V.2.

From the Devonian evolution of Ossa-Morena Zone (SW Iberian Variscides) to the SW Iberian Variscan Ocean subduction in the Early Devonian

Index

V.2.1. Introduction

The beginning of oblique subduction process of the SW Iberian Variscan Ocean under the Ossa-Morena Zone (OMZ) is poorly constrained. Although it is considered that the process began during Devonian times (e.g. Ribeiro 1983; Quesada, 1990; Oliveira *et al*. 1991; Moreira *et al*. 2010; 2014a; Nance *et al*., 2012; Dias *et al*., 2016; Pérez-Cáceres *et al*., 2016a), some authors consider that it may have started earlier, during the Silurian (e.g. Ribeiro *et al*. 2007; 2010). Thus, although the Silurian-Devonian age is generally accepted, the precise age to the beginning of subduction process is generally not mentioned.

Stratigraphic (e.g. Quesada *et al*., 1990; Oliveira *et al*. 1991; Robardet and Gutiérrez-Marco, 2004; 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 from OMZ show the existence of early tectono-metamorphic episodes during Devonian times, which allow to constrain the first events correlated with the subduction of the SW Iberia Variscan Ocean.

The precise age of subduction onset is extremely important to the paleogeographic reconstruction models of Late Palaeozoic times and consequently for the correct evaluation of the geodynamic evolution of the Iberian and European Variscides. In the following sections the geological features of the OMZ are described, emphasizing the available tectono-metamorphic, magmatic and sedimentary data that allows to discuss the timing of the subduction onset and, consequently, its evolution during Devonian times.

V.2.2. Geological Setting

The Rheic Ocean was one of the most significant oceans of the Palaeozoic Era, developing between Gondwana and northern continental blocks, namely the Avalonia Continent (Nance *et al*., 2012; Matte, 2001; Ribeiro *et al*., 2007). Although it is generally considered that the SW Iberian suture represents the Rheic Ocean (e.g. Ribeiro *et al*., 2007; Nance *et al*., 2012), other authors considers that the suture between OMZ and South Portuguese Zone (SPZ) represents the Pulo do Lobo Ocean suture, closed during Famenian-Lower Carrboniferous times (Fig. 1A; Quesada, 1991; Oliveira *et al*., 2013a). It is unknown the basement of SPZ and, although it is possible that the SPZ basement is Avalonia Continental block, there is no data that makes it possible to affirm it. Thus, from now on, this ocean will be mentioned as SW Iberia Variscan Ocean.

Regardless of the ocean and continental blocks involved, during Late Neoproterozoic-Early Palaeozoic times, the Iberian Massif is part of Northern margin of Gondwana (Ribeiro *et al*., 2007; Linnemann *et al*., 2008; Nance *et al*., 2012). During Early Palaeozoic times, the continental stretching of the North Gondwana margin begins, possibly as a continuation of Neoproterozoic orogenic activity (Nance *et al*., 2012). During Cambrian times, the continental stretching generates a continental rifting process, which produces a syn-rift sedimentary succession (Sánchez-Gárcia *et al*., 2010) in OMZ, culminating with the SW Iberia Variscan Ocean opening during Early Ordovician times at South of OMZ (current coordinates; Fig. 1A; Ribeiro *et al*., 2007; Pedro *et al*., 2010; 2013; Nance *et al*., 2012; Sánchez-Gárcia *et al*., 2010). During Ordovician and Silurian times, the OMZ was located in thinned North Gondwana margin, with sedimentation typical of stable continental margins, until Lower Devonian times (Quesada 1990; Robardet and Gutiérrez-Marco 1990; 2004).

During Late Devonian-Early Carboniferous times, evidences of syn-tectonic sedimentation, generally with flyschoid and molassic features, is reported across the OMZ (Palacios González *et al*, 1990; Quesada *et al*., 1990; Oliveira *et al*., 1991; Armendariz *et al*., 2008). The age of these syn-tectonic deposits is oldest in the southernmost domains of OMZ, being progressively younger to northeast, which has been interpreted as an indication that deformation migrates from the suture zone to the most internal domains of the hinterland (Apalategui and Quesada, 1987; Quesada *et al*., 1990).

Evidences of continental collision begin in Early Carboniferous (Jesus *et al*., 2007; Moreira *et al*., 2014a), which leads to consider that Early Carboniferous successions are already controlled by the collisional processes. This is also supported by the existence of an unconformity between the Carboniferous series and the older Palaeozoic ones, sometimes with conglomerates including deformed clasts derived from Early Palaeozoic successions (Quesada *et al*., 1990).

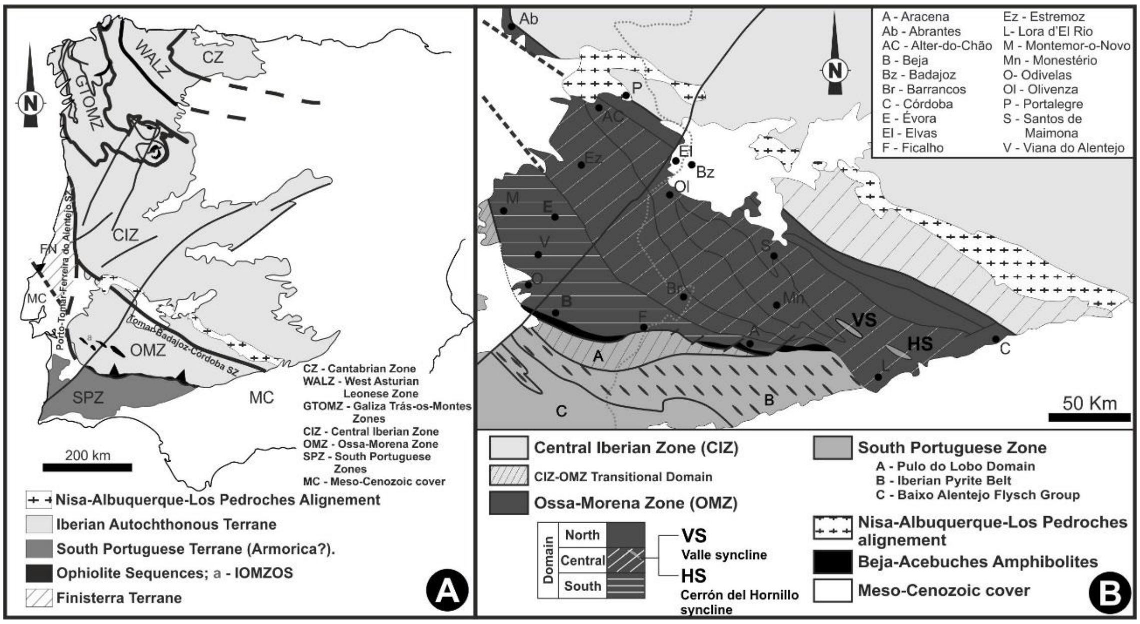

Figure 1 – (A) Main tectono-statigraphic zones of Iberian Variscan Massif (adapted from San-José *et al*., 2004; Ribeiro *et al*., 2007; 2010; Romão *et al*., 2014). (B) Subdivision of OMZ in North, Central and South domains based on geological features (adapted from Oliveira *et al*., 1991; San-José *et al*., 2004; Robardet and Gutierrez-Marco, 2004).

V.2.3. Stratigraphic Evidences; the Devonian Series

After the SW Iberia Variscan Ocean oceanization in the SW of the OMZ (Pedro *et al*., 2010; 2013; Sánchez-Gárcia *et al*., 2010), from the Ordovician to the Silurian-Early Devonian, passive margin sedimentation prevail in the OMZ (Quesada 1990; Robardet and Gutiérrez-Marco 1990; 2004; Sánchez-Gárcia *et al*., 2010).

The Silurian (Llandovery-Ludlow) sedimentation was characterized by great uniformity throughout the OMZ. The "Xistos com Nódulos", Papuda Formations and Lower Shales with

Graptolites Series (Central OMZ; Fig. 1B) are characterized by the presence of condensed sedimentation with very fine-grained facies (carbonaceous black shales and siltstones) and flints, typical of euxinic environments (Oliveira *et al.*, 1991; Piçarra, 2000; Robardet and Gutierrez-Marco, 2004; Piçarra *et al.*, 2009; Araújo *et al.*, 2013), suggesting a stable tectonic framework, that is consistent with the absence of Silurian magmatism in OMZ (Fig. 2).

Overlying the Silurian euxinic sedimentation, two distinct Late Silurian-Early Devonian types of sedimentation are described in the OMZ, which will be described in the next sections.

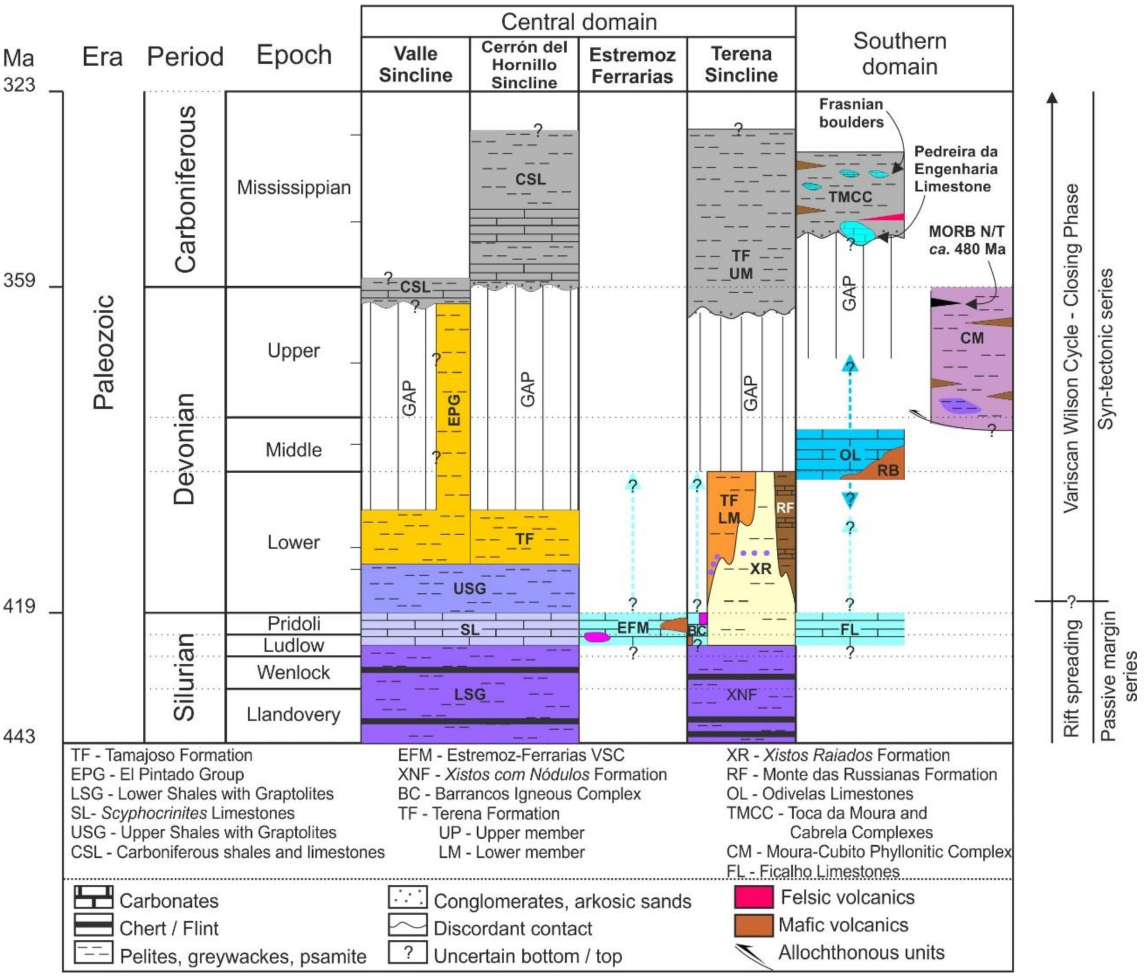

Figure 2 – Stratigraphic synopsis of Silurian to Carboniferous successions in Central and South Domains of the OMZ (see references on text).

V.2.3.1. Siliciclastic Sedimentation in the Terena Basin

In the Central Domains of the OMZ (Fig. 1B), after the deposition of the Silurian black shales, the sedimentation became progressively more shallow and energetic, marked by a prevalent environment oxidation with sedimentation of shales at the bottom, gradually with more sandstones and impure quartzites towards the top of the sequence (Xistos Raiados Formation -

Fig. 2 and 3A; Piçarra, 2000; Araújo *et al*, 2013). The sedimentation of Xistos Raiados Formation extends from Pridoli until the end of the Early Devonian (Emsian; Oliveira *et al*., 1991; Pereira *et al*., 1999; Piçarra, 2000; Gutiérrez-Marco and Robardet, 2004; Araújo *et al*, 2013). The top of the unit includes clasts of Early Silurian units, as well as gravitational landslides (Araújo *et al*., 2013).

