Stylolite networks in dolomitized limestones and their control on polished decorative stones:a case study from Upper Cretaceous Khur quarries, central Iran

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Abstract

Stylolite networks and their insoluble residues (IR) are among the major concerns and the fundamental controls on the mining and processing of sedimentary decorative stones, largely made from dolomitized limestones. They are mainly used, as natural rock blocks and polished slabs, to construct and decorate floors and walls of buildings and monuments. Representative quarries in Khur areas, east of Esfahan Province, central Iran, are selected for this study in order to evaluate the type and geometry of the stylolite networks in differentially dolomitized limestones and their control on the quality of the mined rock blocks and processed polished rock slabs. Field observation, examining the mined wall-rock cuttings in quarries, and petrography of the selected thin sections of Upper Cretaceous Haftoman Formation were performed with a comparative study of thickly developed, rudist-bearing rudstones-grainstones to bioclastic packstone-wackestone microfacies. What is typically considered in this study is evaluating the geometry of stylolite networks (cells), as they merge and result in a 3D network, rather than laterally continuous single stylolites. This study highlights the primary lithofacies types and diagenesis controls on the mining and processing of sedimentary decorative stones and documents that under relatively ideal tectonic conditions, slightly dolomitized, thick-bedded, relatively clay-free (<10% IR), mud-dominated packstones-wackestones provide the best shallow marine, carbonate lithofacies for preparing polished rock slabs. This is in contrast to clay-rich argillaceous limestones with dissolution seams or stylolite networks and pervasively dolomitized, grain-rich platform carbonate lithofacies characteristically with stylonodular, brecciated and chalky textures.

Key words: *Stylolite, Dolomitization, Decorative stone, Diagenesis, Insoluble residue, Central Iran.*

Introduction

Stylolites often occur in limestones and dolomites as rough paired surfaces that develop by localized stress-enhanced, pressure dissolution and are characterized by insoluble residue (IR) concentrations (Bathurst, 1987; Tada & Siever, 1989; Railsback, 1993; Brouste, *et al*., 2007; Lun, *et al*., 2010; Benedicto & Schultz, 2010). Stylolite surfaces are characterized by a series of pronounced roughness with "teeth"- or "pen"-like geometries. IR concentrations, commonly as clays, iron oxides and silt-sized quartz, are concentrated along the stylolite surfaces and as pressure solution remove such soluble minerals, such as soluble carbonates. Assuming the insoluble material was initially evenly distributed in the rock and that there has been no contamination by circulating fluids, the thickness of IR along a stylolite would be proportional to the amount of material dissolved and would therefore be proportional to the displacement across the stylolite (e.g Railsback, 1998; Koehn, *et al*., 2007; Ebner, *et al*., 2009). Stylolite initiation is still highly debated and the mechanism of formation of stylolites in general, and of the differentiated type in particular, is problematic (e.g. Tada & Siever, 1989; Andrews & Raisback, 1997; Bäuerle, *et al*., 2000; Renard, *et al*., 2004; Merino, *et al*., 2006). There are fundamental issues and unresolved problems concerning the types of stylolite networks and their relationship to the fabric and composition of the host rocks (Railsback, 1993; Brouste, *et al*., 2007). It is generally accepted that stylolites are diagenetic structures resulted during burial pressure dissolution in rocks and tend to grow perpendicular to the maximum compressive stress direction represented by seams of IR concentrated along rough surfaces (e.g. Bathurst, 1987; Railsback, 1993; Benedicto & Schultz, 2010).

Stylolites are significant in several fields, for example, they control the porosity and permeability of rocks, as barriers to fluid flow and in other settings as conduits for migration of fluids and brines resulting in the accumulation of hydrocarbons, water and mineral resources (e.g. Peacock and Azzam, 2006; Ehrenberg, *et al*., 2006; Taberner, *et al*., 2010). They are geological patterns that are very common in polished limestone slabs, a type of decorative stone largely used to decorate walls of buildings and monuments. Stylolite are either as a flat surface, normally parallel to bedding, or usually they occur as networks (here defined as *"cells"*, see below), which are three-dimensional, rough surfaces (e.g. Renard, *et al*., 2004). If the dimension of this network is small and the concentration of the IR is considerable, a stylonodular to brecciated texture will appear. Stylolite-cell geometry is a key factor in controlling the quality of carbonate decorative stones in different carbonate lithofacies. Bed thickness, rock strength, general color, the appearance of allochems versus matrix, clay content, degree of water absorption and the general behavior of rocks during mining for blocks and their processing for polished slabs are also the controlling factors in the quality of decorative stones. The rock (blocks and slabs) strength is mainly controlled by the composition, diagenesis and fractures of the rock (e.g. Katsman, 2010). Stylolites, which are diagenetic structures, are the subject of this study.

Development of the stylolite networks are a common feature of dolomitized limestones, used as polished, natural decorative slabs. They are widely mined as rock blocks and processed as polished rock slabs (named "*Marmarite*") in central Iran and are used to decorate walls of buildings or comprise an important income-resource, as exported to other countries. The mined rock blocks are economically ideal when they are normally up to 8 m^3 in volume and 20 tones in weight and their processed polished rock slabs yields typical sizes ranges such as 80-120 cm in length, 30-50 cm in width and 2-4 cm in thickness.

Stylolites are one of the key factors to control the quality of decorative stones and there are many examples of limestone decorative-stone mines progressed or failed in central Iran (Arzani, 2000). Stylolite networks could be positive if their IR are very thin, for example as iron oxide concentrations and could give the white polished slabs a reddish painting. They could be very negative and destructive parameters if the IR could lower the resistance of the slabs and, for example clays, could absorb water break through during the cutting and polishing stages in the factory.

Despite the importance and the large volume of decorative stones mined and processed and used in many countries, there has been no detailed study on how to deal with the different types of stylolites during the exploration, mining and processing as miners are usually concerned. Decorative stones are also an important income resource in some countries, like Iran. In order to gain insight how the stylolite control the quality of natural decorative stones, the Khur quarries in E. Esfahan Province, are selected for this study. The main aims of this study is to highlight the stylolites, as one of the major natural and diagenetic controls in mining and processing of these rocks, and to find a simple general method to compare and evaluate the exploration-processing potential of differentially dolomitized limestones in the field. The Khur quarries in central Iran are ideal for such a study as they are extensively mined and have a simple tectonic deformation and variable units of dolomitized, shallow platform carbonates. They represent typical examples of quarries in which the extent of the sedimentary (diagenetic) stylolite networks and their control on the quality of decorative stones could be evaluated in different dolomitized limestones.

