CHAPTER-IX

CONCLUDING DISCUSSION

The entire exposed thickness of the continental sediments in the Sabarmati as well as in the Lower Luni and other river basins of north Gujarat, is seen to comprise dominantly products of more than one fluvial cycles and form a sequence of events dating back to Middle Pleistocene. The sequence stratigraphy shows a diverse depositional environment (fluvial and aeolian) and the successive horizons provide important facts in respect of their original nature. The sequence of depositional events, resulting sediments, factors controlling their deposition, the periods of non-deposition accompanied by effects of sub-aerial weathering and renewal of depositional activities provide a very fascinating picture (Table 9.1).

The sequence with its lithological characteristics very clearly brings out the depositional environments and the related climate (Table 9.1). The variable thicknesses of successive units as well as that of the total bulk in the various parts of the study area is attributable to the basin configuration which in turn reflect the control exercised by numerous lineaments. The study has amply established the control of tectonic factor and it has been possible to understand to some extent the role played by uplifts and subsidences prior to, during and after the major part of depositional activity. Some of the salient features of the various events that make up the evolutionary history of the continental deposits of north Gujarat have been recapitulated in the following lines.

The entire continental sequence resting over the basal bluish marine clays has preserved within itself a succession of depositional events. In a general way the composite thickness is seen to comprise major fluvial cycles in its lower part separated from one another by very well defined periods of non-deposition. The aeolian sediments successively cap the fluviatile deposits. The depositional activity came to a halt during the periods of non-deposition and the sediments were subaerially exposed to pedogenetic changes. Even the lower most basal clays point to a reasonably protracted interval before the onset of the fluvial sedimentation. Extensive development of calcrete in the form of veins, tubes and strings, criss-crossing the clays and the phenomenon of mottling are good

	STRATIGRAPHY	EVENTS	ENVIRONMENT	ENERGY CONDITIONS	LITHOLOGY	PEDOGENESIS	CLIMATE
MAHUDI FORMATION	Ogadpura member	Deposition of present day unconsolidated sand sheets and dunes		Moderate to low	Sand and silt		Arid to semi-arid
		Period of non deposition	Sub aerial weathering			Stabilisation and soil formation	Sub-humid
		Deposition of dunal sands	Aeolian environment	High velocity winds	Sand and silt		Arid
		Period of non deposition	Sub aerial weathering			Stabilisation and ped-ogenisation of silts. Paleosol formation and calcretisation.	Sub-humid
	Deesa member	Sudden depo-sition of sedi-ments of silt and fine sand	Aeolian environment	High velocity winds	Fine to medium grained silts and coarse sand		Arid
LAKRODA FORMATION	Saroli formation	Deposition of third fluvial cycle	Fluvial environment	Reduced energycond-itions. Deposition in the form of intermittent flash floods.	Mud, coarse sand and lenses of gravel, chiefly composed of quartz grains, felspars and micas		Semi-arid
		Period of non deposition	Sub aerial weathering			Pedogenetic changes including the rubification of silts and develop-ment of calcrete nodules at the base.	Humid to sub-humid
	Hirpura formation	Continuing depo-sition of second fluvial cycle.	Fluvial environment	Moderate to low energy conditions.	Silts and sands		Semi-arid
	Sindari member	Deposition of second fluvial cycle	Fluvial environment	High to shallow energy conditions.	Gravels comprising clasts of varying sizes of quartzitesand other rock fragments capped by mud.		Semi-arid
		Period of non deposition	Weak sub aerial weathering			Weak pedogenesis of the top part (mud) of Valasana member.	Sub-humid
	Valasana member	Deposition of first fluvial cycle	Fluvial environment	High to shallow energy conditions.	Gravels comprising clasts of quartzite, granite, chert, jasper and other rock frag-ments overlain by mud.		Semi-arid
		Period of non deposition	Sub aerial weathering			Pedogenetic changes in basal clay	Sub-humid
	Basal clay	Marine conditions (High sea)	Tidal environment	Low energy	Clay rich in illite, smectite and montmorillonite and silt comprising mainly quartz, felspar and micas		Humid

Table 9.1 : Synoptic view of sequential stratigraphy, depositional environment and paleoclimate.

indicators of the time gap during which the underlying sediments were subaerially exposed and subjected to the process of calcretistion.

The fluvial cycles typically characterised by gravelly horizons have been interpreted as products of high energy depositional processes initiated abruptly carrying a large bulk of sediments and dumping them in their existing locations. This high energy phenomena comprising the two lower cycles was episodic such that the debris brought by high energy streams was dumped perhaps near the base of the tectonic scarps. The fining upward points to the loss of energy and carrying power. The second fluvial cycle though more or less might have been controlled by almost identical fluvial conditions. Howevere, taking into account the overall size of the clasts, it can be presumed that relatively the second fluvial action was less energetic.