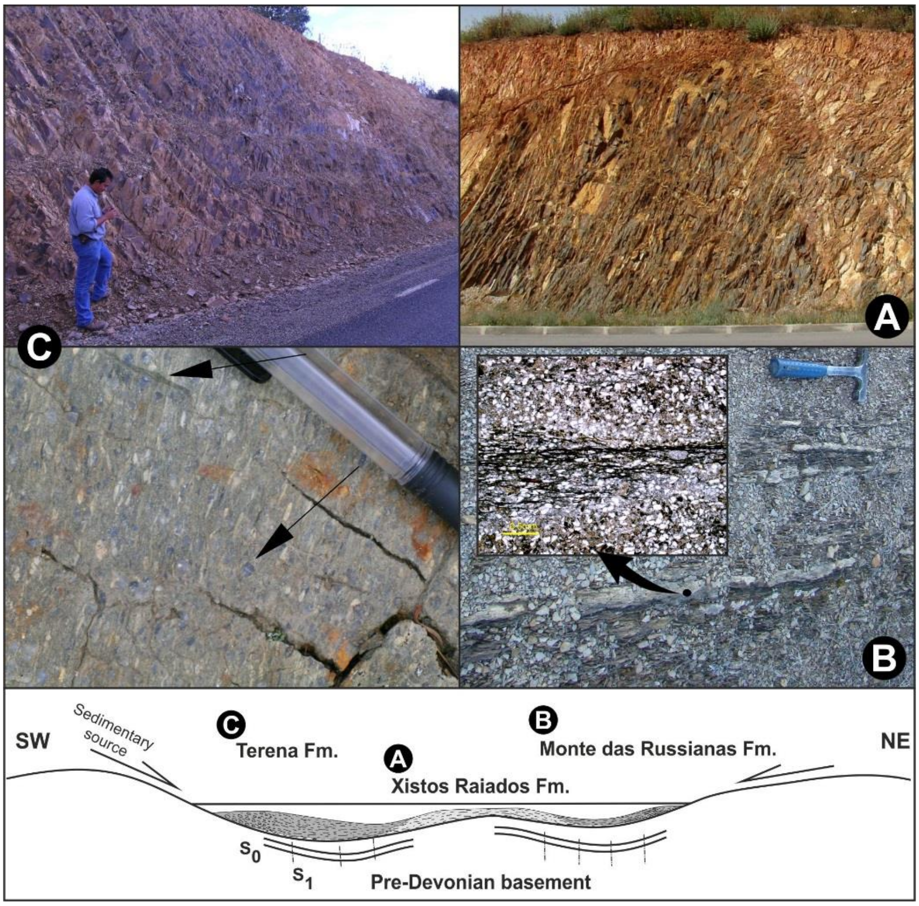

Figure 3 – Schematic interpretative sketch of the Terena Basin showing the lateral facies transition between Monte das Russianas (A), Xistos Raiados (B) and Terena Formations (C). The arrows indicates the Silurian flints contained in Terena Formation conglomerates.

Simultaneously to the deposition of the Xistos Raiados Formation, during Pragian-Emsian times a siliciclastic unit with black shales, siltstones and sandstones with calcite cement was deposited (Monte das Russianas Formation - Fig. 2 and 3B; Perdigão *et al*., 1982; Araújo *et al*., 2013). This formation presents many similarities with Xistos Raiados Formation and its lateral transition is gradual (Oliveira *et al*., 1991; Robardet and Gutiérrez-Marco, 2004; Araújo *et al*., 2013). With the same age, the Terena Formation was also deposited as a flysch sequence composed of shales and greywackes (Fig. 2 and 3C), occasionally with conglomeratic levels, mainly in the bottom of sequence (Pereira *et al*., 1999; Piçarra, 2000). The Terena Formation includes clasts of Silurian flints (Fig. 3C), as well as lithoclasts of the Devonian units described above and magmatic rocks (Borrego, 2009; Araujo *et al*., 2013). Geochemical studies of the Terena Formation greywackes and sandstones suggest a probable volcanic arc and a recycled orogen sediment sources (Borrego *et al*., 2006; Borrego, 2009), in contrast with the Colorada Formation (siliciclastic unit of Ordovician to Early Silurian age; Borrego *et al*., 2006) which indicates continental platform sedimentation in stable conditions. Detrital zircons studies on the Terena Formation (Pereira *et al*., 2014) show that the youngest population was Ordovician in age, thus inconclusive as respect to the age of sediment source areas, specifically to the age of the volcanic arc magmatism.

It is important to emphasize that in Spain, an Upper Member was described (Fig. 2), with (Famennian?) Tournaisian-Visean age (Boogaard and Vázquez, 1982; Geise *et al*., 1994; Gutiérrez-Marco and Robardet, 2004), in the Terena Formation. According to Azor *et al* (2004), the Carboniferous Member is, probably, deposited discordantly on top of the Devonian member.

The above mentioned Devonian formations are deposited in the Terena Basin (Araujo *et al*., 2013 and references therein), with a spatial and temporal arrangement that seems to shows lateral facies variation (Fig. 3 and 4). Indeed, the Terena flysch outcrops in the western domains of the basin, showing coarse-grained rocks (greywacke and conglomerates) at the bottom of sequence, while the Monte das Russianas Formation only crops out in Eastern domains, with Xistos Raiados Formation as a transitional unit. The Terena and Xistos Raiados Formations have evidences of syn-sedimentary deformation and also erosion followed by reworking of Silurian rocks within these Early Devonian siliciclastic Formations (Fig. 4C; Borrego *et al*., 2005; Araújo *et al*, 2013).

V.2.3.2. Devonian Carbonate Sedimentation

Devonian carbonate sedimentation is poorly developed in OMZ. In the south-western branch of this zone, several Early to Late Devonian limestone occurrences are known (Fig. 1B; Boogaard, 1972; 1983; Conde and Andrade, 1974; Piçarra and Sarmiento, 2006; Machado *et al*., 2009; 2010; Machado and Hladil 2010; Oliveira *et al*., 2013b). Late Silurian-Devonian limestones are also described in the Estremoz-Ferrarias-Barrancos alignment (Fig. 4; Piçarra and Le Menn, 1994; Sarmiento *et al*., 2000; Piçarra and Sarmiento, 2006; Araújo *et al*., 2013; Piçarra *et al*., 2014) and in some synclines in Spain. Upper Devonian-Carboniferous limestones are also described (see below; Robardet and Gutiérrez-Marco 1990; 2004; Lenz *et al*., 1996). The description, regional framework and significance of these limestones are the subject of the next section.

V.2.3.2.1. Southwestern OMZ Limestones

In Southwestern OMZ a set of limestone scattered occurrences is observed. Initial paleontological work carried out by Boogaard (1972; 1983) and Conde and Andrade (1974) reveals the Devonian age of these occurrences. Most of the known localities are aligned NNW-SSE close to the trend of the OMZ-SPZ boundary. These localities are restricted to loose boulders, small quarries and natural outcrops spanning in areas usually less than 1km^2. The limestones are found scattered around the Odivelas reservoir area (Ferreira do Alentejo), named as Odivelas Limestone, in the South, and near the Cabrela village in the North (near Montemor-o-Novo; Fig. 4). They are usually associated to volumetrically reduced cherts, tuffites and marly limestones (Fig. 5A).

The Devonian limestones are found interbedded or spatially associated with the Rebolado basalts (Fig. 2 and 5B; Odivelas Limestone; Andrade *et al*. 1976; Santos *et al*. 1990; Moreira *et al*., 2010) or with the Toca da Moura-Cabrela Complex (Fig. 2; Pena, Caerinha, Cabrela, Pedreira da Engenharia and Estação de Cabrela Limestones; Pereira and Oliveira, 2003; Pereira *et al*., 2006a; Machado and Hladil 2010; Oliveira *et al*., 2013b).

Most of the limestone occurrences are composed of crinoidal wackestones (with subordinate proportions of other bioclasts such as forams, tentaculites, corals and stromatoporoids; Fig. 5C) and fine-grained calcimudstones. These have occasional mixing of coarser grains such as crinoidal fragments, tentaculites and radiolarians. These two lithofacies are interbedded and generally interpreted as calciturbidites, in more distal (calcimudstones) or more proximal (wackestones) settings, with evidences of slumping and convolute bedding (Fig. 5D; Machado *et al*. 2010).

The origin of the carbonate material is most likely a reef system, although the only locality with bioherm/biostromal facies is Cortes (Machado *et al*., 2009). Here, the authors describe very coarse grained packstone-grainstones (locally rudstones and boundstones) with abundant crinoids (Fig. 5C), rugose and tabulate corals, brachiopods and stromatoporoids occur in the central part of the outcrop area, surrounded by calciturbidite facies. The age of Odivelas Limestone is constrained by paleontological data (e.g. conodonts, crinoids), being Middle Devonian in age, with the exception to Covas Ruivas succession that also includes the latest Emsian (Early Devonian) conodont biozone (Machado *et al*., 2009; 2010).

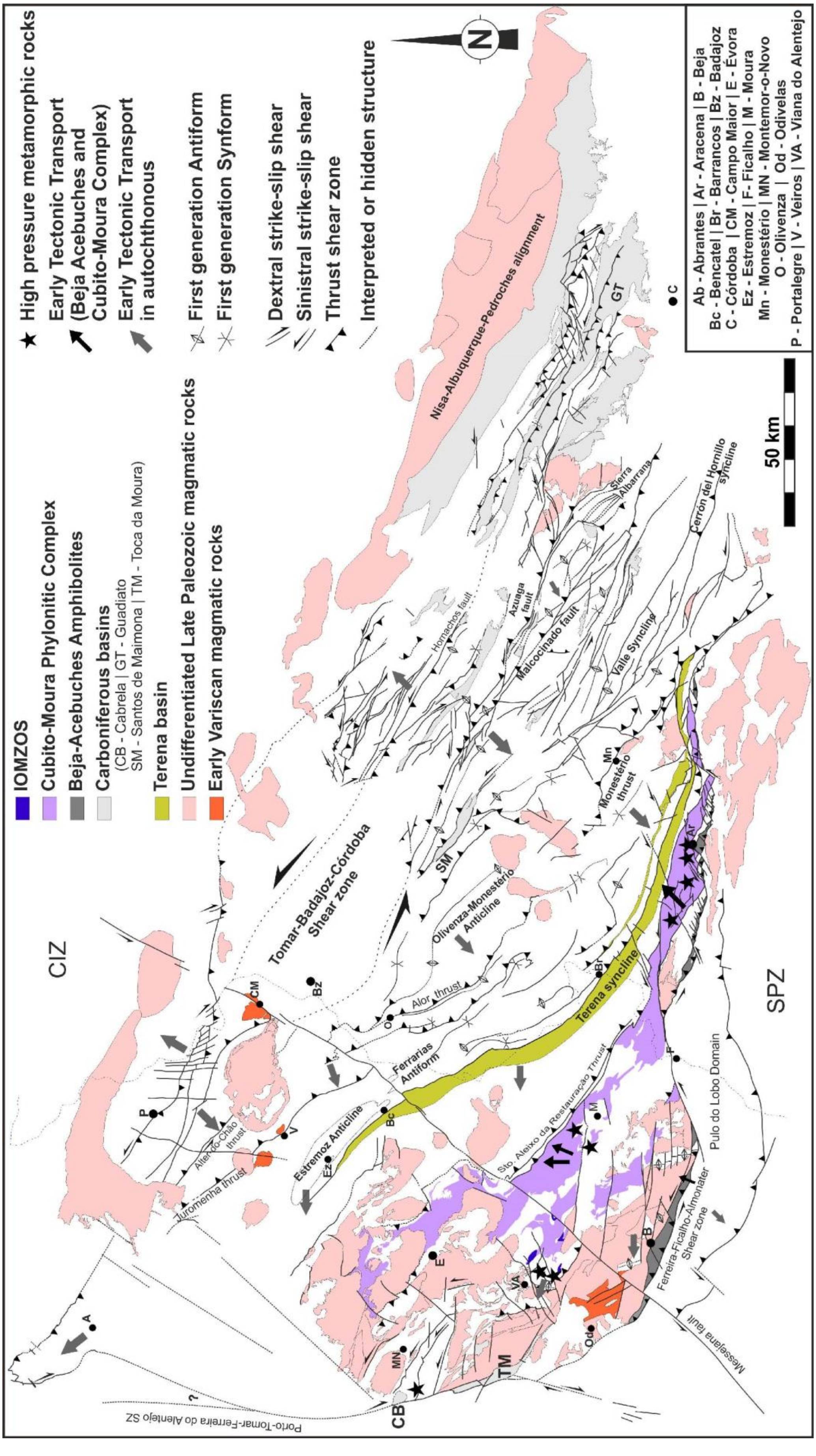
IOMZOS
Cubito-Moura Phylonitic Complex
Beja-Acebuches Amphibolites
Carboniferous basins
(CB - Cabrela | GT - Guadiato
SM - Santos de Maimona | TM - Toca da Moura)
Terena basin
Undifferentiated Late Paleozoic magmatic rocks
Early Variscan magmatic rocks
High pressure metamorphic rocks
Early Tectonic Transport (Beja Acebuches and Cubito-Moura Complex)
Early Tectonic Transport in autochthonous
First generation Antiform
First generation Synform
Dextral strike-slip shear
Sinistral strike-slip shear
Thrust shear zone
Interpreted or hidden structure
N
Ab - Abrantes | Ar - Aracena | B - Beja
Bc - Bencatel | Br - Barrancos | Bz - Badajoz
C - Córdoba | CM - Campo Maior | E - Évora
Ez - Estremoz | F- Ficalho | M - Moura
Mn - Monestério | MN - Montemor-o-Novo
O - Olivenza | Od - Odivelas
P - Portalegre | V - Veiros | VA - Viana do Alentejo
50 km
CIZ
SPZ
Nisa-Albuquerque-Pedroches alignment
Tomar-Badajoz-Córdoba Shear zone
Olivenza-Monestério Anticline
Alor thrust
Ferrarias Antiform
Estremoz Anticline
Terena syncline
Sto Aleixo da Restauração Thrust
Monestério thrust
Hornachos fault
Azuaga fault
Malcocinado fault
Valle Syncline
Sierra Albarrana
Cerrón del Hornillo syncline
Pulo do Lobo Domain
Ferreira-Ficalho-Almonater Shear zone
Messejana fault
Porto-Tomar-Ferreira do Alentejo SZ
Juromenha thrust
Alter-do-Chão thrust
GT
SM
TM
CB
A
P
CM
Bz
O
Br
Mn
Ar
V
Ez
Bc
F
M
E
VA
B
MN
Od
C
?

