Tectonophysics 681 (2016) 278–304

Contents lists available at ScienceDirect

Tectonophysics

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

Gondwanan basement terranes of the Variscan–Appalachian orogen: Baltican, Saharan and West African hafnium isotopic fingerprints in Avalonia, Iberia and the Armorican Terranes

Bonnie J. Henderson [a,*], William Joseph Collins [b], James Brendan Murphy [c], Gabriel Gutierrez-Alonso [d,e], Martin Hand [a]

[a] Department of Geology and Geophysics, School of Physical Sciences, The University of Adelaide, SA 5005, Australia
[b] School of Environmental & Life Sciences, University of Newcastle, Newcastle 2308, Australia
[c] Department of Earth Sciences, St. Francis Xavier University, P.O. Box 5000, Antigonish, NS B2G 2W5, Canada
[d] Departamento de Geología, Universidad de Salamanca, 33708 Salamanca, Spain
[e] Tomsk State University, Prosp. Lenina 36, Tomsk 634050, Russia

ARTICLE INFO

Article history:
Received 22 July 2015
Received in revised form 17 November 2015
Accepted 20 November 2015
Available online 11 December 2015

Keywords:
Hafnium
Neoproterozoic
Zircon
Iberia
Avalonia
Gondwana

ABSTRACT

Iberia, Avalonia and the "Armorican" terranes form key constituents of the Variscan–Appalachian orogen, but their Neoproterozoic origins along the northern Gondwanan margin continue to be strongly debated. Here, we present a new detrital zircon U–Pb–Hf dataset from Neoproterozoic–Silurian sedimentary sequences in NW Iberia and Avalonia, in conjunction with the comprehensive existing datasets from potential source cratons, to demonstrate that the provenance of each terrane is relatively simple and can be traced back to three major cratons. The enigmatic Tonian–Stenian detrital zircons in autochthonous Iberian rocks were derived from the Saharan metacraton in the latest Neoproterozoic–early Cambrian. Avalonia is commonly considered to have been derived from the Amazonian margin of Gondwana, but the hafnium isotopic characteristics of the detrital zircon grains in early Neoproterozoic rocks bear much stronger similarities to Baltica. The hafnium isotopic array also suggests the early Avalonian oceanic arc was built on a sliver of "Grenvillian-type crust" (~2.0–1.0 Ga) possibly of Baltican affinity at ~800 Ma, prior to accretion with a continental margin at ~640 Ma. The Upper Allochthon of Iberia is frequently linked to the West African Craton in the late Neoproterozoic–early Cambrian, however the hafnium isotopic array presented here does not support this connection; rather it is more similar to the hafnium array from Avalonia. The Armorican terranes have strong detrital zircon isotopic links to the West African Craton during the late Neoproterozoic–Cambrian.

1. Introduction

Modern provenance studies have routinely focussed on obtaining the U–Pb crystallisation age of individual detrital zircon grains to build statistically significant populations that can be "matched" to the age of tectonomagmatic events recognised in potential source terranes (Anderson, 2005; Dickinson and Gehrels, 2009; Ireland et al., 1998; Košler et al., 2002). The method becomes problematic if the potential source terranes preserve coeval tectonothermal events, because they yield overlapping zircon age spectra. Hafnium isotope analysis of the same zircons allows the data to be presented in composite hafnium (εHf) arrays, thereby allowing for more rigorous comparisons with the evolution of putative source areas (Howard et al., 2009; Wang et al., 2010). Moreover, Hf arrays have the potential to evaluate geodynamic links between dispersed blocks that otherwise show only weak geological connection. Comprehensive hafnium isotope arrays define the nature of the zircon-forming tectonomagmatic events at the cratonic scale (Smits et al., 2014), and as such generate an isotopic "fingerprint" for that craton that can be directly compared to exotic continental terranes.

