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Detrital dolomite: characterization and characteristics

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Investigating dolomite fragments derived from pre-existing dolomite-containing sediments or rocks, that is detrital dolomites, constitutes a challenge in carbonate sedimentology. Detrital dolomites are generally difficult to recognize and their presence can have profound consequences, even in small quantities, on the interpretation of the tectonosedimentary evolution and palaeoenvironmental conditions of the enclosing basin. In addition, identification and quantification of detrital dolomites may provide insight into provenance and sediment transportation, quality of hydrocarbon reservoirs, and some aspects of the dolomite problem. Typically, detrital dolomites are recognized by their clastic behaviour, such as 1) their wide range of grain sizes and shapes, 2) evidence for transportation and weathering, and 3) their association with other detrital grains. Detrital dolomite can be derived from dolomite-containing sediments (by reworking) or dolomite-containing rocks (by disintegration) and can be transported by various means including wind, water, glaciers and sediment gravity flows. Detrital dolomite can be found in a variety of lithofacies confirming that they are controlled by availability of dolomite detritus and not by depositional environment. The role of detrital dolomite in promoting diagenetic dolomitisation is examined whereby they have provided nucleation sites, for syntaxial overgrowth, or a source of Mg, through dissolution.

Key words: dolomite diagenesis, dolomite problem, dolomitisation models, syntaxial overgrowth, extraclasts.

INTRODUCTION

Sedimentary dolomites are commonly assigned to one of two categories: syngenetic dolomite (primary), formed penecontemporaneously in its environment of deposition, or diagenetic dolomite (secondary), formed by later dolomitisation (replacement of calcite by dolomite) and dolomite cementation (precipitation of dolomite from aqueous solution in pore spaces) (Sabins, 1962). Others use the term “primary” to refer to precipitation of dolomite from aqueous solution in pore spaces because it occupies space in the rock not previously occupied by calcite (Sander, 1951). Others further subdivide the “secondary dolomite” category into diagenetic and epigenetic to differentiate between dolomite replacing limestone at or after the time of lithification and dolomite replacing limestone associated with post-depositional structural elements, respectively (Friedman and Sanders, 1967).

Dolomite derived from pre-existing dolomite represents a third, less common, category (the topic of this paper). This third type of dolomite has different terminologies in the literature (Table 1). In this review, the term “detrital dolomite” is used for two reasons. First, it is the oldest and the most widely used term in the literature (Amsbury, 1962; Sabins, 1962; Lindholm, 1969; Mitchum et al., 1969; Lyday, 1985; Bone et al., 1992; Martire et al., 2014). Second, most of the other terms indicate that all detrital dolomites have been subjected to transportation, which is not a prerequisite (see chapter on transportation).

The concept that some dolomite crystals/grains could be detrital in origin is commonly ignored even though it can have a profound impact on the interpretation of the dolomite. Failure to recognize this kind of dolomite can result in: misjudging the degree of dolomitisation, misinterpreting conditions of dolomitisation (Talbot, 1990), and losing information on the tectonosedimentary evolution of the enclosing basin (Martire et al., 2014).

The study of detrital dolomite has application to both industry and academia. Some detrital dolomites host significant volumes of hydrocarbons (Lyday, 1985). Detrital dolomites can act as a tracer for sediment transport (Ravaioli et al., 2003; Li et al., 2007) or as environmental proxy (Cullen et al., 2000; Kozłowski, 2015). In addition, studying detrital dolomite has provided some clues to one of the long-lasting debate in the field of carbonate petrology, namely the “dolomite problem” (Lindholm, 1969).

Studying detrital dolomite is usually challenging and requires utilizing sophisticated methods. This is because detrital dolomites have a wide range of characteristics and occurrences depending on:

1) the nature of the original source material,
2) transportation mechanisms and distance,
3) type of associated minerals,
4) degree of diagenesis to which it had been subjected.

For instance, in sandy dolomite, a very slight degree of recrystallisation is probably adequate to hide the clastic appearance of dolomite. On the other hand, in the finer-textured dolo-

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Table 1

Detrital dolomite terminology in the literature

Synonyms	Etymology	Geological meaning	References
"Detrital" dolomite	from Latin detritus (the act of rubbing away)	made from fragments of pre-existing rocks	Amsbury (1962); Sabins (1962); Lindholm (1969); Mitchum et al. (1969); Lyday (1985); Bone et al. (1992); Martire et al. (2014)
"Clastic" dolomite	from Greek κλαστόζ (broken in pieces)		Bogacz et al. (1973)
"Terrigenous" dolomite	from Latin terra (earth) and *gignere* (to be born)	derived from the erosion of land-based rocks	Freeman et al. (1983); Lojen et al. (1999)
"Allochthonous" dolomite	from Greek áλλοζ (other) and χθϖν (earth, ground)	originating in a place other than where it is found	Wiggins and Harris (1985); Sarg (2001)
"Allogenic" dolomite	from Greek áλλοζ (other) and γενεá (generation)		Mitchell and Horton (1995)

mite, the changes involved in ordinary lithification would effectively remove all microscopic evidence of their origin (Hatch and Rastall, 1965).

