CHAPTER 4

PETROGRAPHY OF THE DOLOMITIC LIMESTONE

4.1. Introduction :

The basal part of the lower member (Lakadong limestone stage) of the Shella Formation is dolomitic. It is light grey to dark grey in colour and houses foraminifera, corals and mollusks.

The petrographical studies are made to decipher the nature and origin of different constituents, depositional environment, cementation, diagenetic changes and classify the limestone.

An attempt is made to determine the poresize configuration and their significance framing the rock texture, mineral composition and structural discontinuties in the fabric of the dolomitic limestone during the process of early and post lithification. The petrographical properties such as porosity, permeability, capillary pressure are studied to determine the physical characteristics of the limestone. The textural parameters deduced from the size-frequency distribution curves of fossils and fossil-fragments are utilized to decipher the environment of deposition. The crystal size distribution curves are utilized to understand the diagenetic environment of the limestone.

The mineralogical compositions of the dolomitic limestone is established with the help of powder X-ray, Infra-red spectra and Differential Thermal Analysis besides thin section petrography; the metallic minerals are identified under the reflected light.

4.2. Petrography :

The petrographical constituents are grouped under (1) Terrigeneous (2) Allochemical (3) Orthochemical constituents after Folk (1959).

4.2.1. Terrigeneous constituents :

The non carbonate terrigeneous constituents are represented by quartz and opaque minerals.

4.2.1(1). Quartz :

Quartz occurs as anhedral to subhedral, colourless to grey, sub-rounded detrital grains. It often contains inclusions and air cavities. Volumetrically quartz ranges from 0.011 to 2.45% (Table 1). It varies from 0.034 mm. to 0.850 mm. in size.

4.2.1(2). Opaque minerals :

The opaque minerals include pyrite, magnetite and hematite. They occur as small patches with irregular shapes within the shells of allochems and between the matrix and sparry calcite boundaries. The opaque minerals are either absent or range upto 0.46% (Table 1).

4.2.2. Allochemical constituents :

It includes fossils, intraclasts, pellets and oölites.

4.2.2(1).Fossils :

Volumetrically fossils are the most abundant allochem in dolomitic limestone. They range from 0.40 to 44.19% (Table 1). In the total allochems they range upto 98.74% (Table 3). The fossil allochems show the tendency to increase in volume in the upper part of the stratigraphical section (Table 2) and are represented by foraminifers, corals and mollusks. The fossil are entomed as broken, irregular fragments. Their size varies from 0.2 to 2.00 mm. (Table 4). Generally the internal morphology of the shell and test structures are well preserved.

Foraminifers :

The limestones have both larger and smaller foraminifers. The foraminiferal test are composed of radial and concentric cryptocrystalline and granular crystals. The chambers of foraminifers are generally filled up with sparry calcite and occasionally by microspers (Pl. IV Fig. 1). Relying on the orientation of the granular calcite crystalls and radial aragonite on the walls of foraminiferal test, the foraminifers are grouped as follows :

The cryptocrystalline fibrous calcite are disposed radially to the shell walls. The C-axis is invariably oriented in perpendicular direction to the wall of the test. The cryptocrystalline hyalline aragonite arranged concentrically or radially, displays the black cross under cross nicols. . . . .

Stained slides and peels reveal that the shells are bimineralic

(Pl. IV , Fig. 2) and are composed of calcite and aragonite (Dickson, 1966, Evamy, 1969 and Katz and Friedman, 1965).

4.2.2(2). Intraclast :

Intraclasts are oval or elongate in shape and black in colour. Intraclasts are either absent or range upto 11.50% (Table 1). Among the total allochems, percentage of intraclast is either absent or range upto 53.41% (Table 3). The size of the intraclast is found to be within 0.22 to 0.55 mm.

4.2.2(3). Pellets :

Pellets are either absent or when present range upto 7.37% (Table 1).

Pellets are oval to spheriesl in shape and composed of microcrystalline calcite matrix.

