V.1

Devonian sedimentation in Western Ossa-Morena Zone and its geodynamic significance

Index

V.1.1. Introduction

Devonian carbonate sediments are poorly developed in Ossa-Morena Zone (OMZ). In the south-west branch of this zone, several Devonian limestone occurrences are known and its description, regional framework and significance are the subject of this subsection.

V.1.1.1. Regional overview of Devonian sedimentary rocks in OMZ and neighboring regions

From the Ordovician to the Early Devonian the sedimentation in the OMZ was generally occurring in a passive margin setting (Quesada 1990; Robardet and Gutiérrez-Marco 1990; 2004). This is recorded in metasedimentary rocks cropping out in areas from Portalegre to Cordoba and more to the south in the Barrancos-Estremoz area (Robardet and Gutiérrez-Marco 1990; 2004; Oliveira *et al*. 1991; Piçarra 2000), Terena syncline (Piçarra 2000) and Valle, Venta de Ciervo and Cerron del Hornillo synclines in Spain (Robardet and Gutiérrez-Marco 1990; 2004). Most of the paleozoic rocks are siliciclastics, composed of proximal deposits to deep fan turbidites (Oliveira *et al*. 1991; Piçarra 2000; Borrego *et al*. 2005). Lower Devonian reefal and other carbonate sedimentation in the OMZ is rare, but reported by May (1999) and Rodríguez *et al*. (2007) in Spain and Piçarra (2000) and Piçarra and Sarmiento (2006) in Portugal. Middle Devonian (meta)sedimentary rocks are very rare in the OMZ. This has been explained by a generalized uplift of this area during the Middle Devonian, creating a regional scale hiatus, as a consequence of the first pulses of the Hercynian orogeny (Robardet and Gutiérrez-Marco 1990; 2004; Oliveira *et al*. 1991). In Western OMZ, several scattered occurrences of reefal and peri-reefal carbonates were described near Cabrela (Boogaard 1972; 1983; Ribeiro 1983; Pereira and Oliveira 2003a; 2006), and within the Beja Igneous Complex (BIC) around the Odivelas water reservoir (Conde and Andrade 1974; Machado *et al*. 2009; 2010; Fig.1). Other rare occurrences of limestones in the same domain are reported near the contact area with the South Portuguese Zone (SPZ) around the Caeirinha mine and Pena (Pereira *et al*. 2006; Oliveira *et al*. 2013), shown to be Middle Devonian in age (Machado and Hladil 2010).

Together with the reefal and peri-reefal sediments, these occurrences frequently have interbedded or spatially related black cherts (with radiolarite lenses), tuffites and marly limestones.

During the Late Devonian and Carboniferous, the sedimentation is controlled by the pulses and geometry of the oblique collision occurring between the SPZ and the OMZ in a synorogenic phase (Quesada *et al*. 1990).

V.1.1.2. Magmatism in Western boundary of OMZ

In the southwesternmost domains of the OMZ, a suite of magmatic rocks is present, generally included in the BIC (e.g. Andrade 1983; Oliveira *et al*. 1991; Jesus *et al*. 2007; 2016). This igneous Complex includes plutonic (*e.g.* Beja Layered Gabbroic Sequence) and volcanic rocks (*e.g.* Toca da Moura and Cabrela volcano-sedimentary Complexes) related with different stages of a convergent process between OMZ and the South Portuguese Zone (*e.g.* Jesus *et al*. 2007; Ribeiro *et al*. 2010; Fig. 1). This suite presents a Devonian-Carboniferous range of ages, distinct magmatic natures and consequently distinctive geodynamic significances.

The description of the magmatism is not the objective of this work, thus only two distinct volcanic units will be briefly described because they present key features of the western OMZ carbonate sedimentation general framework:

- Rebolado basalts (Peroguarda Unit; e.g. Andrade *et al*. 1976; Santos *et al*. 1990);

- Toca da Moura and Cabrela Volcano-Sedimentary Complexes (e.g. Oliveira *et al*. 2013).

