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Diagenetic Pattern in the Citarate Carbonate Rocks, Cilograng Area, Lebak Regency, Banten Province

Pola Diagenetik pada Batuan Karbonat Citarate, Daerah Cilograng, Kabupaten Lebak, Provinsi Banten

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Abstract

The carbonate sequence overlies conformably the tuffaceous sandstone unit, and in turn is conformably underlain by the tuff-sandstone unit, both of which are members of the Citarate Formation. The Citarate carbonate rocks were deposited in an open platform back reef environment, which was temporarily drowned by local sea level rise. Regional Middle Miocene deformation formed NNE-WSW trend faults and E-W trend folds in the researched area. This paper discusses the nature of diagenetic alteration of the Citarate carbonate rocks based on petrographic analyses of twenty surface samples. Carbonate rocks from bottom to top comprise algae packstone, packstone-grainstone, coral-algae packstone, and foraminifer wackestone-packstone. Fragments of coral, coralline red algae, and large foraminifera are the dominant bioclasts in most of the observed samples, whereas echinoids and bivalves are less abundant; they are set in a recrystallized micrite matrix. Planktonic foraminifera are abundant only in few samples. Fragments of plagioclase, igneous volcanic rocks, pyroclastic rocks (tuff), and much less abundant quartz are commonly present in all the studied samples. A generalized diagenesis includes early marine cementation by fibrous aragonite, compaction, aragonite dissolution and/or neomorphism, precipitation of equant-grained calcite cement in a phreatic environment, dissolution to form moldic porosities, dolomitization, the formation of stylolites and fractures, and precipitation of late ferroan calcite during burial. Multiple carbonate cements occur as pore-filling phases, with ferroan calcite cementation taking place during later-stage burial. Secondary porosities were formed during different stages in diagenetic processes, such as dissolution, dolomitization, and stylolite and fracture formations. Although precipitation of nonferroan and ferroan calcite cement occluded porosities, porosity enhancement during early selective dolomitization might still be significant. Current observations also revealed the presence of intraparticle, micro-vuggy, and fracture porosities in different samples.

Keywords: Citarate Formation, carbonate rocks, diagenesis, porosity

Sari

Runtunan batuan karbonat menindih selaras satuan batupasir tufan, dan ditindih secara selaras oleh satuan tuf-batupasir yang keduanya merupakan anggota Formasi Citarate. Batuan karbonat Citarate diendapkan pada lingkungan terumbu belakang paparan terbuka, yang kadang-kadang tenggelam oleh naiknya permukaan air laut setempat. Deformasi Miosen Tengah regional membentuk sesar berarah utara timur laut - barat barat daya dan lipatan berarah timur - barat pada daerah penelitian. Makalah ini membahas sifat perselingan diagenetik batuan karbonat Citarate berdasarkan analisis petrografi dua puluh percontoh. Batuan karbonat dari dasar ke atas terdiri atas packstone ganggang, packstone-grainstone, packstone koral - ganggang, dan wackstone-packstone foraminifera. Pecahan koral, ganggang merah-koral, dan foraminifera besar merupakan bioklas yang dominan dari hampir semua percontoh, sementara ekinoid dan bivalvia terdapat dalam jumlah yang lebih sedikit; semuanya tergabung dalam matriks mikrit terkristalkan. Foraminifera plankton melimpah hanya pada beberapa percontoh. Pecahan plagioklas, batuan beku vulkanik, batuan piroklastik (tuf), dan kuarsa dalam jumlah kurang lebih sama pada umumnya

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terdapat pada hampir semua percontoh yang diteliti. Diagenesis umum meliputi penyemenan laut awal oleh serat aragonit, pemampatan, pelarutan aragonit, dan/atau neomorfisme, pengendapan semen kalsit berbutir sama dalam lingkungan freatik, pelarutan yang membentuk kesarangan cetak, pendolomitan, pembentukan stilolit dan retakan, dan pengendapan kalsit feroan akhir selama penguburan tingkat akhir. Penyemenan karbonat berulang terjadi sebagai fase pengisisan rongga, dengan penyemenan kalsit feroan yang terjadi selama penguburan tahap selanjutnya. Kesarangan kedua dibentuk selama tahap yang berbeda pada proses diagenetik, seperti pelarutan, pendolomitan, serta pembentukan stilolit dan retakan. Walaupun pengendapan semen kalsit feroan dan nonferoan menghambat kesarangan, percepatan kesarangan selama pendolomitan selektif awal masih berarti. Pengamatan saat ini juga mengungkapkan adanya kesarangan intrapartikel, mikro-vuggy, dan retakan dalam percontoh yang berbeda.

