Rifting along the northern Gondwana margin and the evolution of the Rheic Ocean: A Devonian age for the El Castillo volcanic rocks (Salamanca, Central Iberian Zone)

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Abstract

Exposures of volcanic rocks (El Castillo) in the Central Iberian Zone near Salamanca, Spain, are representative of Paleozoic volcanic activity along the northern Gondwanan passive margin. Alkaline basalts and mafic volcaniclastic rocks of this sequence are structurally preserved in the core of the Variscan–Tamames Syncline. On the basis of the occurrence of graptolite fossils in immediately underlying strata, the El Castillo volcanics traditionally have been regarded as Lower Silurian in age. In contrast, most Paleozoic volcanic units in western Iberia are rift-related mafic to felsic rocks emplaced during the Late Cambrian–Early Ordovician, and are attributed to the opening of the Rheic Ocean. We present new zircon U–Pb TIMS data from a mafic volcaniclastic rock within the El Castillo unit. These data yield a near-concordant, upper intercept age of 394.7 ± 1.4 Ma that is interpreted to reflect a Middle Devonian (Emsian–Eifelian) age for the magmatism, demonstrating that the El Castillo volcanic rocks are separated from underlying lower Silurian strata by an unconformity. The U–Pb age is coeval with a widespread extensional event in Iberia preserved in the form of a generalized paraconformity surface described in most of the Iberian Variscan realm. However, in the inner part of the Gondwanan platform, the Cantabrian Zone underwent a major, coeval increase in subsidence and the generation of sedimentary troughs. From this perspective, the eruption age reported here probably represents a discrete phase of incipient rifting along the southern flank of the Rheic Ocean. Paleogeographic reconstructions indicate that this rifting event was coeval with widespread orogeny and ridge subduction along the conjugate northern flank of the Rheic Ocean, the so called Acadian "orogeny". We speculate that ridge subduction resulted in geodynamic coupling of the northern and southern flanks of the Rheic Ocean, and that the extension along the southern flank of the Rheic Ocean is a manifestation of slab pull along the northern flank. This scenario provides a uniform explanation for many features that form at ca. 395 Ma along the Gondwanan margin and has implications for the origin of the coeval oceanic Devonian mafic rocks currently exposed in the Variscan suture of NW Iberia.

Keywords: U–Pb geochronology; Devonian; Central Iberian Zone; Rheic Ocean

1. Introduction

Oceanic lithosphere plays a highly important role in the tectonic evolution of the Earth; nevertheless, because it is typically subducted and only rarely preserved in ophiolites, the processes that take place in oceanic lithosphere are obscured and in most cases overlooked. One of the most important processes that take place in the tectonic evolution of any ocean is the ridge subduction that must occur as oceans close and continents collide (Cloos, 1993). Most models explaining the Rheic Ocean closure and the origin of the Variscan–Alleghenian Orogenic belt do not

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consider the timing and effects of the subduction of oceanic ridges below one of the Rheic margins, Gondwanan or Laurentian (Díaz García et al., 1999; Pin et al., 2002, 2006; Sánchez Martínez et al., 2007; Arenas et al., 2007). Recently, however, Woodcock et al. (2007) link the subduction of the Rheic oceanic ridge to the Acadian deformation in the overriding Laurussian plate. Despite the disappearance of a ridge under an overriding plate, effects of its subduction should be recognized along both margins of the ocean. On the side where the ridge subducts, the resulting thermal event may resemble the effects of mantle plume subduction (Lagabrielle et al., 2000). However, if the opposing margin was a passive margin at that time, ridge subduction may result in the coupling of the passive margin with the subducting slab. Such coupling would cause extension along that margin which can be identified in the form of increased subsidence, enhanced thermal gradients or the presence of rift-related volcanic rocks.

The potential significance of simultaneous tectonic events at a plate scale needs to be evaluated in terms of global scale processes. The potential geodynamic linkages between coeval events at plate scale are commonly obscured in the geologic record by subsequent plate tectonic processes. However, in some cases, evidence for such linkages may be found when rocks/events occur simultaneously in a variety of continental and oceanic lithospheric settings.