Figure 4 – Simplified geological map of OMZ, putting on evidence the location Devonian magmatic rocks, the Moura-Cubito Phyllonitic Complex and Terena Basin, as well the general structural pattern emphasizing the Early Variscan deformation episode structures (cartographic sources: Magna 50 – 2nd series – of IGME; Geological map of Portugal at the scale 1:50 000 of LNEG; Geological map of Portugal at the scale 1:500 000 of LNEG; Geological map of Iberia at the scale 1:2 000 000 of IGME).

In some of the localities (Pena, Caerinha, Cabrela) these lithofacies are partially 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. In Pena and Caeira localities, Machado and Hladil (2010), describe crinoidal fragments, indicating a Middle Devonian age.

Frequently, these calciturbidites are interbedded with tuffites (Fig. 5A), always volumetrically less relevant than the carbonates. They are interpreted as hemipelagic sediments, frequently cherty or with millimetric carbonate lenses, which in some levels have radiolarians, tentaculites and ostracod shells (Machado *et al*., 2010; Moreira and Machado, in press).

Within the Mississippian Cabrela Complex, mainly composed of shales and greywackes, Middle Devonian (Eifelian) limestone occurrences were described (Fig. 2; Pedreira da Engenharia Limestone; Boogaard 1972), but also limestone boulders of Frasnian age embedded in the Mississippian shales (Fig. 2; Estação de Cabrela Limestones; Boogaard, 1983). Fransnian limestones are not described in SW OMZ and thus its source area is unknown, being interpreted as olistoliths (Pereira and Oliveira, 2003). Therefore, the carbonate sedimentation continued from the Early-Middle Devonian, possibly extending into the Frasnian.

$^{87}Sr/^{86}Sr$ isotopic data (Moreira *et al*., 2016) show clear similarities between the strontium ratio signature presented in Pena, Cortes and Covas Ruivas limestones which are in agreement with the global values defined for Early-Middle Devonian times (Veizer *et al*. 1999; McArthur *et al*. 2012). In turn, the Pedreira da Engenharia Middle-Devonian dolomitized limestones presents significant higher $^{87}Sr/^{86}Sr$ values, which could be the result of post-depositional secondary dolomitization (Moreira *et al*., 2016).

The Odivelas Limestone, clearly in situ, is associated to Rebolado volcanics (see below), although the other limestone occurrences along the Western border of the OMZ may be tectonically displaced or remobilized into the Toca da Moura and Cabrela Complexes (Fig. 2).

Finally a mention to the Ficalho region, where unclassifiable fragments of conodonts in black limestones have been described (Piçarra and Sarmiento, 2006), which suggest Upper Silurian or Devonian ages, based on denticulation type and shape of the basal cavity (Fig. 2).

Figure 5 – General features of Odivelas Limestones:
A – Intercalation between calciturbidite limestone and hemipelagic tuffites;
B – Pyroclastic rocks from Rebolado Basalts, clearly showing primary textural features;
C – Transverse or slightly oblique sections of (?) *cupressocrinitids columnals* from Odivelas Limestones;
D – Syn-sedimentary deformation of limestones showing slump structures.

V.2.3.2.2. Estremoz-Ferrarias-Barrancos Limestones

These limestones occur in the Central Domain of the OMZ (Fig. 1B and 2), in a NW-SE alignment, spreading through Bencatel (SE termination of SW Estremoz Anticline limb), Ferrarias Anticline and Barrancos (Fig. 6A). These limestones are spatially associated with bimodal magmatic rocks, with unknown age, and occasionally breccias (Fig. 6A$_1$; Piçarra, 2000; Araújo *et al.*, 2013).

The marbles from Estremoz Volcano-Sedimentary Complex, considered by some authors (e.g. Piçarra, 2000; Sarmiento *et al*., 2000) equivalent to the Ferrarias Limestones, have been considered to be Early Cambrian to Late Ordovician-Silurian (see Oliveira *et al*., 1991 and Araujo *et al*., 2013 for a discussion).

However, the discovery of crinoid fragments (Fig. 6A$_2$) and conodont faunas in the Ferrarias Limestone seems to show a Late Silurian or Devonian age for some of these limestones (Piçarra and Le Menn, 1994; Piçarra, 2000; Sarmiento *et al*., 2000). The conodont fauna is fragmentary and inconclusive, notably with *Oulodus* sp. and *Ozarkodina* sp. (Fig. 6A$_3$). The limestones with conodont faunas are found in layers that contain clasts of quartzites and black shales, suggesting reworking of Palaeozoic units (Sarmiento *et al*., 2000). Also in Bencatel-Alandroal and Barrancos, fragments of crinoids are found (Piçarra and Le Meen, 1994; Piçarra and Sarmiento, 2006) in black impure limestones. The fragmentary fossiliferous content brackets the age as younger than Ordovician, possibly Early Devonian, based on free-living tentaculitoids found near Bencatel-Alandroal (Piçarra *et al*., 2014).

Recently, a radiometric age of 499.4 ± 3.3 Ma (U-Pb in zircons) have been obtained for a rhyolite from Estremoz (Fig. 6B; Pereira *et al*., 2012a). According to these authors this Middle-Late Cambrian age should also be the age of the Estremoz Marbles in which the rhyolite is intercalated. However, the regional geological maps clearly show that the rhyolite sample (ETZ-1) is not interbedded in the marble sequence, outcropping along the boundary between this unit and the overlying Silurian / Devonian ones (Fig. 6B). Moreover, this boundary has been considered a mechanical contact (Coelho and Gonçalves, 1970), which made the stratigraphic relation between the rhyolite and the Estremoz marbles debatable (Fig. 6C; Coelho and Gonçalves, 1970; Gonçalves, 1972; Piçarra *et al*., 2014). Thus the previous rhyolite age could not be considered equivalent of the marbles.

The correlation between Estremoz Marbles and Ferrarias Limestones, with Upper Silurian-Devonian age, is not totally accepted. Alternatively, some authors (Lopes, 2003; Pereira *et al*., 2012a) argue that the Upper Silurian-Devonian ages are not the carbonated depositional age, but the result of remobilization of younger Devonian faunal material during sub-aerial exposure, which is not excluded by Piçarra and Sarmiento (2006). Despite the discussion, the presence of Late Silurian-Devonian carbonated sedimentation in this area is clear.

Besides the $^{87}Sr/^{86}Sr$ isotopic signature is not conclusive in this case and the Estremoz, Ferrarias and Barrancos carbonates do not present a similar signature with the previously described Early-Middle Devonian limestones of SW OMZ (Moreira *et al*., 2016), showing values most similar to Cambrian marbles and limestones.

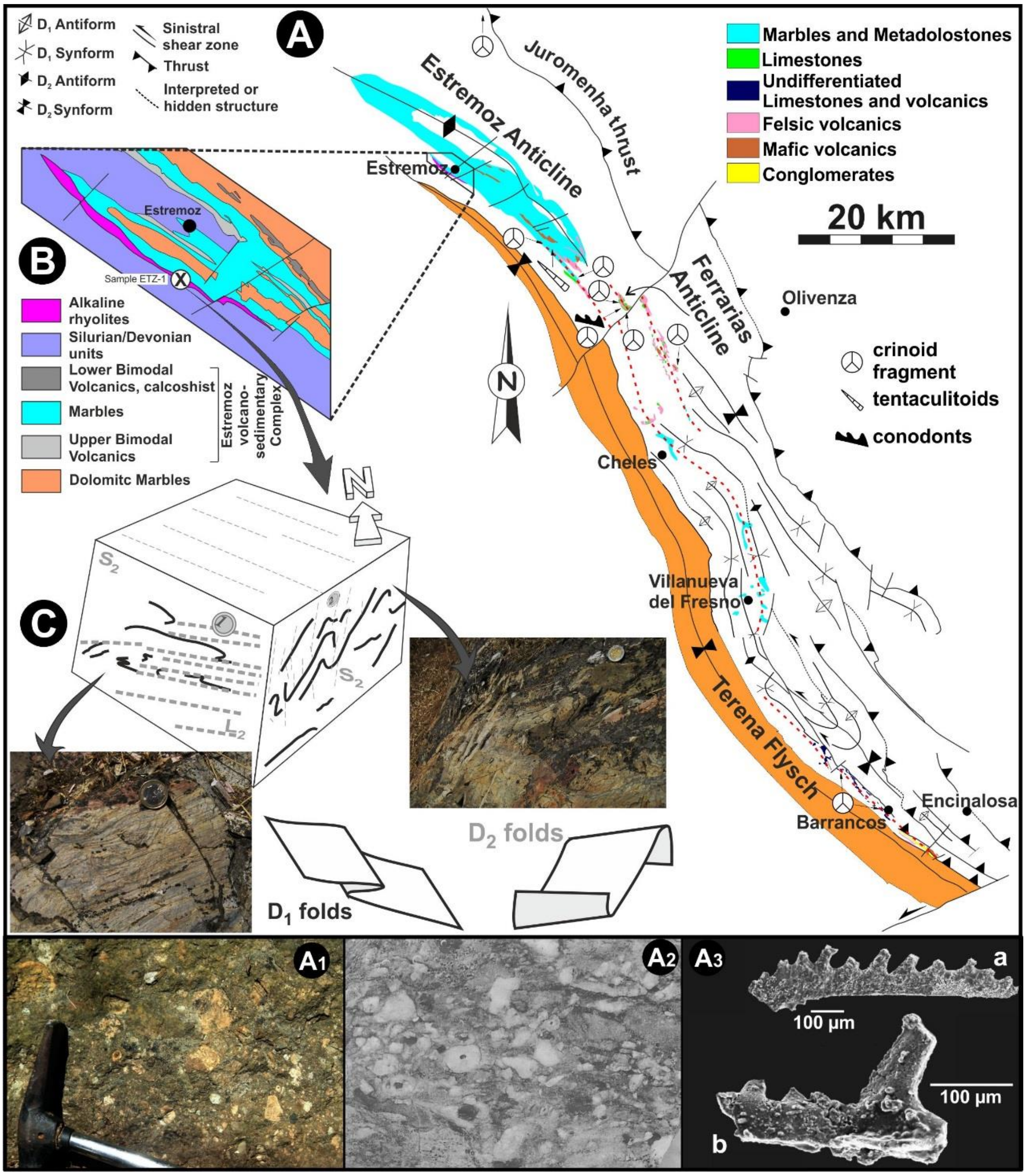

Figure 6 – General framework of Estremoz-Ferrarias-Barrancos Limestones alignment:

A – Simplified geological mapping (adapted from LNEG, 2010) and characterization of lithologic and paleontological features of limestones: (A1) Breccia from Barrancos locality, showing siliciclastic and magmatic remobilized clasts; (A2) Crinoid fragments from Ferrarias Limestones; (A3) conodonts from Ferrarias Limestones (a - Ozarkodina ? sp. ; b - Oulodus ?; adapted from Piçarrra and Sarmiento, 2006);

B – Geological context of the Estremoz volcanics (sample ETZ-1) dated by Pereira *et al* (2012) (Coelho and Gonçalves, 1970; Gonçalves, 1972; LNEG, 2010);

C – Interference between main variscan folding events in the ETZ-1 sample locality.

