Facies and Stratigraphic Controls of the Palaeokarst Affecting the Lower Jurassic Coimbra Group, Western Central Portugal

Luca Antonio Dimuccio, Luís Vítor Duarte and Lúcio Cunha

Abstract An evolutionary geological/geomorphological model is proposed to explain the spatio–temporal distribution of palaeokarst affecting a Lower Jurassic shallow-marine carbonate succession (Coimbra Group; Sinemurian), cropping out in the Coimbra–Penela region (western central Portugal), in a specific morpho-structural setting (dolomitic hills). Field and laboratory data allowed a detailed facies/microfacies characterization and diagenetic interpretation to be made, with special regard to the evolution of porosity. High facies/microfacies heterogeneity and contrasts in porosity, providing efficient hydraulic circulation by the development of meso- and macropermeability, significantly influenced and controlled the earliest karst-forming processes (i.e., inception), as well as the subsequent degree of karstification during the mesogenetic and telogenetic stages of the Coimbra Group.

Keywords Shallow-marine carbonates · Lower Jurassic · Facies/Microfacies analysis · Dolomitization · Carbonate porosity evolution

L. A. Dimuccio (✉) · L. Cunha
CEGOT—Centro de Estudos em Geografia e Ordenamento do Território and Departamento de Geografia, Faculdade de Letras, Universidade de Coimbra, Praça da Porta Férrea 3004-530 Coimbra, Portugal
e-mail: luca@ci.uc.pt

L. A. Dimuccio · L. V. Duarte
Departamento de Ciências da Terra, Faculdade de Ciências e Tecnologia, Universidade de Coimbra, Largo Marquês de Pombal 3000-272 Coimbra, Portugal

L. V. Duarte
IMAR-CMA, Centro do Mar e do Ambiente, Universidade de Coimbra, 3004-517 Coimbra, Portugal

R. Rocha et al. (eds.), *STRATI 2013*, Springer Geology,
DOI: 10.1007/978-3-319-04364-7_148,

Introduction

In western central Portugal, the Lower Jurassic of the Lusitanian Basin is exposed in a few discrete patches. The most extensive exposure forms the Dolomitic Hills (Cunha 1990) in the Coimbra–Penela region (the studied area). A muddy evaporitic Hettangian/lower Sinemurian complex, detrital at the base (Pereiros and Dagorda formations; Soares et al. 2007), overlies Triassic siliciclastics. The evaporitic complex is capped by Coimbra Group carbonates (the studied succession), ranging in age from the early Sinemurian to the early Pliensbachian and recorded in two distinct subunits: the Coimbra Formation (= Coimbra beds sensu Soares et al. 1985, 2007), essentially dolomitic; and the overlying S. Miguel Formation (= S. Miguel beds sensu Soares et al. 1985, 2007), essentially dolomitic limestone and limestone. Due to the complex dolomitization processes, the transition between the two subunits is diachronous and progressively earlier westwards, where the older body is thicker and generally more marly with alternating marly limestone, calcareous marl, and black shale beds (the Água de Madeiros Formation of the Peniche and S. Pedro Moel regions; Duarte and Soares 2002). In the Coimbra Group, despite the local lateral and vertical distributions of dolomitic character and the presence of few thick marly interbeds, karstification has been identified, including several microkarstification features. All types of karst forms are commonly filled by autochthonous and/or allochthonous post-Jurassic siliciclastics, implying a palaeokarstic nature.

The main aim of this work is to infer the interplay between depositional facies, early diagenesis, syn- and postdepositional discontinuities, and the spatio–temporal distribution of palaeokarst. Here, the palaeokarst concept is not limited to the definition of a landform, and/or possibly to an associate deposit (both resulting from one or more processes/mechanisms), but is considered as part of the regional geological record.

Field information from stratigraphic sections and from structural geological and geomorphological surveys was mapped and recorded on graphic logs showing the lithological succession, including sedimentological, palaeontological, and structural data, as well as the stratigraphic position of the (palaeo) karst features. Facies determination was based on field observations of textures and sedimentary structures and petrographic analysis of thin-sections. Artificial mixtures of calcite and dolomite were prepared to calibrate the X-ray diffraction (DRX) system and quantify the abundance of calcite/dolomite. Clay mineral assemblages were also estimated using DRX. Various orders of discontinuity surfaces were recognized and characterized.

Results

The identified facies were subsequently grouped into six genetically related lithofacies associations: (1) predominantly argillaceous dolomites alternating with thick- to medium-bedded dark-grey/red marls with gypsum crystals (supratidal environment; sabkha); (2) rhythmic organization of massive oolitic dolomites with pellets and intraclasts (high-energy shoal environment); (3) intraformational thick-bedded breccias and very thin microbial laminated dolomites (from an intertidal environment to supratidal flat; sabkha-like); (4) thin-bedded marly limestone and dolomitic limestone alternating with thin-bedded grey marl (intertidal environment); (5) thick to massive well-bedded micrite and dolomitic limestone (restricted shallow-lagoon environment); (6) thin well-bedded marly limestone, marls, and dark limestone alternating with bioclastic limestone (perishoal environment).

Discrete thick and thin lens-shaped bodies of quartz sandstone are interbedded with lagoonal/peritidal facies. Benthic fauna (gastropods, bivalves, rare remains of foraminifers, ostracods, and echinoderms), as well as very rare ammonoids, are recognized in lithofacies associations (5) and (6). Some *Rhizocorallium* are identified along hardground surfaces, but they are not environmentally diagnostic, since they may be found in shallow-marine-restricted to open-marine subtidal settings.

