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The Cadomian Orogeny and the opening of the Rheic Ocean: The diacrony of geotectonic processes constrained by LA-ICP-MS U–Pb zircon dating (Ossa-Morena and Saxo-Thuringian Zones, Iberian and Bohemian Massifs)

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ABSTRACT

Cadomian orogenic processes and their continuum to the opening of the Rheic Ocean were modeled by making use of new LA-ICP-MS U–Pb ages from detrital zircons of sedimentary rocks of Late Neoproterozoic (Ediacaran) and Cambro-Ordovician sediments of the Ossa-Morena Zone (Iberian Massif) compared with those from the Saxo-Thuringian Zones (Bohemian Massif). Presented data constrain a diachrony of Cadomian and related geotectonic processes along the northern realm of the Gondwana Supercontinent. Early stage of Cadomian evolution is characterized by a continental magmatic arc at the periphery of the West African Craton and a related back-arc basin opened at c. 590 to 570 Ma. Diacronic arc–continent collision was caused by oblique vector of subduction and started first in the East of Peri-Gondwana at c. 560–570 Ma and resulted at c. 543 Ma in the formation of a short-lived Cadomian retro-arc basin in the Saxo-Thuringian Zone. In contrast, more to the West in the Ossa-Morena Zone, the Cadomian back-arc basin was longer active, at least until c. 545 Ma. In that region, final magmatic pulse of the Cadomian magmatic arc at c. 550 Ma is documented by new zircon data. Closure of the Cadomian back-arc basin and arc–continent collision in the Ossa-Morena Zone occurred between c. 545 Ma and the overall onset of Cambrian plutonism at c. 540 Ma. A mid-oceanic ridge was subducted underneath the Cadomian orogen accompanied by slab break-off of the subducted oceanic plate. Oblique incision of the oceanic ridge into the continent caused the formation of rift basins during the Lower to Middle Cambrian (c. 530–500 Ma). This process continued and finally caused the opening of the Rheic Ocean documented by thick Lower Ordovician siliciclastic sediments and a final magmatic event at c. 490–485 Ma. Opening of the Cambrian rift basin and of the Rheic Ocean again was diachronic and started from the West of Peri-Gondwana and expanded eastward.

1. Introduction

The U–Pb dating of detrital zircon grains from clastic sediments by LA-ICP-MS (Laser Ablation and Inductive Coupled Plasma Mass Spectronometry) in the last decade became a powerful tool in provenance analysis (e.g. Fernández-Suárez et al., 2002; Jeffries et al., 2003; Gerdes and Zeh, 2006; Linnemann et al., 2007).

Our paper is an attempt to use the age spectra of detrital zircons from clastic sediments derived from the periphery of the Gondwana Supercontinent to reconstruct the main tectono-magmatic and basement exhumation events in the source area. Further, we attempt to demonstrate (i) common characteristics in the crustal evolution of the overall source area, and (ii) the utility of the ages from detrital zircon grains for the reconstruction of a diachrony of orogenic events along the Peri-Gondwanan margin in Late Neoproterozoic (Ediacaran) to Cambro-Ordovician time.

We use the age data of detrital zircons from two prominent basement inliers in the Variscides of Central and Western Europe, the Ossa-Morena Zone in the Iberian Massif and the Saxo-Thuringian Zone of the Bohemian Massif (Fig. 1). Both areas formed by a combination of Ediacaran Cadomian orogenic processes and Cambro-Ordovician rifting, an extensional event that led to the opening of the Rheic Ocean (e.g. Robardet, 2002; Linnemann et al., 2007). In our paper we first present new U–Pb LA-ICP-MS datings of detrital zircons of Ediacaran and Cambro-Ordovician sandstones in the Ossa-Morena Zone (Iberia). The data are compared with U–Pb dates of detrital zircons from coeval volcano-sedimentary units of the Saxo-Thuringian Zone by Linnemann et al. (2007). Our results demonstrate the east to

