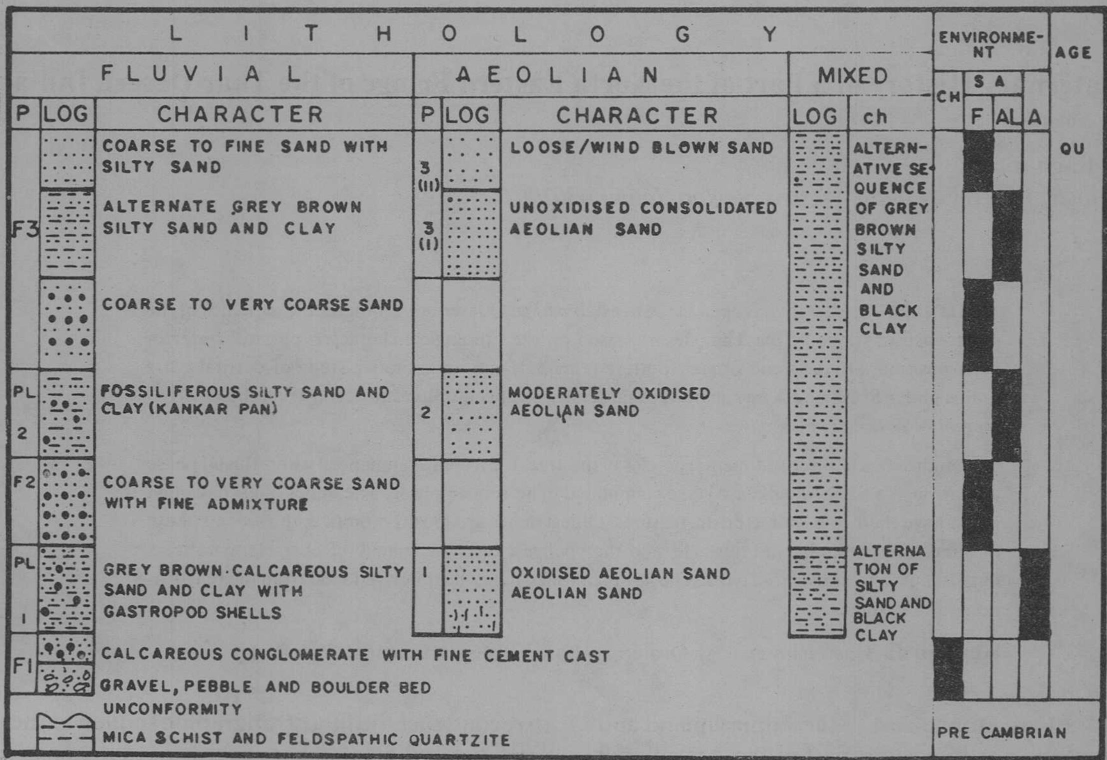

Fig 1 Lithostratigraphic correlation. P-phase, Ch-Character, CH-Humid, Sa-Semi arid, F-Fluvial, Al- Aeolian, A-Arid, Pl-Playa, Dominant Phase, Log- Lithological Unit, Qu-Quaternary

First sedimentary cycle : The cycle begins with a fluvial phase (F 1), having a boulder gravel bed at the base (colluvial/hill wash/fan material), occurring mostly at the foot of the hills. These are overlain by an alternating sequence of polymictic conglomerate and fine to coarse sand with calcareous cement (Fig 1). The clasts and the sand grains are angular and sub-rounded. The sand layers enclose fresh water gastropods.

In the south of the Sambhar Salt Lake, a calcrete bed resting over the rocky pediplain is overlain by 1 to 2 m thick calcareous silty sand and clay bed, enclosing gastropoed shells. This sequence is a possible time equivalent of the above mentioned fluvial phase (Raghav 1991).

