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Short Communication

Is there an Upper Devonian rift zone under the northern front of the Alps separating East and West Armorican crustal segments?

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Abstract: Many Cadomian and Early Paleozoic basement units in the Alps are considered to be derived from the East Armorican segment of the Gondwana margin. A common assumption is that this East Armorican crustal segment was shifted into the hinterland of West Armorica via a Variscan dextral shear zone. However, the tectonic separation of West and East Armorica could have started earlier during a Late Devonian rifting event. The respective rift zone is supposed to be hidden under the northern nappes of the Alpine–Carpathian chain. This newly proposed sub-Alpine "Cetic rift" was presumably connected with the Upper Devonian Brevenne rift, which is documented in the northern French Massif Central, the southern Vosges and the southern Black Forest. The combined Brevenne–Cetic rift zone may thus represent a major trans-European structure. It is tentatively interpreted as an ephemeral back-arc rift that opened due to southward subduction activities on the northern side of West Armorica.

Keywords: pre-Variscan rocks in the Alps, Devonian rifting event, Cetic Massif, West Armorica, East Armorica.

Introduction

An important starting point for understanding the geological architecture of central Europe (Fig. 1) is the Cadomian paleogeography of the Armorican (now intra-European) sector of the Gondwana margin (Nance et al. 2008; Žák & Sláma 2018 and references therein). We refer in this paper mainly to the recent paleogeographic reconstruction of Siegesmund et al. (2021), which is depicted in Figure 2. Those parts of the Gondwana margin that originally lay in front of the Latea Metacraton (Fig. 2) and were largely incorporated in the (extra-Alpine) Variscides, are termed, following Matte (2001), Armorica or, more precisely, West Armorica. Easterly adjoining parts of the Gondwana margin, that resided in front of the Sahara Metacraton and the Arabian Nubian Shield, are now mainly exposed in the intra-Alpine basement (Haas et al. 2020; Siegesmund et al. 2021; Neubauer et al. 2022), and are referred to here as East Armorica.

This short communication focuses mainly on the question of when and how the intra-Alpine E-Armorican rocks finally came into a position south of the Bohemian Massif and into the hinterland of W-Armorica (Fig. 1). A common belief is that they were displaced relative to W-Armorica by a Carboniferous–Permian dextral shear zone (von Raumer 1998; von Raumer et al. 2013). We propose a modified model, which invokes an incipient Late Devonian rifting event between W- and E-Armorica. In this scenario, we present arguments for the existence of a hidden "Cetic rift zone" in the Helvetic basement under the northern front of the Alps. We postulate a link between this Cetic rift and the Brevenne rift (Faure et al. 2009, and references therein), which extends from the northern French Massif Central into the southern Vosges and the southern Black Forest (Lardeaux et al. 2014).

The "Cetic rift zone" interfaces the Bohemian Massif (W-Armorica) and the intra-Alpine E-Armorican rocks of the European plate (e.g., in the Tauern Window). Thus, there is support for the suggestion that the tectonic separation between E- and W-Armorica was induced by Late Devonian rifting.

The Brevenne rift and its potential eastward continuation

The Brevenne basin with Upper Devonian ophiolite remnants (Sider & Ohnenstetter 1986; Pin & Paquette 1998; Faure et al. 2009) is a well-established geological element in the northern Massif Central. It is associated with Upper Devonian to Lower Carboniferous volcanosedimentary rocks and pronounced Upper Devonian intermediate magmatism (Morvan arc, Limousin tonalite line – Lardeaux et al. 2014; Shaw et al. 1993). The tectonic origin of these associated intermediate igneous rocks is not clear. Geochemically, they are of the volcanic arc type (mostly low-K calc-alkaline, with a mantle isotope signature). Therefore, the Brevenne zone is tentatively interpreted by some authors as a back-arc rift linked either to a southward dipping Saxothuringian subduction zone or

a northward dipping Paleotethys subduction zone (Faure et al. 2009; Skrzypek et al. 2012). However, it is also feasible that the intermediate magmatic rocks of that area simply represent rift-related melt products sourced from an older (Ligerian?) subduction-modified mantle wedge that was thermally reactivated (see model in Vanderhaeghe et al. 2021, their fig. 18c).