Geological setting

The study area is located about 20 Km south of

Khur City in the E. of Esfahan Province, where the Upper Cretaceous Haftoman Formation (Reyre & Mohafez, 1972) are thickly developed and widely distributed in so-called Yazd Block in Central Iran (Aghanabati, 2004, Alavi, 2004; Zanchi, *et al*., 2009). The Haftoman Formation starts with a basal transgression conglomerate and grades into shallow-water dolomitized limestones containing rudist biostromes and bioclastic limestones of a large carbonate platform. The thickness of this formation reaches to 150 m in the study area but it is several hundred meters thick and widespread in Anarak to Khur region. It is representative of relatively uniform platform carbonate deposits and only towards the top of this formation a deepening trend is indicated by the appearance of the marly facies with echinoids, inoceramid bivalves and ammonite of Late Cretaceous age (Early Coniacian to Late Campanian, *cf.* Wilmsen, *et al*., 2011). The marly facies of the Farokhi Formation deposited over the Haftoman carbonates during the Maastrichtian. Parts of the Haftoman Formation in S. Khur area, comprising cliff forming, rudist-bearing, whitish-cream to reddish dolomitized limestones, are mined for the decorative and construction stones. The mined areas are normally selected within the side limbs of gentle folds, where the beds do not exhibit closely spaced joints and fractures and represent relatively ideal tectonic conditions for mining undisrupted large (4-8 m^3) rock blocks. In this study a representative section of the Haftoman Formation in mined quarries (Kohi mine) is selected at N 33° 27′ E 54° 22′ in Taher Abad area, for evaluating how the stylolite networks controls the quality of decorative stone in different shallow water carbonates (Fig. 1).

Methods

The stylolite networks, developed in Khur quarries, have been studied in the field, rock blocks and polished slabs, hand specimens, photographs and also in thin sections under the microscope. A totally 70 m of rocks in valleys and four vertical mined walls, in different levels of the studied quarries, have been studied for their stylolite network geometries (Fig. 1). The orientation, dipping, cross-cutting relations and filling of stylolites, extensional fractures and brittle shear zones were studied in the field. The shape of the stylolite network was measured by visual descriptions in two dimensional views and on the polished slabs and according to Buxton and Sibley, (1981) and Railsback (1993). In this method, the stylolite roughness was recorded and the maximum length and the height of single, laterally continuous stylolites (solution seams) have been measured. However, what is important in this study is the geometry of stylolites, as they merge and result in a rather network. The term "*stylolite cell*" is defined here, which facilities the comparison, and is the surface in 2D and 3D network (volume) of the rock enclosed between two cross-cut, merged stylolites. In this case, the maximum height (H) and length of the cell (D) have been measured in the field. Representative and selected areas (~40 × 40 cm) on the washed walls of the quarries and the surfaces of cut blocks and polished slabs were drawn in the notebook and photographed for further analysis of their stylolite networks. The side effects of the joints and fractures have been eliminated by keeping away and selecting wide areas between these destructive parameters. Vertical, as well as, lateral sampling of beds was considered in the field. Thickness and type of the IR concentrations along the stylolite surface was measured in 2D in field exposures and also in thin sections (total 43) under the microscope. Selected oriented hand samples were cut along and perpendicular to stylolite cells and thin sections were prepared from subsamples to evaluate the cell dimensions. Thin sections were stained with alizarin red S and potassium ferricyanide to distinguish Fe-rich and Fe-poor calcite and dolomite (Dickson, 1965). Petrography of the thin sections was carried out under the normal polarized microscope and the relative abundance of allochems, orthochems and diagenetic processes were investigated in order to describe and differentiate the microfacies. As a comparative study and for simplicity as well as the applicability of the results, a broad scheme has been considered for lithofacies classification into dominant microfacies. However, classification was based on Dunham (1962) with modification of Embry and Klovan (1971) and Wright (1992). The degree of dolomitization, as cement and replacement, was visually estimated in the field and in thin sections and presented as percentages. Insoluble residue (IR) contents of selected samples (12 samples) were determined by dissolution of powdered subsamples in hydrochloric acid (100 gram subsample in 20% vol. acid and according to Ontario Laboratory Testing Manual, 1996).

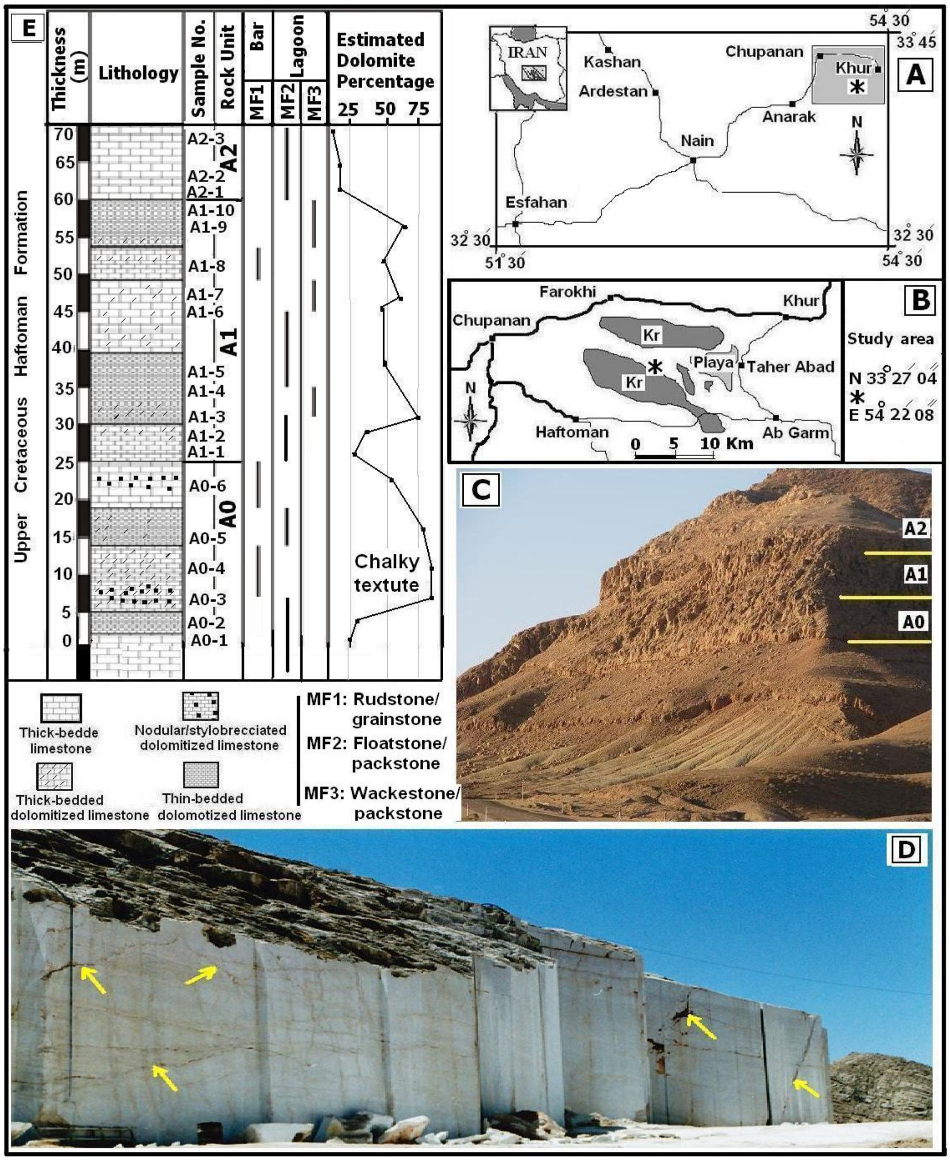

Figure 1: Location of the study area (A & B), field exposure of the Upper Cretaceous Haftoman Formation (C), unit A2 in a 9 m cut and mined wall with their major fractured (arrowed, D) and the sedimentological log of the three mined rock units and lithofacies showing their degree of dolomitization (E).