The playa stage sediments (P1) conformably overlie the F1 deposits. These essentially comprise, alternation of compact calcareous grey-brown to gypsum white silty sandy layers and clay, enclosing fresh water *molluses* and ostracodes. Black silty sand and clay beds are also present in this sequence. The P1 deposits have intertonguing relationship in the upper part with the aeolian deposits (Fig 2 Stage 2). These are well exposed in the dug well sections to the south-southeast of the Sambhar Salt Lake. The organic remains found in these sediments include *Viviparous* sp., *Unio* sp., *Limnocythere* sp., and *Cyprids.*

The aeolian phase (A1) deposits have been largely modified by later geomorphological processes. Locally A1 deposits can be identified as obstacle dunes around the hills, longitudinal and transverse sand-ridges around the depressions (e.g. playa and lakes) and as flat sand sheet in areas away from the hills (Raghav 1991). The deflated

Table 1 *Mineralogy of the sediments*

Environment and stage	Minerals								
	Qz.	Plg.	Cal.	Dol.	Amp.	Kao.	Mont.	Ill.	Alk. Fel.
Swamp	D	D	R	–	T	R	D	D	–
(P_3)	D	–	D	D	–	R	R	D	–
(P_2)	D	R	D	D	–	R	R	D	–
(P_1)	D	–	D	D	–	R	R	R	R
Fluvial									
(F_3)	D	D	–	–	R	–	–	–	R
(F_2)	D	D	R	R	–	D	R	D	–
(F_1)	D	D	R	R	–	–	–	–	–
Aeolian									
(A_3)	D	D	–	–	R	–	R	R	–
(A_2)	D	D	–	–	R	–	R	R	–
(A_1)	D	D	–	–	R	–	R	R	R

P3 – Younger playa, P2 – Older playa, P1 – Oldest playa; F3 – Younger flood plain, F2 – Older flood plain, F1 – Oldest flood plain; A3 – Younger dunes, A2 – Older dunes, A3 – Oldest dunes.

Qz – Quartz, Plg – Plagioclase, Cal – Calcite, Dol – Dolomite, Amp – Amphibols, Kao – Kaolinite, Mont – Montmorillonite, Ill Illite, Alk.Fel – Alkali Feldspar

top surfaces of the dunes and sand sheet are covered by mesolithic stone implements.

The A1 sediments comprise reddish brown oxidised, non-calcareous rounded sand, having a thickness between 1.5 to 3.5 m. This oxidised layer is underlain by light yellowish to grey, calcareous sand with 1 to 15 cm thick calcareous concretions at depth.

Second sedimentary cycle : The palaeodrainage of this phase in the Mendha river basin is largely aligned in E-W direction. The fluvial Phase (F2) sediments rest over the pedogenised F1, P1 and A1 deposits (Fig 1). These are exposed as flood plain deposits south of the Sambhar Lake, along the banks of the Kantli river and in the upper reaches of the Bandi river. The sediments consist of alternation of light grey, coarse to fine grained sand, silty sand and clay. These show well developed calcareous soil profiles (Raghav 1991).

The surface of the abandoned playas represents playa stage of second sedimentry cycle (F2) and are exposed in the central part of the area. These playas are regionally aligned along the palaeochannels of the F2 system. These generally form broad flats or gentle centripetal depressions of subrounded or oval shapes, the latter being elongated in E-W direction. At places the present day rivers drain through these depressions (Raghav 1991). The P2 sediments consist of fossiliferous calcareous silty sand and clay alternation with 1 to 1.5 m hard kankar horizon in the Mendha river basin. These have an intertonguing relationship with A2 sediments (Fig 2). A 10 m thick sequence is exposed to the west of Sanjariya in the upper reaches of the Bandi river. The fossils in P2 sediments include gastropods, palecypods, ostracodes and a few doubtful vertebrates.

The aeolian deposits (A2) of this second cycle occur as stabilised longitudinal, transverse, parabolic and obstacle dunes and sand sheets.

