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Diagenetic Aspects of the Lower Paleocene Sachun Formation Carbonates, Zagros Basin, Southwestern Iran

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ABSTRACT: The Sachun Formation in the Zagros Mountains Ranges was sampled on the basis of changes in lithology and 150 vertically oriented thin-sections were prepared and subjected to detailed petrographic study. Evaporite, carbonate and shale/marl facies are identified here. These facies which have been laid in 4 facies belts of supratidal, intertidal, lagoon and barrier, deposited on a ramp platform. Petrographic studies showed that the Sachun Formation has had a complex diagenetic history. The following diagenetic events occurred in the carbonate microfacies: micritization, dissolution, silicification, dolomitization, hematitization, compaction, fracturing and stylolitization. The diagenetic features observed petrographically in the carbonate microfacies represent changes which took place under three diagenetic environments (eogenic, mesogenic, and telogenic) with three different marine, burial, and meteoric diagenetic conditions. The diagenetic sequence of events that affected the Sachun Formation includes micritization and micrite envelope features which have been reported from an eogenic/marine environment.
KEY WORDS: Iran, Zagros, Sachun Formation, carbonate diagenesis, petrography.

0 INTRODUCTION

The Sachun Formation is named after the village of Sachun in Fars Province (James and Wynd, 1965). This rock unit was first investigated by Perri and Player in 1962. The type section was measured at Kuh-e Sachun about 4–5 km north in the village of Sachun in Fars Province by James and Wynd in 1965. Its lithology and paleontology were studied by Kalantari (1976) National Iranian South Oil Company (N. I. O. C.) revised the study of the Sachun Formation in 2005. Bordenave (2002) in his studies on the Zagros Oil System (Middle Cretaceous–Lower Miocene) has interpreted the Sachun Formation as a sabkha deposited in a subsiding area. The Sachun Formation in the Late Maastrichtian to Late Eocene megasequence is the lowest unit, and is restricted to the northeastern internal part of the Zagros fold-thrust belt. It overlies unconformably the Upper Cretaceous megasequence (Alavi, 2004).

Totally, the Sachun Formation of the studied section is extended 456 m in thickness. Lower litho stratigraphic limit of the Sachun Formation is marked by vertical changes in lithologic aspect between Gurpi shale and limestone and marls at base of the Sachun Formation (Fig. 1). It comprises from base to the top over 210 m of alternation of cream marls with gray algal bioclastic limestone, about 42 m green shale and marls with alternation of glauconitic sandy limestone which terminates to 206 m of shale and marl alternation with cream dolomite limestone which is underlined by Jahrom Formation as sharp contact. The main objective of this paper is to describe the diagenetic aspects of the Sachun Formation based on petrographic study.

1 GEOGRAPHICAL AND GEOLOGICAL SETTING

The Zagros Basin is the second largest basin in the Middle East with an area of about 553 000 km^2 (Alsharhan and Nairn, 1997). It extends from Turkey, northeastern Syria and northeastern Iraq through Northwest Iran, and continues into southeastern Iran. This foreland basin developed with the disappearance of Neotethys as suturing began in the northwest and migrated southeast during the Middle to Late Eocene. The suturing was accompanied by crustal thickening and movement along the originally passive margin of Arabian Plate and is related to the spreading movements in the Red Sea and Gulf of Aden (Hempton, 1987). The Zagros Basin is divided into three zones, the Zagros fold-thrust zone, the Zagros imbricated zone, and the Urumieh-Dokhtar magmatic zone (Alavi, 2004). The studied stratigraphic section is located in the Zagros fold-thrust zone (Fig. 2). James and Wynd (1965) have divided the Zagros into four main zones which are Khuzestan, Lurestan, Coastal Fars, and Interior Fars. Based on their study Sachun Formation is expanded in Interior Fars area. Stratigraphic position of the Sachun is recorded between Tarbur and Jahrom formations (Lasemi et al., 2007; James and Wynd, 1965). Studied stratigraphic column is named Chah-Anjir which is located at 29º15' N, 52º53'E (Fig. 3).

Petrography investigations show that, 480 m thickness of

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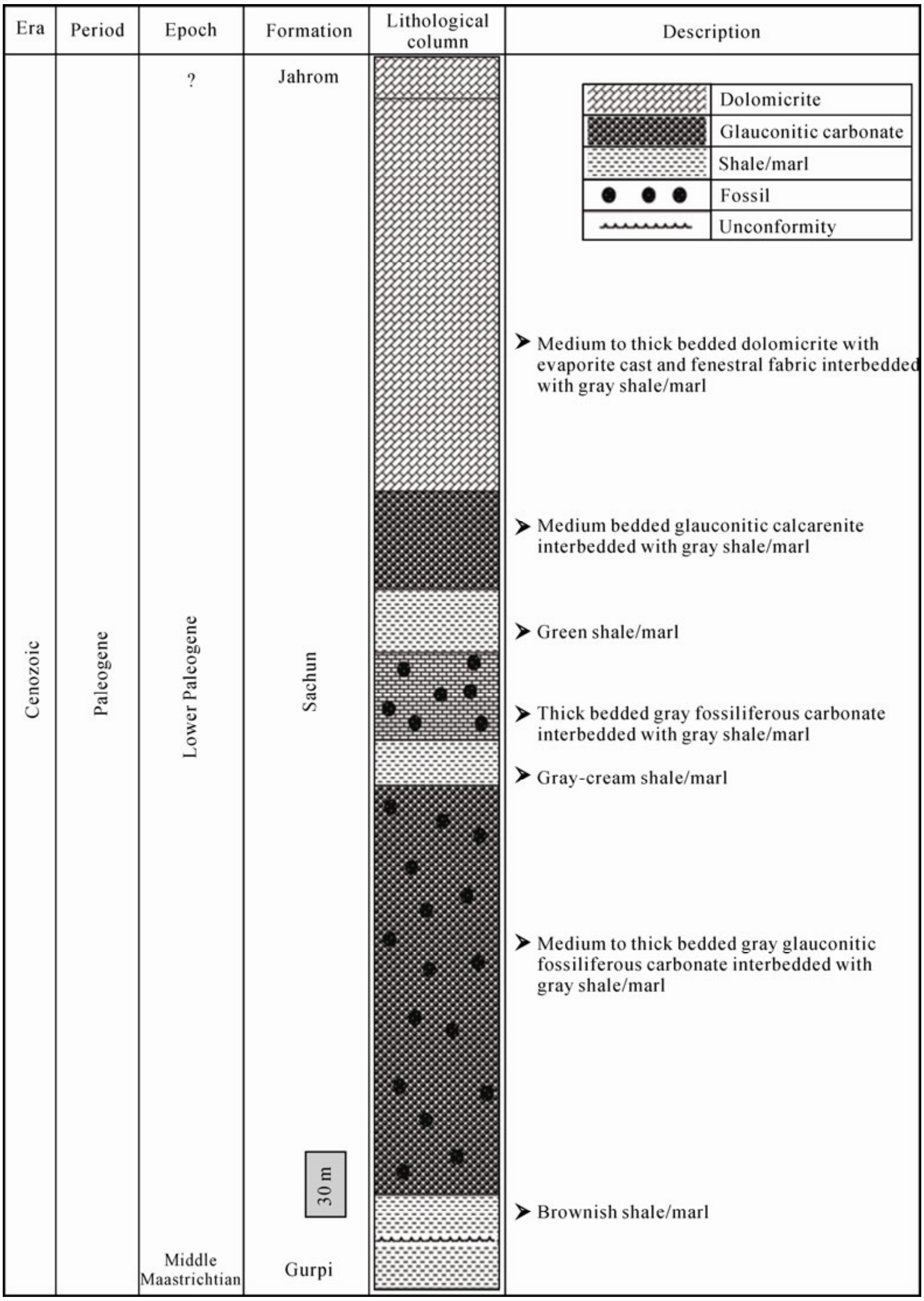

