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Peri-Gondwanan terrane interactions recorded in the Cambrian–Ordovician detrital zircon geochronology of North Wales

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ABSTRACT

Precambrian to Ordovician sedimentary basins of Wales display contrasting histories across major NE-striking fault systems. Northeast of the Menai Strait Fault System the Monian Supergroup is a deformed succession of mainly metaclastic rocks. Within the fault system the Arfon Basin contains sandstone and slate overlying Neoproterozoic volcanic rocks. South of the fault system, in the Harlech Dome of the Welsh Basin, a distinctive succession of clastic rocks has been correlated with those of the Meguma Terrane in the northern Appalachian orogen, together comprising the domain Megumia. A detrital zircon analysis from Cambrian sandstone in the Harlech Dome is consistent with this correlation. However, the Early Ordovician Dol-cyn-afon Formation higher in the succession and the overlying Late Ordovician Conway Castle Sandstone show a more diverse provenance, consistent with derivation from the Monian Supergroup. Cambrian sandstone from the Llanberis Slates Formation in the Arfon Basin shows a distinct provenance dominated by a Neoproterozoic source. None of the samples analyzed contains Laurentian detritus. These results suggest that the Welsh Basin was juxtaposed with the Monian Supergroup and its Precambrian substrate along the Menai Strait Fault System by the Tremadocian, and indicate that the Iapetus Ocean remained open at least until the Silurian. The Cambrian detrital zircon record from the Arfon Basin does not show clear similarity to the Monian Supergroup, nor to the Welsh Basin and adjacent Midland Platform, indicating that the basin was isolated from these sedimentary sources within the fault system. The juxtaposition of these terranes probably took place during strike-slip to transpressional tectonism close to the northern margin of Gondwana during the Early Ordovician.

1. Introduction

The ages of detrital zircon grains in clastic sedimentary rocks offer important information about source regions for sedimentary basin fill, and therefore can potentially provide critical information to help constrain the paleogeographic evolution of orogens and the timing of juxtaposition of different terranes.

The Caledonide–Appalachian Orogen preserves evidence for tectonic events spanning the Early Ordovician to the Middle Devonian that record closure of the Iapetus Ocean and the collision of Laurentia, Baltica, and terranes that originated on the margins of Gondwana (e.g. Harland and Gayer, 1972; van Staal et al., 1998; McKerrow et al., 2000; Hibbard et al., 2007). Within the orogen, the passive margin of Laurentia, and associated peri-Laurentian terranes, are recognized to extend along most of eastern North America, northern parts of Ireland, Scotland, and part of Greenland (Fig. 1). Outboard of this Laurentian realm is a mosaic of terranes, including most of England, Wales, southern parts of Ireland, and much of Atlantic Canada, interpreted as a series of ribbon continents and arcs formed along the Iapetan margin of West Gondwana, collectively described as peri-Gondwanan; these have been classified in the Appalachians into several domains including Ganderia, Avalonia, and the Meguma Terrane of Nova Scotia (Fig. 1a; Hibbard et al., 2007).

Several links have been made between peri-Gondwanan elements involved in the Caledonide Orogen in the British Isles and Appalachian Orogen of Atlantic Canada (Fig. 1). East and West Avalonia (Fig. 1) are generally characterized by condensed Lower Paleozoic successions of platformal aspect overlying Precambrian arc-related volcanic suites (Nance et al., 1991; Nance and Murphy, 1994). The adjacent Cambrian successions of the Harlech Dome within the Welsh Basin (Fig. 1) and the Meguma Terrane (Fig. 1) of Nova Scotia have been linked by Waldron et al. (2011) in a newly defined domain, Megumia. Portions of the island of Anglesey and the Leinster–Lakesman Terrane (Fig. 1) have been correlated with the domain Ganderia of Newfoundland and New Brunswick (e.g., van Staal et al., 1996 and references therein, 1998; Waldron et al., 2014).

Most reconstructions (Linnemann et al., 2004; Murphy et al., 2004a; Nance et al, 2008) locate these domains along the northern margin of Amazonia–West Africa, facing toward Baltica. The dispersal of these domains into the Iapetus Ocean is poorly understood, but probably involved components of both rifting and sinistral shear relative to the margin of Gondwana, as portrayed by Fernandez-Suarez et al. (2002a,b),