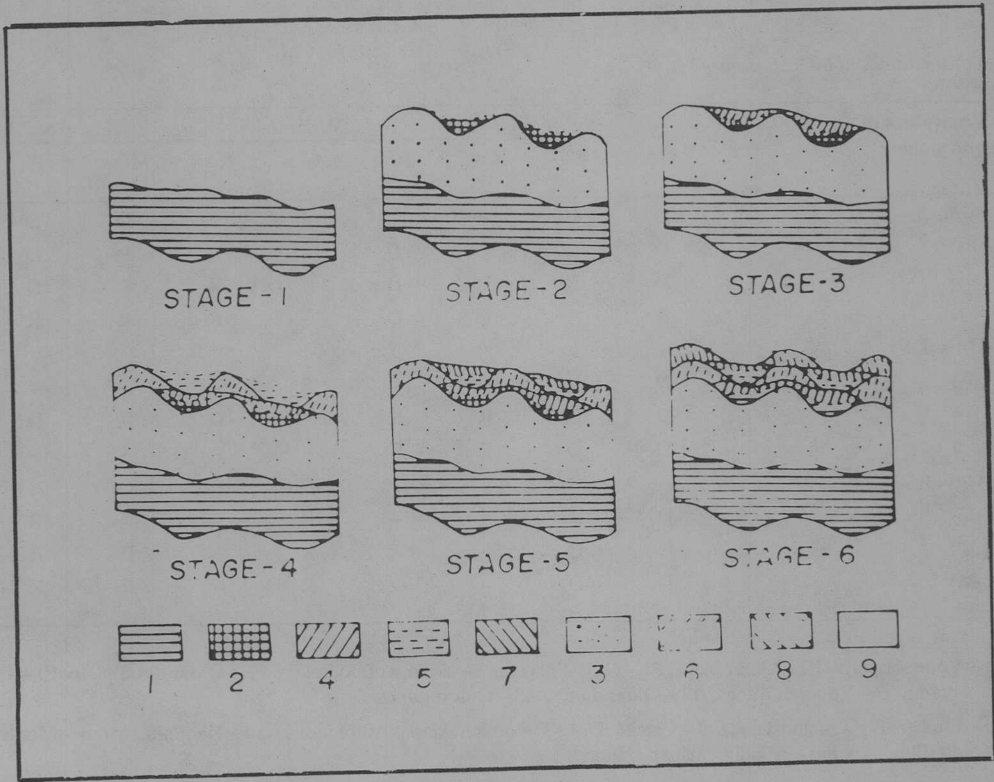

Fig-2 Geomorphic evolution of the North-Eastern part of the Aravalli Hill Gaps, Jaipur Upland, Rajasthan. Legend- 1. First phase of fluvial cycle, 2. First phase of lakes and playas, 3. First phase of aeolian cycle, 4. Second phase of fluvial cycle, 5. Second phase of lakes and playas, 6. Second phase of aeolian cycle, 7. Third phase of fluvial cycle, 8. Third phase of aeolian cycle, 9. Present lakes, playas and rivers.

These have been modified at places by biotic, aeolian and fluvial actions. These dunes have exercised parental control on subsequent topographic features (Fig 4).

The A2 deposits, showing interfingering with the P2 sediments in basal part, consist of moderately oxidised to light brown, non-calcareous rounded sand, underlain by pale yellow sand with sporadic 0.8 to 4.0 cm thick calcareous concretions at depth. The surfaces of these dunes/sand sheets are generally covered by black and red pottery.

Third sedimentary cycle : This pertains to the present day drainage which is broadly dendritic and is partly controlled by the structure. These fluvial phase (F3) sediments consist of light coloured calcareous to non-calcareous, coarse to fine silty sand and clay, alongwith common transported calcareous concretion and gastropod shells. These occur along the present channel courses. This sequence is gradually followed upward by alternation of silty sand and clay with aeolian sand along the flood planes.