Pellets are more or less uniform in size in a given specimen . In the limestone they range from 0.024 to 0.620 mm. In the total allochems they found to vary from 0 to 17.71% (Table 3).

4.2.2(4). Oölites :

Oölites are either absent or when present range upto 0.05%(Table 1). They are more or less round in shape. The core is made up micrite, surrounded by unoriented calcite. They are encircled by dark ring of oölitic coat. Following owardty from the nucleus, it is enveloped by calcite and tiny dark particles and again surrounded by thiek coating of oölite (Pl. IV , Fig. 3).

4.2.3. Orthochemical constituents :

Orthochemical constituents are represented by microcrystalline calcite matrix,sparry calcite, dolomite (p. 29) and microcrystalline dolomite matrix.

4.2.3(1). Matrix :

Matrix are represented by microcrystalline calcite and dolomicrite. Microcrystalline calcite matrix of the dolomitic limestone ranges from 0.107to 20.11% (Table 1). Petrographically, the matrix of the dolomitic limestone is characterized by clay-sized carbonate grains of grey to brownish grey colour.

It occurs between and within the fossil debris (Pl. IV , Fig. 1). The limestone also contain dolomicrite which are identified after staining.

4.2.3(2). Cement :

Amongst the orthochems, sparry calcite as cement is most dominant constituents in the dolomitic limestone. It varies from 34.31 to 99.00% (Table 1), with crystal size from 0.3 mm. to 1.2 mm. (Table 5). Generally, the sparry calcite boundaries are interlocking and are optically continuous.

Syntaxial calcite cement is found around dolomite crystal as rims and they are even and uniform in thickness (Zenger 1973)(Pl. V , Fig. 1). Occurrence of void filler calcite is also noticed in this limestone.

Other cementing material :

Peel and staining reveals occurrence of dolomite and aragonite as cement. The stained dolomite cement on combined solution of alizarin red-S and potassium ferricyanide imparts blue colour. Dolomite cement is found in between the grain boundaries (Pl. V , Fig. 2) and in the test of the fossil allochems.

Ferroan and nonferroan calcite :

Ferroan calcite shows mauve colour when treated with combined solution of potassium ferricynanide and alizarin red-S. Ferroan calcite cement is either absent or occurs upto 6.21% (Table 6) in the dolomitic limestone. Nonferroan calcite ranges from 64.30 to 85.22%.

Ferroan and nonferraan dolomite and aragonite :

Dolomite cements are differentiated into ferroan dolomite and nonferroan dolomite.

When treated with alizarin red-S and potassium-ferricyanide, ferroan dolomite stains with bluish colour. The volumetric distribution of ferroan dolomite varies from 0 to 10.24% (Table 6).

Nonferroan dolomite is recognised by light blue colour after the staining with alizarin red and potassium ferricyanide. Volumetrically it varies from 9.02 to 14.81% (Table 6). Aragonite gives black to greyish black colour when treated with Feigl's solution. It occurs sparsely in between the grain boundaries and inside the shells of fossil allochem (Pl. IV , Fig. 2).

4.2.4. Microtextures and fabrics :

The terms "texture" and "fabric" are used following Friedman (1965).

In general, the carbonate minerals of the dolomitic limestones are anhedral in shape (Pl. V , Fig. 3) but subhedral grains are also not uncommon.

Both inequigranular and equigranular fabrics are present; the former type of fabric is always conspicuous and predominates over the latter type. The inequigranular fabric is well represented by porphyrotopic fabric and occasionally by poikilotopic fabric. The porphyrotopic fabric is formed by the crystals of calcite and dolomite of centimicron size, entombed in finer matrix of the carbonate minerals. The poikilotopic fabric is characterised by the occurrence of smaller grains (microspar) of carbonate minerals inside the larger grains (Pl. VI , Fig. 1). The equigranular fabric with the crystal sizes ranging from micron to decimicron, form the xenotopic fabric.

4.2.5. Microstructures :

The petrographical studies revealed the following microstructures.

Strained calcite :

Strained calcite is probably formed by diagenetic neomorphism of microcrystalline calcite matrix under stress. Strained calcite crystals are turbid or faint and have sutured boundaries with sharp cleavage surfaces.

