Elementos traço característicos das unidades detríticas Paleozoicas da Zona de Ossa-Morena (Portugal): constrangimentos geodinâmicos

Trace element features of Palaeozoic detrital units of the Ossa-Morena Zone (Portugal): geodynamic constraints

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Resumo: O quimismo dos metassedimentos correspondentes às diferentes unidades litoestratigráficas detríticas do Paleozoico (Câmbrico a Devónico) do sector português da Zona de Ossa-Morena regista particularidades geoquímicas características do seu ambiente deposicional, o que permite tirar ilações relativas à evolução geodinâmica do Terreno Autóctone Ibérico durante o Ciclo Varisco. As relações entre vários elementos traço (essencialmente Nb/Ta, Zr/Hf, Th/U, La/Th-Sc e padrões normalizados de ETR) nas sucessões detríticas revelam que as diferentes formações derivam maioritariamente de uma fonte ácida continental, embora com particularidades que sugerem misturas com outras componentes sedimentares. As amostras representativas das unidades do Câmbrico, Ordovícico e Silúrico apresentam influências significativas de sedimentos típicos de margem continental passiva, enquanto as amostras do Devónico aparentam contribuições de arco oceânico com maior componente básica, o que poderá indicar uma transição do ambiente tectónico durante a sua deposição, ou seja, durante o Devónico inferior.
Assim, as formações Variscas ante-Devónicas podem ser interpretadas como resultantes da sedimentação derivada do desmantelamento progressivo de um soco continental (arco Cadomiano e terrenos Gondwanicos) em bacias geradas durante o episódio de estiramento crustal ocorrido durante o Câmbrico. Por outro lado, as unidades do Devónico Inferior podem corresponder a rochas metassedimentares resultantes do desmantelamento de um arco vulcânico (básico a intermédio), revelando a presença de uma margem ativa no SW da Zona de Ossa-Morena durante este período.

Palavras-chave: Litogeoquímica; Proveniência Siliciclástica; Unidades Detríticas; Zona de Ossa-Morena

Abstract: Chemical features regarding the different detrital lithostratigraphic Palaeozoic (Cambrian – Devonian) units from the Portuguese sector of the Ossa-Morena Zone regist geochemical aspects typical of their depositional environment, which allow inferences on the geodynamic evolution of the Iberian Authoctonous Terrain during the Variscan Cycle. Trace elements relationships (essentialy Nb/Ta, Zr/Hf, Th/U, La/Th-Sc and REE chondrite-normalized patterns) of the detrital succession reveal that the different formations derive mostly from an acid continental source, though with features that suggest mixed sedimentary components. Cambrian, Ordovician and Silurian representative samples show significative influences typical of passive margin sediments, while Devonian samples appear to have an oceanic arc contribution, with an increase in basic components, which may indicate a transition on the tectonic environment, during their deposition.
Ante-Devonian Variscan formations are therefore interpreted as representing debris deposition, derived from the progressive dismantling of a continental basement (Cadomian arc and Gondwana terranes), in sedimentary basins formed during the lower Cambrian crustal thinning episode. Contrastingly, Devonian units correspond to metasedimentary rocks derived from a dismembered (basic-intermediate) volcanic arc, revealing an active margin in the SW Ossa-Morena Zone during this period.

Keywords: Lithogeochemistry; Siliciclastic Provenance; Detrital Units; Ossa-Morena Zone

1. Introduction

Trace element geochemical data of detrital rocks may be a relevant tool to study the depositional environment, sedimentary sources and tectonic setting of siliciclastic units. Such methodologic approach is feasible because some trace elements do not tend to fractionate during physical and chemical weathering, mineral sorting during transport and diagenesis or regional metamorphism.

In the Ossa-Morena Zone (OMZ, SW Iberia), several metasedimentary and metavolcanic rock suites are defined and distinguished based on bio- and litho-stratigraphic correlations, structural features, zircon geochronological data and metavolcanic rocks lithogeochemistry (e.g. Robardet & Gutierrez Marco, 2004; Pereira et al., 2006; Sanchez Garcia et al., 2010; Araújo et al., 2013). However, geochemical data for the OMZ metasedimentary rocks are scarce.