The size, shapes and lithological differences between the coarser and the finer clastics suggest a rather unique transportational pattern and diverse processes of their formation. The clasts showing reasonably good rounding (rounded to well rounded) are made up almost exclusively of quartzites and give an impression as if they have been subjected to long distance transport. On the other hand, the finer fragments appear to have been collected on the way. A substantial percentage having come from not very far and showing diverse mineralogy and lithology. Such an episodic deposition could be brought about by rather big rivers with long courses, the actual events of deposition in all probability pointing to a semi-arid environment. The end of the first cycle marked by mud horizon (fractured and pedogenised) is indicative of a progressive weakening of depositional processes finally culminating into a total stoppage after the accumulation of mud horizon. On the other hand in matters of detail, the sequence of events in the second fluvial cycle is somewhat different. As already mentioned earlier, this cycle was characterised by decreased carrying capacity. But the provenance distance might also have been less as compared to the first cycle. The size of the clastics as well as their lithological and mineralogical nature to a considerable extent is different.

The precise reason for this difference is difficult to visualise. Both belong to the same river system, so the difference as enumerated above could be the reflection of decreased water flow or some tectonic changes in the upper reaches of the river which caused changes in the behaviour of the river. The mud horizon overlying the gravel in the second fluvial cycle is the usual stilwater fine sediment accumulation. The most interesting deposit is however the unstratified (10 m thick) fluvial silt horizon (which was subsequently rubified); no break of deposition is indicated between the underlying mud and this fluvial cycle. The silt horizon resting over the mud has to represent a fresh fluvial regime under rather low energy conditions. Such a non-stop deposition of uniformly sized grains point to a fluvial action over a considerable time span during which few changes took place either in the provenance conditions or in the carrying capacity of the river water.

This horizon with total lack of layering or lamination can be easily mistaken for aeolian silts, but laboratory studies have conclusively established their fluvial origin. With the deposition of these silts the second fluvial cycle seems to have come to an end. A break in deposition followed by the subsequent exposure to atmospheric agencies were the main factors for the rubification of these silts. The reddening of the silts was a phenomenon akin to pedogenetic changes. This conclusion is amply supported by the widespread development of calcrete nodules. With the onset of the third fluvial cycle that followed, a fresh instalment of fluvial sediments was deposited over the rubified silts of the second cycle. The nature of the material of these river borne sediments is quite different. The main bulk is sand and silt interspersed with thin layers of coarse sand and fine gravel. The entire formation is unconsolidated and friable and is made up of clastic grains which show much less rounding, dominantly sub angular and appear to have been brought from nearby sources. An interesting feature of this cycle is the coarsening of the sediments upward, in contrast to the lower two fluvial cycles. This phenomenon typically illustrates a very gradual increase in the fluvial activity with the passage of time and its sudden termination. Perhaps the abrupt onset of the aridity (at the close of Pleistocene) was the main reason for this drying up of the fluvial regime.

Obviously, the three fluvial cycles deposited during the late Pleistocene (from Middle Middle to Upper Pleistocene) came to an end with the onset of the main arid phase which is represented by the extensive aeolian cover over the fluvial deposits. The absence of any pedogenetic feature in the topmost part of the third fluvial cycle perhaps suggests that the onset of aridity was relatively rapid and there was very little time interval for subaerial processes to operate.

The arid phase which began at the close of Pleistocene and continued during the lower Holocene must have more or less disrupted the pre-existing drainage system. The arid phase is represented by a sizable thickness of aeolian deposits (Mahudi formation) spreading practically all over south Rajasthan and north Gujarat, extending even upto some parts of central Gujarat (Mahi river). The entire aeolian activity as preserved in the sediments is divisible into two episodes of accumulation of wind blown deposits separated by a brief spell of increased humidity during which the silts were partially stabilised. Ofcourse no continuity can be deciphered in this phenomena. The stabilised aeolian deposits belonging to the Deesa member show very well defined pedogenesis, reveal quite good soil profiles and extensive calcrete development. The two members of this aeolian formation impart the most striking undulating topography characterised by a hummocky landsurface dotted with numerous clusters or individuals of dunal hill like features.

The depositional history of the study comprising a major fluvial period followed by that of aeolian activity, when examined in details have provided some interesting facts in respect of the role played by the factors of climate, pedogenesis and tectonism. In the preceeding pages of the thesis the salient features of the controls exercised by these factors and relevant evidences preserved in the sediments of different horizons have already been described. It may however be emphasized that the entire depositional history giving rise to the succession of diverse lithologies, thicknesses and surface of non-deposition and pedogenisation, were more or less in close combinations. The net result of the present day sequence and the landscape.

