CHAPTER 9

DISCUSSION

The Lakadong Limestone of the Shella Formation were deposited in the shelf condition in marine environment during Eocene time. The basal part of it measuring 5.78 to 10.29 metres is dolomitic limestone and upper part with a thickness of 52.53 to 95.75 metres is the magnesian limestone. The bottom part of the dolomitic limestone is more compact and contains more dolomite crystals. The basal part of the Lakadong limestone contains 10.22 to 23.31% of dolomitic minerals and considered in the present investigation as dolomitic limestone. The upper limestone possesses 2.75 to 8.50% dolomite and is named as magnesian limestone (Greensmith 1971).

At places light brown colour dolomite crystals form interlocking mosaic in the dolomitic limestone and form irregular dolomitic mottling. On weathering, dolomite and calcareous surfaces often show mark difference in their appearence.

As pointed out by Sanders and Friedman (1967) the subject of dolomite is more complex and it embraces a large number of array of additional complications besides the interlocking problems associated with limestone.

On the basis of petrographical constituents, the dolomitic limestone is predominently found to be sparry allochemical rocks (Type 1) with subordinate amount of microcrystalline rocks (Type 11). In order of preponderance, the magnesian limestone contains Sparry allochemical rocks (Type 1), Microcrystalline rocks (Type III) and Microcrystalline allochemical rocks

(Type II). The limestones of sparry allochemical type are formed in high energy environment having strong or presistent current. In contrast to that, microcrystalline allochemical rocks are formed in an environment where currents are not capable enough to winow away the microcrystalline ooze. In absence of persistent strong current and rapid rate of precipitation of microcrystalline ooze, microcrystalline rocks with little or no allochem are formed (Folk 1959).

The dolomitic limestone is primarily dolomitized biosparite with subordinate amount of dolomitized crystalline dolomite and biomicrite rock. Biogenic and intraclastic are two rock types in the magnesian limestone. Folk 1959 opines that biosparite is characteristically formed in environments where vigorous current action played the role to remove the microcrystalline ooze (Folk 1959). As a result, the fossil allochems are affected by abration. Preponderance of sparry calcite cement in the Intraclastic rocks also provide support in favour of existence of strong current. Intraclastic rocks are formed by deposition of calcite ooze, pellets or fine grained fossils in a protected calm water environment, with all probability in a shallow depth and abrapt change caused by storm or lowering of sea level. Such a condition augment the current energy in a shallow water deposition.

Nagappa (1951) recorded coralline algae from the limestone of the area (p.12). To survive algae require sunlight for photosynthesis. Algae survive up to a depth of approximately 68 metres (200 ft) from water surface. They are prolofic in shallow water and even may be exposed to the atmosphere (Chanda 1967). Mac Gregor (1983) considered corelline algae as primary high magnesian calcite.

In tracing the diagenetic history of the limestones, preponderance of low-magnesian calcite over high-magnesian calcite renders assistance. Coralline algae is known to secrete particle of high-magnesian calcite. In both the limestone low-magnesian calcite always predominent over the high-magnesian calcite. The algae in the limestone though often maintain the original textures, now made up by low-magnesian calcite. Such a change from high-magnesian to low-magnesian calcite is caused by diagenetic processes (Sanders and Friedman 1967).

The dolomitic and magnesian limestone contain ooids with randomly oriented calcite core and external formed by concentric envelopes are common in the dolomitic limestone. But the ooids of magnesian limestone have core of dark materials and are smaller in size. According to Simone (1981) concentric ooids with cortical envelopes having randomly or tangentially arranged crystals always appear to be aragonite. Most of aragonite of the ooids of the limestones are leached out and replaced by calcite. Gaffey (1983) observed that pit formation and infilling lead to alteration in the marine ooid cortex. Friedman (1964) pointed out that selective replacement of ooids and drusy calcite cement of the intarparticle porespace is directly related with the diagenesis and lithification. Simone (1981) also attributed diagnetic modification for such replacement of oolitic texture. However, ooids of magnesian limestone have less concentric envelopes and have nucleus of cryptocrystalline material or small pellets.

