Dolostone origin in the Riópar area (SE Spain): implications on the geology of the Prebetic Zone

Origen de las dolomías en la zona de Riópar (SE España): implicaciones sobre la geología de la Zona Prebética

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Abstract: In the present study a petrographic description and C-O stable isotope data of dolostone occurrences at the Riópar area (Mesozoic Prebetic Zone) are presented. Results constrain the origin and dolomitization processes for each dolomitic unit providing new insights on the geology of the Prebetic. Dolostones are grouped in: i) large seismic-scale stratabound dolostones hosted in limestones of Lower Jurassic, Middle Jurassic and Upper Cretaceous ages; and ii) stratabound and patchy dolostones hosted in a carbonatic sequence of Upper Jurassic to Lower Cretaceous age. Two dolomitizing origins have been distinguished: i) a low-temperature dolomitization originated from seawater (seismic-scale stratabound dolomitized limestones); ii) a hydrothermal dolomitization originated by high temperature brines (stratabound and patchy dolomitized limestones). Results of this study can be used as a guide for other poorly known dolomitic areas in the Prebetic Zone.

Key words: dolostone, stable isotope, Prebetic, Riópar.

Resumen: *En este estudio se presenta la descripción petrográfica y los datos isotópicos de C y O de distintos cuerpos de dolomías en la zona de Riópar (Zona Mesozoica del Prebético). Los resultados obtenidos permiten acotar el origen de cada miembro dolomítico, aportando nuevos datos geológicos en el Prebético. Dichos cuerpos se agrupan en: i) dolomías estratiformes de gran extensión hospedadas en calizas del Jurásico Inferior y Medio, así como del Cretácico Superior; ii) dolomías de tipo estratiforme y en forma de parches hospedadas en una secuencia carbonatada del Jurásico Superior al Cretácico inferior. El origen de estas dolomitizaciones se atribuye a: i) interacción con agua marina presumiblemente a baja temperatura (dolomías estratiformes de gran extensión); ii) presencia de salmueras hidrotermales de alta temperatura (dolomías estratiformes y parcheadas). Estos resultados pueden servir de guía para otras áreas dolomitizadas poco estudiadas en la zona del Prebético.*

Palabras clave: *dolomía, isótopos estables, Prebético, Riópar***.**

INTRODUCCIÓN

Dolostone formation has been linked with different geological processes and settings and after more than two hundred years of intensive research their origin is still controversial (Machel, 2004), although most authors agree that dolomite is rarely precipitated as a primary phase. Various dolomitization models have been proposed by a large number of workers (e.g. Warren, 2000). In essence, the resulting dolostones can be classified as low temperature, referring to those formed from cold Mg-seawater, or burial dolomites, those formed at slightly to much higher temperatures by other Mg-bearing fluids. Quite commonly it is difficult to unravel their precise origin.

The Prebetic zones (SE Spain) are home to extensive outcrops of dolostones, some of which constitute important Natural Parks with particular landscapes (e.g. Calares del Mundo, Albacete). Several dolostone bodies are hosted in Lower Jurassic to Upper Cretaceous carbonates. Navarro-Ciurana et al. (2016) discussed the origin of the dolomites hosted in Upper Jurassic to Lower Cretaceous carbonates in the Riópar area. However, in their study, these authors did not include the Prebetic dolostones hosted in Lower and Middle Jurassic as well as in Upper Cretaceous carbonates. On the other hand, the geologic maps of the area assign specific ages to these dolostones, assuming that they occurred more o less cogenetically with the host carbonates. These assumptions may lead to geological errors as dolomites can result from secondary geological processes, replacing calcitic host rocks well after the host carbonate formed.

In this contribution, the description of the different Riópar dolostone occurrences together with C and O isotope data are presented. Results constrain the origin of dolomitization processes for each dolomitic unit providing new geologic information on the geologic history of the Prebetic.

GEOLOGICAL SETTING

The studied area is located near the Riópar village, where siliciclastic rocks, limestones and dolostones occur. This area is situated at the limit between the External and Internal Prebetic Zones, in the outer portion of the NNW-verging fold-and-thrust belt of the Betic Cordillera (e.g. García-Hernández et al., 1980). The Prebetic is dominated by a Mesozoic to Cenozoic sedimentary sequence up to 2000 m thick, originally deposited in the southern part of the Iberian continental paleomargin (Vera et al., 2004). The External Prebetic Zone shows extensively exposed Triassic and Jurassic rocks and scarcity of Cretaceous and Paleogene sediments. In contrast, the Internal Prebetic Zone is characterized by absence of Triassic rocks, scarcity of Jurassic strata and extensively exposed Cretaceous and Paleogene sediments (Vera et al., 2004).

