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Depositional Environment, Diagenetic Alteration and Porosity Development in the Early Eocene Carbonates, Encountered in Adhi-7 Well, Potwar, Pakistan

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ABSTRACT

The measured portion of the Early Eocene rock, encountered in Adhi-7 well, constitutes dominantly of limestone with subordinate partially dolomitized limestone and shale. On the bases of fossil contents, underlying and overlying rock units, these carbonates have been designated as Sakesar Limestone. Five microfacies have been delineated on the bases of petrographic analysis. Fossil assemblage, especially abundance of calcareous larger benthonic forams, locally common occurrence of green algae and echinoids etc., indicate warm shallow marine environment of deposition for these carbonates. Mud supported nature of the rock, i.e., occurrence of high content of matrix (in the form of carbonate mud) supports low energy environment, probably below wavebase.

Chemical compaction (pressure solution) has played dominant role during diagenesis, resulting in the development of nodular structure, stylolites, grain contact sutures, sutured and non-sutured seams. Dolomite crystals have formed locally along some of the stylolites and sutured seams. Primary porosity could not develop due to mud-supported nature of these carbonates, as these were deposited in low energy environment. Similarly secondary porosity could not formed due to the influence of chemical compaction during diagenesis. Presence of dark brown and black residual bitumen in association with the dolomite crystals along some of the stylolites, is probably the only evidence of some very localized effective secondary porosity within these carbonates.

INTRODUCTION

Adhi-7 well was drilled by Pakistan Petroleum Limited (PPL) in 1981. The well is located in the eastern portion of Potwar Basin (Figure 1) with coordinates (N 33° 06' 56.5", E 73° 07' 30"). The well was drilled to a total depth of 2818 m upto the Khewra Sandstone. Formation depths information was collected from the Hydrocarbon Development Institute of Pakistan (HDIP) report "Pak Well Data" (Kamran and Ranke, 1987), and the nomenclature of the required formations has been taken from Stratigraphy of Pakistan (Shah, 1977).

Classification of the rock samples and interpretation of the depositional environment are based on rock texture and nature of the organic remains, according to Folk (1962), Dunham (1962), and Fluegel (1982). Information on the habitat of benthonic forams was obtained from Haynes (1981), etc. Cores, belonging to Early Eocene carbonates, were logged at the core-house of PPL in Karachi and thus twenty-two samples were collected from different depths for subsequent study in the HDIP laboratory. The study is based on twenty-two polished slabs and twenty-two thin sections.

The study was initially carried out in 1990 as a part of follow-up regional evaluation of the depositional environment and porosity development in the Early Eocene carbonates in the Potwar Basin (Jurgan et al., 1988).

Before describing the depositional environment, diagenetic alteration and porosity development in the carbonates, encountered in Adhi-7 well, a brief general introduction has been added under the subheading of "Concept". This addition has been carried out for the young geoscientists who have recently graduated from various universities of Pakistan and also for those geoscientists who are not directly involved with the sedimentological aspects of carbonates. The authors are fully aware of the fact that these additions will be of little use for the subject experts.

LITHOLOGY

Main lithologies of the measured portion of the core sequence have been shown in Figure 2. The upper part of the section (core # 1, core # 2 and core # 3) is olive grey, argillaceous mudstone and benthonic foraminiferal argillaceous wackestone, which is dolomitized at places. Calcite filled fractures occurred within the mudstone portion. The basal portion of the upper part of the section constitutes of light to medium grey, nodular wackestone with common to abundant biodebris and benthonic forams (core # 3).

The middle part of the section (core # 4 to core # 8) constitutes of light to medium grey, nodular wackestone with common to abundant biodebris and benthonic forams. Partial dolomitization has taken place, specially along the microstylolites (Figure 3). Pressure dissolution has resulted in the development of stylolites, nodular structure and pressure solution seams (Figures 4, 5, 6). Fractures, filled with whitish grey calcite and dark grey to black coloured solid bitumen, are locally common (Figure 5).

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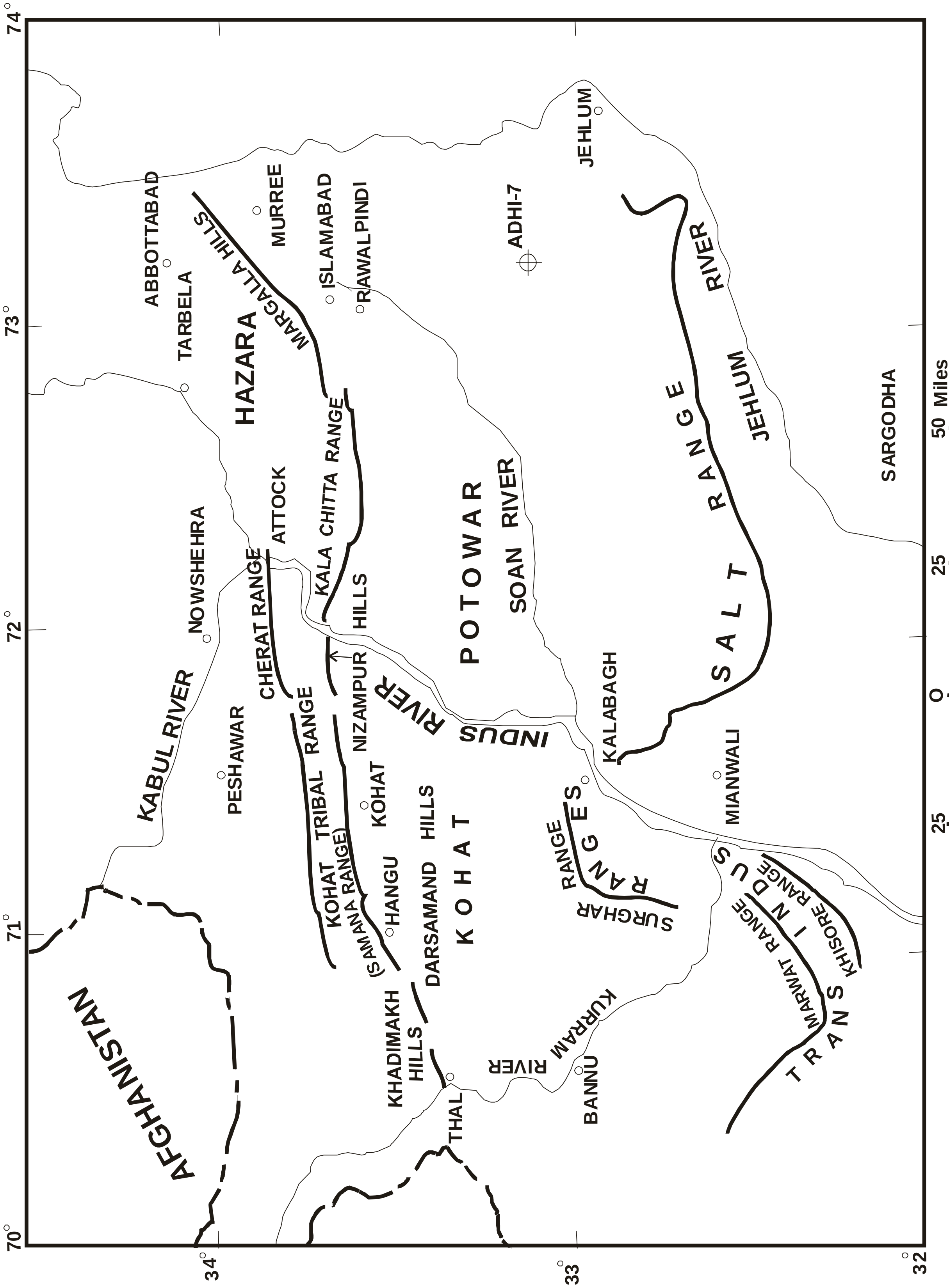

Figure 1- Location map of Adhi-7 well in Kohat Potwar Province (modified after Fatmi, 1973).