V.2.3.2.3. Valle and Cerrón del Hornillo Synclines Limestones

The Devonian sequence in Spain is clearly developed in 2nd order synclines (e.g. Valle and Cerrón del Hornillo; Fig. 1B) located in limbs of the Olivenza-Monestério Antiform (Gutiérrez-Marco and Robardet, 2004; Robardet and Gutiérrez-Marco, 2004). The Early Devonian (Pragian-Emsian; Robardet *et al*., 1991) sequence is siliciclastic, mainly composed of siltstones and shales (e.g. Tamajoso Formation and Lower part of El Pintado Group; Fig. 2) in stratigraphic continuity with Late Silurian ones (Lenz *et al*, 1996; Robardet and Gutiérrez-Marco, 2004). Over this siliciclastic series, a Middle Devonian hiatus is present (Fig. 2; Robardet and Gutiérrez-Marco 1990; 2004).

In these synclines, Late Devonian to Early Carboniferous limestones are described (Robardet and Gutiérrez-Marco, 2004). In the Valle Syncline, in the uppermost part of El Pintado Group, limestones, sandy limestones and shales with limestones nodules are described and attributed to the Late Devonian (Famennian), based on conodont and brachiopod faunas (Robardet *et al*., 1991; García-Alcalde *et al*., 2002; Gutiérrez-Marco and Robardet, 2004). The uppermost part overlies concordantly the Early Devonian part of the El Pintado Group (Robardet and Gutiérrez-Marco, 2004). Similar Early Devonian successions are described in Cerrón del Hornillo syncline, however this succession is unconformably overlain by Early Carboniferous conglomerates and limestones (Robardet *et al*., 1991; Gutiérrez-Marco and Robardet, 2004; Robardet and Gutiérrez-Marco, 2004).

V.2.4. Odivelas and Veiros-Vale Maceira Magmatism; the Devonian Volcanic-Arc

Devonian magmatism is poorly known in the Iberian Massif. However, some relics of this magmatism seem to be present in OMZ. Indeed, in southwestern domains of the OMZ, occurs a suite of magmatic rocks, generally included in the Beja Igneous Complex (BIC; e.g. Andrade 1983; Oliveira *et al*. 1991; Jesus *et al*. 2007; 2016). The BIC is Carboniferous in age (Jesus *et al*. 2007; Pin *et al*., 2008) and obliterate the previous structure and magmatism.

However, in the Peroguarda Complex, mainly composed of mafic to intermediate volcanic rocks, Andrade *et al*. (1976) individualize three distinct units, among which the Rebolado Basalts (Fig. 4; OD-6 for Santos *et al*., 1990). This volcanic unit presents mafic to intermediate nature with abundant effusive lithotypes and tephra rocks (Fig. 5B; Santos *et al*. 1990; Silva *et al*. 2011). The Early-Middle Devonian Odivelas Limestones are spatially associated to this unit, being its sedimentation substrate (Conde and Andrade 1974; Andrade *et al*., 1976; Machado *et al*., 2010; Moreira *et al*., 2010). 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.

Geochemical data suggests that the mafic-intermediate sub-alkaline volcanic rocks contained in the Rebolado Basalts 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 North sector (Odivelas-Penique) where the calc-alkaline signature is more pronounced and the South sector (Alfundão-Peroguarda) where a predominant tholeiitic nature is found. 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 North sector shows some evidences of crustal assimilation.

Also with (Late) Devonian age, in Central Domains of OMZ, shoshonitic to calc-alkaline magmatic bodies (Fig. 4; Vale Maceira, Veiros and Campo Maior; Costa *et al*., 1990; Moita *et al*. 2005a; Carrilho Lopes *et al*., 2005) are described. These massifs provide radiometric ages of 362±12Ma for Gabbro-Dioritic body of Veiros-Vale Maceira cooling age (Rb/Sr whole rock-felspar pair and K/Ar in amphibole; Moita *et al*., 2005a) and 376±22Ma for the emplacement age Campo Maior Massif (Sm-Nd Carrilho Lopes *et al*., 2005).

Indirect evidences of Devonian magmatism are also present in Carboniferous syn-orogenic metasedimentary rocks of the Cabrela Complex (OMZ), as well as in the Mértola, Mira and Santa Iria Formations of the SPZ, where significant populations of inherited zircons (with no overgrowths or inherited cores, implying a magmatic origin; Pereira *et al*., 2012b) are found, ranging from Early to Late Devonian (Braid *et al*., 2011; Pereira *et al*., 2012b; 2013; Rodrigues *et al*., 2015; Pérez-Cáceres *et al*., 2016b). Indeed, the Mississippian Cabrela Complex siliciclastics provide two Devonian inherited zircons clusters, with Eifelian-Givetian and Famennian ages (Pereira *et al*. 2012b). Similar clusters are also obtained in the SPZ Mississippian siliciclastic lithotypes of Mértola and Mira Formations (Pereira *et al*. 2012b; 2013; Rodrigues *et al*. 2015). In turn, the Santa Iria Formation presents a Late Devonian cluster of inherited zircons (Braid *et al*. 2011; Pérez-Cáceres *et al*. 2016b), 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*. 2016b).

V.2.5. Early Metamorphism and Structure of OMZ

The spatial distribution of early metamorphism and structure is heterogeneous in the OMZ (Fig. 4). In the SW border of the OMZ, an early HP-LT metamorphic event is described by several authors (e.g. Fonseca *et al*., 1999; Araújo *et al*., 2005; Moita *et al*., 2005b; Booth-Rea *et al*., 2006; Pedro *et al*, 2013; Rubio Pascual *et al*., 2013). This metamorphic prograde high-pressure event was produced blueschists and eclogites (P=8-18 kbar in Viana do Alentejo-Alvito region, Fonseca *et al*., 1999 and Rosas *et al*., 2008; 16-18 kbar in Safira (Montemor-o-Novo), Moita *et al*., 2005b; 7-12 kbar in Moura-Cubito Phyllonitic Complex, Moita *et al*., 2005b and Rubio Pascual *et al*., 2013). Geochronological data indicate a Late Devonian age to HP metamorphism peak (371 ± 17 Ma; Sm/Nd isochronous whole rock-garnet; Moita *et al*, 2005b; Pedro *et al*., 2013). The effects of HP-LT metamorphism were also recognised by the occurrence of aragonite remnants in calcite-rich marbles of Viana-Alvito region associated with pelitic rocks comprising kyanite + garnet + onfacite + glaucophane (Fonseca *et al*, 2004).

The HP rocks are spatially associated to the Moura-Cubito Phyllonitic Complex and to parautochthonous units from OMZ (Fig. 4; Fonseca *et al*., 1999; Araújo *et al*., 2005; Moita *et al*., 2005b; Booth-Rea *et al*., 2006; Pedro *et al*, 2013; Rubio Pascual *et al*., 2013).

The Moura-Cubito Phyllonitic Complex is interpreted as an allochthonous imbricate complex, emplaced over the OMZ southernmost autochthonous domains (Araújo *et al*., 2005; 2013; Booth-Rea *et al*., 2006; Ponce *et al*., 2012). The complex is mostly formed by monotonous and strongly deformed phyllites, including dismembered fragments of internal ophiolite complexes (IOMZOS; Pedro *et al*., 2010), as well slivers of autochthonous units (Cambrian marbles, Silurian flints and anorogenic volcanic rocks), in addition to the above mentioned HP metamorphic rocks (Araújo *et al*., 2005; 2013).

This complex displays a fold and thrust pattern characterized by a mylonite foliation, showing tangential transport with top to N-NNE in the Western sectors (Fig. 7A; Araújo *et al*., 2005) and to ENE in the Eastern ones (Ponce *et al*., 2012). This deformation episode is only preserved in this complex and in the Beja-Acebuches Amphibolites (Fig. 2; Fonseca *et al*., 1999; Araújo *et al*., 2005), being considered a local deformation episode possibly related to the emplacement of this allochthonous unit (Ribeiro *et al*., 2010; Moreira *et al*., 2014a). The Moura-Cubito Phyllonitic Complex develops a sinistral sigmoidal cartographic pattern, quite wide in the Western sectors of the OMZ, but considerably condensed in the East ones (Fig. 4).

The emplacement of this unit is interpreted as Middle to Late Devonian in age (Araújo *et al*, 2005; Ribeiro *et al*., 2010). The structural pattern related to the emplacement of this allochthonous imbricate complex produces an interference pattern with the autochthonous deformation, characterized by recumbent folding, facing to SW-W quadrant (Fig. 4). The interference shows a northern propagation of the deformation related to the emplacement of the Moura-Cubito Phyllonitic complex, with synchronous deformation of autochthon with a distinct geometric pattern (Ribeiro *et al*., 2010).

The age of early deformation episodes is constrained by the deposition of Toca da Moura and Cabrela Volcano-Sedimentary Complexes. These complexes are characterized by syn-sedimentary deposits constituted by shales, siltstones and greywackes, sometimes with carbonated levels (e.g. Pedreira da Engenharia Limestone) and bimodal volcanics (Oliveira *et al*., 1991, 2013b). The palynomorph associations in the siliciclastic sequence indicate a Late Tournasian to Late Viséan age (Pereira *et al*., 2006a). The Cabrela Complex stratigraphic succession presents a basal conglomerate, emphasising an angular unconformity with the deformed Pre-Carboniferous basement (Ribeiro, 1983; Pereira *et al*., 2006a; Oliveira *et al*., 2013b and references therein).

In the Central domains of the OMZ, during early Variscan evolving stage (D_1), a prograde metamorphic event under low grade metamorphic conditions, not exceeding greenschist facies (Expósito *et al*. 2002; Araújo *et al*., 2013; Moreira *et al*, 2014b), is described. This metamorphic event is associated to a progressive deformation regime, with intense strain partition, characterized by N-S to NW-SE recumbent folds and low dipping shear zones with transport with top to W-SW quadrant (Fig. 4 and 7B; e.g. Expósito *et al*, 2002; Simancas *et al*., 2004; Araújo *et al*., 2013; Moreira *et al*, 2014b). The seismic profile shows a basement control (thick skinned tectonics) associated with kilometre scale recumbent folds, rooting in the northern sectors of the OMZ (Simancas *et al*., 2004).

The genesis of the Terena Basin is attributed to D_1 (Araújo *et al*., 2013), which could explain the N-S anomalous orientation of Terena Syncline, in its central domains, with respect to NW-SE regional trend (Fig. 4). Indeed, the anomalous trend is interpreted as conditioned by the development of the N-S D_1 structures, which are contemporaneous of basin genesis during the Devonian (Rocha *et al*., 2009; Araújo *et al*., 2013).

The Terena Formation (Pragian-Emsian in age; Araújo *et al*., 2013) is deposited in this syn-tectonic trench. This Formation does not present evidences of the first deformation episode, although presenting evidences of syn-sedimentary deformation (Borrego *et al*., 2005; Rocha *et al*., 2009; Araújo *et al*., 2013), showing flyschoid nature and containing clasts of Silurian flints (Borrego *et al*., 2005). The deposition of Terena flysch is considered contemporaneous of the D_1, showing a lateral facies variation, with the presence of coarse-grained lithotypes in SW, which seems to shows proximal sources from the SW (Fig. 3; Borrego *et al*., 2005; Araújo *et al*., 2013). The Terena Formation only has one foliation related to NW-SE subvertical folds, attributed to the third regional tectonic event (D_3; Rocha *et al*., 2009; Moreira *et al*., 2014a).

As mentioned, an upper member with Late Carboniferous age is described in the Terena Formation, which was probably deposited discordantly on top of the Devonian member (Azor *et al*., 2004). This Carboniferous member is also deformed by the regional D_3 event (e.g. Apalategui *et al*., 1987), showing similar structural behaviour to the Cabrela Complex.

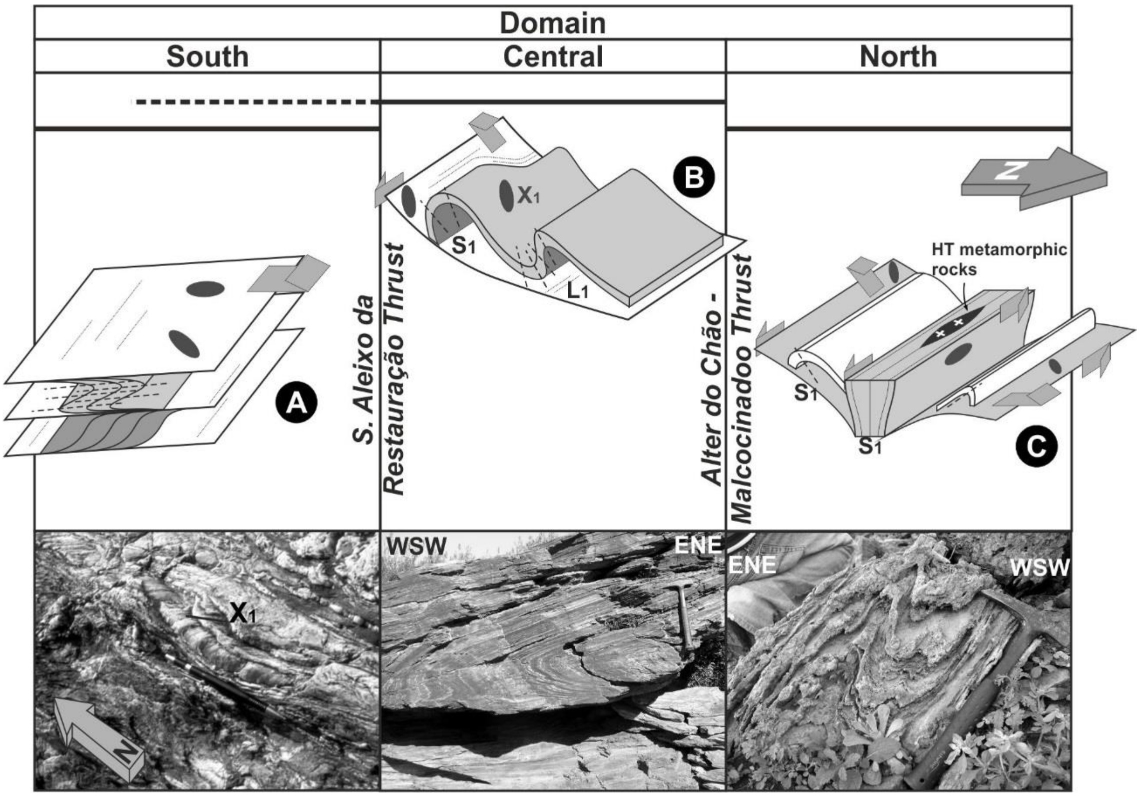

Figure 7 – Devonian structural features of the OMZ:

A – Imbricated complex with top-to-north transport of Moura-Cubito Phyllonitic Complex;

B – Recumbent folds and thrusts facing to southwest from Central Domain;

C – Flower structure of North Domain, rotting in TBCSZ.