In this paper, we provide U–Pb geochronological data for the El Castillo volcanics of the Central Iberian Zone in Spain. When evaluated with the large amount of published stratigraphic and geochronological data on coeval rock units, this data suggests the existence of a tectonic event that affected both margins of the Rheic Ocean during the Lower Devonian, at around 395 Ma. Our data show that the El Castillo alkaline volcanic rocks in the Central Iberian Zone (Iberian sector of the Variscan belt, Fig. 1), previously thought to be Silurian, are coeval with enhanced subsidence along the northern passive margin of Gondwana. These data suggest that stretching of the platform may have been coeval with respect to many other tectonic events around the margins of the Rheic Ocean. Furthermore, our data also provide an example of the importance of establishing the age of the volcanic rocks directly to corroborate the sedimentary ages based on fossils from adjacent strata.

2. Geological setting

The studied rocks lie within the Iberian–Armorican Arc, which forms the arcuate western sector of the European Variscan belt (Matte and Ribeiro, 1975; Brun and Burg, 1982; Matte, 1986; Franke, 1989; Matte, 2001). If the Iberian–Armorican Arc is restored to a pre-Variscan geometry (Weil et al., 2001), the northern Gondwana platform is shown to be extremely extensive as indicated by its stratigraphic record, which preserves mostly a thick, lower Paleozoic, mostly siliciclastic sequence. This sequence includes the Late Cambrian–Early Ordovician Armor- ican quartzite and, in some places, well preserved passive margin Silurian, Devonian and Carboniferous successions.

Recent paleogeographic reconstructions place NW Iberia adjacent to West Africa along the southern flank of the Rheic Ocean throughout the Paleozoic (e.g. Martínez Catalán et al., 1997, 1999; Robardet, 2002, 2003). Paleozoic rocks of Iberia are divided into zones based mainly on their Lower Paleozoic sedimentary differences, which are interpreted to reflect their relative proximity to the Gondwanan margin (Fig. 1). The Cantabrian Zone, located in the core of the arc (Fig. 1) preserves a coastal environment, whereas the West Asturian-Leonese, Central Iberian, Galicia-Trás-os-Montes (Schistose Domain) and/or Ossa-Morena zones preserve more outboard tectonos-tratigraphy (Lotze, 1945; Julivert et al., 1972; Farias et al., 1987; Pérez-Estaún et al., 1990; Quesada, 1990; Ribeiro et al., 1990; Quesada et al., 1991; Martínez Catalán et al., 1997, 1999; Gutiérrez-Marco et al., 1999; Aramburu et al., 2002; Robardet, 2002, 2003; Marcos et al., 2004; Robardet and Gutiérrez- Marco, 2004). Current boundaries between these zones are major Variscan thrusts and reverse faults that were in some cases reactivated during extension in the aftermath of the Variscan orogeny (e.g. Martínez Catalán, 1990).

The Central Iberian Zone (Fig. 1A) is the most extensive zone in Iberia and is characterized by: (i) a predominance of Ediacaran and Lower Paleozoic sediments; (ii) a large number of Variscan granitoids intruding Paleozoic strata; (iii) NW–SE upright folds that preserve Silurian, Devonian and, in some cases, Carboniferous sediments in synclines. One of these synclines, the Valongo–Tamames syncline, extends for more than 250 km along strike from Portugal to the province of Salamanca. Its core preserves rocks of Silurian and Devonian age (Fig. 1B) which are terminated c. 10 km to the west in a periclinal syncline and to the east by the Carboniferous Central System Batholith (Fig. 1B).

In the core of the Valongo–Tamames syncline, near a hill called El Castillo, outcrops a clastic sequence composed of sandstones, greywackes and shales, being the shales more abundant towards the top. The clastic sediments are interbedded with alternating intermediate to mafic volcaniclastic tuffs and minor basaltic beds that are strongly altered and replaced by carbonates in the section where the studied sample was collected. This sequence overlies a formation composed of quartzites and interbedded black shales attributed that contain Lower Silurian graptolites (Díez Balda, 1986; Martín Herrero et al., 1990) which overlies Middle Ordovician rocks para- conformably. These paleontological data have been used to suggest a Silurian age for the overlying volcanic units (Jiménez Fuentes and Saavedra Alonso, 1971; Saavedra Alonslo et al., 1973; Rölz, 1975; Gutiérrez Marco and Rabano, 1983; Jiménez Fuentes, 1983). This interpretation is challenged by the geochronological results provided herein.