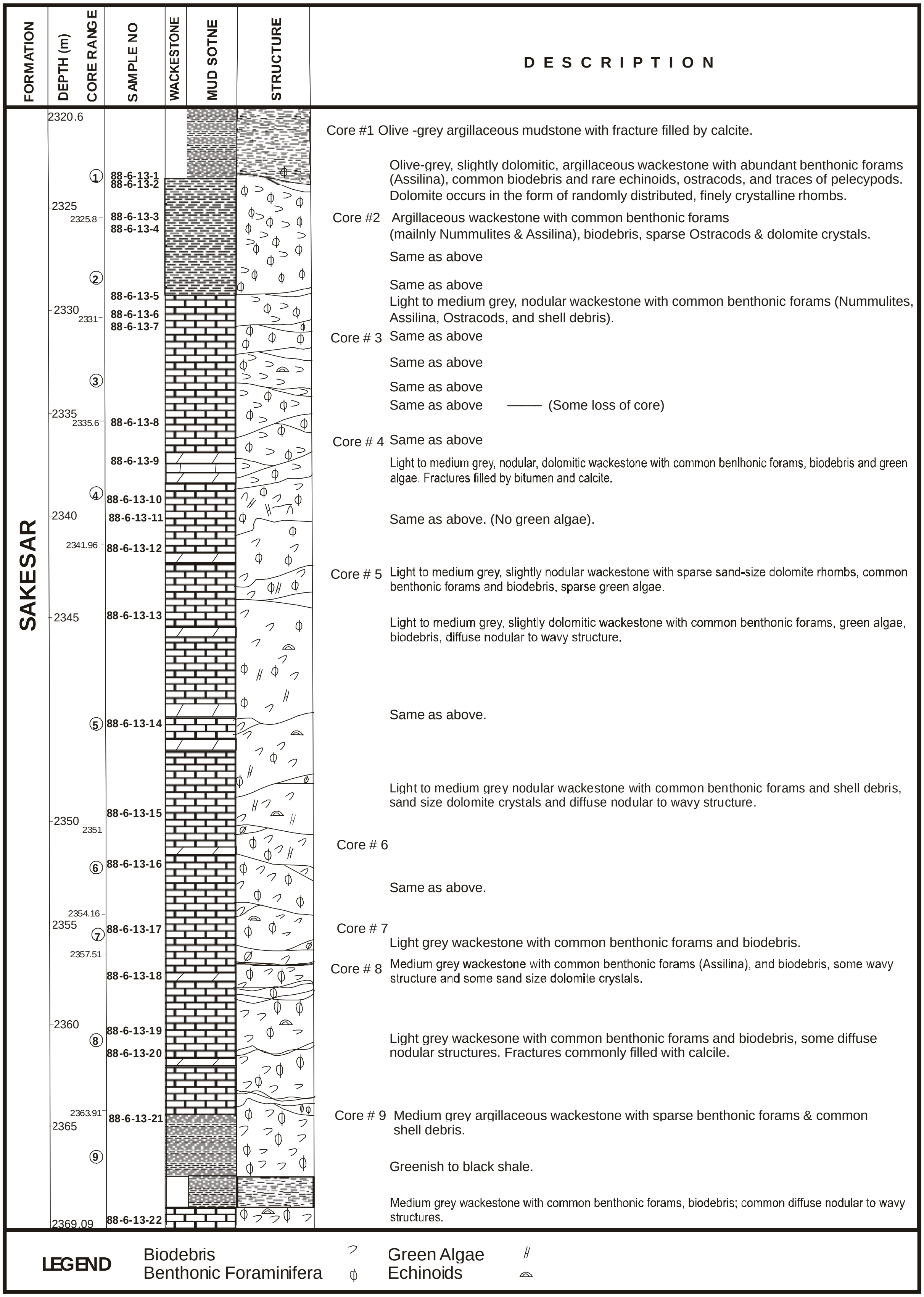

Figure 2- Core lithologic log of Adhi-7 well.

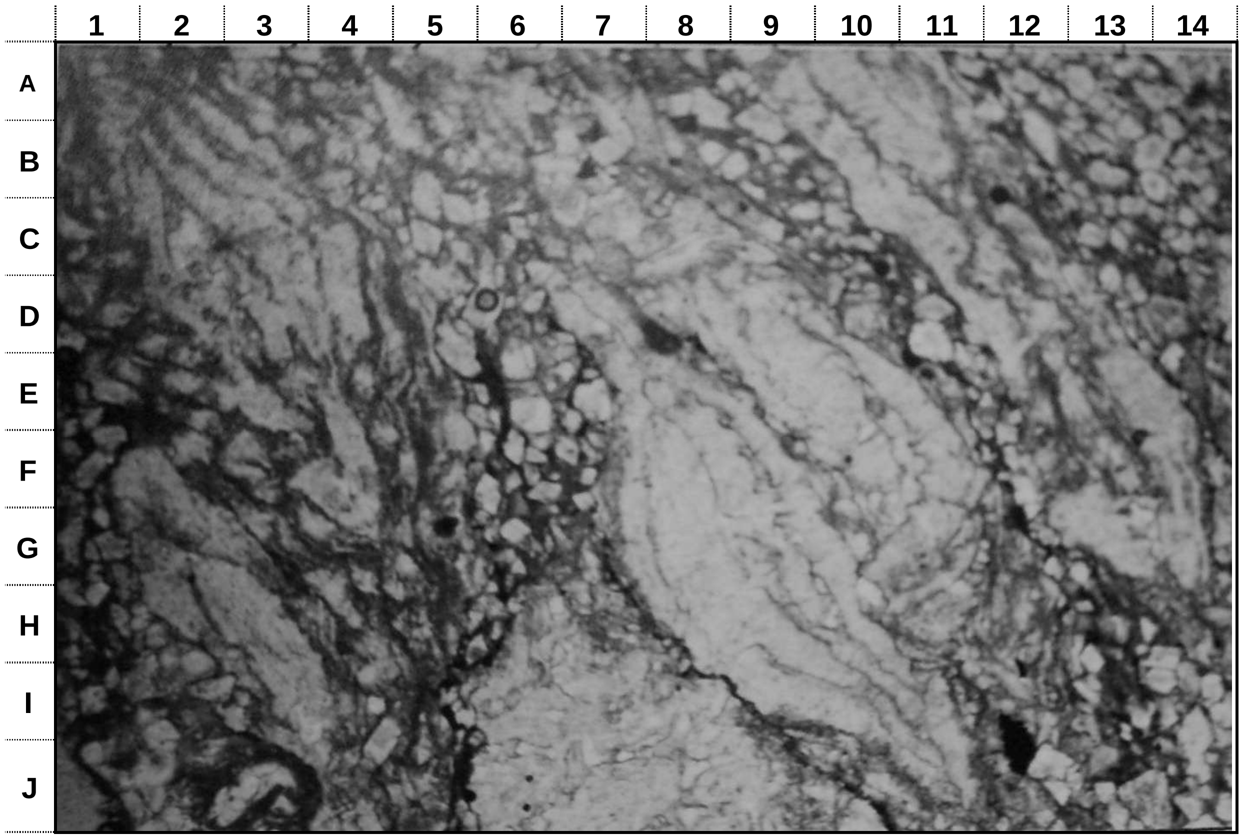

Figure 3- Tests of benthonic forams deformed by pressure solution. Note sutured grain contacts, occurrence of dolomite rhombs and concentration of iron oxide in pressure solution seams.
Thin Section # 88.6.13-15 Mag. X 58

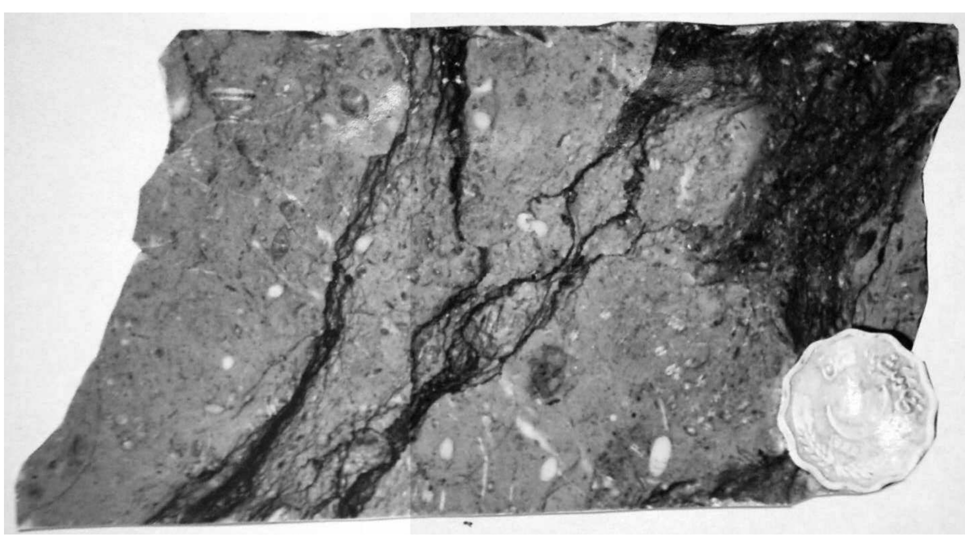

Figure 4- Benthonic foraminiferal wackestone affected by sutured, as well as, non-sutured-seams.
Polished slab, Sample # 88.6.13-14 Scale: Coin Diameter 22 mm

