CHAPTER V

STRATIGRAPHY AND SEDIMENTATION

The stratigraphy of Chamapner Series typically illustrates the various events of sedimentation in a miogeosyncline. Field and petrographic studies have established a distinct correlation between the characteristics of various sedimentary assemblages and the mobility of the tract of accumulation. The disconformity between Lower and Middle Champaners, and the paraconformity separating the Upper and Middle Champaners, represent significant events of environmental change. These changes, essentially related to the tectonism of the basin and

the source areas, comprise distinctive features of the Champaner geosynclinal cycle.

The lithology and the primary structures of the various formations belonging to the three divisions, not only indicate depositional conditions, but also exhibit a connected sequence of events marking the different stages of the evolution of a basin marginal to the main eugeosyncline in which the Aravallis were deposited.

The successive lithological associations, each characterising distinct environment and provenance are obviously indicative of maintenance of a particular set of conditions that produced a basin wide pattern of sedimentation during a significant interval of geological time. Potter and Pettijohn (1963, p.248) have called such patterns as 'sedimentary models'. Such a model according to them, is distinguished by (1) basin geometry, (2) type of lithic fill (sedimentary association), (3) arrangement of lithic fill (lithofacies), (4) current system and (5) tectonic setting.

Though, occasionally a single particular model may prevail during the complete filling of a sedimentary basin, it is usually seen that several such models comprise the deposition in a basin.

The author has built up a succinct and coherent account of the successive sedimentary models that comprise the stratigraphy of the Champaners.

The stratigraphy and the depositional history, as worked out by the author is summarised in Table No. V.

The thicknesses of the various formations at different places have been shown in the stratigraphical columns (Fig.4).

From the above, it becomes apparent that the Champaner geosynclinal cycle does not show a complete sequence from marine to paralic or continental sedimentation. The rocks of molasse facies are totally absent and it is seen that the course of events took an entirely new turn after the deposition of graywacke suite. Instead of continued shallowing and filling up of the basin, a subsidence resulting into deposition of finer sediments in quiet waters (below wave base) was initiated.

Perhaps, the changes in the Champaner basin were controlled by the tectonic events affecting the source area as well as the main geosyncline. The author has come to this conclusion on the basis of his observations

TABLE V

	Name of the formation	Depth of water	Facies Name	Associations in Beloussov's Classification of Geosynclinal Cycle
Upper Champaners	Rajgad Slates	Shallow		
	----------Paraconformity----------			
	Bamankua Limestones	Shallow		
	Shivarajpur Quartzites and Phyllites	Shallow		Upper part of Upper Terrigenous Sequence
Middle Champaners	Bhat Slates	Shallow	Black shale facies	
	Jaban Conglomeratic Graywackes	Deep to shallow	Graywacke suite	Lower part of Upper Terrigenous Sequence
	Jaban Slates	Shallow to deep	Black shale facies	
	Narukot Quartzites	Shallow	Beach sands	
	----------Disconformity----------			
	Gandhra Pelitic Group	Shallow (Restricted Basin)	Black shale facies	Lower Terrigenous Sequence
Lower Champaners	Chhota Udepur Dolomites	Shallow	Orthoquartzite-Carbonate suite	Limestone Sequence
	Basal Conglomeratic Quartzties	Shallow		

of changes in the material of detritus in successive lithologic associations, in their structures, the shapes of the lithologic bodies, and their relations.

EARLY STAGES OF CHAMPANER GEOSYNCLINAL CYCLE

Orthoquartzite-Carbonate association (Chhota Udepur dolomites)

This association comprises the two earliest formations of the series viz. Basal conglomeratic quartzites and Chhota Udepur Dolomites laid down during the initial stages of the Champaner geosynclinal cycle. Originally an interbedded sequence of sandstones and carbonates, rests over the stable crystalline basement with an intervening small thickness of arkosic conglomeratic material. The carbonate dominates over sandstone.

The 'Basal Conglomeratic Quartzites' that intervene between the gneissic basement and the overlying dolomite-quartzite sequence, are typically discontinuous. Although, lenses of these rocks occur everywhere at the same horizon over the basement gneiss, its differing pebble content is significant. The quartz pebbles are always present, while those of jasper and chert are localized in the beds around

Deohat and indicate that the material delivered to the basin of deposition came from different directions and different source areas.