The entire sequence is affected by D1 Variscan deformation (Díez Balda, 1986; Martín Herrero et al., 1990; Yenes et al., 1999) which produced the upright syncline and related axial planar cleavage that is penetrative in most fine grained lithologies. Deformation took place under very-low to low grades of metamorphism and there is no evidence of late Variscan static re-crystallization related to the intrusion of the nearby granitoid bodies.

The studied sample is one of the lowermost volcanic layers found in El Castillo area, about 3 km northeast of the village of San Martín de Robledo (Salamanca province), (Fig. 1B) area. The

El Castillo volcanic rocks have been studied in detail by Díez Balda (1986). In the field, they appear as massive lava flows sometimes with intercalations of shales and or sandstones. The lava flows often display amygdaloidal texture, this being particularly abundant towards the top of individual lava flows. The rocks are commonly altered and typically contain sec- ondary chlorite, albite, calcite, phrenite, quartz and iron oxides. However, primary biotite, amphibole and pyroxene also are observed in thin sections. Based on microprobe analyses of primary amphibole and biotite and whole rock chemical analyses of the less altered samples, Díez Balda (1986) interpreted these lava flows as alkaline basanites. The studied sample is a green rock that was selected from one of the flows and it predominantly consists of chlorite, biotite, quartz, plagioclase,