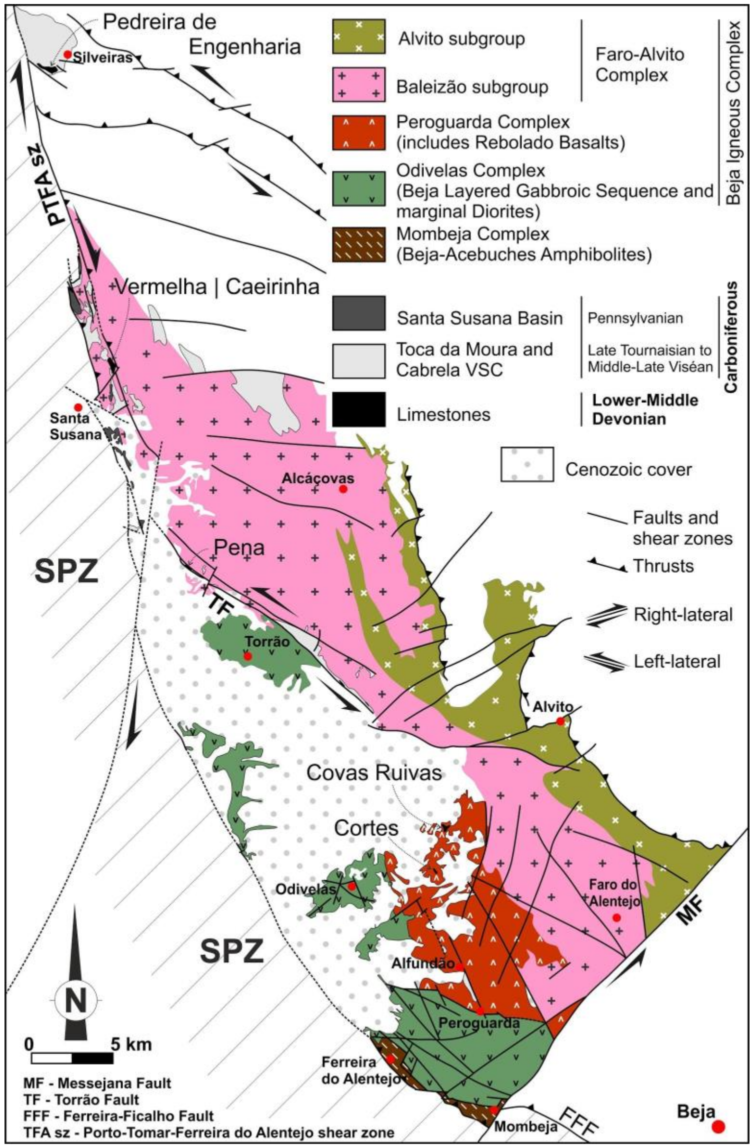

Figure 1 – Simplified geological sketch of western OMZ emphasizing magmatic and Late Paleozoic sedimentary rocks (adapted from Geological map of Portugal at 1:500.000 scale (1992); Andrade *et al*. 1976; Santos *et al*. 1990; Oliveira *et al*. 2013; Machado *et al*. 2013; Jesus *et al*. 2016).

Andrade *et al*. (1976) divide the magmatic rocks in the Odivelas-Alvito cross section in three distinct Complexes: Odivelas, Peroguarda and Faro-Alvito. The Odivelas and Faro-Alvito Complexes are mainly composed of plutonic rocks, with gabbro-diorite or granitic composition and a Carboniferous age (Andrade *et al*. 1976; Pin *et al*. 2008; Jesus *et al*. 2007; 2016). In turn, the Peroguarda Complex is mainly composed of mafic to intermediate volcanic rocks. This Complex is subdivided in three units, among which the Rebolado Basalts (OD-6 in Santos *et al*. 1990 nomenclature). This unit is spatial and stratigraphically associated with the (Lower-)Middle Devonian limestones in Covas Ruivas and Cortes locations (Conde and Andrade 1974; Andrade *et al*. 1976; Machado *et al*. 2009; 2010; Moreira *et al*. 2010; Fig. 1 and 2), presenting a mafic to intermediate nature with abundant effusive lithotypes and tephra rocks (Santos *et al*. 1990; Silva *et al*. 2011). These basalts exhibit low grade hydrothermal metamorphism (Andrade *et al*. 1976; Santos *et al*. 1990; Silva *et al*. 2011), which does not obliterate the original volcanic textures.

Santos *et al*. (1990) refers a spatial association between Peroguarda and Odivelas Complex, showing plutonic facies in SW border (Odivelas Complex) which laterally pass to the volcanic ones in NE branch (Peroguarda Complex). Recent studies (Jesus *et al*. 2016) also show a NW-SE to WNW-ESE magmatic layering in the Odivelas Complex (designated as Layered Gabbroic Sequence by the authors), which is congruent with Santos *et al*. (1990) data. However, the Odivelas Complex is Carboniferous in age (Jesus *et al*. 2007; 2016; Pin *et al*. 2008). Geochemical data suggests that the mafic-intermediate sub-alkaline volcanic rocks contained in the Rebolado Basalts unit present significant similarities with the typical orogenic volcanic arc magmatism, exhibiting a low-K tholeiitic to calc-alkaline signature (Santos *et al*. 1990; Silva *et al*. 2011). However, Santos *et al*. (1990) remark a slight difference between two sectors: the Odivelas-Penique, in the North, where the calc-alkaline signature is more pronounced, while the Alfundão-Peroguarda sector presents a predominant tholeiitic nature. Recently, Santos *et al*. (2013) supported this distinction based in isotopic data (Sm-Nd and Rb-Sr isotope pairs). The data provide evidences of common mantle (or very similar) sources for the mafic magmas in both sectors, although the Odivelas-Penique group shows some evidences of crustal assimilation.