Kata kunci: *Formasi Citarate, batuan karbonat, diagenesis, kesarangan*

Introduction

The study on carbonate rocks of the Citarate Formation was carried out in Cilograng Village, Lebak Regency, Banten Province, about 10 km north west of Pelabuhan Ratu. Based on physiographic zones of Bemmelen (1949), the researched area is part of median ridge in the Central Depression of West Java that is bordered by recent volcanoes in the north (Figure 1). During Late Oligocene - Early Miocene, the researched area was part of the northern margin of the Southern Mountains of West Java, which are a southward tilted uplifted block. Along this margin, carbonate platforms were formed, including the Citarate carbonates and the Rajamandala Formation to the northeast.

This paper discusses the nature of diagenetic alteration of the Citarate carbonate rocks including secondary porosity development. The work is still in progress as more samples and data from adjacent areas are being analyzed in an attempt to construct Late Oligocene - Early Miocene carbonate platform model and evolution along the northern margin of the Southern Mountains.

Geological Setting

Lithologic units found in the area from older to younger are tuff-sandstones, limestone, tuff sandstones with breccias, polymictic breccias, monomictic breccias, and andesite intrusion (Figures

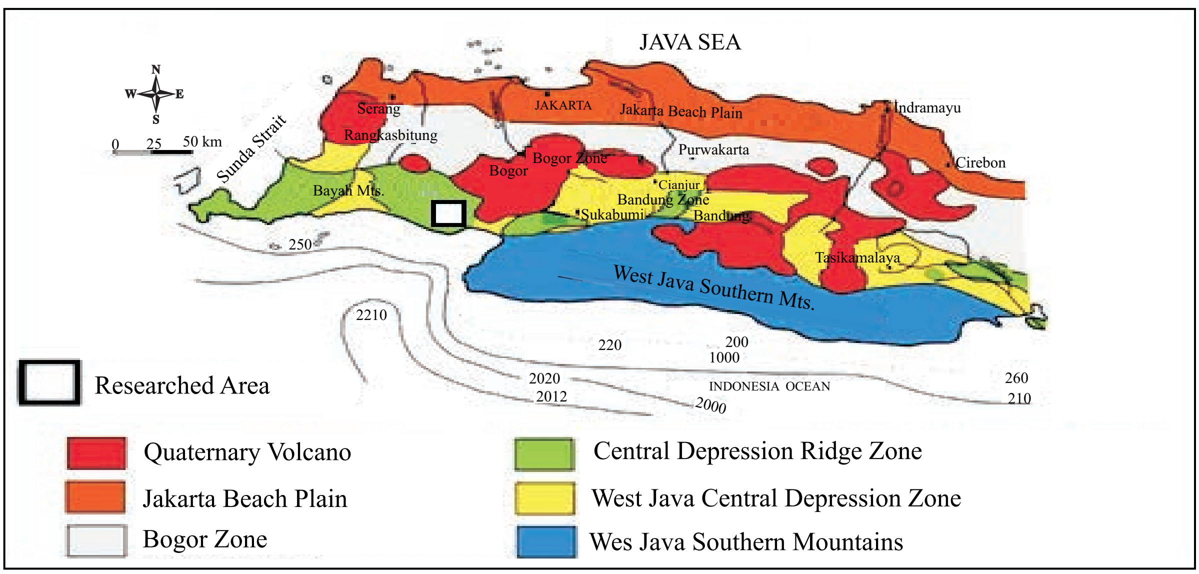

Figure 1. Physiographic map of West Java based on Bemmelen (1949).

