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CONCLUDING DISCUSSION

CHAPTER 8

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The Mainland Gujarat alluvial plains constitute an important segment of the Quaternary terrain of western India, and these provide an insight into the late Quaternary depositional history, diverse climatic fluctuations and tectonic activity. The present study deals with the Mahi river, especially the upper part of the Quaternary deposits exposed in the Lower reaches of the river. The Mahi channel has incised an older Quaternary succession in the form of high cliffs ranging between 5 m to 35 m. Studies carried out by most of the previous workers on the Mahi basin concentrated on archaeology, geomorphology and to some extent on palaeoclimatic aspects, but none had attempted studies of stratigraphic and sedimentological aspects. The present study has therefore mainly emphasized on two aspects of the exposed sediment succession, highlighting the role played by tectonism and palaeoclimate in controlling the sedimentation pattern, channel morphology, sculpturing of the present landscape and the various events of the depositional history.

The three geomorphologic units of the Mahi basin, viz. the rocky uplands, the alluvial plains and the coastal zone, show an array of landforms, which are the reflections of the processes of tectonism, and climate related depositional and erosional events. These processes have given rise in each of the three geomorphic units to a variety of polygenetic landforms. The trunk stream is marked by a clearly defined channel following a zig-zag course with a major portion of it marked by cliffy banks and ravine topography. The rocky uplands show highly rugged terrain. The landscape of the rocky uplands comprises numerous denudational landforms attributed to combination of erosional and tectonic processes of the Late Quaternary. The main tectonic trends viz. NNW-SSE, NNE-SSW and ENE-WSW have influenced the evolution of the landscape and controlled the channel trend. The features like right angle deviation of channel, deep entrenchment in rocky terrain, distorted meanders and cut-off channel are all conclusive evidences of active tectonic control. The Mahi river basin exhibits two distinctive surfaces i.e. S_1 and S_2 (occurring in the alluvial and coastal zone). The S_1 surface belongs to the older drainage system and represent the oldest aggradational surface in the area, which today lies beneath a thick blanket of aeolian deposit. Close to the river banks within the valley portion the S_1 surface is marked by highly dissected ravine erosion (badland topography). The second surface S_2, occurs in the form of younger unpaired terraces of fluvial and fluvio-marine sediments. This S_2-surface represents deposition along the new channel and marks post fracturing phenomenon, that occurred sometime after the aeolian event (~6 ka B.P.).

A major portion of the Mahi basin is located within the Tertiary Cambay Basin. The Cambay Basin faults were active all throughout Quaternary period, and these were responsible for the formation of grabens and half grabens that provided sites for sediment accumulation during Quaternary. The major Precambrian lineaments occurring in the upper reaches are the Rakhabdev lineament trending NNW-SSE, Udaipur-Sardarpur lineament trending NNW-SSE and Jaisalmer-

Barwani lineament trending WNW-ESE to NW-SE. In the lower reaches (within the alluvial plain) the Tertiary Cambay Basin consists of bounding faults trending NNW-SSE, alongwith smaller faults trending NNE-SSW, NE-SW and E-W. The various tectonic trends show ample evidences that they were active during Quaternary period: this is revealed by the differential subsurface thickness of Quaternary sediments.

The complexity of the tectonic adjustments in the Mahi basin is not yet fully understood. Not much evidences related to tectonic controls are observed in the field. To a considerable extent , the field manifestation of the changes in the various landforms and the discordances in the sediments influenced by tectonic activities are seen to have been obliterated by successive aggradational and degradational events. The lineament studies have established that the major structural trends that influenced the Mahi channel segment match well with the Precambrian and Cambay basin tectonic trends mainly trending NNW-SSE, ENE-WSW and NNE-SSW. The other significant observation made is that the lineament trending NW-SE (almost parallel to Jaisalmer-Barwani lineament) marks the major geomorphic divide between the rocky uplands and the alluvial plain.

In the upper part of the river where it flows within rocky areas, the streams follow a horse-shoe shaped drainage flowing SSE-NNW, ENE-WSW and NNE-SSW. The deflections in the flow trends are suggestive of structural control. But the most important tectonic orientations which control the present day main stream in the rocky as well as in alluvial and coastal zones are the NNE-SSW, ENE-WSW and NNW-SSE trending lineaments. Along these trends at many places the channel shows sharp right angle deviation, distorted meanders and cut-off channels. Also it is observed that the tributaries join the main Mahi channel at right angles and that tributaries meeting from either sides at the same spot. All these features suggest strong structural control.

