Earth-Science Reviews 112 (2012) 126–154

Contents lists available at SciVerse ScienceDirect

Earth-Science Reviews

journal homepage: www.elsevier.com/locate/earscirev

The Cambrian to Devonian odyssey of the Brabant Massif within Avalonia: A review with new zircon ages, geochemistry, Sm–Nd isotopes, stratigraphy and palaeogeography

Ulf Linnemann [a], Alain Herbosch [b,*], Jean-Paul Liégeois [c], Christian Pin [d], Andreas Gärtner [a], Mandy Hofmann [a]

[a] Senckenberg Naturhistorische Sammlungen Dresden, Museum für Mineralogie und Geologie, Sektion Geochronologie, GeoPlasma Lab, D-01109 Dresden, Germany
[b] Département des Sciences de la Terre et de l'Environnement, Université Libre de Bruxelles, B-1050 Brussel, Belgium
[c] Isotope Geology, Royal Museum for Central Africa, B-3080 Tervuren, Belgium
[d] Laboratoire de Géologie, Université Blaise Pascal, CNRS UMR-6524, 63038 Clermont-Ferrand Cedex, France

ARTICLE INFO

Article history:
Received 21 December 2011
Accepted 16 February 2012
Available online 25 February 2012

Keywords:
Avalonia
Lower Palaeozoic
Gondwana
Zircon age
Meguma

ABSTRACT

This study provides an up-to-date and comprehensive review of the Early Palaeozoic evolution of the Brabant Massif belonging to the Anglo-Brabant Deformation Belt. Situated at the southeastern side of Avalonia microplate, it is the only well-known part of the northern passive margin of the Rheic Ocean. The Cambrian–Silurian sedimentary pile is >13 km thick, with >9 km for the Cambrian only. The unraveling of this continuous registration reflects the successive rifting and drifting of Avalonia from the Gondwana mainland, followed by soft-collisional processes with Baltica and finally the formation of Laurussia. Based on recently established detailed stratigraphy, sedimentology and basin development, on U–Pb LA-ICP-MS analyses of igneous and detrital zircon grains along with geochemical data including Sm–Nd isotopes, a new geodynamic and palaeogeographic evolution is proposed. Brabant Megasequence 1 (lower Cambrian to lowermost Ordovician, >9 km thick) represents an embayment of the peri-Gondwanan rift from which the Rheic Ocean has evolved. Detrital zircon ages demonstrate that the Brabant is a typical peri-Gondwanan terrane with a major Pan-African (Neoproterozoic age) and a mixed West African and Amazonian source (Palaeoproterozoic, Archaean and some Mesoproterozoic age). The transition towards the Avalonia drifting is marked by an unconformity and a short volcanic episode. The northward drift of Avalonia towards Baltica is recorded by the Megasequence 2 (Middle to Upper Ordovician, 1.3 km thick). The source for Mesoproterozoic zircons vanished, as the result of the Rheic Ocean opening and the isolation from Amazonian sources. The transition to Megasequence 3 is marked by a drastic change in palaeobathymetry and an important (sub)volcanic episode during a tectonic instability period (460–430 Ma), reflecting the Avalonia–Baltica soft docking as also shown by the reappearance of Mesoproterozoic detrital zircons, typical of Baltica. Unradiogenic Nd isotope signature (ε_{Nd} −4/−5) and T_{DM} model ages (1.3–1.7 Ga) for Brabant magmatic rocks indicate an old recycled component. Megasequence 3 (uppermost Ordovician to lowermost Devonian; >3.5 km thick) includes the onset of a Silurian foreland basin that reflects the tectonic inversion of the core of the massif (Brabantian orogeny) in response to the Baltica–Avalonia–Laurentia collision. Finally, the comparison with the strikingly similar Cambrian successions of the Harlech Dome (Wales, Avalonia) and the Meguma terrane (Nova Scotia, peri-Gondwana) allows the construction of a new Early Cambrian palaeogeographic model for the whole Avalonia microplate, in which the Meguma terrane is included.

Contents

* Corresponding author. Tel.: +32 2 650 2201.
E-mail addresses: ulf.linnemann@senckenberg.de (U. Linnemann), herbosch@ulb.ac.be (A. Herbosch), jean-paul.liegeois@africamuseum.be (J.-P. Liégeois), c.pin@opgc.univ-bpclermont.fr (C. Pin).