2 and 3). The first three units are parts of the Early Miocene Citarate Formation, whereas the polymictic and monomictic breccias are of the Early Miocene Cimapag Formation (Wiyoga and Basuki, 2010). The tuff-sandstone unit is characterized by interbedded tuff and sandstones. Thin, fine-grained limestone intercalation with fine lamination is locally present. Tuff is yellowish brown with abundant glass materials and minor crystals. Sandstones are fine- to medium-grained with moderate sorting, predominated by volcanic lithic fragments, quartz, and plagioclase grains. Partial carbonate alteration after lithic fragments and plagioclase is common.

The Citarate limestone comprises algae packstone, packstone-grainstone, coral-algae packstone, and foraminifer wackestone-packstone. Fragments of coral, coralline red algae, and large foraminifera are the dominant bioclasts, whereas echinoids and bivalves are less abundant. Planktonic foraminifera are abundant only in few samples. Fragments of plagioclase, igneous volcanic rocks, pyroclastic rocks (tuff), and much less abundant quartz grains are commonly present in all the studied samples. Recrystallized micrite matrix and sparry calcite cement occupy open spaces between fragments. The Citarate carbonate rocks are interpreted to be deposited in an open platform back reef environment, which was temporarily drowned by a local sea level rise.

Tuff sandstone with breccia unit shows similar characteristics to tuff-sandstone unit, except that this unit contains polymictic breccias and/or rudstone intercalations. Breccias and rudstones are poorly sorted with fragments floating in sand to mud-sized matrix. Fragments of volcanic rocks (andesitic) and less abundant sandstones and limestones are the constituents of breccias, whereas rudstones contain fragments of coral, volcanic rocks, intraclasts and red algae.

Polymictic breccias consist of volcanic rocks (andesitic and basaltic), sandstones and limestone fragments that are poorly sorted (5 - 25 cm in size), loosely packed without any distinct bedding. Partial calcite replacement of the matrix is common. This unit unconformably overlies tuff sandstone (with breccia intercalation) unit (Sujatmiko and Santosa, 1992). Following deposition of polymictic breccias are monomictic breccias, which comprise poorly sorted andesitic rock fragments (up to 40 cm in size), set in a tuffaceous sand-sized matrix. All the previous lithologic units are intruded by andesite intrusions, evident by local backing effect at contact with sedimentary rocks. Andesite shows porphyritic texture with plagioclase and pyroxene phenocrysts in