From a tectonic standpoint, the Prebetic Zones are characterized by the Cazorla-Alcaraz-Hellín structural arc (Rodríguez-Estrella et al., 1979). In general, it is constituted by two major fault systems: i) NE-SW to E-W trending and SE- to S-dipping Alto Gualdalquivir-San Jorge fault; and ii) NW-SE to W-E trending Socovos-Calasparra dextral strike-slip fault perpendicular to the fold axes. These is thought to separate the Internal Prebetic (to the S) from the External Prebetic (to the N) zones (Fig. 1).

In the Riópar area a large number of Mesozoic sedimentary units can be observed (Fig. 2). Triassic sandstones with clays and gypsum and Lower to Middle Jurassic carbonates crop out in the N block of the Socovos fault, whereas carbonates of Upper Cretaceous age appear in the S block of the San Jorge fault. Upper Jurassic to Lower Cretaceous age carbonates crop out between the two faults.

OCURRENCE OF DOLOSTONE GEOBODIES

Several dolomitized carbonates are identified in the Riópar area. Their distribution along the stratigraphic section are illustrated in Figure 2.

Lower Jurassic stratabound dolomites

The Lower Jurassic stratabound dolomitized Carretas and partly Contreras-Madroño limestone Fms. (Fig. 2) are characterized by red to grey colors. The thickness of these formations exceeds 150 m in the Riópar area. They are constituted by microcrystalline subhedral to euhedral (planar-s to planar-e) replacive dolomite crystals, showing a massive aspect in hand samples. At the top of the sequence, non-dolomitized fossiliferous intra-pelsparitic and intra-oosparitic grainstones to packstones, and intra-pelmicritic wackstones to mudstones occur. The dolomitization is mainly fabric-retentive, as oolitic allochems and porosity of precursor limestones are recognized, preserving the original depositional fabrics (i.e., stratification).

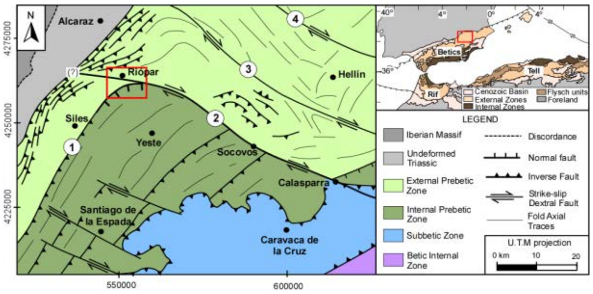

FIGURE 1. *Schematic geologic map (modified from: Pérez-Valera et al., 2010) of the Prebetic Zones and Riópar area: (1) Alto Guadalquivir-San Jorge fault; (2) Socovos fault; (3) Liétor fault; and (4) Pozohondo fault.*

Middle Jurassic stratabound dolomites

The Middle Jurassic stratabound dolomitized limestones, which replace the Chorro carbonate Fm. (Fig. 2), are characterized by white colors in more than 250 m thick sediments in the studied area. They are constituted by fine to coarse planar-e sucrosic dolomite crystals, which replace fossiliferous intra-oosparitic grainstones to packstones and to a lesser extend, mudstones. The replacement is fabric-retentive as oolitic ghosts can be identified, although original sedimentary structures, such as stratification, are rarely preserved.

Upper Jurassic to Lower Cretaceous stratabound and patchy dolomitized carbonates

Stratabound dolostones connected by patchy dolostone bodies are hosted in the Upper Jurassic to the Lower Cretaceous carbonate succession (Fig. 2). In the Riópar area, they outcrop over an area of 4.6 km^2 between San Jorge and Socovos faults.

Two stratabound dolostones are identified replacing intra-oosparitic grainstones to packstones and mudstones of the Lower and Upper Members of Sierra del Pozo Fm. respectively, preserving the original depositional fabrics. They are constituted by microcrystalline planar-s to planar-e replacive dolomite crystals. The Lower Mb. is partially dolomitized as it preserves oolitic limestone lenses; the dolostones contain abundant oolitic ghosts. However, the Upper Mb. has always been observed completely dolomitized, only showing abundant orbitolinid moldic porosity.

Different patchy dolostones have been mapped affecting the Lower Mb. of Sierra del Pozo to the Arroyo de los Anchos Fm. They are constituted by planar-e sucrosic dolomite crystals and fine to coarse non-planar saddle dolomites. The patchy dolomitization fronts are irregular and gradual with the stratabound dolostone units, obliterating the sedimentary fabrics. Nevertheless, the contact with the undolomitized carbonates is sharp, cross-cutting bedding and stratification. Moreover, patchy dolostone outcrops nearer the San Jorge than Socovos strike-slip dextral fault, suggesting a structural control for these dolomitization (Navarro-Ciurana et al. 2016).