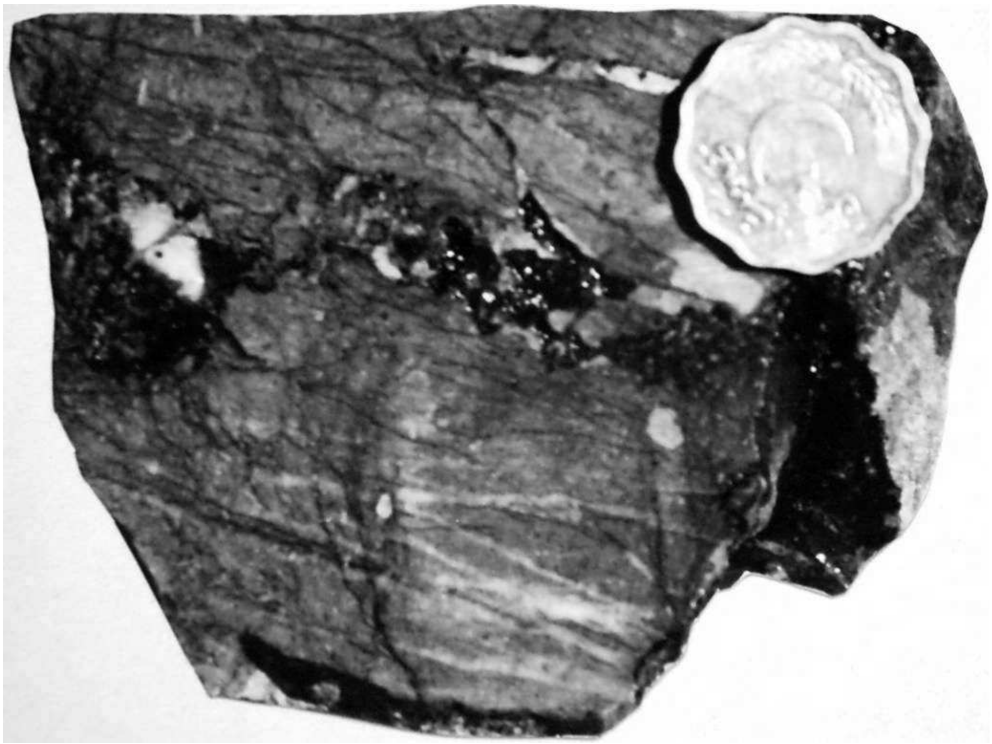

Figure 5- Wackestone with fracture and microstylolites. Note the dark black solid bitumen within the fractures. ***Polished slab, Sample # 88.6.13-11*** ***Scale: Coin Diameter 22 mm***

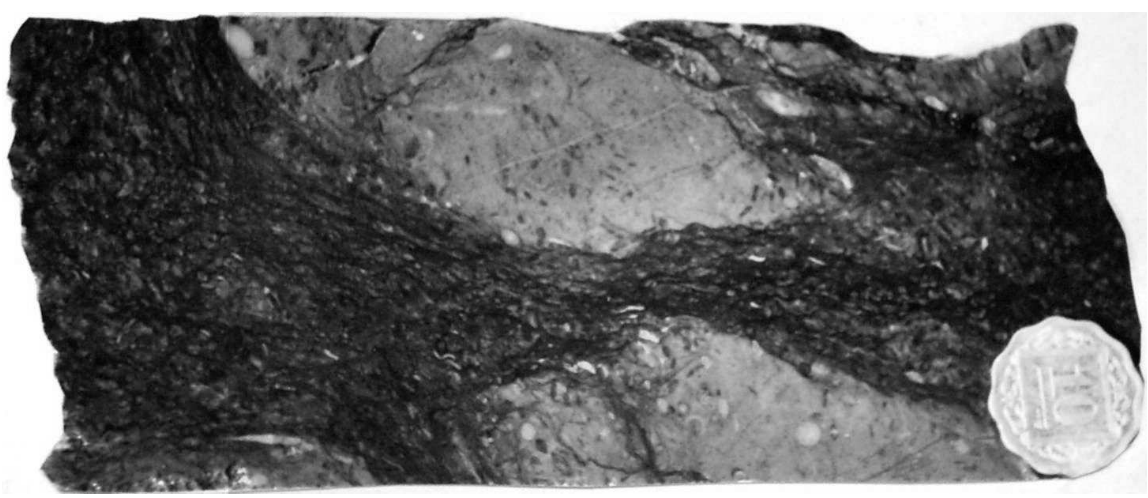

Figure 6- Nodular structure developed in benthonic foraminiferal wackestone by non-sutured-seam pressure solution. ***Polished slab, Sample # 88.6.13-15*** ***Scale: Coin Diameter 22 mm***

The lower part of the section (core # 9) consists of three portions. The top portion constitutes of medium grey, argillaceous, fossiliferous wackestone. The middle portion consists of 1.60 m thick greenish-black shale; whereas the basal portion represents medium grey, nodular, fossiliferous wackestone. Pressure dissolution has resulted in the development of sutured and non-sutured seams throughout this portion of the sequence. Some partially filled fractures are also present.

MICROFACIES

Facies has been defined as the total sum of lithologic and faunal characteristics of a given stratigraphical unit; whereas, microfacies are based on those characteristics and distinctive aspects of a sedimentary rock which are visible and identifiable only under the microscope (at low power magnification). Based on the petrographic analysis (Figure 7 and microscopic descriptions of twenty two samples) of the studied portion of Early Eocene carbonates of Adhi-7 well, following five main microfacies have been delineated:-

1. Benthonic foraminiferal wacke to packstone.
2. Green algal benthonic foraminiferal, wacke to packstone.
3. Benthonic forminiferal wackestone.
4. Green algal benthonic foraminiferal, wackestone.
5. Partially dolomitized benthonic foraminiferal wackestone.

ENVIRONMENT OF DEPOSITION

Concept

Formation of carbonate sediments results mainly from biochemical and biological processes in warm shallow marine and lacustrine environments. In contrast to siliciclastic sediments, warm-water marine carbonates are intrabasinal in origin. Transport of carbonate sediments by waves and tidal currents is limited to local and small-scale redistribution of their constituents. The only exception of possible transport is from carbonate platforms to adjacent basins by turbidity currents (Carozzi, 1993). Petrographic study reveals the evolution and extinction of numerous groups of marine organisms, which either precipitated calcium carbonate from seawater or secreted carbonate skeletons, which, upon death of their respective organisms, released skeletal particles. These skeletal grains are called bioclasts and are of greatly variable shape and size. Bioclasts are associated with non-skeletal grains, such as, ooids, peloids and intraclasts.

Environmental interpretation of limestone relies to a large extent on the identification of the above-mentioned types of grains, in particular bioclasts, which represent the remains of organic communities living in place and therefore provide critical data on depth, salinity, clarity and temperature of water. Although the grain size of bioclasts results mainly the original size of the skeletal constituents, the mechanical action of waves and currents finally shapes skeletal and non-skeletal grains into particles. The grain size expresses to a large extent the energy level (bedshear) of the environment of deposition. Naturally, carbonate particles differ in their hydrodynamic behavior from quartz grains because of their more complicated original shape, lower density due to internal microporosity and variable content of organic matter. Therefore, sorting and rounding coefficients of carbonate particles, particularly skeletal grains, are not reliable criteria as in siliciclastic rocks.

Two other approaches are used for evaluating the energy level of a carbonate environment: 1) mud-supported versus grain-supported texture, and 2) mud to cement ratio in the interstitial spaces of grain-supported framework. Since carbonate mud deposition occurs only under shallow or deep water quiet conditions, increasing energy of the environment leads to a decrease in the amount of carbonate mud and to the generation of a grain-supported framework, with open interstitial pores which are subsequently filled by a variety of precipitated carbonate cement.

This Study

In case of the studied portion of Early Eocene carbonates, encountered at Adhi-7 well, bioclasts and carbonate mud are the dominant constituents. Among the bioclasts, benthonic forams are abundant with subordinate green algae, echinids and pelecypods (Figure 7). Among the benthonic forams Nummulites and Assilina are more common than Lockhartia, Miliolidae, Soritidae and Alveolinidae.

The fossil assemblage, high content of matrix and the presence of fine-grained terrigenous material indicate a warm, shallow marine environment of perhaps restricted circulation. The factors which support this interpretation are: 1) dominance of warm water, shallow marine benthonic forams and absence of plankton, 2) occurrence of green algae (dasyeladaceans) in some of the samples, and 3) mud supported fabric. The common occurrence of calcareous foraminifers, molluscs (Figures 8, 9, 10 and 11), and especially the presence of echinoids and scarce corals indicate a fully marine environment of deposition. The common presence of green algae in some of the samples, indicates shallow water conditions. The relative proportion of mud matrix to cement is an index of water agitation or mechanical energy. Carbonate muds (matrix) generally accumulate in protected areas. Limestone of Adhi-7 have a high percentage of the sedimentation which took place in a low energy environment, probably below wavebase.

