Late porosity development in Jurassic Dolomites (Garraf Mountains, Catalan Coastal Range, NE Spain): a permeability barrier origin

Porosidad tardía en Dolomías Jurásicas (Montañas del Garraf, Cordillera Costera Catalana, NE España): Modelo de barrera de permeabilidad

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ABSTRACT

La Formación Dolomías Superiores del Garraf (Salas et al.*, 1991) aflora en el sector Este de las Montañas del Garraf. Está formada por dos unidades deposicionales separadas por una discontinuidad local. La unidad inferior está constituida por dolesparitas masivas, de coloraciones oscuras y negras, olor fétido y con fantasmas de ooides y moldes de componentes esqueléticos. La unidad superior está formada por dolmicritas y dolmicroesparitas laminadas de coloraciones más claras grises.*
Abundante porosidad vug (hasta 25 cm de diámetro) se observa en un nivel de 75 m de grosor. La porosidad se concentra a lo largo de planos de fractura (y superficies de estratificación). Este nivel con máximo desarrollo de porosidad se localiza en la unidad inferior, cerca de la superficie de discontinuidad local. Porosidad intercristalina microcorrosiva también se ha observado alrededor de la macroporosidad vug y/o se las paredes de fractura; esta microporosidad se halla distribuida irregularmente a lo largo de toda la secuencia dolomítica. No existen evidencias de porosidad diagenética temprana generada durante la exposición subaérea relacionada con la discontinuidad local que separa ambas unidades. Los vugs y fracturas están cementados por una primera generación de cemento de dolomita en disposición rim y otros estadios multifásicos posteriores de cemento de calcita.
En las dolomías jurásicas de las Montañas del Garraf, la formación de la porosidad vug se ha relacionado con la ascensión de fluidos corrosivos a través de las fracturas que fueron selectivamente atrapados debajo de barreras de permeabilidad. Estas barreras son la consecuencia de los cambios de la medida cristalina de las diferentes unidades deposicionales.

Palabras clave: *Dolomías; Porosidad Vug; Geofluidos; Cordillera Costera Catalana; Jurásico superior.*

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Geological setting

The studied area is located along the Catalan Costal Range, an alpine zone on the NW flank of the Gulf of Valencia; it is located in the southeastern part of the Garraf region (Fig. 1), which corresponds to a SW tilted block.

The Jurassic sediments are up to 2.5 km thick and include eleven depositional sequences. The Upper Jurassic sediments (Malm) are characterized by Ammonitic limestones, massive dolomites, tidalites, sponge mounds, shoals, laminated black limestones and shales, arranged in the Les Agulles Dolomites and Upper Garraf Dolomites (Fig. 1). The Upper Garraf Dolomites has a transitional contact towards the La Pleta Limestones Fm (Salas *et al*., 1991).

The study of porosity has been focalized in the Upper Garraf Dolomites Fm within La Pleta section (Fig. 1).

The Dolomites

The lowest part of the Upper Garraf Dolomites Fm (150 m in thickness) is constituted by black dolomite, fetid-smell (H_2S?) when smashed. Dolomite crystals are 50 mm to 1 mm in size (average values rounding 100-200 mm) and, xenothopic to equant idiothopic. Former sedimentary structures (ripple and large-scale cross-bedding) are often preserved after dolomitization. This dolomite unit is broadly characterized by vuggy porosity which is especially abundant in the 50 m to 120 m of the succession. These vugs average 1-10 cm in size and they are irregular to lensoidal in shape. This porosity type occurs isolated and also controlled by fracturing and bedding planes.

The upper part of the Upper Garraf Dolomites Fm (150 m in thickness) is composed of grey dolomite alternating with decimeter-thick dolsparite levels. These dolsparitic levels are black in colour and with a fetid-smell. This formation becomes weakly dolomitized to the top, showing most of its former sedimentary features. Dolomite textures are dominantly equant-xenothopic. The crystal size ranges between 25-150 mm; occasionally up to 400 mm. The original limestone fabric was mainly muddy-supported and laminated with some intercalations of bioclastic wackestone-

