3.1 INTRODUCTION

Regional facies established on the basis of detailed petrography of various Lithofacies have been most useful in delineating the depositional environment of limestones and dolomites. Petrography of the sediments in particular has become the most useful tool not only to evaluate the depositional environment but also to trace the post depositional history of the sediments. Stauffer (1962) suggested that quantitative petrographic data provide the basis for classification and interpretation of the depositional conditions of carbonate sediments.

Petrography based on thin section study of different representative lithotypes of Raipur limestone were
carried out and the textural terminologies are based upon the classification proposed by Folk (1959, 1962).

Since the carbonate rocks are easily susceptible to diagenetic alteration involving changes in grain size and replacement often resulting in complete destruction of original textures and structures. The distinction between sparry calcite (spar) and recrystallised calcite (neomorphic spar) is vital to the classification and interpretation of the genesis of limestone. Criteria of Stauffer (1962) and Bathurst (1958, 1971) are used to distinguish between cement spar and neomorphic spar and both were independently estimated.

The term sparry calcite is used by Folk (1959) is employed here for calcite which has deposited from solution on a free surface. The criteria for identification of sparry calcite are of two kinds (Stauffer, 1962): (a) Criteria directly indicative of sparry calcite; (b) Criteria indirectly indicative of sparry calcite.

In present petrographic studies, the criteria directly indicative of sparry calcite, are: an increase in crystal size away from the wall of an allochem (Plates 6 B);
a decrease in the number of crystals away from the wall of an allochem (Plates 6 B ); preferred orientation of the longest diameter normal to the wall (Plate 7 A ); plane boundaries between crystals (Plate 7 A ).

In addition to the above, the following are the indirect criteria which are suggestive of sparry calcite: crystal size generally larger than 10 micron (Plate 7 B); clear inclusion free crystals (Plate 6 A ); sharp contact between crystal mosaic and wall of an allochem (Plate 7 A ).

Recrystallised or neomorphic spar is defined here as spar that has occupied its present space by replacing another mineral or assuming a different form of the same mineral. The criteria direct indicative of recrystallised calcite are: Irregular grain size of crystal mosaic with no systematic variation (Plate 6 A ); embayment by calcite crystals which may have plane sides into microcrystalline calcite or allochems (Plate 14 A ); curved serrated or interlocking intergranular boundaries between crystals (Plate 14 B ).

Besides these there are number of other criteria which would indirectly suggest that a crystal mosaic is
recrystallised calcite spar they are: gradational boundary between calcite mosaic and microcrystalline calcite (Plate 14 A); calcite size never smaller than 4 micron and generally larger than 7 micron (Plate 6 A); irregular patches of crystal mosaic in microcrystalline calcite (Plate 14 A); residual, irregular 'floating' patches of microcrystalline calcite in the midst of a coarser calcite mosaic (structural grameleuse) (Plate 4 A).

3.2 PETROGRAPHY OF RAIPUR LIMESTONE:

One well exposed Sheonath traverse including Nandini mines was selected and sampled to close intervals so as to obtain representative samples from each lithologically distinct unit in the field. Thin sections cut perpendicular to the bedding, were made from each representative sample and the percent composition of both the allochemical and orthochemical constituents were estimated by point counter. The results are shown graphically in fig. 7 & 8. The details of petrographic compositions are as follows:

3.2.1 MATRIX

The dominant matrix of the Raipur limestone is micrite/microcrystalline calcite and varies between 15 to 90
**FIG. 7. HISTOGRAM SHOWING DISTRIBUTION OF DIFFERENT PARTICLES IN RAIPUR LIME-STONE**

**LITHOFACIES - A.**

1. Massive micrite (Purple)
2. Bedded micrite
3. Stromatolitic micrite (Gray)
4. Stromatolitic micrite (Gray)
5. Stromatolitic micrite (Purple)
6. Stromatolitic micrite (Purple)
7. Stromatolitic micrite (Pink)
8. Stromatolitic micrite (Gray)

**LITHOFACIES - B.**

9. Microdolomite (Gray)
10. Microdolomite (Purple)
11. Microdolomite (Purple)
12. Microdolomite (Grayish White)
13. Dolomitized micrite (Purple)
14. Dolomitized micrite (Purple)
15. Dolomitized micrite (Purple)
16. Dolomitized micrite (Purple)
17. Dolomitized micrite (Purple)
18. Dolomitized micrite (Purple)
19. Dolomitized micrite (Purple)
20. Dolomitized micrite (Purple)

**LITHOFACIES - C**

1. Dolomitized purple Calc. shale
2. Shale pebble Conglomerate
3. Conglomerate
4. Pelmicrite
FIG. 8. TRIANGULAR DIAGRAM SHOWING VARIATION IN GRAIN COMPOSITION OF DIFFERENT CARBONATE FACIES OF RAIPUR LIMESTONE.