It has been possible for the present author to decipher the successive stages of the late Quaternary fluvial regimes and understand to a considerable extent the nature of the depositional history. His studies have adequately established that the fluvial sedimentation was brought about by an ancient drainage system which now stands partially disrupted. This disposition was caused by the factor of climate and tectonism. These two factors have significantly operated even during the deposition of the successive fluvial cycles. This is seen quite clearly in the presence of several periods of non-deposition during which the exposed sediments were subjected to subaerial processes, dominantly pedogenesis and calcrete formation. The role played by each factor has been recapitulated in the following lines to understand the history of geological evolution in proper perspective.

All throughout the deposition of sediments starting from the upper Middle Pleistocene to the present day, climatic changes have significantly influenced the course of deposition and brought about mineralogical and chemical changes in the sediments during periods of non-deposition considering the various climatic and sea-level curves given by numerous workers, the rise and fall of the level reflecting the climatic changes in terms of warm and cold periods, the sequence of the study area can be considered to fall broadly within the last interglacial and the last glacial stage. In the absence of precise radiometric dates, it is only possible to suggest an approximate time framework to correlate the various events of alluvial deposition, periods of non-deposition and pedogenesis and periods of aeolian activity. The interglacial stage which broadly has a time span from around 240 K.Y. to 120 K.Y. and it was during this time interval the two fluvial cycles appear to have been deposited.

The climatic conditions perhaps fluctuated between sub-humid to semi-arid and whereas the two major cycles of deposition might be representing wet spell with augmented streams action, the periods of non-deposition and pedogenesis indicate a more or less humid to sub-humid climate operating over subaerially exposed fluvial sediments lying up perhaps by some tectonism . The climatic conditions were just wet enough to weakly pedogenise the uplifted sediments. Absence of a well developed soil profile and calcretes is indicative of such climatic conditions.

The rubification of the silts of the second fluvial cycle is again a process of pedogenic nature and perhaps represent decreased humidity during the closing period of the last interglacial broadly coinciding with 5e stage of Shackleton and Opdyke (1973). Ofcourse this correlation is quite tentative but broadly the climatic conditions conducive for the rubification could be prevailing around 120 to 130 K.Y. The third fluvial cycle which broadly falls during the glacial stage represents a warm spell that preceded the onset of main aridity. The arid phase represented by aeolian deposits of Holocene period indicates an intervening sub-humid climatic period during which the stabilisation and pedogenisation of the aeolian silty horizon was brought about. This event could have taken place around 3000-4000 years B.P. The present day climate which is characterised by several years of dry spells followed by periodical high monsoon years could have prevailed since the last advent of the ameliorating conditions.

The entire depositional history right from the beginning to the end has been significantly controlled by tectonic activity, the basin which received the sediments since the advent of the Quaternary comprised a feature controlled by differential subsidences along various structural lineaments related to the Cambay basin tectonics. The basin configuration reflected pre-depositional tectonism. Tectonic activity during the deposition of the two. main fluvial cycles is represented (i) in the well marked lateral differences in the vertical thickness of some of the horizons. Ofcourse this is a more conjectural statement than actual conclusive observations, but the role of syn-depositional tectonism cannot be ruled out, because of the continued uplifts and subsidences; evidences of which are well recognized in the pre-depositional and post depositional periods.

The various tectonic features have already been described in an earlier chapter. The most salient features that stand out as conclusive role of tectonism is the most evident nature of the pre-depositional basin It is conclusively a graben bounded by major faults. Syn-depositional tectonism could be invoked not only for the variable thickness, but also for the events of non-deposition, exposure of sediments to weathering processes, pedogenesis and calcretisation. It is also quite likely that the various rivers amongst which the Sabarmati happens to be a major stream, prior to its present course flowed along major lineaments trending NE-SW to ENE-NSW. As it has already been firmly established that the present south-southwesterly course follows a major fracture. This provides an ideal example of post depositional tectonism. The configuration and limits of the Great and Little Ranns on the western flank of the basin also provide an example of this late tectonism.

The main highlight of the present study comprises ~~of the present~~ existence of an ancient super fluvial system which generated the major bulk of the non-marine (continental) sediments and a subsequent disruption of this drainage giving rise to the present stream pattern. Whereas the earlier drainage which was mainly responsible for the main bulk of deposition, the superimposed drainage system does not deposit much. The Sabarmati channel in its cliffy sections provides much information on the nature of sedimentation of the earlier fluvial system. A synthesis of the data obtained from various river sections and boreholes, recognition of abandoned and relict channels and a critical appraisal of geomorphic features, has enabled the author to arrive at a reasonably coherent evolutionary history of the study area, throwing much light on the various late Quaternary geological events.