It has been proposed in earlier work that the Brevenne rift zone likely continues from the Massif Central into the southern Vosges and the southern Black Forest (Lardeaux et al. 2014). Skrzypek et al. (2012) documented significant rift-related mafic and ultramafic magmatism of Late Devonian age in the Klippen Belt of the southern Vosges. A study by Hann et al. (2003) reports remnants of isotopically primitive, Upper Devonian trondhjemites in the Rand granite unit in the southern Black Forest that correlate well with the low-K, calc-alkaline magmatism associated with the Brevenne rifting event in the Massif Central.

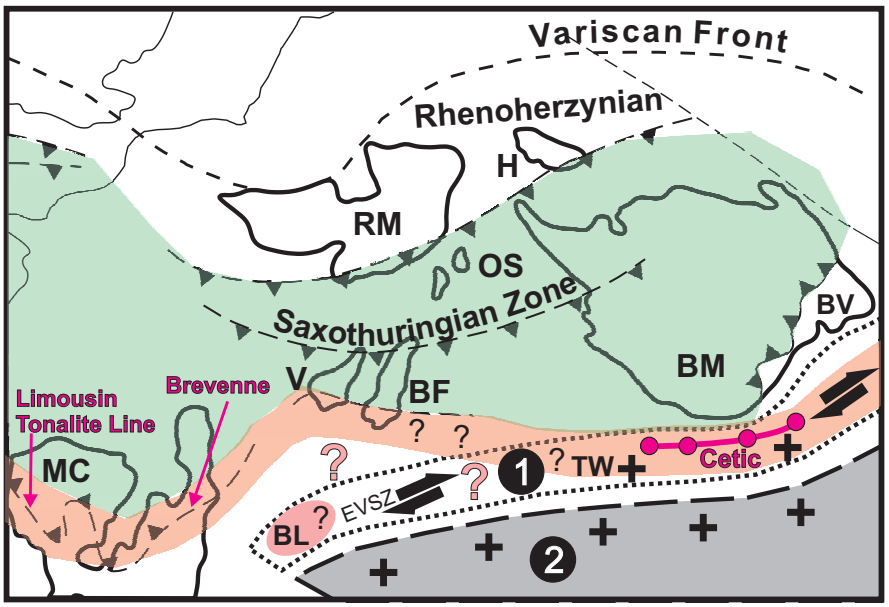

Fig. 1. Sketch map of central Europe showing the inferred location of the newly proposed Upper Devonian Brevenne–Cetic rift zone. The Cetic tonalite line (Frasl & Finger 1988) is shown in red. Field 1 refers to the covered sub-Alpine basement of the European plate. Field 2 (grey) approximates the pre-Permian position of the Austroalpine units. Crosses are E-Armorican crust. The W-Armorican Gondwana segment is in green (contours are approximate). Abbreviations: BF=Black Forest, BL=Belledone, BM=Bohemian Massif, BV=Brunovistulian Domain, H=Harz, MC=Massif Central, OS=Odenwald and Spessart, RM=Rheish Massif, TW=Tauern Window, V=Vosges.

