Diagenetic Transformations in Carbonate Rocks at Thayet area, Thatyet Township, Magaway Region

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Abstract

Diagenesis is the term used to define all the changes which occur in sediments during the interval between deposition and lithification. These diagenetic changes may take place in the submarine, subaerial, fresh water and subsurface environments. Diagenesis of the Tondaunglimestones in Thayet near Thebu–Yeganzin area includes cementation, micritization, neomorphism, compaction, dissolution and stylolization. Micrite and sparry calcite are the most common cementing materials in the Oligocene limestones of the Okhmintaung Formation. The majority of the skeletal grains in the Oligocene limestone appear to have been effected to some degrees by micritization. In the study area, at least two types of micritic products are observed. They are bioclasts with micritic coating and completely micritizedbioclasts and tests of microfossils (peloids). Based on the diagenetic evidence observed under microscope, the limestones at Tondaung have experienced four major diagenetic environments, namely sediment–water (marine), phreatic (marine), vadose (meteoric) and phreatic (metoric) respectively. These four environments are grouped into three stages, namely eodiagenesis {sediment–water (marine)}, mesodiagenesis {phreatic (marine)} and telodiagenesis {vadose (meteoric) and phreatic (metoric)}.

Keywords: Diagenesis, Tondaunglimestones, eodiagenesis, mesodiagenesis, telodiagenesis

Introduction

General Statement

The study area is situated at about 4 miles southwest of Thayet town in Magwe Region. It lies between North Latitude 19° 15′ and 19° 18′ and East Longitude 95° 7′ and 95° 11′ and falls within the one inch to one mile scale topographic map of 85 M/3. Being situated on the western bank of Ayeyarwaddy River, the study area is easily accessible by car and boat throughout the year.

Diagenesis is the term used to define all the changes which occur in sediments during the interval between deposition and lithification. These diagenetic changes may take place in the submarine, subaerial fresh water and subsurface environments. The various diagenetic processes usually reduce limestone fabric and produce mineralogical changes, dissolution, precipitation and textural modification. As a result, cementation, micritization, neomorphism, compaction, dissolution and stylolization are common

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diagenetic phenomena in the Thebu area. These diagenetic processes might have taken place soon after deposition or some shorter or longer time after deposition and after burial condition as late diagenetic processes. The study of the diagenetic aspects was mainly undertaken under the light microscope on thin sections cut from representative rock specimens that were systematically collected from the successive beds of the carbonate rocks near Thebu–Yegyanzin area. This paper examines the diagenetic characteristics of the carbonates of the Okhmintaung Formation mainly based on petrographic data. The processes acting on the carbonate rocks during diagenesis include cementation, micritization, neomorphism, compaction and stylolization.

Cementation

Cementation is the process of precipitation of space filling crystals. Carbonate cements are precipitated in many different environments, from marine through meteoric to burial. As a whole, micrite and sparry calcite are the most common cementing materials in the carbonate rocks of the Okhmintaung Formation. At least, six types of sparite cement can be observed namely, isopachous, fibrous, drusy, irregular spar, syntaxial rim and equantrespectively.Commonly, irregular voids are partly filled by fine sediment that accumulated concurrently with the precipitation of isopaches cement (Fig. 1A and B). Figures(1. A) and (1. B) mainly show two generations of cement. The first cements are isopachous rim cements rimming along the peloids and bioclasts, and the second ones are cloudy micrite cement. Drusy cement is the type of cavity filling cement. Typically, crystals of spar have grown into any pore, increasing in crystal size from wall to center of pore (Fig.2 A and B).

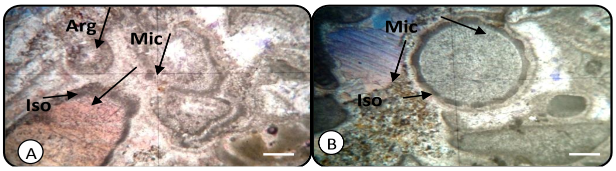


Fig.(1.A&B)Two generations of cement containinganisopachous rim cement (iso) and a cloudy micrite cement (mic). Aragonite cement (arg) is locally found around the grains. Scale bar is 0.1 mm.

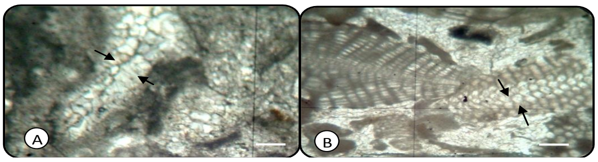


Fig. (2 A and B) shows drusy calcite cement in which crystals are very small sizes at the margins of cavities and get larger towards the centre of cavities. Scale bar is 0.1 mm.