The well sorted quartz-pebble-conglomerate represents relatively stable material derived from eroded granitic basement with winnowing out of finer textures and less stable lithologic types. The chert pebble conglomerate is, perhaps, derived from a limestone terrain in which the chert occurred as residual fragments. Krumbein and Sloss (1963,p.164) have suggested that such well sorted lithologically homogeneous conglomerates commonly occur as relatively thin, widespread, or patchy sheets interbeded with quartz type sandstones, representative of the basal deposits of transgressive seas.

It is obvious that this orthoquartzite carbonate facies, is the product of sedimentation marginal to a very low-lying stable land surface. The rocks might have been deposited in shallow water marine conditions of neritic (sublittoral) type (Pettijohn, 1957,p.610). The presence of dolomite also suggests shallow water marine conditions, the dolomite significantly suggesting warm sea waters (Twenhofel, 1961,p.350; Folk, 1968, p.170). The fact that the dolomites of the area are entirely free from rocks of 'evaporite facies', indicates absence of very shallow water

environment. This is further supported by total absence of primary sedimentary structures. Absence of evoporites and sedimentary structures indicate that throughout the depositional history, the waters were below intertidal (supralittoral) zone, and that the climate was not arid (Pettijohn, 1957,p.160,613,615).

Black Shale Facies (Gandhra Pelitic Group)

The Gandhra Pelitic Group that overlies the dolomites, typically represents rocks of the Black-shale facies deposited over the carbonates. In the present metamorphosed state, the rocks of the facies consist of slates, phyllites and quartzites. Closely associated with these metapelites are bands of impure argillaceous and siliceous dolomites and dolomitic limestones, thin layers of bedded jaspers, manganese ores and iron ores. Occasional cubes of limonite pseudomorph after pyrite are present. Also associated is carbonaceous material now seen as graphite. The bedded jaspers occurring in the dolomites, are the typical examples of S-chert of Dunbar and Rogers (1957,p.238-239).

Rocks of black shale facies originate in different environments, but they almost invariably indicate deposition under anaerobic conditions (Pettijohn, 1957, p.363). Even for a thick and uniform black shale accumulation, anaerobic

conditions rather than the depth of water is postulated as the controlling factor (Weller,1960,p.487). Krumbein and Sloss (1963,p.565) have also affirmed that "taken as a group the rocks of the black shales facies always indicate deposition in euxinic conditions - a quiet water, reducing environments. According to Pettijohn (1957,p.625) euxinic sediments are exclusively marine. However, considerable difference of opinion prevails whether the basin of accumulation was shallow or deep and whether it was landlocked or freely connected with the sea or was only a stagnant area in the open sea. The reducing conditions requisite to black shale deposition may be encountered in a variety of tectonic and environmental circumstances. Among these, three major types of occurrence are described by Krumbein and Sloss (1963,p.565-566). These types are: (1) black shales in graywacke associations (2) black shales in restricted basin associations, and (3) black shales in lagoonal associations. According to them, "the black shales in graywacke associations" are commonly metamorphosed to slate by the regional metamorphism typical of eugeosynclinal troughs. Black shales of this type in eugeosynclinal troughs and along eugeosynclinal borders of marginal basins give every evidence of deep water deposition. On the other hand, 'black shales in restricted basin associations' are

commonly interbedded and intercalated with argillaceous carbonates. These shales in marginal basins pass uninterruptedly into the graywacke associations noted above.

Euxinic bottoms are also characteristic of lagoons cut off from the main body of the sea by barrier beaches, banks, or reefs, and that black shales in lagoons are formed in shallow water environment. (Krumbein and Sloss, 1963,p.560). It is thus obvious that the Gandhra Pelitic Group was deposited in euxinic conditions probably of starved basin types or restricted basin association of Krumbein and Sloss (1963).

Shallow water deposition of the rocks of Gandhra group is evident from the associated Poyelli quartzite which contains sedimentary structures like simple current ripples.

This association of carbonates (predominantly dolomitic), sandstone, jasper, pyrite, iron ores and carbonaceous material with laminated black shales has been described by many workers (Pettijohn 1957,p.622-625; Krumbein and Sloss, 1963, p.566; Twenhofel, 1961,p.259).