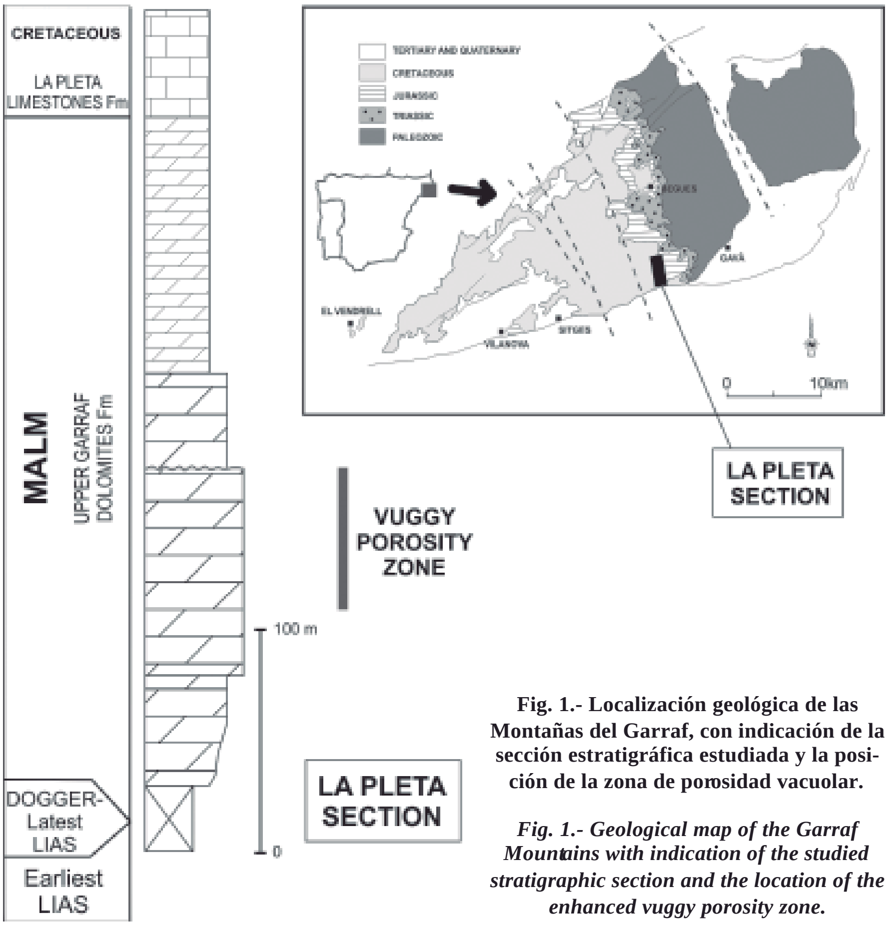

Fig. 1.- Localización geológica de las Montañas del Garraf, con indicación de la sección estratigráfica estudiada y la posición de la zona de porosidad vacuolar.

Fig. 1.- Geological map of the Garraf Mountains with indication of the studied stratigraphic section and the location of the enhanced vuggy porosity zone.

grainstones, interpreted as intertidal deposits. Most of the sedimentary fabric, such as plane lamination and bedding, are preserved. Oolithe ghosts occur in the dolsparite levels. This dolomite unit has low porosity, although it is strongly affected by a Plio-Quaternary karstic episode. The top of this unit is expressed in a transition to upper Portlandian intertidal limestones of the La Pleta Limestones Fm.

In general, most of the dolomite crystals show an outer overgrowth zoning. Under CL-microscope, dolomite of both units units appears to be homogeneously orange-dull luminescent.

Porosity

Vug, fracture, moldic and intercrystalline porosity are present in the studied Jurassic dolostones (Fig. 2 and 3).

Vug porosity is the most remarkable porosity type (Fig. 2A). It is especially concentrated in a 75 m thick band in the uppermost part of the lower part (the black and fetid dolomites; Fig. 1). Pore density is higher than >50 vug/m^2 and the vug size vary from some mm to 25 cm. Two vuggy porosity types have been distinguished:

a) Isolated vug porosity (1-10 cm in size and with assorted pore shapes, lensoidal, rounded, elongated and irregular).
b) Enlarged fracture vug porosity (occurs related to fractures and is irregular in shape, 2-25 cm in size).

Fracture porosity (Fig. 2B) refers to those created by the opening of a fracture, which has not been enlarged by dissolution. A special type of fracture porosity is breccia porosity (porosity in breccia deposits observed along fracture planes, with angular clasts sized 0.1-4 cm, and composing cement-supported or clast-supported textures according to the degree of cementation).

Moldic porosity occurs occasionally and shows flatted to rectangular and rounded shapes, 0.5 to 3 cm in size.

Intercrystalline porosity occurs either as crystal growth (Fig. 2C) or as microcorrosion between the crystals (Fig. 2D). The pore size ranges 10-50 mm. The microcorrosion intercrystalline porosity is observed affecting the whole section, increasing towards the top of the Upper Garraf Dolomites Fm. This partly dissolution is non-fabric selective, locally concentrated in fractures and/or surrounding the vugs (Fig. 2D). The corroded area shows sucrosic texture and brownish colour.