This review will focus on:

- the methods utilized for identifying and quantifying the detrital dolomite,
- the characteristics of detrital dolomite including petrography, provenance, transportation, occurrences and diagenesis.

In addition to critical analysis of literature data, we will provide new data on the detrital dolomite of the Upper Cretaceous Chimney Rock Sandstones in Utah.

CHARACTERIZATION

IDENTIFICATION

Detrital dolomites are usually recognized if the dolomite under investigation shows a sign or signs of clastic behaviour (Fig. 1A). There are many signs that can indicate that dolomite was derived from pre-existing dolomite-containing sediments or rocks.

Detrital dolomites' grain-sizes and shapes vary widely (Poros et al., 2013). Detrital dolomite grain-size ranges from boulders (Arnaud and Eyles, 2002) to very finely crystalline examples. Detrital dolomite grains may occur as isolated crystals, crystal clusters, or both (Bone et al., 1992).

Detrital dolomite grains usually, but not necessarily, show evidence of transportation and weathering (Bone et al., 1992; Martire et al., 2014). Their edges might be sharp (Fig. 2B), abraded (Fig. 2C), irregular (Fig. 2D) or well-rounded (Fig. 1B). Slight weathering can darken the grains, making them appear cloudy in thin-section. Importantly, some detrital dolomite grains may be subjected to breakage along cleavage planes during transport. Under such condition, the detrital dolomites can exhibit clear, sharp-edged rhombs (Fig. 2A). Using standard petrography (polarizing microscope), evidence of dolomite transportation, as shown by the well-rounded and clearly abraded nature of the grains, can be observed. A detrital nature can also be suggested by fabric relationships indicating that contacts between detrital dolomite and adjacent grains are depositional. Pitting, striations and fractures along the planes of detrital crystals suggesting they have experienced transportation can be observed using scanning electron microscope (SEM) and cathodoluminescence (CL) microscope.

Detrital dolomites show some distinguishing features if subjected to diagenesis. Detrital dolomite particles may act as nuclei for different types of coated grains (e.g., ooids and oncoids) and they may be overgrown by syntaxial cement. Overgrowth mineralogy will typically be dolomite (Fig. 1B) or calcite (Hansley and Whitney, 1990). Overgrowth shape does not necessarily follow the inner shape, as would be expected in zonation. While the inner cores may show extremely irregular outlines, outer rims are progressively approaching a rhombic outline. Outer rim zones would have the same CL signature regardless of the CL colour of the core. According to Martire et al. (2014), outer rims can grow further around monocrystalline cores than around fine-grained, polycrystalline lithoclasts.

In case where the original dolomite grains are overgrown by syntaxial cement, the overgrowths may be distinguished from detrital cores by differences in clarity between the core and the rim (cloudy core and clear rim; Bone et al., 1992; Martire et al., 2014). If there is a difference in iron content between the core and rim, overgrowths may be distinguished by differences in staining behaviour in the presence of a potassium ferricyanide stain (iron-rich carbonates appear dark blue and iron-poor carbonates appear light blue; Evamy, 1963). One of the most efficient techniques used to identify differences in various part of dolomite (e.g., core *versus* rim) is cathodoluminescence microscopy. Differences in cathodoluminescence between the core and the rim can reveal the detrital nature of the core. SEM-based CL imaging can clearly show the detrital nuclei of some dolomites that appear entirely authentic when seen using CL attached to polarizing microscope. CL can also demonstrate, in some cases, the multicycle nature of many of dolomite grains (Fig. 2J). Grains exhibiting zones of contrasting luminescence that abruptly terminate at grain margins suggest abrasion of larger zoned crystals (Young and Doig, 1986).

Detrital dolomite grains are usually accompanied by other detrital grains (e.g., detrital quartz). Good correlation between the dolomite grains and associated clastic grains (in terms of grain-size distribution and relative abundances) may suggest that they all were deposited by the same medium (Lindholm, 1969). Grain-size correlations can be investigated by careful point-counting, and amount correlations can be confirmed by x-ray diffraction or quantitative mineral analysis (e.g., *Qemscan*).