DIAGENESIS

Concept

Diagenesis refers to all those processes which occur to a sediment after deposition, during burial and any subsequent uplift. Carbonate rocks are particularly susceptible to diagenesis partly because carbonate minerals are more soluble in water than many other naturally occurring minerals and so are subject to dissolution and reprecipitation. This is enhanced because primary marine carbonate mineral, i.e; aragonite is metastable under sedimentary conditions. Diaganesis can begin on the sea-floor and sometimes grains can be re-worked and

LOCATION: **ADHI-7**

Components / Thin Section No.	88-6-13- 1	88-6-13- 2	88-6-13- 3	88-6-13- 4	88-6-13- 5	88-6-13- 6	88-6-13- 7	88-6-13- 8	88-6-13- 9	88-6-13- 10	88-6-13- 11	88-6-13- 12	88-6-13- 13	88-6-13- 14	88-6-13- 15	88-6-13- 16	88-6-13- 17	88-6-13- 18	88-6-13- 19	88-6-13- 20	88-6-13- 21	88-6-13- 22
Biodebris	○	○	○	○	●	○	○	○	○	●	○	○	○	○	○	•	●	○	○	●	○	○
Blue Green Algae																						
Green Algae										○			○									
Red Algae																						
Planktonic Forams																						
Benthonic Forams	●	●	●	○	●	○	●	○	•	●	○	○	○	○	●	○	○	○	●	○	○	○
Textulariidae						•				○	•	•		•				•	•	•	•	•
Miliolidae						•				○		•	○	○			•		•	•		
Soritidae						•	•	•		○		•	•	•	•	•						
Alveolinidae						•	•					•	•	•	•	•	•	•	•			
Rotaliidae (smaller)																						
Rotaliidae (larger)	●	●	●	○	●	○	●			○	•	○	○	○	●	●	●	○	○	○	•	○
Nummulites	•		•	○	•	○	●	○				○	○	○	○	●	●	•	○	•		•
Assilina	●	●	●	•	●		●	○					•	○	○	○	○	○	●	●	•	○
Lockhartia							•	•		•	•		•		•		•	•	•	•	•	•
Discocyclina																	•			•		○
Operculina																						
Echinoids			•		•	•	•	•		•	•	•	•	○	•	•	○	•	•	○	○	•
Ostracods		•		•	•	•	•	•	•	•	•	•	•					•	•	•	•	•
Corals																	•					
Sponges																						
Gastropods																						
Pelecypods	•													•			•	•		•		
Intraclasts							•															
Peloids/Pellets																						
Ooids																						
Quartz (Detr.)																						
Chert																						
Quartz (Diag.)																						
Radiolaria																						
Dolomite	○	•	○	•	•				○			•	•	•	○	●		•		•	•	
Anhydrite																						
Molds (Open)																						
(Filled)					•					○			○	•	•					•		
Vuggs (Open)																						
(Filled)																•	•					
Fractures (Open)		•		•			•			○										•		•
(Filled)		•		•			○			○	○		○	•	•	○	○		•	○		•
Microfacies	W	W	W/P	W	W	W	W	W	W	W/P	W	W	W	W	W	W	W	W	W/P	W	W	W

LEGEND

- • Sparse (1-10%)
- ○ Common (10-20%)
- ● Abundant (> 20%)
- W Wackestone
- P Packstone
- W/P Wacke to Packstone

Figure 7- Semi-quantitative sample analysis sheet.

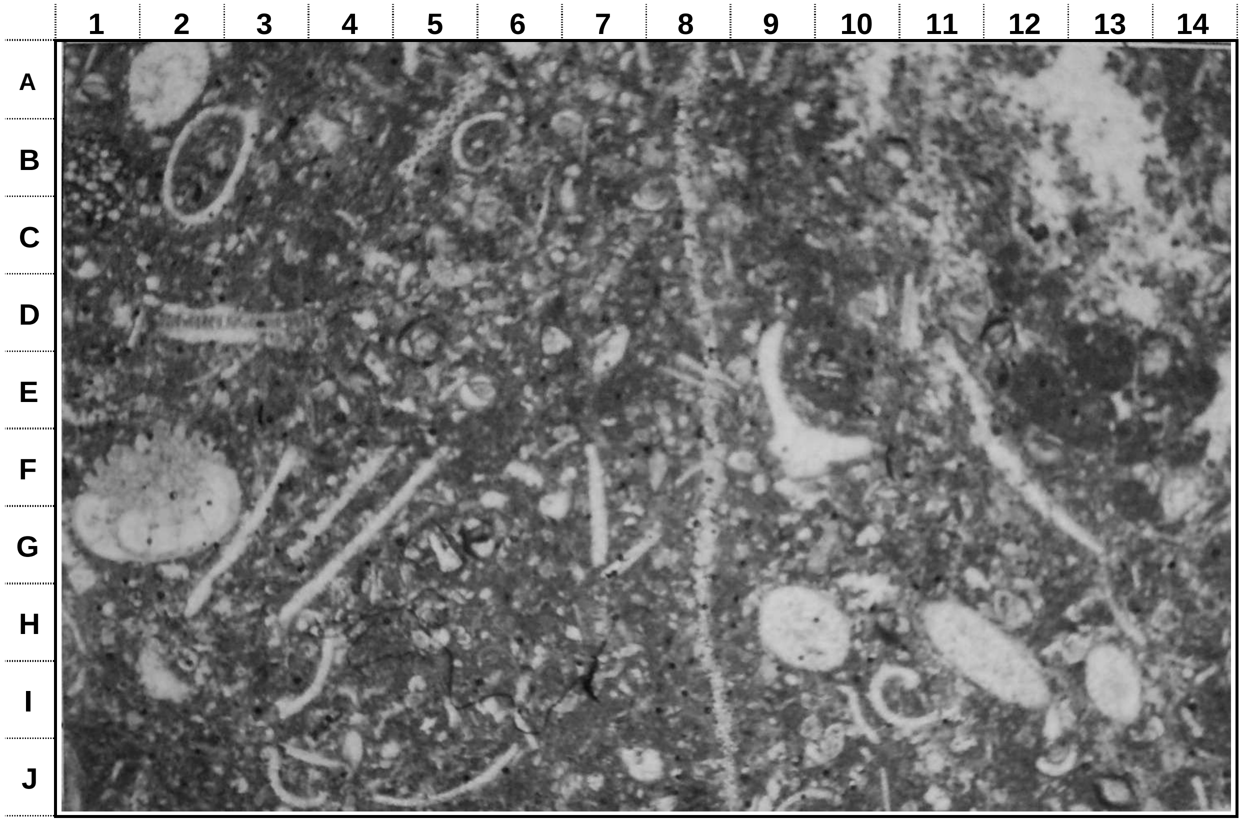

Figure 8- Green algal, benthonic foraminiferal packstone with common biodebris green algae (D-2/3, H/I-11/12), Lockartia sp. (F/G-1/2), Miliolidas (D/E-5, D-12), common shells of molluscs (E/F-9/10), sparse ostracods and sparse filled molds (E/F-9/10). ***Thin Section # 88.6.13-10*** ***Mag. X 20***