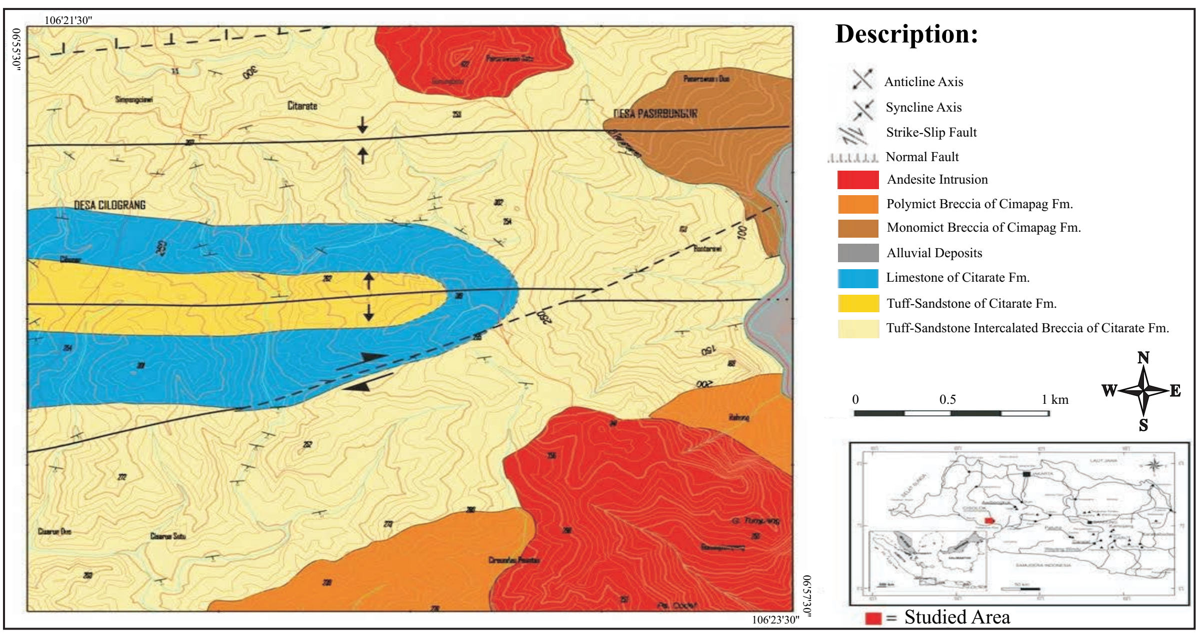

Figure 2. Geological map of the Cilograng area (after Wiyoga and Basuki, 2010).

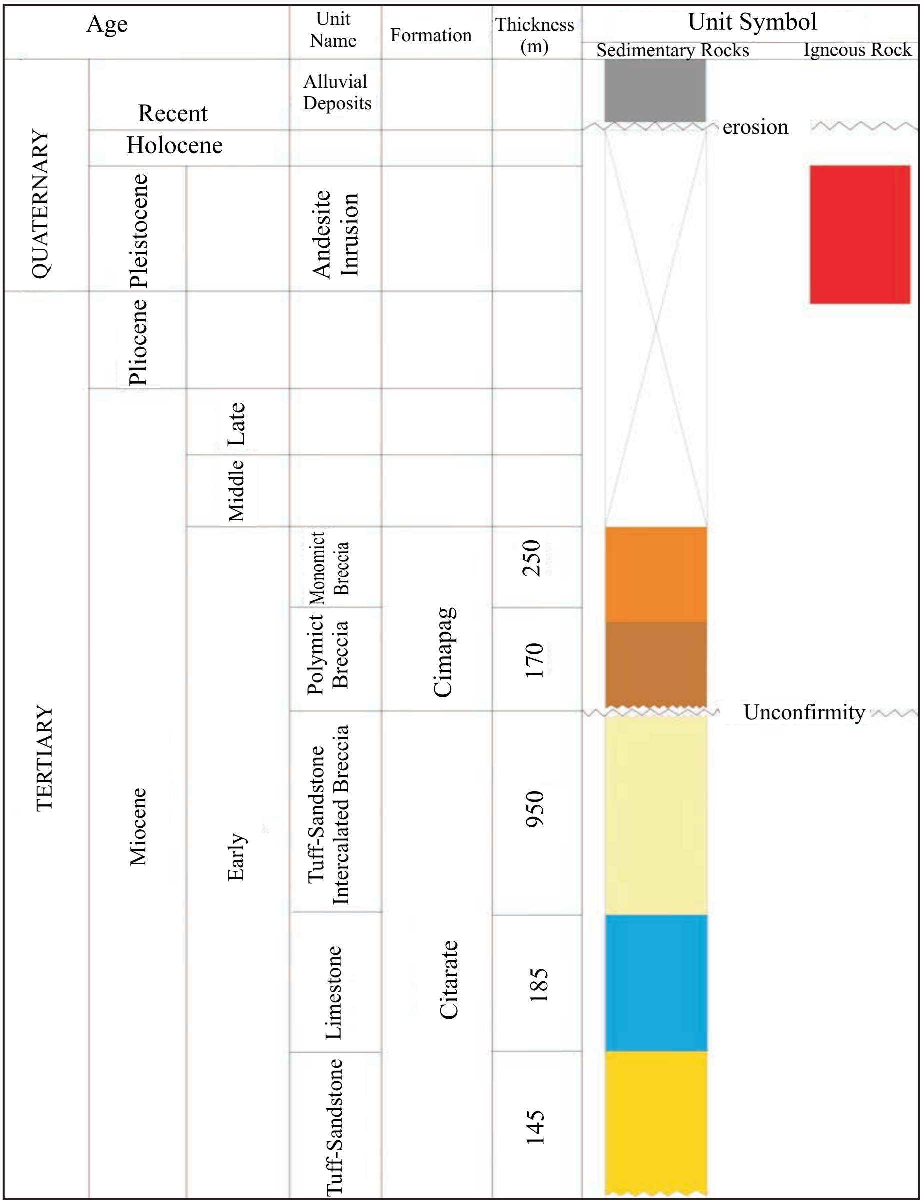

Figure 3. Stratigraphic column of the Cilograng area (after Wiyoga and Basuki, 2010).

an aphanitic groundmass. Koolhoven (1933; op. cit. Sujatmiko dan Santosa, 1992) suggested Quaternary age (Pleistocene) for this intrusion unit.