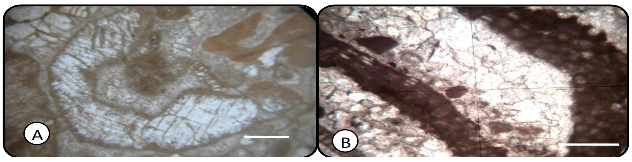


Fig. (3) (A): Twin planes crossing from grain to cement show syntaxial relationship. (B) The void filled with secondary pore–filling clear equantdrusy spar. Scale bar is 0.1 mm.

Syntaxial rim cement is developed on echinoderm fragments and spines. Twin planes crossing from grain to cement show syntaxial relationship (Fig. 3 A). This syntaxial overgrowth cement on echinoderm fragment is common in the freshwater phreatic environment of active zone (Longman, 1981).

The equant spar is paragenetically second generation and it does not form early (Fig.3B). Small vugs to extensive cavern systems form as a result of dissolution (Fig. 4 A& B). These paleokarstic surfaces indicate a subaerial, eodogenic origin in which cement is thickened down the side to the undersurface (pedant cement) (Fig. 4C) point out a vadosediagenetic environment (Adam et al., 1988). The poikilotopic nature of calcite cement (coarse cement crystals enclose grains) is also found in figure (4C). This texture indicates a burial environment.

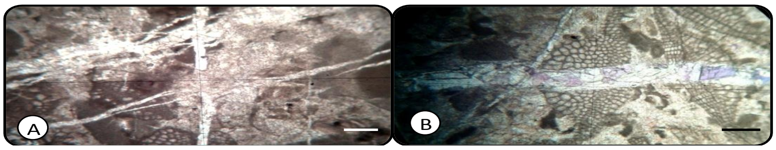


Fig.4 (A–B): Fractures of late stage calcite veins produced by equant blocky cement.

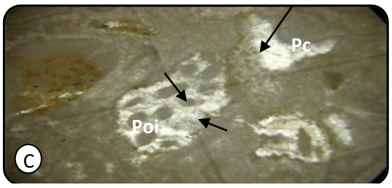


Fig.(4C): Pendant cement) (Pc) and poiki–lotopic texture (Poi). Scale bar is 0.1mm.

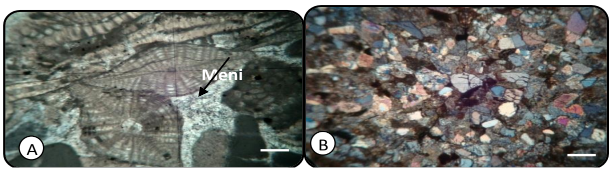


Fig. (5) (A):Meniscus fabrics (Meni) between the bioclasts and(B) Cemented mixture of sand sized quartz and rock fragments. Scale bar is 0.1mm.

In some thin sections, bioclasts are held by meniscus cements (Fig. 5.A). These meniscus fabrics are diagnostic criteria for vadose environment. In this case, the cement is micritic calcite of probable marine origin. Figure (5.B) shows cemented mixture of sand sized quartz and rock fragments. The cement is not present on all grain surfaces, but is mostly concentrated at grain contacts.

Micritization

In the study area, at least two types of micritic products occur, namely bioclasts with micritic coating (Fig. 6. A) andbioclasts and tests of microfossils that have lost their original microstructure completely to become peloids (Fig. B) due to complete micritization. The first type of micritization is a dense array of micritic rods arranged centripetally in bioclasts. \The second category occurs in the event of progressive intense micritization of bioclasts, which results in loss of their original microstructure.

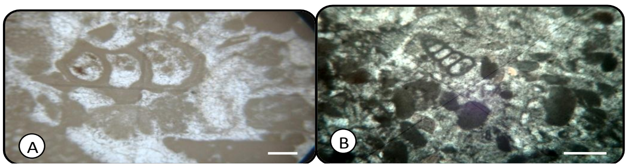


Fig. (6): Two types of micritic products namely bioclasts with micritic coating (A) and bioclasts and tests of microfossil (B).Scale bar is 0.1mm.