Field observations

Selected areas and sides of several valleys in the study area have been mined and cut as walls, each up to 9 m in height, 40 m in width and with a pavement floor, which provided very smooth 2D and 3D surfaces to observe the stylolite geometries and fractures and joints (Figs. 1 & 2). The studied exposure can be divided into three separate rock units, based on the degree of dolomitization, weathering properties and mining preference observed in the field (Fig. 1 C & E). The highest amplitude and the length of the stylolite networks is in the biostromal lithofacies, which show a positive correlation with the size of their associated large bioclasts. This unit is composed of large rudist fossils and is remarkably thick-bedded and stylonodular in the field (see below). The pervasively dolomitized lithofacies, with a characteristic porous chalky texture in the field, are not hard enough to yield high quality polished slabs. As the result, unit A0 is not suitable for mining, while the best is unit A2, which yield up to 40% undisrupted blocks (> 2 m in each dimension and at least 8 m^3 in volume) in the field (see below).

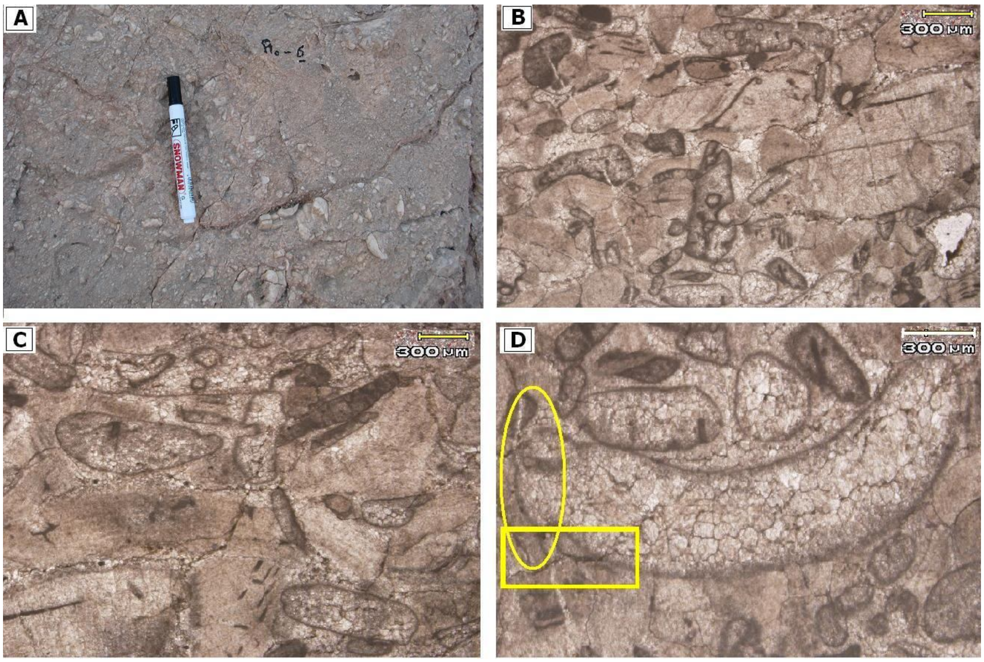

Figure 2: Bioclastic (rudists and cortoids) rudstone/grainstone microfacies (MF2), showing extensive dolomite cement, cross-cut by stylolites. Stylolites cross cut the allochems and pore-filling cement (rectangle area in D). It is noteworthy that cortoids are not compacted and instead stylolites pass through their micritic envelopes and internal dolomitic cements (circled in D).

Facies and diagenesis

The upper Cretaceous Haftoman Formation comprises thick bedded to stylonodular, dolomitized limestones with rudist biostromes and bioclastic fragments, which are the dominant lithofacies of the studied area (Fig. 1 E). Dolomitization, stylolite network and fracture-system development are the major diagenetic events, which controlled the potential of different lithofacies for mining of decorative stones. Three distinctive microfacies (MF1 to MF3) were distinguished based on the texture of the rocks.

Bioclastic rudstone/grainstone (MF1)

This microfacies is grain-supported and is more common in the basal parts of the studied section (unit A0, Figs. 1 E & 2). The main components of this microfacies are the rudist fragments, cortoids, intraclasts, echinoid fragments and minor fractions of benthic foraminifers, which are cemented with the drusy and pore-filling dolomite cement.

Degree of dolomitization of this microfacies is variable, but is mostly limited to the cementation and minor replacement of the selected allochems. Dolomite crystals, which fill the internal parts of the cortoids, have not replaced their micritic envelopes. Stylolites cross cut the allochems and pore-filling cement. It is noteworthy that cortoids are not compacted and instead stylolites pass through their micritic envelopes and internal dolomitic cements (Fig 2). Stylolite networks grade this microfacies in some of the beds into stylobrecciated rudstones and fitted grainstones (Fig. 2C). However, nodular and brecciated textures are more common in the biostromal beds with high density and concentrated stylolite networks (see below).

Bioclastic floatstone-packstone (MF2)
Bioclastic and rudist-bearing floatstones to grain-dominated packstones are the dominant lithofacies in the studied section (Figs. 1 E, 3, 4 & 5). The other components are cortoids, gastropods, echinoid fragments and benthic foraminifers, such as milliolids. They have stylonodular to thick-bedded structures and whitish-cream to reddish color in appearance. Dolomitization is relatively common in this microfacies and mostly concentrated in their micritic matrix and also concentrated along the stylolite surface. Chalky texture is also observed in lower parts of the studied section.