Figure 1. Stratigraphic column of Sachun Formation, Maharloo Section.

the Sachun Formation comprise of alternative colored shale/marl and carbonate beds. From base to top the beds are as below; the lowermost limit is Gurpi Formation, 30 m of brown marl beds, 181 m of bioclastic carbonates alternate with cream marl beds, 37 m of massive bioclastic carbonate, 27.6 m of green shale/marl beds, 186 m of dolomite alternate with gray shale/marl and the uppermost beds are Jahrom Formation dolomite beds.

2 METHODS

This study involves a stratigraphic section from the Sachun Formation, that was measured bed by bed and investigated sedimentologically. More than 150 samples were collected from a profile and then the samples were classified in the field using a hand-lens and their depositional fabric described (Dunham, 1962), followed by hand sampling for thin-section analysis.

3 DIAGENETIC FEATURES OF THE SACHUN FORMATION

Petrographic studies represent that the Sachun Formation has reflected a complex diagenetic history. The following

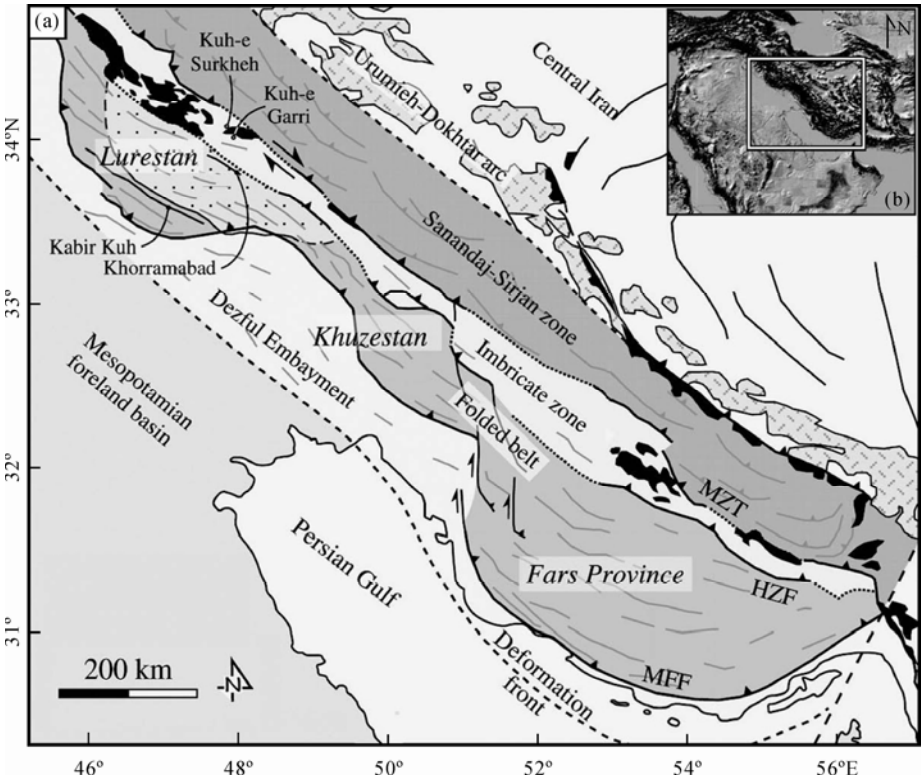

Figure 2. Structural map of the Zagros belt (after Homke et al., 2009; Falcon, 1974). MZF. main Zagros thrust; HZF. high Zagros fault; MFF. mountain front fault.

aspects of digenetic changes in the Sachun Formation strata are described in detail. The diagenetic processes are as follow: micritization, cementation, dissolution, silicification, hematitization, dolomitization and compaction. Mineralogical composition, textural characteristics, and sedimentary features were interpreted to obtain detailed information concerning the history of the depositions. The sediments of the Sachun Formation were exposed to several different diagenetic processes, which include both early and late stages (Fig. 4). These have led to modification of original textures and compositional characteristics. Using the terminology of Choquette and Pray (1970), three major diagenetic episodes in the studied stratigraphic column of the Sachun Formation are recognizable: eogenetic, mesogenetic and telogenetic.

3.1 Micritization

Submarine micritization by boring algae is common in the carbonate sediments of the Sachun Formation, being displayed by micrite envelopes around skeletal particles (Fig. 5a). These micrite envelopes have been described as opaque jackets or rims surrounding the carbonate particles and formed by filling of the closely overlapping empty algal bores which penetrated inward from the exterior of skeletal particles. Since micritization has been distinguished in the shallower facies of the Sachun Formation, there can be no doubt that the carbonate borers are microorganisms: fungi (Burford et al., 2003), microalgae and cyanobacteria (Golubic, 1969) that actively dissolve carbonate grains. It is clear that cyanobacteria tend to dominate intertidal and shallow-water carbonate-boring assemblages, and that red and green algae are typically less limited in their extent by the depth of light penetration into the typically diaphanous substratum (Garcia-Pichel, 2006). Boring by microorganisms is most commonly reported from shallow lagoon areas (MacIntyre et al., 2000). According to Kobluk and Risk (1977a, b), microorganisms may produce a constructive micrite envelope in sea water. It probably formed as a result of precipitation, where the ambient waters are supersaturated by calcium carbonate (Bathurst, 1975, 1966). In fact, the micritization process is inferred to have taken place predominantly in shallow marine, or possibly meteoric to shallow burial environments (Wilson and Evans, 2002), and it also has been reported from the marine phreatic environment (El-Saiy and Jordan, 2007; Longman, 1980).