Restraints imposed upon normal marine circulation, whether by encircling reefs and banks or by tectonic effects on topography, may create deoxygenated, still-bottom environments not markedly different from those formed in deep water. The author is of the opinion, that the tectonism in the basin was responsible for the restricted conditions.

Usually euxinic sediments occur above the orthoquartzite-carbonate association and below the graywacke-shale assemblages (Pettijohn 1957,p.26). But in the present area, the above succession of environments is not so ideally exhibited. The orthoquartzite-carbonate association is overlain by the rocks of black shale facies. However upwards, the Narukot quartzites are seen intervening between the black shale facies and the graywacke shale association. These quartzites suggest extreme shallowing of the basin after the deposition of shales, and represent a blanket type of beach deposits. The tectonism that culminated in the formation of widespread beach deposits perhaps was the main cause for the restricted conditions.

The Jaban slates and the conglomeratic graywackes (graywacke-shale assemblage) that overlie the quartzites indicate renewal of progressive transgression and deeping of the basin.

MIDDLE STAGES OF GEOSYNCLINAL CYCLE

Blanket Sand Association (Narukot Quartzites)

The formation younger to the rocks of black shale facies, overlie with a well marked disconformity and has all the characters and attributes of beach sandstones. Obviously at the close of the deposition of Gandhra Pelitic Group, the basin was uplifted in such a manner that widespread littoral deposits of sand, forming a vast blanket, were formed. This striking formation, designated as Narukot Quartzites, has furnished very valuable data. Study of its lithological and structural characters have led the author to arrive at vital conclusions regarding the stratigraphy and sedimentation of the series as a whole.

Narukot Quartzites, originally quartz-pebble sandstones with a basal conglomeratic horizon, represent the culmination of a shallowing process of the basin. This shallowing was perhaps caused by a progressive uplift of the part of the basement, which was responsible for the prevalence of the restricted basin environment during the deposition of Gandhra Pelitic Group ending up with the formation of beach deposits.

Basal portion of the Narukot Quartzites is conglomeratic. The pebbles are those of vein-quartz, quartzite and shale

(now slate or phyllite). Upwards the pebble content decreases, though sporadically quartz and quartzite pebbles are met with right up to the top of the formation. Significantly the slate pebbles are comfined only to the lowermost part near the contact with the upper phyllites of the Gandhra Pelitic group, and almost abruptly disappear only a little higher up. The slate pebbles are fairly angular and lie flat along the bedding, giving rise to a 'flat-pebble conglomerate' (Plate VI A). Such conglomerate typically indicates an intraformational origin having been formed under shallow marine conditions where partially consolidated materials are torn up by strong waves and redeposited (Twenhofel 1961, p.217). According to Krumbein and Sloss (1963,p.163-64), such quartz pebble conglomerates belong to the class of well sorted, lithologically homogeneous conglomerates which commonly occur as relatively thin widespread or patchy sheets, interbedded with quartz-type sandstones, representative of the basal deposits of transgressive seas.

Considering the mode of occurrence and lithological characters of the conglomerate, it is obvious that the basal beds of Narukot Quartzites, were deposited in a near shore marine environment of infra-littoral type (Krumbein and Sloss,

1963, p.510). The shale pebble content suggests a temporary uplift and exposure of the underlying phyllites (shales) above the tide level. This intraformational conglomerate further points to the fact that the junction between phyllites and overlying Narukot Quartzites does not mark any major break in the cycle of deposition. As Weller (1960, p.404) has pointed out, "pebble of local derivation may indicate no more than very brief interruption of deposition and slight nearby erosion." Thus, the base of the Narukot Quartzites marks a disconformity; and though the break is clearcut and well defined, the dips and strikes of the formations above and below do not show much divergence (Dunbar and Rogers,1957, p.119; Krumbein and Sloss, 1963, p.305).

The main bulk of this quartzite formation typically represents an original quartzose sandstone with occasional quartz pebbles. This sandy formation has much lateral extent and practically it does not contain any shaly beds. Such sandstones represent beach deposits showing stable conditions of sedimentation with very mild subsidence during accumulation, and with considerable transport and winnowing action before final accumulation. Such shore line deposits covering large areas and of relatively small

and uniform thickness, form sheets and blankets of well sorted sand, and for the development of such sheets, according to Krumbein and Sloss (1963,p.213), it is necessary that turbulent conditions occur over the entire area of deposition. Such turbulent conditions typically indicate shore zones of encroaching seas of unusually agitated waters over large areas. The "cut and fill" structures frequently recorded in these quartzites are in fact good indicatinns of deposition in agitated waters. These quartzites at many places, have preserved, sedimentary structures typically indicating the shallow environment. Cross laminations, current ripples and oscillation ripples, all point to a shoreline deposition.