In this study we verify if trace element geochemistry of the OMZ siliciclastic units corroborate previous geological and geochemical data on tectonic setting, and also we assess their provenance, consequently contributing to the knowledge of the geodynamic evolution of the OMZ and Iberian Variscides.

1.1. Geological Setting

The lower-middle Palaeozoic detrital suites of the OMZ consist in a succession of low-grade metasedimentary rocks, discordantly settled on top of the 'Série Negra' Neoproterozoic basement (Oliveira et al., 1991; Araújo et al., 2013, and references therein).

Structural and stratigraphic studies distinguished several lithostratigraphic formations in the Portuguese tectono-stratigraphic sectors of the OMZ, which can be organized in a simplified OMZ lithostratigraphic succession, as represented in Fig. 1.

2. Methods

Fifteen OMZ metasedimentary rock samples, representing the Carvalhal, Barrancos, Colorada, *Xistos com Nódulos* and Terena formations (ages ranging from Cambrian to Lower Devonian), were collected and trace element analyses were carried out in ALS laboratories (Sevilla). This new data was compared and assembled with published data from the Vila Boim, Terrugem, Carvalhal, Colorada, *Xistos Raiados* and Terena formations (n = 56; Pereira et al., 2006; Borrego, 2009; Cruz, 2013).

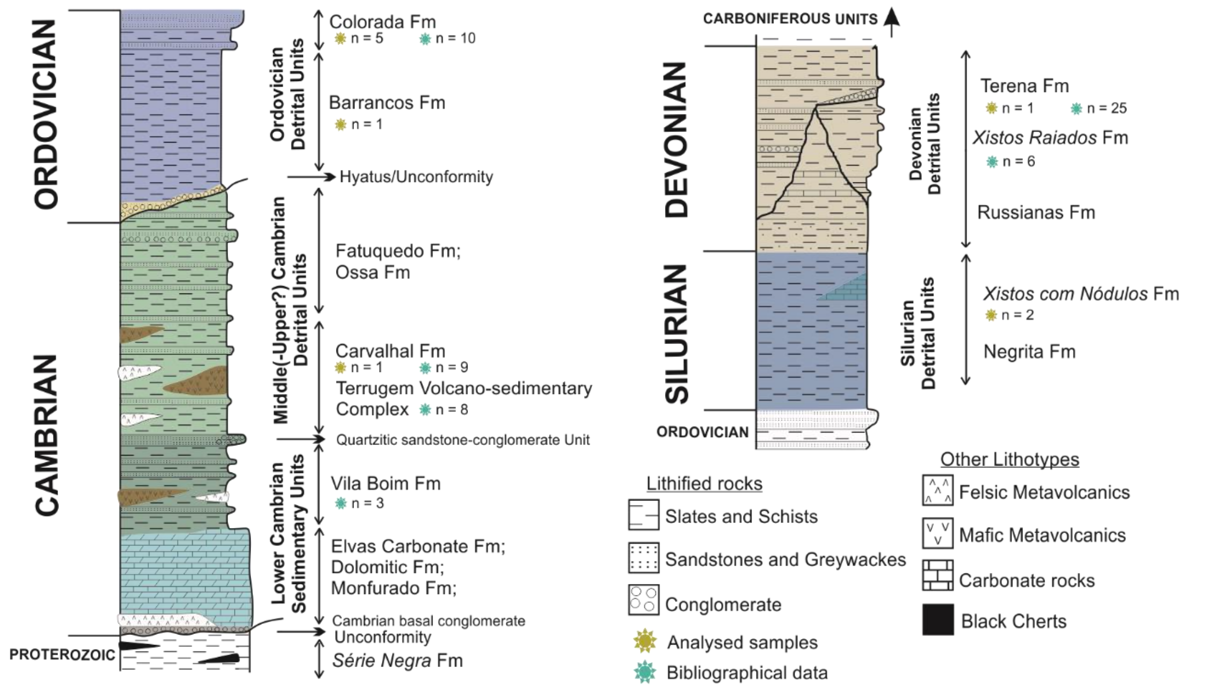

Fig. 1 – Simplified Ossa-Morena Zone lithostratigraphic column of the Cambrian – Devonian (meta)sedimentary sequences (adapted from Oliveira et al., 1991; Araújo et al., 2013).

