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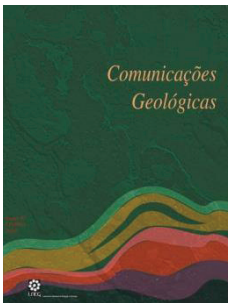
Devonian sedimentation in the SW boundary of the Ossa-Morena Zone: state of art and paleogeography



Sedimentação devónica do bordo SW da Zona de Ossa-Morena: estado dos conhecimentos e paleogeografia

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Abstract: The Devonian sedimentary record of the Ossa-Morena Zone is scarce. In its southwestern domains, the Odivelas Limestone and correlatable units represent the single evidence of latest Early Devonian to Middle Devonian (possibly into Frasnian) sedimentation in this area. Reefal and peri-reefal sediments are frequently, but not always, associated to coeval volcanic rocks that probably supported atoll-like systems on the top of volcanic edifices. The northernmost occurrences are spatially associated with mississippian volcanic-sedimentary complexes. Their geometrical relation is still unclear, the limestones are possibly embedded as olitoliths, but can also be tectonically imbricated or simply reflecting draping of younger sediments around and above older (Devonian) sea-bed topography.

Keywords: Ossa-Morena Zone, Middle Devonian, carbonated sedimentation, paleogeography.

Resumo: O registo sedimentar Devónico da Zona de Ossa-Morena é escasso. Durante o Devónico Inferior a sedimentação apresenta geralmente um carácter siliciclástico, sendo que o Devónico Médio-Superior é caracterizado pela presença de um hiato na sedimentação, interpretado como resultante do início da Orogenia Varisca. Contudo, no Domínio Beja-Aracena surge um conjunto de ocorrências de unidades carbonatadas de idade compreendida entre o Devónico Inferior terminal ao Devónico Médio (estendendo-se possivelmente até ao Frasniano), nomeadamente os Calcários de Odivelas e outras unidades correlacionáveis (Calcários da Pena, Caerinha ou da Pedreira de Engenharia). Esta sedimentação carbonatada, de natureza recifal a peri-recifal, encontra-se frequentemente associada a rochas vulcânicas coevas da sedimentação que provavelmente serviriam de suporte a uma estrutura do tipo atol que se terá desenvolvido no topo dos edifícios vulcânicos. Este vulcanismo estaria relacionado com o processo de subducção do Oceano paleozóico localizado no bordo sul da Zona de Ossa-Morena, que teria já iniciado o seu levantamento, resultando daí a ausência quase generalizada de sedimentação devónica. Contudo, algumas das ocorrências setentrionais estão espacialmente associadas a depósitos de natureza vulcano-sedimentar de idade mississíppica e não se reconhece a associação com rochas vulcânicas coevas da sedimentação carbonatada. A sua relação estratigráfica e geométrica com estes complexos vulcano-sedimentares é dúbia, surgindo assim um conjunto de hipóteses: os calcários foram remobilizados e depositados na bacia carbónica (olistólitos); encontram-se tectonicamente imbricados na sequência mississíppica; ou simplesmente estão cobertos e rodeados por sedimentos mais recentes, encontrando-se *in situ* sobre o substrato do Paleozóico inferior.

Palavras chave: Zona de Ossa-Morena, Devónico Médio, sedimentação carbonatada, paleogeografia.

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1. Introduction

The Devonian (meta)sedimentary record of the Ossa-Morena Zone (OMZ) displays a switch from passive to active margin setting (Quesada, 1990; Robardet and Gutiérrez-Marco, 2004; Moreira *et al.,* 2014). The Lower Devonian successions cropping out in several areas of the OMZ, generally present a siliciclastic nature (Robardet and Gutiérrez-Marco, 2004), although carbonate sedimentation, locally with reef-like facies, was described near the boundary between the OMZ and the Central Iberian Zone (Obejo-Valsequillo Domain; *e.g*. Gourvennec *et al.,* 2008; Rodríguez *et al.,* 2010; May and Rodríguez, 2012). Middle-Upper Devonian (Eifelian to Early Famennian) sedimentary rocks are rare in the OMZ. This regional scale hiatus was interpreted as the result of the beginning of Variscan Orogeny (Oliveira *et al.,* 1991; Robardet and Gutiérrez-Marco, 2004; Moreira *et al.,* 2014). However, in the southwestern domains of the OMZ, several scattered occurrences of Lower to Upper Devonian reefal and peri-reefal carbonates were described (*e.g*. Boogaard, 1972, 1983; Machado *et al.,* 2009; 2010).