Dolomitic mottling is discernable in the field as well as in the petrographical studies of the dolomitic limestone. The later investigation shows interlocking mosaic of subhedral dolomitic crystals replacing fine grained carbonate minerals and often shows dipper margins by the particles having mottling.

Arrested dolomitization results dolomite mottling according to Bissel and Chilingar (1967). Prior to infusement of replacement, limestones having large particule of skeletal or non skeletal material set in matrix with fine texture preferentially replace the matrix by dolomitization. Beales (1953) also pointed out that dolomite mottling is the product of local replacement of original limestone during diagenesis and effective diffusion prosity is the controlling factor.

The petrographical studies reveal that the dolomite are often housed inside the algae that has been diagenetically altered from high-magnesian to low-magnesian calcite (p. 37). The crystal boundary of the low-magnesian calcite are often distorted by the dolomitic crystals (p.37, 38) during the process of dolomitization (p. 117). Carozzi (1960) observed that dolomitization is often selective in the process of development. He further pointed out instances of dolomitization of oölites proceeds independently earlier than cement. Greensmith (1971) is of the opinion that aragonetic shell of gastropods and cepholopods are succeeptible for dolomitization and often alter prior to alteration of matrix.

Often shells of calcitic fossils such as rugosecera, crinoids and brachiopods shells resist the advent of dolomitization. Greensmith (1971) is of the opinion that occurrence of dolomitized fossils is a diagenetic proof in favour of dolomitization and rules out the formation of dolomite as primary dolomite. According to him dolomitization takes place in early (Pre-contemporaneous) diagnetic stage.

Syntaxial over growth, according to Bathurst (1971) (p. 32) are due to either passive precipitation or neomorphism. But, Zener (1973) also considers replacement as an another cause for syntaxial overgrowth and recognised two types of synthaxial calcite boarders; they are (1) calcite rims-- It is even and uniform in thickness ranging between 5 to 25 M and (2) Resembling calcite envelope-- It is coarse void filling calcite, very irregular in thickness and optically continuous with dolomite.

Out of the two types, the former one occurs in the dolomitic limestone sparcely. Zenger (1973) attributed the cause of formation of calcite rim to the dedolomitization of the margin of the dolomite crystals. Relatively high concenteration of ca^{++}/Mg^{++} ratio in the solution during the time of formation of the overlying magnesian limestone may have been acted as the dedolomitizing agent for the formation of the rims.

The dolomitic limestone also possesses well developed rhombs of dolomite. Calciteswith corroded boundary are housed inside the rhombs, displaying poikilotopic texture. According to Friedman (1964), the poikilitic texture of the nature owes its original to replacement of calcite by dolomite.

A good number of workers on carbonate petrology pointed out about the significance of grain coating on unoriented cryptocrystalline aragonite. Such coatings are termed as micritic envelopes by Friedman (1964) and micritic envelopes by Bathurst (1964). Illing (1954) attributed its origin to the alteration process by which tiny aragonite micrite aggregate to form sand-size grains. It is also possible, as shown by Friedman (1967) to develope envelopes as a result of physiological processes of micro-organisms. Micritic envelopes are common in dolomitic and magnesian limestone. They outline the molds of skeletal fragments. Drusy calcite mosaic occluded the original interparticle porosity. The molds of the skeletal fragments are also infilled with drusy calcite. From Bermada, Friedman (1964) traced the progressive stages of mineralogical and textural changes of carbonate sediments and is of the opinion that infilling of molds with drysy calcite mosaic takes place under subaerial condition.

The crinoidal fragments of biosparites of the magnesian limestone possess optically continuous calcite overgrowth (p. 58). Bathurst (1958) has shown that the overgrowth is the resultant product of replacement of carbonate mud or filling of pore-spaces surrounding the crinoidal fragments. He coined the term "rim cement" to represent the pore filling overgrowth and syntaxial rimbs for carbonate mud replacement. Lucia (1962) has drawn attention to the fact that early diagnitic process in grain supported crinoidal limestone leads to the formation of a calcite overgrowth having optical continuity on crinoidal fragments.

