CHAPTER VI

DISCUSSION

In this chapter, the author has made attempts to discuss some significant aspects of occurrence of the carbonates, processes of formation, diagenesis and other petrogenetic considerations based on detailed petromineralogical and geochemical investigations carried out during the present study. These data, their appraisal and interpretation in the light of relevant parameters available in literature comprise the thesis.

Limestone occurs in all parts of the world at almost all levels in the stratigraphic spectrum though probably it is less common in Precambrian strata. Limestones are estimated to comprise 19-22% of measureable stratigraphic sections (Leith and Mead, 1915; Schuchert, 1931; Pettijohn, 1957). The occurrence of limestone may be considered from several points of view. One view which particularly became common in the U.S.A., in the first half of this country, was to assign all calcium carbonate rocks to this single group—"limestones", in order to contrast them from other types of non-carbonate deposits. Thus, "limestone" has been taken to denote a "chemical rock" as against the "terrigenous or clastic" rocks, which were subdivided on the basis of grain-
size and/or mineralogic composition. This approach essentially ignored the variations within limestone that reflected initial variations in the calcium carbonate sediments from which most limestones have been derived. Another approach, which also observed the variations within the original carbonate sediments, was to subdivide limestones according to different gross tectono-stratigraphic "facies" e.g. "platform", "basin" and "geosynclinal" limestones (Sloss, 1947).

6.1 TECTONO-STRATIGRAPHIC FACIES

Most often the term "platform" is used in conjunction with the facies and for the sedimentological characterization of shallow water carbonates. Some authors use this term for a very extensive carbonate deposit of the type comparable to the Recent Great Bahama Bank. Other workers have used it to represent paleogeographic and geodynamic evolution (e.g. Jenkyns, 1970; Argenio, 1976).

Wilson (1975) considered carbonate platforms as extended carbonate bodies characterized by more or less horizontal surfaces or sedimentary base and by an abrupt change in relief along the shelf edge or platform margin. The shelf edges exhibit high-energy sediments. Absence of benthonic organisms, ooids, cross-bedding, algal mats, stromatolites, birds eye, fenestrated fabrics, caliche, pisoids etc. indicate that the carbonates of the study area
do not qualify to be called platform type of limestone.

"Geosynclinal" limestones are identified by their occurrence in thick sequence and are characterized by siliceous composition, dark colour, and interstratification within deep sea shales. The studied carbonates show these characters and may be treated as geosynclinal limestone. "Basin" or "Basinal" limestones are characterized by the presence of (a) common discontinuity planes often associated with condensed fauna, (b) solution structures, (c) abundant planktonic organism in contrast with benthonic ones, (d) small amount of terrigenous quartz, (e) often very small amount of residual clay, (f) large proportion of micritic sediments or micrite clasts, the former recycled, (g) dominance of calcilutites over calcarenites. Besides these, no evidence of algal activity and absence of fenestral fabrics are noteworthy. The carbonates, under investigation, exhibit these features and may be classified as "basin type". It is evident from the above discussion that these carbonates show characters of geosynclinal and basin type limestones.

6.2. **NATURE AND AGE OF CARBONATES**

The study area lies within the Manipur-Nagaland Orogenic Belt (MNOB) and the carbonate rocks occur at several localities viz. Sokpao, Hundung, Ukhrul, Paoyi, Kangkhui, Changa and Phungyar of Ukhrul district of Manipur
state. Evidently, the author had to cover large areas because of the exotic nature of these deposits. Recently these limestones, occurring in the Disang Formation, have been considered to represent olistostromal facies which contain olistoliths of less than 10 cm to 100 m sizes (Acharyya, 1991). These limestones have yielded rich autochthonous fauna, dominantly planktonic foraminifera, which indicate a Campanian-Maestrichtian age. However, the fossil assemblage points to dominance of Maestrichtian element as discussed in a preceding section of the work. It is further observed that the foraminiferal assemblage from these carbonates is more close to those of Meghalaya region (Pandey, 1976), Baratang Island (Rajshekar et al., 1990), Bagh Beds, M.P. (Sharma, 1976) which indicate their wider biogeographic distribution. The lower age limit of the Disangs has been extended to Cretaceous on the basis of Maestrichtian microfauna from the olistostromal facies - the carbonates (Acharyya, 1991). He further considers the olistostromal facies as of late Mid-Eocene age based on his observations that the fossiliferous units are either olistoliths or they belong to olistostromal facies as well as because of the sparse occurrence of Mid - and later Mid-Eocene limestone olistoliths (Acharyya et al., 1986 b; Mitra et al., 1986).