This work aims to review and integrate the published data, inferring on the paleogeography and pointing out the knowledge gaps in this area.

2. Southwestern OMZ Devonian limestones

The southwestern OMZ devonian limestones are found in restricted areas, between the Odivelas reservoir (Ferreira do Alentejo) in the South, extending to Silveiras (Montemor-o-Novo) in the North (Fig. 1). These occurrences are found near the boundary between

the OMZ and the South Portuguese Zone, in the Beja-Aracena Domain (Quesada, 1990). The limestones are generally associated with volcanic rocks (Odivelas Limestone) (Machado *et al.,* 2009, 2010) or to Mississippian Volcano-Sedimentary Complexes (Pena, Caeira, Estação de Cabrela and Pedreira de Engenharia occurrences) (Oliveira *et al.,* 1991, 2019; Pereira and Oliveira, 2003; Pereira *et al.,* 2006; Machado and Hladil, 2010).

2.1. Odivelas Limestone

The Odivelas Limestone is latest Early Devonian to Middle Devonian in age and composed of calciturbidites and reefal limestones with very low-grade metamorphism (Machado *et al.,* 2009, 2010; Oliveira *et al.,* 2019). The known occurrences are closely associated with the Rebolado Basalts that show tholeiitic geochemical affinities (Andrade *et al.,* 1976; Santos *et al.,* 1990; Silva *et al.,* 2011). Two distinct sections, Covas Ruivas and Cortes (Fig. 1), compose this unit, described below.

2.1.1. Covas Ruivas section

This section comprises circa 200 m thick Upper Emsian to Eifelian carbonate-volcaniclastic sequence. The ages are constrained by conodont biostratigraphy (*patulus* to *australis* biozones; Machado *et al.,* 2010). This section is mainly composed of bioclastic (mostly crinoidal) calciturbidites and debris-flow deposits, intercalated with thin hemipelagic tuffites (Fig. 2A), sometimes fossiliferous, with radiolarians, tentaculites and ostracod shells (Machado *et al.,* 2010; Moreira *et al.,* 2010). The calciturbidites were interpreted as peri-reefal sedimentation extending, at least, to the base of slope (Oliveira *et al.,* 2019), associated to a reefal system (not observed in this locality). The calciturbidite section has several evidences of syn-sedimentary deformation, such as convolute bedding (Fig. 2A) and slump structures, which could be related with the contemporaneous volcanic and/or tectonic activity. The magnetic susceptibility and lithological record of the basal part of this section is consistent with the Basal Choteč Event, a global transgressive event just above the Emsian-Eifelian boundary (Machado *et al.,* 2010). Also the $^{87}Sr/^{86}Sr$ isotopic ratio from this section is correlatable with the seawater $^{87}Sr/^{86}Sr$ ratio during the Early-Middle Devonian (Moreira *et al.,* 2016, 2019).

2.1.2. Cortes section

A Middle-Late Devonian age for the Cortes section limestones was reported by Conde and Andrade (1974), based on crinoid, coral, brachiopod and bryozoan faunas, subsequently refined by Machado *et al.* (2009). The dominant presence of *Cupressocrinites* sp. (Fig. 2B) and *Gasterocoma* sp. crinoidal columnals, in addition to several genera and species of rugose and tabulate corals, brachiopods and stromatoporoids, indicating a typical reefal assemblage of Late Eifelian–Early Givetian age (Machado *et al.,* 2009); recent conodont data support the Eifelian–Givetian age (Machado *et al.,* 2020). In this section, the bioherm/biostromal facies was preserved (Machado *et al.,* 2009; Oliveira *et al.,* 2019), which is surrounded by coeval peri-reefal calciturbidites. Also in this section, the magnetic susceptibility record of calciturbidites and the abundance of putative fungal hyphae and prasinophycean algae seem to be compatible (although with a higher degree of uncertainty) with the Kačák Event (Machado *et al.,* 2009, 2020). The $^{87}Sr/^{86}Sr$ ratio is also correlatable with the $^{87}Sr/^{86}Sr$ signature of seawater during the Middle Devonian (Moreira *et al.,* 2016; 2019).