Geological structures found in the area include an E-W trend anticline and syncline, and a NNE-WSW trend strike-slip fault. An inferred east-west normal fault is probably present in the northern part of the area (Figure 2). According to Sujatmiko and Santosa (1992), a north-south trend stress regime was the principal stress that controlled structure formation in the South Banten region in Middle Miocene. The same stress regime was probably responsible for the development of structures in the researched area.

Methodology

The studied samples were taken from carbonate rock outcrops that are parts of plunging anticline flanks around Cilograng Village (Figure 2), representing different depositional environments from back reef to basinal slope. Hand specimen and thin section petrographic analysis were conducted to determine components of carbonate, microfacies, and diagenetic processes. Porosity data were obtained from visual estimation on thin sections impregnated with alizarin-red S to distinguish different carbonate minerals. Carbonate rock classification by Dunham (1962) was used to name carbonate samples. Recognition of diagenetic fabrics and their interpretation are mainly based on Bathurst (1975) and Longman, (1980).

Diagenesis of the Citarate Carbonate Rocks

The Citarate carbonates displays several diagenetic events, most notably multiple generations of carbonate cement, with small amounts of glauconite, zeolite, and chlorite. The diagenetic processes can be broadly divided into early and late diagenetic stages. Many of the studied samples appear to have undergone similar diagenetic processes of early marine diagenesis, followed by later meteoric to burial diagenesis. The relative timing of these diagenetic events is presented in Table 1, which shows nine phases of pore fluid evolution. Micritization, cementation, dolomitization, mechanical compaction, fractures, and carbonate dissolution textures are commonly observed, whereas stylolite and pressure solution are less common. Some of diagenetic products, such as early dolomite and ferroan calcite precipitation, seem to be more commonly present in certain carbonate rocks, *i.e.* those deposited in back-reef platform environments.

Phase I diagenesis took place during sedimentation and very early, shallow burial. Including in this phase are micrite envelope formation, glauconite precipitation, and deposition of early cement that covers mainly the internal chambers and exterior surface of bioclasts. The cement is of fine-grained calcite, but aragonite was probably the primary constituent as indicated by local acicular calcite pseudomorph after aragonite (Figure 4a). Several bioclasts are filled with minute grains of opaque minerals, accompanying early carbonate cement. In general, Phase I has led to a decrease of primary porosity.

Dolomitization and/or recrystallization of micritic matrix occurred following Phase I diagenesis. Dolomitization of mudstone intraclasts by silt-sized, nonferroan dolomite crystals, which show different crystal size and appearance to dolomitized ''in situ'' matrix of the current rocks (Figure 4b), may suggest that dolomitization occurred prior to ripping and redeposition of the intraclasts in the current rocks. Thus, dolomitization of micritic matrix by silt-sized dolomite is interpreted to take place early in diagenetic processes. Porosity and permeability were, in general, enhanced during Phase II diagenesis.

Phase III diagenesis is characterized by development of microfractures and local dissolution of certain bioclasts (*e.g.* aragonite-based shells) and carbonate matrix, leading to the formation of moldic and microvuggy porosities. Subsequently, the enhanced secondary pores were filled by equant, fine- to medium-grained, non-ferroan calcite spar, locally accompanied by ferroan calcite (Phase IV). Very fine-grained, dog-teeth textured calcite is locally present, precipitating on the substrate, followed by precipitation of medium-grained, equant calcite spar. Therefore, secondary porosities, in general, became less abundant during Phase IV diagenesis. Partial calcite replacement of dolomite crystals (dedolomitization) locally occurred. Chlorite is present as selective alteration of groundmass of volcanic lithic fragments, which are abundant in one of the studied samples.

