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CHAPTER XI

CHARACTERISTICS OF SEDIMENTS, SEDIMENTARY ENVIRONMENTS AND THE BIOTA OF INTERTRAPPEAN BEDS AT THE K/T BOUNDARY LEVEL

After consideration of the lithostratigraphy, biostratigraphy, magnetostratigraphy and geochemistry of K/T boundary sections in Kutch, it will now be appropriate and logical to attempt reconstruction of the sedimentation history and sedimentary environments as revealed by their lithologic and boitic characters. This precisely is being dealt in the following paragraphs:

XI.1. ANJAR AREA:

XI.1.1 First and Second intertrappean beds:

In the Anjar area, the first intertrappean bed was deposited in a shallow/pond fed by small streams and gullies on the Trappean/Mesozoic topographic surfaces.

After the eruptions of second flow, the small depressions on the trappean country were covered and converted into lakes by seasonal streams in which the finely laminated shales, porcellanites, sandy limestone and bentonitic clays etc. were deposited in a warm to temperate climate with active volcanic environments still continued in the background. The small algae and mosses (about 1 to 1.5 cm in height) possibility thrived near these lake margins and on their shallow bottoms possibly on calcareous muddy floor. Some such lakes appear to be quite large and perhaps spread about 2 to 3 km in length and 1 to 1.5 km in width. Intermittent active volcanic phases provided ash, porcellanites and lensoid bodies of pyroclastics and thin flowlets of basaltic materials.

In the later part, the increased sedimentation added fair amount of clastics to form channel/bar sands like features. During this time the sedimentation rate must have been comparatively faster as evidenced by vertical and inclined burrow structures filled with sands in the basal part of the upper sandy units. The burial and upward vertical burrowing/ migrations continued alongwith the sedimentation. In the upper part, the sedimentation rate was reduced and as a result, the colonies of horizontal ophiomorpha burrows thrieved on along bedding plain of sandy units There were frequent subaerial exposures which permitted the burrowing activity of organisms to be flourished A calcitic geode and burrow filling structures by brown calcite suggest calcification in the warm to temperate conditions.

The third Intertrappean bed (on the basis of the detail studies presented earlier) are suggestive being deposited in comparatively a large, shallow brackish water lagoon spread almost 3 km in length with more than a kilometre of width. This lagoon remained largely shallow through out the history of its deposition and received sediments from the Trappean country by small ephemeral streams. Frequent subaerial exposures lead to calcification and pedogenesis Incursions of brackish water were common through low lying channels

The marl contains frequent voids and pore counting which show their deep lamellar calcitisation as described by Wright et al (1988), were common through low lying channels. There was insitu growth of small herbaceous bushes of charophytes (as identified by calcified woods and shealths within and around the margins of the lagoons. Abundant fragments of calcareous shealth of chara plants can be seen on surface near pit locality. The lithological association can broadly be subdivided into: (a) basal marl dominated sequence with few cherty bands and mottled clay bands, (b) middle muddy and shaly sequence in alternations with limestone/marl bands and gypsum, (c) top mottled clayey and sandy (mottled sequence with few cherty intercalations. The mottling and calcritisation is prominent in the basal and upper units, whereas the middle part of the sequence shows association of evaporites with limestone marl and mud suggesting frequent alternations, substantial longer drier spells during which calcareous mud and gypsum were deposited in alternations of black muds (indicating shorter water spells). The climate fluctuated from frequent dry and wet spells with higher and longer spells of precipitation in the initial phases during which black shales, volcaniclastics and trap washes were deposited in alternations with basaltic debris and few lensoid compact, nodular, marly bands. The marly lenses and shales are burrowed by annelids. Burrows are mainly inclined and vertical in nature indicating comparatively higher rates of sedimentation by ephemeral streams and gullies during active seasonal sedimentation. During the drier periods, the marly bottom provided hard ground on which the soft bodied biota scavenged and burrowed and took shelter. The burrows are filled by reddish ochrous and sandy material. These burrows are common in the marly bands, limestones and shales and are thus synsedimentational post sedimentational and in some few instances of pre-sedimentational phases. This suggests that the lagoons were very shallow throughout their existence and were subjected to frequent subaerial exposures. Certain parts of the lagoons (peripheral marginal areas) formed the ideal hatching grounds for small reptiles, dinosaurs and contemporary birds., This fact is suggested by the documentation of small crushed egg shells and fragments of eggs of varied types within localised areas. Such horizons are extremely mottled and burrowed suggesting preferrential habitation by the scavenges in soft horizons in vicinity of the hatching grounds.

The middle parts of the sequence contains numerous thin gypseous partings in alternations to the white marly bands and black mud bands indicating overall longer phase of drier climate with few temporary, shorter spells of wet conditions. This resulted in restricted supply of material, hence the limestone/marl bands developed voids, cavernous open spaces with encrustations of gypsum and calcite. The salinity and alkalinity was on the higher side which did not permit the habitation of burrowing organisms, except very small and tiny organisms which have produced various fibrous colonies and other structures on the limestone within the voidal portions. At times the birds used marginal areas of vast dried flats for hatching purposes as evidenced by the avian egg shell fragments found within the marly bands.