All these porosity types can be empty, partly or fully occluded by cements. There are two main cement generations (dolomite and sparry-poikilotopic calcite). The dolomite crystals are white, euhedral, 30-500 mm in size, orange luminescent and show an isopachous-rim disposition. The sparry-poikilotopic calcite cement is the most important volumetrically, and it occurs partially or completely filling the porosity. Crystals are limpid, mainly anhedral and locally poikilotopic composing blocky textures, and size ranges 100 mm-2 mm.

Which is the origin of the enhanced vuggy porosity?

Dolostone dissolution and cavity formation in deep dolostones is a commonly observed feature, which has been differently interpreted. The formation of vugg porosity in carbonate rocks has been traditionally attributed to a meteoric karstic origin. However, in the recent literature other origins are pointed out such as mixing of a dilute groundwater with an acidic brine (Corbella *et al.*, 2006) or mixing of formation water with a tectonically and topographically driven fluids (Nadal, 2001; Vandeginste *et al.*, 2006).

In the Upper Garraf Dolomites, the zone of enhanced vuggy porosity is clearly associated to enhanced corrosion along fractures in the lower unit (coarse, black, foul-smelling dolomites), while it is very scarce in the upper grey dolomicrites-dolomites (mean crystal size: 25-150 μm). These differences in crystal size are clearly controlled by the original depositional textures of the two dolomite units. Additionally, the two Jurassic dolomite parts show pervasive microcorrosion and microvugs in the intercrystalline pore spaces, slightly more intense in the uppermost section.

The generation of this corrosion can be interpreted as related to corrosive fluids circulating along fractures and microfractures and penetrating into the intercrystalline pore spaces of the host rock. Given the reduced permeability and throats of the intercrystalline pores, it is suggested that the corrosive fluids should have circulated under important pressure gradients. These pressure gradients are more consistent with ascending fluids in deep burial diagenetic environments than with descending fluids in shallow meteoric settings. In addition, the

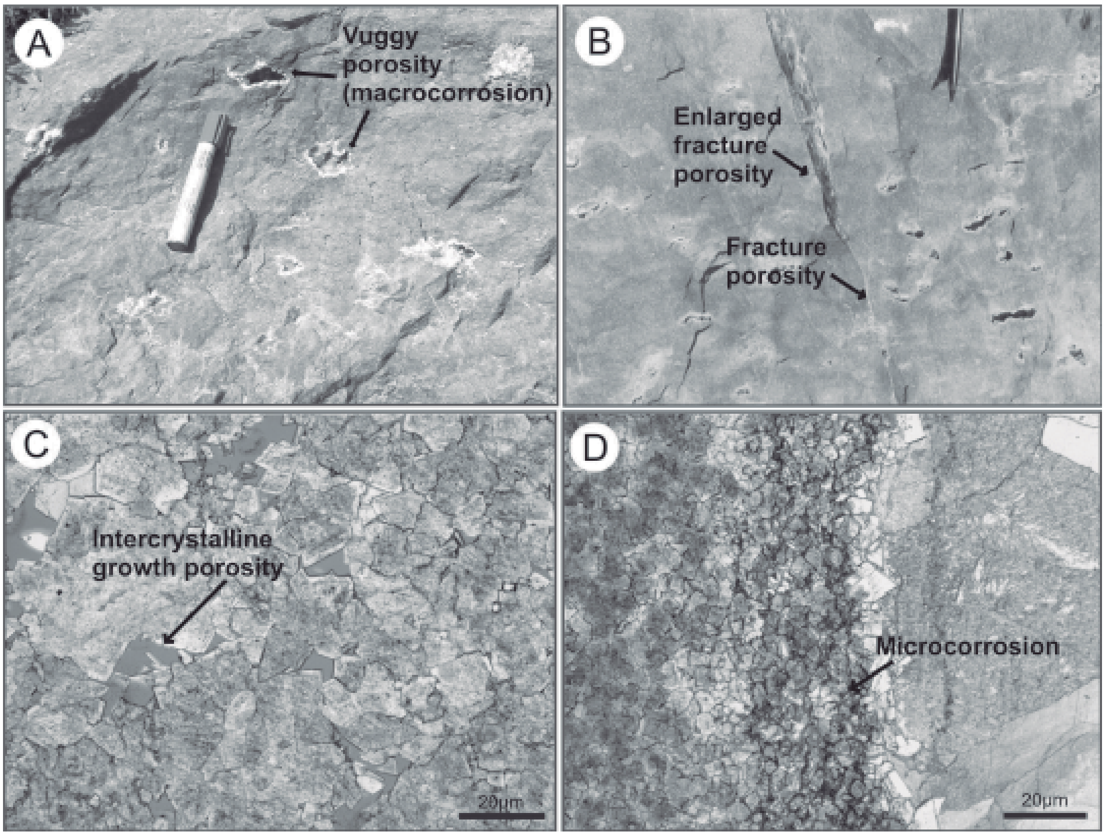

Fig. 2.- Relaciones entre la roca encajante dolomitizada, la porosidad y las generaciones de cemento.