The interval between the late Neoproterozoic supercontinent Gondwana and the Carboniferous assembly of Pangea is shaped largely by the events surrounding the development and subsequent destruction of the Rheic Ocean and the evolution of the 'peri-Gondwanan' microcontinental terranes that occupied the oceanic realm between Gondwana and Laurussia (Nance et al., 2012; Pollock et al., 2011; van Staal et al., 2012). Closure of the Rheic Ocean was accompanied by collision between Gondwana and Laurussia forming the Appalachian–Variscan Orogen of North America and western Europe (Hibbard et al., 2010; Scotese, 2004; Stampfli et al., 2013). The events prior to the amalgamation of Pangea are controversial essentially because there are insufficient constraints on the late Neoproterozoic–early Paleozoic provenance and paleogeography of the microcontinental terranes that

* Corresponding author.
E-mail addresses: Bonnie.henderson@adelaide.edu.au (B.J. Henderson), Bill.collins@newcastle.edu.au (W.J. Collins), bmurphy@stfx.ca (J.B. Murphy), gabi@usal.es (G. Gutierrez-Alonso), Martin.hand@adelaide.edu.au (M. Hand).

http://dx.doi.org/10.1016/j.tecto.2015.11.020
0040-1951/

form the basement of the Appalachian–Variscan orogen. Robust paleogeographic constraints for the Late Neoproterozoic microcontinental terranes that are commonly thought to have formed along the northern Gondwanan margin are required to provide the framework for unravelling the Paleozoic crustal evolution of the Pangean amalgamation.

The late Neoproterozoic provenance and paleogeography of the peri-Gondwanan terranes has been previously constrained by matching the U–Pb zircon age spectra in clastic sedimentary and igneous rocks with coeval tectonothermal events in the potential source cratons of northern Gondwana (see compilation in Eckelmann et al., 2014 and references therein). The addition of hafnium isotope analyses to these U–Pb zircon studies provides a powerful tool in further defining the isotopic "signature" of these terranes, the nature of the tectonomagmatic events and can distinguish between tectonic processes dominated by the input of juvenile crust and those that involve the reworking of older crustal material (Hawkesworth and Kemp, 2006).

The basement terranes of the Variscan–Appalachian orogen include (but are not limited too) Avalonia, Iberia, "Armorican" terranes and the Pontides of Turkey. Avalonia is commonly subdivided into east and west Avalonia, with eastern Avalonia located in Europe and the United Kingdom and western Avalonia underlying much of the eastern seaboard of Atlantic Canada (Cocks et al., 1997). Here, we present a new comprehensive U–Pb–Hf detrital and magmatic zircon data set from Neoproterozoic–Ordovician rocks from NW Iberia and western Avalonia, which we use in conjunction with published data from Iberia and eastern Avalonia, to test the provenance of Iberia and Avalonia during the Neoproterozoic–Ordovician interval. We compare these data against a wealth of hafnium isotopic data published in the last decade from cratonic domains within the Gondwanan supercontinent including: the West African Craton (WAC), Arabian–Nubian Shield (ANS, Morag et al., 2012; Ali et al., 2013; Robinson et al., 2014), Saharan Metacraton (SMC, Iizuka et al., 2013; Be'eri-Shlevin et al., 2014; Meinhold et al., 2014), Amazonia (Hurai et al., 2010; Matteini et al., 2010; McGee et al., 2015; Reimann et al., 2010), the central African region (Congo Craton and Mesoproterozoic orogenic belts) (Foster et al., 2014; Iizuka et al., 2013), and Baltica (Beranek et al., 2013; Kristoffersen, 2011; Kuznetsov et al., 2010, 2014; Romanyuk et al., 2014).

We use these comprehensive hafnium isotopic arrays from Avalonia, Iberia and Armorica, in addition to major cratonic domains of Gondwana and Baltica, to demonstrate that distinct hafnium isotopic fingerprints are identifiable in the basement terranes of the Variscan–Appalachian orogen. The data have direct implications for late Neoproterozoic paleogeography, the geodynamic evolution of the Rheic Ocean and subsequent amalgamation of Pangea.

2. Geological background

2.1. The evolution of the Variscan–Appalachian Orogen

The evolution of the Paleozoic Variscan–Appalachian orogen is dominated by the late Cambrian–early Ordovician opening and Devonian closure of the Rheic Ocean (Fig. 1). The Rheic Ocean opened when Neoproterozoic arc-related terranes, collectively termed the "peri-Gondwanan" terranes, separated from the northern margin (present coordinates) of West Gondwana in the early Paleozoic (Pollock et al., 2011; Stampfli and Borel, 2002; van Staal et al., 1998, 2012). These