The playas of this age (P3) are located along the channels of the present day aggrading rivers. Several shallow depressions and the Sambhar and the Zeenmata Lakes represent this stage. The dry surfaces of playas and lakes of the area are covered with glistening carbonate salt. This salt seems to have been washed down from the surrounding sand dunes by meteoric water and precipitated over the surfaces of the playas and lakes due to high rate of evaporation. The P3 sediments are made up of thinly laminated silt, sand and black clay with sporadic mud and fine sand. These are coeval with F3 and A3 deposits and show interfingering relationship with both at several places. In some places evidences of old habitation have been found in the playa deposits, suggesting flooding of these areas in recent times.

The aeolian sediments of this cycle (A3) can be further sub-divided into two : (1) semi-consolidated longitudinal, transverse, parabolic, barchanoid and obstacles dunes. These comprise pale non-calcareous to calcareous sand with minor calcareous concretion in the obstacle dune fields. Aeolian deposits of this kind are under the processes of erosion, accretion and stabilisation, and (ii) the barchan, linear, star and shrub coppice shapes dunes. These are shifting dunes which occur (a) at the top of the older dunes, (b) bordering the courses of the presently aggraded rivers, (c) around the playas, shallow depressions and (d) around the civil construction sites.

Paleo-environment

Dominance of quartz, feldspars, kaolinite and illite minerals in sediments (Table 1), and disc shaped pits and irregular to en echelon patterns of V-shaped pits and troughs along the clevages (Fig, 3.a,b) indicate the sediments of pluvial environment. Higher content of calcite, and illite with quartz, plagioclase, montmorillonite minerals with polyphase upturned plates and prism shaped pits with an en echelon V-shaped pits and irregular V-shaped troughs on detrital quartz surface (Fig. 3 c) showed the playa environment. The absence of calcite and kaolinite minerals in sediments and arc, crescent and disc shaped irregular pits, mender and sharp fractures on detrital quartz (Fig. 3d) evidenced aeolian environment.

Discontinuous imbricated ribs and furrows (Fig 3c) striations and trough features observed on sand grains of dunes indicate that the sediments could have glacial provenance.

Quaternary History

The above study suggests the commencement of the Quaternary sedimentation in this part with a fluvial cycle, possibly accompanied by neotectonics which rejuvenated the slopes and generated colluvium and fans. During this period present day lakes like Sambhar and Zeenmata probably constituted part of a well organised drainage. The onset of aridity reduced the discharge resulting in unloading of the sediments (F1). The sediments thus deposited caused formation of playas along various river channels. The playas became sites of deposition of the P1 sediments. As the aridity increased, the river beds further dried up and possibly became sources of aeolian sands, contributing to A1 dunes and sand sheets (Fig 2). The presence of quartz having glacial history, suggest partial derivation of sand from moraines and/or loess of the Himalayan terrain due to southerly flowing rivers and winds.

The presence of mesolithic implements over A1 surfaces marks the end of the first fluvial aeolian cycle during certain period, which is still a controversy and is yet to be ascertained. Different authors have given their different dates but no one arrived at the exact quantification. Pedogenesis of F1, P1 and A1 sediments took place towards the end of this period (Fig 2).

The climate once again ameliorated as is evidenced by the cutting of the A1 dune by the channels of the F2 phase (Fig 2, Stage 2). The entire cycle through P2 stage reached upto A2 was was once again undergone repetition during the period between mesolithic implement and blackred potteries. The A2 dunes posed obstruction over which the A3 sand got accumulated. After the pedogenesis of the F2, P2 and A2 sediments, the third and final cycle commenced. This cycle, represented by the present day rivers, indicates yet another amelioration of the climate which soon relapsed in the semi-arid phase. Though broadly a fluvial-playa-aeolian chronological order can be established, much of the sedimentation under all the regimes is also simultaneous. Thus, based on the present day model, it may be suggested that in