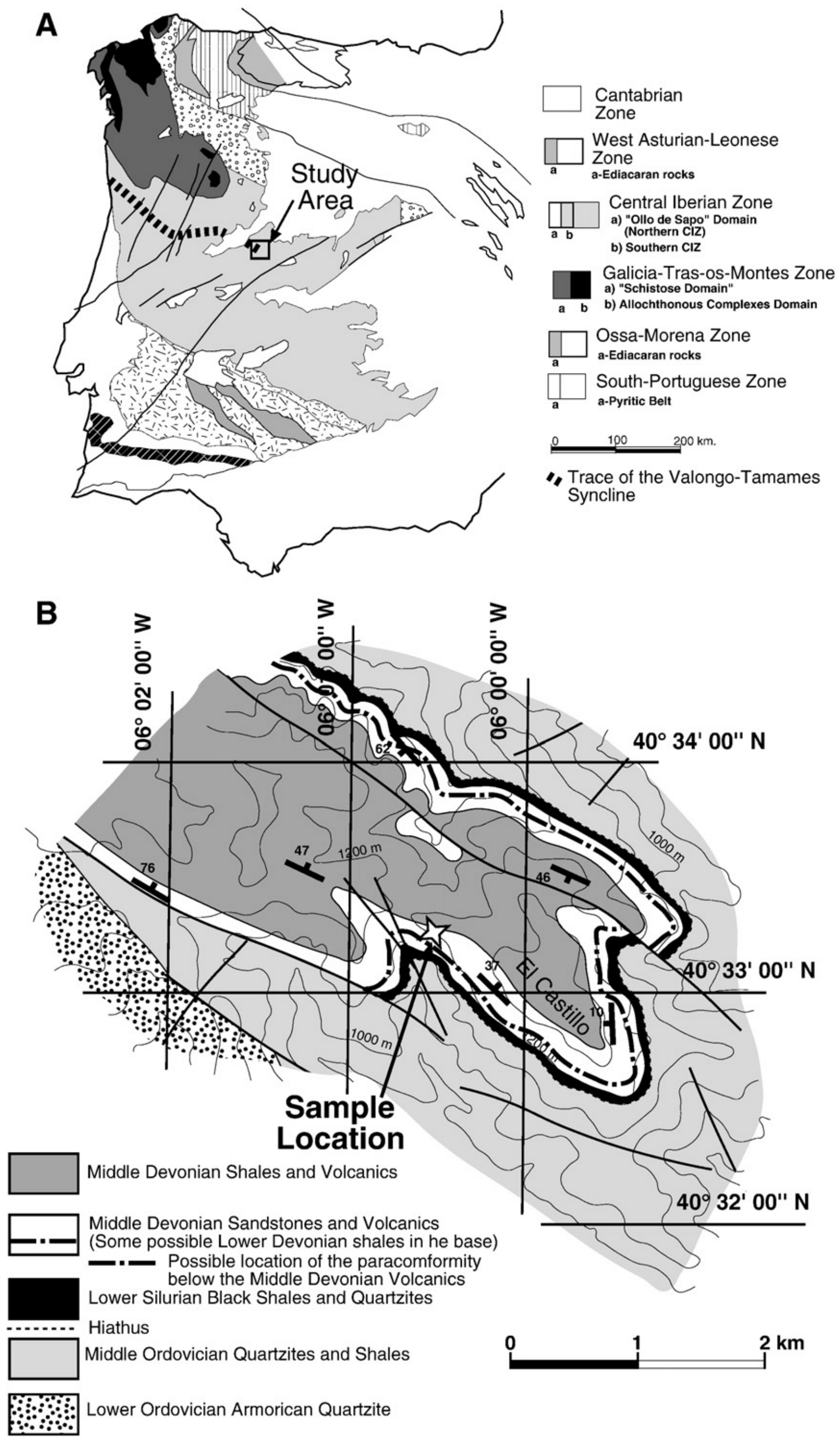

Fig. 1. (A) Geological sketch of the Iberian Massif with the different paleogeographic zones used in the text. From Julivert et al. (1972), Farias et al. (1987) and Pérez- Estaún et al. (2004). It also indicates the location of the Valongo–Tamames syncline and the location of the area where the sample was collected. (B) Geological map of the eastern end of the Valongo–Tamames syncline (Díez Balda, 1986; Martín Herrero et al., 1990), with the location of the studied sample and the inferred position of the paraconformity between the lower Silurian sediments and the Middle Devonian metavolcanics.

epidote and opaque minerals. The dated sample preserves volcanic textures as irregular opaque mineral aggregates that probably resulted from the alteration of original glass shreds. The sample preserves an incipient cleavage of Variscan age and contains abundant amygdales filled mostly with calcite.

3. Analytical procedures

Heavy mineral concentrates were initially prepared from the El Castillo volcanic rock at the Department of Petrology and Geochemistry at the Universidad Complutense in Madrid, Spain, through conventional crushing, grinding and Wilfley table methods. Further sample processing was completed in the Jack Satterly Geochronology Laboratory at the University of Toronto using standard techniques, including heavy liquids and Frantz magnetic separation of heavy mineral fractions. Highest quality zircon grains were selected from the least paramagnetic separates by hand picking under a binocular microscope (Fig. 2A) and were then air abraded (Fig. 2B) according to the method of Krogh (1982). Weights of each final, selected fraction (consisting single grains) were determined by making a volume estimate from digital photomicrographs and using the density of zircon. Uncertainties in the calculated weights are estimated to be b20% in most cases. This uncertainty only affects the calculation of Pb and U concentrations and has no influence on age data.

The selected grains were washed and loaded into Teflon bombs with HF along with a mixed ^{205}Pb–^{235}U isotopic tracer solution (Krogh, 1973). Dissolution occurred over 4 to 5 days at 195 °C. U and Pb were separated from larger zircon fractions using 50 ml anion exchange columns. For small fractions, no chemical isolation of U and Pb was carried out on the dissolved grains; instead, fractions were dried down with phosphoric acid and loaded with silica gel directly onto outgassed rhenium filaments. The isotopic compositions of Pb and U were measured either using a single Daly collector with a pulse counting detector, in multidynamic, or in static multicollector mode with a solid source VG354 mass spectrometer. A detector mass discrimination of 0.033% per atomic mass unit (AMU) and a dead time of 24 ns were employed for Daly detector measurements. A thermal source mass discrimination correction of 0.1% per atomic mass unit was applied for both Pb and U. Amplifier gains and Daly characteristics were monitored using the SRM982 Pb standard.

The assigned laboratory blank for U was 0.2 pg, while that for Pb is routinely measured below 1 pg. Error estimates were calculated by propagating known sources of analytical uncertainty for each analysis including within-run ratio variability, uncertainty in the fractionation correction, and uncertainties in the isotopic composition of laboratory blank. Decay constants used are those of Jaffey et al. (1971). Uncertainties are given at the 95% confidence level. Initial corrections were made using the in-house data reduction program UTILAGE; graphical data presentation and quoted ages were generated using the Microsoft Excel Add-in Isoplot/ Ex v. 3.00 of Ludwig (2003).