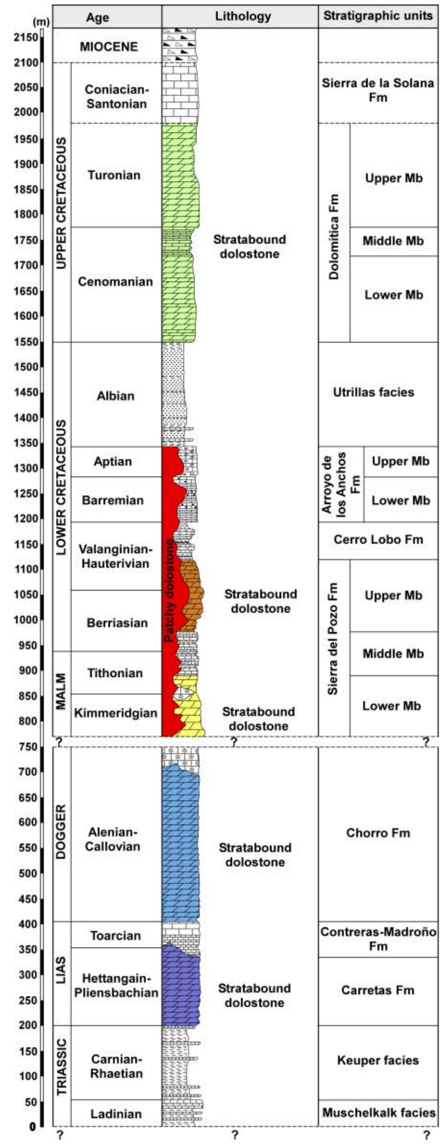

FIGURE 2. *Stratigraphic section of the Riópar area with sedimentary units and location of the studied dolostone geobodies.*

Upper Cretaceous stratabound dolomites

The Upper Cretaceous stratabound dolomitized Cenomanian to Turonian limestones (Fig. 2) are formed by fine planar-s to planar-e dolomite crystals. They are characterized by three different zones: i) the lower part, which is constituted by ochre dolostones with orbitolinid ghosts; ii) the middle zone, formed by white dolostones with oolitic ghosts and interbedded thin dolomitic marls; and iii) the uppermost part, which is constituted by grey dolostones. The thickness of these formations exceeds 250 m in the Riópar area.

C AND O ISOTOPE DATA

Samples of host limestones and dolomite crystals were analyzed for their carbon and oxygen isotope composition (Fig. 3). The isotopic signature of non-dolomitized limestones of Jurassic to Cretaceous age ranges from +0.5 to +3.2‰ for $\delta^{13}C_{V\text{-}PDB}$ and from +27.6 to +30.9‰ for $\delta^{18}O_{V\text{-}SMOW}$. These values are compatible with carbonates precipitated from seawater of Jurassic to Cretaceous age (Veizer et al., 1999).

Stratabound dolostones hosted in Lower and Middle Jurassic limestones have $\delta^{13}C_{V\text{-}PDB}$ values from +3.2 to +3.8‰ and $\delta^{18}O_{V\text{-}SMOW}$ from +29.0 to +29.8‰. Stratabound and patchy dolostones hosted in Upper Jurassic and Lower Cretaceous limestones show similar C and O isotope values ($\delta^{13}C_{V\text{-}PDB}$: -2.3 to +0.8‰; $\delta^{18}O_{V\text{-}SMOW}$: +25.1 to +27.6‰), although stratabound dolostone shows more restricted C isotope values ($\delta^{13}C_{V\text{-}PDB}$: +0.0 to +0.6‰) than patchy dolostones. On the other hand, the isotopic signature of dolomitized Upper Cretaceous limestones ranges from +2.5 to +2.7‰ for $\delta^{13}C_{V\text{-}PDB}$ and from +26.9 to +29.5‰ for $\delta^{18}O_{V\text{-}SMOW}$.