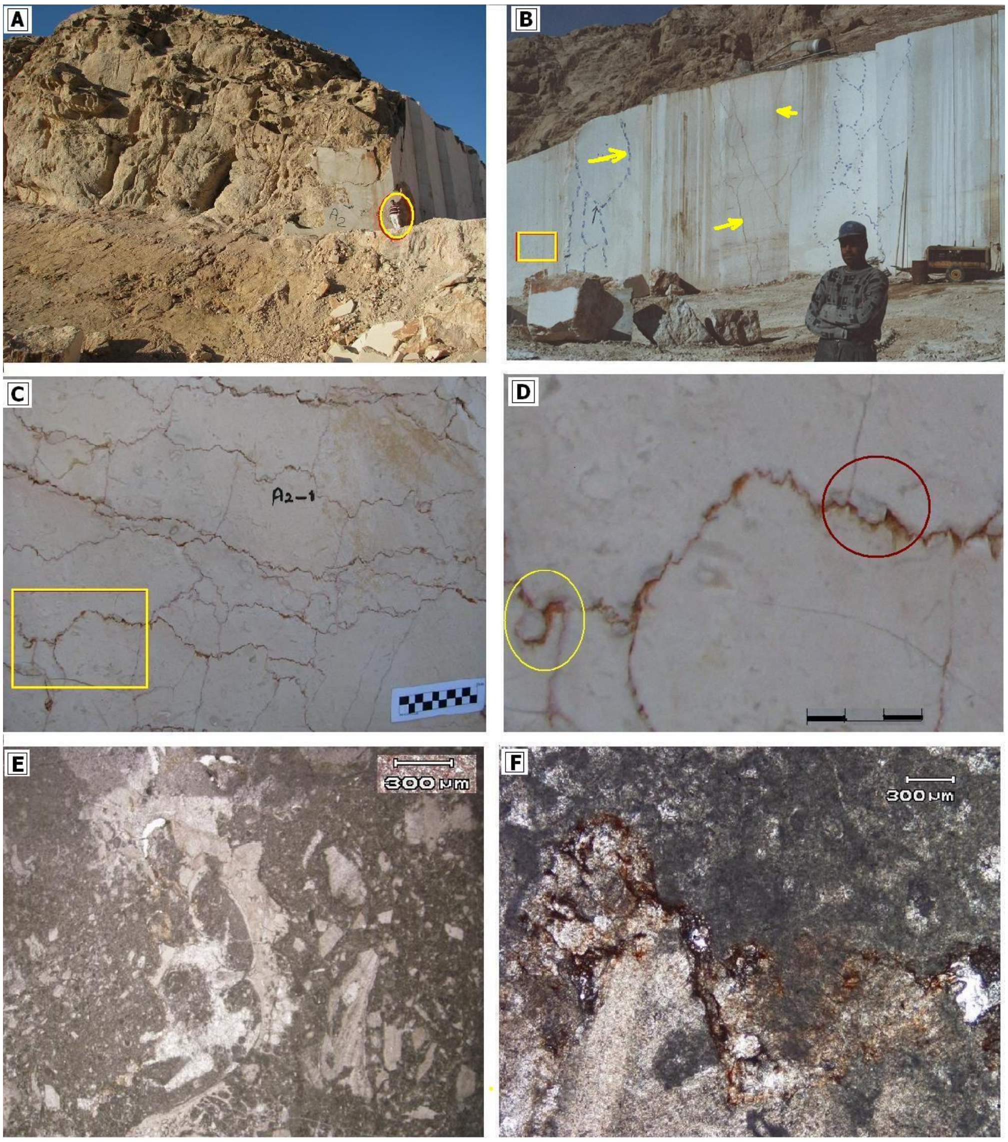

Figure 3: Field exposures (A-D) and thin section photomicrographs showing the stylolite networks with their insoluble residue (IR) concentrations. Unit A2, a 9 m cut and mined wall with the general joint networks (arrowed in B) and the details of stylolites (C & D). Dolomitization is concentrated along the stylolite cutting through matrix and bioclasts of the floatstone-packstone microfacies (E & F).

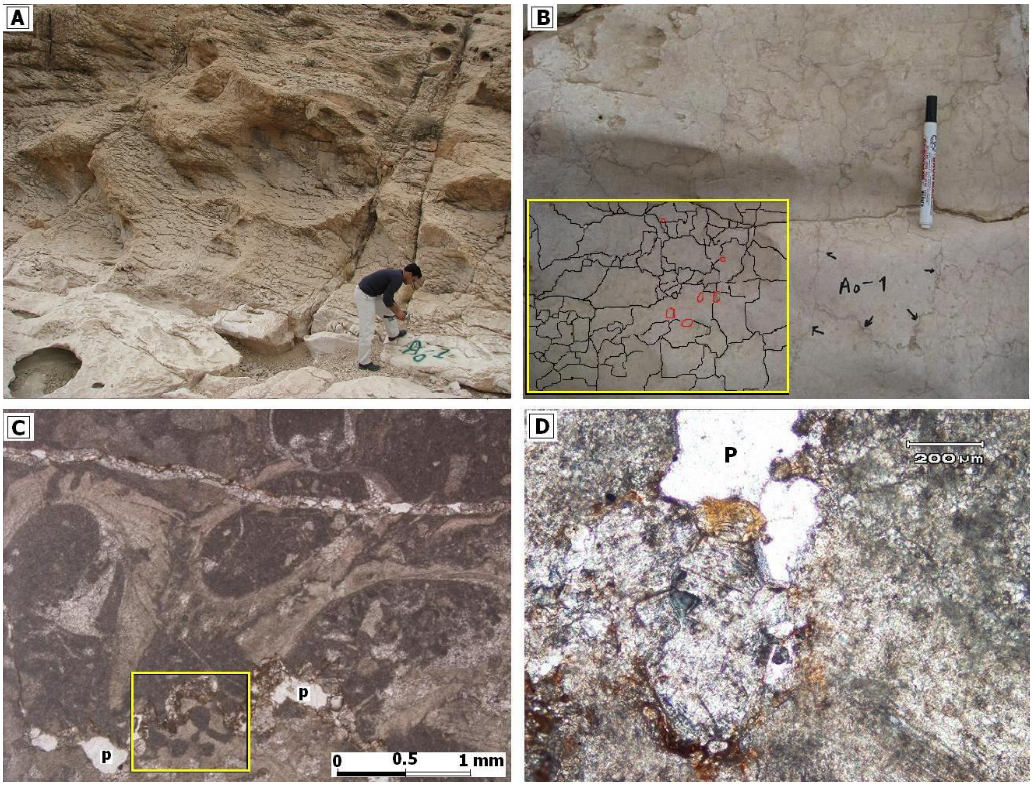

Figure 4: Lithologic unit A0 in the field (A & B) and in thin section photomicrographs of bioclastic floatstone/packstone microfacies (C & D) showing the concentration of dolomite rhombs and iron oxide insoluble residue with later solution-enlarged porosity (P) along stylolite. The dolomite rhombs are mildly ferroan with an inclusion rich, cloudy appearance.