Range values for analyses of most relevant components presented at Table 1.

Tab. 1 – Value range of analyses for the different Ossa-Morena Zone detrital units. Obtained data assembled with bibliographical data from cited references.

	Cambrian				Ordovician		Silurian		Devonian	
	lower(n = 3)		middle-upper?(n = 18)		(n = 16)		(n = 2)		(n = 32)	
	min.	*max.*	*min.*	*max.*	*min.*	*max.*	*min.*	*max.*	*min.*	*max.*
Ba	21	295	45	1256	105	2494	46	1115	17	1285
Sr	58	111	30	165	12	157	15	270	10	273
Rb	2	149	3	246	14	282	9	271	2	249
V	52	121	35	273	19	1220	225	360	39	287
Cr	90	280	30	160	30	230	30	160	30	150
Zr	157	192	81	508	142	530	17	246	127	858
Hf	4	4	2	13	4	13	0	8	3	21
Nb	7	14	2	23	3	29	1	31	5	26
Ta	1	1	0	2	0	2	0	2	0	3
Th	5	12	0	22	4	27	0	25	3	23
U	1	3	0	4	1	11	2	3	1	6
Y	18	27	17	47	10	75	6	58	13	43
Sc	6	19	4	43	2	30	2	22	3	26
La	15	42	3	74	15	77	3	87	14	77
Ce	32	88	9	148	34	159	4	167	30	154
Sm	3	7	3	11	3	14	1	13	3	13
Eu	1	2	1	2	1	3	0	2	1	3
Gd	3	6	3	9	2	12	1	11	2	9
Yb	2	3	2	4	1	6	1	5	1	5

3. Geochemical Features

Geochemical data here reported are given in *average* ± *standard deviation* or ranging *minimum – maximum*.

Lower Cambrian rocks show slightly low Nb/Ta ratios (14.5 ± 0.9), but high Zr/Hf (40.3 ± 3.8), and Th/U = 4.75 ± 0.3, whereas Middle (to Upper?) Cambrian units display average lower Nb/Ta (13.3 ± 2.5) and Zr/Hf (37.8 ± 1.8) ratios, but similar Th/U (4.49 ± 1.6) contents. All Cambrian rocks have similar chondrite-normalized (CN) REE patterns: $[La/Sm]_{CN}$ = 3.0 – 4.3, $[La/Yb]_{CN}$ = 6.1 – 14.2, $[Eu/Eu^*]_{CN}$ = 0.55 – 1.0 and $[Ce/Ce^*]_{CN}$ = 0.8 – 1.0. Analyses for Ordovician and Silurian samples display chemical features similar to those described in Cambrian successions. Ordovician units show slitlhy lower Nb/Ta (13.6 ± 1.8), Zr/Hf (37.6 ± 4.1) and Th/U (3.6 ± 1.4) ratios, and comparable REE patterns, with $[La/Sm]_{CN}$ = 2.3 – 4.5, $[La/Yb]_{CN}$ = 6.2 – 12.9, $[Eu/Eu^*]_{CN}$ = 0.6 – 0.8, and $[Ce/Ce^*]_{CN}$ = 0.9 – 1.2. Silurian units exhibit average Nb/Ta = 13.3, Zr/Hf = 32 – 56, Th/U = 0.3 – 9.1, and REE patterns with $[La/Sm]_{CN}$ = 2.5 – 4.1, $[La/Yb]_{CN}$ = 3.2 – 11.1, $[Eu/Eu^*]_{CN}$ = 0.5 – 0.6, and $[Ce/Ce^*]_{CN}$ = 0.7 – 1.0.

The Lower Devonian successions display distinct trace element features, with significantly lower ratios: Nb/Ta = 11.7 ± 1.2, Zr/Hf = 38.5 ± 3.0, Th/U = 4.3 ± 1.8, and REE patterns with $[La/Sm]_{CN}$ = 2.6 – 4.5, $[La/Yb]_{CN}$ = 4.9 – 13.2, $[Eu/Eu^*]_{CN}$ = 0.7 – 1, and $[Ce/Ce^*]_{CN}$ = 0.9 – 1.1.