With the advent of plate tectonics, some terms like melange, olistostromes, wildflysch and tectonite have been profusely used at times without any specific connotations.
The terms "olistostromes" and "olistoliths" ("olistolites") originated in Central Sicilian basin. They were first introduced by Flores (1955) which was summarized by Beneo (1955). These terms are of Greek origin ("olistomai" = to slide; "stroma" = layer) and "olistolith" ("olistolite") denotes a mass included within the olistostrome. Broquet (in Fairbridge and Bourgeois, 1978) defines it as "an olistostrome is a mappable stratigraphic layer representing a horizon of slumped material" (p. 508). Flores (1955; in op.cit., 1978) defined them as "those sedimentary deposits occurring within normal geologic sequences that are sufficiently continuous to be mappable, and that are characterized by lithologically and/or petrographically heterogeneous materials, more or less intimately admixed, that were accumulated as a semifluid body. They show no true bedding, except for possible large inclusions of previously bedded materials" (p. 509). In fact the term lacks precise connotation. Jacobacci (1965) defined their genetic characteristics which included sedimentary sliding which is "frequent in sedimentary sequences of unstable and subsiding zones" (p. 509, op. cit., 1978). Two attendant sub-types, "allolistostromes": (= wild flysch, having exotic components) and "endolistostromes" in which components are local, have also been suggested. Some other terms like "tectonic melange" (chaotic mixture tectonically produced) and "sedimentary melange" (mixture originated by slumping
and sliding = olistostromes) have more or less identical significance in such milieu. However, it has been pointed out that "no important tectonic influences are directly involved in the emplacement of olistostromes, so that they can only form beds or lenses of minor thickness and area (Broquet, in Fairbridge and Bourgeois, 1978, p. 509). Such bodies can be emplaced on the sea floor.

In the present case, these carbonate bodies exhibit some characteristics of olistostromal (= sedimentary melange) facies. This observation is of value in relation to the tectono-stratigraphic evolution of the belt. However, no attempt is being made to delve on this issue which can be solved only on the basis of regional investigations and, therefore, falls outside the purview of the present work by the author.

6.3. **ENVIRONMENT OF DEPOSITION: ORIGIN**

The data obtained from petrographic and geochemical investigations, discussed in the preceding sections of the work, indicate that the carbonates under study belong to neritic to upper bathyal environment. This is evidenced by the 1. absence of ripple marks and cross-bedding, 2. biomicrite as dominant microfacies, 3. high Ca/Mg ratio (Cf. Chillingar, 1960) and low phosphorous content (Ronov and Korzina, 1960), 4. fossil content, 5. absence of oolite and birds eyes in these carbonates, 6. mineralogic composition of calcium carbonate and 7. colours of these rocks.
Absence of the above mentioned primary structures (no.1) points to deeper environment. In the studied carbonates, sparse biomicrite or biomicrite is the dominant microfacies in which the fossil allochems are embedded in the groundmass of calcite matrix or the fossil allochems are cemented by calcite matrix which is indicative of low energy environment.

As revealed by Scanning Electron Microscopy examination, majority of the carbonate grains, in the present case, are less than 0.004 mm in size. Some grains are rounded and have reached up to 0.01 mm. This may be due to intergranular solution during the diagenesis indicating Bathurst's overgrowth mechanism. It has been observed that microfacies analysis of carbonate rocks further helps in the interpretation of the sub-environment. A plot of grain size distribution on probability paper (Fig. 38) helps in the recognition of gradual transition between micrite and microspar fields. Folk (1965) pointed out that micrite grains show a very good "sorting" probably on account of a resultant competition between space and grain growth. The degree of sorting, moderately well sorted, can therefore be used as a measure of textural maturity of micrites. In fig. 38 of micrite boundary, these carbonates show that the grains of more than 0.0035 mm (3.5 microns) are very less (< 5%), indicating thereby absence of high energy environment. The data suggest a neritic and upper
Fig. 38 Plot of grain-size distribution of carbonate (micrite) samples of the study area.
bathyal environment for the studied carbonates.