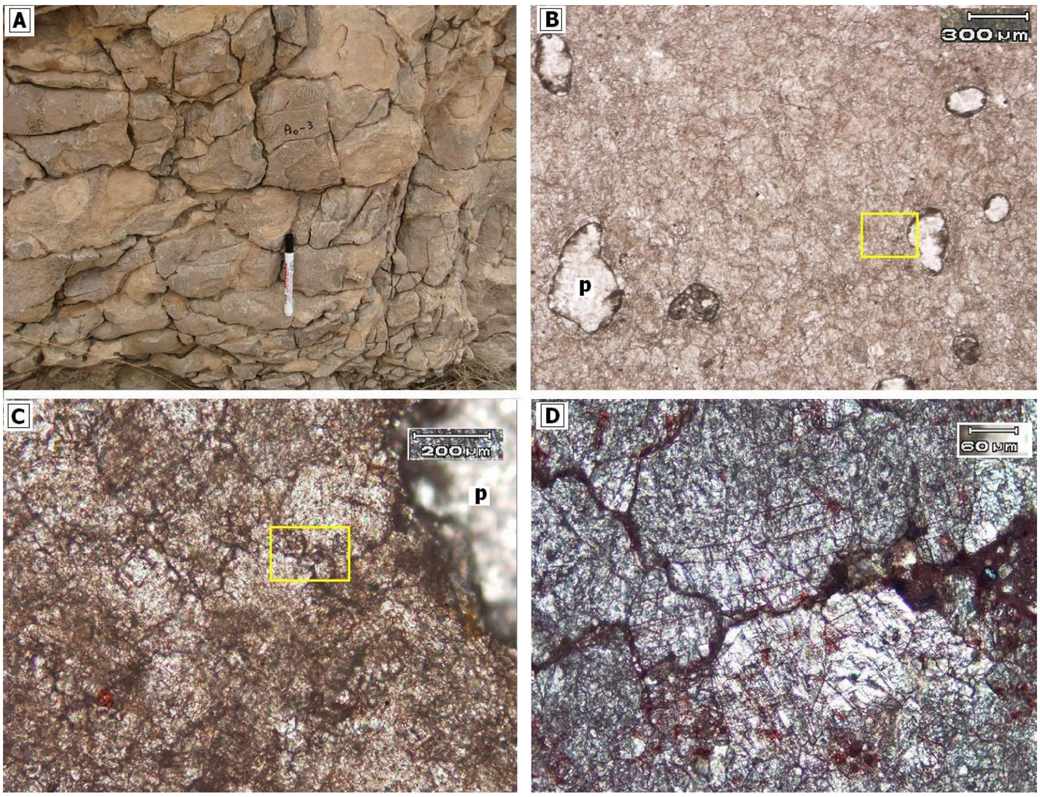

Figure 5: Rudist-bearing floatstones to packstones microfacies with stylonodular and chalky appearance in the field (A) and brecciated texture and porosity (P) in the thin section photomicrographs (B, C). Dolomitization is relatively common in this microfacies and stylolite cross cuts mildly-ferroan dolomite crystal rhombs as cement (C & D).

Wackestone to packstone (MF3)

Thick-bedded, wackestones to mud-dominated packstones are the main microfacies in the middle towards the upper parts of the studied section (Figs. 1E, 6 & 7). Rudist fragments, peloids, echinoid fragments and benthic foraminifers (milliolids) are the skeletal components scattered in a partly dolomitized micritic matrix. Scattered, large dolomite rhombs, floated in the micritic matrix, comprises the dominated replacement of the fine fraction of the rock (Figs. 6D & 7C). Dolomite cement also is presented as pore-filling bioclastic fragments, which they in turn have been also partly dolomitized. The stylolites are much more flat that the other microfacies and there is a pronounced change in their amplitude, where this microfacies vertically grades into brecciated rudstones and fitted grainstones (Fig. 7).

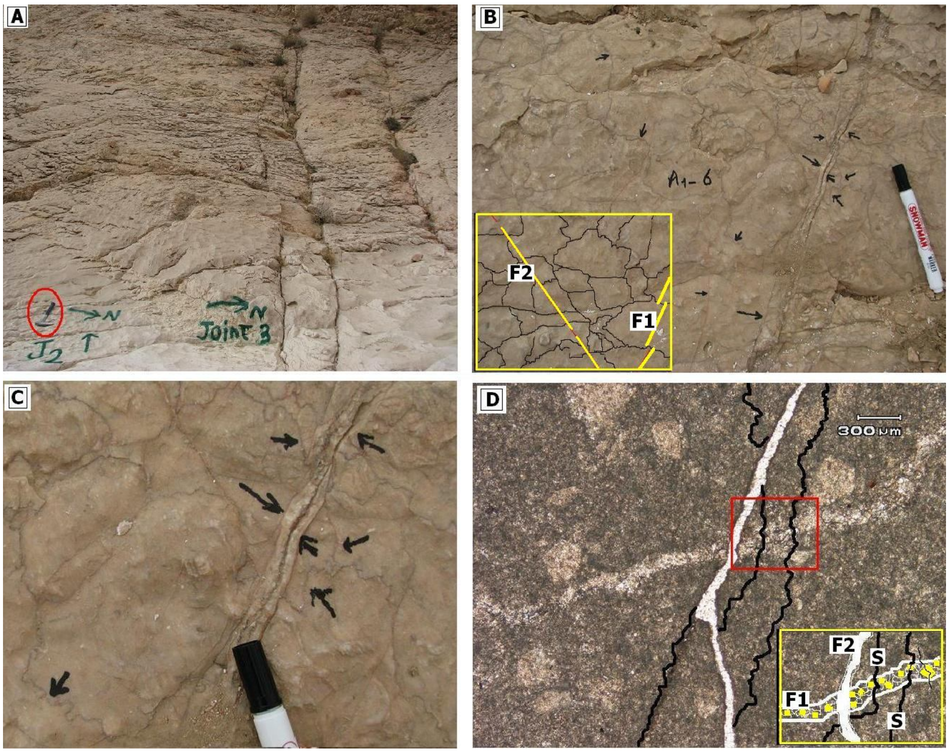

Figure 6: Mud-dominated packstones to wackestone microfacies in the field (A & B) and in thin section photomicrographs (C & D). Early (filled with dolomite cement) and late fractures cross cut the stylolite and slightly dolomitized micritic matrix. Three sets of joints are present. The spacing between the main joint systems is wide enough to provide large rock blocks during miming for decorative stones.

Stylolite geometry

Stylolites form conspicuous networks (cells) as macroscopic structures in the studied mined walls, blocks and polished slab surfaces. Single, laterally continuous stylolites and solution seams are very rare, instead they usually merge and die out laterally and their amplitude of peaks reduces gradually towards the terminations ending in zero. The size of stylolite cells, as the height (H) and the lateral distance (D) within a single cell and measured in the field, are very variable in different studied microfacies (Fig. 8). The H values varies between 3 to 16 cm, whereas, D values are in broader range (5- 75 cm). The lowest is in the pervasively dolomitized floatstones to packstones which have a chalky texture and the highest is in the rudist rudstones to grainstones. The latter, which are also dolomitized, are not suitable for preparing the polished slabs. The micritic-rich microfacies show much uniform, rather smooth stylolite, relative to the large grainy and bioclastic-rich lithofacies. The roughness (superimposed noise) of individual stylolite has amplitude (as peak to trough) range between 0.2-6 cm and their wavelength varies between 0.1-15 cm in different lithofacies (Figs. 3, 4 & 8).

