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South Variscan terrane accretion: Sardinian constraints on the intra-Alpine Variscides

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Abstract

Structural data are presented that show that the Sardinian Variscides form the boundary of the Variscan intra-Alpine terrane, thrust onto a Gondwana foreland. This model replaces the currently held hypothesis that the south Armorican suture zone continues into the Sardinian Variscides. The orogenic activity propagated toward the foreland in two distinct waves: (1) thrusting, burial and Barrovian type metamorphism that reached the internal orogen in Late Devonian times and lasted in the external orogen until Early Carboniferous times. Transpressional strain partitioning is suggested by frontal thrusting in the external orogen and lateral displacement in the internal orogen. (2) Normal faulting, exhumation and local Buchan type metamorphism were superimposed on the internal orogen probably since Early Carboniferous times and reached the external orogen contemporaneously with the Late Carboniferous emplacement of voluminous granitic intrusions. Extensional doming and lateral displacement indicate a transtensional regime. The sense of orogen-parallel displacement during both stages was left-lateral on inward dipping movement planes and right-lateral on outward dipping movement planes. The resulting left-lateral displacement between the intra-Alpine terrane and the Gondwana foreland is due to the bending of the Variscan belt, during which the Sardinian segment underwent a bookshelf type movement within an overall right-lateral displacement regime.

Keywords: Sardinia; Variscan Orogeny; Suture zone; Transpression; Transtension; Oroclinal bending

1. Introduction

The Variscan Orogen resulted from the late Paleozoic collision of the high-latitude-derived Gondwanan terranes with the low-latitude terranes of Laurussia (Fig. 1). Paleogeographical reconstructions of this period support a longitudinal drift with right-lateral displacement between both domains in the order of 6000 km (Shelley and Bossière, 2000). Paleomagnetic data indicate significant clockwise vertical-axis rotations of the intervening terranes (Edel, 2001). The Variscan Orogen covers large parts of Europe and is represented by the Avalonian, Armorican and intra-Alpine terrane assemblages (Fig. 2). Their basement consolidated at the Neoproterozoic Gondwana margin during the Avalonian–Cadomian Orogeny (Nance and Murphy, 1994). Avalonia originated from Grenvillian basement of about 1.3–1.0 Ga, and was therefore situated closer to Laurentia than Armorica, which recycled ancient West African crust of about 2–3 Ga (Murphy et al., 2004). The intra-Alpine terrane is thought to be a segment of this Neoproterozoic belt, located east of Armorica on the North African boundary of Gondwana (Von Raumer, 1998).

In early Paleozoic times, Avalonia left Gondwana and collided with Laurentia and Baltica to accomplish the Laurussian terrane assemblage (Caledonian orogeny in Fig. 3). At the same time, Armorica was subjected to a passive margin evolution and rifting within the peri-Gondwanan realm, while the intra-Alpine terrane was still exposed to active margin tectonics (Frisch and Neubauer, 1989; Von Raumer et al., 2002). A mid-Devonian orogenic event coincides with the migration of non-marine fish and flora across the Rheic Ocean (McKerrow et al., 2000). It is preceded by Eo-Variscan high-pressure metamorphism and succeeded by the ultimate closure of the Rheic seaway in Carboniferous times. The post-collisional igneous activity is commonly associated with Buchan type metamorphism and right-lateral wrenching. The orogenic signature of the widespread late Variscan magmatism in the intra-Alpine terrane was probably caused by an active margin (Finger and Steyrer, 1990), facing the Paleotethys Ocean at the SE Variscan flank (Fig. 1).

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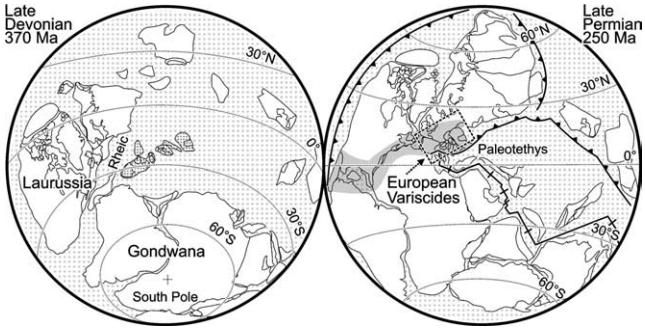

Fig. 1. Paleogeographic reconstructions (after Torsvik and Cocks, 2004; © 2004, with permission from the Geological Society, London), illustrating the right-lateral displacement between Laurussia and Gondwana during Variscan times.

Single- and multiple-suture models have been proposed for the Variscan Orogen in Europe. Biostratigraphic data only support the closure of the Rheic Ocean (Robardet, 2003). Other closed oceans, for example south of the Armorican terrane, are mainly inferred from intercalations of eclogitic and oceanic rocks, thrust over foredeep deposits (Matte, 2001). According to Stampfli et al. (2002), the Paleotethys occupied not only the southeastern, but also the southern vicinity of the European Variscides until early Triassic suturing with Gondwana.