Fig. 2.- Observed relationships between the dolomitized host-rock, porosity and the cement generations.

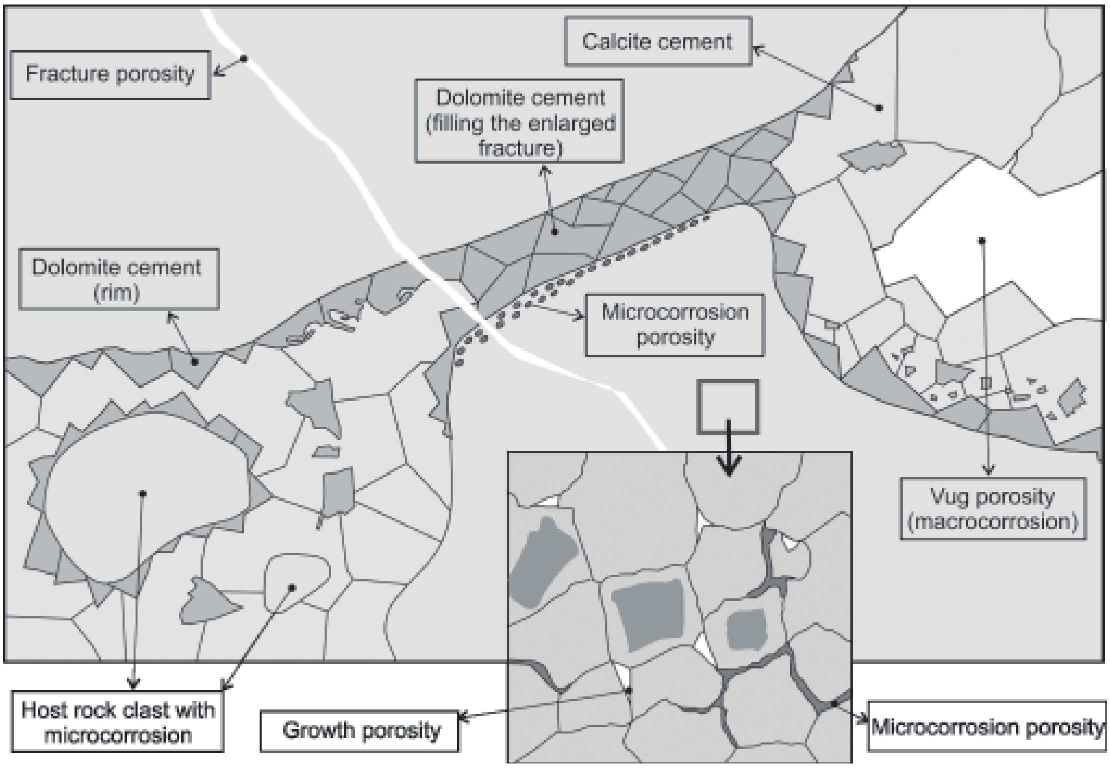

Fig. 3.- A) Zona de porosidad vacuolar (macrocorrosión) en la Formación de Dolomías Superiores del Garraf (sección de La Pleta). B) Porosidad de fractura parcialmente disuelta y transformada en porosidad vacuolar de fractura. C) Dolomía con porosidad intercristalina de crecimiento; luz polarizada en nícoles paralelos. D) Porosidad intercristalina de corrosión en dolomía, la cual aumenta claramente hacia el plano de fractura; luz polarizada en nícoles paralelos.

Fig. 3.- A) Vuggy porosity zone (macrocorrosion) in the Upper Garraf Dolomites (La Pleta section). B) Fracture porosity partially corroded to enlarged fracture vug porosity. C) Dolomite with intercrystalline growth porosity; plane polarized light. D) Intercrystalline corrosion porosity in dolomite, which increases clearly to the adjacent fracture plain; plane polarized light.