Mechanical compaction is, in most studied samples, evident by slightly broken fossil tests, and formation of discontinuous microfractures within several bioclasts, which is less commonly observed. In general, fossils are still intact and undeformed, probably due to early cement infill in the bioclasts chambers. Precipitation of early cement, on the exterior surface of bioclasts, has probably also prevented bioclasts from major deformation or collapsing during compaction. Nevertheless, strong compaction due to burial diagenesis can be observed in some samples, evident by broken or deformed bioclasts at grain contacts (Figure 4c), and by stylolite formation. Stylolites crosscut equant calcite spar cement of Phase IV.

Another development of fractures and carbonate dissolution characterizes Phase V diagenesis that resulted in the formation of vuggy pores, which crosscut micro fractures and equant calcite spar cement of Phase IV. Ferroan, blocky, coarse-grained calcite subsequently precipitated in the pores (Phase VI), which reduced secondary porosities (Figure 4c).

Table 1. Paragenetic Sequence of the studied Citarate Carbonate Samples with Relation to the Development of Porosities
Note: Porosity Development: (+) increase; (-) decrease

Diagenetic Products/Processes	Fluid Event	Porosity Development
Micrite envelope Glauconite Early (aragonite) cement Opaque mineral	I	P (-)
Dolomite alteration of micritic matrix and bioclasts Micrite recrystallization to microspar calcite	II	P (+)
Dissolution of matrix and bioclasts (molds and microvugs) Fractures (1)	III	P (+)
Ferroan and nonferroan calcite spar Dedolomitization, chlorite (trace)	IV	P (-)
Mechanical compaction Pressure solution/stylolite formation		P (-)
Fractures (2) Vuggy and moldic pores	V	P (+)
Ferroan and nonferroan, coarse, blocky calcite spar Opaque mineral	VI	P (-)
(Micro) Fractures (3), Intraparticle pores	VII	P (+)
Zeolite	VIII	P (-)
Carbonate dissolution (interparticle pores and microvugs) Microfractures	IX	P (+)

Some opaque minerals, present as subhedral grains and as partial replacement of bioclasts, probably was formed during this stage of diagenesis.

The main diagenetic processes during Phases VII and VIII were the formation of minor microfractures and intraparticle pores by partial dissolution, and subsequent zeolite precipitation that occluded the pores (Figure 4e). Irregular fractures were observed to form near contacts between ferroan-calcite vein of Phase VI and host rocks. Small flakes of ferroan calcite are commonly present in zeolite veins. Phase IX is marked by local and minor carbonate dissolution to form interparticle pores, intraparticle pores, and microvugs, which are still open (Figure 4f). Some studied samples are devoid of Phase IX diagenetic products.

Conclusions

Diagenesis of the Citarate carbonate rocks occurred in nine phases. Phases I - III represent synsedimentary/near surface to shallow depth diagenetic stages, whereas Phases IV - VI likely occured during deeper to maximum burial diagenesis. Phases VII - IX might not be as important as other phases, since they represent time between maximum burial and the present (subaerial exposure). Multiple fracturing and carbonate dissolution took place in different phases during diagenesis that created or enhanced secondary porosities. Following the development of secondary porosities was precipitation of ferroan/ nonferroan calcite spar that occluded fractures, moldic, and vuggy pores. Nonetheless, porosity