The Toca da Moura and Cabrela Volcano-Sedimentary Complexes are located in the southwestern border of the OMZ (Fig. 1). These Complexes are composed of a sequence of slightly deformed pelites, siltstones and greywackes, interbedded with felsic, intermediate and basic volcanic rocks, although felsic volcanics are predominant in the Cabrela Basin (e.g. Oliveira *et al*. 2013). At the base of the sequence, conglomeratic levels are identified (Ribeiro 1983; Oliveira *et al*. 1991). In both Complexes, Devonian limestones (Boogaard 1983; Machado and Hladil 2010) are also present. However, its geometric and stratigraphic relation with the siliciclastic sedimentation is poorly constrained (Oliveira *et al*. 1991; 2013). Pereira and Oliveira (2003a) suggest these limestones are, at least in part, olistoliths. The Toca da Moura and Cabrela Complexes are coeval, providing miospore associations which indicate a late Tournaisian to Middle-Late Viséan age

(Pereira and Oliveira 2003b; Pereira *et al*. 2006; Oliveira *et al*. 2013; Lopes *et al*. 2014). These complexes are deposited over a well-structured Silurian(?) basement defining an angular unconformity (Pereira and Oliveira 2003a; Pereira *et al*. 2006).

In the Toca da Moura Complex, Santos *et al*. (1987) characterize basalts, dolerites, andesites and rhyodacite rocks. All these rocks present a low grade metamorphism related to late Variscan deformation episodes. The same authors argue the orogenic calc-alkaline geochemical signature of these volcanic series, explaining the diversity of lithotypes with fractional crystallization processes. The Cabrela felsic volcanics (rhyodacites; Chichorro 2006) present geochemical similarities with the previously described Toca da Moura volcanics and some felsic and intermediate dykes intruded in the Évora Massif (Chichorro 2006), also showing a calc-alkaline signature. According to Chichorro (2006), this volcanism can represent the effusive member of the Évora Massif magmatism.

V.1.2. Lower-Middle Devonian rocks in Western OMZ

Despite the relevance of the initial paleontological work carried out by Boogaard (1972; 1983) and Conde and Andrade (1974) who studied the limestone occurrences in western OMZ, there was still a big gap on the knowledge of these units, notably on the range of the sedimentation ages, integration with other occurrences in neighboring regions and especially their geodynamic significance.

V.1.2.1. Geographic distribution

The Odivelas Limestone and correlatable units are presently found scattered in from the Odivelas reservoir area (Ferreira do Alentejo) in the South to the Cabrela village in the North (Vendas Novas and Montemor-o-Novo). Most of the known occurrences are aligned NNW-SSE close to the OMZ-SPZ boundary (Fig. 1). Other, spatially restricted occurrences of carbonate rocks, cherts, tuffites and marls are known further to the East (to Vidigueira area), but these may represent older Cambrian(?) rocks.

Each of the occurrences is composed of loose boulders, small quarries and natural outcrops spanning in areas usually less than 1km^2. They are found interbedded or spatially associated with the Rebolado basalts (see below) or Toca da Moura-Cabrela Complex rocks which are volumetrically much more important (Fig. 2).

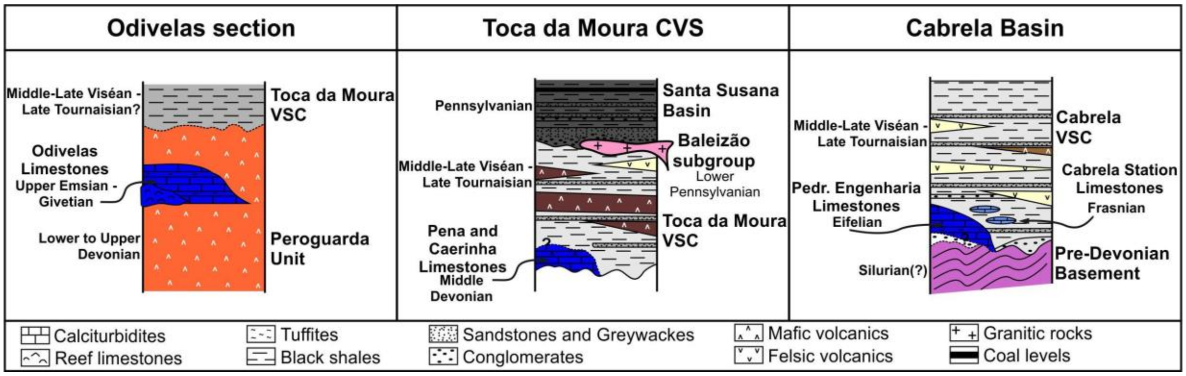

Figure 2 – Schematic stratigraphic sections on the Odivelas, Toca da Moura and Cabrela areas (based on data from Carvalhosa 1977; Ribeiro 1983; Oliveira *et al*. 1991; 2013; Chichorro 2006; Pereira *et al*. 2006; Machado *et al*. 2009; 2010; Machado and Hladil 2010; Moreira *et al*. 2010).