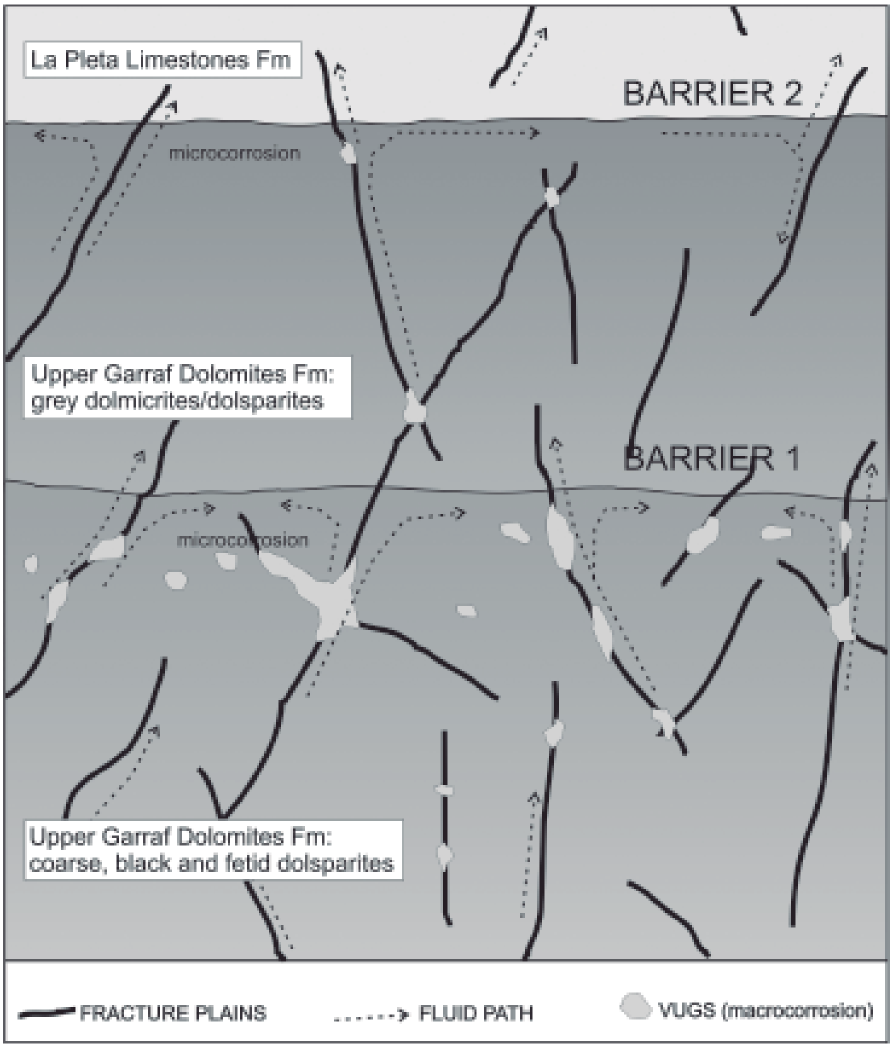

Fig. 4.- Modelo conceptual interpretado de la doble barrera de permeabilidad y de circulación preferencial de fluídos a lo largo de las fracturas.

Fig. 4.- Interpreted conceptual model of double relative permeability barrier and preferential fluid circulation along fractures.

observed diagenetic sequence clearly indicates that the corrosive phases occurred prior to the surface-related karstification in the region.

The lower part of the dolomite unit is coarser and more permeable than the upper part of the Upper Garraf Dolomites. In addition, permeability further decreases upwards in the La Pleta Limestones Fm.

The location of the enhanced porosity zone in the lower part of the dolomites is interpreted as formed by circulation of ascending corrosive fluids which were progressively trapped due to the decreasing permeability of the stratigraphycally higher units (Fig. 4). The intercrystalline microcorrosion is slightly more intense in the upper part of the Upper Garraf Dolomites and below to the La Pleta Limestones Fm. This is also interpreted as the effect of the local seal of the basal Cretaceous micritic limestones. There is no record of micro-macrocorrosion in the Cretaceous limestones overlying the Jurassic dolomites (Esteban, 1973).

Distribution of micro-macrocorrosion appears controlled by precursor depositional textures and the resulting response to fracturing. The same corrosive fluids could have been involved in the generation of the intercrystalline microcorrosion and larger vugs (macrocorrosion). The intercrystalline microcorrosion originated in areas with less fracture density, smaller crystal size, or reduced permeability. The larger vugs originated where pre-existing fabrics included skeletal molds, higher fracture density, or coarser crystal size dolomites with important original intercrystalline porosity.

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