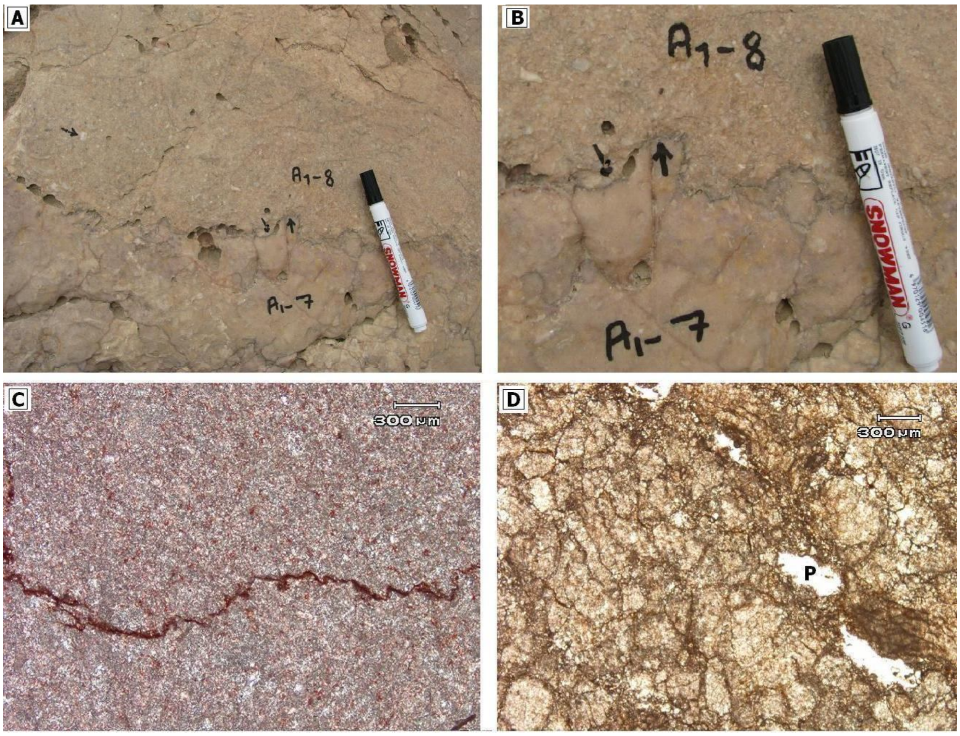

Figure 7: Field exposure (A & B) of stylolite (arrowed) along the contact of two contrasting lithofacies (wackestone below and floatstone above), and thin section photomicrographs (C) of low amplitude stylolite and scattered, large dolomite rhombs, floated in the micritic matrix of wackestone microfacies and (D), the brecciated texture, dissolution seams and porosity along the pressure dissolution structures in the floatstone microfacies.

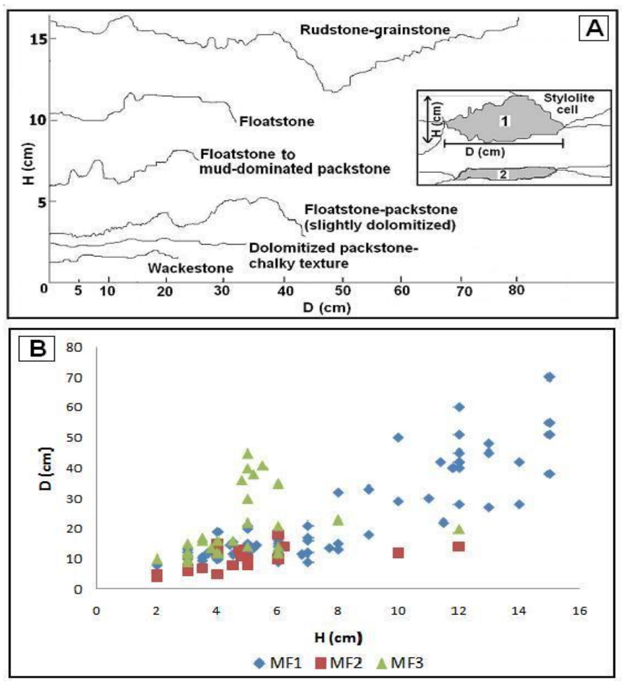

Figure 8: Representative stylolite geometries (sketch of cells, A, and graph, B) in the studied microfacies. The size of stylolite cells, as the height (H) and the lateral distance (D) within a single cell and measured in the field, are very variable in different studied microfacie. The smallest is in wackestones and in the pervasively dolomitized floatstones to packstones which have a chalky texture and is in the rudist rudstones to grainstones (see also Figs. 3 to 7).

However, the geometrical characteristics and morphologies of the studied stylolite networks vary sometimes within a single bed. There are also microstylolite systems within the larger stylolite sets. Those which are considered here are the main stylolite networks that are important and control the behavior of the polished rock slabs.

The residue thickness of the studied stylolites is between <1mm to 1.5 cm (Figs. 3 and 4) and this is consistent with the measured IR percentage by acid digestion of selected samples, which shows relatively very low IR (up to 8%). Iron oxides and clays are the major and minor IR respectively, which their concentration along the stylolites give rise to the reddish color and with absorption of the water they add to the effect of joint networks for disrupting the blocks and polished blocks during the mining and processing in the factory. Three sets of joints are present in the study area, but their spacing is wide enough to provide rock blocks during miming for decorative stones (Figs. 3B, 4A & 6). However, mining from thick beds with IR<10% and where they could provide even at least 30% vol. cubic-rock blocks (up to 70% vol. gangue), are economically acceptable.

Discussion

The stylolite networks (cells and individual seams), developed in Khur quarries are bedding-parallel and when they cross cut the large bioclasts (rudists) typically exhibit partial dissolution of allochems. These types of stylolites are generally considered as sedimentary (diagenetic), which should be differentiated from similar tectonic (post-diagenetic) structures. The latter are at an angle relative to the bedding planes. Stylolite initiation is a subject of controversy. Several mechanisms for formation of stylolites have been proposed among which are: formation and development of stylolite (I) along preexisting anisotropies (Bathurst, 1987) (II) as anticracks that propagate due to stress concentrations and (III) by stress induced self-organization (Railsback, 1998; Renard, *et al.*, 2004; Merino, *et al.*, 2006). It has been suggested that stylolites develop under stress at sites of textural heterogeneity caused by uneven distribution of mineral grains of variable pressure solubility (Bathurst, 1987; Brouste, *et al.,* 2007). The sedimentary stylolites are formed as a result of gravity and sediment compaction. However, the necessary overburden and the burial depth for the onset and formation of bedding parallel, sedimentary stylolites are still debated and a wide range of the burial depth, 90 m (Tada & Siever, 1989) to 1000 m (e.g. Bathurst, 1987; Railsback, 1993) has been suggested.