In the northernmost domain of the OMZ, a Devonian HT metamorphic event was described, associated to central units of the Tomar-Badajoz-Córdoba Shear Zone (TBCSZ; Fig. 4 and 7C). Geochronological data from mylonite, paragneisses and migmatites (Las Grullas, Sierra Albarrana and Campo Maior Migmatite) show a Middle-Late Devonian age for an early metamorphic event related to this lithospheric scale structure (390-360Ma; Rb/Sr whole rock-muscovite pair García Casquero *et al*., 1988; Ar-Ar in amphiboles Quesada and Dallmeyer, 1994; U/Pb in zircons Pereira *et al*., 2012c). During the D_1, this structure acts as a sinistral transpressive intra-continental shear zone (Burg *et al*., 1981; Abalos and Cusí, 1995; Ribeiro *et al*., 2009), generating the mentioned high-grade metamorphic rocks. The transpressive regime of the TBCSZ presents evidences of strain partition, with generation of a composite flower structure, with a facing to SW in most developed SW branch and a short NE branch facing to NE (Fig. 4; e.g. Ribeiro *et al*., 2009; Romão *et al*., 2010). This thick-skinned structure could be responsible for the Central Domain early deformation episode, with recumbent folds facing to W-SW (Fig. 7B and 7C). The western propagation of this structure is blocked by the Porto-Tomar-Ferreira do

Alentejo Shear Zone, generating in Abrantes region during the D_1 a kilometric scale sheath fold (Fig. 4; Ribeiro *et al*, 2009; Moreira *et al*., 2011).

V.2.6. Proposal for OMZ Geodynamic Evolution during Devonian Times

The first stratigraphic evidence of uplift in the Central and Southern domains of the OMZ is preserved in the Devonian sedimentary record, reflecting most probably the tectonic instability triggered by the subduction beginning, being the Ludlow succession characterized by stable environment sedimentation (Fig. 8A).

The Odivelas Limestone (SW area of the OMZ), with Early-Middle Devonian ages are spatially associated with orogenic volcanism with tholeiitic to calc-alkaline geochemistry (Rebolado Basalts), indicating that basalts were generated in a supra-subduction setting (Fig. 8B; Santos *et al*., 1990; 2013; Silva *et al*., 2011). Indeed, during the Early-Middle Devonian, volcanic processes become active, showing geochemical features that are compatible with proximal volcanic-arc magmatism. This magmatism is developed near the suture zone between South Portuguese Terrane (Ribeiro *et al*, 2007) and the Iberian Autochthonous Terrane (which includes the OMZ, included in North Gondwana Margin), being interpreted as the suture of the SW Iberian Variscan Ocean (Fig. 8B). Preserved Ordovician magmatic rocks with MORB geochemical features are obducted over the OMZ during Devonian times (see below), being interpreted as ophiolite fragments (Pedro *et al*., 2010).

Associated to the volcanism, a reef shallow carbonate sedimentation is developed. The association between tuffites and peri-reef limestones with Emsian-Givetian age (Machado *et al*., 2009; 2010; Moreira *et al*., 2010) clearly shows the association between magmatism and sedimentation. Indeed, Machado *et al*., (2009, 2010) and Moreira and Machado (in press) interpret the Odivelas Limestone as a reef system developed around the top of volcanoes like atolls, in shallow environments. On the volcanic edifices flanks, coeval peri-reef sedimentation occurred related to dismantled reef structures, represented by calciturbite facies.

At the same time, in the Central Domains of the OMZ, the Silurian euxinic sedimentation gives rise to Early Devonian flyschoid, deposited in the Terena syn-tectonic basin (Fig. 8B). The genesis of this basin is probably conditioned by N-S to NNW-SSE recumbent folds, developed during the earlier episodes of Variscan chain edification (Exposito *et al*., 2002; Borrego *et al*., 2005; Araújo *et al*., 2013; Moreira *et al*, 2014a; 2014b). This fact could also explain the anomalous geometry of this trench, with N-S trend in its central segment, and that should have conditioned the shape of the Terena Syncline (Rocha *et al*., 2009; Araújo *et al*., 2013).

The turbiditic nature of Terena Formation with basal facies variation (coarse-grained in the South and fine-grained in the North), the absence of strain accommodation during the first deformation phase and the presence of syn-tectonic sedimentation (with remobilized volcanics and Silurian sedimentary rocks) show that the deposition of this Formation was conditioned by the presence of an active orogenic environment in the SW of the OMZ (Fig. 8B; Borrego *et al*., 2005; 2006; Borrego, 2009; Araújo *et al*., 2013 and references therein). Also the geochemical data in greywackes from the Terena Formation (Borrego *et al*., 2006; Borrego, 2009) indicates a probable volcanic arc and a recycling orogen provenance for these siliciclastic lithotypes. The proximal Devonian subduction related volcanic-arc magmatism was partially obliterated by BIC, Carboniferous in age (e.g. Jesus *et al*., 2007). The Rebolado Basalts can be considered as relics of OMZ proximal early volcanic arc preserved within BIC.

The significance of Late Silurian-Devonian limestones in the Estremoz-Ferrarias-Barrancos axis are unknown and its spatial association with bimodal magmatic rocks and intense fracturing and fluid circulation its clear, being deformed during D_2 episode. Several hypotheses must be considered:

- they represent (Early?) Devonian discontinuous reef structures developed in the North of the Terena basin, being associated to volcanism. Although the fossiliferous record is fragmentary, preventing its age and stratigraphic precise control, the isotope fingertprint of these limestones are clearly distinct from Odivelas Limestone (Moreira *et al*., 2016), which seems to show that they are not similar in age;
- they represent the Late Silurian-Early Devonian Limestones, similar to *Scyphocrinites* Limestones, Pridoli-Lochkovian in age, described in Valle and Cerrón del Hornillo synclines (Lenz *et al*., 1996; Gutiérrez-Marco and Robardet, 2004). The spatial disposition is not totally concordant with this hypothesis, because in Barrancos, they are spatially associated to Monte das Russianas Formation and the described stratigraphic sequence from Early Silurian until Emsian are continuous and well controlled based on paleontological content (Piçarra, 2000);
- they are olistholiths, remobilized during early deformation episodes, which includes Late Silurian-Devonian limestones and bimodal magmatic rocks, being associated to breccias. In this case, two possibilities arise: (a) they represent an intraformational breccia within the Terena Basin, as described by Bard (1965) in Alamo Breccia (Robardet and Gutiérrez-Marco, 2004) or (b) they are included in a non-described unit, which could be discordant over the Cambrian to Devonian Formations, or;
- they represent Late Devonian to Early Carboniferous limestones, which are described in some Carboniferous basins in North and Central Domains of the OMZ, as in Santos de Maimona or Guadiato (Azor *et al*., 2004; Armendáriz *et al*., 2008) basins and in Valle and Cerron del Hornillo synclines.

Although, all these possibilities could be tested, none of them could be excluded at this time. However, the most probable hypotheses are (a) the presence of Early Devonian discontinuous reef structures developed at north of Terena Basin, which is also compatible to the existence of carbonated cement of Monte das Russianas Formation sandstones (North of Terena Basin), and (b) the remobilized nature of these limestones, being contained in a non-mature syn-tectonic unit. It is important to emphasize, that the Bencatel-Ferrarias-Barrancos alignement (Fig. 6A), in Spain, intersects the Villanueva del Fresno and Cheles limestones, interpreted as Cambrian klippes related to D_1 fold and thrust episodes (Vegas and Moreno, 1973; Moreno and Vegas, 1976). This seems to indicate that these limestones could also be remobilized (possibly sedimentary). In both hypothesis, the presence of these limestones seems to constrain temporally the beginning of deformation episodes as Early Devonian.

A Middle Devonian gap is described in the OMZ (Oliveira *et al.*, 1991; Robardet and Gutiérrez-Marco, 1990; 2004), with the exception of the Eifelian-Givetian Odivelas and Pedreira de Engenharia Limestone (Boogaard, 1972; Machado *et al.*, 2009; 2010; Moreira and Machado, in press). This could be interpreted as related to a generalized uplift of OMZ during this period, possibly related to the subduction process, creating a regional scale hiatus, in some cases marcated by an angular unconformity or a paraconformity.

The metamorphic and structural pattern during Devonian times is clearly controlled by the SW Iberian Oceanic Suture and the 1st order TBCSZ. Indeed, in the South Domain, near the suture, a HP-LT path is recorded, reaching eclogite facies conditions (e.g. Fonseca *et al.*, 1999; Booth-Rea *et al.*, 2006; Pedro *et al.*, 2013; Rubio Pascual *et al.*, 2013). Geochronological data limits the baric peak of this HP-LT metamorphism at 370 Ma (Moita *et al.*, 2005b), materializing an active subduction process (Fig. 8B and 8C).

The majority of HP metamorphic rocks are spatially associated to the Moura-Cubito Phyllonitic Complex, interpreted as an imbricated complex resulting from the emplacement of this pile of slivers as a consequence of the progression of subduction / obduction process that generates the SW Iberian ophiolite complexes (Araújo *et al.*, 2005; 2013; Ribeiro *et al.*, 2010).

The age of the HP metamorphic rocks contained in Moura-Cubito Phyllonitic complex is poorly constrained. As a Late Devonian age was obtained in Alvito and Safira HP metamorphic rocks (Moita *et al.*, 2005b) and the Odivelas Limestones (Early-Middle Devonian in age) are also affected by top-to-north thrusts (Moreira *et al.*, 2010), the emplacement of ophiolite complexes and, consequently, the Moura-Cubito Phyllonitic Complex, must also be Middle-Late Devonian (Fig. 8C). On top of Moura-Cubito Phyllonitic Complex, the Mississippian Toca da Moura-Cabrela Complexes are deposited (Araújo *et al.*, 2005; 2013). This constrain the maximum age for the installation of the Phyllonitic Complex as pre-Carboniferous, which is compatible with the absence of early deformation episodes in Toca da Moura and Cabrela Carboniferous Complexes (Ribeiro, 1983; Oliveira *et al.*, 2013b). The emplacement of the Moura-Cubito Phyllonitic Complex could be related with the last subduction pulses of the SW Iberia Variscan Ocean and, consequently, the beginning of the collision process during Mississippian (e.g. Moreira *et al.*, 2014a).

In the North Domain of the OMZ, the TBCSZ is responsible by the strain accommodation of early Variscan deformation. Geochronological data show that during Devonian times this lithospheric scale shear zone was active (at least since 390-380 Ma; García Casquero *et al.*, 1988; Quesada and Dallmeyer, 1994; Pereira *et al.*, 2012c), as a sinistral transpressive intra-continental shear zone (Fig. 8B and 8C; Ribeiro *et al.*, 2009). The recumbent folds and thrusts with transport to SW-W quadrant of the Central Domain roots in this lithospheric scale shear zone.

During Late Devonian times (Fig. 8D), in the Central Domain of the OMZ, a calc-alkaline to shoshonitic magmatism was established, preserved in the Veiros-Vale Maceira and Campo Maior Massifs (Costa *et al.*, 1990; Moita *et al*, 2005a; Carrilho Lopes *et al.*, 2005). This suggests that volcanic-arc magmatism related to subduction activity should have migrated to the North and extends until Upper Devonian (ca. 365 Ma), as suggested by the age of the shoshonitic magmatism (Moita *et al.*, 2005a; Carrilho Lopes *et al.*, 2005; Araújo *et al.*, 2013).