Veins and vugs :

Veins are usually composed of sparry calcite. Veins vary in shape from straight to irregular and measure 0.123 to 1.50 mm. in length.

Numerous vugs or voids with irregular shape occur between sparry calcite, microcrystalline calcite matrix, dolomite cement and dolomite matrix. Open vugs formed within the microcrystalline calcite matrix are known as "birds eyes" (Wolf, 1965). Some vugs are interconnected with canals. Vugs range in size from 0.023 to 0.54 mm. The length and breadth of canal vary in size from 0.24 to 0.56 mm. and 0.02 to 0.04 mm. respectively.

Microstylolites :

Microstylolites occur as two interlocking net work surfaces and have lateral extension. The surfaces are characterized by accumulation of insoluble residue. The stylolites of the dolomitic limestone are parallel to the bedding plane having 0.01 to 1.75 mm. in length and smaller amplitude. Stylolites seems are formed by the process of solution pressure (Wagner 1913; Park and Schot 1968a, 1968b) during and post lithification. Stylolitization may develope as a continuous process or periodically during diagenesis. Thick accumulation of seam materials, length and small amplitude of the stylolites suggest that they are formed periodically (Park and Schot, 1968a, 1968b).

4.2.6. Neomorphic fabrics :

Neomorphism or recrystallization (Folk 1965) of microcrystalline calcite matrix to sparry calcite matrix and microspar are observed in the dolomitic limestone. The neomorphic fabric suggests the crystal enlargement (Folk 1966, Germann 1968). Cumulative frequency curves of the grains of dolomitic limestone reflect the idea of crystal enlargement (p. 41). Microcrystalline calcite matrix and dolomite matrix have been recrystallized or neomorphosed to sparry calcite and sparry dolomite. This type of change from microcrystalline calcite to sparry calcite and microcrystalline dolomite to sparry dolomite is termed as aggrading neomorphism (Pl. VI , Fig. 2) (Folk 1965).

Two types of aggrading neomorphism are noted, namely coalescive neomorphism and porphyroid neomorphism. But coalescive neomorphism is predominant and porphyroid neomorphism is only occasionally noticed (Pl. VI , Fig. 3).

Most of the aragonite in molluscan shells show the partial inversion of aragonite to calcite. Probably microcrystalline calcite matrix was formed from carbonate mud. Due to neomorphism, the micritic matrix changes into microspar and sparry calcite.

Presence of ferraminiferal tests in a good quantity in the dolomitic limestone suggest that they were originally composed of high magnesian calcite but subsequently neomorphosed to low-magnesian calcite by leaching of magnesian solution and paramorphic inversion solution in the depositional process (Friedman 1958, 1959, 1964 and Bathurst 1964).

4.2.7. Carbonate minerals :

The carbonate minerals are identified from thin sections after staining (Friedman 1959 and Dickson 1966). These are quantitatively measured from stained sections and represented in a triangular diagram (Fig. 1 A). High-magnesian calcite, low magnesian calcite, dolomite and aragonite are the carbonate minerals of the dolomitic limestone of the Shella Formation.

4.2.7(1). High-magnesian calcite and low-magnesian calcite :

Calcite is represented by two types, namely, low and high-magnesian calcite. Calcite is identified with the help of red colour, obtained after the treatment with alizarin red-S solution. When the thin sections are stained with alizarin red-S and 30% NaoH solution, low-magnesian calcite remains unstained and high-magnesian calcite gives purple colour. Low-magnesian calcite being dominant, occurs from 95.10 to 97.79% (Table 7) in the dolomitic limestone. The high-magnesian calcite occurs from 0.80 to 2.61% (Table 7). Occurrence of low-magnesian calcite in preponderance over the high-magnesian calcite and aragonite suggests that low-magnesian calcite was dominantly formed by the process of alteration of metastable minerals namely high-magnesian calcite and aragonite by the process of leaching of magnesium by solution and inversion solution deposition.