Some geochemical indicators can suggest a detrital origin of dolomite. Elemental data indicating an association of

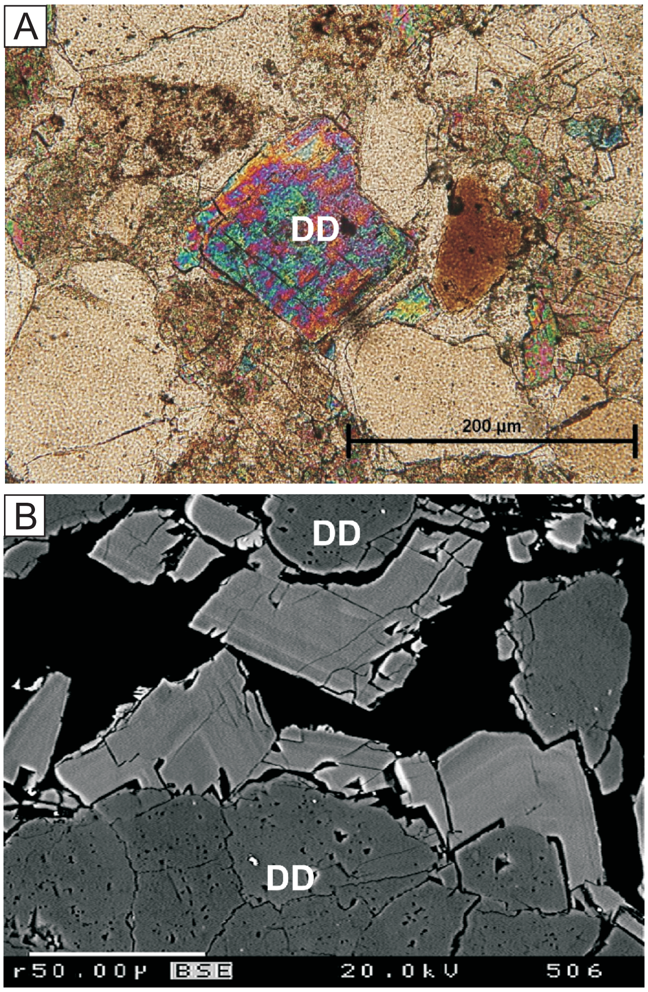

Fig. 1. Detrital dolomite (DD) grains in Upper Cretaceous Chimney Rock Sandstones, Wyoming and Utah, USA

A – photomicrograph of sandstone containing very fine sand-sized, isolated, abraded detrital dolomite (crossed polars); **B** – backscattered electrons image showing dolomite overgrowths on detrital dolomite

$CaCO_3/MgCO_3$ with Al_2O_3, SiO_2 and K_2O points to the presence of feldspar and clays (Martire et al., 2014). An extra-basinal provenance of detrital dolomite grains can be verified also by dissociating the oxygen-isotope values of the dolomite and the bulk-rock (Clayton and Jones, 1968).

QUANTIFICATION

Quantification of detrital dolomite is crucial for estimating the actual degree of dolomitisation in deposits containing co-occurring polygenetic dolomite types (e.g., detrital dolomite and authigenic dolomite). Alkuwairan (2012) utilized quantitative evaluation of minerals by scanning electron microscopy (*Qemscan*®) in identifying and quantifying different dolomite types in Kuwait Bay sediments. *Qemscan*® analysis can acquire modal abundance, mineralogical distribution and mineral association that could assist in characterizing different types of dolomite.

The quantity of detrital dolomite contained within a host rock can have a significant effect on its isotopic signature. Different approaches have been applied to isolate detrital dolomite from other carbonate fractions in order to reduce the influence of isotopic "contamination" among disparate components. Mangili et al. (2010) reviewed these approaches and their limitations, and proposed a new methodological approach combining sedimentological and mineralogical examination to evaluate efficiently the impact of different quantities of detrital grains in carbonate samples.

APPROACH 1: PHYSICAL APPROACH

This approach depends on the physical separation of the detrital dolomites through grain-size separation (Kelts and Hsü, 1978; Teranes et al., 1999). This approach assumes that the host-rock (endogenic) grains are typically smaller or larger than those of detrital dolomite. The challenge to determine a precise grain-size boundary between detrital and endogenic components limits this approach.

APPROACH 2: CHEMICAL APPROACH

This approach depends on the chemical separation of detrital dolomites from other carbonate components based on differences in dissolution rate of dolomite and endogenic grains, with more soluble grains reacting/dissolving before dolomite grains (Degens and Epstein, 1964; Epstein et al., 1964). The method collects CO_2 at different times, with the assumption that grains of different origin are being separated. However, it is clear that CO_2 produced from dolomite can be contaminated by CO_2 produced from calcite, and *vice versa*, and it is impossible to ensure pure fractions of either.