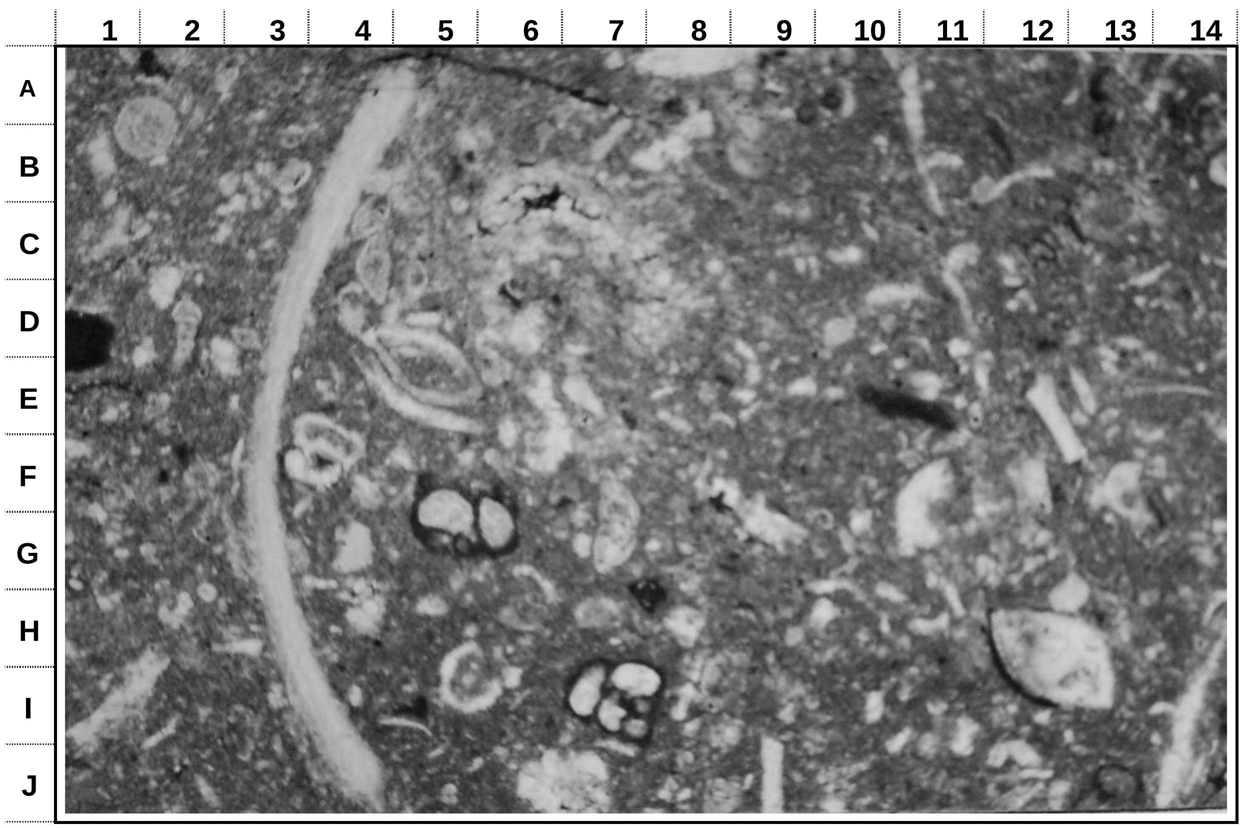

Figure 9- Nummulitic wackestone with common biodebris, benthonic foraminifera, sparse Nummulities, shells of pelecypods (A/J-4/3), ostracods (H/I-12/13) and spine of sea-urchin (A/B-1/2).
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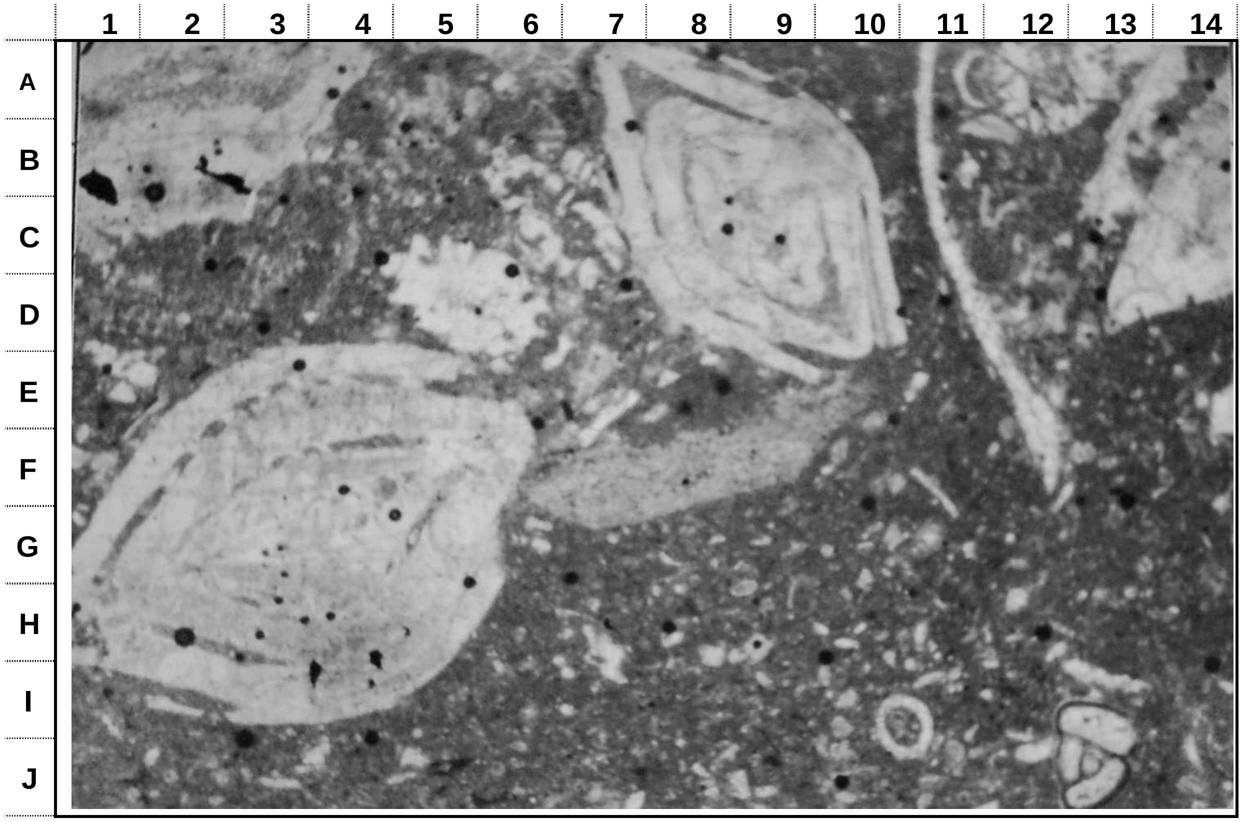

Figure 10- Benthonic foraminifera wacke to packstone with common biodebris, green algae (D-5), Nummulites (A/D-7/8/9/10), sparse Miliolidae, shells of pelecypods and echinoid (E/F-6/7/8/9).
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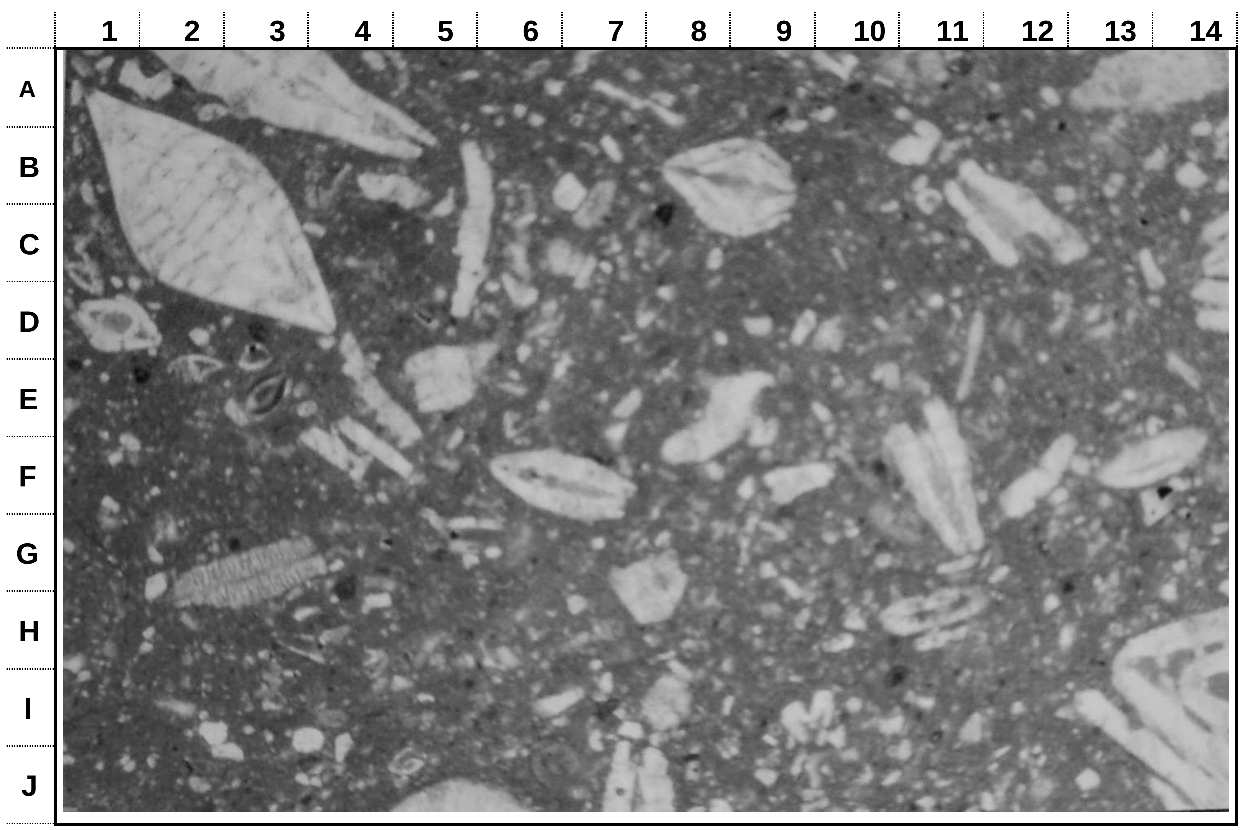

Figure 11- Bioclastic and benthonic foraminiferal wackestone with common Nummulites (A/D-1/2/3), Assilina (A-2/3/4), sparse Discocyclina (G/H-2/3) and miliolidae.
Thin Section # 88.6.13-17 ***Mag. X 17***

re-deposited after some very early diagenesis, such as, micritization or marine cementation.

The fundamental feature of the diagenesis of limestones is their interaction with marine and meteoric waters and with subsurface solutions. Each of these fluids leaves a unique diagenetic imprint at the time of its reaction with the limestone. This imprint can be considered as a distinct diagenetic environment and qualify in time as a diagenetic phase, although this imprint may be largely or totally destroyed by subsequent diagenetic phases. In deep burial environment, the prominent processes are dewatering, decrease of porosity, mechanical compaction, microfracturation, chemical compaction (represented by pressure solution), cementation, various types of replacement by dolomite and other minerals.

Although the general result of deep burial diagenesis is a gradual decrease of porosity by combined affect of compaction and cementation, pore fluid may often change composition to the extent of becoming aggressive solution capable of generating secondary porosity.

Chemical compaction represented by pressure solution is an important diagenetic process in limestone. It produces reduction in the thickness of individual beds and entire formations on the order of 20 to 35%, which are added to the effects of physical compaction. Pressure solution is also a producer of carbonate cement in deep burial conditions, which completes the process of porosity destruction that began in the initial stages of limestone diagenesis. The most significant products of pressure solution are stylolites.

This Study

The most prominent diagenetic feature observed in the studied core samples is the phenomenon of pressure solution. According to the classification of Wanless (1979), the pressure solution response displayed by Adhi-7 limestone falls into two styles; 1) sutured-seam solution (common stylolites, nodulees and grain-contact sutures) and 2) non-sutured seam solution (microstylolites, microstylolite swarms and clay seams with or without dolomite growth along seams). Sutured-seam solution occurs due to the presence of fabric-elements which are structurally resistant to stress and with little or no platy insoluble material in limestone (platy insoluble material includes clay, micas, platy-silt and carbonaceous material). In case of Adhi-7 limestone common bioclasts and benthonic forams have structural resistant elements under conditions of pressure dissolution, resulting in the formation of stylolites (Figure 4) and grain-contact sutures (Figure 12).