4.2.7(2). Dolomite :

They occur as individual grains and in between the fossil shell. They are anhedral to subhedral in nature. The fossil shells having high and low-magnesian calcite (p.50,51) often houses crystals of dolomite (Pl. V ,

Fig. 2). Dolomite crystals, at places disturb the crystal boundary of calcite and penetrate into it (Pl. VII , Fig. 1). Dolomite crystals are occasionally surrounded by calcite grains and forms calcite rim (p. 32). Mottling of dolomite occasionally replaces calcite (Pl. VII , Fig. 2). The volumetric percentage of dolomite varies from 9.12 to 23.31%(Table 6).

4.2.7(3). Aragonite :

Aragonite occurs from 0.48 to 4.30% (Table 6). Generally the foraminiferal test and shells of mollusk exhibits both grey colour and colourless low-magnesian calcite. The bimineralic shells and test indicate selective neomorphic inversion of aragonite to low-magnesian calcite.

4.2.8. Petrographical classification :

The dolomitic limestones are classified, following the approach of Folk (1959, 1962). To classify them petrographically, the three end members namely, allochems, microcrystalline calcite matrix and sparry calcite cements are plotted in a triangular diagram (Fig. 1 B , Table 2). Further subdivisions are obtained on the volumetric proportion of allochems (Fig. 1 C).

The triangular plotting shows that the dolomitic limestone includes two types namely, type I (sparry allochemical rocks) and type II (microcrystalline allochemical rocks).

Type I (sparry allochemical rocks) :

The dolomitic limestone belonging to this type contains 18.99 to 34.33 percent allochems, cemented dominantly by sparry calcite and with subordinate amount of micritic matrix and dolomites. Volumetrically sparry calcite, micritic matrix and dolomites vary from 56.16% to 98.50%, 1.12% to 51.35% and 10.22 to 23.3% respectively in the sparry allochemical rocks. About sixty percent of the dolomitic limestones belong to type I.

This type of dolomitic limestones were formed in high energy environment where strong or persistent current winnowed away microcrystalline ooze (Folk 1959).

Type II (microcrystalline allochemical rock) :

This type of limestone consists of 45.56 to 55.72% allochems with 10.23 to 20.11% and 34.31 to 44.02% microcrystalline calcite matrix and sparry calcite cements. The dolomitic limestones of this type were formed in weak current, not sufficiently strong or persistent to remove the microcrystalline calcite ooze (Folk 1959).

About 45% of the rock contains no intraclast and rest of them includes upto 11.50% of intraclast (Table 1) with well representatives of fossil allochems. The volume ratio of fossil to pellet is greater than 3:1 (Table 1). They are named as biogenic rock (Table 13).

Rest of the rock contains more than 25% intraclast as allochemical particles and are termed as intraclastic rock.

Texturally the dolomitic limestones are classified as dolorudite and doloarenite (Fig. 1 D) Folk (1959).

Rock name :

Amongst the total allochemical percentage, majority of the rock contain more than 25 percent intraclast and more than 10% allochems. These are named as Dolomitized Intrasparrudite (Li DLa), Dolomitized Intrasparite (Li, DLa) and Dolomitized Intramicrudite (IIi, DLa), Dolomitized Intramicrite (IILi, DLa). This division is further extended on the basis of fossil to pellet ratio.

About 60% of the rock contains more than 3:1 fossil to pellet ratio. They are Dolomitized biogenic rock and termed as Dolomitized Biosparrudite (La; DLa), Dolomitized Biosparite (Ib; DLa) and Dolomitized Biomicrudite (IIi, DLa) and Dolomitized Biomicrite (IIb; DLa). 35% of rock contain between 3:1 and 1:3 percent of fossil to pellet ratio; they are Dolomitized Biogenic pellet rock and named as Dolomitized Biopelsparite (1lp; DLa) and Dolomitized biomicrite (LLip, DLa). Rest 5% of the rock contains 1: 10% fossil to micrite; they are termed as Dolomitized fossiliferous micrite. A few percent of the rock contain no Allochem and they are medium grained in size and named as medium crystalline Dolomite (V, p4). Foraminifera and corals are abundant in the dolomitic limestone. The presence of fossils, the names of the fossils are prefixed before the rock names and they are named as coral, foraminifera, Dolomitized Biosparite and coral foraminifera Fossiliferous micrite (Folk 1959).