APPROACH 3: STATISTICAL APPROACH

This approach depends on excluding outliers in isotope data, supposing that these data must have been influenced by detrital carbonate (Mangili et al., 2010). This perhaps helps to screen out samples with a significant contamination, but it is improbable that all affected samples will be spotted.

APPROACH 4: COMBINED APPROACH

This approach is based on combining microfacies, XRD and μ-XRF analyses (Mangili et al., 2010). After analysing all samples using the previous techniques, three categories of sample are prepared for isotope analyses:

- pure endogenic grains,
- pure detrital grains,
- "mixed" samples including endogenic grains and detrital grains.

After identifying and quantifying the detrital dolomites in the mixed samples, the threshold value of detrital dolomite above which $\delta^{18}O$ values are considerably shifted towards higher or lower values has to be determined. Finally, the quantitative assessment of the bias in $\delta^{18}O$ and $\delta^{13}C$ values, depending on the quantity of detrital dolomite included in a sample, can be calculated.

Not only does contamination with detrital grains affect isotopic composition, but it also affects the covariance calculations between $\delta^{13}C$ and $\delta^{18}O$, which has been used to deduce palaeohydrological conditions (Talbot, 1990). A good illustration comes from studies of lacustrine carbonates from Piànico palaeolake in Italy. Initially, the samples were found to have a strong covariance between stable carbon- and oxygen-isotope values, interpreted as reflecting a hydrologically closed lake basin (Talbot, 1990; Leng and Marshall, 2004). However, when

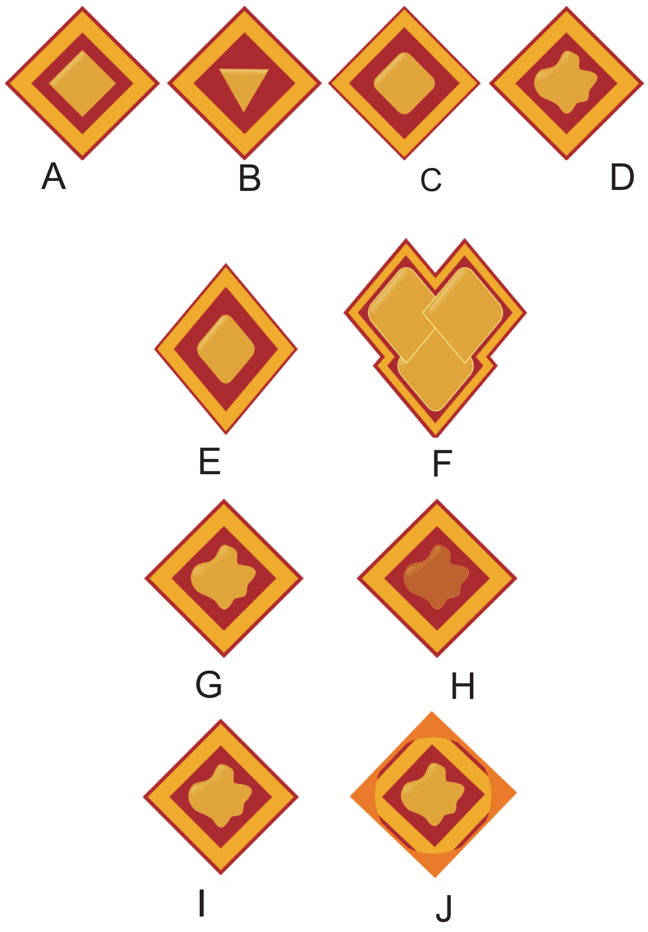

Fig. 2. Schematic drawing of a syntaxially overgrown detrital dolomite's petrographic characteristics under CL (core is detrital dolomite and rim is diagenetic dolomite)

A – perfect rhomb core; **B** – sharp-edged core (not rhomb); **C** – abraded rhomb core; **D** – irregular – rounded core (A–D – rims tend to increasingly approach a rhombic habit, so that they are thicker where the core edge was farther from the rhomb faces); **E** – isolated rhomb/crystal core; **F** – rhombs/crystals cluster core; **G, H** – the core may have different CL signatures (suggesting different parent material) but the rim (overgrowth) is always the same; **I** – grain exhibiting zones of contrasting luminescence; **J** – grain exhibiting zones of contrasting luminescence that abruptly terminate at grain margins suggest abrasion of larger zoned crystals

the samples with a detrital carbonate component were excluded a negative correlation coefficient was acquired, suggesting a hydrologically open lake, which is consistent with the sedimentological data (Moscariello et al., 2000).

CHARACTERISTICS

PROVENANCE

There are two possibilities for the parent material of detrital dolomite: primary (penecontemporaneous) dolomite or secondary (later diagenetic) dolomite.