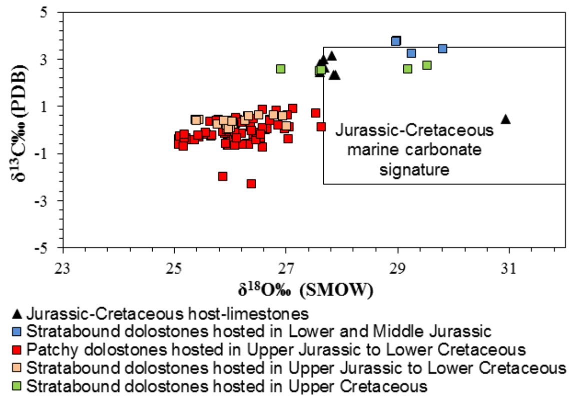

FIGURE 3. *$\delta^{18}O$ vs. $\delta^{13}C$ cross-plot of host-limestone and dolostones from the Riópar area (Prebetic) with a Jurassic-Cretaceous marine carbonate box according to Veizer et al. (1999).*

ORIGIN OF DOLOSTONE GEOBODIES

Sparse remains of fauna (e.g., orbitolinids) and oolitic and peloidal ghosts in thin sections suggest that the Riópar dolostones replace an original marine limestone. Textures and isotopic data support a seawater dolomitization model for the large stratabound dolomite bodies hosted in the Lower and Middle Jurassic and Upper Cretaceous limestones. However, for the stratabound dolostones connected by patchy geobodies and hosted in the Upper Jurassic to Lower Cretaceous carbonate succession, a fault-controlled hydrothermal dolomitization model is favored (Navarro-Ciurana et al., 2016).

The C and O isotopic values of the Lower and Middle Jurassic and Upper Cretaceous dolostones are similar to data of Jurassic to Cretaceous host-limestones. Moreover the carbon and oxygen data of dolostones are within the range of Jurassic to Cretaceous marine carbonates (Veizer et al., 1999), supporting a seawater dolomitization model, which commonly involve lower temperatures of precipitation (Warren, 2000). These three separated stratabound dolostone geobodies probably formed just after the diagenesis of host-limestones, as grain component dissolution (e.g., orbitolinids and ooids) occurred previous to dolomitization.

The C and O isotopic distribution of Upper Jurassic to Lower Cretaceous stratabound and patchy dolomitized limestones depicts a horizontal trend with a small $\delta^{13}C$ (≈2‰) and $\delta^{18}O$ (≈3.5‰) shift. Compared to the host-limestone, these dolostones show relatively depleted $\delta^{13}C$ and $\delta^{18}O$ values. This distribution can be modeled from an interaction of regional carbonates ($\delta^{13}C_{V\text{-}PDB}$: +2.3‰; $\delta^{18}O_{V\text{-}SMOW}$: +28.3‰) with a hydrothermal fluid ($\delta^{13}C_{V\text{-}PDB}$: -8‰; $\delta^{18}O_{V\text{-}SMOW}$: +17‰). Microthermometrical data (Navarro-Ciurana et al., 2016) from stratabound and patchy dolostones (T_h: 150-250ºC; salinity: 5-25 wt.% eq. NaCl) supports the presence of hot dolomitizing brines. Tectonic and stratigraphical considerations suggest that hydrothermal fluids probably circulated upwards through the San Jorge fault.

REGIONAL SCALE IMPLICATIONS

Field and petrographic observations only, do not allow in differentiating the dolostone units or to determine the dolomite types in the Riópar area. Instead, stable isotopic data turned out to be useful to differentiate the dolomitic units (Fig. 3). The area comprised between the Socovos and San Jorge faults in the Riópar zone, had previously been considered and mapped as Middle Jurassic dolostones (Fernández-Gianotti et al., 2001). Nevertheless, we observed clear evidences that this zone is constituted by dolostones that replace a Middle Jurassic to Lower Cretaceous carbonate sequence (e.g., orbitolinid moldic porosity) by fault-controlled hydrothermal processes. The textures of these dolostones (i.e., sucrosic aspect, presence of oolitic ghosts) are very similar to those of dolostones hosted in Middle Jurassic carbonates, leading to confusions between them. Commonly, the dolostones that outcrop in the footwall block of the Alto Guadalquivir-San Jorge fault in the External Prebetics are interpreted as Middle Jurassic in age. From the data presented here, a revision of these dolostones is suggested, as at least some of them could be of hydrothermal origin.

CONCLUSIONS

The petrographic characterization of the different dolostone occurrences at Riópar together with C and O isotope data constrains the origin of the different dolomitic units: i) seawater dolostones originated presumably at low temperatures (Lower and Middle Jurassic and Upper Cretaceous stratabound dolomitized limestones); and ii) hydrothermal dolostones originated by hot dolomitizing brines (Upper Jurassic to Lower Cretaceous stratabound combined with patchy dolomitized carbonates). Further studies of dolostones at the footwall block of the Alto Guadalquivir-San Jorge fault, assumed to be of Middle Jurassic age should be carried out. The combination of petrographical and isotope studies may be a useful tool to reassess their origin.

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