We establish here the hypothesis that the Brevenne rift was part of a much longer Upper Devonian rift structure that continued from the Black Forest eastwards into an area, which became later overridden by the northern Alpine and Carpathian nappes. The following arguments support this hypothesis:

- Boulders of low-K granitoids in Mesozoic and Paleogene sedimentary rocks between Salzburg and Vienna are macroscopically, geochemically and geochronologically (Thöni 1991) strikingly similar to the Limousin tonalites of the northern Massif Central, as has been stated already by Finger et al. (1997). These so-called "Cetic granitoids" represent basement rocks from the covered European plate under the Alps (Frasl & Finger 1988).
- Remnants of metabasic and ultrabasic rocks are found in the same structural zone (Zirkel 1957; Vielreicher 1991). These rocks remain relatively unstudied and undated. However, the speculation is justified that they could represent Upper Devonian rift-related mafic and ultramafic rocks comparable to those exposed in the southern Vosges (Skrzypek et al. 2012).
- Striking aeromagnetic anomalies are detected under the northern margin of the Alps between Salzburg and the Slovakian border (Blaumoser 1992). They could be interpreted in terms of larger bodies of Upper Devonian mantle rocks in the underlying European plate.

The Brevenne–Cetic rift zone may continue further in subcrop of the Outer Western Carpathians (Fig. 1), where abundant chromspinel detritus in Paleogene sedimentary rocks has been interpreted to indicate a buried Paleozoic ophiolite source (Winkler & Slaczka 1992). Upper Devonian metaophiolites at the NW margin of the Tatric superunit, in the Strážovské vrchy Mts (Putiš et al. 2009; Ivan & Méres 2015) may have a relationship to this Brevenne-Cetic rift zone as well. Also, certain Devonian–Lower Carboniferous rocks in the Tauern Window (Kebede et al. 2005; Lerchbaumer et al. 2010) and in the Belledonne Massif (von Raumer et al. 2009) are closely related.

Discussion and conclusions

Von Raumer et al. (2013) proposed that the intra-Alpine E-Armorican units (N-Galatia in their terminology) were displaced many 100 kilometres towards the south-west relative to W-Armorica during the Early Carboniferous, in connection with an anticlockwise rotational movement of Gondwana. The displacement process is modelled by von Raumer et al. (2013) in terms of a dextral strike slip fault system that is now hidden underneath the Alps. Corsini & Rolland (2009) and Rossi et al. (2009) hold a somewhat different view and propose an orogen-wide East Variscan Shear Zone (EVSZ) of

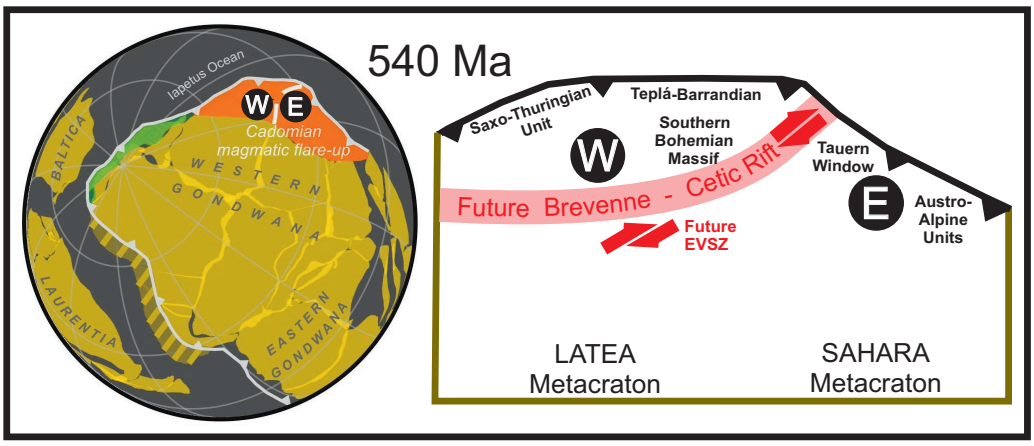

Fig. 2. Paleogeography of the active northern Gondwana margin at the beginning of the Cambrian (slightly modified after Siegesmund et al. 2021). The postulated Brevenne–Cetic rift system and the East Variscan Shear Zone are schematically indicated in red. "W" and "E" refer to the West and East Armorican crustal segments as defined in the text. Note, according to von Raumer et al. (2013), both segments were included in an archipelago-like ribbon continent in the Devonian that has become slightly detached from main Gondwana (not considered in the figure).