The carbonates of the study area contain diverse fauna with dominance of planktonic foraminifera but are free from algal mat structures, ooids and grapestones which point to their formation in marine conditions. This is further supported by small skeletal detritus observed in electron micrographs of these rocks which can be used as indicators for the bioclastic origin of micrites. High Ca/Mg ratio (15.87-146.76) and low-Mg calcite with notable absence of aragonite as well as appreciable predominance of Ca over Mg and clay contents in these carbonates are indicative of deeper water marine environment in which \( \text{CaCO}_3 \) - secreting marine organisms (forams) flourish in relatively clear and semi-restricted sea. The mineralogy of deep-sea carbonate sediments is in fact a reflection of the composition of the planktonic skeletals (mainly \( \text{CaCO}_3 \)) remains that are the chief contributors to the sediments though partly it may be due to dissolution of high -Mg calcite (HMC) and aragonite. In deep sea sediments, planktonic sources of \( \text{CaCO}_3 \) are Globigerina (with low-Mg calcite tests) besides the coccoliths which also have low-Mg calcite.

In relation to the temporal global distribution of carbonate rocks, in contrast to the benthonic shelly fossils, the Cretaceous pelagic ooze signifies deeper environment corresponding to the explosive evolution of pelagic foraminifera. Fine grained matrices and abundance
of this type of fauna in the studied carbonates point to either weak current or rapid accumulation (Folk, 1962). Radiolarians, which are planktonic and exclusively marine organisms, support moderately deep to very deep basinal conditions. In cases where radiolarian cherts overlie pelagic limestones, bathymetric interpretations in terms of the fluctuation of carbonate compensation depth (CCD) are appropriate (Boselline and Winterer, 1975; Garrison, 1974). Radiolarians play a significant role in silica cycle in the oceans and ancient radiolarian cherts have been taken to characterize deposits in moderately deep to very deep oceanic basins.

A perusal of literature suggests that during the Cretaceous foraminifera occupied vast majority of niches. Planktonic foraminifera have been used as tools for interpretation of ancient climatic and oceanographic conditions. However, to come to some tangible conclusions alternating distribution pattern of the fauna has to be studied which is beyond the scope of the present work. Presence of organic remains and absence of primary dolomite in the studied carbonates negate the existence of hypersaline, higher temperature environment and occurrence of pyrite grains suggest reducing conditions.

6.3.1. Pelagic character:

Planktonic forams, predominantly calcitic, are
essentially restricted to normal marine though benthonic ones also occur in hypersaline and brackish waters. The occurrence of radiolarian skeletons in the studied sequence and opaline silica (chert), particularly nodular ones testify to the pelagic character of these carbonates. The characteristic features of pelagic limestone are 1. largely calcitic mineralogy, 2. dominance of pelagic fauna (forams, coccoliths etc.), 3. condensed nature, 4. evidence of synsedimentary cementation like hardgrounds, lithoclasts etc.

Starved basins, shelves and submarine rises are the favourable sites for pelagic carbonate sedimentation. Modern pelagic carbonates are formed on outer continental shelves, continental slopes and ocean floors starved of terrigenous clay and submarine rises. At 50-100 m depth, carbonate sediments comprised of pelagic organisms accumulate in the absence of clays and the ocean is saturated with CaCO₃ in upper few 100 m. Carbonate Compensation Depth (CCD) is envisaged to be the depth at which the rate of solution is balanced by the rate of supply and it varies with depth of the ocean. The position of CCD is controlled by calcareous plankton productivity conditioned by nutrient supply and water temperature. The depths of CCD for calcite and aragonite differ in tropical regions viz. 4500-5000 m and at about 1000 m less than the former, respectively. Calcareous ooze can accumulate on sea floor, shallower than CCD, whereas siliceous ooze and
red clays occur below this depth (Tucker, 1988). Carbonate deposition takes place in equitorial area where warm climate and widespread transgressions occur concurrently. The transgressions lock up much carbonate on the shelves and thereby they do not reach the deep sea. This global interaction between shelf and deep oceanic environment were envisaged by Kuenen (1950).