- MICRITE
- INTRASPARITE
- PELLMICRITE
- MICRODOLOSPARITE
- ALLOGHEMS
percent. In the stratigraphic section under study, there is considerably more micrite in the Lithofacies-A of the section than in the Lithofacies B & C. Neomorphic spar is present in most of the samples and attains to significant amount in Lithofacies C.

3.2.2. (b) ALLOCHEMICAL CONSTITUENTS

The percent allochemical constituents is inversely proportional to the matrix. The dominant allochemical constituents present in the Raipur limestone are intraclasts and pellets. These are sporadic in the Lithofacies A & B, but become dominant in the Lithofacies C.

3.2.3. (c) OTHER CONSTITUENTS

Detrital quartz accounts for approximately 1% by volume of the Raipur limestone. The quartz grains are rounded to sub-rounded and are conspicuous in shale pebble conglomerate (Intrasparite).
3.3 DESCRIPTION OF MICROFACIES OF RAIPUR LIMESTONE

As discussed earlier in Chapter 2 (Stratigraphy) that Raipur limestones are broadly divided into three lithofacies based on field studies. The major petrographic constituents are micrite, intraclast, sparry calcite cement, pseudospar and replacement dolomite. Based on thin section petrography the following microfacies has been recognized in the study area: stromatolite bearing micrite; "structureless micrite; bedded micrite; dolomitized micrite; pelmicrite and intrasparite/Shale pebble conglomerate.

3.3.1 STROMATOLITIC MICRITE

Stromatolitic micrite is characteristic of Lithofacies A, and made up of clay sized calcite grains. The interlaminar areas are composed of microspar. The algal laminae tend to discontinuous arching convex to the top. Scanning Electronic Micrograph shows that the micrites are arranged parallel to algal filaments (Plate 17 A). At places the interlaminar areas are dolomitized with the formation of well developed dolomitic rhombs. Cavity filling spar in older literature often referred to as "Birdseyes" (Ham 1952). Folk (1959) referred to these textures as laminoid fenestral fabric. The term corresponds to the
elongate stratification produced by fine carbonate silt particles separated by long horizontal irregular formed fenestrae which later are filled with microspar or spar (Plate 12 A, B).

3.3.2 MASSIVE/STRUCTURELESS MICRITE

It also occur in Lithofacies-A, and characterized by homogeneous and structureless groundmass, composed of clay sized particles of calcite. Cavities filled with cement spar are quite frequent and may represent either original shrinkage cracks or have originated due to escape of gases (Plate 5 B, 6 A).

3.3.3 LAMINATED MICRITE

Laminated or bedded micrite occurs in Lithofacies A and consists of continuous laminae made up of micrite. These laminae, are separated by micrite and interpreted to be the original algal mat. Minute grains of quartz are found distributed parallel to laminae (Plate 4B).
3.3.4 **DOLomitized Micrite**

Dolomitized micrite occurs in Lithofacies-B as purple grey crystalline dolostones. It comprises of 60 to 80% dolomites by volume. The dolomite crystals are decimicron to centimicron in size and show ideotopic to xenotopic fabric. Dolomitization involves large scale obliteration of primary textures and structures. The end product has a granoblastic texture, consisting of coarsely crystalline mosaic in which many of dolomite crystals tend to show euhedral form (Ideotopic fabric of Friedman, 1965) (Plate 9B, 15A). Incomplete dolomitization produces a scattering of dolomite crystals in an unaltered calcite matrix (Porphyroid texture of Friedman, 1965). The shape of dolomite crystals in replacement mosaic vary from anhedral to euhedral rhombs, with the terms xenotopic to Ideotopic referring to the mosaics (Sibley and Gregg, 1987) (Plate 13A). In places dolomite crystals show distinct zoning (Plate 15B). The zoning owes its origin to minor differences in the composition of dolomite. Further varying amounts of foreign matter incorporated in the growing crystals may also produce zoning in dolomite crystals.
Natrajan et al (1970) considered dolomitization in Chilhati area of Bilaspur district as secondary. Adyalkar and Dube (1978) opined that the dolomitization of limestone in the northern part of basin pertains of both early and late diagenesis. Similarly Murti (1978) considered both epigenetic and diagenetic origin of dolomite.

The following evidences are suggestive of secondary origin of dolomite present in Raipur limestone:

i) Presence of dolomite along joints, fractures and algal laminations (Plate 11 A).

ii) Clouded core of micrite within the dolomite rhombs (Plate 11B).

iii) Progressive dolomitization obliterating the primary textures and structures (Plate 10A).

iv) Coarse grain size of dolomite rhombs in comparison to calcite matrix (Plate 13A).