Evidences of neotectonic and active tectonic activities that have controlled the channel and the landscape evolution of Mahi basin are summarized as under :

1. The E-W and ENE-WSW fractures form the earlier tectonic trend during Quaternary. These probably controlled the older drainage network that flowed due W to WSW and, also played a significant role in the formation of grabens and half grabens which acted as probable sites for sediment accumulations.
2. The trend of the fractures that controlled the younger channel and its tributaries are NNE-SSW and ENE-WSW. The effect of these tectonic trends are well evidenced by the incised channel and straight valley development at some places. A major strike-slip component of this late tectonism is indicated by well-developed NNE-SSW slickensides on the exposed face of pedogenised silty-sand horizon in the upper reaches, pointing to a post-depositional tectonic movement.
3. In the lower reaches folded calcrete layers, high angle tilting of the forsets and slump structures are indicative of syn-depositional as well as post-depositional tectonic activity.

4. Development of ravines along the banks of the channel suggests subsequent uplift along the fault bounded horst blocks.
5. From the late fracturing trends it can be said that NNE-SSW fracture trend was reactivated after the dunal sand deposition (around late Holocene), that controlled the present day course of Mahi channel flowing SSW against the regional slope due WSW to W.

The composite lithostratigraphy of the exposed sediment in Mahi valley comprise four formations. They are Rayka formation, the Shihora formation, the Singrot formation and the Kothiyakhad formation. These represent sediments deposited under three major environments - fluvial, aeolian and marine (estuarine). The basal portion over which rests the fluvial and the aeolian succession, is made up of marine deposits, which later due to subsequent pedogenesis and calcretization (prior to the onset of the first fluvial sedimentation) formed a well-developed vertisol. The fluvial succession overlying this vertisol horizon is made up of well developed planar and trough cross-stratified calcrete conglomeratic lithounits, separated by units of horizontally stratified sand and buried vertisol (Rayka formation). These in turn are overlain by a fine sediment unit consisting of multiple palaeosol horizons made up of silty sand. This succession of fine sediment comprises two yellowish brown buried soil horizons and one rubified (red soil) soil horizon (Shihora formation). The rubified horizon acts as a marker horizon between the fluvial and overlying aeolian sediments (Singrot formation). The top most part of these aeolian sediments (mainly silts and fine sands) show dunal topography

(S_1-surface). The next younger succession comprises sediments deposited as bank attached bars within the valley under fluvial (inland) and marine-estuarine (coastal zone) environment (S_2-surface, Kothiyakhad formation). The fluvial sediments show cross-stratified gravels (made up dominantly of quartzitic clasts), horizontally stratified sand and cross-stratified sand, whereas the horizontally laminated fine silty-mud, mud and planar cross-stratified fine sand horizons showing herringbone structure represent the marine-estuarine deposition.

The characteristics of the sediments exposed in the basin reveals that the main bulk of succession was deposited by the older drainage, marked by fluvial cycles. Over these lie the aeolian sediments. Later the present day new Mahi channel was responsible for the deposition of the younger fluvial and marine sediment succession.

The exposed succession in the Mahi valley exhibits diverse facies such as trough cross-stratified conglomerate (Gt), planar cross-stratified conglomerate (Gp), horizontally stratified sand (Sh_1) and (Sh_2), trough cross stratified sand (St), massive silts (Sim) alongwith contemporaneous palaeosol horizons of vertisol, red (rubified) soil and brown soil (P), planar cross-stratified sand (Sp), horizontally laminated silty-mud (Fl). The interpretation of these facies has revealed that the deposition in the Mahi basin took place under 4 major aggradational phases. The individual lithofacies reveals the nature of syn-depositional climate regimes.

The aggradation phase 1 marks the first fluvial sedimentation in the Mahi valley and consists of the lithofacies viz. Gp, Sh, St and Gt of Rayka formation, that rests over the basal vertisol lithounit. This aggradation took place under low-sinuous braided channel complex (Fig. 6.9 a,b,c), and in various depositional setting that gave rise to the development of different lithounits. These were resulted mainly due to downstream migration of straight crested transverse bars (Gp-facies), overbank sedimentation (Sh-facies), channel avulsion (St-facies), downstream migration of sinuous crested dunes, longitudinal bars alongwith minor channel fills (Gt-facies). The channels were relatively shallow and characterized by its high ephemeral nature (Fig. 6.9 b and c).

The aggradation phase 2 marks change in fluvial regime, where the flow velocity was reduced. This phase comprises mainly the multiple soil units overlying the sediment succession of aggradation phase 1 and represents the Shihora formation. During this phase the river mainly transported medium grained sands and silt, in a shallower channels with a high width to height ratio under sheet-flooding (Fig. 6.9c). A high degree of ephemerality of the channel is well evidenced by the presence of horizontally stratified sand alongwith calcrete layers and multiple soil horizons. Formation of red-soil on both intra-channel and probable extra-channel deposits is indicative of infrequent sedimentation with intervening prolonged periods of pedogenesis.

The aggradation phase 3 marks an intensive aeolian activity. The homogenous massive silts (Sim) dominate this period of deposition. This sediment column represent the Singrot formation. During this phase the channels were very shallow and valley width was narrowed down (Fig. 6.9d). The landscape was covered with aeolian dunes. The aeolian sediments show characters similar to the classical loess sequences of Kashmir but have a lower silt percentage. Within this aeolian silt horizon periods of aggradation reflect dryness while intervening relatively humid periods are manifested as carbonate nodules. The absence of soil illuvial typically point to shorter duration's of such stabilization events which curtailed horizonation.