The Narukot Quartzites when traced from bottom to top represent a transition from a shallow water platform type environment (that marked the deposition of Lower Champaners) to that characterised by deeper water.

The lithology and structure of the upper portions of these quartzites, together with the nature of the overlying formations, point to the fact that the deposition of this formation in later stages heralded a period of deposition over an "unstable shelf". The topmost beds of the formations

where it graded into the overlying shaly formation (Jaban Slates) show a gradual increase in finer material indicating a poorer degree of sorting. This suggests lack of continuous reworking. It is further observed that the subsidence during the accumulation of Narukot sands, was rather uneven and this fact is reflected in the formation of more than one lensoid bodies of the overlying shales.

Interpretation from statistical parameters

The statistical parameters of five analyses reveal that average grain size of the particles is fine sand. These sands are moderately sorted, both positively and negatively skewed with kurtosis varying between platy- and lepto-kurtic type.

The grain size determinations and the textural characters of upper part of Narukot Quartzites agree with the Friedman's (1967) observations. According to him on some beaches where sediment supply exceeds energy, and the sediment mixture transported by longshore currents is composed of sand, silt and clay, mud or silt are plastered onto the beaches. These beaches may be composed

of mud, sandy mud, muddy silt or various other mixtures of sand, silt and clay. Such mixtures will ultimately result into moderate to poor sorting with positive skewness.

The poorer degree of sorting and increasing tendency of fines in the upper part of Narukot Quartzites, show less reworking of sediments probably on account of net rate of subsidence exceeding deposition, the condition met with on unstable shelves (Krumbein and Sloss, 1963,p.425).

Black shale facies of Marginal basin association (Jaban Slates)

A salient feature of Jaban Slates is that their basal portion indicates deposition in shallow water environment and that the water gradually deepened during the deposition of its upper beds. At the base, as already stated, the Jaban Slates have a gradational contact with the beach type Narukot Quartzites. The transitional beds at the base of the shaly formation consist of intercalated siltstone and fine sandstones, and the phenomenon typically characterises shale deposition in near shore marine environment (Twenhofel, 1961, p.251). Such shallow zones of water produce structures of special kind like "flaser bedding" and small scale "scour-casts" or "wash outs" and such structures are frequently

recorded near the base of this formation and indicate zones of intermittent turbulance (Pettijohn,1957, Plate 22, p.367).

Evidences of deep water deposition of the main bulk of the shaly formation, are (i) gradual disappearance of variegated colour laminations, (ii) absence of shallow water sedimentary structures and (iii) presence of graphitic shale. Anaerobic conditions existed due to the depth of water below wavebase, to allow accumulation of black shale (Krumbein and Sloss, 1963, p.566). In the uppermost portions of the formation, the rock is very compact, non-fissile-almost an argillite, and indicates a further deepening of the basin.

The Jaban Slates, thus indicate deposition in a basin which was initially shallow but gradually became deeper and deeper, and by the time, the overlying graywacke suite was being deposited, the waters had become quite deep. It was this deep basin which provided an ideal environment for the deposition of typical graywacke rocks.

Graywacke Suite (Jaban Conglomeratic Graywacke)

The variation in the lithology from bottom to the top of this graywacke suite, throws significant light on the

changes in the depositional conditions prevailing during the formation of this suite. The deposition of the typical gfaywackes with pebbly lenses just above the Jaban Slates, was initiated under deep waters. But it is very obvious that the rate of sedimentation was quicker than that of subsidence and as a result, the basin tended to get shallow. This change of environment is reflected in the lithological, textural, and structural features of the upper portions of the suite. The uppermost beds are almost protoquartzitic and show all characters of a shallow water deposition.

Submergence of the beach characterised by the Narukot sands, was obviously not uniform and the manner in which the overlying graywackes form two widely separated exposures, indicate this fact. Two distinct basins appear to have formed one at Jaban-Shivarajpur and the other in NE at Undhania, the graywacke suite having developed at both the places. Jaban-Shivarajpur basin shows a more complete cycle of sedimentation. The incompleteness of the Undhania basin is seen in the absence of protoquartzites. The differing basin conditions of the Jaban and the Undhania exposures, are ideally reflected in their respective grain size, and sedimentary structures.