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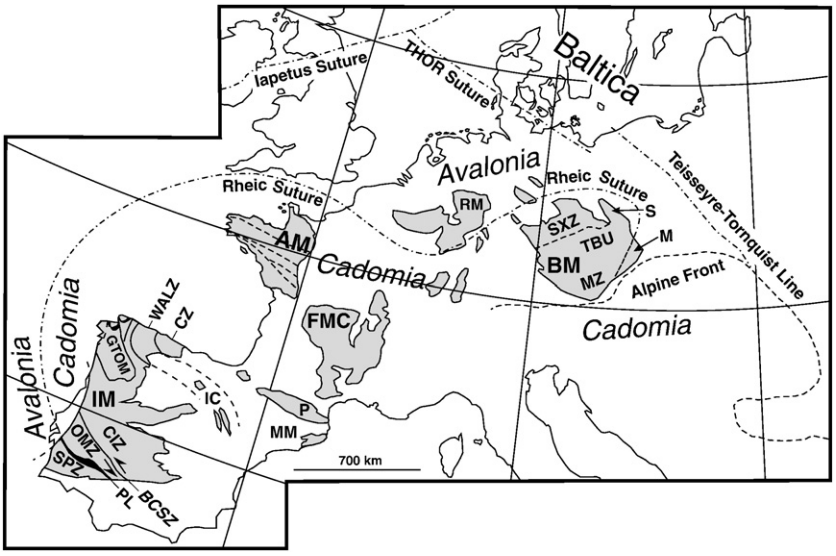

Fig. 1. Cadomian and Variscan Massifs in southeastern and central Europe with single Variscan oceanic suture of the Rheic Ocean (after Robardet, 2002; Linnemann et al., 2007). IM — Iberian Massif, AM — Armorican Massif, FMC — French Massif Central, RM — Rhenish Massif, BM — Bohemian Massif, SPZ — South Portuguese Zone, OMZ — Ossa-Morena Zone, CIZ — Central Iberian Zone, GTOM — Galicia-Trás os Montes Zone, WALZ — West Asturian Leonese Zone, CZ — Cantabrian Zone, PL — Pulo de Lobo oceanic units, IC — Iberian Chains, BCSZ — Badajoz–Cordoba Shear Zone, P — Pyrénées, MM — Maures Massif, SXZ — Saxo-Thuringian Zone, TBU — Teplá-Barrandian Unit, MZ — Moldanubian Zone, S — Sudetes, M — Moravo–Silesian Zone. Black-oceanic rocks of the Pulo de Lobo suture and ophiolitic units of allochthonous complexes of Galicia.

west diacrony of Cadomian orogenesis along the Gondwanan margin. In contrast opening of the Rheic Ocean in Cambro-Ordovician time running progressed from west to east. Both events are linked, and underlining the continuum of Cadomian Orogeny with opening of the Rheic Ocean as proposed by Linnemann et al. (2007).

2. Geological setting

Many authors have described the similarities of the geotectonic units and the faunal assemblages from the Ossa-Morena Zone of the Iberian Massif and the Saxo-Thuringian Zone in the Bohemian Massif (e.g. Robardet 2002 and references therein). Now for the first time U–Pb datings of detrital zircons from both areas are used to reconstruct an overall geodynamic regime along the northern Peri-Gondwanan margin in Late Neoproterozoic (Ediacaran) to Cambro-Ordovician time. For the better understanding of our reconstructions we present a description of the most significant features of the Ossa-Morena and the Saxo-Thuringian Zones.