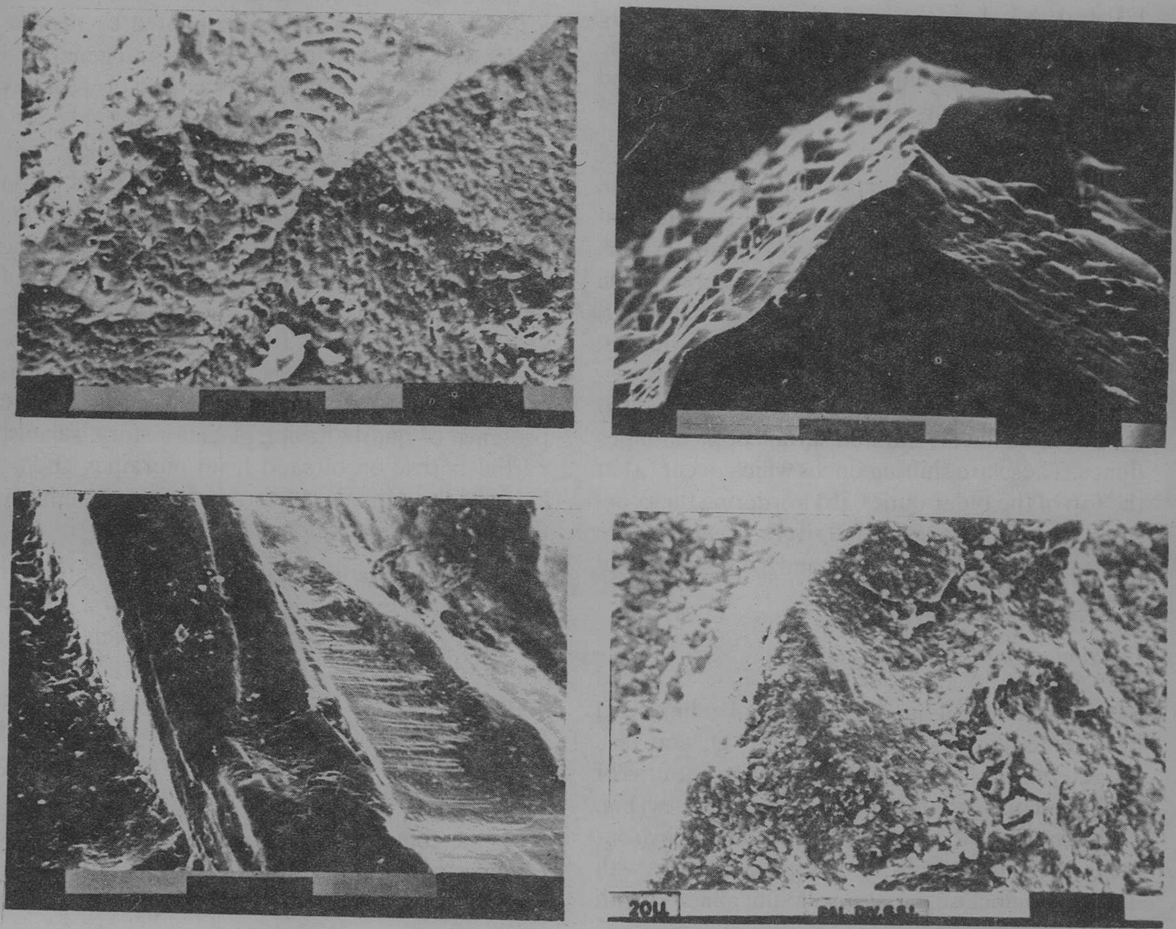

Fig 3 SEM, Microphotographs of Detrital Quartz Sand Grains (a) -Arc and disc Shaped pits and polyphase upturned plate (b) En echelon V shaped pits and etch marks (c)-Striation and trough marks bounded with silica coating (d) Cracks and fractures with solution cavity

the past too atleast some of the fluvial, playa, and aeolian sedimentation was coeval and also the source of most of the sand in the dunes was local, due to remobilisation of fluvial sand with negligible contribution from the Thar desert.

From the present study the following conclusions have been drawn:

1) The basement Precambrian rocks are overlain by 3 cycles of sedimentation during the Quaternary period.

2) The sedimentation in the Quaternary period begin with humid climate, followed by semi-arid to extreme arid phase, and is succeeded by semi-arid climate phase with dominance of alternating wet and dry phase.

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