Considering the stratigraphic correlation between the sedimentological and stratigraphic logs, and the microfacies analysis, it appears that all the observed (palaeo) karst features are associated with the main depositional discontinuity surfaces of different orders (e.g., exposure surfaces with desiccation cracks, hardgrounds, and marly interbeds) and/or stratigraphic horizons with specific syn- or postdepositional characteristics (e.g., brecciated, with microbial laminations, fossiliferous, and/or with important dolomitization/dedolomitization features).

Interpretation

The recognized lithofacies associations are indicative of sedimentation within inter/supratidal, shallow subtidal–lagoonal, and shoal subenvironments, in the context of the depositional systems of a tidal flat and a very shallow, inner part of a low-gradient, carbonate ramp (Read 1982; Shinn 1983; Flügel 2004). The observed quartz sandstone bodies are interpreted as part of a wave-dominated littoral fringe/barrier island system, where the terrigenous materials were introduced through tidal channels. The breccia horizons are associated with synsedimentary slumps (sliding to the W to NW), showing the important activity of N–S and NNE–SSW faults during the Sinemurian. All these deposits are arranged into metre-scale, mostly shallowing-upward cycles (Bosence et al. 2009), in some cases truncated by subaerial exposure events. However, no evidence of mature pedogenetic alteration, or of the development of distinct soil horizons, was observed. These facts reflect very short-term subaerial exposure intervals (intermittent/ephemeral), in a semiarid palaeoclimatic setting but with an increase in the humidity of conditions during the eogenetic stage of the Coimbra Group, which may have promoted the development of micropalaeokarstic dissolution (Esteban and Klappa 1983).

Coupling the field and microfacies analyses, two types of dolomitization are recognized: (1) syndepositional (or early diagenetic), possibly as a result of refluxing brines generated by the evaporation of seawater, under semiarid conditions in the intertidal and supratidal environments, preserving desiccation cracks, evaporites and their pseudomorphs, microbial lamination, and fenestrae (Flügel 2004); (2) partial secondary heterogeneous dolomitization/dedolomitization, common during diagenesis, particularly where dolomitizing fluids followed discontinuities such as joints, faults, bedding planes and, in some cases, pre-existing palaeokarstic features.

The very specific stratigraphic position of the (palaeo)karst features is understood as a consequence of high facies/microfacies heterogeneities and contrasts in porosity (both depositional and its early diagenetic modifications), providing efficient hydraulic circulation through the development of meso- and macropermeability contributed by syn- and postdepositional discontinuities such as bedding planes, joints, and faults. These hydraulic connections significantly influenced and controlled the earliest karst-forming processes (inception sensu Lowe 2000), as well as the degree of subsequent karstification during the mesogenetic and telogenetic stages of the Coimbra Group. Down-cutting structures transferred water from the surface to the underground; along the lines of intersection between fractures and inception horizons, the permeability increases by several orders of magnitude. In other words, both the primary porosity (related to specific depositional facies) and some diagenetic processes (such as early leaching by meteoric water and dolomitization/dedolomitization) controlled the inception of karst and the degree of subsequent karstification.

References

Bosence, D., Procter, E., Aurell, M., Bel Kahala, A., Boudagher-Fadel, M., & Casaglia, F., et al. (2009). A dominant tectonic signal in high-frequency, peritidal carbonate cycles? A regional analysis of Liassic Platforms from western Tethys. *Journal of Sedimentary Research, 79*, 389–415.

Cunha, L. (1990). *As Serras Calcárias de Condeixa, Sicó, Alvaiázere - Estudo de Geomorfologia*. Geografia Física I, Instituto Nacional de Investigação Cientifica, Imprensa Nacional – Casa da Moeda, Coimbra, 329 p.

Duarte, L. V., & Soares, A. F. (2002). Litostratigrafia das séries margo–calcárias do Jurássico inferior da Bacia Lusitânica (Portugal). *Comunicações do Instituto Geológico y Mineiro, 89*, 135–154.

Esteban, M., & Klappa, C. F. (1983). Subaerial exposure environment. In P. A. Scholle, D. G. Bebout & C. H. Moore (Eds.), *Carbonate depositional environments*. American Association of Petroleum Geologists Memoir *33*, 2–95.

Flügel, E. (2004). *Microfacies of carbonate rocks: Analysis, interpretation and application* (p. 976). Berlin: Springer.

Lowe, D. J. (2000). Role of stratigraphic elements in speleogenesis: The speleoinception concept. In A. B. Klimchouk, D. C. Ford, A. Palmer, & W. Dreybrodt (Eds.), *Spleogenesis, evolution of karst aquifers* (pp. 65–75). Alabma: National Speleological Society.

Read, J. F. (1982). Carbonate platforms of passive (extensional) continental margin-types, characteristics and evolution. *Tectonophysics, 81*, 195–212.

Shinn, E. A. (1983). Tidal flat environment. In P. A. Scholle, D. G. Bebout & C. H. Moore (Eds.), *Carbonate depositional environments*. American Association of Petroleum Geologists Memoir *33*, 172–210.

Soares, A. F., Marques, J. F., & Rocha, R. B. (1985). Contribuição para o conhecimento geológico de Coimbra. *Memórias e Noticias, Publicação Museu Laboratório Mineralógico e Geológico da Universidade de Coimbra, 100*, 41–71.

Soares, A. F., Marques, J. F., & Sequeira, A. J. D. (2007). *Notícia explicativa da Folha 19-D Coimbra-Lousã.* Carta geológica de Portugal na escala de 1/50 000, Departamento de Geologia, Instituto Nacional de Engenharia, Tecnologia e Inovação, Lisboa, 71 p.

Acknowledgments: This paper is a contribution to the Project CAVE (PTDC/CTE-GIX/117608/2010), cofunded by Fundação para a Ciência e Teconologia (FCT) and the European Operational Competitiveness Programme (COMPETE).