The last phase of aggradation (Phase 4) in the Mahi basin is related to the new drainage network, that developed after the aeolian aggradation. This phase is marked by yet another fluvial sedimentation event and change in the climate from dry to sub-humid. The new channel incised the older fluvial and aeolian sediment succession, and this was the period when gully erosion commenced. The channel was comparatively narrow and had moderate to high sinuosity. During this aggradation contemporaneous fluvial (in the alluvial plain) and tidal/estuarine (in the coastal zone) sedimentation took place within the confined valley margins (Fig 6.9e). The exposed fluvial and estuarine sediments comprises viz. Gp, Gt, Sp, Fl and Fsc lithofacies of the Kothiyakhad formation. The fluvio-marine sediments are suggestive of transgression of sea characterized by the inland migration of tidal inlet in a wide macrotidal funnel shaped estuary.

This deposition was followed by the phase of degradation due to change in the base level that resulted in the incision of these deposits. This led to the formation of unpaired terraces (Fig. 6.9f). Due to non-availability of data on sea-level fluctuations, it has not been possible to deduce the cause of base-level change.

It is envisaged that the change in base-level must have been caused due to interplay of sea-level fluctuation and tectonic uplift in the area, during the Middle to Upper Holocene.

The exposed sediment succession in the Mahi basin provides a reasonably good palaeoclimatic record from Middle Pleistocene to Holocene. The detailed succession of palaeoclimatic events in the study area is given in Table 7.1. The succession starting with pedogenised mud unit marks the base of exposed Quaternary sediment column in the study area. This pedogenised mud is indicative of the high strandline of the Middle Pleistocene transgression which was deposited under tidal and marginal marine environments, during humid to semi-arid conditions. The first fluvial event (aggradation phase 1) is marked by the deposition of planar cross-stratified conglomeratic facies under humid to sub-humid climate with an intervening dry phase at around <200 ka B.P. The overlying thick pile of horizontally stratified sand facies suggests the change in channel planform and indicates a fluctuating climate. The occurrence of hard pan calcrete within this unit suggests that the sedimentation characterized by a episodic flooding during the arid phase between 180 ka to 140 ka B.P. The overlying medium to coarse grained trough cross-stratified sand lithounit indicates a slightly wetter phase at around 130 ka B.P. The occurrence of vertisol in the extra-channel area along this facies points to the spells of wet and dry phases. Based on the TL-date of the overlying trough cross-stratified conglomeratic facies at around ~108 ka B.P., it is presumed that the deposition of horizontally stratified facies and the deposition as well as the formation of vertisol can be tentatively bracketed between 135-110 ka B.P.

A slightly wetter phase is evidenced by the overlying coarser trough-cross stratified gravel lithounit marks the top of the aggradation phase 1 alongwith an intervening dry spell around ~108 ka B.P. This gravel suggests deposition under highly ephemeral streams that existed in a semi-arid to arid region. This lithounit is overlain by a (12-15m) thick sheet flood deposit comprising three distinct palaeosol horizons viz. two weakly pedogenised brown soils and a well developed rubified red soil unit that marks the top of the aggradation phase 2. The luminescence dates obtained assign an age of around ~86 ka B.P. to brown soil I, around ~60 ka B.P. to brown soil II and the rubified horizon has been dated to around 51 ka B.P. The aggradation phase 3 is bracketed between 86 ka to 50 ka B.P. The clay mineralogy and grain size data suggest that the deposition and sub-aerial weathering of these units took place under fluctuating sub-humid to semi-arid climate. The clay mineral assemblages of these soils suggests slightly wetter phase during the brown soil units. Radiocarbon dates of pedogenic calcrete nodules from the red soil have given an age of around 23 ka B.P. This age of calcrete nodules is considered to be the minimum age for the pedogenic event of red soil. Hence the deposition of the red soil unit is bracketed between 51 ka to 23 ka B.P.

The thick pile of medium to fine silts and sands that overlies the sheet-flood deposits mark the aeolian aggradation phase 3. This is correlatable with the Last Glacial Maximum at around 22 ka to 18 ka B.P. The TL date of around 10 ka B.P.

from the middle portion of the aeolian succession indicates the continuation of Terminal Pleistocene aridity during early Holocene. The stabilization of the aeolian silts and sands resulted into the present day hummocky topography which is suggestive of a wet phase at around 9 ka to 6 ka B.P. The aggradation phase 4 marks the humid phase that occurred after 6 ka B.P. This aggradation comprises sediments of fluvial and fluvio-marine origin and suggests fluctuating sea level during the Middle and Upper Holocene time and marks sub-humid to humid climate.