3.2 Cemantation

Cements in the Sachun Formation sediments display a variety of fabrics suggesting that precipitation took place in diagenetic environments ranging from marine through meteoric to burial. Cements observed in different lithofacies comprise: microspary cement, drusy cement, isopachous cement, granular mosaic, bladed, pendant, and evaporite cement.

3.3 Microspar Cement

This cement is characterized by small pore-filling crystals of approximately equal size and without a preferred orientation (Fig. 5b). This pore-filling cement is most common in marine phreatic settings and also found in the meteoric-phreatic zone, near-surface conditions (Flügel, 2004; Adabi and Rao, 1991), or buried relatively deep where meteoric water has become more saline (Flügel, 2004). It has also been reported from anoxic conditions (Scholle and Halley, 1985).

3.4 Drusy Cement

Recognition of drusy cement is illustrated by pore-filling crystals increasing in size toward the center of interparticle pores or voids (Fig. 5c). Crystal size usually is more than 10 μm. This kind of cement is commonly investigated in near-surface meteoric environments as well as in burial environments (Flügel, 2004).

3.5 Isopachous Cement

Isopachous cement is confirmed by single or multiple cement rims growing with equal thickness around grains. The cement rims may consist of fibrous, bladed (Fig. 5d), or microcrystalline crystals. This type of cement is common in marine-vadose environments and rare in meteoric-phreatic (Flügel, 2004; Heckel, 1983).

3.7 Bladed Cement

This kind of cement is indicated by non-equidimentional and non-fibrous crystals, with broad and pyramid like termination (Fig. 5f). Crystals increase in width along their length, commonly forming thin isopachous fringes on grains. They are abundant in shallow-marine settings and marine-vadose environments (Flügel, 2004).

3.8 Pendant Cement

Distinct thickening of cement crusts beneath grains or under the roofs of intergranular and solution voids are the major characteristics of pendant cement (Fig. 5g). This type of cement forms on droplets beneath grains after the bulk of the mobile water has drained out of the pores, leaving a thicker water film at the lower surface of the grains forms typically gravitational, beard-like patterns. Predominantly calcite formed below the zone of capillarity and above the water table within the meteoric-vadose zone (often associated with meniscus cement), Flügel (2004) has suggested that pendant type cement form in the meteoric-phreatic and sporadically in marine-vadose diagenetic environments.

3.9 Evaporite Cement

Evaporite cements (Fig. 6a) resulting from early diagenetic processes are related to evaporitic conditions at the time of sedimentation, conditions which are typical of an arid to semi-arid climate. In this condition the final stage of progressive evaporation leads to highly saline water. Boles and Ramseyer (1987) have been documented that gypsum and anhydrite cement removal during the evaporite dissolution only takes place where sediments are flushed with meteoric fluids. Evaporite cements may also form from hypersaline subsurface waters even in deep burial. Late dissolution and reprecipitation of evaporites has produced satin-spar gypsum cement in the shallowest part of the platform, whereas blocky and sparry anhydrite cements and void fillings formed deeper within the platform. Dissolution of the evaporites and formation of anhydrite cements post-dated dolomitization.

4 DISCUSSION

4.1 Dissolution

Dissolution features are present in the Sachun Formation carbonates especially within the upper parts. This dissolution resulted in development of several types of porosity including

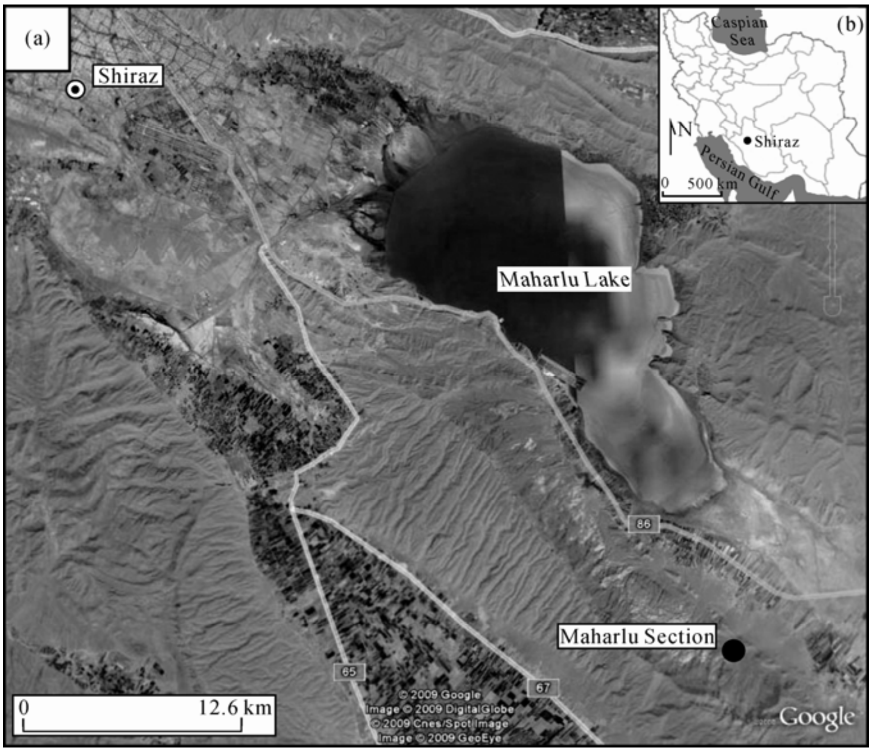

Figure 3. Locational and satellite map of the studied area section within the Sachun Formation.

intergranular, intragranular, moldic, and vuggy (Fig. 6b). Some skeletal grains and non-skeletal grains such as ooids, are composed originally of aragonite, which is more soluble in under-saturated pore fluids than calcite is. Dissolution of ooids gave rise to oomoldic porosity (Fig. 6c); non fabric selective dissolution porosity was also recorded (Fig. 6d). Dissolution of aragonitic bioclasts is most common in shallow-water deposits. This together with much of the biomoldic porosity being infilled with meteoric blocky cements suggests dissolution occurred in a meteoric setting. The majority of these porosity types' results from early shallow diagenesis, but burial diagenesis can also have an effect (Flügel, 2004; Moore and Druckman, 1981). Under-saturation of pore fluids with respect to carbonate leads to dissolution of metastable carbonate grains and cements. Dissolution is particularly effective in shallow near-surface meteoric environments, in deep burial and cold waters (Steinsund and Hald, 1994), as well in the deep sea (Berelson et al., 1994) where seawater becomes undersaturated with respect to aragonite and Mg-calcite (Morse, 2002).