4.3. Size frequency distribution of allochems and crystals :

The cumulative frequency curves of allochems and crystals are drawn on the probability graph paper from the corrected thin section data after Friedman (1958).

They are dominantly bimodal but polymodal types are not uncommon. (Fig. 5A, 2A).

The cumulative curves of crystals generally do not show complete size distribution indicating that the microcrystalline calcite matrix experienced little diagenetic neomorphism. The medium grained crystals volumetrically exceed the fine-grained crystals (Table 8).

Mean grainsize of crystals of dolomitic limestone varies from 1.26 Ø (0.307 mm.) to 2.10 Ø (0.233 mm.)(Table 8). Thus the crystals are medium to finally crystalline.

Standard deviation varies from 0.421 Ø to (0.752 mm.) to 0.722 Ø (0.615 mm.)(Table 8) which shows that the crystals are well to very well sorted. Skewness and kurtosis range from -0.641 Ø (1.526 mm.) to 0.683 Ø

(0.619 mm.) and 0.848 ∅ (0.554 mm.) to 1.96 ∅ (0.257 mm.) (Table 8) respectively. Thus the crystals are negative to symmetrically skewed and normal to moderately peaked.

Again mean-grain size of fossil ranges from 0.183 ∅ (0.882 mm.) to 1.066 ∅ (0.479 mm.)(Table 9) and medium to very coarse in size. Standard deviation varies from 0.0719 ∅ (0.952 mm.) to 0.496 ∅ (0.712 mm.)(Table 9). Thus they are very well sorted. Skewness and kurtosis ranges from -1.269 ∅ (2.395 mm.) to 0.0766 ∅ (0.959 mm.) and 0.66 ∅ (0.632 mm.) to 1.18 ∅ (0.0441 mm.)(Table 9) respectively. Thus, the fossils are negative to symmetrically skewed and moderate to normally peaked.

4.3.1. Mutual relationship of the textural parameters :

Relationship between ∅ Mz (Meangrain size) and $\emptyset \delta_1$ (Standard deviation) :

Binary plot of mean grain size (∅ Mz) and standard deviation ($\emptyset \delta_1$) is established after Folk and Robles (1964). This relationship shows that all the points fall within the beach environment (Fig. 2 B).

Relationship between ∅ Mz (Mean grain size), $\emptyset \delta_1$ (Standard deviation), $\emptyset SK_1$ (Skewness) and ∅ KG (Kurtosis) :

Vertical distribution of mean size (∅ Mz), standard deviation ($\emptyset \delta_1$), skewness ($\emptyset SK_1$) and kurtosis ($\emptyset K_G$) shows that when mean size increases standard deviation and skewness also increase but kurtosis decreases with the corresponding increase of mean grain size (Fig. 3 A).

Relationship between Ø Mz (Mean grain size) and Ø SK_1 (Skewness) :

The scatter diagram of mean size (Ø Mz) and skewness (Ø SK_1) shows that the dolomitic limestones are dominantly finally skewed followed by subordinate amount of nearly symmetrical and strongly skewed sediments (Fig. 2C) after Folk and Robles (1964).

Relationship between Ø Mz (Mean grain size) and Ø K_G (Kurtosis) :

Mutual relationship of mean size (Ø Mz) and kurtosis (Ø K_G) shows that they are represented by widely skewed sediments, that is, they are platykurtic, mesokurtic and leptokurtic (Fig. 2 D) after Folk and Robles (1964).

4.4. Powder X-ray :

Powder X-ray of dolomitic limestones are done for the identification of calcite, dolomite and aragonite. From the powder photographs, the distance between a pair of arch or curves(s) were measured on a light box viewer equiped with a vernier measuring device, for both Bradley jay and Assymetric type and intensity of the lines recorded. The θ, Sin θ and d-spacing have been calculated from the distance(s) (Table 10).