The entire graywacke-protoquartzite association contains scattered pebbles, but in the lower portions of the formation, concentration of pebbles and boulders has given rise to frequent conglomeratic layers and lenses. The boulders and pebbles are of vein-quartz, quartzite, granite-gneiss, slate and limestone. Some of the slate fragments contain within them smaller pebbles of granite, quartzite and limestone. Such an assorted assemblage of rock fragments, embedded in an equally heterogeneous matrix, suggests a deposition under conditions of rapid erosion and deposition not far from the source.

Krumbein and Sloss (1963,p.166) have called such rocks as graywacke conglomerates. According to them, these rocks indicate rapid deposition in subsiding areas.

The conglomerates are essentially 'immature' consisting of many unstable fragments. Generally under normal conditions of weathering and erosion the granitic rocks tend to disintegrate and the limestone would dissolve away. But these very rocks yield blocks and fragments if conditions are such that disintegration and solution are inhibited or subordinated. Such conditions are those marked by high relief and consequent rigorous climate with its attendant rapid erosion and accelerated frost action (Pettijohn, 1957; p.251-252).

The suite, together with these associated pebbly and bouldary horizons, is characteristic of such a deep water environment wherein turbidity currents are most effective. The velocity of turbidity currents and their power of transportation was so high that they scoured the clayey fragments from the bottom and with these clayey lumps the included quartz, granite and limestone pebbles were also lifted up enclosed within the clay mass. This process is one which leads to the formation of intraformational conglomerates typical of a graywacke sequence. Although these slate pebbles are of intraformational type, they are essentially of under-water origin and reflect the power of turbidity currents which gave rise to graded bedding and also brought in very much large boulders and coarse detritus to the site of deposition.

The dominant rock of this suite at Jaban below the protoquartzite, is a typical feldspathic graywacke showing interesting variation in structure, texture, and lithology. On the whole the rock is fairly coarse and generally consists of small sub-angular to sub-rounded fragments of quartzites, shales (slates), limestones, gneisses, etc. At places, especially near its contact with the underlying Jaban Slaty group, the matrix of the rock is rather argillaceous. In

its upper portion the suite consists of protoquartzitic rock and shows a clear cut absence due to winnowing away of finer, black, argillaceous material from the graywacke rocks. Such a sequence is characteristic of a graywacke suite. According to Pettijohn (1957,p.616) a typical graywacke assemblage increases in coarseness upward, the increase in coarseness being associated with an increase in the proportion and coarseness of the sands, which now become cleaner and produce subgraywackes and even protoquartzites.

Taking into account the close genetic relationship that exists between the protoquartzites and the underlying gfaywackes, the author has included both of them within the single suite, as opposed to the previous observer (Rasul, 1964) who considered protoquartzitic rocks separately and gave them the name 'Bhat Quartzites'. The transition of graywackes to protoquartzites is indicative of a progressive shallowing of the basin. This has obviously happened on account of the rate of deposition outpacing the rate of subsidence. Folk (1954) has also considered orthoquartzites occurring along with graywackes, as belonging to the same association; so much so that according to him such quartzites could be called as 'mature

graywackes' formed as a result of washing out of clay particles from 'immature graywackes'.

The graded-bedding is the most characteristic sedimentary structure of the graywackes and points to the settling of sediments in comparatively still and deeper water (Bailey, 1930; Pettijohn, 1957). This type of bedding has a turbidity flow origin (Kaunen and Migliorini, 1950; Keunen, 1953). Graywackes which are characteristically graded, are thus the product of turbidity currents capable of carrying coarse material into deep waters beyond the reach of normal bottom currents or waves (Pettijohn, 1957, p.313). Turbidity flows might be generated by submarine slumps, earthquakes or may form by other means, all these characterising a certain unstable tectonic environment. The graded bedding seen in the Jaban outcrop is quite coarse and on a large scale, each bed being of the order of a metre or so.

Sedimentary brecciation near the base of the formation with the resultant shale fragments, has given rise to the intraformational conglomerate. Shale fragments while being plucked, are seen to have included within them pebbles of quartz and granite-gneiss. These 'pebble-within-pebble'

indicate action of powerful turbidity currents that scoured the underlying semiplastic clay or mud.