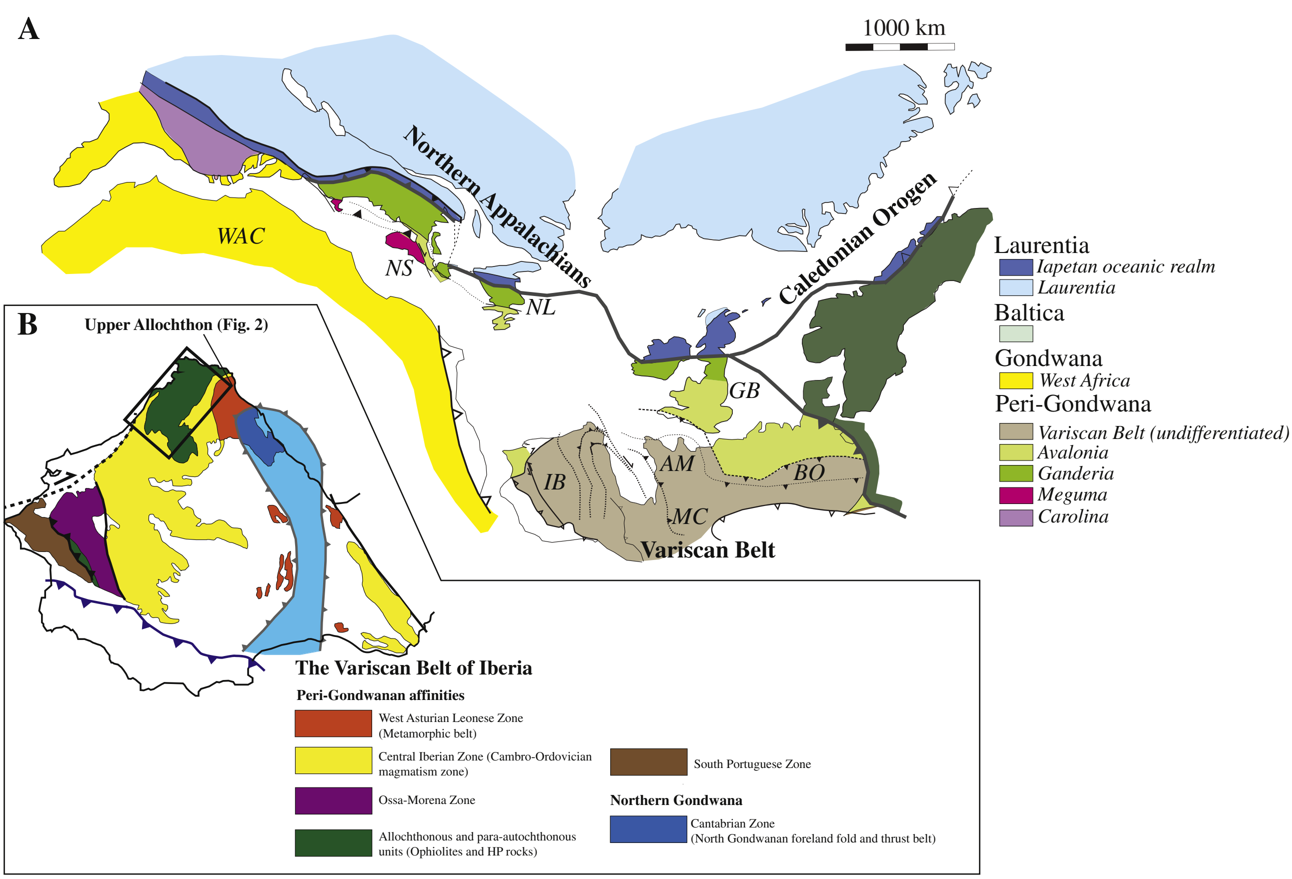

Fig. 1. A) Map showing the distribution of the Appalachian, Variscan and Caledonian belts at the end of the Paleozoic. Shown are the major cratonic and microcontinental components within the orogenic belts including Iberia (IB), Americian Massif (AM), Massif Centrale (MC), Bohemian Massif (BO) and the West African Craton (WAC). This represents the approximate configuration of Pangea following late Paleozoic convergence between Laurentia and Gondwana. B) Geology map illustrating the major tectonic subdivisions of Iberia. Upper Allochthon is highlighted in the box and is detailed further in Fig. 2.
The figure is modified from Barreiro et al. (2007) and Keppie et al. (2008).