Indeed, the subduction of the SW Iberia Variscan Ocean beneath the Iberian Autochthonous Terrane (North Gondwana Margin) should have polarity to the North (current coordinates), with proximal tholeiitic to calc-alkaline volcanic-arc represented by the Rebolado Basalts and the distal shoshonitic volcanism represented by Veiros-Vale Maceira and Campo Maior Massifs.

Thus, the Rebolado basalts, the Veiros-Vale Maceira and the Campo Maior Massifs represent relics of early volcanic arc magmatism in the OMZ. Part of this earlier Variscan magmatism, associated to the first episodes of the Variscan Orogeny, was obliterated (eroded or melted?) during Carboniferous times. Some indirect evidences of Devonian magmatic episode are also preserved through Early to Late Devonian detrital zircons present in Early Carboniferous syn-orogenic basins in OMZ and in SPZ (Braid *et al.*, 2011; Pereira *et al.*, 2012b; 2013; Rodrigues *et al.*, 2015; Pérez-Cáceres *et al.*, 2016b).

While in OMZ the generation of HP-LT metamorphic rocks and the volcanic-arc are a consequence of subduction progression, to the South of suture zone (now marked by Ferreira-Ficalho-Almonaster Shear zone) begins the deposition of siliciclastic sediments, generating an accretionary prism. The Middle-Late Devonian uplift of the orogenic chain induces the erosional processes that will feed these basin. These sediments could be represented in Pulo do Lobo Domain by the Early Frasnian Ribeira de Limas and Atalaia Formations and by Pulo do Lobo

Formation, older than previous ones, but with unconstrained age (Oliveira *et al.*, 1991; 2013; Pereira *et al.*, 2006b). However, some authors attribute an exotic nature to the Pulo do Lobo Domain, being still a matter of debate (e.g. Braid *et al.*, 2011).

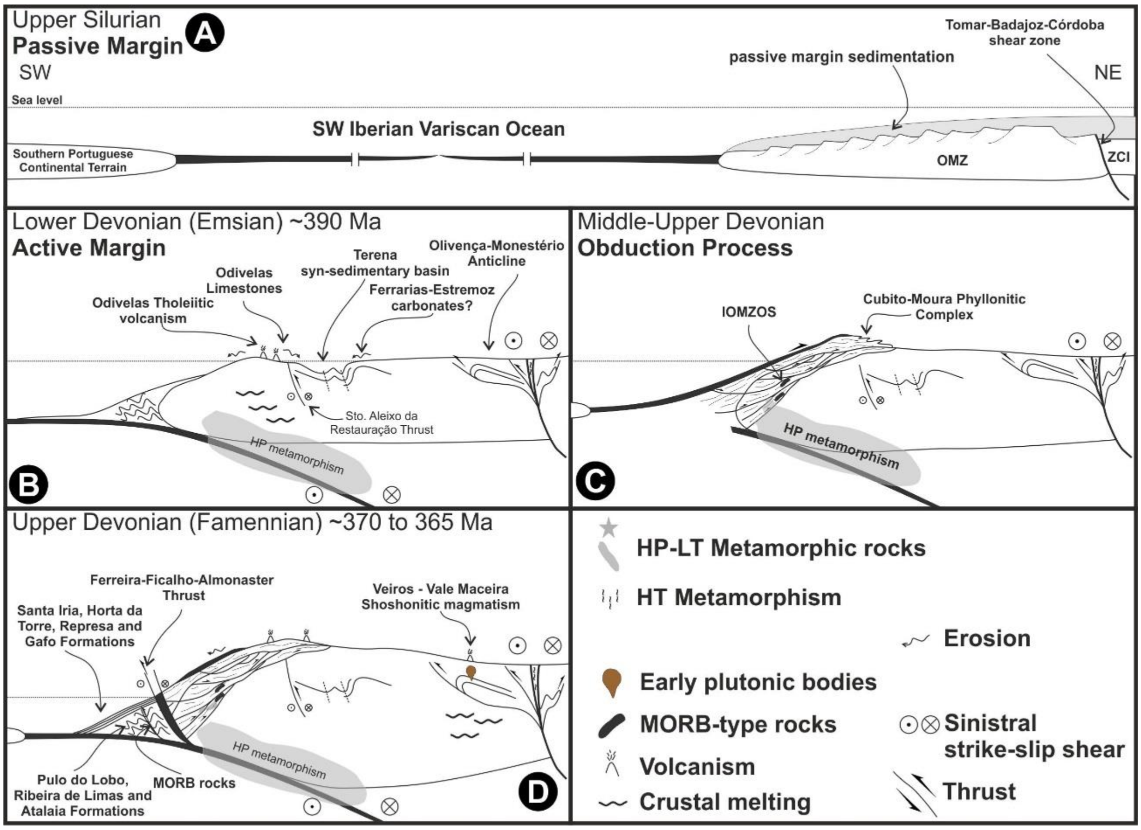

Figure 8 – Geodynamic evolution of OMZ during last episodes of passive margin setting (A) and early convergent phases of the Variscan Cycle (B to D).

With the evolution of the subduction, these sedimentary units were buried, deformed and metamorphosed. These lowermost formations attained higher metamorphic grade conditions, presenting multiphase deformation episodes in comparison with the top ones, as expected in an accretionary prism (Fig. 8D; Eden, 1991; Ribeiro *et al.*, 2007, 2010). The early deformation phases preserved in all these metasedimentary flysch-like sequences took place before Middle-Late Famennian (Oliveira *et al.*, 1991; 2013a). The Santa Iria, Horta da Torre, Represa and Gafo Formations, with Famennian age, cover unconformably the previous ones, constraining the early deformation episode (Oliveira *et al*, 2013a and references therein). These data are compatible with a subduction beginning at Early Devonian times.

V.2.7. Final Remarks

The review of data shows the presence of early deformation processes during Devonian times, being interpreted as related to subduction of the SW Iberia Variscan Ocean. This subduction probably initiated during Early Devonian times, more precisely during early Pragian times (ca. 410 Ma). The subduction related processes was active until the Late Devonian (latest Famennian). During Famennian-Tournaisian times (ca. 360-355 Ma) a change of sedimentation, magmatism and type of metamorphism took place (Quesada *et al*., 1990; Quesada, 1990; Oliveira *et al*., 1991), which could be interpreted as the result of a transitional step between subduction and the beginning of collisional processes.

During Devonian a North forward migration of volcanic-arc magmatism is expressed, being in agreement with spatial disposition of metamorphic rocks, with HP rocks near the suture, in South Domain of OMZ. The almost absence of Middle Devonian sedimentary rocks is in agreement with general uplift of OMZ, having started yet in Early Devonian times, as reported by stratigraphic record.

The Devonian oblique subduction generates a general sinistral transpressive regime (Oliveira *et al*., 1991; Dias *et al*., 2016; Pérez-Cáceres *et al*., 2016a), which is responsible by the reactivation of TBCSZ as a sinistral transpressive structure with intense strain partition in a thick-skin regime (Ribeiro *et al*., 2009). The SW thrusting and early recumbent folds developed during early deformation episodes in Central Domains could be related with the previous mentioned general framework.

References

Abalos, B., Cusí, J. D. (1995). Correlation between seismic anisotropy and major geological structures in SW Iberia: a case study on continental lithosphere deformation. Tectonics, 14, 1021-1040. DOI: 10.1029/95TC01204

Andrade, A., Pinto, A., Conde, L. (1976). Sur la géologie du Massif de beja: Observations sur la transversale d`Odivelas. Comun. Serv. Geol. Portugal, 60, 171-202.

Andrade, A.A.S. (1983). Contribution à l'analyse de la suture hercynienne de Beja (Portugal): perspectives métallogéniques. Laboratoire de Métallogénie I Nancy, Institut National Polytechnique de Lorraine. PhD thesis, 137 p.

Apalategui, O., Quesada, C. (1987). Transversal geologica Zona Ossa-Morena. Field trip Guidebook, 90p.

Apalategui, O., Contreras Vázquez, F., Eguiluz, L., (1987). Mapa Geologico de España escala 1: 50.000. Hoja N° 918 (Sant Olalla del Cala) and memoria descritiva (1990). IGME.

Araújo, A., Fonseca, P., Munhá, J., Moita, P., Pedro, J., Ribeiro, A. (2005). The Moura Phyllonitic complex: An accretionary complex related with obduction in the Southern Iberia Variscan Suture. Geodin Acta, 18(5), 375-388. DOI: 10.3166/ga.18.375-388

Araújo, A., Piçarra, J., Borrego, J., Pedro, J., Oliveira, J.T. (2013). As regiões central e sul da Zona de Ossa-Morena. In: Dias, R., Araújo, A., Terrinha, P., Kullberg, J.C. (Ed.) Geologia de Portugal (Vol. I), Escolar Editora, Lisboa, 509-549

Armendáriz, M., López Guijarro, R., Quesada, C., Pin, C., Bellido, F. (2008). Genesis and evolution of a syn-orogenic basin in transpression: Insights from petrography, geochemistry and Sm–Nd systematics in the Variscan Pedroches basin (Mississippian, SW Iberia). Tectonophysics, 461, 395–413. DOI: 10.1016/j.tecto.2008.02.007

Azor, A., Expósito, F., González Lodeiro, F., Simancas, J.F., Martinez Poyatos, D. (2004). Sucesión sinorogénica. In: Vera, J.A. (Ed.) Geología de España, Sociedad Geologica de España, 172-173.

Bard, J.P. (1965). Introduction à la geologie de la chaine hercinienne dans la Sierra Morena occidentale (Espagne). Rev Geogr Phys Geol Dynam, 7 (4), 323-337.

Boogaard, M. (1972). Conodont faunas from Portugal and Southwestern Spain. Part 1: A Middle Devonian fauna from near Montemor-o-Novo. Scripta Geologica, 13, 1-11.

Boogaard, M. (1983). Conodont faunas from Portugal and southwestern Spain. Part 7. A Frasnian conodont fauna near the Estação de Cabrela (Portugal). Scripta Geologica, 69, 1-17.

Boogaard, M., Vazquez, F. (1981). Conodont faunas from Portugal and southwestern Spain. Part 5: Lower Carboniferous conodonts at Santa Olalla de Cala (Spain). Scripta Geologica, 61, 1-8.

Booth-Rea, G., Simancas, J.F., Azor, A., Azañón, J. M., González Lodeiro, F., Fonseca, P. (2006). HP–LT Variscan metamorphism in the Cubito-Moura schists (Ossa-Morena Zone, southern Iberia). C. R. Geosci., 338, 1260– DOI: 10.1016/j.crte.2006.08.001

Borrego, J., Araújo, A., Fonseca, P., Ribeiro, M. A. (2006). Estudos de Proveniência em litologias detríticas do Sinclinal de Terena (ZOM): tectónica e evolução geodinâmica durante o Silúrico e o Devónico inferior. VII Congresso Nacional de Geologia, Estremoz (Portugal), abstract book, 53-56.

Borrego, J., Araújo, A., Fonseca, P.E. (2005). A geotraverse through the south and central sectors of the Ossa-Morena Zone in Portugal (Iberian Massif). In: Carosi, R., Dias, R., Iacopini, D., Rosenbaum, G. (Ed.) The southern Variscan belt, J. Virtual Explorer, 19, 10. DOI: 10.3809/jvirtex.2005.00117

Borrego, J. (2009). Cartografia Geológico-Estrutural de um sector da Zona de Ossa-Morena (Subsector de Estremoz – Barrancos-Ficalho) e sua interpretação Tectónica. PhD Thesis (unpublished), Évora University, Portugal, 479 p.

Braid, J.A., Murphy, J.B., Quesada, C., Mortensen, J. (2011). Tectonic escape of a crustal fragment during the closure of the Rheic Ocean: U–Pb detrital zircon data from the Late Palaeozoic Pulo do Lobo and South Portuguese zones, southern Iberia. J Geol Soc London 168:383-392. DOI: 10.1144/0016-76492010-104

Burg, J. P., Iglesias, M., Laurent, P., Matte, P., Ribeiro, A. (1981). Variscan intracontinental deformation: the Coimbra-Córdoba Shear zone (SW Iberian Peninsula). Tectonophysics, 78, 161-177. DOI: 10.1016/0040-1951(81)90012-3

Carrilho Lopes, J., Munhá, J., Tassinari, C., Pin C. (2005). Petrologia e Geocronologia (Sm-Nd) do Maciço de Campo Maior (Alentejo, Portugal Central). Comunicações Geológicas, 92, 05-30.

Coelho, A., Gonçalves, F. (1970). Rocha hiperalcalina de Estremoz. Bol. Soc. Geol. Portugal, XVII, 181-185.

Conde, L.N., Andrade, A.A.S. (1974). Sur la faune meso et/ou néodévonienne des calcaires du Monte das Cortes, Odivelas (Massif de Beja). Memórias e Notícias, Univ. Coimbra, 78, 141-146.

Costa, D., Viana, A., Munhá, J. (1990). Petrologia e geoquímica dos maciços de Veiros e Vale Maceira. In: Abstrats of the VIII Semana de Geoquímica, Lisboa.