Reworking of primary dolomite. In a tropical shallow-water carbonate setting, supratidal penecontemporaneous dolomites can be reworked by aeolian transport from tidal flats into intertidal and subtidal carbonate sediments (Shinn, 1983; Wells, 1983).

In temperate carbonate settings, penecontemporaneous dolomites precipitated in mildly reducing marine sediments just below the sediment-water interface can be reworked by high-energy waves (Bone et al., 1992). They can be reworked either to be deposited in deeper water or blown into coastal dunes.

Disintegration of secondary dolomite. In this scenario, the parent rock may be either a dolostone or a dolomitic limestone. The latter rock type could yield detrital dolomite because of the lower solubility of dolomite compared to calcite under conditions of subaerial weathering (Lyday, 1985).

Around the world, there are many localities of dolomite which has been fragmented to a dolomite powder. A well-known example of this phenomenon is located in the Transdanubian Range (TR), Hungary, particularly in the Buda Hills (Poros et al., 2013, among others). Table 2 shows the location of some of these occurrences around the world and their proposed mechanism of disintegration.

TRANSPORTATION

Depending on the means of transportation, the size, amount and distribution of the detritus will vary.

Grain-sizes of detrital dolomite transported by wind are very similar to recent dust deposits (generally uniform silt size) originating from arid regions such as the Great Salt Lake (Jones, 1953) or sabkhas and deserts around the Arabian Gulf (Al-Bakri et al., 1984). Streams draining dolomitic terrains that have sub-humid to arid climates can be expected to transport dolomite gravel, sand and silt (Amsbury, 1962). Metre-sized dolomite clasts were reported to be transported by gravity-flow processes (e.g., the Great Breccia, Port Askaig Formation, Scotland; Arnaud and Eyles, 2002).

The amount of the detritus can vary from very minute amounts (e.g., ≈1% in sand dunes of Western Desert of Iraq; Awadh, 2012) to several hundred metres thick (e.g., Atokan Deep Anadarko Basin, Oklahoma; Lyday, 1985)

Early studies have interpreted the provenance of detrital dolomite based on the proximity of potential source rocks (Lindholm, 1969), but in fact the distribution of the detritus varies and does not have to be abundant near the source terrain. Wind transport, for instance, allows the detritus to by-pass the shallow-water environment (Davies, 1997; Davies et al., 1997).

Detrital dolomite can be subjected to one or many cycles of transportation (Young and Doig, 1986; Arnaud and Eyles, 2002). Some cavities filled with detrital dolomite indicate that they were derived from sources in the immediate environment of their present accumulation (e.g., broken down from cave walls), i.e. no transportation (Bogacz et al., 1973; Fu et al., 2006). On the other hand, detrital dolomite can be washed into some caves by vadose waters that ran through and over dolomite bedrock (Jones, 1991).

OCCURRENCES

Detrital dolomites have been described in diverse settings (Table 3) indicating that their distribution is not function of a certain depositional environment but rather of whether loose dolomite grains are available in the source area or not.

Carbonates. Detrital dolomite has been recognized, in small amounts, in recent sediments from Florida Bay (Deffeyes and Martin, 1962) and the eastern Mediterranean (Milliman and

Table 2

Mechanisms of dolostone disintegration

Location	Proposed mechanism of disintegration	Reference
Picentini Mountains of Italy; Sicilian fold-and-thrust belt	mechanical disintegration related to tectonic movements	Pappone and Ferranti (1995); Dewever (2008)
South China	chemical weathering during regional karstification	Ji et al. (2004)
Devonian Winnipegosis Formation (Saskatchewan, Canada) – giant unconventional oil reservoir	by-product of regional karstification	Machel et al. (2012)
Buda Hills, Hungary	recent weathering-induced powderization	(Schafarzik, 1902 and Timkó, 1909) – cited in Poros et al. (2013)
	pre-Cenozoic unconformity-related powderization	(Földvári, 1933) – cited in Poros et al. (2013)
	hydrothermal powderization	(Brugger, 1940; Jakucs, 1950 and Nagy,1979) – cited in Poros et al. (2013)
	cryogenic powderization; repeated freeze –thaw cycles during and/or after the Pleistocene glaciations	Poros et al. (2013)