Non-sutured pressure solution features are formed in limestone with a significant amount of fine platy insoluble material. These features tend to form anastomosing swarms of thin seams. Non-sutured seam solution includes such features as: 1) microstylolites (Figure 13), 2) microstylolite swarms (Figure 14), 3) clay seams and nodules (Figure 6).

Nodular limestones are a typical result of non-sutured seam solution. Limestone nodules, in fact, contain preserved features of depositional origin, such as, the scattered distribution of skeletal grains etc. These features indicate that the limestone nodules remained unaffected by major volume reduction; as compared to areas between and, adjacent to nodules, which are occupied by swarms of microstylolite which underwent differential solution (thinning due to pressure solution Figure 6).

Dolomitization is generally associated with seam growth. Scattered fine dolomite crystals are very common within the sutured and non-sutured seams, and some of the samples show even more common occurrences of dolomite rhombs within the zones of clay seams (Figures 3 and 14). These dolomites appear to be intimately associated with rock volume reduction by pressure solution. They probably formed through a sort of local source of Mg, i.e; either through leaching of Mg from interbedded clays or marls (Wanless, 1979).

RESERVOIR PROPERTIES

Concept

The above-described sequence of diagenetic environments, regardless of its various possible pathways, ends with deep-burial conditions and the gradual destruction of depositional porosity and early acquired secondary porosity which terminates with irreducible porosity along crystal boundaries. However, porosity can be generated in the deep-burial environment by dissolution processes on a much larger scale than assumed earlier. Deep-burial porosity ranges from fabric selective to nonfabric selective and includes molds, enlarged molds, vugs, solution enlarged interstitial voids, channels, stylolites, and fractures etc. Carrozi and Bergen (1987) has stressed the importance of natural stylolitic porosity in the generation of deep-burial reservoirs.

Dolomitization of limestone has resulted in the formation of extremely important reservoirs for the accumulation of oil and gas (Moore, 1989, Choquette et al., 1992). Such dolomite-associated porosity is produced by associations of various other types of porosity, resulting not only from replacement dolomitization processes, but also from dedolomitization and selective leaching of calcite under the action of CO_2-rich circulating waters. When replacement dolomitization develops a coarse mosaic texture, appreciable intercrystalline porosity is produced along the contacts between the various types of rhombohedra.

This Study

Adhi-7 limestone is a skeletal wackestone (biomicrite, composed predominantly of matrix with varying amounts of bioclasts) and with no preserved primary porosity (Figures 8, 9, 10, 11 and 15). Only rarely a few filled molds (Figure 8) and filled vugs have been noticed in some of the samples. Pressure solution did not enhance secondary porosity (Figures 3, 4, 6, 12, 13 and 16). Some closed, partially closed, or open fractures and channel-like features were observed in some of the samples. In general the Early Eocene carbonates in Adhi-7 well are poor reservoirs.

The only localized, but probably effective, porosity observed in the studied column of Early Eocene carbonates, is the association of stylolites and dolomite (Figures 13 and 3). Such porosity clearly shows the presence of dark brown and black residual bitumen.

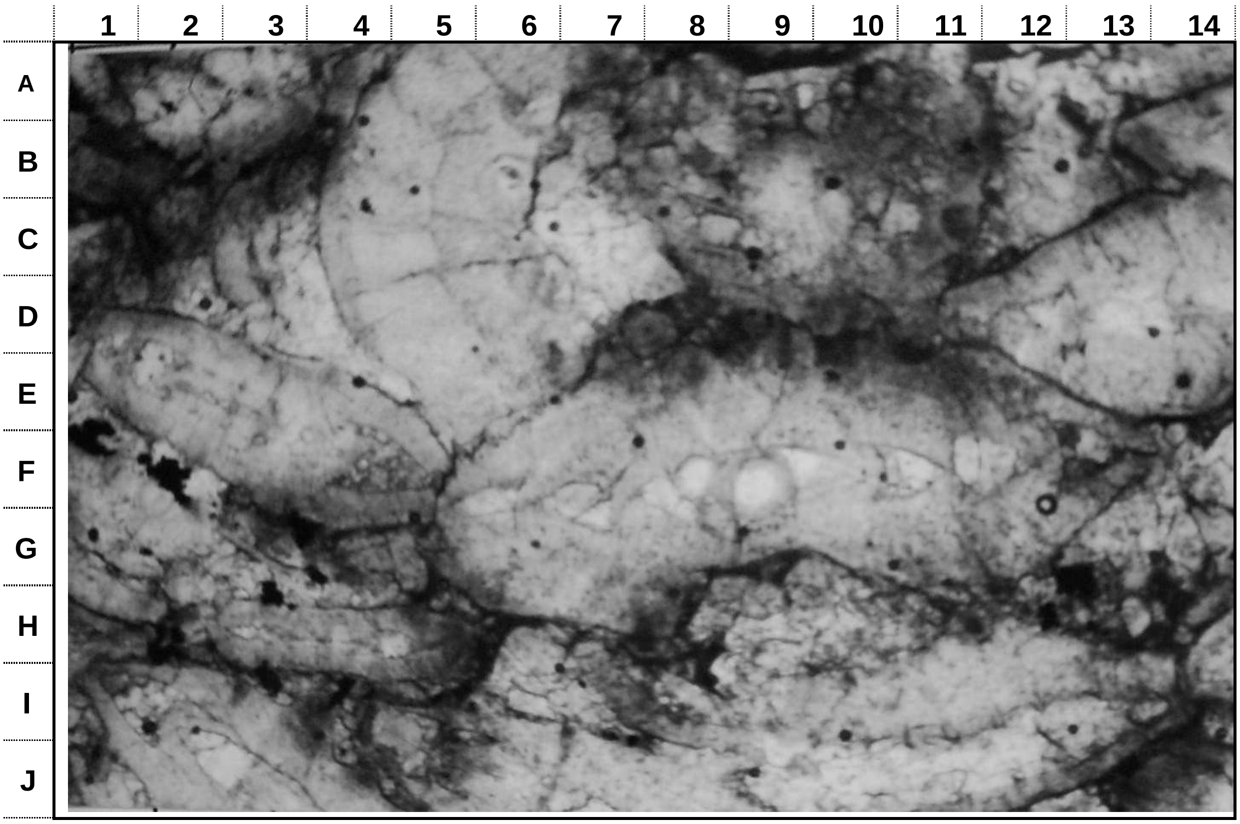

Figure 12- Assilinal wace to packstone, primary texture altered by pressure solution. Note sutured contacts around assilina grains. ***Thin Section # 88.6.13-3*** ***Mag. X 36***

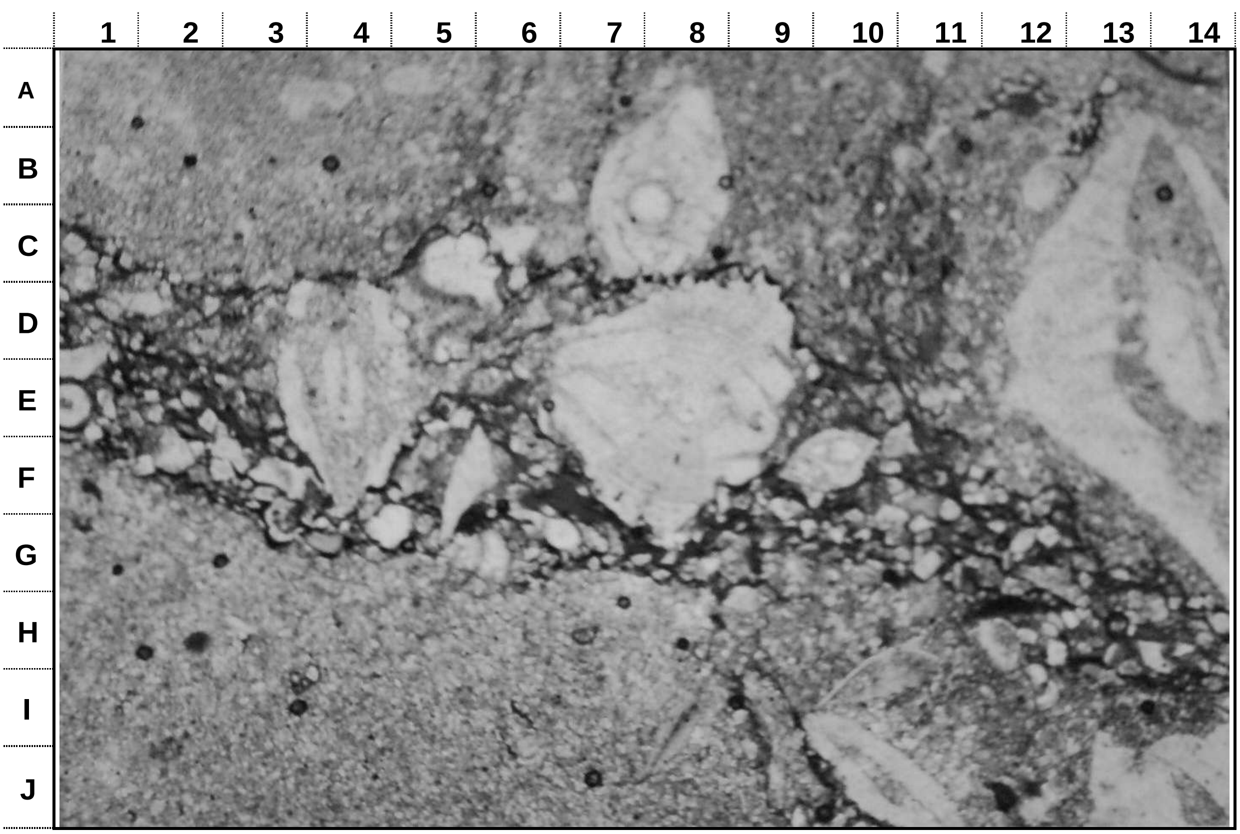

Figure 13- Nummulitic foraminiferal wackestone affected by pressure solution; microstylolitic swarms are surrounding the skeletons and dolomite rhombs. Unaffected portion of wackestone is visible above and below the microstylolitic zone. ***Thin Section # 88.6.13-13*** ***Mag. X 36***