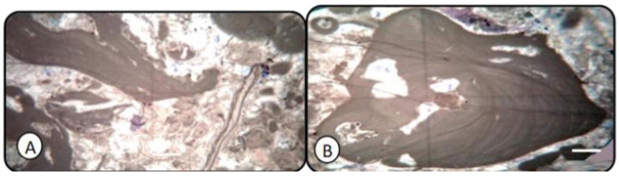


Fig. (7 A & B): The calcitized red algae (*Lithothamnium* sp.) replaced by neomorphic calcite, irregular mosaic crystals having brownish color to the neomorphic spar.

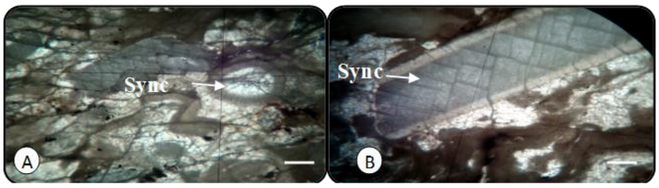


Fig. (8): (A) Thesyntaxial rim cement (Sync) found in bioclast. (B) Syntaxial cement can be clearly seen at the outside margin of bivalve spine. Scale bars are 0.1 mm.

Syntaxial cement can clearly be seen at the outside margin of bivalve Fig (8. B). The equal matrix of rhomb calcites is also replacing the centre of the grains (see also Fig. 8B).

Neomorphism

Figures (7A) and (7B) show the calcitized red algae (*Lithothamnium* sp.) replaced by neomorphic calcite, irregular mosaic of small and large calcite crystals and brownish colour to the neomorphic spar. This shows relics of the original cellular structure and calcite crystals cross–cut the cellular structure.

Compaction

The compaction features expressed in the carbonate rocks of the area are classified into two viz., mechanical and chemical compaction. Mechanical compaction leads to a closer packing of the grains and can lead to the formation of skeletal packstone from skeletal wackestone (foraminifera wackestone to packstone), as a result of the closer packing and fracture of the grains (Fig. 10).Chemical compaction is the result of increasing solubility at grain contacts (Bathurst, 1959,1975). Three common textures result from chemical compaction: fitted fabrics (Fig.10), stylolite (Fig. 10 and 12) and pressure dissolution seams (Tucker, 1991).

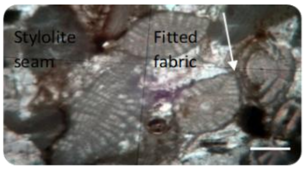


Fig. (10): Formation of foraminifera wackestone to packstone as a result of the closer packing and fracture of the grains, scale bar is 0.1 mm.

Stylolization

Stylolites are through–going sutured surfaces which cut grains, cements and matrix indiscriminately. Clay, iron minerals, organic matter and the insoluable residue are concentrated along stylolites of carbonates at the study area, (Fig. 11).

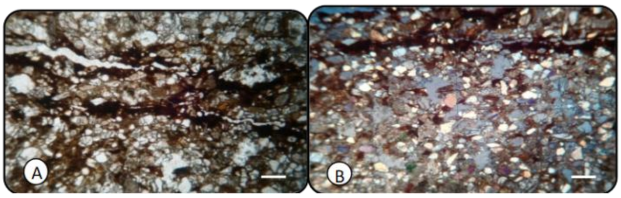
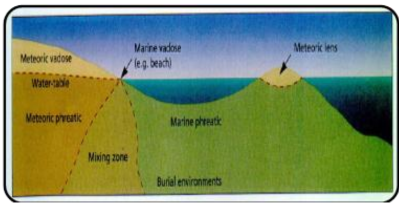


Fig. (11): Stylolite seams containing concentration of clay, iron minerals, organic matter and insoluble residues,scale bars are 0.1 mm.

Diagenetic Environment

According to Longman (1981), near surface diagenesis generally occurs in one or more of four major diagenetic environments. These are the marine phreatic, the mixing zone (where fresh water and marine water mixed), the fresh water phreatic (below water table), and the freshwater vadose (above water table) (Fig.12&13). Marine phreatic zone is formed when all pore space in a sediment or rock is filled with normal marine water. Most carbonates are deposited in marine environments and initiate their diagenetic history in the marine pheratic environment (Longman, 1981). As a result, the water movement combined with other processes results in cementation process especially in active marine phreatic zone. The diagnostic criteria indicate that the marine phreatic diagenetic features observed in carbonate rocks in the study area are isopachous fibrous cement (both aragonite and Mg– calcite) (See also Fig.1A &B), micritic cement (See also Fig. 6), polygonal boundary (sutured boundary) between isopachous cement and micritization (See also Fig. 5B).