Table 3

Detrital dolomite occurrences in different depositional environments

Locations	Depositional environment
Llano uplift of central Texas (Amsbury, 1962)	fluvial system
Atokan Deep Anadarko Basin, Oklahoma (Lyday, 1985)	deltaic system
Taklimakan Desert, Kumtag Desert, Qaidam Desert, Sanjiangyuan, Hexi Corridor, Badain Jaran Desert of China (Li et al., 2007); Western Desert of Iraq (Awadh, 2012); White Sands National Monument in New Mexico, USA (Fenton et al., 2017)	aeolian system
Polarisbreen Group, northeastern Spitsbergen, Svalbard (Fairchild and Hambrey, 1984; Fairchild et al., 1989); ice rafted detritus in the subpolar North Atlantic during glacial periods, Heinrich layers (Bond et al.,1992; Andrews, 1998); Great Breccia, Port Askaig Formation, Scotland (Arnaud and Eyles, 2002)	glacial system
Deep Springs Lake, California (Clayton and Jones, 1968); Paleocene-Eocene Lake Flagstaff, central Utah (Wells, 1983); varved sediments of the interglacial Piànico palaeolake, Southern Alps, Italy (Mangili et al., 2010)	lacustrine system

Müller, 1973). On the other hand, detrital dolomite deposits, also known as dololithites, may form a very thick sedimentary sequences (e.g., Pennsylvanian Atoka Dolomite; Lyday, 1985). However, this kind of dololithite is very rare, due to the soft and soluble nature of carbonate minerals.

Siliciclastics. Sandstones, in marine to non-marine settings, can have detrital-dolomite grains (Al-Ramadan et al., 2013) but generally only minor amounts. The difference in abundance of detrital dolomite within sandstone units has been attributed to several factors (Amsbury, 1962; Pettijohn et al., 1972; Folk, 1980):

1 – the existence of an arid or sub-humid climate in which weathering by carbon dioxide – charged water is kept to a minimum;

2 – rapid erosion due to high-relief source terrain (Folk, 1980 cited examples of carbonate-rich deposits accumulating in areas of vigorous uplift, even under humid climatic conditions);

3 – lack of significant transportation of the detrital grains (i.e., proximity to source area) or

4 – rapid burial with little reworking.

Therefore, the paucity of detrital dolomite is probably related to textural and mineralogical maturity of the sandstones. The prolonged reworking required for production of such mature deposits would undoubtedly have destroyed any detrital dolomite before the sediment was buried. The study of Al-Ramadan et al. (2013) of the Upper Cretaceous Chimney Rock Sandstones in Utah has revealed that the amount of detrital dolomite increases upward towards the transgressive surface.

DIAGENESIS

The diagenesis of detrital dolomite, through formation of dolomite overgrowths or dolomite dissolution, can act as a facilitator for the dolomitisation process and modify the ultimate character of a dolomite deposit.

Detrital dolomite as nuclei. For dolomite to form, it is much easier to grow on previously formed nuclei than to nucleate directly because of the kinetic barrier (Lindholm, 1969; Freeman et al., 1983). Therefore, the presence of detrital dolomite grains can assist in reducing the induction period of dolomitisation by supplying the system with nucleation points. If supratidal dolomite crystals, for instance, were transported to intertidal and subtidal settings, later dolomitisation could continue under easier conditions than those needed to nucleate dolomite in the first place.

Detrital dolomite diagenesis was proposed by Lindholm (1969) to be one of the mechanisms that can explain “pervasive dolomitisation”. He introduced two conceptual models (Fig. 3) based on studies of the Onondaga Limestone of New York. He suggested that the transportation of detrital dolomite and associated detritus (e.g., quartz) to their final depositional site will result in a decrease in their amount and size away from the source. However, this is not always the case, because later diagenesis can cause adverse distribution. If, after deposition, the detrital dolomite was subjected to diagenetic overgrowth formation until the host rock was completely replaced by dolomite, the size of dolomite would increase away from the source. Since grain-size is controlled by mutual interference of the growing dolomite crystals as the rock reaches complete replacement, the wider the spacing between the detrital dolomite nuclei, the larger the size of the final diagenetic dolomite crystals.

Dolomitisation can be very selective and it may occur only around detrital dolomite grains. It is worth mentioning that in the absence of such detrital dolomite grains, no dolomitisation would occur and the flow of potentially dolomitising fluids would leave no evidence (Lindholm, 1969). This claim is supported by the preferential growth of dolomite crystals around the dolomite detrital grains and their absence where there are no dolomite detrital grains. Crystals lacking obvious cores would appear to be entirely authigenic in origin. However, their growth might have been triggered by detrital dolomite, but the nuclei, if existing, could be too minute to resolve. Generally reworked primary dolomite results in a very narrow size range (Deffeyes et al., 1965; Illing et al., 1965). A wider range of grain-sizes would be expected in the case of disintegrated secondary dolomite which had not been transported far (Lindholm, 1969).

Detrital dolomite as Mg-source for later dolomitisation and precipitation of dolomite cement. The dissolution of detrital dolomite may enrich the diagenetic fluid with magnesium which later could be precipitated as dolomite cement. This dissolution has been reported to be brought about by the action of migrating meteoric fluids containing organic acids generated from coal measures, as suggested by Taylor and Gawthorpe (2003) (Fig. 4). The dolomite cement reported in the previous case significantly decreases potential reservoir quality of the sandstones (Al-Ramadan et al., 2013).