4. Results

Analyzed zircons from the El Castillo volcaniclastic sample are the only ones retrieved from a 12 kg sample, and consisted of glassy fragments of clear and colorless to pale yellow or

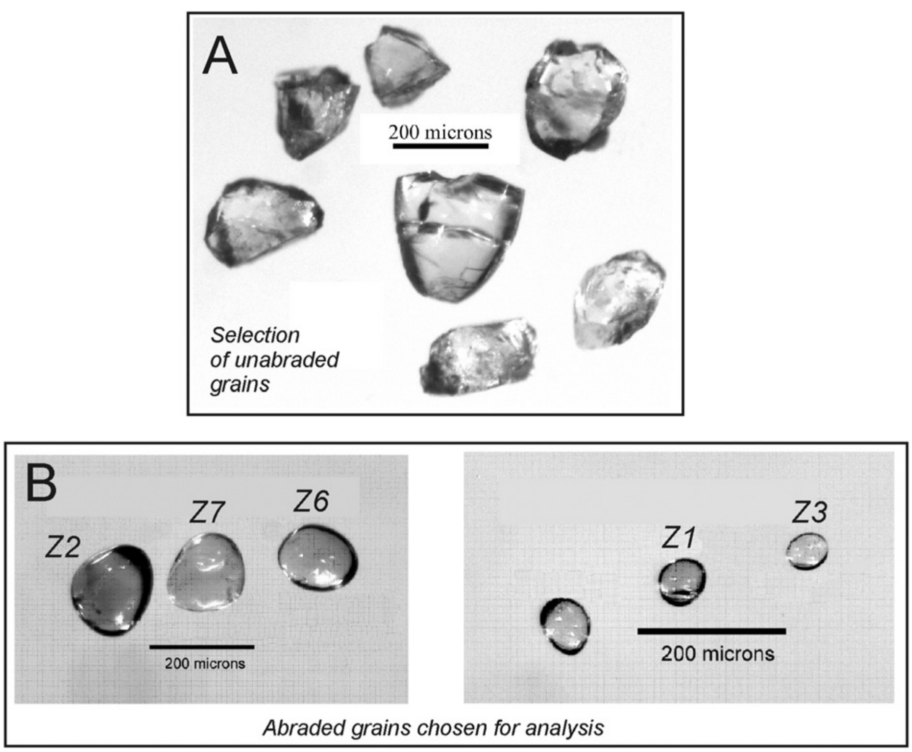

Fig. 2. Pictures of the retrieved zircons from the sample (A) and the analyzed portions after abrasion (B). See text for explanation.

Table 1
Zircon U–Pb isotopic data for the El Castillo tuff

Lab no.	Fraction	Weight (µg)	U (ppm)	Pb* (pg)	Pb_C (pg)	Th/U	$^{206}Pb/^{204}Pb$	$^{206}Pb/^{238}U$	±2σ	$^{207}Pb/^{235}U$	±2σ	$^{207}Pb/^{206}Pb$	±2σ	Ages (Ma) $^{206}Pb/^{238}U$	±2σ	$^{207}Pb/^{235}U$	±2σ	$^{207}Pb/^{206}Pb$	±2σ	Disc. (%^)
MAH5137	1 pale yel, clr, frag	9.2	609	477.1	0.70	1.67	32315	0.062627	0.000156	0.471201	0.001477	0.054569	0.000083	391.6	0.9	392.0	1.0	394.6	3.4	0.8
MAH5138	1 pale yel, frag, incl	6.4	490	308.9	6.70	1.73	5696	0.062021	0.000124	0.466835	0.001521	0.054591	0.000112	387.9	0.8	389.0	1.1	395.5	4.6	2.0
MAH6029	1 cls, clr, frag	23.0	294	580.4	0.55	1.70	49463	0.062757	0.000122	0.472145	0.001158	0.054564	0.000056	392.4	0.7	392.7	0.8	394.4	2.3	0.5
MAH6030	1 pale yel–brn, clr, frag	3.2	865	234.5	0.66	1.65	16843	0.062630	0.000119	0.471115	0.001214	0.054556	0.000073	391.6	0.7	392.0	0.8	394.1	3.0	0.6
MAH6031	1 pale yel, clr, frag	25.0	471	1001.0	2.52	1.73	18541	0.061925	0.000121	0.466301	0.001329	0.054613	0.000095	387.3	0.7	388.6	0.9	396.4	3.9	2.4

Notes:
All analyzed fractions represent least magnetic, air — abraded zircon grains, free of cores or cracks.
Abbreviations: clr — clear; cls — colourless; yel — yellow; brn — brown; frag — fragment; incl — fluid or melt inclusions present. Pb* is total amount (in picograms) of radiogenic Pb.
Pb_C is total measured common Pb (in picograms) assuming the isotopic composition of laboratory blank: 206/204 — 18.221; 207/204 — 15.612; 208/204 — 39.360 (errors of 2%). Pb/U atomic ratios are corrected for spike, fractionation, blank, and, where necessary, initial common Pb; $^{206}Pb/^{204}Pb$ is corrected for spike and fractionation.
Th/U is model value calculated from radiogenic $^{208}Pb/^{206}Pb$ ratio and $^{207}Pb/^{206}Pb$ age, assuming concordance. Disc. (%) — percent discordance for the given $^{207}Pb/^{206}Pb$ age.
Uranium decay constants are from Jaffey et al. (1971).