In contrast, the graywackes of Undhania basin, show a much finer graded bedding and the lithology and other sedimentary structures, here, show the deposition by turbidity currents in an environment slightly different from that prevailing in the Jaban basin.

At Undhania, the graywackes are much finer, show small scale grading in beds and laminations. Also the conglomeratic layers are fewer. Unlike Jaban, the graywackes here do not grade upward into protoquartzite. Instead, they are abruptly overlain by the rocks of Shivarajpur Quartzites and Phyllites and Rajgad Slates.

The pebbly horizons at Undhania are lithologically identical to those of Jaban. However, the main bulk of suite comprises evenly and uniformly deposited fine graded beds. Each bed shows a gradational distribution of grains with coarsest at the bottom and finest at the top. The gradation from graywacke to mudstone (argillite) takes place within a few millimetres and the thinner graywacke bands frequently show a regular alternation with the dark

mudstone above, similar to that described and figured by Pettijohn (1943, p.954, Plate 8). Despite the lithological division of the beds into graywacke and mudstone, the latter is included as part of the graded units. These mudstone layers themselves contain very faint, often graded laminations of variable thickness and persistence. An interesting feature of this graded bed sequence is the almost invariable presence of grains of finer sizes throughout the bed, from base to top. Such a type of graded bedding, is according to Pettijohn (1957, p.171), a product of sedimentation from a suspension in which all sizes decrease upward but the sorting remains constant; in the present case, the mean size diminishes but with this the sorting improves.

Another significant structural feature that throws light on the mechanism of deposition of this suite at Undhania is the presence of well preserved laminations within the graded beds. Dewey (1962, p.243) has suggested progressive laterla and vertical differentiation in axial turbidites and development of laminar flow to be responsible for better sorted laminar sub units in a graded unit. McBride and Kimberly (1963,p.1851) interpret the graded

silt lamine in claystone to have deposited either from small, slow moving turbidity currents, or from storm generated waves and currents, that carried suspended silt seaward. It appears that these laminations are the product of same turbidity currents which produced the graded beds, and therefore, the rock does not split along these laminations, nor the latter loose the general appearance of enclosing unit. It was a process of selective and differential settling through still water from turbidity currents that gave rise to such micro-bandings.

The distinctness and the degree of preservation of these laminations suggest deposition under quiet water condition and indicate absence of strong bottom currents. These laminations further denote deposition below wave base. Both these facts are adequately supported by the absence of ripple marks, scarcity of large scale flow and groove markings.

An interesting modification of this formation is seen in the form of several distinct lenses within the main mass, showing a highly calcareous matrix. In its present form, it looks like a calc-schist. The whole

aggregate constitutes such a mess that the previous workers considered these as a metamorphic breccia (Sharma, 1964,p.215). Obviously, this rock is a product of an intrusion of a carbonate laden turbidity flow (Jambusaria and Merh, 1969, p.206). Pettijohn (1957,p.616) has also reported such rocks from some sections of graywackes.

The two distinct lenses of gfaywacke suite at Jaban and Undhania, each characterised by distinct lithology and structures, suggest differences in depositional history. It is likely that these two distinct basins received detritus from the same source, but the rate of deposition was faster in Jaban than in the Undhania basin. Also the force of turbidity currents was stronger at Jaban. This is indicated by the prevalence of wide varieties of boulders and pebbles. At Jaban, the transition of graywacke upward into protoquartzites is suggestive of the shallowing of the basin and this implies that the supply of detritus was so high that it exceeded the subsidence of the basin, as a consequence of which the deeper water conditions were changed to those of shallow water, the product of sedimentation resembling to paralic or molasse type rather than flysch at the top of the

graywacke suite horizon. On the other hand at Undhania, the entire formation appears to have been deposited below wave base and thus no protoquartzites developed there.

The graywackes are indicative of a special tectonic environment. Fischer (1933, cf. Pettijohn,1957,p.313) regards graywacke as a "poured in" type of sediments characteristic of geosynclinal sedimentation. According to Krynine (1941) graywackes are the normal arenaceous sediments of middle to late stages of geosynclinal cycle. To Pettijohn (1943), graywackes earmark sedimentation in tectonically unstable regions.