V.1.2.2. Brief description of facies and biostratigraphy

The vast majority of the known limestone occurrences are composed of crinoidal wackestones (up to 90% crinoidal fragments) with subordinate proportions of other bioclasts such as forams, tentaculites, ostracods, bryozoans, corals and stromatoporoids (Fig. 3B, G, I). Associated with this lithofacies fine-grained calcimudstones with abundant peloids (up to 75 %) occur. These have occasional mixing of coarser grains such as crinoidal fragments, tentaculites and radiolarians. These two lithofacies are interbedded (dm to m-thick beds) and generally interpreted as calciturbidites, in more distal (calcimudstones) or more proximal (wackestones) settings. While this is clear in continuous outcrops such as Covas Ruivas (Machado *et al*. 2010) the interpretation is only tentative in localities with small discontinuous outcrops, as Pena and Caeirinha. The origin of the carbonate material is most likely a reef system updip. This is corroborated by the highly diversified reef fauna found in the few, very coarse carbonate breccias. The only locality with bioherm/biostromal facies (Fig. 3H) is Cortes, where very coarse grained packstone-grainstones (locally rudstones and boundstones) with abundant crinoids, rugose and tabulate corals, brachiopods and stromatoporoids occur in the central part of the outcrop area and indicative of latest Eifelian to earliest Givetian ages (Machado *et al*. 2009). Unpublished conodont work by the authors confirms the age determination. This central area is surrounded by calciturbidite facies (Machado *et al*. 2009). Cortes and Covas Ruivas occurrences constitute the Odivelas Limestone s.s.

In some of the localities (Pena, Caerinha, Cabrela) these lithofacies are overprinted by intense dolomitization and/or silicification (Machado and Hladil 2010; Moreira *et al*., 2016). Nevertheless, crinoid columnal sections and remnants of the original facies are partially preserved and allow petrographic and biostratigraphical work to be conducted (Fig. 3I).

Other notable lithofacies present are tuffites interbedded with the calciturbidites. These form cm-thick beds, frequently cherty or with millimetric carbonate lenses, which in some levels have radiolarians, tentaculites and ostracod shells (Fig. 3B, C, D, E). These are always volumetrically less relevant than the carbonates and are interpreted as hemipelagic sediments. They also occur in the volcaniclastic sequences of the Rebolado basalts, that under and overlay the limestones (Fig. 3C). The tuffites have been described in detail in the Odivelas reservoir area (Machado *et al*. 2010). In the Cabrela area, both calciturbidite and (possible) tuffites seem macroscopically identical, but have not been studied petrographically (Fig. 3J).

As briefly described above, nearly all the known occurrences of the Odivelas Limestone and correlatable units are Middle Devonian in age. A notable exception is the very base of the sequence in Covas Ruivas which includes the youngest Emsian (Early Devonian) conodont biozone (*patulus*) and ranges to the *australis* biozone. The presence of crinoid ossicles of *Gasterocoma* sp. and *Cupressocrinities* sp. (and dominance over other crinoids) is quite distinctive of many of these localities (except in Covas Ruivas), indicating a late Eifelian to early Givetian age. The presence of large limestone boulders, Frasnian in age (Boogaard 1983), within the Mississippian Toca da Moura/Cabrela Complex and often spatially associated with Middle Devonian limestone outcrops (Eifelian; Boogaard 1972) is puzzling. Frasnian carbonate rocks are not known in the area, thus the source area of the boulders (likely olistoliths) is currently unknown. Possibly the carbonate sedimentation continued in some areas from the Early-Middle Devonian into the Frasnian. A reanalysis of the limestone boulders in the basal conglomerates and other scattered limestone occurrences in the Cabrela area is underway and will shed light on this subject.

Recent work performed by Moreira *et al*. (2016) also shows clear similarities between the $^{87}Sr/^{86}Sr$ ratio signature presented in Pena, Cortes and Covas Ruivas Limestones (ratio value lower than 0,70800) with the global values defined for Early-Middle Devonian times (Veizer *et al*. 1999; McArthur *et al*. 2012). However, the Pedreira da Engenharia dolomitized limestones, with similar age and genesis, presents higher $^{87}Sr/^{86}Sr$ values (0,70972), which, according to Moreira *et al*. (2016), could be the result of secondary dolomitization processes.

Thus the sedimentation of the Odivelas Limestone and correlatable units occurred in an interval between the latest Emsian to the Early Givetian, possibly extending into the Frasnian.