4.2 Silicification

Silicification can provide a window to the original composition of the sediment, the diagenetic history, and the biota of the host rock due to its low susceptibility to further diagenetic alterations (Maliva, 2001). On the microscopic scale, chert can be described as micro-quartz, with equidimensional grains. This quartz is so fine-grained that, when replacing micritic grains, the shape of these grains is conserved; thus, they are called develops radial fibers. The micro-quartz mainly replaces carbonate grains (Fig. 6e), and chalcedony is mainly pore-filling cement (Fig. 6f). Textural evidence in both Figs. 6f and 6g represents that micro quartz and chalcedony were formed by progressive replacement of the original carbonate minerals of the shells or calcite cavity filling, where carbonate dissolution rarely occurred immediately adjacent to the silicified parts. This indicates that calcite dissolution is linked to silica precipitation during the silicification process and they may have occurred simultaneously. Silicification resulted in the small cavities filled with chert, pointing to an earlier episode of silica precipitation, previous to the burial stage (Tobin, 2004). Silicification that preserves carbonate grains from strong deformation is interpreted as an early diagenetic stage process pre-compactation (Gao and Land, 1991). There is also some evidence of subaerial exposure or indications of environmental restriction associated with the areas of chert location within the Sachun Formation in this area of study, such as mud-cracks and evaporites, among others. Knauth (1979) suggested a model for chertification of limestones in the diagenetic mixing zone between the meteoric vadose/phreatic and the underlying marine zones where dolomitization also occurs. In general, the prerequisites for near-surface silicification appear to include prolonged subaerial exposure, relatively slow rate of tectonic uplift and erosion, and temperate to tropical climate (Smith et al., 1997).

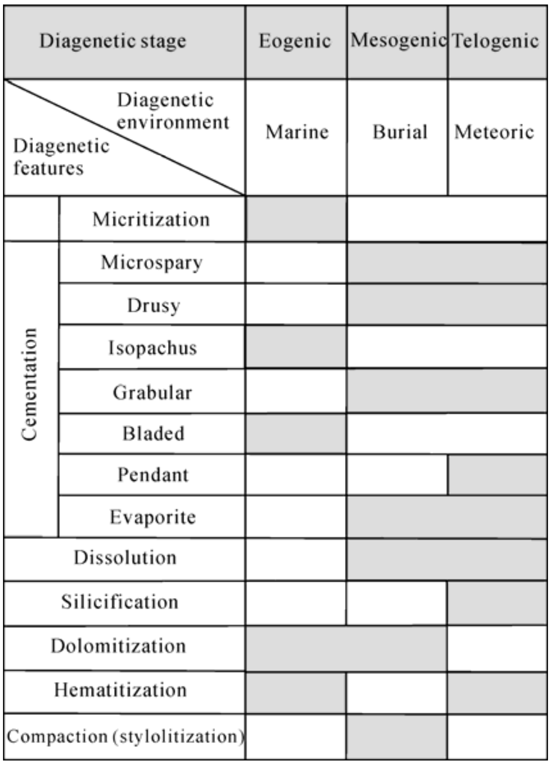

Figure 4. Different diagenetic features in diagenetic environments found in the Sachun Formation (dark zones show the accurence possibility of diagenetic features in the mentioned diagenetic environments).

4.3 Hematitization

In some facies of the Sachun Formation scattered crystals of cubic pyrite/hematite were investigated (Fig. 6g). Some of collected samples comprise extensive hematitization and reddish color of hematite all over the facies (Fig. 7a). Iron minerals in these samples, represented by ferric-oxide and sulphides, are obviously of diagenetic origin and could have formed in an oxidation environment (Schogenova and Kleesment, 2006). Deposition of hematite can be explained by frequently changing reduction conditions during diagenesis. In order to perception of hematite forming in Sachun Formation, it is applicable of oxidation condition which is assigned to a low water table and lack of organic remains during early diagenesis (Houten, 1973). The whole iron content of the sedimentary rocks was mainly controlled by detrital input during the sedimentation process. Iron-bearing minerals become dominant due to an oxygen-rich environment, low water table, and arid climate (Shogenova and Kleesment, 2006). The iron oxides and hydroxides can be of primary, early diagenetic and/or later diagenetic (secondly) origin. Authigenetic pyrite could have formed at all diagenetic stages. During dolomitization and dolomite cementation detrital iron content could decrease from primary detrital values.

4.4 Dolomitization

The rate of dolomitization increases upward along the Sachun Formation, reaching a maximum in the upper part. The dolomite has occurred as micro to coarse-crystalline, clean, anhedral to subhedral, as well as disseminated rhombs. Dolomitization may occur at two stages, early and late diagenetic stages. The early diagenetic dolomites form concurrently with deposition or immediately after this process and reflect the conditions of environment in which they form. Selective dolomitization is recorded where the original calcitic matrix has been partially replaced by dolomite. The fabric of the dolostones may be described as equigranular hypidiotopic to