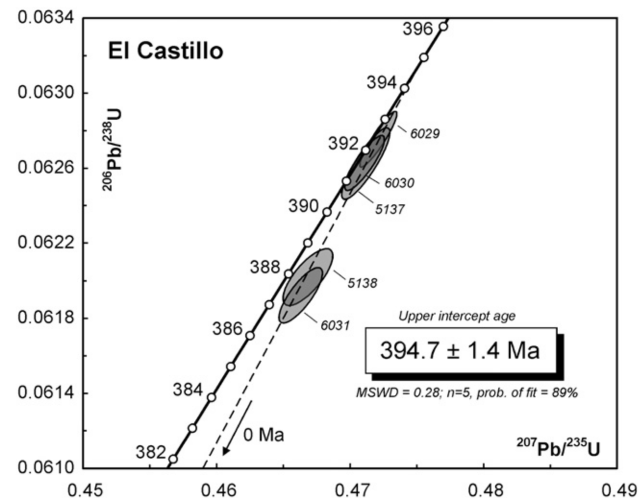

Fig. 3. Concordia plot of the obtained results for El Castillo volcanic rocks.

yellow–brown irregular grains with few well-developed crystal faces (Fig. 2). Evidence for rounding and pitting of zircon grains from sedimentary abrasion was not observed. Uranium–lead isotopic data for five analyzed single grains are presented in Table 1 and shown graphically in Fig. 3. Three of the fractions overlap with Concordia (0.5–0.8% discordant), while two other fractions are slightly less concordant but lie on a simple Pb-loss trajectory to the present day. Calculated Th/U ratios for all grains are approximately uniform at 1.7, supporting the interpretation that all of the zircons have a similar origin. The relatively high Th/U ratios are consistent with crystallization from a relatively mafic magma (Heaman et al., 1990). Regression of all five fractions through the origin yields an upper intercept age of 394.7 ± 1.4 Ma with a low MSWD (Mean Square of Weighted Deviates = 0.28) and a high probability of fit (89%). We interpret this as a primary magmatic age, reflecting the time of igneous crystallization and eruption of the El Castillo volcanic rocks, contemporaneous with the interbedded surrounding basaltic volcanics, which are devoid of zircons and therefore more difficult to date. The stratigraphic age repre- sented by the obtained radiometric age would correspond to the Emsian stage according to Kauffman (2006) or to the Eifelian stage according to Gradstein et al. (2004). For consistency we will use the Gradstein et al. (2004) scale throughout the text.

5. Discussion

Subduction of the Rheic Ocean ridge is a necessary precursor to the continent–continent collision that gave rise to the Appalachian–Variscan orogen. Based on a wealth of geologic data, most workers view that Devonian–Carboniferous con- traction of the Rheic Ocean was produced by northward- directed subduction beneath Laurussia and that the Gondwanan margin of the Rheic Ocean was dominated by a passive margin (e.g. Martínez Catalán et al., 2007 and references therein). In that scenario, subduction of the Rheic Ocean ridge beneath Laurussia would have resulted in geodynamic coupling between opposing sides of the Rheic Ocean. According to Woodcock et al. (2007), the Rheic Ocean ridge subduction probably occurred beneath the northern flank of the Rheic Ocean at ca. 395 Ma. Ridge subduction is therefore coeval with passive margin stretching along the southern flank of the Rheic Ocean which also produced the El Castillo volcanic rocks.

New zircon U–Pb (ID-TIMS) data from a mafic volcani- clastic rock from El Castillo (CIZ, Salamanca, Spain) yield a near-concordant, upper intercept age of 394.7±1.4 Ma that is interpreted to reflect a Middle Devonian (Eifelian) age for the magmatism, and, given that it is not a sill as the field rela- tionships and the lithology indicate, suggests that the El Castillo volcanic rocks most probably lie unconformably on top of fossiliferous lower Silurian strata. These data extend the geographic range of similar aged igneous rocks and coeval extensional-related tectonic activity in peri-Rheic Ocean realms.