Pelagic clays and other clay-size particles contain ferromanganese (concretions) hydroxides, quartz, feldspars, pyroxenes, palagonite and other minor components besides the high proportions of Co, Ni and Cu in considerable amount. Ni, Cu, Zn tend to covary with Mn while others show positive relationship with Fe (Ti, Zr). The geological, petromineralogical and fabric data of the studied carbonates are in consonance with the observations made above about pelagic carbonates. These are further substantiated by geochemical data including the stable isotope fractionation trend.

6.4. **DIAGENESIS**

The author has endeavoured to discuss some of the geochemical attributes of significance in interpreting depth, temperature, parameters of genetic relevance, diagenesis, interplay of physiography and environment of deposition and of tectonic importance. These data are
discussed in relation to the results presented in the preceding chapters of the work. Biomicrites and pelmicrites are typical of less agitated environment (low energy) e.g. lagoons, tidal flats, deeper waters, areas of shelves, platforms and basins.

Most limestones composed of remnants of marine organisms, during diagenesis from carbonate sediments to the rock, are lithified by exposure to fresh water. Ample changes in texture, mineralogy and chemistry of sedimentary particles take place though major element chemistry is unaffected but for dolomitization. Mineralogical stabilization attendant with changes in minor and trace elements as also the resultant modifications provide important clues to the lithification processes. The trace element data of great value in this respect and particularly those elements of double positive charge (e.g. Zn$^{2+}$, Sr$^{2+}$, Mn$^{2+}$, Mg$^{2+}$) which substitute for Ca$^{2+}$ in the calcite lattice. In the analysed carbonates of the study area, Sr and Ca exhibit a sympathetic rise, a positive relationship (Fig. 29). Diagenetic behaviour of such elements has been worked out in detail by many workers. For example, Zn$^{2+}$ and Mn$^{2+}$ have proper radii and charge to substitute for Ca$^{2+}$ in calcite lattice and therefore they possess significant potential as tracers of diagenetic processes. While the reaction of manganese is influenced by pH and Eh (Krauskopf, 1967), Zn is sensitive to complexing of chloride ions (Stumm
and Morgan, 1970). Sr and Mn provide evidence about subaerial diagenetic conditions.

The higher manganese contents in well-cemented beds are a function of diagenetic addition of the Mn-bearing calcites while a paucity of this element indicates its incorporation into diagenetic or biogenetic carbonates as it is released into solution. Several sources of Mn for the solution have been considered in oxygen-deficient water during the Cretaceous. These are as given below:

1. Vigorous sea floor spreading-related hydrothermal activity probably contributed to an increased Mn supply throughout this time period (e.g., Pomerol, 1983).

2. The contribution of Mn fluctuated during the Cretaceous on account of repeated changes in the exposed areas of continents and climate.

3. Remobilization of manganese oxides from oceanic settings during diagenesis concurrent with deficient sediment accumulation rates. This may have been related to expansion of oceanic oxygen-minimum zones eg. during Cenomanian-Turonian. Maximum Mn reported is 800 ppm with Sr = 400 ppm (Pratt et al., 1991).

In some modern oxygen-deficient water bodies, the dissolved Mn appears to be controlled by the sum of fluvial and diagenetic sources. Manganese is a redox sensitive
element and therefore remobilization of this element is a function of intensification and expansion of marine oxygen-minimum zones coupled with shifts in redox gradients and boundaries. The carbon and manganese cycles are linked through the reducing potential of oxygen-minimum zones as in the present case. Both can show simultaneous appreciable excursions (77-1471 ppm Sr in study area) in such a suitable depositional site. Low oxidation state (Mn$^{2+}$) is highly soluble while higher oxidation state (Mn$^{4+}$) usually occurs as insoluble particles in the water column. Manganese, therefore is incorporated into carbonates during the formation of authigenic minerals and during biological precipitation in the regime of oxygen-minimum zones or anoxic bottom waters. The solubility of Mn in reduced sea water is greater by orders of magnitude than in oxygenated water (Hem, 1972). The enrichment of this element takes place in marine sediments on shallow oxygenated margins of anoxic basin in either carbonate or oxide phases (Cannon and Force, 1983; Frakes and Bolton, 1984) and in manganese-rich anoxic water column, manganese enrichment in early diagenetic carbonates is observed (Suess, 1979; Renard et al., 1979; Force and Cannon, 1988). The highest value of 1471 ppm Mn is recorded in Ukhrul carbonates of the study area. The Mn/Fe ratio is locally a sensitive indicator of basin morphology (Stann and Thein, 1982). This can reflect separation of Mn from Fe by pyrite precipitation in the basinal facies (Cannon and Force, 1983) as is witnessed in
the studied carbonates.