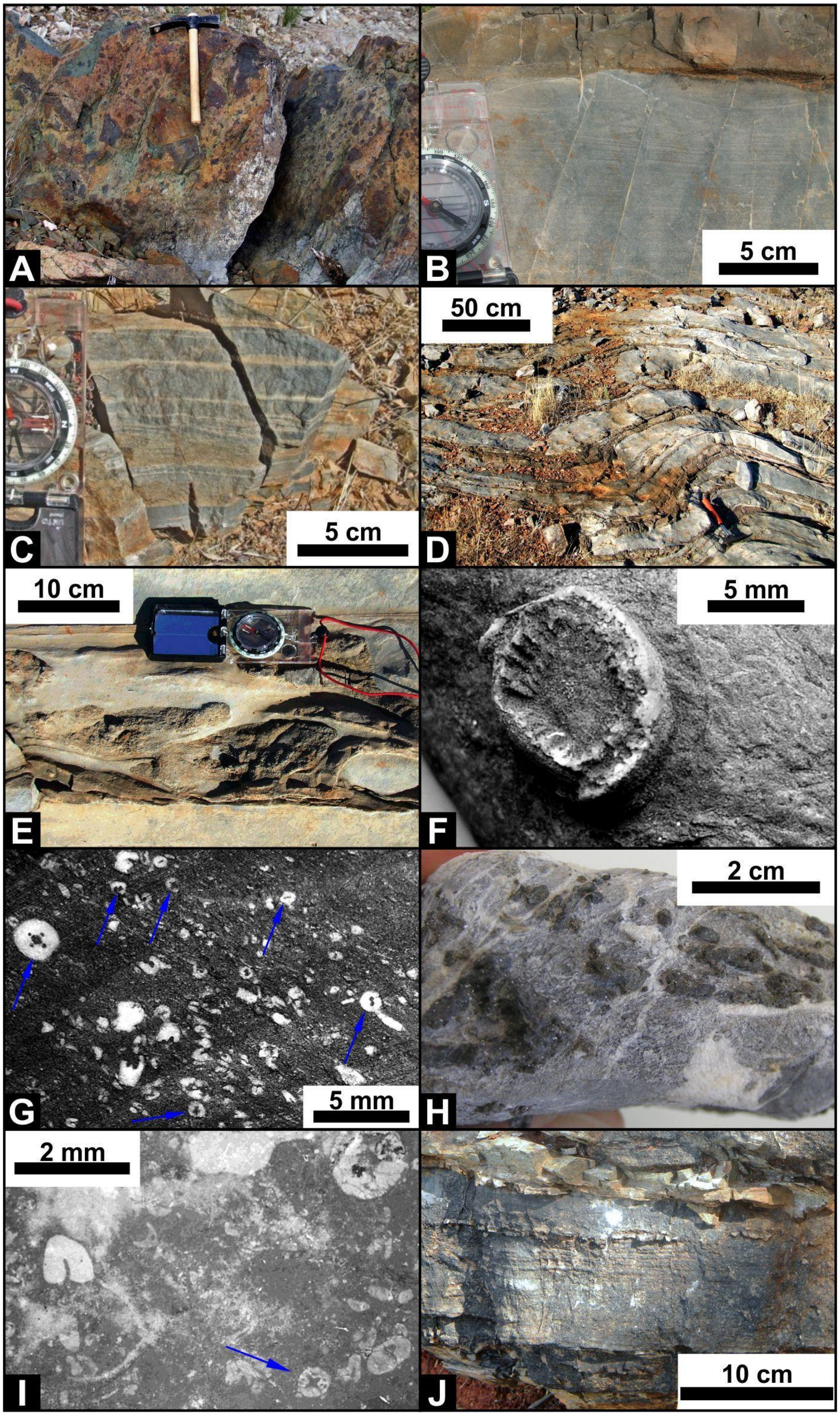
A
B
5 cm
C
5 cm
50 cm
D
10 cm
E
5 mm
F
G
5 mm
2 cm
H
2 mm
I
J
10 cm

Figure 3 – Outcrop and polished sections photographs of the Odivelas Limestone and correlatable units:

A-E Covas Ruivas locality: A - Pyroclastic rocks below the first calciturbidite beds; B - Detail of calciturbidite bed (note fining upward character and cross bedding on top) and sharp contact with the tuffite bed above (adapted from Machado *et al*. 2010); C - Thinly bedded tuffite near the base of the calciturbidite sequence (adapted from Machado *et al*. 2010); D - Alternation of calciturbidites (thicker lighter beds) and tuffites (thinner darker beds) gently folded; E - Convolute bedding showing a mix of tuffite material (darker) in a calciturbidite bed as evidence of slope syn-sedimentary deformation;

F-H Cortes locality: F - *Pseudamplexus* sp. coral weathered out in loose limestone boulder (adapted from Machado *et al*. 2009); G - Crinoidal limestone with small cupressocrinitid and gasterocomids columnals (arrows). Polished slab (adapted from Machado *et al*. 2009); H - Packstone with amphiporids (high relief) and crinoidal, brachiopod and ostracod fragments;

I - Caeirinha locality. Crinoidal limestone with small cupressocrinitid columnals (arrow). Thin section (adapted from Machado and Hladil 2010);

J - Cabrela locality. Pedreira de Engenharia Fm. Calciturbidite bed with fining upward trend and sharp contact with the (?)hemipelagic sediment above. Note similarity with B.

V.1.2.3. Post deposition evolution

The current distribution of Devonian limestones reflects their original disposition, but also post deposition processes, tectonic and possibly sedimentary. Their current small areal extent is likely a consequence of their original limited extent, but also the erosional processes of Devonian rocks (along with older and younger Paleozoic rocks) in the Alentejo peneplain.