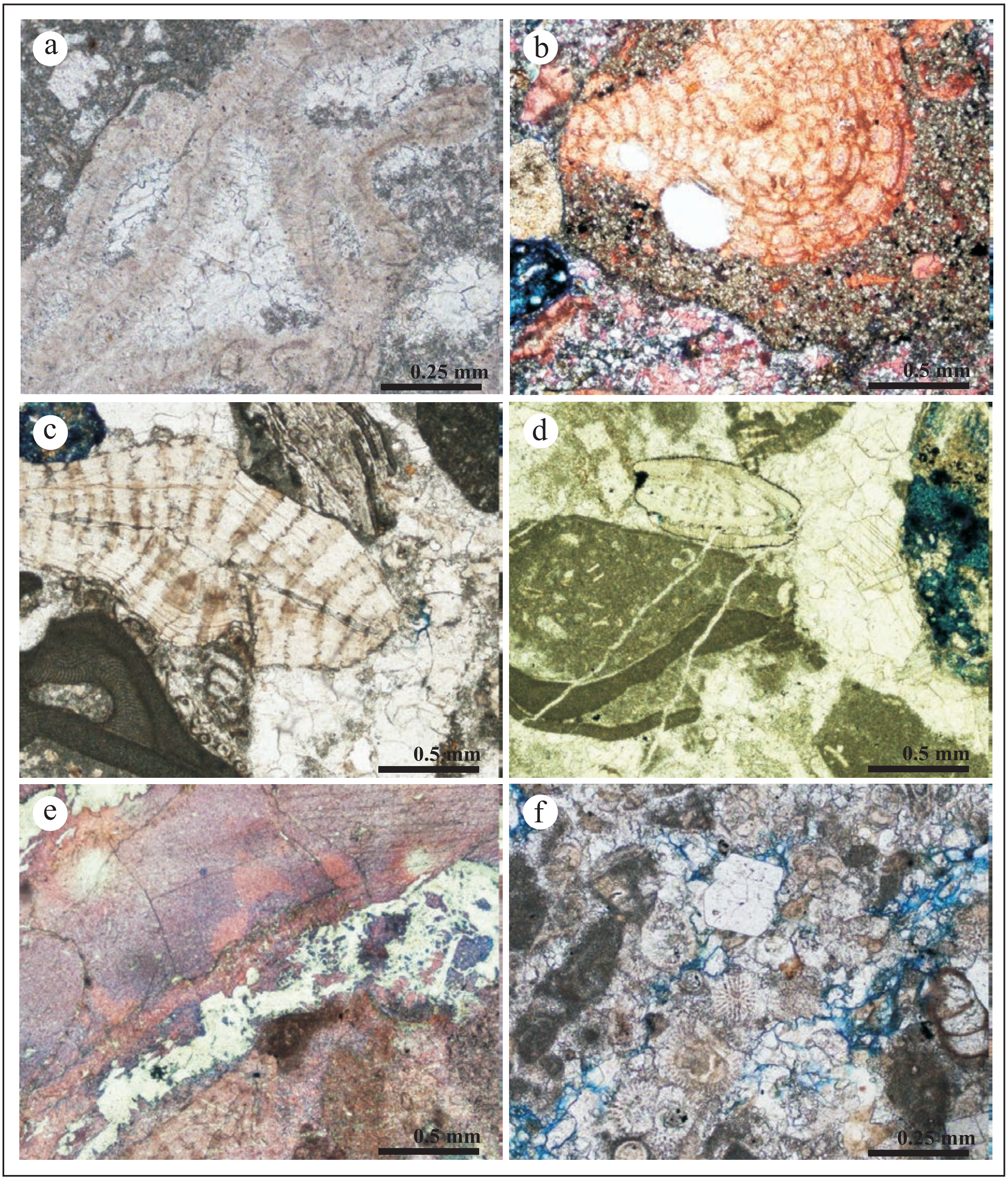

Figure 4. (a) Early calcite cement that line internal chambers of fossils locally displays remnants of primary acicular aragonite. (b) Nonferroan dolomite crystals in the dolomitized mudstone intraclasts show a different size (finer-grained) and appearance (brownish colour) compared to dolomite in the matrix of the current rocks (clear, coarser-grained). (c) Strong compaction due to burial diagenesis, evident by broken or deformed bioclasts at grain contacts. (d) Vuggy pores of Phase V crosscut equant calcite spar cement of Phase IV. Ferroan, blocky, coarse-grained calcite spar subsequently precipitated in the vuggy pores (Phase VI). (e) Ferroan calcite spar of Phase VI was fractured, which was subsequently occluded by zeolite precipitation. (f) Local and minor carbonate dissolution has formed interparticle pores, intraparticle pores, and microvugs (blue colour; Phase IX).

enhancement during early selective dolomitization of micritic matrix might still be significant because of insignificant de-dolomitization during diagenesis.

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