The IR of the studied decorative stones is relatively very low (up to 8%) and the role of clay minerals in their evolution is uncertain. The heterogeneity (IR) of carbonates, such as the presence of clays, is known to affect the nucleation and evolution of stylolites and it has suggested that the higher the clay content in the rock the smoother the stylolite and its general shape as dissolution seams (e.g. Bathurst, 1987). Furthermore, clay is known to significantly enhance processes of pressure solution in carbonates (e.g. Bathurst, 1987; Carozzi & Von Bergen, 1987**;** Railsback, 1993; Ebner, *et al.*, 2009).

Stylolites cross cut both the allochems and cements in all the studied microfacies and postdate substantial cementation and lithification. Pervasive post cementation pressure dissolution and development of stylolites is a common feature of many carbonate sequences (see reviews in Choquette and James, 1987; Demicco and Lawrence, 1994).

The smoother surface of the stylolites in the studied fine-grained, micritic-rich microfacies (MF3), relative to the large grainy and bioclastic-rich lithofacies (MF1), may exhibit comparable grain-size control, rather than the composition of matrix, on the geometry of stylolites. Despite this remarkable contrast, the general geometry and morphology of the stylolite networks are not constant in the grain-rich rudite lithofacies. This is why the exact classification of stylolites in the field is a difficult task. Normally, there is a wide range of geometries, such as conical, columnar and wavy types of mutual interdigitations between rock-block partners, and are often transitional even within a single outcrop (Bathurst, 1987; Tada & Siever, 1989; Railsback, 1993; Brouste, *et al.*, 2007). Moreover, some studies have shown that the stylolite networks are initiated as discontinuous, discrete and smooth pressure solution seams (planar type), which progressively change into conical, columnar and wavy types (Koehn, *et al.*, 2007).

The concentration of the dolomite crystals along the studied stylolite surfaces, especially in the studied samples may represent the role of these sedimentary structures as a conduit for the dolomitizing fluids. Stylolites are normally good conduits for fluids, when the IR is not clay-rich sediments (e.g. Moss & Tucker, 1995; Petit and Mattaur, 1995; Clari and Martire, 1996; Smith, 2000). The growth of isolated large (up to 50μ) crystals of dolomite in the matrix of wackestone and mud-dominated packstones and their concentrations along stylolites may increase the strength and the quality of carbonate decorative stones, as observed in other comparable quarries in Iran (Arzani, 2000).

Stylonodular and brecciated textures are more common in the studied pervasively dolomitized rudstones/grainstones (MF1) relative to the slightly dolomitized mud-dominated packstones-wackestones (MF3). This finding may highlights the original rock textures as a major control for fluid flows and diagenesis of the rocks and their major control for later chemical compactions (e.g. Bathurst, 1987; 1995; Arzani, 2006). The dolomitized, cemented grain-rich beds were hard enough for pressure solution, whereas the interbedded carbonate mud-rich lithologies were soft and quite ductile before deformation. It has been suggested that dissolution seams may be more abundant, relative to stylolites, in rocks containing fine-grained dolomite (Railsback, 1993), or because rates of pressure solution are lower in dolomites, the number of these sedimentary structures may be quite different in limestones and dolomites (Peacock and Azzam, 2006) and the rate of pressure solution in limestones is twice that in dolomites (Zhang, *et al.,* 2002; Peacock & Azzam, 2006; Ehrenberg, *et al*., 2006). However, dolomitized limestones are more susceptible to brittle fracturing than non-dolomitic units and the extent of dolomitization measures the porosity of the rock (e.g. Marfil, *et al*., 2005) and as the result it largely controls the quality of decorative stones. Fractures, which their evaluations were far beyond the scope of this study, could be very constructive and positive, if they are filled with cement; otherwise they are destructive and add to the problem of stylolites. Cemented fractures could bind the rock, where they cross cut the stylolite networks.

Conclusion

Examination of the stylolite networks in thick bedded, dolomitized limestones of the upper Cretaceous Haftoman Formation, mined as blocks and processed for decorative polished rock slabs from selected quarries in Khur areas, E. Esfahan Province, support the following conclusions:

The stylolite networks, developed in the studied quarries are bedding-parallel and their overall geometries are distinctive in three differentially dolomitized microfacies (rudstone/grainstone, floatstone/packstone and wackestone/packstone). The term "*stylolite cell*" is defined here, and is the surface in 2D and 3D network (volume) of the rock enclosed between two cross-cut, merged stylolites. The geometry of cells is relatively flat and small in the slightly wackestone-packstone and pervasively dolomitized floatstone-packstones with a chalky texture, whereas the cells are bigger in the rudist rudstones to grainstones. Stylonodular and brecciated textures are more common in the studied pervasively dolomitized rudstones/grainstones relative to the slightly dolomitized mud-dominated packstones-wackestones. The micritic-rich microfacies show much uniform, rather smooth stylolite, relative to the large grainy and bioclastic-rich microfacies.

Stylolite networks in slightly dolomitized, thick-bedded, relatively clay-free (<10% IR), mud-dominated packstones-wackestones provide the best lithofacies for mining and processing decorative stones. This is in contrast to the development of the stylolites in other pervasively dolomitized, grain-rich lithofacies characteristically brecciated with stylonodular to or chalky textures. These are not comparable to clay-rich argillaceous limestones in limestone/marl alternations and their dolomitized interprets, which normally show dissolution seams and are normally not suitable for preparing decorative stones. The results of this study should allow a better prediction of the mining potential and the quality of their rock slabs from different dolomitized limestone lithofacies used as decorative stones. Such insights should in turn allow a better prediction of the durability and sensitivity to weathering of such decorative stones used to decorate walls and floors of buildings. However, the above conclusions are under relatively ideal tectonic conditions with fracture system either cemented or its network wide enough to provide large rock blocks and reasonable polished slabs.

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References

Aghanabati, A., 2004. The Geology of Iran. Geological Survey of Iran, 389 pp.

Alavi, M., 2004. Regional stratigraphy of the Zagros fold-thrust belt of Iran and its proforland evolution: American Journal of Sciences, 304, 1-20.

Andrews, L.M., Raisback, L.B., 1997. Controls on stylolite development: morphologic, lithologic and temporal evidence from bedding-parallel and transverse stylolites from the US Appalachians. Journal of Geology, 105, 59-73.

Arzani, N., 2000. Stylolitization and degree of cementation in carbonate rocks, an evaluation of the carbonate decoration stones in Central Iran. Proc. 4th Geological Society Conference. Tehran, Iran.

Arzani, N., 2006. Primary versus diagenetic bedding in the limestone-marl/shale alternations of the epeiric seas, an example from the Lower Lias (Early Jurassic) of SW Britain. Carbonate & Evaporate Journal, vol. 21, 94-109.