According to Krumbein and Sloss (1963, p.529) such suites of graywackes are characteristic of bathymetric zones, and are deposited in typically but not exclusively low mechanical energy environment with low pH and negative Eh. These rocks occur in eugeosynclinal flank of marginal basin (miogeosyncline). The absence of volcanies is also indicative of miogeosynclinal accumulation (Pettijohn, 1957,p.616). Folk (1968, pp.133-134) has suggested that the miogeosynclinal graywackes accumulate in a linear trough which may be quite thick in the middle and thin on

both the sides, and this is true for the graywacke suite of the Champaner Series also.

Bhat Slates

Bhat Slates, originally a group of shales, indicate deposition in an environment characterised by quiet waters. These sediments were deposited in a basin marked by a subsidence. Quiet water conditions are indicated by fine laminations and occurrence of concretions of manganese ores.

The bodies of manganese ores occurring in these slates, were considered as nodules by Rasul (1964, pp.617-618). But the present author is more inclined to call them "concretions" rather than nodules. According to Pettijohn (1957,pp.200-201) the nodules are wholly irregular bodies with warty or knobby surface and are formed of mineral matter unlike that of the host rock. The nodules are normally without any internal structure and are primarily the result of post-depositional replacement of the host rock. On the other hand, the true 'concretions' (Pettijohn, 1957, pp.203-204) are subspherical, oblate to irregular bodies formed generally

by an orderly precipitation of mineral matters in the pores of a sediment adjacent to a nucleus.

According to the above definitions, the segregation bodies of manganese oxides in Bhat Slates and Shivarajpur Quartzites and Phyllites, fall into the category of 'concretions'. During the time of segregation of manganese oxides into concretions, the enclosing matrix is seen to have been pushed aside. The concretions thus have grown by pushing apart the laminations (Plate xiii A). Similar deformation of laminations has been invoked by Pettijohn (1957,p.200).

Shivarajpur Quartzites and Phyllites

An interbedded sandstone shale sequence coming over the Bhat Slates (Shivarajpur Quartzites and Phyllites) indicate probably shallow water but quiet depositional conditions. These constitute marine sediments laid down near the shore of a shallow seas and occur in alternating thin beds of coarse and fine sediments. The sandy beds singularly show absence of ripple marks and cross bedding, and it is very clear that the entire deposition took place in a standing body of water below the wave base. Such

environment is typically indicated by widespread occurrence of manganese ores as beds and concretions.

Such syngenetic manganese bodies of sedimentary origin, according to Fermor (1909, pp.284-285) have originated in areas which received both mechanical and chemical sediments. The incoming water containing salts of manganese in solution, on reaching the stationary waters, dropped in velocity and consequently, the solutions were subjected to atmospheric oxidation to precipitate oxides with intervals of silt and clay deposition, resulting into an alternating sequence of laminated shales and manganese ores.

It is rather not clear how the concretions have originated. No doubt they are syngenetic, but the exact mode of origin cannot be made out. It is likely that quite a few of them represent segregations on the sea floor prior to their consolidation within shaly matrix. In such cases the precipitated oxides segregated as concretions instead of forming distinct layers. Some of the concretions might be post-depositional segregations having originated in a consolidated matrix.

Bamankua Limestones

Lenses of limestones that rest over the Shivarajpur formation, are obviously chemical precipitates deposited in the local troughs in the main basin. By the time this precipitation of carbonates started, the influx of clastics from external source must have been at its minimum. The only material added was sand grains which got mixed up with the precipitated carbonates and gave rise to beds of sandy limestones.

LATE STAGE OF GEOSYNCLINAL CYCLE

Rajgad Slates

Renewed subsidence and a fresh period of deposition is marked by the Rajgad Slates, which rest over the older rocks with a marked paraconformity. The subsidence was such that almost all the pre-existing formations of the Champaner Series came under fresh sedimentation. Thus the Rajgad formation is seen coming in contact with almost all the underlying strata right upto Narukot Quartzites.

The paraconformity thus, represents a major event in the depositional history of Champaners. These shales with intercalated sandstones and limestones, mark a site

of deposition characterised by still but shallow waters. Slump structures noted at various places indicate adjustment of the unconsolidated sediments during subsidence of the bottom.