0012-8252/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
doi:10.1016/j.earscirev.2012.02.007

1. Introduction

Although largely concealed, the Brabant Massif is now very well known for its overall geology, due to recent multidisciplinary research and detailed (1/25,000 scale) geological mapping. The Lower Palaeozoic of the Brabant Massif is of major interest because it offers a nearly continuous record of the sedimentation from the upper part of Cambrian Stage 2 (~525 Ma) to the lowermost Lochkovian (~415 Ma) within a strongly developed,>13 km thick, sedimentary sequence. This sedimentary succession constitutes the only well known witness of the southern side of the eastern part of Avalonia facing Gondwana during Cambrian and subsequently the Rheic Ocean until its closure. The palaeogeographic positions of the Brabant Massif are broadly inferred from its location within Avalonia but no direct, or detailed provenance constraints are available from this thick sequence. Also, the nature and the significance of the magmatism have not been reassessed recently since the pioneering works 30 years ago.

This study provides an up-to-date review of the recently established stratigraphy of the Lower Palaeozoic of the Brabant Massif together with new constraints on geodynamic setting and palaeogeographic positions based on LA-ICP-MS U–Pb ages on single grains of detrital and igneous zircons (over 1000 spot analyses on 8 sediments and on 4 (sub)volcanic rock samples), and major, trace element and Nd isotope whole-rock analyses (24 samples). For the first time, a comprehensive evolutionary model is proposed for the Avalonian Brabant Massif during the Early Palaeozoic. This includes Cambrian rifting from Gondwana, drifting during the opening of the Rheic Ocean, soft docking with Baltica, the far-field effects of the remote Caledonian collision with Laurentia, and finally its behavior as a passive margin to the north-west of the Rheic Ocean, as part of the southern Old Red Sandstone Continent (Laurussia). Later, the Brabant Massif played the role of an indenter during the Variscan orogeny, and was not significantly affected except along his southern edge corresponding to the Variscan Front (Fig. 1). These new tight palaeogeographic constraints allow to place the Brabant Palaeozoic odyssey within the evolution of the entire Avalonia terrane, including both its American and European counterparts.

Throughout this paper, we follow the conception of Cocks and Fortey (2009) who consider that: "Avalonia was internally unified throughout the Lower Palaeozoic and not two independent "East" and "West" Avalonian terranes of some authors". In consequence we use "East" (in North America) and "West" (in Europe) Avalonia only for descriptive purposes. The chronostratigraphy and time scale by Ogg et al. (2008) is followed throughout.

2. Brabant Massif: general features

The Brabant Massif (Figs. 1, 2) consists of a largely concealed WNW–ESE directed fold belt developed during Early Palaeozoic times, documented in the sub-surface of central and north Belgium (Fourmarier, 1920; Legrand, 1968; De Vos et al., 1993; Piessens et al., 2006). At first sight, it appears as a gently ESE plunging broad anticlinal structure, with a Cambrian core flanked on both sides by Ordovician to Silurian strata. To the S, SW and SE, it is unconformably overlain by the Devonian to Carboniferous deposits of the Brabant Parautochthon (Mansy et al., 1999). The southern border of the latter shows Upper Palaeozoic thrust sheets belonging to the Brabant Massif (Condroz inlier, a 70 km long to 1 to 3 km large strip, elongated W–E along the Sambre and Meuse rivers; Michot, 1980; Vanmeirhaeghe, 2006). The Brabant Parautochthon is tectonically overlain by the Ardenne Allochthon along the Midi Fault System (Variscan overthrust; Fig. 2A). To the NW, the massif continues beneath the North Sea and links up with the East-Anglia Basin (Lee et al., 1993). Both areas form part of the Anglo-Brabant Deformation Belt (ABDB; Pharaoh et al., 1993, 1995; Van Grootel et al., 1997), the eastern branch of a predominantly concealed slate belt molded around the Neoproterozoic Midlands Microcraton. The ABDB belongs to the Avalonia microplate (Figs. 1 and 2A).

The Brabant Massif is poorly exposed and is almost completely covered by Meso-Cenozoic deposits (Fourmarier, 1920; Legrand, 1968). Along its southeastern rim, incising rivers (Figs. 2 and 3) provide narrow outcrop areas that were recently mapped at the 1/25,000 scale (Herbosch and Lemonne, 2000; Delcambre et al., 2002; Hennebert and Eggermont, 2002; Delcambre and Pingot, 2008; Herbosch and Blockmans, in press; Herbosch et al., in press-a,b). A substantial part