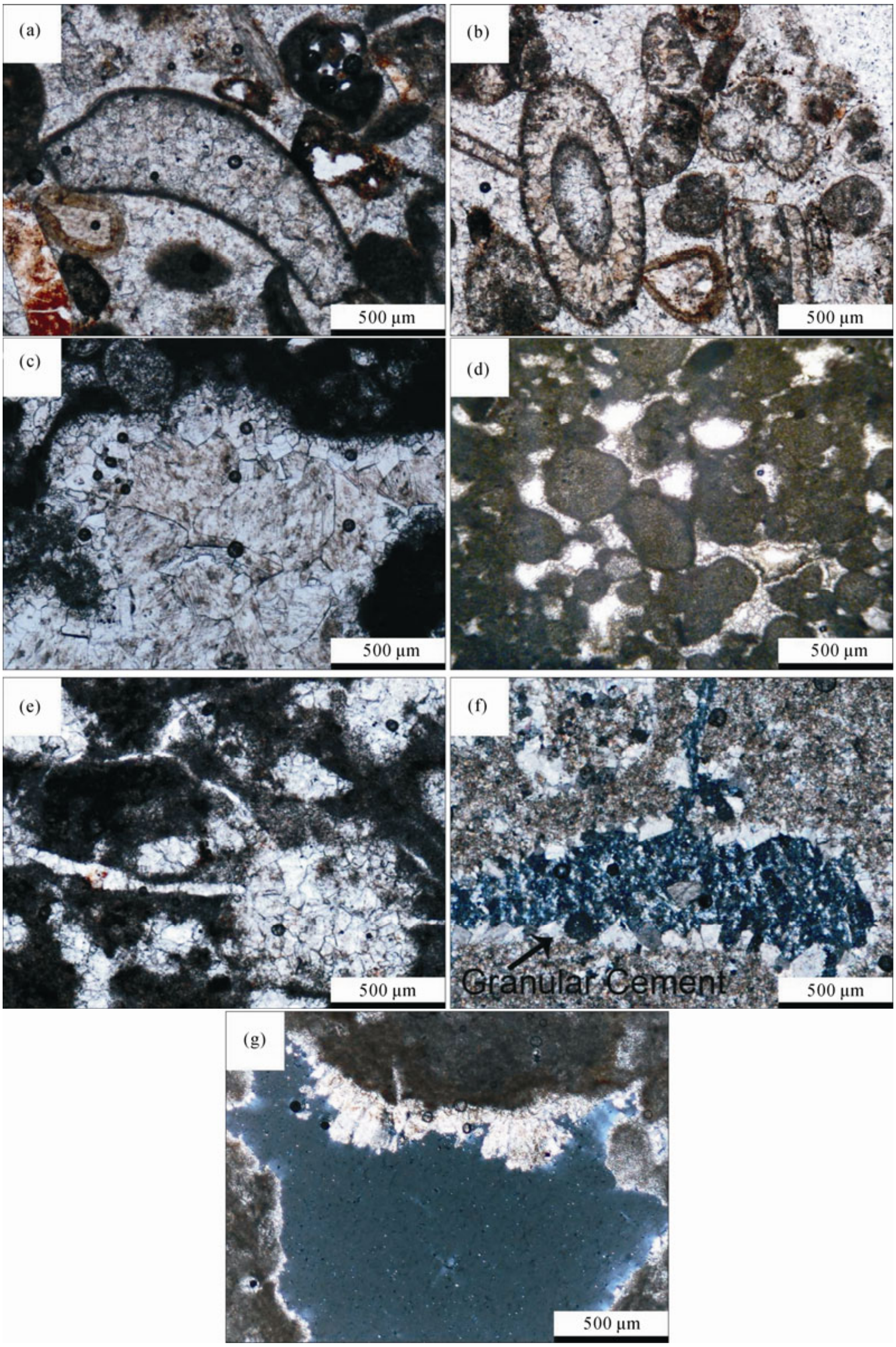

Figure 5. (a) Micritization by boring algae, being displayed by micrite envelope around skeletal particle. The grain developed a micrite envelope before dissolution, which in turn occurred before the drusy cement filled the mold; (b) small pore-filling microspar cement, note the Dasyclad algae; (c) drusy cement increasing in size toward the center of interparticle pore; (d) isopachous cement rims consist of microcrystalline crystals growing with equal thickness around grains; (e) small pore-filling granular cement, without a preferred orientation; (f) silicification within the void and bladed cement around the void; (g) pendant cements under the solution voids' roofs.

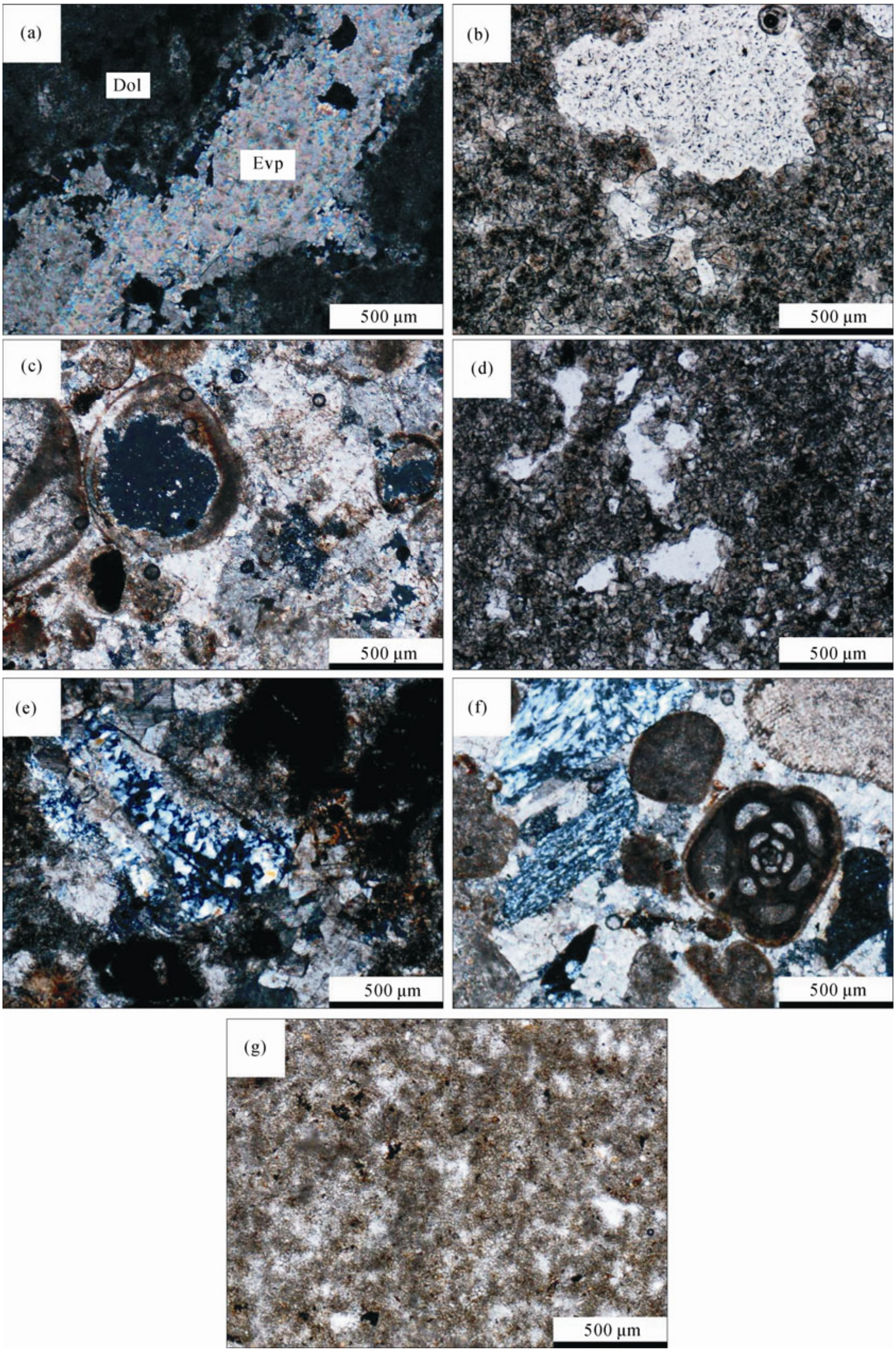

Figure 6. (a) The anhydrite is replacing carbonate; (b) vuggy pore, caused by irregular distributed early or late diagenetic dissolution, also not a cement and therefore not indicating original pore size or shape; (c) moldic porosity caused by leaching of metastable minerals such as aragonite; (d) non fabric selective dissolution porosity; (e) silicification affected skeletal grain. Silica occurs in the form of microcrystalline quartz; (f) silica occurs in the form of chalcedony; (g) scattered crystals of cubic pyrite in dolomicrite facies. Dol. dolomite; Evp. evaporate.