The source of magnesium for the extensive dolomitization in the area is supposed to be within the basin, as trapped brines in the subsurface.

3.3.4 PELMICRITE

It occurs in Lithofacies-C and consists of pallets in a matrix of micrite and hence be termed as pelsmicrite,
Pelmicrite is encountered in the upper part of Haipur limestone. This unit is characterised at places by parallelly arranged pellets in a matrix of micrite (Plate 3B).

At places pelmicrite exhibit structure-gromeleuse fabric (Cayeux, 1935). This fabric is characterised by micrite (pellets) in the groundmass of microspar, some clots are rhomb shaped and probably are relics of rhombic dolomite (Plate 4A).

3.3.5 INTRASPARITE/SHALE PEBBLE CONGLOMERATE

It encountered in Lithofacies-C and exposed approximately 10 km NE of Vill. Pendritarai. The intraclasts consisting of calcareous shaly pebbles which are cemented by ferruginous material. The intergain areas are occupied by detrital quartz grains. These intraclasts are fragments of lithified or partly lithified sediments. An abundance of these fragments or flakes produces shale pebble conglomerate/flat chip conglomerate. They generally derived from desiccated tidal flats. (Plate 5A)
3.4 GENESIS OF RAIPUR LIMESTONE

DEPOSITIONAL ENVIRONMENTS

Based upon petrographic studies an attempt is made here to interpret the genesis and environment of deposition of various lithofacies of Raipur limestones of the study area.

3.4.1 LITHOFACIES-A

Stromatolite bearing micrite, the main constituent of this lithofacies suggests the tidal flat, low energy environment of deposition. Tidal flat carbonates are dominantly micrites often pelleted may represent tidal channel fills (Nankatti village). Fenestrae are the characteristic structure in this facies giving rise to 'Birds-eyes' limestone. Stromatolites and algal mats (bedded micrite) are typically of tidal flat deposits. A few varieties may show desiccation cracks (Jhenjhiri vill. Plate 24) and laminoid fenestrae (Nandini mines). Stromatolitic limestones of this Lithofacies belonged to low energy intertidal environment. However, the presence of mud cracks in this sequence is suggestive of upper parts of intertidal to supratidal condition (periodically exposed to sun).
This Lithofacies is almost entirely composed of dolomitized-stromatolite-micrite. Massive bioherm occurring in limestone are suggestive of their growth in intertidal zone (Pettijohn, 1984). The deposition appears to be a shallow near shore uneven basin, which may be divided into a number of basins. Depositional environments under such conditions would show large variations. Working in Bahamas, Cloud (1962) concluded that under higher values of pH, $P$co$_2$ and $C_3$ ionic concentration in the deposition milieu, the Mg/Ca ratio in the sea water increase to a degree which is sufficient to cause early dolomitization. Investigation by Shinn et. al. (1965) on limemud flats of the Caribbean sea have shown that the evaporation of sea water increased the Mg/Ca ratio in the intertidal waters to a value that permits replacement of calcium carbonate sediments by dolomite. Lithofacies B was deposited in upper intertidal to supratidal conditions and has the same depositional conditions as Lithofacies A; but it has been affected by dolomitization. Slight marine regression leads to increase of Mg/Ca ratio, which may be responsible for the dolomitization.
The presence of gypsum in nearby Dotu/Kodwa formation (Das & Ganguli, 1989) is suggestive of evaporitic conditions for the deposition of Lithofacies B. Dolomitization is confined to the upper parts of Chandi formation (Lithofacies B). The source of Mg for extensive dolomitization is supposed to be within the basin as trapped brine in the subsurface.

3.4.3 LITHOFACIES-C

Purple calcareous and dolomitic shale is the main constituent of this Lithofacies. It shows pelletic, intraclastic and desiccation structures which are indicative of intertidal to supratidal environments (Shinn, 1968, Shinn et al 1969). Absence of algal stromatolites suggest that the deposition of this Lithofacies was under conditions not suitable for the growth of stromatolites.

Kendal and Skipwith (1968) and Davies (1970a & 1970b) demonstrated on the basis of their observations on recent tidal flat deposits in the Persian Gulf and Shark bay areas that algal mats develop typically near the upper edge of intertidal zone and the transition zone on to supratidal flats. Flats which are permanently exposed to subaerial conditions do not permit algal growth. By analogy with
recent deposits, a greater part of Lithofacies C generally devoid of algal mat, represents deposition in supratidal environments and prolonged exposure to the sun.