Dias, R., Ribeiro, A., Romão, J., Coke, C., Moreira, N. (2016). A review of the Arcuate Structures in the Iberian Variscides; Constraints and Genetic Models. Tectonophysics, 681C, 170-194. DOI: 10.1016/j.tecto.2016.04.011

Eden, C. (1991). Tectonostratigraphic analysis of the northern extent of the oceanic exotic terrane, northwestern Huelva province, Spain. PhD Thesis, University of Southampton, 223 p.

Expósito, I., Simancas, J. F., González Lodeiro, F., Azor, A., Martínez Poyatos D. J. (2002). Estructura de la mitad septentrional de la zona de Ossa-Morena: Deformación en el bloque inferior de un cabalgamiento cortical de evolución compleja. Rev. Soc. Geol. Esp., 15, 3–14.

Fonseca, P., Fonseca, M., Munhá, J. (2004). Ocorrência de Aragonite em Mármores da Região de Alvito-Viana do Alentejo (Zona de Ossa Morena): Significado geodinâmico. Cad. Lab. Xeo. Laxe, 29, 79-96.

Fonseca, P., Munhá, J., Pedro, J., Rosas, F., Moita, P., Araújo, A., Leal, N. (1999). Variscan Ophiolites and High-Pressure Metamorphism in Southern Ibéria. Ophioliti, 24(2), 259-268. DOI: 10.4454/ofioliti.v24i2.106

García Casquero, J.L., Priem, H.N.A.I., Boelrijk, N.A.I.M., Chacón, J. (1988). Isotopic dating of the mylonitization of the Azuaga Group in the Badajoz-Córdoba belt, SW Spain. Geol. Rundsch. 77(2), 483-489. DOI: 10.1007/BF01832393

García-Alcalde J. L., Carls P., Pardo Alonso M. V., Sanz López J., Soto F., Truyols-Massoni M., Valenzuela-Ríos J. (2002). Devonian. In: Gibbons W., Moreno T. (eds) The Geology of Spain. Geological Society, London, 67–91.

Giese, U., Hoegen, R. von, Hollmann, G., Walter, R. (1994). Geology of the southwestern Iberian Meseta I. The Palaeozoic of the Ossa-Morena Zone north and south of the Olivenza-Monesterio Anticline (Huelva province, SW Spain). Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, 192, 293-331.

Gonçalves, F. (1972). Geological Map of Portugal, scale 1:50 000, 36-B (Estremoz), Serviços Geológicos de Portugal, Lisboa.

Gutiérrez-Marco, J.C., and Robardet, M. (2004). Ordovícico-Silúrico-Devónico inferior. In: Vera, J.A. (Eds.) Geología de España, Sociedad Geologica de España, 170-172.

Jesus, A.P., Munhá, J., Mateus, A., Tassinari, C., Nutman, A.P. (2007). The Beja layered gabbroic sequence (Ossa-Morena Zone, Southern Portugal): geochronology and geodynamic implications. Geodin Acta, 20, 139-157. DOI: 10.3166/ga.20.139-157

Jesus, A.P., Mateus, A., Munhá, J.M., Tassinari, C.G.C., Bento dos Santos, T.M., Benoit, M. (2016). Evidence for underplating in the genesis of the Variscan synorogenic Beja Layered Gabbroic Sequence (Portugal) and related mesocratic rocks. Tectonophysics, 683(30), 148-171. DOI: 10.1016/j.tecto.2016.06.001

Lenz, A.C., Robardet, M., Gutierrez-Marco, J.C., Picarra, J.M. (1996). Devonian graptolites from southwestern Europe: a review with new data. Geological Journal, 31, 349-358. DOI: 10.1002/(SICI)1099-1034(199612)31:4<349::AID-GJ714>3.0.CO;2-K

Linnemann, U., Pereira, M.F., Jeffries, T., Drost, K., Gerdes, A. (2008). Cadomian Orogeny and the opening of the Rheic Ocean: new insights in the diacrony of geotectonic processes constrained by LA–ICP–MS U–Pb zircon dating (Ossa-Morena and Saxo-Thuringian Zones, Iberian and Bohemian Massifs). Tectonophysics, 461, 21–43. DOI: 10.1016/j.tecto.2008.05.002

LNEG (2010). Geological map of Portugal at 1:1.000.000, 3rd edition, Laboratório Nacional de Energia e Geologia, Lisboa.

Lopes, J.L. (2003). Contribuição para o conhecimento Tectono-Estratigráfico do Nordeste Alentejano, transversal Terena-Elvas. Implicações económicas no aproveitamento de rochas ornamentais existentes na região (Mármores e Granitos). PhD Thesis (unpublished), Évora University, Portugal 568 p.

Machado, G., Hladil, J. (2010). On the age and significance of the limestone localities included in the Toca da Moura volcano-sedimentary Complex: preliminary results. In: Santos A, Mayoral E, Melendez G, Silva CMD, Cachão M (Ed), III Congresso Iberico de Paleontologia / XXVI Jornadas de la Sociedad Espanola de Paleontologia, Lisbon, Portugal. Publicaciones del Seminario de Paleontologia de Zaragoza, 9, 153-156.

Machado, G., Hladil, J., Koptikova, L., Fonseca, P.E., Rocha, F.T., Galle, A. (2009). The Odivelas Limestone: Evidence for a Middle Devonian reef system in western Ossa-Morena Zone. Geol Carpath, 60(2), 121-137.

Machado, G., Hladil, J., Koptikova, L., Slavik, L., Moreira, N., Fonseca, M., Fonseca, P.E. (2010). An Emsian-Eifelian Carbonate-Volcaniclastic Sequence and the possible Record of the basal choteč event in western Ossa-Morena Zone, Portugal (Odivelas Limestone). Geol Belg,, 13, 431-446.

Matte, P. (2001). The Variscan collage and orogeny (480-290 Ma) and the tectonic definition of the Armorica microplate: a review. Terra Nova, 13, 122-128. DOI: 10.1046/j.1365-3121.2001.00327.x

McArthur, J.M., Howarth, R.J., Shields, G.A. (2012). Strontium Isotope Stratigraphy. In: Gradstein FM, Ogg JG, Schmotz MD, Ogg GM (Ed), A Geologic Time Scale 2012 (Chapter 7), Elsevier, 127-144.

Moita, P., Munhá, J., Fonseca, P.E., Tassinari, C., Araújo, A., Palácios, T. (2005a). Dating orogenic events in Ossa-Morena Zone. In: Abstract of the XIV Semana de Gequimica/VIII Congresso de geoquimica dos Paises de Lingua Portuguesa, Aveiro, 2, 459-461.

Moita, P., Munhá, J., Fonseca, P., Pedro, J., Tassinari, C., Araújo, A., Palacios, T. (2005b). Phase equilibria and geochronology of ossa morena eclogites. In: Abstracts of the XIV Semana de Gequimica/VIII Congresso de geoquimica dos Paises de Lingua Portuguesa, Aveiro, 2, 471-474.

Moreira, N., Machado, G. (in press). Devonian sedimentation in Western Ossa-Morena Zone and its geodynamic significance. In Quesada. C., Oliveira, J.T. (Eds.), The Geology of Iberia: a geodynamic approach. Springer (Berlin), Regional Geology Review series.

Moreira, N., Machado, G., Fonseca, P.E., Silva, J.C., Jorge, R.C.G.S., Mata, J. (2010). The Odivelas Palaeozoic volcano-sedimentary sequence: Implications for the geology of the Ossa-Morena Southwestern border. Comunicações Geológicas, 97, 129-146.

Moreira, N., Pedro, J., Dias, R., Ribeiro, A., Romão, J. (2011). Tomar-Badajoz-Córdoba shear zone in Abrantes sector; the presence of a kilometric sheath fold?. Deformation mechanisms, Rheology and Tectonics, DRT 2011 Meeting, Oviedo, Espanha, 90.

Moreira, N., Araújo, A., Pedro, J., Dias, R. (2014a). Evolução geodinâmica da Zona de Ossa-Morena no contexto do SW Ibérico durante o Ciclo Varisco. Comunicações Geológicas, 101 (I), 275–278.

Moreira, N., Dias, R., Pedro, J.C., Araújo, A. (2014b). Interferência de fases de deformação Varisca na estrutura de Torre de Cabedal; sector de Alter-do-Chão – Elvas na Zona de Ossa-Morena. Comunicações Geológicas, 101 (I), 279-282.

Moreira, N., Pedro, J., Santos, J.F., Araújo, A., Romão, J., Dias, R., Ribeiro, A., Ribeiro, S., Mirão, J. (2016). 87Sr/86Sr ratios discrimination applied to the main Palaeozoic carbonate sedimentation in Ossa-Morena Zone. In: IX Congreso Geológico de España (special volume). Geo-Temas, 16(1), 161-164. ISSN 1576-5172.

Moreno, F., Vegas, R. (1976). Tectónica de las séries ordovícias y siluricas en la región de Villanueva del Fresno. Estudios geológicos, 32, 47-52.

Nance, R.D., Gutierrez-Alonso, G., Keppie, J.D., Linneman, U., Murphy, J.B., Quesada, C., Skrachan, R; Woodcock, V., (2012). A brief history of the Rheic Ocean. Geoscience Frontiers, 3(2), 125- 135. DOI: 10.1016/j.gsf.2011.11.008

Oliveira, J.T., Oliveira, V., Piçarra, J. (1991). Traços gerais da evolução tectono-estratigráfica da Zona de Ossa-Morena, em Portugal. Comun. Serv. Geol. Portugal, 77, 3-26.

Oliveira, J. T., Relvas, J., Pereira, Z. Matos, J., Rosa, C. Rosa, D. Munhá, J. Fernandes, P. Jorge, R., Pinto, A. (2013a). Geologia da Zona Sul Portuguesa, com ênfase na estratigrafia, vulcanologia física, geoquímica e mineralizações da Faixa Piritosa. In: Dias, R., Araújo, A., Terrinha, P., Kullberg, J.C. (Ed.), Geologia de Portugal (Vol. I), Escolar Editora, Lisboa, 673-765.

Oliveira, J.T., Relvas, J., Pereira, Z., Munhá, J., Matos, J., Barriga, F., Rosa, C. (2013b). O Complexo Vulcano-Sedimentar de Toca da Moura-Cabrela (Zona de Ossa Morena): evolução tectono-estratigráfica e mineralizações associadas. In: Dias, R., Araújo, A., Terrinha, P., Kullberg, J.C. (Ed.), Geologia de Portugal (Vol. I), Escolar Editora, Lisboa, 621-645.

Palacios González, M.J., Palacios, T., Gómez Valenzuela, J.M. (1990). Trilobites y goniatited de la cuenca carbonífera de los Santos de Maimona: deducciones bioestratigráficas. Geogaceta, 8, 66-67.

Pedro, J.C., Araújo, A., Tassinari, C., Fonseca, P.E., Ribeiro, A. (2010). Geochemistry and U-Pb zircon age of the Internal Ossa-Morena Zone Ophiolite Sequences: a remnant of Rheic Ocean in SW Iberia. Ofioliti, 35(2), 117-130. DOI: 10.4454/ofioliti.v35i2.390

Pedro, J., Araújo, A., Fonseca, P., Munhá, J., Ribeiro, A., Mateus, A. (2013). Cinturas Ofiolíticas e Metamorfismo de Alta Pressão no Bordo SW da Zona de Ossa-Morena. In: Dias, R., Araújo, A., Terrinha, P., Kullberg, J.C. (Ed.), Geologia de Portugal (Vol. I), Escolar Editora, Lisboa, 647-671.

Perdigão, J.C., Oliveira, J.T., Ribeiro, A. (1982). Notícia explicativa da folha 44-B (Barrancos) da Carta Geológica de Portugal à escala 1:50 000, Serviços Geológicos de Portugal, Lisboa.

Pereira, M.F., Solá, A.R., Chichorro, M., Lopes, L., Gerdes, A., Silva, J.B. (2012a). North-Gondwana assembly, break up and paleogeography: U–Pb isotope evidence from detrital and igneous zircons of Ediacaran and Cambrian rocks of SW Iberia. Gondwana Res, 22(3–4), 866-881. DOI: 10.1016/j.gr.2012.02.010

Pereira, M.F., Chichorro, M., Johnston, S.T., Gutiérrez-Alonso, G., Silva, J.B., Linnemann, U., Drost, K. (2012b). The missing Rheic Ocean magmatic arcs: Provenance analysis of Late Palaeozoic sedimentary clastic rocks of SW Iberia. Gondwana Res, 22(3-4), 882-891. DOI: 10.1016/j.gr.2012.03.010

Pereira, M.F., Silva, J.B., Chichorro, M., Ordóñez-Casado, B., Lee, J.K.W., Williams, I.S. (2012c). Early Carboniferous wrenching, exhumation of high-grade metamorphic rocks and basin instability in SW Iberia: constraints derived from structural geology and U-Pb and 40Ar-39Ar geochronology. Tectonophysics, 558-559, 28-44. DOI: 10.1016/j.tecto.2012.06.020

Pereira, M.F., Ribeiro, C., Vilallonga, F., Chichorro, M., Drost, K., Silva, J.B., Albardeiro, L., Hofmann, M., Linnemann, U. (2013). Variability over time in the sources of South-Portuguese Zone turbidites: evidence of denudation of different crustal blocks during the assembly of Pangaea. International Journal of Earth Sciences, 103 (5), 1453-1470. DOI: 10.1007/s00531-013-0902-8

Pereira, M.F., Chichorro, M., Lopes, C., Solá, A.R., Silva, J.B., Hofmann, M., Linnemann, U. (2014). Provenance analysis of Lower Palaeozoic siliciclastic rocks of SW Iberia (Ossa-Morena Zone): distal shelf deposition in the North Gondwanan passive margin. In: Rocha, P., Pais, J., Kullberg, J.C., Finney, S. (Eds.), First International Congress on Stratigraphy – At the cutting edge of Stratigraphy. STRATI2013, Elsevier, 747-751. DOI: 10.1007/978-3-319-04364-7_141

Pereira, Z., Oliveira, J.T. (2003). Estudo palinostratigráfico do sinclinal da Estação de Cabrela. Implicações tectonostratigráficas. Cienc. Terra UNL Lisboa, 5, 118–119.