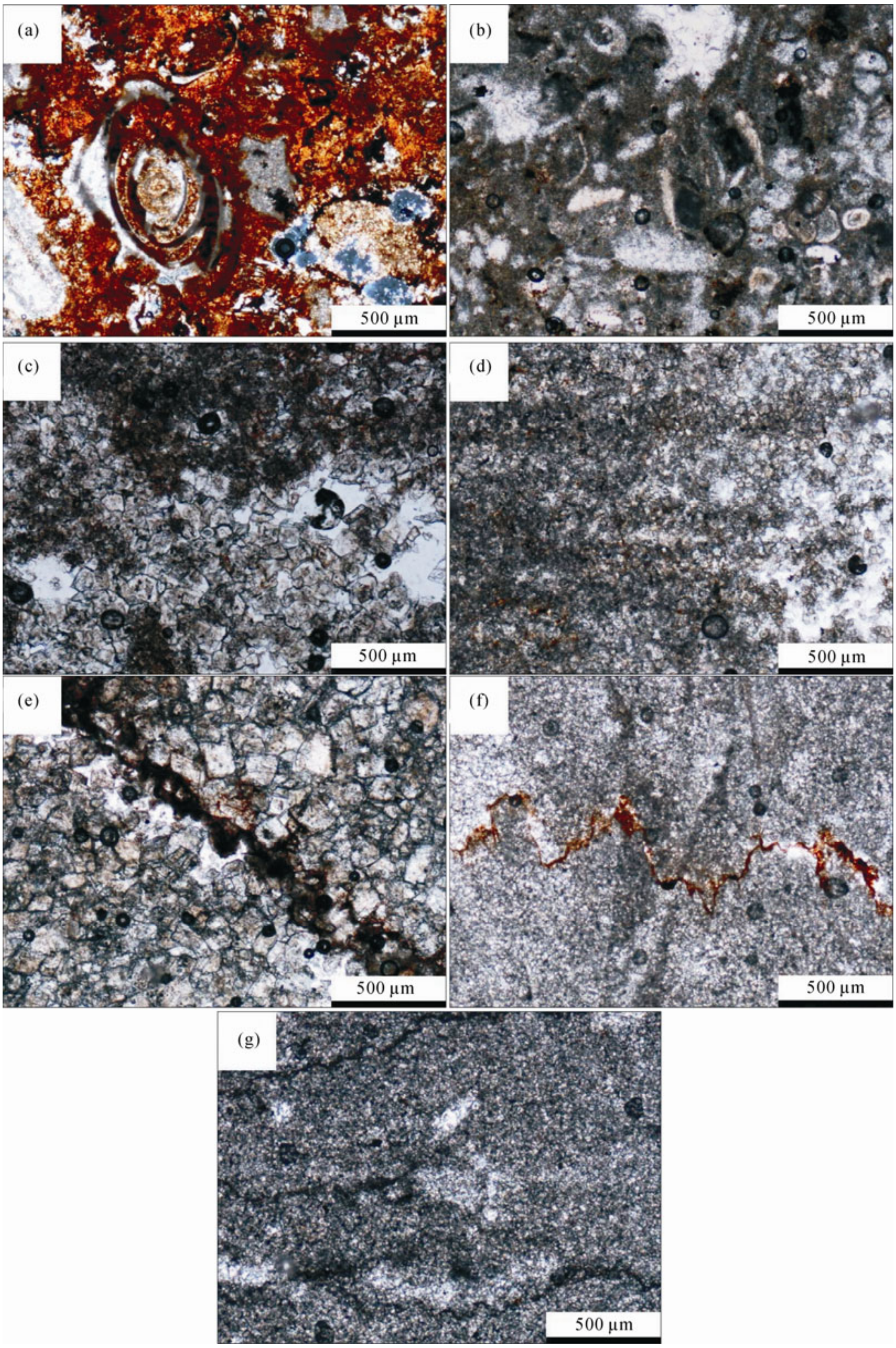

Figure 7. (a) The feature indicate extensive hematitization reddish color of hematite can be seen all over the facies; (b) relic structures of allochems suggest replacement of a precursor carbonate; (c) the polymodal crystal size of dolomite, probably reflects textures of different original components; (d) dolomite showing faint lamination, which are caused by discontinuous streaks of organic matter; (e) dolomite crystals across pressure-solution surfaces; (f) pressure solution post-dates compaction. This sutured type of stylolite is typified by grain contact structures and forms in limestones with very low amounts of insoluble residual material; (g) bedding-parallel irregular anastomosing sutured seams in lime mudstone. Dark insoluble residue along pressure solution surfaces.

xenotopic according to Friedman (1965). According to the widely accepted classification of Sibley and Gregg (1987), the abondance texture is polymodal (varying crystal size) nonplanar crystal boundaries (xenotopic) to planars (hypidiotopic). Relic structures of allochems (Fig. 7b) suggest replacement of a precursor carbonate of unknown texture. The polymodal crystal size of dolomite (Fig. 7c) recommends multiple dolomitization events, a phenomenon which ischaracteristic for many dolomite occurrences (Machel, 2004). Faint lamination may be recognized in these rocks under the petrographic investigation (Fig. 7d). This lamination is caused by discontinuous and wavy streaks of organic matter and changes in the crystal size.

4.5 The Dolomitization Models

The dolomitization models are subdivided in three groups.

A. The evaporative dolomitization model. This model explains the formation of massive dolomite by hypersaline brines. In the evaporative model penecontemporaneous dolomites is formed by direct precipitation in evaporitic environments like sabkhas (McKenzie, 1981). The rate of deposited dolomite is generally low in these environments.

B. The seawater model assume normal marine water, or seawater only slightly modified by water-rock interaction, as the most likely dolomitising fluids (Morrow, 1990; Land, 1985). These fluids can be put into motion from different mechanisms, and various hydrologic systems have been proposed. For the studied samples seawater thermal convection or Kohout model (Sanford et al., 1998), is suggested.