The formation of pelmicrite began with the deposition of limemud. Exposure to subaerial agencies such as sunlight and consequent drying leads to desiccation cracks. Small chips of dried out mud spalls off to give rise to intraclasts which on subsequent abrasion and rounding by wave energy may produce fine sand-sized pelletoids.

The flat pebble conglomerate is formed due to exposure of limemud to subaerial agencies with the development of desiccation cracks. Then subsequent deposition near shore, high energy environment gave rise to intrasparite. The intergrain areas are filled with angular detrital quartz grains. Both intraclasts and detrital quartz grains were later cemented by iron oxide, scattered dolomite rhombs in the lithotype suggests initiation of dolomitization. Lenses of pelmicrites and flat pebble conglomerate occurring in the Lithofacies C, are interpreted as deposits of supratidal flats.
A: Stromatolite bearing micrite (Lithofacies-A)
Dolomite rhombs are aligned parallel to the algal laminae; Alternate dark and light areas represent micrite and microspar respectively.

Bar Scale: 2 mm

B: Pelmicrite (Lithofacies C), Pelletoids randomly distributed in micrite groundmass.
A: Clots of micrite and spar cement; The structure resembles grumeleus structure (Cayeux, 1935); Some clots are rhomb-shaped (arrows) and are probably relicts of rhombic dolomite crystals; The cavity to the left represent fenestral occupied by clear microspar. (Lithofacies-A)

Bar Scale: •2 mm

B: Bedded micrite (Lithofacies A) Find laminated micrite/microspar (Dark) with alternate sand sized quartz grains (clear transparent grains) parallel to the laminae.
A: Shale pebble conglomerate; The shale clasts are derived from older shaly limestone; Angular detrain quartz grains to the upper right are cemented by ironoxide cement (Lithofacies-C)

Bar scale : 2 mm

B: Structureless micrite (dark) with microspar (light) (Lithofacies-A).
A: Micrite with a central cavity occupied by clear microspar (Neomorphic spar) (Lithofacies-A)

Bar scale: 2 mm

B: Cavity filling spar showing increase in the size of crystals towards the centre of the cavity (Lithofacies-A).
A: The long diameters of crystals are arranged perpendicular to the wall of cavity plane. Boundaries between crystals are clearly visible.

Bar scale: *2 mm

B: Intraclasts (rounded) with fibrous calcite cement.
A: Intraclasts are surrounded with fibrous accicular elongated spar crystals (first generation) and cavity filling spar (second generation).

Bar scale: 2 mm

B: Microdolosparite, dolomitization showing subhedral dolomite crystals have clouded cores of calcite dust Hypidiomorphic mosaic of anhedral dolomite (After Sibley & Gregg, 1987).
A: Dolomitized micrite with inclusion free dolomite rhombs.

Bar scale : 2 mm.

B: Dolomitized micrite with dolomite rhombs producing many rhombic dolomite, crystals have cloudy core. Idiotopic mosaic of Euhedral dolomite (After Sibley & Gregg, 1987).
A: Primary calcite spar being replaced by dolomite rhombs (arrow); later generation cavity filling spar at the right is also being replaced by dolomite rhombs (star).

Bar scale: 2 mm

B: Micritic limestone with a stylolite vein. The later has scattered dolomite rhombs.
A: Calcite spar (pink being replaced by dolomite rhombs (colourless and clouded). Thin section stained with Alizarin red-S.

Bar scale: 2 mm

B: Same section showing preferential dolomitization along algal laminae. (Calcite pink, dolomite colourless) Many dolomite rhombs are clouded.

Bar scale: 2 mm

B: Stromatolite bearing micrite with fenestral void filling calcite. Stained section with a few unstained dolomite rhombs.
A: Dolomitized micrite with clear and clouded dolomite crystals. Porphyroblasts of dolomite scattered through an anhedral mosaic of calcite.

Bar scale: 2 mm

B: Dolomitized micrite representing a very advanced stage of dolomitization producing granoblastic texture. (Idiotopic mosaic of anhedral dolomite) Pink stained cores suggest original micrite patches.
A: Micrite being replaced by Neomorphic spar. At the centre a probable cavity filled with cavity filling sparry calcite.

Bar scale: 2 mm

B: Same section in cross nicols.
A: Dolomitic limestone showing Idioblastic texture of dolomite rhomb (right centre). Remaining part shows Granoblastic texture (Idiotopic mosaic of euhedral dolomite).

Bar scale: 2 mm

B: Dolomitized micrite with zoning in dolomite crystals clearly visible.
An original micrite totally dolomitized producing a mosaic of subhedral dolomite crystals (Hypidiotopic fabric) (After Sibley & Gregg, 1987)