A noticeable feature of peri-Rheic realms is the widespread occurrence of tectonic events dated at about 395 Ma. Most studies have provided a tectonic analysis that has focused on relatively small areas, and these events are traditionally interpreted as several independent tectonic processes. Here, we favour a unified explanation for these individually enig- matic events, and we propose that the Early Devonian age for the El Castillo unit extends their geographic significance into the interior of the Central Iberian Zone. These pene- contemporaneous events are therefore viewed as an age "reference line" that links processes that occurred along both flanks of the Rheic Ocean. The El Castillo volcanic event may therefore be linked with other volcanic and/or extensional events that took place in the northern Gondwana margin recorded in the stratigraphy (unconformities, increased sub- sidence) or in related volcanic or hydrothermal events. In the Cantabrian zone, for example, a coeval slight increase in the rate of subsidence in the troughs of the Huergas–Naranco Formation (Veselovski, 2004) is recorded and some ca. 395 Ma (Rb–Sr whole rock, Loeschke, 1983) sub-volcanic continental tholeiitic basalts have been documented. Farther outboard from the Gondwanan margin, the West Asturian-Leonese zone does not preserve Devonian rocks. However, in the northern part of the Central Iberian Zone, Devonian rocks are abundant, especially in the Alcañices synform where volcanic rocks of Middle Devonian age (paleontological data from interbedded strata, González Clavijo, 1997) and olistostromic deposits (González Clavijo and Martínez Catalán, 2002) may be related to this extensional event. Other rift-related volcanic rocks that may be of this age are described along the eastern margin of the Central Iberian Zone (Ancoechea et al., 1988).

In the central part of the CIZ, north of the Carboniferous Pedroches Batholith, the Devonian sequence occurs in the cores of the Variscan synclines. Wherever the sequence is well documented, there is a ubiquitous hiatus in the sedimentation that began in Eifelian times (Puschmann, 1967; Pardo Alonso and García Alcalde, 1996). In the southern realm of the CIZ, south of the Pedroches Batholith, the mid-Devonian hiatus is present in all the Devonian successions. Also occurring within the Almadén syncline of the Central Iberian Zone are world class Hg Almadén deposits that result from hydrothermal alteration at ca. 395 Ma (Hall et al., 1997).

Within the Ossa-Morena Zone occur the same mid-Devonian hiatus (Robardet and Gutiérrez Marco, 1990; Robardet and Gutiérrez-Marco, 2004) and a probable volcanic sequence of this age (the Estremoz volcanic–sedimentary complex, Piçarra, 2000).

Taken together, the aforementioned features suggest that a regional extensional event and related magmatism occurred along the Iberian portion of the northern Gondwana margin during the lower Middle Devonian. A tectonic scenario that would: produce a pulse of magmatism within an otherwise protracted sequence of passive margin sedimentation is proble- matic. However, a magmatic event of the same age occurs along the northern Laurussian flank of the Rheic Ocean (Murphy et al., 1999; Murphy and Keppie, 2005; Brown et al., 2008) and we propose that there may be geodynamic linkage between magmatic events on opposing flanks of the Rheic Ocean. One possible mechanism that would have introduced accelerated extension and related magmatism in the Iberian passive margin setting is if the passive margin became geodynamically coupled with the subduction zone located along the northern flank of the Rheic Ocean (Fig. 4). Coupling may have occurred during the contraction of the Rheic Ocean when the ocean ridge was subducted beneath the Laurussian margin. In this coupled scenario, slab pull beneath the Laurussian margin would have exerted an extensional force along the Iberian passive margin.

Along the Laurussian margin, voluminous magmatism of this age typifies the "Acadian" orogenic event. In Maritime Canada, the Acadian orogeny is considered to reflect subduction of an anomalously hot mantle (Murphy et al., 1999; Murphy and Keppie, 2005), which could be the manifestation of an ocean ridge or mantle plume Synchronously with this event, a ca. 395 Ma. exhumation/magmatisation event has been documented in the Upper Units of the Allochthonous Complexes of NW Iberia, which were located along the Laurussian flank of the Rheic Ocean at that time, (Fernández-Suárez et al., 2007). Exhumation could have also been driven by the heat input produced by the same oceanic ridge subduction.