Now, the calculated d values have been compared with A.S.T.M. card and the khl indexing was done by compering d values with their respective intensity. From the d-spacing and intensity of the every ray, the identification of calcite, dolomite and aragonite are made. The d-spacing of calcite varies from 1.473 A˚ to 3.27 A˚ and intensity varies from very weak to strong (Table 10).

The d-spacing intensity of dolomite varies from 1.44 A˚ to 2.19 A˚ and is very weak to weak (Table 10).

The d-spacing of aragonite is within 1.832 A˚ to 2.70 A˚ and intensity varies from strong to weak (Table 10).

4.5. Infrared spectra :

The mineralogical composition of the dolomitic limestone is also established from the study of infrared spectra (Fig. 3 B). Semiquantative relative percentages of calcite, aragonite and dolomite are measured from the infrared spectra after Huary and Kerr (1960). Distinguishing bands of calcite, aragonite and dolomite occur at 11.41 μ (879 cm^{-1}), 11.65 μ (853 cm^{-1}) and 11.35 μ (885^{-1}) respectively.

The ratio of intensity of calcite, aragonite and dolomite is approximately proportional to their concentration in the carbonate rocks (Huary and Kerr 1960). The relative intensity of calcite dolomite and aragonite peak gives some indication about the semiquantative presence of minerals in a sample (Adler and Kerr 1962, Cement Research Institute, India 1962). From this study it is observed that the present carbonate rock is mineralogically composed of calcite and dolomite with a minor amount of aragonite.

4.6. Differential Thermal Analysis :

The D.T.A. curves show development of characteristic endothermic peaks around 800° and 950°c, indicating preponderance of dolomite in the limestone (Fig. 3C).

4.7. Metallic minerals :

The polished blocks are studied under the reflected light and shows pyrite and magnetite as metallic minerals (Uytenbogaardt 1951).

Pyrite :
Colour— yellowish white
Under cross nicols— Isotropic

Reflectivity (measured with photometer occular)

	In air	In light
Green light	34.20	45.70
Orange light	53.22	46.50
Red light	52.3	45.5

Etch test :- Stains with Hno_3, Negative with Hcl, aquaregia, $Hgcl_2$, KoH, $Fecl_3$. It is found as individual grains.

Magnetite :

Colour— grey, with grenish tint

Under cross nicol— Isotropic

Reflectivity (Measured with photometer occular)

	In air	In oil
Green light	20.6	9.2
Orange light	20.4	8.5
Red light	20.5	9.0

Etch test :- Stains with Hno_3 and Hcl — it becomes dark with aquaregia. It occurs as individual grains.

4.8. Petrophysics :

The petrophysics deals with the porespace configuration. The laboratory investigation includes determination of porosity, permeability and capilary pressure of the limestone and for these characteristics, the shape, size and type of the porospace are measured with the help of optical microscope.

4.8.1. Porosity :

Petrophysics study reveals both primary and secondary porosity which is formed at the time of deposition and post-lithification. It is greatly influenced by the crystal enlargement, textures and fabrics. As a result, it is often very difficult to draw the demarcating lines between primary and secondary porosity. The primary porosity is divisible into (i) intercrystalline porosity and (ii) vuggy porosity, whereas the secondary porosity is represented only by vuggy porosity.

The percent of porosity of the dolomitic limestone varies from 10.2% to 29.76% (Table 11), that is porosity is good to excellent (Robinson 1966).

The average poresize of the crystals vary from 0.04 to 0.128 mm. (Table 12). The size of the pore is found to be larger in this type of limestone.

The type of pores are mainly type IV together with a subordinate amount of type 3 and type 5 (Table 12). Some pores are isometric in shape whereas majority of the porespaces are elongate in nature.