$\text{Sr}^{2+}$, $\text{Na}^+$ and possibly $\text{Mg}^{2+}$ should decrease, while $\text{Fe}^{2+}$ and $\text{Mn}^{2+}$ should rise with increasing diagenetic equilibration. The degree of diagenesis is best demonstrated, statistically, by the co-variance of $\text{Sr}^{2+}$ and $\text{Mn}^{2+}$. These elements have widely divergent partition coefficients and show large compositional differences in marine and meteoric water (Bodine et al., 1965; Kinsman, 1969; Turekian, 1972). An increase in textural maturity of the carbonate matrix from micrite-microspar-pseudospar. It is obvious that chemical and textural variations of carbonate components describe the degree of carbonate diagenesis in the meteoric environment. A closed diagenetic system, Sr to Ca ratio of the solution increases as dissolution-precipitation progresses and the ratio of Sr/Ca increases concomitantly in calcite. In an open system, Sr may escape from the transformation site and the resultant calcite will contain less Sr than that of closed system.

The concentration of Sr is depleted in the analysed carbonates (study area) with the rise in Mn content but no appreciable textural maturity (sparite formation) has been observed. However, the concentration of Sr (293-437 ppm) with the mean value of 376 ppm Sr, is lower than the averages of 745 ppm Sr and 965 ppm Sr reported from Turonian and Cenomanian limestones, respectively. The Turonian
limestone has been reported to be more recrystallized
diagenetically (Baker et al., 1982) which does not hold true
for those of the study area. The absence of marked textural
maturity, lower concentration of Sr, small depletion in Sr
content with rise in Mn (Fig. 30), decrease of Sr with
increase in Insoluble residue (Fig. 40) in relation to the
maximum calcite content (80-95%) and commensurate with the
highest Sr concentration (437 ppm) in these carbonates are
noteworthy. These may be explained by biogenic factors in
the shallow bathyal environment. Low Sr concentration
characterizes shallow bathyal limestones of organogenic and
organodetrital types which is also true for these carbonates
under study. The predicted chemical- textural covariance
between Sr$^{2+}$ and Mn$^{2+}$ is brought out by Fig. 39 of the
present work in which the analysed data plot in biomicrite
(2-3) to biosparite (4-5) fields indicative of some textural
maturity.

In the typical meteoric environment, low-Mg calcite
(LMC) is a stable phase and therefore it should resist
alteration and retain its original chemical imprint. LMC,
the stable phase, which primarily constitutes 80-95% of the
studied carbonates is relatively more abundant in the deeper
water environment. It is generally accepted that diagenetic
stabilization of carbonate sequences proceeds after exposure
of the metastable assemblage to meteoric water. Veizer and
Demovic (1974) and Veizer (1977) have advocated a similar
Fig. 39 Plot of Sr/Ca vs. Mn showing fields indicating different localities (ref. Fig. 4 of Brand and Veizer, 1980). Symbols represent samples from study area (ref. Fig. 12 for sample numbers).
Fig. 40 Plot of Sr (ppm) vs. Insoluble residue in carbonates of study area.
mineralogical control based on the studies of Mesozoic and Paleozoic carbonates of Czechoslovakia and Australia.