Mixing zone environment is defined the place where there is the boundary between the marine phreatic and freshwater phreatic environment.The most diagenetic process found in the mixing zone is dolomitization. Actually, mixing zone is narrow and very small in amount in the study area.



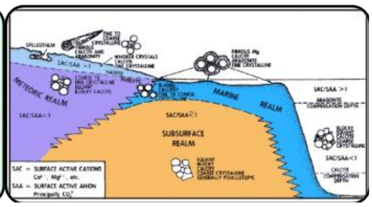


Fig. (12): Sketch cross-section through a typical carbonate shelf showing the principal diagenetic environments (Source: Adam and Mackenzie, 1998)Fig. (13): Schematic diagram showing anticipated growth habits of pore-fill calcitecement in the principal diagenetic environments (Source: Moore, 1997).

Fresh water phreatic zone is extensive and has rapid early cementation and much porosity formation. This zone is the most important diagenetic environment in most carbonate deposited in shallow marine environment (Longman, 1981). The indicative criteria observed in the carbonate rocks in the study area are development of moldic porosity (Fig.6), neomorphism of unstable grains (red algae) (Fig.7A &B), abundant equant calcite (Fig.3A & Fig.4), crystals coarsen toward center of pores andsyntaxial overgrowth on echinoderms (Fig. 2A &B).Vadose zone, vadosediagenetic environment is the subaerial zone lying below the land surface and above the water table and is very important because extensive leaching may occur (Longman, 1981). The supportive criteria in the carbonate rocks are extensive solution, formation of vug (Fig.11B) and equant calcite (Fig. 3A & Fig. 4).

Burial stage is the combination of tectonic stability, compaction. Burial related diagenetic fabrics is also developed and there are features such as fracturing, secondary pores. The diagnostic criteria in the carbonate rocks at Thebu-Yegyanzin are fitted fabrics (solution, compaction) (Fig.10), solution seams (Fig.11 and 12).

Sequence of Diagenetic Events

The nature of transformations, diagenetic processes, zones of diagenesis and environments are based on the diagenetic diagram proposed by Moore (1997) &Tucker (1991). It is here to interpret that the diagenetic history of the carbonate rocks commenced at depositional stage itself and continued various diagenetic processes at different points of times as follows.

Eodiagenesis

The earliest stage of diagenesis on the sediments took place during depositional stage in marine regime at sediment–water interface (Fig14). The biological processes were controlled by light penetration. Judging upon the thick population of these organisms, it is presumed that the enhanced PCO_2 might have increased the dissolved state of calcium carbonate in surrounding waters, resulting in precipitation of fibrous cement characteristic of sediment–water interface. Though the depositional energy controlled the behavior and population of organisms, diagenesis in this stage was influenced, if not controlled by biological processes. The open system of diagenesis and continuity of sedimentation and lithification allowed this stage to pass onto marine phreatic–burial stage without any hiatus.

Mesodiagenesis

With the progressive burial of sediments deposited, a new set of environmental conditions were introduced commencing re–equilibration of sediments to newer environment that form mesodiagenetic history (Fig.14). Physical compaction such as realignment of grains, dissolution of less stable mineralogicbioclasts (aragonite and high magnesium calcite) and cement spars, neomorphism and complete filling of voids with cement spars characteristic of marine phreatic – burial zone have taken place at this stage. Precipitation of blocky calcite or *in situ* transformation to blocky calcite was formed at deeper regions of phreatic–burial zone. At this stage, physicochemical processes dominated the biological processes. Among physical and chemical processes, chemical transformations dominated over physical processes as revealed by complete chemical overprinting on the signatures of sediment–water interface zone. The burial zone of diagenesis continued until the sediments were completely cut–off from circulating fluids through complete filling up of pores through stable calcites accompanied by leaching of less stable bioclasts into forming more stable low magnesium calcite.

Telodiagenesis

The sediments were deposited and they experienced diagenesis under marine conditions to meteoric conditions – a system consisting of entirely different set of physicochemical and biological processes (Fig. 14). The telogenetic stage of diagenesis consists of two zones, viz., meteoric vadose, and meteoric phreatic.

The vadose zone is also characterized by dissolution and corrosion of less stable mineralogicbioclasts and cement spars and negligible amounts of cementation. All these indicate that the meteoric vadose zone is typified by chemical processes and particularly dissolution representing quick initial reaction of diagenetic components.