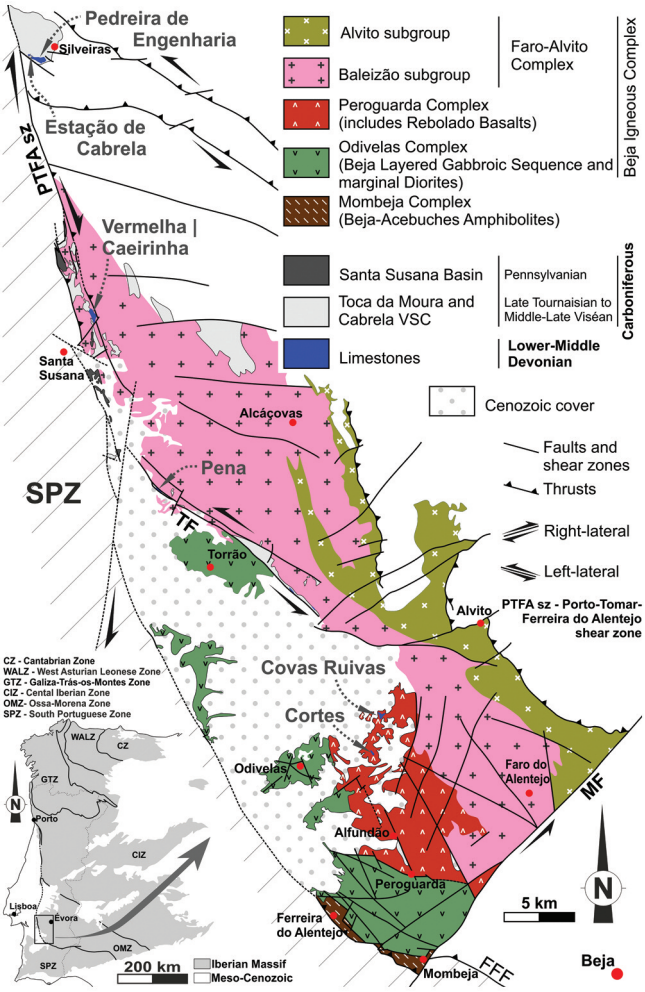

Figure 1. Simplified geological sketch of the Ossa-Morena Zone southwestern domains, emphasizing the location of devonian limestone occurrences (adapted from Andrade *et al.* 1976; Santos *et al.* 1990; LNEG, 2010; Oliveira *et al.,* 2019).

Figura 1. Mapa Geológico simplificado dos domínios sudoeste da Zona de Ossa-Morena, enfatizando a localização das ocorrências carbonatadas de idade devónica (adaptado de Andrade *et al.,* 1976; Santos *et al.,* 1990; LNEG, 2010; Oliveira *et al.,* 2019).

2.2. Limestones spatially associated with Mississippian Volcano-Sedimentary Complexes

In this section, the devonian limestone occurrences spatially associated with the Mississippian Toca da Moura and Cabrela Volcano-Sedimentary Complexes are described (Fig. 1).

2.2.1. Pedreira da Engenharia Limestones

The Pedreira (=quarry) de Engenharia Limestone is a calciturbiditic unit (Pereira *et al.,* 2006; Jorge *et al.,* 2018), spatially associated with the Cabrela Complex, with similarities to the Odivelas Limestone (Fig. 2C) (Oliveira *et al.,* 2019). The limestone samples collected in the basal floor of Engenharia quarry provided Eifelian conodonts (Boogaard, 1972). In order to re-evaluate conodont stratigraphy, a new investigation was recently started, confirming the Eifelian age (Liao *et al.,* 2018; Silvério *et al.,* 2019). Two polygenic conglomerate levels, at the top and bottom of the Pedreira da Engenharia Limestone, define two major unconformities (Ribeiro, 1983): the basal conglomerate covers the previously deformed Carvalhal For-