C. The burial (subsurface) dolomitization model. Dolomitization in burial environments may be related also to pressure-solution processes. Dolomite forms if Mg-bearing fluids react with limestones across pressure-solution surfaces (Fig. 7e). Precursor limestones, particularly if they are tight and fine-grained, may also release considerable quantities of autochthonous Mg upon dissolution (Wanless, 1979). However, in order to form high content of dolomite, other sources of Mg are required (Morrow, 1990). This very broad group of models is based on the evidence that under moderate to deep burial conditions (after Choquette and Pray, 1970) the kinetic requirements for dolomite formation are more easily satisfied than at surface. The increasing temperature and depth causes the burial environment so appropriate for dolomitization, since it reduces the proportion of hydrated Mg^{2+} and increases the dolomitization rates. The compaction flow is induced by the compaction of sediments under burial and consequent pore water squeezing (Illing, 1959).

4.6 Stylolitization

Different stylolites in size and geometry have been investigated throughout the studied thin sections (Figs. 7f and 7g). Stylolites form by dissolution of rock under the control of oriented pressure, most concentrated at the interface of two interpenetrating rock masses. This process operates on lithified sedimentary rocks during deep burial (Alsharhan and Whittle, 1995). Resulting from a combination of mechanical and chemical processes, stylolitization is activated by increasing overburden of sediments during burial and increasing temperature and pressure conditions (Flügel, 2004). Compaction and pressure solution reducing porosity and permeability are factors (Mossop, 1972; Coogan, 1970; Dunnington, 1967). Stylolites hosted in a limestone or dolomite matrix are widely recognized pressure solution features thought to indicate burial depths in excess of 0.5–1 km (Bathurst, 1980). Their architecture is either very irregular or displays a saw-tooth type waveform. They exhibit opaque phases along their trace. These phases consist of clays accumulated along the stylolites as insoluble residue, framboidal pyrite and the products of pyrite oxidation. The axes of the stylolite peaks are mostly perpendicular to the plane of stylolites and consequently to the lamination and bedding planes of the host limestones. The amplitude of the peaks rarely exceeds 2 mm, suggesting a little amount of dissolution across the stylolite planes (Choquette and James, 1990).

5 CONCLUSIONS

The conclusions drawn from the detailed field observations, laboratory and petrographic studies on sediments of Sachun Formation are given as under. The results strongly indicate that the diagenetic history of the Sachun Formation can be divided into three diagenetic phases with different aspects. The diagenetic settings favored the production of a variety of features, which include micritization, cementation, dissolution, silicification, hematitization, dolomitization and stylolitization. Early diagenetic processes affecting carbonates on the Sachun Formation occurred in marine phreatic to shallow burial environments. Common micritization of bioclasts, development of isopachus and bladed cements, the formation of dolomite and Hematitization are likely related to marine phreatic conditions, which is accomplished just after deposition. Possible evidence for early subaerial exposure of marine deposits includes the formation of cavities, silicification and expanding of microspary, drusy, granular, evaporite and pendant cements, although some of these features may also be marine source. Later diagenesis occurred in meteoric to burial environments. Dissolution that resulted in the appearance of vuggy and moldic pores likely reflects vadose zone conditions. Post-depositional compaction is well illustrated in the form of grain to grain sutured contacts as well as the occurrence of frequent wispy stylolites.

REFERENCES CITED

Adabi, M. H., Rao, C. P., 1991. Petrographic and Geochemical Evidence for Original Aragonitic Mineralogy of Upper Jurassic Carbonates (Mozduran Fm.), Sarakhs Area, Iran. *Sedimentary Geology*, 72: 253–267

Alavi, M., 2004. Regional Stratigraphy of the Zagros Fold-Thrust Belt of Iran and Its Proforeland Evolution. *American Journal of Science*, 304: 1–20

Alsharhan, A. S., Nairn, A. E. M., 1997. Sedimentary Basins and Petroleum Geology of the Middle East. Elsevier, Amsterdam. 843

Alsharhan, A. S., Whittle, L., 1995. Carbonate-Evaporite Sequences of the Late Jurassic, Southern and Southwestern Arabian Gulf. *AAPG Bulletin*, 79: 1608–1630

Bathurst, R. G. C., 1966. Boring Algae, Micritic Envelopes and Lithification of Molluscan Biosparites. *Geological Journal*, 5: 15–32

Bathurst, R. G. C., 1975. Carbonate Sediments and Their Diagenesis. *Developments in Sedimentology*, 12: 658

Bathurst, R. G. C., 1980. Deep Crustal Diagenesis in Limestones. Revista del Instituto de Investigaciones Geologicas, Deputacion Provincial, Universidad Barcelona. 34: 89–100

Berelson, W. M., Hammond, D. E., McManus, J., et al., 1994. Dissolution Kinetics of Calcium Carbonate in Equatorial Pacific Sediments. *Global Biogeochemical Cycles*, 8: 219–235

Boles, J. R., Ramseyer, K., 1987. Diagenetic Carbonate in Miocene Sandstone Reservoir, San-Joaquin Basin, California. *AAPG Bulletin*, 71: 1475–1487

Bordenave, M. L., 2002. The Middle Cretaceous to Early Miocene Petroleum System in the Zagros Domain of Iran, and Its Prospect Evaluation. American Association of Petroleum Geologists Annual Meeting, Houston, Texas. 10–13

Burford, E. P., Fomina, M., Gadd, G. M., 2003. Fungal Involvement in Bioweathering and Biotransformation of Rocks and Minerals. *Mineralogical Magazine*, 67: 1127–1155

Choquette, P. W., Pray, L. C., 1970. Geologic Nomenclature and Classification of Porosity in Sedimentary Carbonates. *AAPG Bulletin*, 54(2): 207–250

Choquette, P. W., James, N. P., 1990. Limestones—The Burial Diagenetic Environment. In: McIlreath, I. E., Morrow, D. A., eds., Diagenesis. *Geoscience Canada*, *Reprint Series*, 4: 75–112

Coogan, A. H., 1970. Measurements of Compaction in Oolithic Grainstone. *Journal of Sedimentary Petrology*, 40: 921–929

Dunham, R. J., 1962. Classification of Carbonate Rocks According to Depositional Texture. In: Ham, W. E., ed., Classification of Carbonate Rocks. *American Association of Petroleum Geologists Memoir*, 1: 108–121

Dunnington, H. V., 1967. Aspects of Diagenesis and Shap Change in Stylolitic Limestone Reservoirs. Proceedings of 7th World Petroleum Congress, Mexico City. 2: 339–352

El-Saiy, A. K., Jordan, B. R., 2007. Diagenetic Aspects of Tertiary Carbonates West of the Northern Oman Mountains, United Arab Emirates. *Journal of Asian Earth Sciences*, 31(1): 35–43

Falcon, N. L., 1974. Southern Iran: Zagros Mountains, in Mesozoic–Cenozoic Orogenic Belts, Data for Orogenic Studies. *Geological Society of London Special Publications*, 4: 199–211

Flügel, E., 2004. Microfacies of Carbonate Rocks. Analysis, Interpretation and Application. Springe*r*, New York. 976