Finally, there is a large body of evidence for the generation of oceanic crust within the Rheic Ocean at 395 Ma in the NW Iberian allochthonous complexes (Díaz García et al., 1999; Pin et al., 2002, 2006; Sánchez Martínez et al., 2007; Arenas et al., 2007) that was subsequently obducted during the Variscan orogeny, consistent with the hypothesis of a fundamental change in the tectonic regime at ca. 395 Ma. Although the models proposed for the generation of this oceanic lithosphere of supra-subduction affinity vary in detail (compare Martínez Catalán et al., 1996, 1999, 2007; Pin et al., 2006; Sánchez Martínez et al., 2007), they all are consistent with our idea of generalized extension within and around the Rheic Ocean realm at ca. 395 Ma.

It is also noticeable that other outcrops with oceanic affinities that are also interpreted to be the ophiolites resulting from the closure of the Rheic Ocean, the Acebuches-Beja–Lizard ophiolite, also show protolith ages that cluster around 395 Ma. (i.e. Clark et al., 1998). Models proposing that more than one ocean closed during the Variscan orogeny or those that include opposing subducting directions are more difficult to reconcile with our hypothesis (i.e. Simancas et al., 2002).

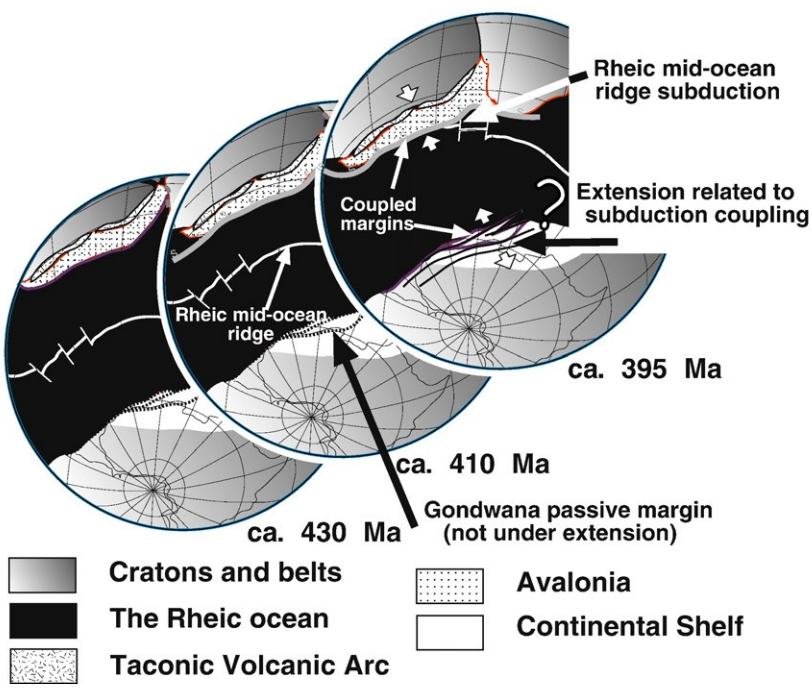

Fig. 4. Paleogeographic schematic reconstructions of the Rheic Ocean and its surrounding continental masses. Reconstruction at ca. 430 Ma., taken from Murphy et al. (2006). At ca. 410 Ma it is noticeable the diminishing width of the Rheic Ocean, the Gondwana passive margin is not coupled to the subduction margin in the northern flank of the ocean as there is a mid ocean spreading ridge in between. By ca. 395 Ma most of the Rheic mid ocean spreading ridge has been subducted and the Gondwana passive margin stretches as the result of the coupling of both margins. Paleogeographic results of the extension in the Gondwana margin are only represented as illustrative of the process.

In summary, we argue that the subduction of the Rheic oceanic ridge gave rise to the geodynamic coupling of opposing flanks of the Rheic Ocean, and provides a unified explanation for the Acadian thermal event, the exhumation of the NW Iberian Upper Units, and the extension that caused the early- Middle Devonian extensional volcanism, enhanced subsidence, and a regional lower mid-Devonian unconformity along the southern flank of the Rheic Ocean. This scenario may also explain the origin of the coeval Devonian mafic ophiolitic rocks currently exposed in the Variscan suture of NW Iberia and other European Variscan realms. (Fig. 4). Further detailed studies are needed on the Iberian sequences to test our model.

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