Though some pore spaces are filled up by calcite others are not completely plugged. Diagenetic alteration of rock texture, structure and carbonate mineral composition at the time of deposition and post deposition are factors for the development of pore-spaces. Petrophysical properties like porosity, permeability and capiliary pressure have interelationships with pore-space configuration. It envisages the necessity to classify the pore space types and subtypes from the stand point of carbonate reservicur rocks (Teodorovich 1943), Aschenbrenner and Achauer(1960) and Aschenbrenner and Chilingar(1960).

The petrophysical properties of the limestones show that as pore-diameter increases calculated permeability also increases but porosity decreases. The type IV pore-space is predominent in the dolomitic limestone with subordinate amount,of type 3 and type 5. The type IV is the dominant pore-space and type 5 and 6 are subordinate in order of preponderance in the magnesian limestone. The intercrystalline porosity is represented by very fine pore, formed between mud and crystals. It is poorly represented in the dolomitic and magnesian limestone. This type of porosity is also known as micritic porosity (Archie 1952) and mud porosity (Harbaugh 1967) vugs are available in both the limestones and ascribed to vuggy porosity, generally formed during the post lithification.

The capillary pressure curves or poresize distribution curves of both the limestone display steep slope. This medium c-factor relates the medium sorted pore space. It also represents entry pressure or medium initial displacement. Besides, it shows existence of smaller poresize and pointed to the fact that maximum unsaturated pore volume is high. The slopes having the characteristics reveal that with increase of mercury pressure the smaller pores are gradually invaded by mercury. In few cases however flat angle curve of the capillary pressure shows medium to poorly sorted porespace and low initial displacement or entry pressure signifying occurrence of larger pore size. The flat angle curves represent the invasion of mercury in the minimum unsaturable pore volume is usually high. On comparing the curves obtained from the limestones having vuggy porosity with the curves of Purcell (1948), Archie (1952), Aschenbrenner and Achauer (1960) and Robinson (1966) it is found that they have low to medium porosity and possess high unsaturated pore volumes and good permeability.

The size frequency distribution curves of the dolomitic and magnesian limestone are dominantly bimodal, though unimodal and polymodal distributions are not uncommon. The entombed fossil allochems are very well sorted in both the limestones. Their crystals are also well to very well sorted. The distribution signifies beach depositional environment. Mostly the size frequency distribution curves of the carbonate crystals do not show complete range of distribution. This is attributed to the less degree of diagenetic effect of the limestone (German 1968).

Amongst them, P_2O_5, TiO_2 and MnO are genetically related and have got very low solubility in natural water (Strakhov 1967, Srivastava and Mehrotra 1981).

The variation of the insoluble residues in the dolomitic and magnesian limestone parallel to those of the MgO, Fe_2O_3, MnO, Al_2O_3, TiO_2 and P_2O_5.

The dolomitic limestone houses pyrite and magnetite. There is also an association of metallic minerals with the preponderence of pyrite and magnetite over hematite in the magnesian limestone. The occurrence and preponderence of pyrite and magnetite over hematite suggest a reducing environment of deposition of limestones (Krumbein and Garrels 1952).

However, CaO decreases with the increase of insoluble residue. From the carbonate rocks of the Russian platform, Ronov and Enmishkina (1959) established similar relationship of insoluble residues, TiO_2 and Al_2O_3. From the adjacent part of the shelf limestones of the Tertiary age of Meghalaya plateau, India (Goswami et al. 1970) showed similar behaviour of insoluble residue and magnesium content. The positive relationship between insoluble residue and MgO is controlled by primary solution. The selective leaching of CaO by solution increases the concentration of MgO content (Chilingar 1956, Goswami and Panday 1970).