While in Odivelas area the limestone rocks are clearly *in situ* (stratigraphically bounded by Rebolado volcanics; Fig. 3A), the other occurrences along the Western border of the OMZ may be tectonically displaced, as in the Cabrela and Toca da Moura Complexes. The limestones interpreted as olistoliths in these Complexes (which are at least partially Frasnian in age) and the limestone boulders in the basal conglomerate of the Toca da Moura complex show that during the Mississippian the Odivelas Limestone was being eroded.

Although the Devonian limestone outcrops are few and small, in Covas Ruivas two distinct episodes of folding can be discriminated (Moreira *et al*. 2010), which seem to represent the most recent (Carboniferous?) deformation events. However, the post-depositional tectonics in western OMZ are clearly dominated by brittle to brittle-ductile structures. Three main families can be highlighted: a N-S to NNW-SSE right-lateral faults, which also mark the limit between the OMZ and SPZ near Cabrela and in the Santa Susana Carboniferous Basin, the WNW-ESE to W-E ones, which include the Torrão and Ferreira-Ficalho Faults, and finally a NE-SW sinistral ones, genetically associated to Messejana Fault (Fig. 1). These faults were active during the Variscan Cycle (e.g. Moreira *et al*. 2010; 2014; Machado *et al*. 2012), and possibly some of them could control the Carboniferous sedimentation. However, some of these families have Meso-Cenozoic reactivation (e.g. Pimentel and Azevedo 1994; Cabral 2012), which further complicates the structural pattern and partially obliterates its kinematic record during post-Devonian evolution of Western OMZ.

V.1.3. Global events and intercontinental correlation

The Basal Choteč Event (BCE) is a global event which corresponds to a transgressive pulse just above the Emsian-Eifelian boundary. In carbonate slope conditions this is materialized by suboxic organic-rich sediments and lower carbonate sedimentation rates. These sediments are frequently overlain by coarse bioclastic calciturbidites or debris-flow carbonate breccias (e.g. Berkyová *et al*. 2008; Chlupáč and Kukal 1986). This sequence of lithologies is precisely what is observed in the Covas Ruivas section from upper *partitus* to *costatus* conodont biozones, consistent with the BCE ages of other localities around the World. The magnetic susceptibility record is also consistent and correlatable with other sections such as Lone Mountain, Nevada USA; Issemour, Morocco; Red Quarry, Barrandian Czech Republic and Khoda-Kurgan Gorge, Uzbekistan (see Machado *et al*. 2010 and references therein for details).

The end-Eifelian Kačák-otomari Event is another anoxic event which is potentially recorded in a small (2m thick) calciturbidite section in the Cortes locality. The organic-rich limestones with chert nodules, low magnetic susceptibility magnitudes and pattern, correlatable with other sections in the Czech Republic (Hladil *et al*. 2006) are tentative, but not definitive indications of the record of this event (see Machado *et al*. 2009 for details).

Overall, the age, local paleogeographical setting associated with volcanic buildings, the reef fauna and even the timing and nature of the magmatism are strikingly similar to other areas in Variscan Europe, notably the Rhenish area (Braun *et al*. 1994; Konigshof *et al*. 2010) in Germany, Horní Benešov in Moravia; (Hladil *et al*. 1994; Galle *et al*. 1995) and neighboring regions (Krebs 1974). These occurrences are part of the peri-Laurussian realm of the inner side of the Variscan tectonic facies belt. In both Cortes (Late Eifelian-Early Givetian) and in Covas Ruivas (Early Eifelian) the reef fauna is particularly diversified, containing elements which are typical of the Rhenish area, but also Peri-Gondwana elements (Machado *et al*. 2009; 2010).

V.1.4. Geodynamic evolution; Implications to SW Iberia Variscisdes

V.1.4.1. Local and regional paleogeography

Considering the known lithofacies, both carbonate and volcaniclastic, the fossil content and their stratigraphic and spatial relationships, the local paleogeography can be modelled with significant detail. Reef systems developed around the top of volcanic edifices (Fig. 4) where their top would be close enough to the sea surface to allow colonization and development of reef building taxa. These were probably isolated reefs, not larger than a few km across, possibly forming atolls and perhaps small detached carbonate platforms where the seabed morphology allowed it. On the flanks of the volcanic edifices, coeval peri-reefal sedimentation occurred, essentially as calciturbidites, extending at least to the base of slope.

Volcanic and volcaniclastic rocks pre-date and post-date carbonate sedimentation and constitute the majority of the rocks filling the accommodation space in the basin, together with younger rocks (Toca da Moura/Cabrela Complex?). In the Cabrela area, the absence of direct evidence for coeval volcanic rocks suggests these reefs and consequent peri-reefal sedimentation could also develop in basement highs (Fig. 4).