Bathurst, R. G. C., 1987, Diagenetically enhanced bedding in argillaceous platform limestones: stratified cementation and selective compaction: Sedimentology, 34, 749-778.

Bathurst, R.G.C., 1995. Burial diagenesis of limestones under simple overburden. Stylolites, cementation, and feedback: Bull. Soc. géol. Fr., 166, 181-192.

Bäuerle, G., Bornemann, O, Mauthe, F, Michalzik, D., 2000. Origin of stylolites in Upper Permian Zechstein anhydrite (Gorleben Salt Dome, Germany): Journal of Sedimentary Research, 70, 726-737.

Benedicto, A. Schultz, R.A., 2010. Stylolites in limestone: Magnitude of contractional strain accommodated and scaling relationships. Journal of Structural Geology, 32, 1250–1256.

Brouste, A., Renard, F., Gratier, J.P., Schmittbuthl, J., 2007. Variety of stylolites morphologies and statistical characterization of the amount of heterogeneities in the rock. Journal of Structural Geology, 29, 422-434.

Buxton, T.M., Sibley, D.G., 1981. Pressure solution features in shallow buried limestone. Journal of Sedimentary Petrology 51, 19–26.

Carozzi, A.V., Von Bergen D., 1987. Stylolitic porosity in carbonates: a critical factor for deep hydrocarbon production: Journal of Petroleum Geology, 10, 267-282.

Choquette, P.W., James, N.P., 1987. Burial (12): Geoscience Canada, 14, 3-35.

Clari, P.A., Martire, L., 1996. Interplay of cementation, mechanical compaction, and chemical compaction in nodular limestones of the Rosso Ammonitico Veronese (Middle-Upper Jurassic, north-eastern Italy). Journal of Sedimentary Research 66, 447-458.

Demicco, R.V. Lawrence, A.H., 1994. Sedimentary structures and early diagenestic features of shallow marine carbonate deposits. SEPM, Atlas Seris Number 1, 265pp.

Dickson, J.A.D., 1965. A modified staining technique for carbonates in thin section. Nature, 205, 587.

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, 108-121.
Ehrenberg, S. N., Eberli, G. P., Keramati, M., S. A. Moallemi., 2006. Porosity and permeability relationships in interlayered limestone-dolomite reservoir: AAPG Bull., 90, 91-114.
Ebner, M., Koehn, D., Toussaint, R., Renard, F., 2009. The influence of rock heterogeneity on the scaling properties of simulated and natural stylolites. Journal of Structural geology, 31, 72-82.
Embry, AF, Klovan, JE, 1971. A Late Devonian reef tract on Northeastern Banks Island, NWT: Canadian Petroleum Geology Bulletin, 19, 730-781.
Koehn, D., Renard, F., Toussaint, R., Passchier, C.W. 2007. Growth of stylolite teeth patterns depending on normal stress and finite compaction. Earth and Planetary Science Letters, 257, 582–595.
Katsman, R., 2010. Extensional veins induced by self-similar dissolution at stylolites: analytical modeling. Earth and Palnetary Science Letter, 299 (1-2), 33-41.
Lun, Z., Gianxin, L., Kongchou, L., Zifei, F., Heng, S., Xubin, C., 2010. Development and genetic mechanism of complex carbonate reservoir fractures: A case from the Zanarol Oilfield, Kazakhstan. Petroleum Exploration and development, 37 (3), 304-309.
Marfil, R., Caja, M.A., Tsige, M., AlAsam, L.S., Martin-Crespo, T., Salas, R., 2005. Carbonate-cemented stylolites and fractures in the Upper Jurassic limestoness of the Eastern Iberian Range, Spain: A record of palaeofluids composition and thermal history. Sedimentary Geology, 178 (3-4), 237-257.
Merino, E., Calas, A., Fletcher, R.C., 2006. Genesis of self-organized zebra textures in burial dolomite veins, induced stress, and dolomitization. Geological Acta 4, 383-393.
Moss, S., Tucker, M.E., 1995. Diagenesis of Barremian±Aptian platform carbonates (the Urgonian Limestone Formation of SE France): near-surface and shallow-burial diagenesis Sedimentology 42, 853-874.
Petit, J.P., Mattaur, M., 1995. Palaeostress superimposition deduced from mesoscale structures in limestone: Matelles exposure, Languedoc, France. Journal of Structural Geology, 17 (2), 245-256.
Peacock, D.C.P., Azzam, I.N., 2006. Development and scaling relationship of a stylolite population. Journal of Structural Geology, 28, 1883-1889.
Railsback, L.B., 1993. Lithologic controls on morphology of pressure-dissolution surfaces (stylolites and dissolution seams) in Paleozoic rocks from the Mideastern United States: Journal of Sedimentary Petrology, 63, 513-522.
Railsback, L.B., 1998. Evaluation of spacing of stylolites, and its implications for self-organization of pressure dissolution: Journal of Sedimentary Research, 68, 2-7.
Renard, F., Schmittbuhl, J., Gratier, J.-P., Meakin, P., Merino, E., 2004. Three-dimensional roughness of stylolites in limestones. Journal of Geophysical Research 109.
Reyre, D., Mohafez, S., 1972. A first contribution of the NIOC-ERAP agreement to the knowledge of Iranian geology. Edition Technips, Paris, 58pp.
Smith, J.V., 2000. Three-dimensional morphology and connectivity of stylolites hyperactivated during veining Journal of Structural Geology, 22, 59-64
Taberner, C., Vahrenkamp, V., Hollis, C., Esteban, M., 2010. Diagenetic patterns and rock properties of the Naith Formation in Field F, North Oman. 2nd Arabian Plate Workshop, UAE, 23-27th January, 2010.
Tada, R., Siever,R., 1989. Pressure solution during diagenesis. Annual Reviews Earth and Planetary Sciences 17, 89–118.
Wilmsen, M., Fursich, F.T., Majidifard, M.R., 2011. Cretaceous stratigraphy and facies development of the Yazd Block, Khur area, Central Iran. 10th International Symposium on Fossil Algae, Cluj-Napoca, Romania, 12-18 Sep. 2011.
Wright, V.P., 1992. A revised classification of limestones. Sediment. Geol., 76: 177-185.
Zanchi, A., Zanchetta, S., Garzanti, E., Balini, M., Berra, F., Mattei, M., Muttoni, G., 2009. The Cimmerian evolution of the Nakhlak–Anarak area, Central Iran, and its bearing for the reconstruction of the history of the Eurasian margin. Geological Society, London, Special Publications, 312, 261-286.
Zhang, X.D., Salemans, J., Peach, C.J., Spiers, C.J., 2002. Compaction experiments on wet calcite powder at room temperature: evidence for operation of intergranular pressure solution, in: De Meer, S., Drury, M.R., De Bresser, J.H.P., Pennock, G.M. (Eds.), Deformation Mechanisms, Rheology and Tectonics: Current Status and Future Perspectives. Geological Society of London, Special Publication 200, pp. 29-39.