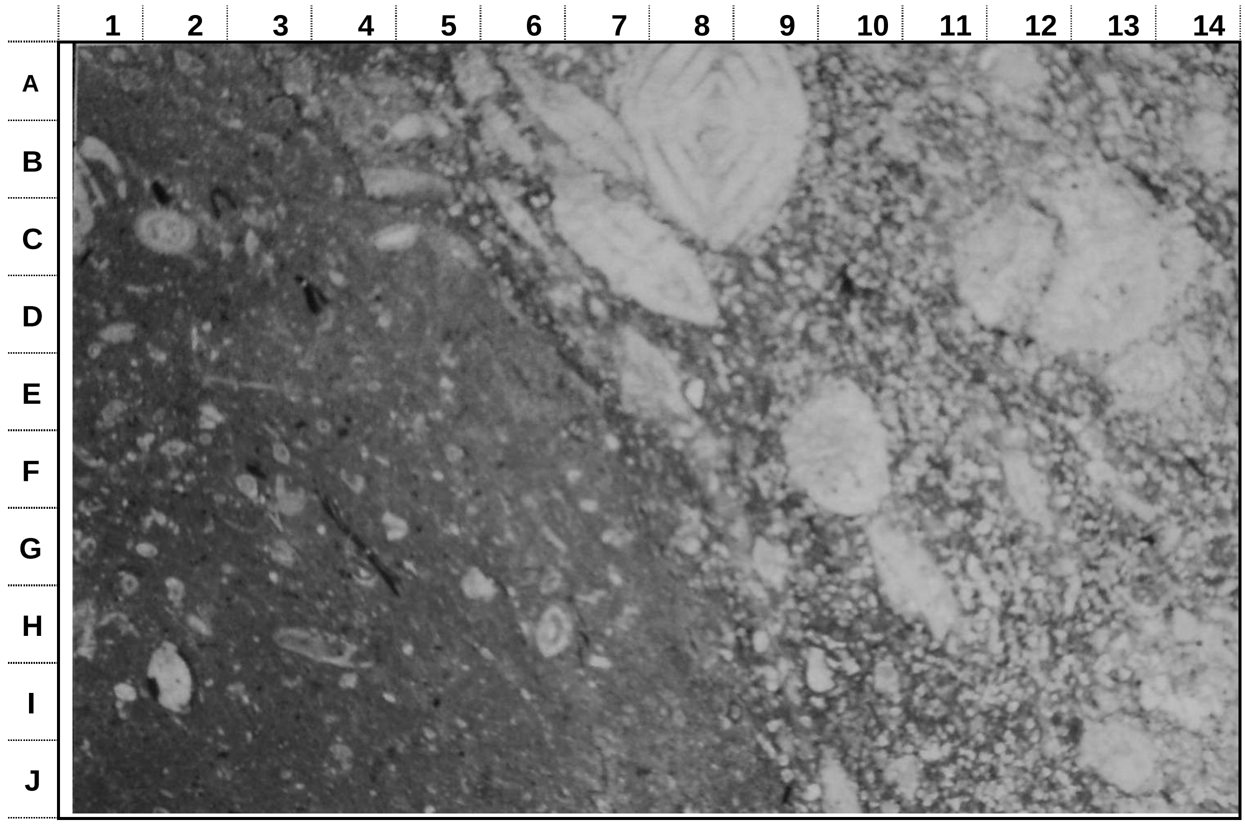

Figure 14- Benthonic foraminiferal wackestone (left) separated from dolomitized wackestone (right); note abundance off dolomite rhombs in non-sutured seam zone and sutured grain contacts between tests of Nummulites (A/C-6/7/8). ***Thin Section # 88.6.13-15*** ***Mag. X 15***

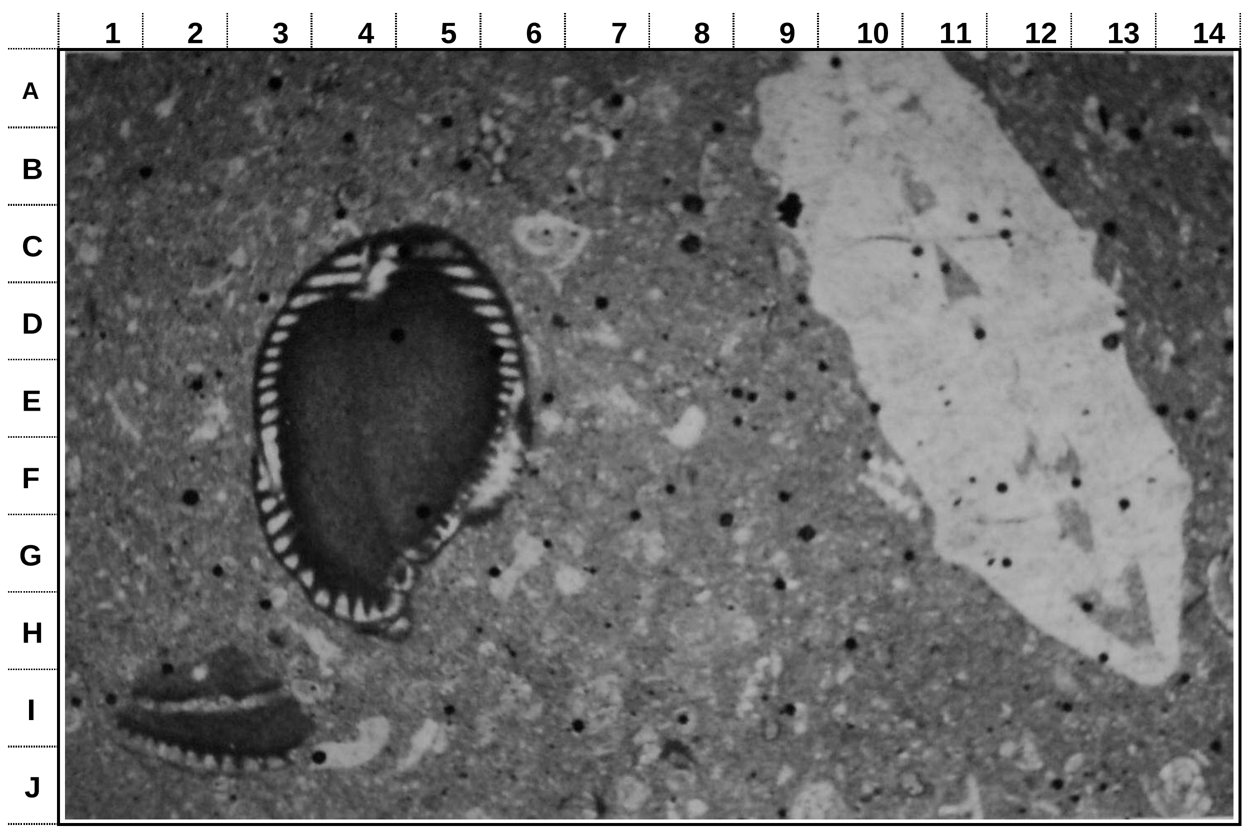

Figure 15- Benthonic foraminiferal wackestone with distorted test of an Alveolinida C/H-3/4/5).,Assilina (A/H, 9/10/11/12/13/14). ***Thin Section # 88.6.13-14*** ***Mag. X 37***