According to Andersen *et al*. (2003), the formation of calciturbidites is influenced by several factors, among which stands out sea level fluctuations and local slope and seafloor topography, although some calciturbidite sequences are directly related to tectonic activity. In Devonian western OMZ, the tectonic environment and the seafloor topography seem to be coupled. The subduction process, which probably begins during Early Devonian (see below), generates a volcanic arc and seafloor elevations (basement highs) during the deformation process (Fig. 5A). Over these tectonic reliefs, under the previous mentioned favorable environmental conditions, reef systems could develop that would be eroded/dismantled along its edges, generating calciturbidite sequences on the slopes (Fig. 4), including occasional debris-flow breccias and syn-sedimentary deformation (Fig. 3E).

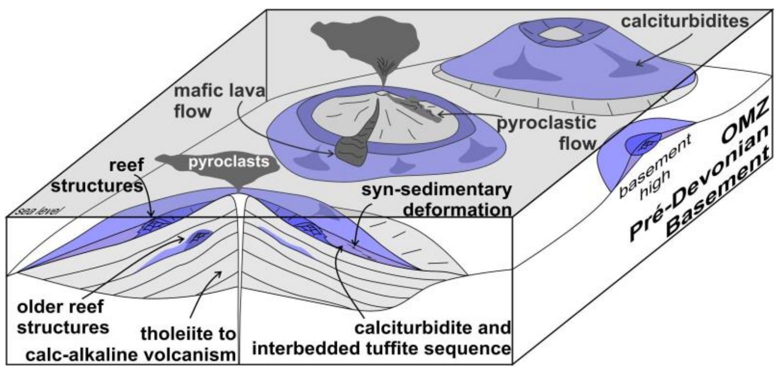

Figure 4 – Latest Early Devonian to Middle Devonian schematic model of the local/regional paleogeography of the Odivelas-Cabrela area in Western OMZ.

V.1.4.2. Subduction timing; a proposal to Devonian evolution of SW Iberia

The beginning of oblique subduction process of the Rheic Ocean under the OMZ is poorly constrained. Although it is considered that the process begins during the Devonian (e.g. Ribeiro 1983; Quesada, 1990; Oliveira *et al*. 1991; Moreira *et al*. 2014), some authors consider that it may even started at the time of the Silurian-Devonian boundary (e.g. Ribeiro *et al*. 2010). Stratigraphic (e.g. Oliveira *et al*. 1991; Machado *et al*. 2010; Araújo *et al*. 2013), magmatic (e.g. Costa *et al*. 1990; Santos *et al*. 1990; Moita *et al*. 2005a; Silva *et al*. 2011), metamorphic (e.g. Quesada and Dallmeyer 1994; Moita *et al*. 2005b; Pedro *et al*. 2013) and structural (e.g. Ribeiro 1983; Araújo *et al*. 2005; 2013) data clearly show the presence tectono-metamorphic events during Devonian times.

The sedimentary and biostratigraphic data are consistent with crustal uplift of the OMZ during Early Devonian (at least during the Emsian; circa 400 Ma) times, possibly related to the beginning of the subduction process (Moreira *et al*. 2014). Indeed, the characteristic euxinic marine sedimentation of the Silurian times (Black Shale Series; e.g. Piçarra 2000; Araújo *et al*. 2013) is replaced by shallow carbonate sedimentation in central OMZ (Ferrarias and Barrancos) although here the age is poorly constrained (Late Silurian to Devonian), because the sedimentary record is fragmentary (e.g. Piçarra 2000; Piçarra and Sarmiento 2006; Araújo *et al*. 2013). This trend is possibly present in the in the Odivelas sector, but the sedimentary record is incomplete. The carbonate sedimentation in the SW branch of the OMZ seems to persist until the Frasnian, although only some remobilized limestones were found in the Cabrela Formation (Boogaard 1983; Pereira and Oliveira 2003a; 2003b; Pereira *et al*. 2006).

The Devonian magmatism, poorly represented in the OMZ, can be observed in the Peroguarda Unit. Although there are no geochronological data which supports its Devonian age, the presence of Lower-Middle Devonian limestones interbedded with the Rebolado Basalts (Oliveira *et al*. 1991; Moreira *et al*. 2010) constrains its age. The orogenic low-K tholeiitic to calc-alkaline geochemical signature of the Rebolado Basalts (e.g. Santos *et al*. 1990; 2013; Silva *et al*. 2011) seems to indicate that proximal volcanic arc magmatism is represented by this unit. With (Late) Devonian age and far from subduction (Central OMZ), a calc-alkaline to shoshonitic magmatism is developed in Veiros-Vale Maceira (Costa *et al*. 1990; Moita *et al*. 2005a). The geochemical and spatial arrangement of Devonian magmatism suggests that subduction related magmatic activity migrates to the north, assigning a north polarity to the Rheic subduction under the OMZ, extending up to 365 Ma - Famennian (e.g. Moita *et al*. 2005a; Araújo *et al*. 2013).