Strontium content of limestone can be related to the clay content. This is related to Sr-enrichment in the pore space during the aragonite-calcite transition, a mechanism already discussed by Muller (1962). The distribution coefficient of Sr between solution and clay minerals (Na- or Ca-illites) is constant up to concentrations of $10^{-3}$ Sr in solution. Since sea water is $10^{-4}$ molar Sr solution, clay minerals further increase their Sr content (Wahlberg et al., 1965). Vinogradov and Ronov (1956) plotted the Sr content against the geologic age of carbonate rocks of Russian platform indicating increase in Sr content with a decrease in the geologic age of the formation. Harder (1964) reported higher values of Sr in Cretaceous limestone. Sr distribution is a function of a facies type and is not random. The facial dependence of distribution of Sr cannot be obscured even by two-times standard variations of the elemental concentration. Basinal limestones show variable Sr contents like 1800 ppm (Flugel and Flugel-Kahler, 1963), 600 ppm (Bausch, 1965), 533 ppm (Chester, 1965) and 500-3000 ppm (Flugel and Wedepohl, 1967). High Sr-content of recent sediments is reduced diagenetically and the distribution of facies area is changed simultaneously. As per the distribution coefficients of Oxburgh et al. (1959) and Holland et al. (1963, 1964), it has been observed that in
case of calcite precipitated in sea water the Sr value should be about 950 ppm.

A positive covariance between Sr and IR (insoluble residue; partly clay content) as depicted (Fig. 40) by the analysed carbonate rocks (study area) between the values of 300-500 ppm Sr and 15-21% I.R. It has been reported that very pure limestones (reef) contain 100 to 300 ppm Sr, limestones with 5-15% clay content contain 400 to 700 ppm Sr and those with more than 20% clay contain 1000 ppm Sr and even more.

A fraction of the IR determined in these carbonates indicates clay content. X-ray diffraction and DTA data point to the occurrence of illite in these rocks. Clay content indicates deep sea condition as clayey carbonates are known to exist in deeper water or close to coast at some places where the amounts of terrigenous deposits are high (Arrhenius, 1952). Many factors control formation of clay minerals which may be (a) detrital, (b) alteration product of volcanic material, and (c) precipitated within coarser terrigenous clastic sediments during diagenesis. Mg$^{2+}$ is selectively adsorbed by illite clays and the gross ratio may reflect the total illite content or perhaps the degree of diagenesis (Fairbridge, 1967). The distribution of clay minerals in modern sediments is largely a manifestation of the climate and weathering pattern of the source area. This is very well illustrated by the clay mineralogy of the
Fig. 41 Plot of Sr vs. carbonate (%), study area (ref. Bausch, 1967).
continuation with that presented in Geochemistry section, which are of petrogenetic, diagenetic, paleogeographic, paleoclimatological and regional significance.

The nature of the studied carbonates are well brought out by the plot of stable isotopic values (\( \delta^{13}\text{C} \) and \( \delta^{18}\text{O} \)) in relation to world data (Fig. 36). Further, in the plot of Sr Vs Carbonate (%), the analysed rocks of the study area fall in Mesozoic field supporting the paleontological evidences.

During the diagenesis of carbonates, the isotopic compositions of most of the whole rock probably do not change significantly. This is because of the fact that the volume of carbon within the carbonate rock is several folds greater than in pore-water reservoir and the fractionation between calcium carbonate and dissolved bicarbonate is relatively small at near-surface temperature (Emrich et al., 1970). Some local effects, during diagenesis, on the major isotopic variations in such a system may be envisaged. Dean et al., (1986) have observed that photosynthetic fractionation of carbon isotopes during the Cretaceous (vide preceding chapter) was augmented by a "greater availability of CO\(_2\)". This is evidenced by the isotopic difference between carbonate and primary organic material during the Mesozoic and early Cenozoic was 7%. more than at present. Nevertheless, such data from the Phanerozoic sequence of
Fig. 36. Isotopic compositions of groups of carbonate sediments and cements. (Ref. Fig.5, Bathurst, 1983).
- data for study area (present work)
world's ocean-floor sediments and is a reflection of contemporaneous volcanic activity (Griffin et al., 1968; Rateev et al., 1969). Illite is more common in ocean floor muds of higher latitude. The distribution of smectite, largely derived from alteration of volcanic material, is related to mid-oceanic ridge systems and volcanic oceanic islands. Smectite during diagenesis, changes to illite through a mixture of smectite-illite particularly during early and late diagenesis. This alteration is affected by the rise in temperature accompanying depth of burial. The change from smectite to illite is on account of incorporation of $K^+$ into the structure of the former and loss of inter-layer water. Kaolinite is also replaced by illite and chlorite at slightly greater depth and high temperature.