Intercrystalline porosity :

It occurs as tiny pores or void, within and between the microcrystalline calcite matrix. It evolves during the lithification of the dolomitic limestone. The size of the pores varies from 0.04 to 0.06 mm. This type of porosity is also designated as "Micritic porosity" (Archie 1952) and "Mud porosity" (Harbaugh, 1967). Intercrystalline porosity is very poorly represented in the limestone.

Vuggy porosity :

The sub type, vuggy porosity of primary and secondary porosity is well represented in the dolomitic limestone. It occurs between and within the fossils, fossil fragments, calcite and dolomite crystal boundaries.

The size of the vugs varies from 0.04 mm. to 0.18 mm. in the dolomitic limestone (Table 12). Usually vugs remain undisturbed by the crystals, but in a few cases development of crystals partially close up the vugs or voids.

4.8.2. Poresize distribution (capillary pressure) :

A log log plot of capillary pressure versus mercury injection of the rock samples are plotted after Robinson (1966) and Purcell (1949). The capillary pressure curve shows mainly one type (Fig. 3D). From these capillary pressure curves, the physical parameters such as (1) the entry pressure (pd) measured in PSIA, (2) minimum unsaturated porevolume (S_m) expressed in percent and geometric description of the curve "C" factor that is measure of pore sorting are determined.

The entry pressure that is pd ranges from 30 to 70 PSIA (Table 12)
which suggest medium entry pressure.

The minimum unsaturated pore-volume varies from 20 to 79%, that is, rock contains medium to good unsaturated porevolume (Table 12).

Pore sorting (C-factor) ranges from 0.3 to 0.4 mm, that is, the pore sorting in the limestone is good (Table 12).

4.8.3. Permeability :

Permeability is primarily dependent upon the size and shape of pores. The calculated permeability of the dolomitic limestone varies from 58 md to 80 md (Table 12). According to Aschenbranner et al. (1960) and Ricks et al. (1978), the limestones with this characteristics are good permeable rock.

The calculated porosity is a function of the average porodiameter. The plot of porosity and calculated porodiameter (Fig. 3E) after Talash and Crawford (1965) displays increase of permeability from 58 md to 80 md with the increase of pore diameter from 0.04 mm. to 0.128 mm., but the porosity decreases.

4.9. Depositional Environment and diagenesis :

4.9.1. Depositional Environment :

The depositional environments of the dolomitic limestone are studied with the help of following :

1. Distribution of sparrycalcite, microcrystalline calcite matrix, and abundance of broken fossils.
2. Presence of metallic minerals like pyrite and magnetite.
3. Size frequency distribution of fossils and crystals.

Majority of the dolomitic limestone contains wellsorted, medium grained sparrycalcite and dolomite. Moreover, they house a good quantity of broken fossils. With the characteristics, the dolomitic limestone indicate high energy environment of the depositional area where currents were strong to winnowed away the microcrystalline matrix (Folk 1959). However, some of the dolomatic limestone contain unbroken fossils and microcrystalline matrix (p. 39) and they indicate low energy environment or week current where microcrystalline calcite matrix can persist.

The metallic minerals studies show traces of pyrite and magnetite minerals (p.44,45) which suggest a low reducing environment in the depositional area (Krumbein and Garrels 1952).

Mutual relationship of size frequency distribution of fossils and crystals show beach environment of deposition. In this environment increasing current improves the sorting of material. Presence of broken fossil and fragment (p. 30) suggest good attrition.

4.9.2. Diagenesis :

Diagenesis of the limestones are established with the help of texture and mineralogical changes. Petrographical analysis gives the idea of the following types of diagnesis :

(1) Inversion

(2) Neomorphism

(3) Silicification

(4) Solution

(5) Cementation

The dolomitic limestone of the Shella Formation composed of calcite, dolomite and aragonite. The percentage of dolomite is more than ten percent. The calcite is subdivided in to high-magnesium calcite and low-magnesium calcite. The low-magnesian calcite is predominate over the high-magnesian calcite (p. 37) in the limestone. These minerals are secreted by foraminifera, gastropod and lamellibranchia. However, aragonite may formed by direct precepipation from sea water.