Al-Ramadan et al. (2005) have demonstrated the importance and impact of detrital compositions on the diagenetic and related reservoir-quality evolution pathways of siliciclastic sequences. Detrital dolomites can contribute to porosity and permeability deterioration by favouring the growth of carbonate cements and by being a source of pore-filling carbonate cement (Morad et al., 2010).

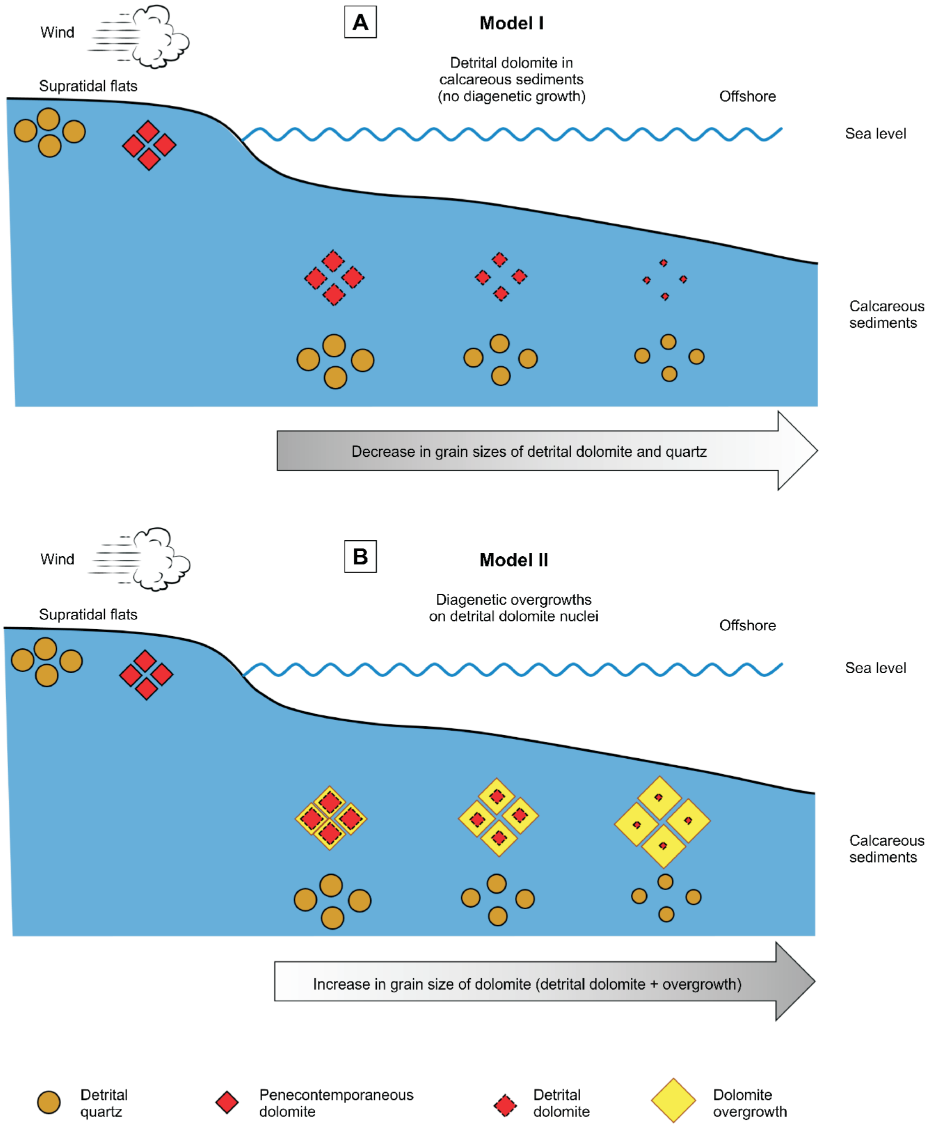

Fig. 3. Lindholm's model for dolomitization of carbonate sediments (modified after Lindholm, 1969)

Grain size and abundance of detrital quartz and dolomite in carbonate sediments:
A – after deposition, **B** – after diagenetic overgrowth on detrital nuclei