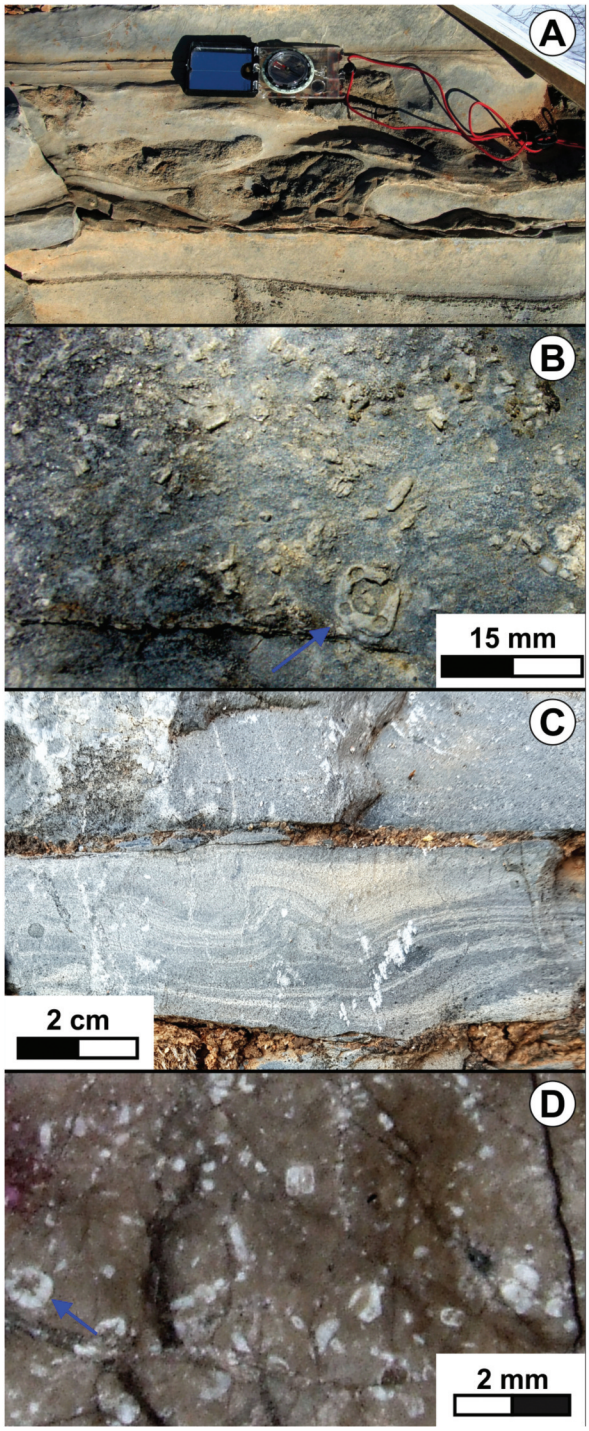

Figure 2. Petrographic, textural and fossiliferous features of Lower to Middle Devonian limestones form southwestern domains of the OMZ:
A – Convolute bedding showing the mixing of tuffite hemipelagic sediments (usually occurring at the top of calciturbidite beds) with grainstone/wackestone carbonates – Outcrop photo; Covas Ruivas locality.
B – Detail of crinoidal grainstone with a larger columnal of a *Cupressocrinites* sp. crinoid stem (blue arrow) – Outcrop photo; Cortes locality.
C – Calciturbidite bed(s) showing decimetrical fining-upward cycles and convolute bedding – Outcrop photo; Pedreira da Engenharia locality
D – Detail of a bioclastic grainstone, probably crinoidal, heavily dolomitized and recrystallized. Arrow indicating (?)*Cupressocrinites* sp. columnal – Polished section photo; Caerinha locality.

Figura 2. Características petrográficas, texturais e fossilíferas dos calcários do Devónico Inferior a Médio localizados no domínio sudoeste da Zona de Ossa-Morena:
A – Estrato com estratificação convoluta mostrando a mistura de tufitos hemipelágicos (geralmente ocorrendo no topo dos estratos carbonatados) com calcários do tipo "grainstone/ /wackestone" – Foto de afloramento; Localidade de Covas Ruivas.
B – Detalhe de um grainstone crinoidal, com uma secção de pedúnculo de *Cupressocrinites* sp. (seta azul) – Foto de afloramento; Localidade de Cortes.
C – Camada de calciturbidito mostrando um ciclo de sedimentação com gradação positiva e estratificação convoluta – Foto de afloramento. Localidade Pedreira da Engenharia.
D – Detalhe de um "grainstone" bioclástico, provavelmente crinoidal fortemente dolomitizado e recristalizado. Seta azul indica secção de (?)*Cupressocrinites* sp. – Foto de secção polida. Localidade de Caerinha.

mation (Cambrian-Silurian; Carvalhosa and Zbyszewski, 1994) and the upper conglomerate overlain by the turbidites of the Cabrela Formation (Upper Tournaisian-Visean) (Pereira *et al.,* 2006). The spatial association of Eifelian limestones with the Cabrela turbidites led Pereira and Oliveira (2003) to interpret the limestones as olistoliths. The stratigraphic relation between units is dubious and, consequently, the olistolithic nature of this limestones is questionable (Oliveira *et al.,* 2019).