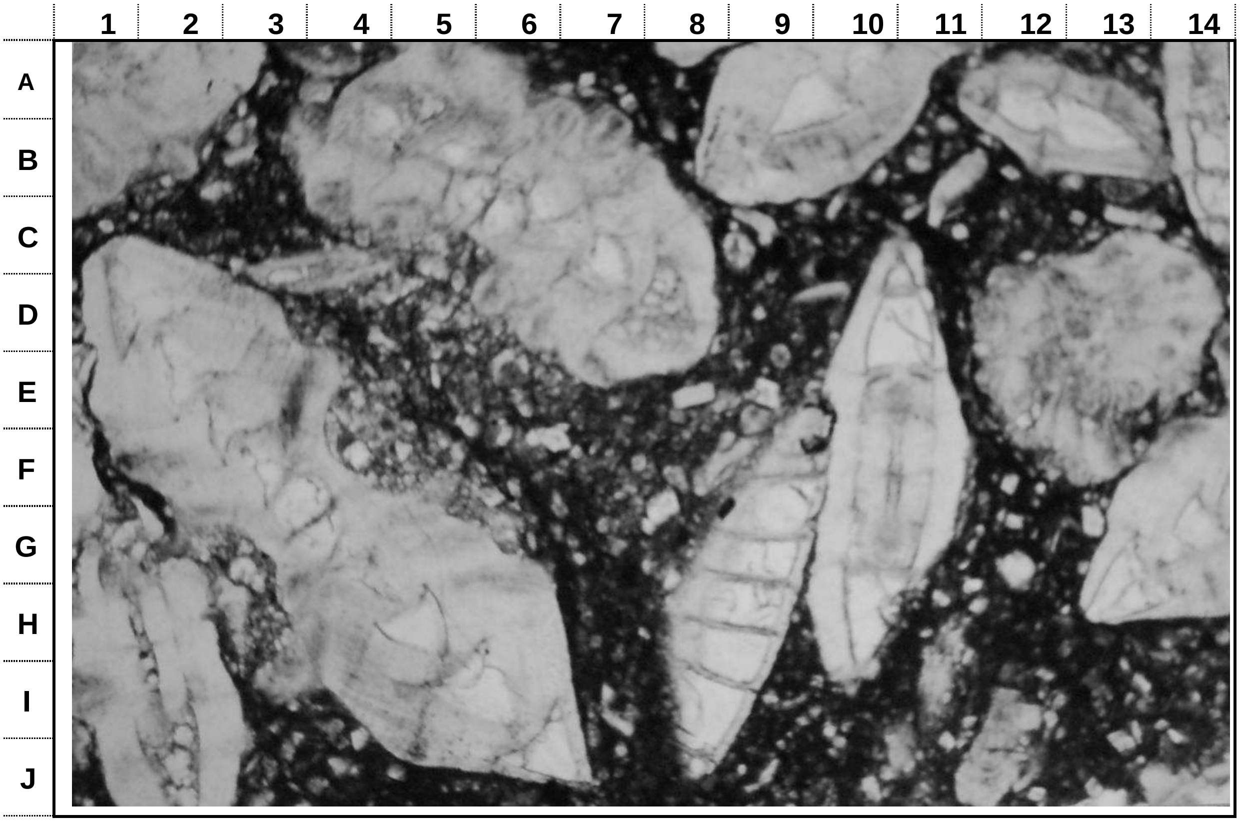

Figure 16- Assilinal wackestone with common biodebris and rhombs of dolomite. Chemical compaction has completely altered the original facric. ***Thin Section # 88.6.13-1*** ***Mag. X 37***

CONCLUSION

High content of matrix (matrix supported), dominance of warm water, shallow marine benthonic forams, local occurrence of green algae, molluscs and echinoids clearly demonstrate low energy, warm water shallow marine environment for the deposition of these Early Eocene carbonates.

Mechanical and chemical compactions (pressure solution) are the dominant diagenetic features of these carbonates. Nodular structure, stylolites, microstylolites, clay seams and stylolite associated dolomites are the prominent products of chemical compaction.

The low energy environment of deposition has resulted in the accumulation of fine matrix, thus, primary porosity could not developed. Similarly chemical compaction, during diagenesis, further resulted in the compaction of sediments and, therefore, there was no chance of creation of secondary porosity. The very localized effective porosity noticed in these carbonates is the stylolites and suture seams, which are at places associated with dolomite crystals.

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SAMPLES DESCRIPTION

Sample No. 88-6-13-1

Assilinal, foraminiferal wackestone. The rock consists of abundant Assilina, sparse Nummulites and Pelecypod fragments. Fine sized dolomite rhombs are abundant in the groundmass as well as in the interior chambers of the tests. Pressure dissolution has resulted in the closer packing of the bioclasts and grain contact sutures. Some of the interior chambers of bioclasts are also filled with solid bitumen.

Sample No. 88-6-13-2

Argillaceous, Assilinal wackestone, with abundant Assilina, sparse Ostracods and common Biodebris. Some open microfractures and microstylolites are present. A few rhombs of fine dolomite are randomly distributed.

Sample No. 88-6-13-3

Assilinal wacke to packstone with common Biodebris, abundant Assilina, sparse Nummulites and rare Echinoids. The shells have been deformed and squeezed due to compaction and pressure dissolution resulting in the development of sutured contacts between the bioclasts. Some clayey patches and randomly distributed dolomite rhombs are also present. Chambers of bioclasts are occasionally filled with black bituminous material.

Sample No. 88-6-13-4

Nummulitic, foraminiferal wackestone. The rock consists of abundant Nummulites, sparse Assilina and Ostracods. Randomly distributed dolomite rhombs are also observed. Open as well as filled microfractures are also present. Chemical compaction has resulted in suture contacts between bioclastic grains.

Sample No. 88-6-13-5

Benthonic, foraminiferal wackestone with Nummulites, sparse Assilina, bracheopods and ostracods. Some scattered dolomite rhombs and molds (filled with black material) are also present. Internal chambers of some of the bioclasts are also filled with black bituminous material.

Sample No. 88-6-13-6

Benthonic foraminiferal wackestone, with common Nummulites & sparse, Milliolidae, Soritidae & Ostracods. Vugs filled with black material are also present. Microstylolites are marked by brown color probably bituminous substance.

Sample No. 88-6-13-7

Assilinal, Nummulitic wackestone, with common Assilinal, Nummulites and biodebris. Pressure dissolution has resulted in grain contact sutures. Chemical alteration has almost entirely altered the original fabric information.

Sample No. 88-6-13-8

Bioclastic wackestone with common biodebris, Nummulites and Assilina. Pressure dissolution has completely altered the original fabric information.

Sample No. 88-6-13-9

Bioclastic wackestone which is partially dolomitized. The bioclasts consist of benthonic forams, sparse ostracods and biodebris. Microstylolites are also present.

Sample No. 88-6-13-10

Green-algal, benthonic foraminiferal wacke to packstone, with common green-algae, Milliolidae, Textuliridae, Soritidae, sparse Lockhartia and abundant biodebris. Pressure dissolution features are also present.

Sample No. 88-6-13-11

Bioclastic wackestone with common biodebris and echinoids, sparse Textuliridae, Lockhartia and ostracods. Pressure dissolution features are common. Intraskeletal pores are occasionally filled with sparry calcite.

Sample No. 88-6-13-12

Nummulitic Wackestone with common Nummulites, biodebris, sparse Milliolidae, Textuliridae, fragments of Alveolinidae, echinoids & ostracods. Microstylolites are common with scattered and randomly distributed dolomitic rhombs.

Sample No. 88-6-13-13

Nummulitic wackestone with Nummulites, green algae, sparse Assilina, Milliolidae, echinoids, Lockhartia. Microstylolites represent pressure solutioning. Microfractures filled with sparite are present. Dolomite rhombs are randomly distributed along the microstylolites.

Sample No. 88-6-13-14

Benthonic foraminiferal wackestone, with common Assilina, Nummulites, Milliolidae, sparse echinoids, Textuliridae & shell fragments of Alviolinidae. Sparse molds and fractures are also present.

Sample No. 88-6-13-15

Benthonic foraminiferal wackestone, with common Nummulites, Assilina, sparse echinoids, Lockhartia & fragments of Alveolinidae. Microstylolites are surrounding tests of bioclastic grains. Dolomitic rhombs are common and present along the stylolites. Fractures are filled with probably black bitumen.

Sample No. 88-6-13-16

Dolomitic benthonic foraminiferal wackestone, with common Nummulites, Assilina, sparse echinoids & Alveolinidae. Pressure solution features are present in the form of grain contact sutures.

Sample No. 88-6-13-17

Nummulitic wackestone, with abundant Nummulites, Assilina, sparse echinoids, Discocyclina, Milliolidae. Pressure solution features in the form of grain contact sutures are present. Abundant dolomitic rhombs are also observed. Sparse vugs & filled fractures are also present.

Sample No. 88-6-13-18

Benthonic foraminiferal wackestone with Nummulites, Assilina, sparse echinoids, Milliolidae, Alveolinidae. Abundant microstylolites and a few dolomite rhombs are observed.

Sample No. 88-6-13-19

Assinlinal wacke to packstone with abundant Assilina, Nummulites, sparse echinoids, Milliolidae, Alviolinidae and some shell debris almost completely filled with sparite are observed. Fractures filled with sparite are also present.

Sample No. 88-6-13-20

Assilinal wackestone with abundant Assilina, biodebris, common echinoids, sparse Nummulites & Lockhartia are present. Abundant microstylolites & sparse randomly oriented dolomitic rhombs are also observed.

Sample No. 88-6-13-21

Benthonic foraminiferal wackestone with biodebris, Assilina, Textulidae & common echinoids and few randomly distributed dolomitic rhombs observed.

Sample No. 88-6-13-22

Benthonic foraminiferal wackestone with Assilina, Nummulites, Lockhartia, Discocyclina, Sparse Textuliridae, Milliolidae, Microstylolites and vugs (filled probably with pyrite) are common. Sparse dolomitic rhombs also present.