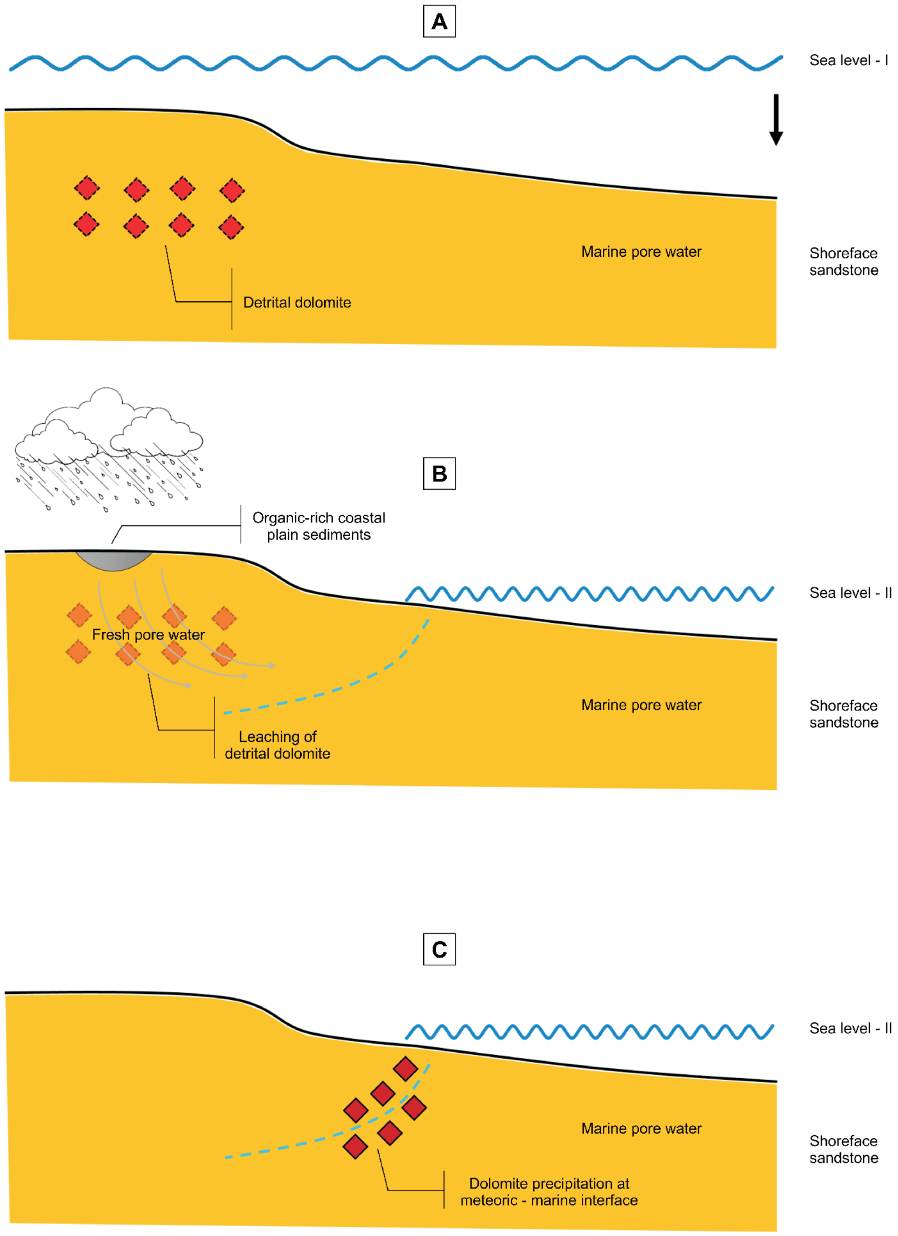

Fig. 4. Taylor and Gawthrope model for dolomite cementation of shoreface sandstones (modified after Taylor and Gawthorpe, 2003)

A – during sea level rise, shoreface sandstone (including the detrital dolomite) progrades basinward; **B** – during sea level fall, organic-rich coastal plain can develop and meteoric water migrate basinward; solution passing through these plain will become enriched in organic-acid and capable of dissolving detrital dolomite within the underlying sandstone, then become enriched in magnesium; **C** – dolomite cementation at the meteoric-marine interface

CONCLUDING REMARKS

From a survey of literature, it is concluded that:

Detrital dolomite grains have a wide range of characteristics including: variations in grain-size (boulders to very fine grains), grain shapes (planar to irregular edges), textures (isolated to clustered and cloudy to clear), means of transportation (wind, water or ice), and lithofacies occurrences. Thus, they can be difficult to identify and a variety of methods may be required to ensure definitive identification of their presence.

Detrital-dolomite grains generally exhibit relict features (i.e. structures, crystal size, CL signature) inherited from the original dolomite strata or protolith.

The supposition that detrital dolomites are necessarily of extra-basinal origin has been challenged by the occurrence of *in situ* dolomite powder and caves filled with clastic dolomite.

Diagenetically overgrown detrital dolomite is proposed as a possible mechanism of “dolomitisation” or at least as an initiator for later dolomite growth.

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