2.2.2. Estação de Cabrela limestones

The Estação (=station) de Cabrela limestones present clear distinctive features with respect to Pedreira de Engenharia Limestone, although both are spatially associated with the Cabrela Complex. The Estação de Cabrela limestones occur as boulders within the Upper Tournasian turbidites of the Cabrela Complex (Boogaard, 1983; Oliveira *et al.,* 1991; Pereira and Oliveira, 2003). The black limestones from Estação de Cabrela include a well-preserved conodont fauna, which indicate a Late Frasnian age (Boogaard, 1983). These limestones were thus interpreted as olistoliths within Cabrela Complex (Pereira and Oliveira, 2003; Pereira *et al.,* 2006). According to Boogaard (1983), the conodont fauna, as well as its preservation, indicates that these limestones were deposited in a low energy environment in deep to moderately deep subtidal marine environment.

Estação de Cabrela limestones crop out poorly, although a revision of the fossiliferous content of these limestones is needed, because this is the single occurrence of frasnian limestones in the southwestern domains of the OMZ.

2.2.3. Pena and Caeirinha limestones

The Pena and Caerinha limestones were recently studied by Machado and Hladil (2010) and, although a precise biostratigraphic age was not obtained, the fossiliferous content (crinoidal elements of gasterocomids and cupressocrinitids) (Fig. 2D) indicate a Middle Devonian age for these dark-grey limestones. In both areas, the limestones crop out poorly and are generally highly silicified, recrystallized and metasomatized. The intense post-depositional activity almost obliterates the sedimentary textural features of these limestones, although occasionally preserved, the facies are similar to crinoidal calciturbidite facies (Fig. 2D) described in the Odivelas Limestone (Machado and Hladil, 2010). No conodont elements were found (Machado and Hladil, 2010). The $^{87}Sr/^{86}Sr$ isotopic ratio from Pena limestone is correlatable with the seawater $^{87}Sr/^{86}Sr$ ratio during the Middle Devonian and with the analysed samples from Odivelas Limestone (Moreira *et al.,* 2016, 2019).

The limestones in both localities are associated with the Toca da Moura Complex (Pereira *et al.,* 2006), although the relationship between the limestones and this volcano-sedimentary complex is unknown. Two possibilities were discussed (Machado and Hladil, 2010; Oliveira *et al.,* 2019): Pena and Caeirinha limestones may be remobilized, representing olistoliths into the carboniferous complex or they are deposited over the Lower Palaeozoic basement of the OMZ, later covered by mississippian sediments and affected by intense tectonism.

3. Discussion and paleogeography

The Odivelas Limestone, and the other correlated limestones, constitute one of the few stratigraphic records of uppermost Lower Devonian to Middle Devonian sedimentation in the OMZ. The carbonate sedimentation of the Odivelas Limestone seems to be paleogeographically associated with coeval volcanic rocks (Rebolado basalts): in shallower waters a bioherm-biostromal system developed with calciturbidite-type sedimentation on the flanks of the volcanic edifice, probably in an atoll-like system (Oliveira *et al.,* 2019). This association between volcanism and coeval reefal and peri-reefal carbonate sedimentation could be interpreted as the result of OMZ uplift related to the subduction activity (that possibly begins during Lower Devonian times; Moreira *et al.,* 2014; Dias *et al.,* 2016), which originated tholeiitic orogenic volcanism (Santos *et al.,* 1990; Silva *et al.,* 2011).

However, in the Pedreira de Engenharia, Pena and Caeirinha localities the basement of the limestones is unknown. It is plausible that some of these reef systems developed over basement highs. The understanding of the stratigraphic and geometric relations between these limestones and the lower Palaeozoic basement and mississippian volcano-sedimentary complexes is crucial to the geodynamic evolution of the OMZ. In addition, at least for Pena and Caeirinha limestones, the possible tectonic displacement of these carbonated bodies, during Carboniferous times, brings further complexity to its interpretation.

Although only the Lower Emsian to Givetian calciturbidites are well represented in the southwestern part of the OMZ, the presence of limestone boulders, Frasnian in age (Boogaard, 1983), within the mississippian Cabrela Formation could indicate that some of the reef systems persisted until Late Devonian times. Nevertheless, it is important to emphasize that no other Frasnian carbonate rocks are known in the OMZ, thus the source area of the boulders (likely olistoliths) is still unknown. Furthermore, it is also necessary to evaluate the several scattered occurrences of Silurian-Devonian limestones in Central and South OMZ, namely Ficalho, Barrancos and Ferrarias (Piçarra and Sarmiento, 2006), and to understand their relation with the ones described in this paper.

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