Smectite tends to disappear at about 700-950°C depth of 2-3 km in areas of average geothermal gradient. In the study area, the formation of illite, some dolomite and chert may be related to depth of oceanic water, tropical - subtropical region (paleogeographic) and temperature dependent upon the volcanic activity of ophiolitic affinity.

The occurrence of chert in the studied carbonates, particularly nodular chert, may be explained by diagenetic (replacement) changes brought in these rocks. Quite a few examples are reported from the Cretaceous and Tertiary sequences of the Alpine - Mediterranean Tethys region.
India are lacking and, therefore, any attempt for correlation of these finds suffers from severe constraints.

The author, based on trace element, isotopic, and mineralogical data, has obtained ample information about the anoxic (reducing) environment during the formation of these biogenic limestones. The observed "oceanic anoxic events" (Schlangar and Jenkyns, 1976) correspond to positive $\delta^{13}C$ values and to periods of relatively high sea level coupled with high paleotemperatures during the early to middle Cretaceous. On the other hand negative $\delta^{13}C$ excursions of $\delta^{13}C$ from 0.5 to 3‰ have been related to biotic changes. In the studied carbonates, this shift is observed from 0.89 to 2.74 $\delta^{13}C$ permil which may be related to the biotic assemblages occurring in these rocks. This negative excursion may also be a function of conditions of rapid oceanic turn over, oxygenation and efficient recycling of nutrients. The marine sediments show increased organic carbon contents corresponding with "oceanic anoxic events" and the pelagic limestones have increased $\delta^{13}C$ values. These have also been correlated with times of stable oceanic stratification. Carbonate isotopic excursions (higher $\delta^{13}C$ episodes) called "heavy events" have been reported to occur close to the Aptian-Albian and Cenomanian-Turonian boundaries. As against this, significant lower intervals, "lower events" occur close to the Jurassic-Cretaceous and Cretaceous-Tertiary (Maestrichtian-Danian) boundaries to
which the studied carbonates belong. These excursions have been reported to be associated with paleo-oceanographic or paleocirculation events as also with stage boundaries (Scholle and Arthur, 1980).

In relation to the global events of Cretaceous paleogeographic situation of India, tectonic setting of the belt and pelagic nature of the analysed carbonates, it can safely be opined that they were deposited in shallow bathyal zone conditioned by variations in carbonate compensation depth (CCD) within "oceanic - anoxic environment" influenced by fluids which is further supported by the following isotopic data base. The observed negative $\delta^{18}O$ and to a lesser extent $\delta^{13}C$, in the present case, are rather difficult to explain if these carbonates were precipitated from marine or hypersaline fluids. These data strongly indicate the presence of isotopically light meteoric water rather than only sea water or concentrated $\delta^{18}O$-rich sea water-derived brines. In meteorically altered Pleistocene limestone from Bermuda or Barbados, prominently negative $\delta^{18}O$ and negative $\delta^{13}C$ values have been observed (Gross, 1964; Allan and Mathews, 1982). The increase in negative $\delta^{18}O$ with that of positive $\delta^{13}C$ values may reflect either increasing temperature or the influx of meteoric water. $\delta^{18}O$ values may be related to paleohydrology of the basin and evolution of the diagenetic solution (Coniglio et al., 1988). Isotopic data obtained during the present
investigation, substantiated with petromineralogical - geochemical data and geologic - tectonic setting of the belt, reflect a hydrothermal influence in the diagenetic fluids which may have been generated by volcanism, dyke injection and attendant events of ophiolitic affinity in the region. Basement faults may have served as conduits for the hydrothermal fluids. However, much investigations on a regional scale are needed to understand the intricacies of the process. The author has made humble attempts to explain various facets of the formation of the studied limestones, and diagenetic changes brought in them based on the data accruing from his own investigations which have been discussed in the light of published literature. The author has not discussed the regional tectonic setting vis-a-vis the evolution of the marine basin and ophiolite magmatism since these aspects were out of the scope of the present research work.