The higher part of the sequence is dominated by sandy clays mottled muds an laminated cherts indicating comparatively longer wet spells with intermittant short temperate dry spells during which the basin must have higher acidic contents (sulphates). It is rather significant that most of the invertebrates cease to appear/exist with end of the marly/clayey/shaly intercalations. This could be either due to the acidic (sulphate dominating) environments or due to absence of fossils. The lithological assemblage of the upper part suggest deposition of marginal clays-as the intent rare clays, which underwent frequent drying producing super-saturated playas with deposition of gypsum bands (and intercalations) during such dry spells in alternations with extremely temperate cycles with little precipitation which permitted to formation of intervening alternate banded chert due to reduction in salinity. Burrowing organisms thrieved during periods of such temporary precipitation. The uppermost unit is mostly extremely fine grained and muddy in nature, indicating onset of humid warm conditions with increased precipitation and tropical to subtropical climate.

In conclusion the over all facies reconstructions of the intertrappean beds suggest highly variable nature of individual units. The highly variable and localised nature of individual units suggest varied and shorter extent of environmental regimes within shorter distances. A lacustrine environment with numerous ephemeral channel gullies has given rise to such a set of depositions.

The fourth Intertrappean bed was deposited in very small isolated ponds. Clastic brought from infratrappeans and Intertrappean by small rivulet/streams, form main influx.

The fifth intertrappean bed comprises volcaniclastic clays and basaltic debris in its basal part; banded chert, lenses of laminated stratified and micro current ripples laminated limestone, sandy limestone and calcareous fossiliferous, sandstones. The chert bands are associated with lenses of banded siliceous and porcellaneous lenticles, in the upper part. The various rocks occurs as highly lensoid bodies which are not traceable over larger distance, but they show local lateral continuity and also continue along down dip directions indicating its insitu sedimentary nature. The deposition was largely in a shallow lagoon on the trappean country. In the initial phase, the sedimentation was largely by chemical precipitation of evaporites. Shallow algal mats covered lakes. Chalcedony (silica) was deposited later from the water due to change of pH conditions. This chalcedony replaced the earlier evaporite minerals, which are seen as pseudomorphs of silica. The chalcedony chert shows length slow optical character indicating its definite molecular replacement origin. Such optically length slow cherts have been found in many places in the world, which have been proved to be after replacement of preexisting evaporite sequence. In the later phase, the pH conditions increased, during which limestone deposition took place. In the initial phases the limestone were deposited as fine to medium to coarse, at times conglomeratic clastic lensoid beds within shallow restricted channels and later on alternating, extremely fine and coarsely stratified limestone bands were formed. The

fossiliferous limestone and calcareous sandstone were deposited in the upper part of the sequence. The associated fauna comprises varied groups of lamellibranchs, gastropods, forams and plant debris which are indicative of brackish lagoonal environment. The marine fossils within the intertrappean suggest short cyclical brackish water interventions.

XI.2. DAYAPAR AREA:

XI.2.1. First Intertrappean:

In Dayapar, the intertrappean sequence comprises five lava flows with intervening four intertrappean sedimentary beds. Of these, the second intertrappean bed is studied in detail, for its similarity of fossil content with those in Anjar. The first Intertrappean bed comprises about 1.5 to 2.0 m thick greyish sandy clay sand green glauconitic fossiliferous sandstone. The deposition was largely in the brackish lagoons.

XI.2.2. Second Intertrappean bed:

The second intertrappean bed is dominantly calcareous and glauconitic in character burrowed in the lower part, clayey with few marly intercalations in the middle part and largely arenaceous burrowed sand and sandstones in the upper part. The basal part is highly fossiliferous and contain both rich vertebrates, invertebrates fauna and plant remains.

The basal part indicate deposition in a larger lake with considerable aerial extent, covering more than six to seven kms. in length and more than 2 to 3 kms. in width between Dayapar and Ashladi areas. Deposition was largely by ephemeral streams draining to the lake from trappean and Mesozoic terrain. The lake margins supported dense shrubby growth of ferns cycades, calcareous colonial spermatophytes (charophytes), and other smaller herbs and shrubs of newly emerging angiosperms (Palmae and others). Bottom of the lakes were covered by sandy clay, muds and calcareous oozes in which the ostracodes, algal oncolites and invertebrates threived. The marginal areas of the lake supported extensive burrowing communities due to frequent sub-aerial exposures. These animals were mostly scavenger types which thrieved on the organic debris brought by streams and dumped within the lake. Small charophytes and algal mats extensively grew and at times increased in such abundance that they covered the most parts of the lakes. The extensive growth of calcareous algal charophytes were also dominant during such episodes. Different skeletal parts of algal plants are also found at Dayapar. The extensive spores of charophytes occur within the yellowish and greenish glauconitic marly bands. The marly layers also show extensive burrowing mostly in vertical and inclined positions. Indicating synsedimentational growth. These marly bands also show some post depositional pre-lithification burrows suggesting that they formed temporary hard grounds, during comparatively dry period when there was reduced influx of terriginous clastics, indicating drier periods. During these drier periods, the lake underwent desiccation on many occasions as evident from multiple polygonal desiccation cracks and mud cracks at different levels in vertical sequence. Such features reflect repeated alternations of dry periods with short humid periods