5. Provenance and Geodynamic Evolution

The trace element geochemical data here presented allows some deductions on the provenance and, wherefore, the geodynamic evolution of the OMZ metasedimentary rock suites. La, Th, Hf and Sc contents, discriminatory diagrams (Fig. 2) and REE CN patterns enables to assign the studied samples to their likely depositional environment: i) metasedimentary successions with ages ranging from Cambrian to Silurian are apparently derived from an acid continental source (continental margin – continental island arc?), showing passive margin chemical affinities with ancient sediments (increasing resistate minerals component, presumably zircon, or/and a coarser debris component; Floyd & Leveridge, 1987), while ii) Lower Devonian detrital rocks chemistry suggests a mixed acid/basic source contribution (volcanic arc component?).

6. Geodinamic Considerations

The provenance of Cambrian-Silurian sediments can be attributed to the progressive dismemberment of a continental basement, coming from the northern rim of Gondwana (which includes the Cadomian arc; Pereira et al., 2006; Dias et al., 2016) while the Lower Devonian units suggest a transitional deposition environment, from a passive margin to an active tectonic setting. New geochemical data regarding OMZ Palaeozoic detrital units supports and agrees with previous works (e.g. Borrego et al., 2006; Ribeiro et al., 2010; Moreira et al., 2014; Moreira & Machado, 2019), supporting geodynamic models, that proposed subduction initiation in SW Iberian Variscides during Lower Devonian ages. Nonetheless, a thoroughly study is needed, regarding major element geochemistry, and correlation with other formations not included in this work, namely in the spanish sectors of OMZ and other Variscan terranes.

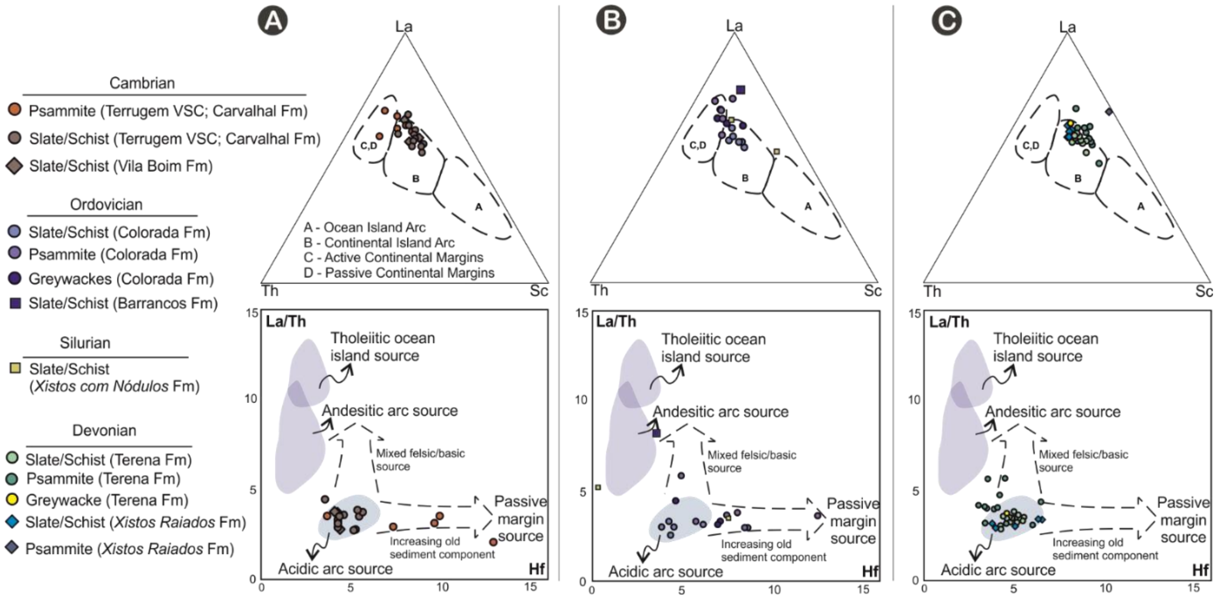

Fig. 2 – Discrimination tectonic diagrams for the different OMZ (A) Cambrian, (B) Ordovician-Silurian and (C) Devonian metasedimentary units. Ternary La-Th-Sc diagram from Bhatia & Crook (1986) and La/Th-Hf diagram from Floyd & Leveridge (1987)

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