Recent geochronological studies (Braid *et al*. 2011; Pereira *et al*. 2012; Rodrigues *et al*. 2015; Pérez-Cáceres *et al*. 2016), based on detrital zircons content in OMZ and SPZ Carboniferous syn-orogenic sedimentary sequences, show large populations of Devonian inherited zircons, which may represent an indirect evidence of subduction-related magmatism during this period. The Mississippian Cabrela Basin siliciclastics provide two Devonian inherited zircons clusters, with Eifelian-Givetian and Famennian ages (Pereira *et al*. 2012). Similar clusters are also obtained in the SPZ Mississippian siliciclastic lithotypes of Mértola and Mira Formations (Pereira *et al*. 2012; Rodrigues *et al*. 2015), although in Mira Formation, only the latter cluster (Famennian) is present. These SPZ units possibly have a source area in SW OMZ (Jorge *et al*. 2013). In the Spanish sector of the SPZ, the Santa Iria Formation presents a Late Devonian cluster of inherited zircons (Braid *et al*. 2011; Pérez-Cáceres *et al*. 2016), while in Ribeira de Limas and Ronquillo Formations Early Devonian

(Emsian) inherited zircons are present, representing the youngest Devonian cluster of these units (Pérez-Cáceres *et al*. 2016).

The previous mentioned data are in agreement with ages attributed to Peroguarda Unit volcanism, which seems to represent a preserved section of volcanic arc magmatism in the SW branch of the OMZ, related with subduction processes, supporting the existence of a magmatic arc during Devonian times, eroded during the Mississippian, intruded by younger plutonic rocks composing the BIC and finally eroded by recent peneplanation.

Also the metamorphic ages obtained from HP-LT metamorphic rocks, in the SW border of the OMZ, are in agreement with a Devonian subduction process. Geochronological data indicate a Famennian age to the baric peak of this HP-LT metamorphism (371 ± 17 Ma; Sm/Nd isochronous whole rock-garnet; Moita *et al*. 2005b; Pedro *et al*. 2013), materializing the active subduction processes.

After the genesis and development of volcanic arc magmatism and the related carbonate sedimentation, the collision process between SPZ and the OMZ begins during the Mississippian (Tournaisian; e.g. Jesus *et al*. 2007; 2016; Ribeiro *et al*. 2010; Moreira *et al*. 2014; Fig. 5B). During this period, the magmatic activity became intense in the BIC (Pin *et al*., 2008; Jesus *et al*. 2007; 2016), but also in the Évora Massif (Chichorro, 2006; Pereira *et al*., 2015).

During the Mississippian (Fig. 5B) the accommodation space continues to be filled (probably controlled by active tectonism), dominated by turbidite sedimentation and volcaniclastics (Toca da Moura and Cabrela Complexes; e.g. Ribeiro 1983; Pereira *et al*. 2006). The previously deformed OMZ substrate is eroded, feeding these basins as indicated by the lenses of Frasnian limestones found in the western border of the Cabrela basin (Cabrela Station Limestones), which some authors interpret as olistholiths within Mississippian turbidites (Pereira and Oliveira 2003a; Pereira *et al*. 2006; Oliveira *et al*. 2013). In the Cabrela Complex, fragments of granites and slates are described in the basal conglomerate (Ribeiro 1983; Oliveira *et al*. 1991; Pereira *et al*. 2006), emphasizing the unconformity between the Cabrela Formation and the previous deformed sequence, consequently dating the first deformation episode as earlier than Late Devonian.

In turn, the Toca da Moura and Cabrela calc-alkaline Carboniferous volcanism may not represent the real volcanic arc magmatism, but the remains of the processes after the subduction stop, i.e. during the collision, as mentioned by Santos *et al*. (1987). This magmatism could be related with the BIC emplacement or the Évora Massif activity (Fig. 5B) as proposed by Chichorro (2006).

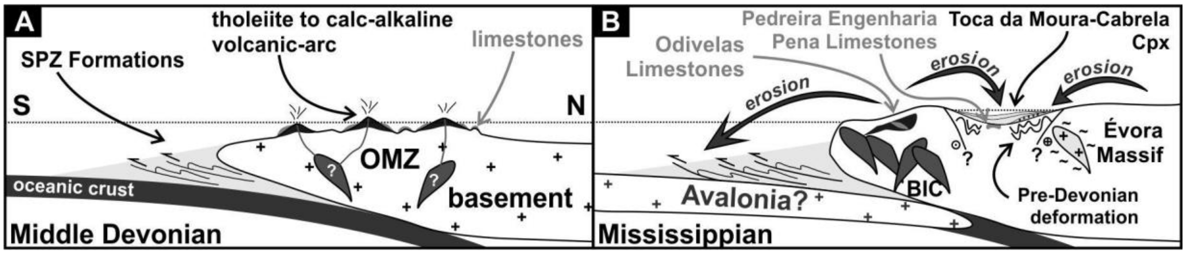

Figure 5 – Schematic model of Devonian-Mississippian evolution of the OMZ southwest branch. N and S are current coordinates:

A – Development of proximal volcanic arc with growth of reef structures, related to subduction during the Middle Devonian;

B – Beginning of continental collision process, with emplacement of large plutonic bodies (BIC). The Devonian volcanic arc and limestones are partially eroded, feeding the OMZ and SPZ syn-orogenic Mississippian basins.

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