Pereira, Z., Piçarra, J.M., Oliveira, J.T. (1999). Lower Devonian palynomorphs from the Barrancos region, Ossa Morena Zone, Portugal. Bolletino della società paleontologica italiana, 38 (2-3), 239-245.

Pereira, Z., Oliveira, V., Oliveira, J.T. (2006a). Palynostratigraphy of the Toca da Moura and Cabrela Complexes, Ossa Morena Zone, Portugal. Geodynamic implications. Rev Palaeobot Palyno, 139, 227-240. DOI: 10.1016/j.revpalbo.2005.07.008

Pereira, Z., Oliveira, V., Oliveira, J.T. (2006b). Palynostratigraphy of the Toca da Moura and Cabrela Complexes, Ossa Morena Zone, Portugal. Geodynamic implications. Review of Palaeobotany and Palynology, 139, 227-240. DOI: 10.1016/j.revpalbo.2005.07.008

Pérez-Cáceres, I., Simancas, J.F., Martínez Poyatos, D., Azor, A., Lodeiro, F.G. (2016a). Oblique collision and deformation partitioning in the SW Iberian Variscides. Solid Earth, 7, 857–872. DOI: 10.5194/se-7-857-2016

Pérez-Cáceres, I., Poyatos, D.M., Simancas, J.F., Azor, A. (2016b). Testing the Avalonian affinity of the South Portuguese Zone and the Neoproterozoic evolution of SW Iberia through detrital zircon populations, Gondwana Research. DOI:10.1016/j.gr.2016.10.010

Piçarra, J.M., Le Meen, J. (1994). Ocorrência de crinóides em mármores do Complexo Vulcano-Sedimentar Carbonatado de Estremoz: implicações estratigráficas. Comunicações do Instituto Geológico e Mineiro, 80, 15-25

Piçarra, J.M., Gutiérrez-Marco, J. C., Sarmiento, G. N., Rábano, I. (2009). Silurian of the Barrancos-Hinojales domain of SW Iberia: a contribution to the geological heritage of the Barrancos area (Portugal) and the Sierra de Aracena-Picos de Aroche Natural Park (Spain), in: Corriga, M.G., Piras, S. (Eds.), Time and Life in the Silurian: a multidisciplinary approach. Rendiconti della Società Paleontologica Italiana, 3 (3), 321-322.

Piçarra, J.M., Sarmiento, G.N., Gutiérrez-Marco, J.C. (2014). Geochronological vs. Paleontolgical dating of the Estremoz Marbles (OMZ)-new data and reappraisal. Gondwana 15 conference, Madrid. Abstract book. 140.

Piçarra, J.M. (2000). Stratigraphical study of the Estremoz-Barrancos sector, Ossa-Morena Zone, Portugal. Middle Cambrian?-Lower Devonian Lithostratigraphy and Biostratigraphy. PhD Thesis (unpublished), Évora University, vol.1, 268p.

Piçarra, J.M., Sarmiento, G. (2006). Problemas de posicionamento estratigráfico dos Calcários Paleozóicos da Zona de Ossa Morena (Portugal). In: Abstract book of the VII Congresso Nacional de Geologia, vol. II, 657-660.

Pin, C., Fonseca, P.E., Paquette, J.L., Castro, P., Matte, Ph. (2008). The ca. 350 Ma Beja Igneous Complex: a record of transcurrent slab break-off in the Southern Iberia Variscan Belt? Tectonophysics, 461, 356–377. DOI: 10.1016/j.tecto.2008.06.001

Ponce, C., Simancas, J.F., Azor, A., Martínez Poyatos, D., Booth-Rea, G., Expósito, I. (2012). Metamorphism and kinematics of the early deformation in the Variscan suture of SW Iberia, J. Metamorph. Geol., 30, 625–638. DOI: 10.1111/j.1525-1314.2012.00988.x

Quesada, C. (1990). Introduction of the Ossa-Morena Zone (part V). In: Dallmeyer, R.D., Martínez García, E. (Ed.), Pre-Mesozoic geology of Iberia, Springer-Verlag, Berlin, 249-251.

Quesada, C. (1991). Geological constraints on the Paleozoic tectonic evolution of tectonostratigraphic terranes in the Iberian Massif. Tectonophysics, 185, 225-245. DOI: 10.1016/0040-1951(91)90446-Y

Quesada, C., Dallmeyer, R.D. (1994). Tectonothermal evolution of the Badajoz-Cordóba shear zone (SW Iberia): characteristics and 40Ar/ 39Ar mineral age constraints. Tectonophysics, 231, 195-213. DOI: 10.1016/0040-1951(94)90130-9

Quesada, C., Robardet, M., Gabaldón, V. (1990). Synorogenic phase (Upper Devonian-Carboniferous- Lower Permian). In: Dallmeyer, R.D., Martínez, García E. (Ed.), Pre-Mesozoic geology of Iberia, Springer-Verlag, Berlin, 249-251.

Ribeiro, A. (1983). Relações entre formações do Devónico superior e o Maciço de Évora na região de Cabrela (Vendas Novas). Comun. Serv. Geol. Portugal, 69(2), 267-269.

Ribeiro, A., Munhá, J., Fonseca, P.E., Araújo, A., Pedro, J., Mateus, A., Tassinari, C., Machado, G., Jesus, A., (2010). Variscan Ophiolite Belts in the Ossa-Morena Zone (Southwest Iberia): geological characterization and geodynamic significance. Gondwana Res, 17, 408-421. DOI: 10.1016/j.gr.2009.09.005

Ribeiro, A., Munhá, J., Dias, R., Mateus, A., Pereira, E., Ribeiro, L., Fonseca, P., Araújo, A., Oliveira, T., Romão, J., Chaminé, H., Coke, C., Pedro, J. (2007). Geodynamic evolution of the SW Europe Variscides. Tectonics, 26(6). DOI: 10.1029/2006TC002058

Ribeiro, A., Munhá, J., Mateus, A., Fonseca, P., Pereira, E., Noronha, F., Romão, J., Rodrigues, J.F., Castro, P., Meireles, C., Ferreira, N. (2009). Mechanics of thick-skinned Variscan overprinting of Cadomian basement (Iberian Variscides). Comptes Rendus Geoscience, 341(2-3), 127-139. DOI: 10.1016/j.crte.2008.12.003

Robardet, M., Groos-Uffenorde, H. Gandl, J., Racheboeuf, P.R. (1991). Trilobites et Ostracodes du Dévonien Inferieur dela Zone D'Ossa-Morena (Espagne). Geobios, 24(3), 333-348.

Robardet, M., Gutiérrez-Marco, J.C. (1990). Passive margin phase (Ordovician-Silurian-Devonian). In: Dallmeyer RD, Martínez García E (Ed), Pre-Mesozoic geology of Iberia, Springer-Verlag, Berlin, 249-251.

Robardet, M., Gutiérrez-Marco, J.C. (2004). The Ordovician, Silurian and Devonian sedimentary rocks of the Ossa-Morena Zone (SW Iberian Peninsula, Spain). J Iber Geol, 30, 73-92.

Rocha, R., Araújo, A., Borrego, J., Fonseca, P. (2009). Transected folds with opposite patterns in Terena Formation (Ossa Morena Zone, Portugal): anomalous structures resulting from sedimentary basin anisotropies. Geodinamica Acta, 22(4), 157-163. DOI: 10.3166/ga.22.157-163

Rodrigues, B., Chew, D.M., Jorge, R.C.G.S., Fernandes, P., Veiga-Pires, C., Oliveira, J.T. (2015). Detrital zircon geochronology of the Carboniferous Baixo Alentejo Flysch Group (South Portugal); Constraints on the provenance and geodynamic evolution of the South Portuguese Zone, J. Geol. Soc. London. DOI: 10.1144/jgs2013-084.

Romão, J., Ribeiro, A., Pereira, E., Fonseca, P., Rodrigues, J., Mateus, A., Noronha, F., Dias R. (2010). Interplate versus intraplate strike-slip deformed belts: examples from SW Iberia Variscides. Trabajos de Geologia, Universidad Oviedo, 29, 671-677. DOI: 10.17811/tdg.30.2010.%25p

Rosas, F.M., Marques, F.O., Ballèvre, M., Tassinari, C. (2008). Geodynamic evolution of the SW Variscides: orogenic collapse shown by new tectonometamorphic and isotopic data from western Ossa-Morena Zone, SW Iberia, Tectonics 27, TC6008. DOI: 10.1029/2008TC002333

Rubio Pascual, F., Matas, J., Martín-Parra, L. (2013). High-pressure metamorphism in the Early Variscan subduction complex of the SW Iberian Massif. Tectonophysics 592, 187-199. DOI: 10.1016/j.tecto.2013.02.022

San-José, M.A., Herranz, P., Pieren, A. P. (2004). A review of the Ossa-Morena Zone and its limits. Implications for the definition of the Lusitan-Marianic Zone. J. Iber. Geol., 30, 7-22.

Sánchez-García, T., Bellido, F., Pereira, M.F., Chichorro, M., Quesada, C., Pin, C., Silva, J.B. (2010). Rift-related volcanism predating the birth of the Rheic Ocean (Ossa-Morena zone, SW Iberia). Gondwana Res., 17, 392–407. DOI: 10.1016/j.gr.2009.10.005

Santos, J.F., Andrade, A., Munhá, J. (1990). Magmatismo orogénico varisco no limite meridional da Zona de Ossa-Morena. Comun. Serv. Geol. Portugal, 76, 91-124.

Santos, J.F., Mata, J., Ribeiro, S., Fernandes, J., Silva, J. (2013). Sr and Nd isotope data for arc-related (meta) volcanics (SW Iberia), Goldschmidt Conference Abstracts, 2132.

Sarmiento, G.N., Piçarra, J.M., Oliveira, J.T. (2000). Conodontes do Silúrico (Superior?)-Devónico nos "Mármores de Estremoz", Sector de Estremoz-Barrancos (Zona de Ossa Morena, Portugal). Implicações estratigráficas e estruturais a nível regional. I Congresso Ibérico de Paleontologia/VIII International Meeting of IGCP 421 (abstract book), Évora, 284-285.

Silva, J.C., Mata, J., Moreira, N., Fonseca, P.E., Jorge, R.C.G.S., Machado, G. (2011). Evidence for a Lower Devonian subduction zone in the southeastern boundary of the Ossa-Morena-Zone. In: Absctracts of the VIII Congresso Ibérico de Geoquímica, Castelo Branco, 295-299.

Simancas, J.F, Carbonell, R., González Lodeiro, F., Pérez Estaún, A., Juhlin, C., Ayarza, P., Azor, A., Martínez Poyatos, D., Almodóvar, G.R., Pascual, E., Sáez, R., Kashubin, A., Alonso, F., Álvarez Marrón, J., Bohoyo, F., Castillo, S., Donaire, T., Expósito, I., Flecha, I., Galadí, E., Galindo Zaldívar, J., González, F., González Cuadra, P., Macías, I., Martí, D., Martín, A., Martín Parra, L.M., Nieto, J. M., Palm, H., Ruano, P., Ruiz, M., Toscano, M. (2004). The seismic crustal structure of the Ossa Morena Zone and its geological interpretation. Journal of Iberian Geology, 30, 133-142.

Vegas, R., Moreno, R. (1973). Sobre la tectónica del flanco meridional de la Antiforma de Burgillos (sur de la provincia de Badajoz). Estudios Geologicos, 29, 513-517.

Veizer, J., Ala, D., Azmy, K., Bruckschen, P., Buhl, D., Bruhn, F., Carden, G.A.F., Diener, A., Ebneth, S., Godderis, Y., Jasper, T., Korte, C., Pawellek, F., Podlaha, O.G., Strauss, H. (1999). 87Sr/86Sr, δ13C and δ18O evolution of Phanerozoic seawater. Chem Geol, 161, 59-88. DOI: 10.1016/S0009-2541(99)00081-9