The meteoric phreatic zone of diagenesis had neomorphosed most of the rock components. Neomorphic transformation in this zone was controlled by access of fluids to the solid phases, mineralogy, chemistry and grain size of the carbonate phases as could be observed elsewhere (Vincent et al. 2004).

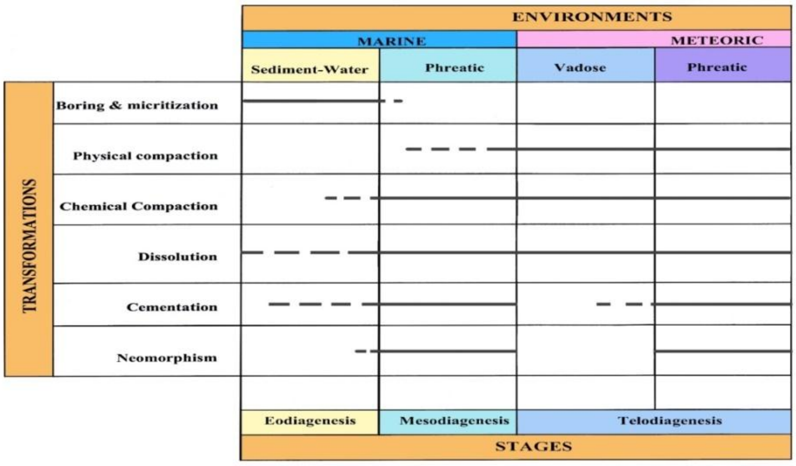


Fig. (15): Sequence, relative intensity and continuity of diagenetic transformations in carbonate rocks at Thebu–Yegyanzin area.(Source, model Ramkumar, M., 1997).

Summary and Conclusion

Diagenesis is the term used to define all the changes which occur in sediments during the interval between deposition and lithification. Diagenesis at Tondaung includes cementation, micritization, neomorphism, compaction and stylolization. Diagenesis at the study area generally occurs in four major diagenetic environments namely the marine phreatic, the mixing zone (where fresh water and marine water mixed), the fresh water phreatic (below water table), and the freshwater vadose (above water table). The diagnostic criteria indicating the marine phreatic diagenetic features observed in the carbonate rocks are isopachous fibrous cement (both aragonite and Mg– calcite), micritic cement, polygonal boundary (sutured boundary) between isopachous cement and micritization. Mixing zone environment is found that the carbonate rocks are caped and replaced with very thin dolomite. Actually, mixing zone is narrow and very small in amount. The indicative criteria for fresh water phreatic zone observed in the carbonate rocks are development of moldic porosity, neomorphism of unstable grains (red algae), abundant equantcalcite, crystals coarsen toward the center of pores and syntaxial overgrowth on echinoderm plates. These four major environments are grouped into three stages, namely eodiagenesis {sediment–water (marine)}, mesodiagenesis {phreatic (marine)} and telodiagenesis {vadose (meteoric) and phreatic (metoric)}.

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References

Adam, A. E. and Mackenzie, W. S., 1998.*A color atlas of carbonate sediments and rocks under the microscope*, Manson Publication. 177p.

Bathrust, R.G.C., 1958. Diagenetic fabrics in some British Dinantian Limestone.LiverpoolManchester.*Geol*. J. 2, P. 11–36.

Bathrust, R.G.C., 1975. Carbonate sediments and their dagenesis. Amsterdam, *Elsevier*,658p.

Longman, M. W., 1981. Carbonate diagenesis as a control on stratigraphic trap. Education course note series # 21, *Amer. Assoc. Petrol. Geol.*, Canada. 159P.

Moore, C. H., 1997. Carbonate Diagenesis and Porosity. Elsevier Science. 2nd edition. 338p.

Ramkumar, M., 1997.Diagenesis in carbonates of the Kallankurichchi Formation, south Indian Cretaceous sequence.Evidences from stable isotopic and petrographic data.*India Jour. Geochem*. V.12. pp 29–37.

Tucker, M. E. & Wright, V. P., 1991.*Carbonate sedimentology.*Oxford, Black well, Scientific Publications, 482p.

Vincent et al., 2004. Meaning of the isotopic signal of shallow–marine carbonates: diagenetic part versus original part (Upper Jurassic, Eastern edge of the Paris Basin, France). Comptes. Rendus.*Geosci.*V.336. pp. 29–59.