Friedman, G. M., 1965. Terminology of Crystallization Textures and Fabrics in Sedimentary Rocks. *Journal of Sedimentary Petrology*, 35: 643–655

Gao, G. Q., Land, L. S., 1991. Nodular Chert from the Arbuckle Group, Slick Hills, SW Oklahoma: A Combined Field, Petrographic and Isotopic Study. *Sedimentology*, 38: 857–870

Garcia-Pichel, F., 2006. Mechanistic Models for the Phototrophic Microbial Boring on Carbonates. *Sedimentary Geology*, 185: 205–213

Golubic, S., 1969. Distribution, Taxonomy and Boring Patterns of Marine Endolithic Algae. *Integrative and Comparative Biology*, 9: 747–751

Heckel, P. H., 1983. Diagenetic Model for Carbonate Rocks in Midcontinent Pennsylvanian Eustatic Cyclothems. *Journal of Sedimentary Research*, 53: 733–759

Hempton, M. R., 1987. Constraints on Arabian Plate Motion and Extensional History of the Red Sea. *Tectonics*, 6: 687–705

Homke, S., Vergés, J., Bernaola, G., et al., 2009. Late Cretaceous–Paleocene Formation of the Proto-Zagros Foreland Basin, Lurestan Province, SW Iran. *Geological Society of America Bulletin*, 121: 963–978

Houten, F. B. V., 1973. Origin of Red Beds. *Annual Review Earth Planetary Science*, 1: 39–61

Illing, L. V., 1959. Deposition and Diagenesis of some Upper Palaeozoic Carbonate Sediments in Western Canada. Fifth World Petroleum Congress, New York. 23–52

James, G. A., Wynd, J. G., 1965. Stratigraphic Nomenclature of Iranian Oil Consortium Agreement Area. *AAPG Bulletin*, 49: 2182–2245

Kalantari, A., 1976. Microbiostatigraphy of the Sarvestan Area, S. W. Iran. National Iranian Oil Company, Geological Laboratories Publications, Iran. 129

Knauth, L. P., 1979. A Model for the Origin of Chert in Limestone. *Geology*, 7: 274–277

Kobluk, D. R., Risk, M. J., 1977a. Calcification of Exposed Filaments of Endolithic Algae, Micrite Envelope Formation and Sediment Production. *Journal of Sedimentary Petrology*, 47: 517–528

Kobluk, D. R., Risk, M. J., 1977b. Micritization and Carbonate Grain Binding by Endolithic Algae. *AAPG Bulletin*, 61: 1069–1082

Land, L. S., 1985. The Origin of Massive Dolomite. *Journal of Geological Education*, 33: 112–125

Lasemi, Y., Afghah, M., Arzaghi, S., 2007. Facies Analysis and Sedimentary Environments of Sachun Formation in Kuh-e-Siah Section, Southeast of Sarvestan (Fars Province). *Journal of Applied Geology*, 3(3): 213–218

Longman, M. W., 1980. Carbonate Diagenetic Textures from Nearsurface Diagenetic Environments. *American Association of Petroleum Geologists Bulletine*, 64: 461–487

Machel, H. G., 2004. Concepts and Models of Dolmitization: A Critical Appraisal. In: Braithwaite, C. J. R., Rizzi, G., Darke, G., eds., The Geometry and Petrogenesis of Dolomite Hydrocarbon Reservoirs. *Geological Society of London Special Publication*, 235: 7–63

MacIntyre, I. G., Prufert-Bebout, L., Reid, R. P., 2000. The Role of Endolithic Cyanobacteria in the Formation of Lithified Laminae in Bahamian Stromatolites. *Sedimentology*, 47: 915–921

McKenzie, J. A., 1981. Holocene Dolomitization of Calcium Carbonate Sediments from the Coastal Sabkhas of Abu Dhabi: A Stable Isotope Study. *Journal of Geology*, 89: 185–198

Maliva, R. G., 2001. Silicification in the Belt Supergroup (Mesoproterozoic), Glacier National Park, Montana, USA. *Sedimentology*, 48: 887–896

Moore, C. H., Druckman, Y., 1981. Burial Diagenesis and Porosity Evolution, Upper Jurassic Smackover, Arkansas and Louisiana. *AAPG Bulletin*, 65: 597–628

Morrow, D. W., 1990. Dolomite-Part 2: Dolomitization Models and Ancient Dolostones. In: McIlreath, I. A., Morrow, D. W., eds., Diagenesis. *Geoscience Canada Reprint Series*, 4: 125–139

Morse, J. W., 2002. The Dissolution Kinetics of Major Sedimentary Carbonate Minerals. *Earth-Science Reviews*, 58: 51–84

Mossop, G. D., 1972. Origin of the Peripheral Rim, Redwater Reef, Alberta. *Bulletin of Canadian Petroleum Geology*, 20: 238–280

Sanford, W. E., Whitaker, F. A., Smart, P. L., et al., 1998. Numerical Analysis of Seawater Circulation in Carbonate Platforms: I. Geothermal Convection. *American Journal of Science*, 298: 801–828

Scholle, P. A., Halley, R. B., 1985. Burial Diagenesis. In: Schneidermann, H. P. M., eds., Carbonate Cements. *Society Economic Paleontologists and Mineralogists Special Publication*, 36: 309–334

Shogenova, A., Kleesment, A., 2006. Diagenetic Influences on Iron-Bearing Minerals in Evonian Arbonate and Siliciclastic Rocks of Estonia. Proceedings of the Estonian Academy of Sciences. *Geology*, 55: 269–295

Sibley, D. F., Gregg, J. M., 1987. Classification of Dolomite Rock Textures. *Journal of Sedimentary Petrology*, 57(6): 967–975

Smith, G. L., Dott, J. R., Byers, C. W., et al., 1997. Authigenic Silica Fabrics Associated with Cambro-Ordovician Unconformities in the Upper Midwest. *Geoscience Wisconsin*, 16: 25–36

Steinsund, P. I., Hald, M., 1994. Recent Calcium Carbonate Dissolution in the Barents Sea: Paleoceanographic Applications. *Marine Geology*, 117(1–4): 303–316

Tobin, K. J., 2004. A Survey of Paleozoic Microbial Fossils in Chert. *Sedimentary Geology*, 168(1–2): 7–107

Wanless, H. R., 1979. Limestone Response to Stress: Pressure Solution and Dolomitization. *Journal of Sedimentary Petrology*, 49: 776–780

Wilson, M. E. J., Evans, M. J., 2002. Sedimentology and Diagenesis of Tertiary Carbonates on the Mangkalihat Peninsula, Borneo: Implications for Subsurface Reservoir Quality. *Marine and Petroleum Geology*, 19: 873–900