Influence of brackish waters during short intervening periods produced extensive glauconites on oncolites and algal muds within sediments in the basal part. The salinity further increased during drier periods during which deposition of gypseous layers and marly bands took place. These lake margins provided favourable hatching sites for different types of reptiles-lizards boidian, chilonia, crocodilian, dinosaurs and birds.

During the later part, the climate appears to have changed to comparatively humid type with longer warm humid periods in alternations to short dry spells, during which the terriginous influx was increased in the lakes. The greenish glauconitic clays with thin glauconitic sandy partings indicate short spells of active precipitation which caused local floods with increased activity of terrestrial streams, and brought coarser clastics. During the remaining periods, the stream flows were minimal which brought assorted clays and sands. The rate of sedimentation was normal which helped the burrowing organisms to keep place with sedimentation. At some places, rare inclined and horizontal burrows are also seen which reflect very short episodes of absence of sediment. The climate changed to more humid with comparatively higher rate of precipitation, indicating increased torrential streams activity, which brought moderate to well sorted sediment forming multiple current bedded sand beds. There is very little clay fraction. Absence of burrowing structures indicate increased rate of precipitation - a period of torrential flash floods. It maybe mentioned that there may have been a widespread short episode of very high precipitation in this part of the area. The lithological association of boulder conglomerate, sand and clay in all the Intertrappean sequences at various places in this area suggest short episodic flash floods. The climatic variation were somewhat erratic due to some reasons and there was a local increased humid phase as compared to the far eastern areas of Deccan province. The biotic diversity of assemblages with eastern province could be due to one such reasons.

XI.3. SEDIMENTOLOGY AND ENVIRONMENT OF DEPOSITION :

Sedimentary characteristic of Upper Member of the Bhuj Formation comprises of assemblage of sandstone, shales and repeated iron stone bands in the basal as well as the upper part of lower member. The basal part is dominated by finely laminated gypsies shale, coaly seams and carbonaceous shales with plant fossils of upper Gondwana affinity. The basal most layer contain glauconitic burrowed sandstone. The ironstones and burrowed units show alternations. There are several gradational cycles of fining upward sequence of multistoried sandstone units. The palaeocurrent laminae show a long steeper unidirectional (west to southwesterly) mode. Associated finely laminated shale and siltstones show highly contorted nature and variety of asymmetrical current dominated ripple marks, load cast and flute casts. A deformation (gentle upwarping), intrusions and erosional episodes are well established in central and western Kutch. Ferruginous sandstone friable sandstone, shale intercalation have yielded well preserved Upper Gondwana plant fossil. Ferruginous burrowed hard and red sandstones also contain one marine incursion in the central Kutch region This marine bed yields well preserved marine fossil, besides dinosaurian foot prints

and foot tracks middle part of Bhuj Formation is marine in north -western Kutch (Fig. 10, Table II). Ukra member is not developed towards further east of Ghaduli. In the Ukra-Guneri area, it comprises of the green glauconitic clays, sand and ferruginous glauconitic sandstones with thin intercalations of fossiliferous marly bands and limestones. The sequence contains well preserved ammonites, brachiopods, bivalves and abundant bored fossil wood. Repeated lateritised sandstones and ocherous bands are found at base. Trace fossils and annelid worm marks are abundantly found in the trough of ripples. The sedimentation of Ukra member was mainly by short transgressive episodes. The basal part of Ukras show short transgressive and regressive events with short but sufficiently longer subaerial exposure to permit deposition of finely laminated ocherous layer and lateritised ironstones band. Four coarsening upwards cycles are found in the Ukra beds.

The upper member comprises friable, coarse to fine, graded bedded, current dominated cyclically repeating overall fining up sequence of sandstone, siltstone and shales. The sandstones form multistoried over bank bars as in a fluvio-deltaic regimes. In the upper part, three intervening marine incursion are recorded during which trigonia bearing calcareous sandstone bands were deposited in the north western Kutch, whereas in the central Kutch fluvial regime with numerous channels distributaries and flood plain sedimentation continued under humid and alternating longer cool humid climate. This turned into increasingly warmer climatic conditions in the uppermost part of Bhuj Formation.

XI.3.1. <u>Sedimentation during volcanosedimentary sequence</u>:

The sedimentational history and environments of deposition of volcanosedimentary sequence of Anjar Formation are dealt separately, elsewhere, and hence are not once again repeated here.

Thanks !

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