4.9.2(1). Inversion :

Inversion of Aragonite :

Aragonite is metastable under the normal pressure and temperature condition (Jamieson 1953 and Clerk 1957). Thus, aragonite may easily change to calcite and low-magnesian calcite.

In changing of aragonite of the fossil shell or leaching of aragonite is occured by solution process.

The aragonite mud of the allochems dissolved and molds and vugs were replaced by solution deposition conversion process (Bathurst 1964 and Friedman 1964). Some foraminiferal test show trace of aragonite minerals and this indicates that aragonite has been replaced by paramorphic replacement. This action is taken by the intervening solution deposition on a microscale (Friedman 1964).

Inversion of high-magnesian calcite and low-magnesian calcite.

High-magnesian calcite is most unstable mineral. The high-magnesian calcite of fossil shell has selectively replaced by low-magnesian calcite by solution deposition process on microscale or slow removal of magnesian from crystal lettice without textural change (Friedman 1964). The foraminiferal and coral test of the dolomitic limestone are composed predominantly by low-magnesian calcite together with subordinate amount of high-magnesian calcite. This indicates that high-magnesian calcite has selectively replaced by low-magnesian calcite by solution deposition process. After the end of diagenesis, the fossil shells are mostly composed of low-magnesian calcite.

4.9.2(2) Neomorphism :

Two types of neomorphism are noticed in the limestones after Folk (1965). They are (1) the more advanced neomorphism of mud--size carbonate to 5-20 micron microspars (2) neomorphism of mud, micrite, fossil etc. to coarse neomorphic sparry calcite.

Probably carbonate mud was deposited as cryptocrystalline grains and ultimately they formed the micritic matrix. The degrading neomorphism formed the microcrystalline calcite matrix and atlast, the microcrystalline calcite matrix neomorphosed to sparry calcite and spars by aggreading neomorphism (Folk 1965). Both coalescive and porphyroid neomorphism is noticed in the limestone. Coalescive neomorphism is most predominent where change in uniform crystal size is observed. Porphoroid neomorphism is locally noticed in this formation (p. 36) where sparry calcite cement developed in between the microcrystalline matrix. Generally the sparry calcite and sparry dolomite are formed by the aggreading neomorphism of micritic matrix of calcite and dolomite. But few amount of sparrycalcite cement is noticed in voids or vugs as filler which indicates their deposition by solution deposition process during the time of deposition.

4.9.2(3) Silicification :

Quartz is either absent or present in a very minor amount in the dolomitic limestone of the shella formation. Therefore, silica has been selectively and completely replaced by calcite.

4.9.2(4) Solution :

The limestone contains a good number of intergranular pore and these indicates that selective and void creating disolution of allochems and crystals have been taken place during and before lithification (Sanders and Friedman 1967, Schmidth 1965).

Therefore, solution played an important role in creating pore space during and after lithification. The cryptocrystalline grains and fibrous aragonite in the allochems have completely or partially dissolved in the solution and created pore spaces or molds (Friedman 1964). Vugs or voids are formed by selective leaching of sparrycalcite cement after lithification. The intergranular pore space occurs in between the grain contact and occurrence of intergranular pore space indicate that allochems were selectively dissolved at the contact of other fossil due to overburden pressure in solution. Therefore, it may be concluded that solution had taken place after the formation of calcite cement. Therefore, solution appears to be a late diagenetic process.

4.9.2(5). Cementation :

Cementation of limestone occurs during early and late diagenetic stages. The limestones are mostly cemented by nonferron, low-magnesian calcite and trace quantity of aragonite, high-magnesian calcite and dolomite. The inversion of nonferroan high-magnesian calcite to nonferroan low magnesian calcite are formed by dissolution under the same environment. Therefore, nonferroan low magnesian calcite is the early diagenetic cement.

The second type of cementing material found in the limestones is ferroan low-magnesian calcite which is regarded as late diagenetic cement. Thus sparry calcite and dolomite cements formed in voids, are the product of both early and late cementation in most of dolomitic limestone of the Shella Formation.