Stephanian–Permian age along which the intra-Alpine units and even parts of Corsica and Sardinia were displaced in a SW direction. The best outcrops of the EVSZ exist in the External Massifs in France and Switzerland, but Guillot & Ménot (2009) suggest that the fault continued further eastwards in the sub-Alpine basement and may be linked with the Moravian–Moldanubian thrust of the eastern Bohemian Massif. The latter contention is, however, problematic because the dextral movements along the Moravian–Moldanubian boundary are pre-Stephanian in age (Dallmeyer et al. 1992; Fritz & Neubauer 1993), whereas Stephanian-Permian faulting in the SE Bohemian Massif generally displays sinistral kinematics (Schermann 1965; Finger & Riegler 1999). It may thus be more appropriate to assume a potential continuation of the EVSZ in the covered sub-Carpathian part of the European plate.

There are good reasons to invoke a tectonic boundary between E- and W-Armorica under the northern front of the Alps: The southern Bohemian Massif, which contains large amounts of relatively mature Cambro–Ordovician granitoids and metasedimentary rocks (Friedl et al. 2004; Košler et al. 2014), can be reasonably interpreted as the back-arc realm of W-Armorica (Figs. 1 and 2). The scarcity of remnant Tonian zircons in the rocks of the southern Bohemian Massif (Friedl et al. 2004; Košler et al. 2014) implies a considerable paleogeographic distance from the Latea Metacraton and the Arabian–Nubian Shield, which are known as major Tonian zircon sources (Dörr et al. 2015; Zulauf et al. 2015). The Tauern Window, on the other hand, which exposes crust from the southern end of the European plate (Fig. 1), shows significantly more Tonian zircon relics (Siegesmund et al. 2021; Veselá et al. 2022) relative to the Cadomian and Early Proterozoic zircon input. The Cadomian–Lower Paleozoic rocks of the Tauern Window can, therefore, be reasonably considered as E-Armorican crustal fragments (Fig. 2). The inferred Cetic rift zone forms the interface between the Bohemian Massif (W-Armorica) and the Tauern Window (E-Armorica). Thus, it is likely that the tectonic separation of E- and W-Armorica has its origins in a Late Devonian rifting event.

The question of how the Brevenne–Cetic rift can be fitted into the overall (eo-)Variscan tectonic framework remains to be elaborated in future studies. We propose that the opening of this rift was initially induced by contemporaneous southward subduction activities in the Saxothuringian Zone (Franke 2000), within an overall back-arc rift setting. This would also explain the volcanic-arc geochemistry of the syn-rift Limousin and Cetic granitoid rocks. Based on geochronological studies in the Massif Central (Melleton et al. 2009), we assume that the extensional stage of the Brevenne–Cetic rift was only of rather short duration so that the structure could not achieve a great width.

The tectonic relationship between the sub-Alpine branch of the Brevenne–Cetic rift and the EVSZ is difficult to assess because of limited exposure. We would tentatively conjecture that, after the Upper Devonian extensional stage terminated, this part of the rift evolved into an Early Carboniferous shear zone, which may have stayed active until Stephanian–Permian times.

A potentially important additional aspect for Variscan geology is that the tectonic movements between W- and E-Armorica could have exerted a profound effect on the eastern Variscides. The detected rotation of the Brunovistulian block (Nawrocki et al. 2021) could be related. Even a south-westward shift of the Brunovistulian plate during the Late Devonian/Tournaisian is theoretically feasible. Such a scenario would explain the curious situation that Avalonia-derived blocks, such as the Brunovistulian unit, allegedly acted as a south-eastern backstop for Carboniferous lower crustal flow derived from a northern Variscan subduction system (Schulmann et al. 2014).

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