SUMMARY OF THE EVENTS OF GEOSYNCLINAL CYCLE

The foregoing account reveals vital facts regarding sedimentation of the Champaner Series. The rocks of this Series comprise miogeosynclinal deposits fromed in a basin marginal to the main Aravalli geosyncline.

The sedimentation in this basin started with conglomeratic quartzites followed upward by the rocks of orthoquartzite-carbonate suite of platform facies. Then followed black shales (now slates, phyllites, etc.) with dolomitic limestones, jasper beds, manganese ores, iron ores, etc. These were deposited in a restricted basin of shallow water conditions. The Narukot Quartzites that overlie Gandhra Pelitic Group indicate uplift and extensive beach environments. The rock formations below the Narukot Quartzites, represent the limestone sequence and lower terrigenous sequence of Beloussov. Had these quartzites been not deposited, the Gandhra group of rocks would have passed uninterruptedly into Jaban slates, the

rocks that grade upward into graywacke suite. This is the normal cycle of deposition in most geosynclines. But as shown by the Narukot Quartzites, in miogeosynclinal basins quite often a beach deposit intervenes between the two environments (Krumbein and Sloss, 1963, p. 418, 550).

The base of the Narukot Quartzites marks a disconformity indicating a temporary inversion of the tectonic conditions. The resumption of subsidence, brought about deposition of shales and graywackes - so typical of deep water turbulent deposition. This deposition was marked by a sharp uplift of the source area to the E and SE. Also the provenance was not far from the site of deposition and thus favoured accumulation of unsorted, angular and coarse clastic fragments comprising largely of unstable materials. The graywackes were deposited in two different basins the larger one at Jaban received sediments at a rate faster than the subsidence. As a result of this, the basin became shallower and gave rise to protoquartzitic rocks above graywackes.

After the deposition of protoquartzites, either rate of subsidence increased or that of clastic supply decreased and as a result, deposition of finer material gave rise to beds of shales (Bhat Slates), and then to a group of alternating sandstones and shales. That this deposition took place in a quiet waters below wave base, is indicated by absence of sedimentary structures and presence of chemically precipitated manganese ores in the form of layers and concretions and limestone lenses.

The most striking and important event in the history of the Champaner sequence took place before the deposition of the rocks represented by Rajgad Slates, and records the paraconformity below this formation. It was at this period that the renewed subsidence brought the entire basin under simultaneous and continuous deposition so that the Rajgad Slates came directly to overlie all the underlying formations upto Narukot Quartzites.

The sedimentation of the Champaner Series has some unique features. In a normal geosynclinal sequence, rocks of molasse facies should succeed the protoquartzites or a graywacke suite. Such a sequence is indicative of

progressive filling up of the basin resulting into deposition of rocks transitional from marine to continental. But in the present case, such rocks are absent. In fact, the sequence above the graywacke suite, ideally corresponds with the ideas of Beloussove (1962,pp.397-398) who has suggested that in many cases the graywackes are succeeded by a group of rocks consisting of shales, sandstones with wide spread mineral and fuel bearing beds. He includes these rocks in his Upper Terrigenous Sequence of geosynclines. According to him the geosynclinal deposits comprise the following sequences:

Molasse Sequence

Lagoonal Sequence

Upper Terrigenous Sequence

Limestones Sequence

Lower Terrigenous Sequence.

In the Champaner geosyncline, it is seen that the Limestone Sequence (Chhota Udepur Dolomites) precedes to Lower Terrigenous Sequence (Gandhra Pelitic Group). His Upper Terrigenous Sequence includes the graywacke suite and the rocks younger to it. While the graywacke suite (flysch) forms one subsequence, those that come over it comprise the other subsequence. He writes (1962,p.398),

"the two subsequences are found either together or separately (when one of them wedges out completely or almost completely). When they occur together, their relative stratigraphic positions may very".

The absence of lagoonal and molasse sequences, in this area, is significant and point to an entirely different history of deposition. Considering the nature of the Bhat Slates, Shivarajpur Quartzites and Phyllites, Bamankua Limestones and Rajgad Slates, and taking into account the distinct paraconformity below the Rajgad Slates, it can be stated with fair certainty that a progressive deepening of the basin followed the deposition of graywacke suite and this phenomenon was such that by the time Rajgad shales and sandstone sequence started depositing, the waters, of the miogeosyncline (Champaner basin) spread almost uniformly and therefore, the youngest Rajgad formation overlapped all the older rocks.