The south European part of the Variscan Orogen became considerably obscured by the superimposed Alpine Orogen. This has made the correlation of the dismembered Sardinian section with other parts of the Variscan belt difficult and highly controversial. On the one hand, the Sardinian section is

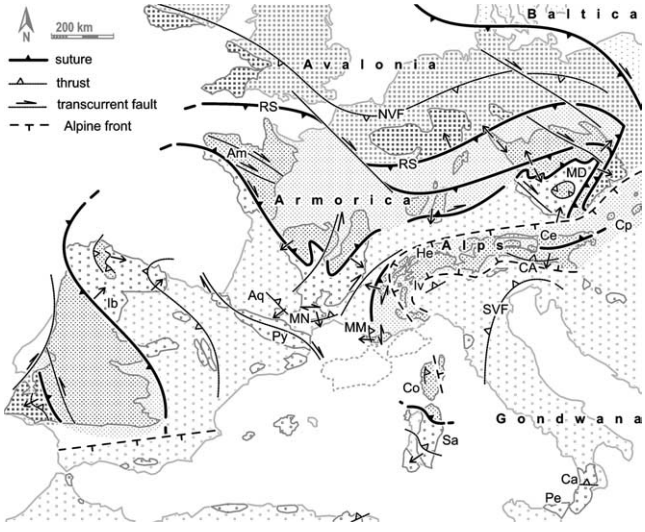

Fig. 2. The principal terranes and sutures in the European Variscides (modified after Cappelli et al., 1992; Matte, 2001; Winchester et al., 2002). The probable Permian positions of Corsica and Sardinia are shown in dotted outline between the European mainland and their present day positions. Am—Armorican massif; Aq—Aquitaine; CA—Carnic Alps; Ca—Calabria; Ce—Cetic basement; Co—Corsica; Cp—Carpathians; He—Helvetic basement; Ib—Iberia; Iv—Ivrea zone, MD—Moldanubian zone; MM—Maures Massif; MN—Montagne Noire; NVF—north Variscan front; Pe—Peloritan; Py—Pyrenees; RS—Rheic suture; Sa—Sardinia; SVF—south Variscan front.

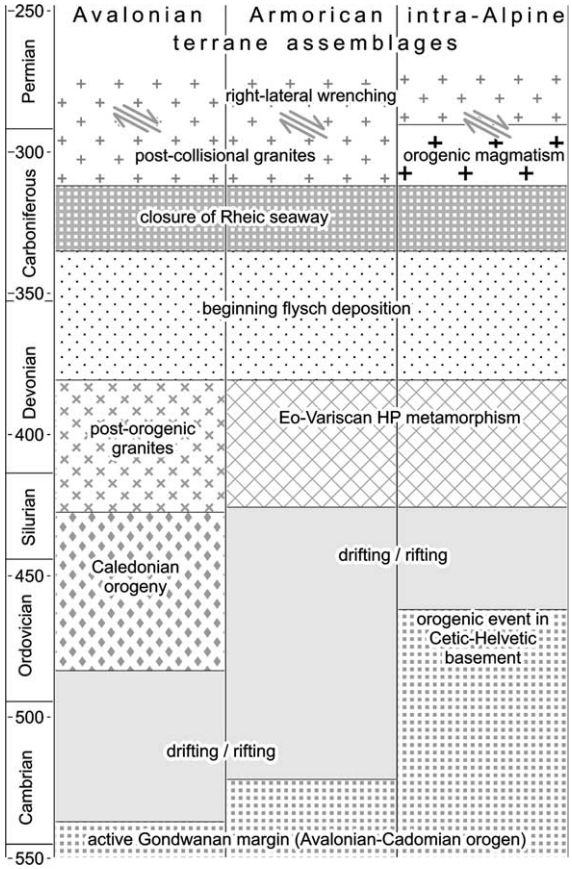

Fig. 3. Schematic tectonostratigraphy of the principal terranes in the European Variscides (modified after Frisch and Neubauer, 1989; Matte, 1991; Von Raumer, 1998; Winchester et al., 2002).

interpreted as continuation of the south Armorican suture zone (Cappelli et al., 1992). On the other hand, it is inferred to be part of the intra-Alpine area (Matte, 1991), whose entity as suspect terrane is suggested by the mid-Ordovician active margin record (Fig. 3), the presence of recycled basement of Grenvillian age, detected in the Calabria–Peloritan section (Trombetta et al., 2004), as well as by the occurrence of Late Ordovician Baltic taxa in the fold-and-thrust belt of the Sardinian Variscides (Loi and Dabard, 1997). Thus, the intra-Alpine terrane may have become right-laterally displaced from a previously closer vicinity to Baltica to its present position with respect to Armorica during the late Variscan Orogeny (Matte, 2001; Stampfli et al., 2002).

The aim of this study is to determine whether the Sardinian Variscides represent the continuation of the south Armorican suture zone, or instead have their origin within the intra-Alpine terrane assemblage. We critically re-examine the deformation history of the proposed suture zone in NE Sardinia (Cappelli et al., 1992), and correlate it with the metamorphic evolution and radiometric age record. The Alpine reorientation is estimated to reconstruct the pre-Alpine geometry and enable correlations with neighbouring areas. Contrary to Cappelli et al. (1992), our data indicate that there is neither a suture zone in NE Sardinia nor a structural correlation with the south Armorican section.