Insoluble residues contain appreciable amount of SiO_2. The dolomitic limestone possesses more insoluble residues (p.78) then the magnesian limestones (p.89). Besides, the basal part of the dolomitic limestone has more concentration of insoluble residues. Similarly, insoluble residues become depleted towards the top of the magnesian limestone. As pointed out by Fairbirdge (1957) the near shore dolomitized carbonate is a non evaporite facies and is enriched in insoluble residue. He also pointed out enrichment of insoluble residues in dolomitized limestone than the non dolomitized limestone and interpreted that dolomitized limestone were closer to the original coastline.

Concentration of calcium and magnesium contents in the dolomitic and magnesiam limestone are comparable with Tertiary carbonate of Russian platform (Vinogradov and Ronov 1956), Teodorovich (1943) mentioned that dolomites of the platform are predominantly diagenetic. Higher percentage of calcium and wide range of it elucidate close and open basinal condition where the limestones were formed (Wolf et al. 1967).

Barium, iron and manganese are environment sensitive in which carbonate rocks are formed. A comparative study of the trace elements (Table29,33) shows poor concentration in both the limestones. Barium varies from 0.03 to 0.063 ppm with an average of 0.023, iron concentrates approximately from 0.002 to 0.020 ppm and manganese ranges from 0.001 to 0.01 ppm in the marine environment. The distributions of the elements in the limestones of the present area are in the line with their usually observed behaviours in the carbonate rocks formed in a marine environment (Friedman 1968). Concentration of manganese is comparatively less in the magnesium limestone than the dolomitic limestone. Ronov and Erimskina (1959) attributed arid climatic condition for low concentration of manganese in the carbonate rocks.

There is an increase of magnesium and phosphate content with the increase of manganese content in the dolomitic and magnesian limestone. Veevers (1969) also recorded similar trend in the limestones of Bonaparte Gulf basin. Ingerson (1962) pointed out that enzymes of lime secreting organisms are active in deposition of calcium carbonate and dolomite and indicated that certain groups of organisms contain relatively higher concentration of certain elements. Ronov and Korzina (1960) from their study of Russian platform observed that living organisms were concentrators of phosphorous during the formation of carbonate rocks. The dolomitic and magnesium limestone have poor concentration of phosphorous. According to Ronov and Korzina (1967) low concentration of phosphorous in limestone indicates an arid climatic depositional condition.

Rao and Naqvi (1977) utilized the molar ratios of the elements of Sr, Mn and Na with respect to Ca as geochemical parameters in tracing depositional and diagenetic conditions. The molar ratio of Sr/Ca of dolomitic limestone and magnesian limestone is related with molar ratios of Mg/Ca. Gradual depletion of Sr/Ca molar ratio is related with the progressive dolomitization. In both the limestone, Na/Ca molar ratio increases with increase of molar Mg/Ca. The behaviour is however, more pronounced in the dolomitic limestone. It suggests that hypersaline brine was responsible for the dolomitization. The molar Mn/Ca is appreciably higher in the dolomitic limestone than the magnesian limestone. Such an increase of molar Mn/Ca with the enrichment of molar Mg/Ca and Na/Ca envisages that dolomitization took place with the help of saline brine, riched in manganese and sodium.

The Mg/Ca ratio is appreciably higher in the dolomitic limestone than the magnesian limestone and opposite is true in case of Ca/Mg ratio (p.85,95). Within the dolomitic limestone, the ratio mg/ca is more in the basal part. Mg/Ca and Ca/Mg ratio are used to appraise the salinity and evaporation condition of the depositional environment (Marchner 1968). As pointed out by **Sanders and Friedman** (1967) dolomitization takes place when Mg/Ca ratio of brine exceeds from that of sea-water ratio. Process of dolomite formation is explained by two processes namely, capillary concentration and refluxion. In supratidal or intertidal zones or along the margins, the capilary concentration effectively plays its role in the formation of dolomite. By the process of dolomite is formed in deeper water condition. Dolomite is a characteristic evaporate mineral formed with the help of brines. The Mg/Ca ratio indicates that dolomitie limestones are formed in a saline environment associated with rapid evaporation. Salinity and evaporation however decreased gradually and a favourable condition for the formation of magnesium limestone is attained.