2.1. The Ossa-Morena Zone and its transition to the Central Iberian Zone (Iberian Massif)

The Iberian Massif represents a segment of the European Variscan Belt, which has been traditionally subdivided in several zones based on stratigraphic, structural, magmatic and metamorphic differences (Lotze, 1945; Julivert et al., 1974; Julivert, 1987). The southwestern Iberian Massif includes the Ossa-Morena Zone bounded to the north–northeast by the Central Iberian Zone. The nature of that boundary is a subject of debate (Eguiluz et al., 2000; Matte, 2001; Bandrés et al., 2002; Robardet, 2003; Simancas et al., 2005). Based on differences in the Cadomian Basement of each zone, Pereira and Silva (2001) proposed the existence of a Central Iberian/Ossa-Morena Transition Zone located in between the Coimbra–Córdoba Shear Zone and the El Pedroches Batholith. In this transition zone the Lower Ordovician rocks with palaeographic affinity to the Central Iberian Zone unconformably overlie Ediacaran and Lower Cambrian rocks typical of the Ossa-Morena Zone (Pereira and Silva, 2002; Bandrés et al., 2002; Silva and Pereira, 2004). Towards the North of this transition zone the Cadomian Basement of the Central Iberian Zone (schist–greywacke complex) can be distinguished from the Neoproterozoic succession of the Ossa-Morena Zone (Série Negra). To the South, the Lower Ordovician Armorican quartzites typical of the Central Iberian Zone are not represented in the Ossa-Morena Zone (Robardet and Gutierrez-Marco, 1990).

Both the Ossa-Morena and Central Iberian Zones contain well-preserved and well-exposed Ediacaran rocks (Cadomian Basement) overlain by Early Palaeozoic sedimentary rocks (Fig. 2). In the Ossa-Morena Zone, the Cadomian Basement is represented by the Série Negra (Alia, 1963; Carvalhosa, 1965) composed by variably deformed and metamorphosed sediments metagreywackes and volcanics (c. 540–570 Ma; Gebauer, 1993; Schäfer et al., 1993; Ordoñez-Casado, 1998; Fernández-Suárez et al., 2002). These rocks are intruded by c. 550 Ma old gabbro and diorite (Bandrés et al., 2002) and granodiorite and granite ranging in age from c. 520 to 530 Ma (Schäfer, 1990; Ordoñez-Casado, 1998). The Ediacaran rocks are overlain by Lower Cambrian c. 510–530 Ma old volcano-sedimentary complexes (e.g. Ordoñez-Casado, 1998; Eguiluz et al., 2000; Sanchez-Garcia et al., 2003; Perejón et al., 2004).

In the studied area of the Northeast Alentejo (Figs. 2, 3), the Série Negra consists mainly of quartzwackes, quartz phyllites, greywackes and graphite-rich pelites and intercalations of black cherts, tholeiitic basalts, and minor limestones. In our working area such rocks are included in the Mosteiros Formation (Gonçalves, 1971; Gonçalves and Oliveira, 1986; Oliveira et al., 1991; Pereira and Silva, 2001, 2002; Pereira et al., 2006). Equivalent rocks in the Spanish part of the Ossa-Morena Zone are called the Montemolín Formation (Eguiluz, 1988; Quesada, 1990, 1992; Eguiluz and Abalos, 1992; Eguiluz et al., 2000; Bandrés et al., 2002). These sediments in Spain have been interpreted to as Cadomian syn-orogenic sedimentary sequences of an arc-related basin (Ribeiro et al., 1990; Quesada, 1990; Quesada et al., 1991; Eguiluz et al., 2000; Sanchez-Garcia et al., 2003; Pereira and Chichorro, 2004; Pereira et al., 2006).

The Mosteiros Formation is overlain by calc-alkaline felsic volcanic rocks such as the Nave de Grou-Azeiteiros volcano-sedimentary complex (Pereira and Silva, 2002; Pereira et al., 2006). That complex is composed by acid-to-intermediate tuffs, tuffites, and conglomerates composed of pebbles of volcanic rocks, granitoids and black cherts and slates derived from the Série Negra. Rhyolites, rhyo-dacites and dacites are also present. Correlatives of the felsic rocks in the Spanish part of the Ossa-Morena Zone are rhyolites (Bodonal Porphyroid) and granites (Tablada and Táliga plutons). This felsic magmatism is coeval