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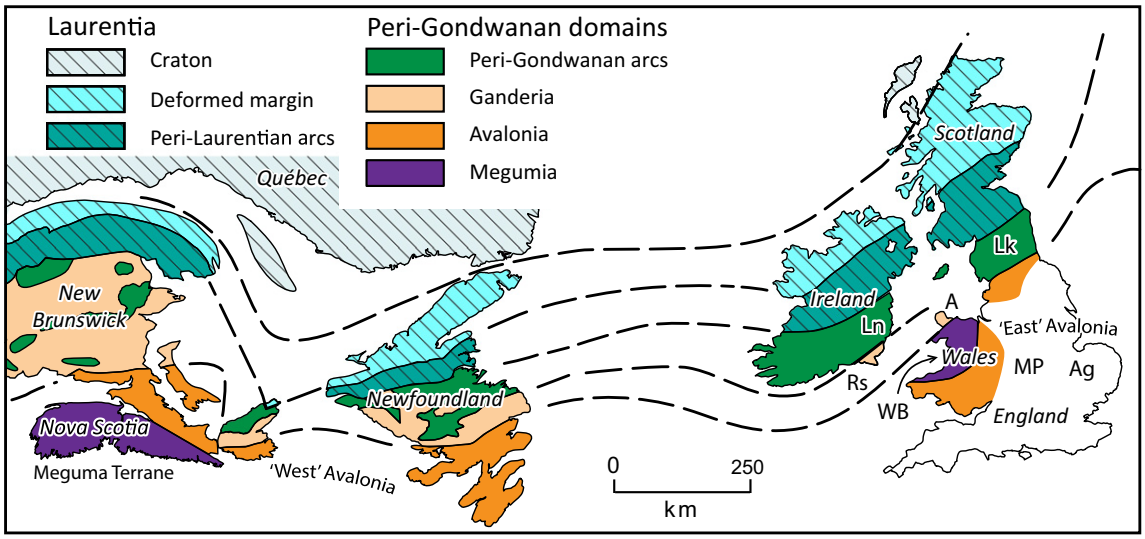

Fig. 1. Terrane map of the North America Appalachians and British Caledonides. Abbreviations in alphabetical order: A—Anglesey; Ag—Anglian Basin; Lk—Lakesman Terrane; Ln—Leinster Terrane; MP—Midland Platform; MT—Meguma Terrane; Rs—Rosslare Terrane; WB—Welsh Basin. Pre-Atlantic fit of continents after Knott et al. (1993). Data and correlations compiled from van Staal et al. (1998), Barnes et al. (2007), Hibbard et al. (2007), and Waldron et al. (2011).

Murphy et al. (2004a) and Nance et al. (2008). Van Staal et al. (2012) suggest a middle Cambrian (~500 Ma) separation of Ganderia from Gondwana. Based on analysis of subsidence curves, Prigmore et al. (1997) conclude that East Avalonia probably separated from Gondwana in the late Cambrian to Tremadocian around 490 Ma, although Landing (1996) suggests that Avalonia was independent of Gondwana from Neoproterozoic onward. Convergent tectonic events also affected some peri-Gondwanan terranes during the Early Ordovician. Penobscot deformation resulted in an important unconformity in Maine (Neuman, 1967; Neuman and Max, 1989) and a "soft collision" that emplaced ophiolites on a margin of Ganderia in Newfoundland (Colman-Sadd et al., 1992). Tremadocian (Monian) deformation is recorded in Anglesey (Fig. 1) where it resulted in metamorphism and fabric development in the Monian Supergroup (e.g. Treagus et al., 2003, 2013). Unconformities occur during this interval in the remainder of the Welsh Basin. The subsequent drift of Ganderia toward Laurentia during the Ordovician is tracked by Van Staal et al (2012) using paleomagnetic data. Components of Ganderia came in contact with Laurentia starting in the Katian (Waldron et al., 2011) but other components, together with Avalonia, do not appear to have collided with Laurentia until the Silurian (~425 Ma; Waldron et al., 2014).

The purpose of this paper is to investigate Cambrian and Ordovician terrane interactions on the margin of Gondwana by examining the detrital zircon record from sandstone units sampled in North Wales spanning the interval from the Cambrian to the latest Ordovician in order to: (1) constrain the timing of the juxtaposition of the Lower Palaeozoic Welsh Basin with contrasting units to the NW along the Menai Strait Fault System; (2) provide new insight into the origin of the Arfon Basin, which lies along the fault system; and (3) determine whether North Wales came into contact with Laurentia during this time interval. We build on the results of Waldron et al. (2009, 2011) who suggested a link between the early Cambrian to Tremadocian successions of the Harlech Dome in North Wales and the Meguma Terrane, both having been derived from sources in Gondwana.

2. Geologic setting

2.1. Regional subdivisions

Precambrian to Early Ordovician sedimentary basins of Wales preserve contrasting histories across first-order fault zones. Most notable are the Welsh Borderland Fault System (WBFS) and the Menai Strait Fault System (MSFS; Fig. 2). The WBFS separates the thick succession of the Lower Paleozoic Welsh Basin from the adjacent more condensed successions of the Midland Platform to the east. It includes the Pontesford and Tywi lineaments, which have had a strong influence on deposition throughout the history of the basin and may mark a terrane boundary prior to the Late Ordovician (Woodcock and Gibbons, 1988) (Fig. 2). The MSFS (Gibbons, 1987) separates the Lower Paleozoic Welsh Basin from an assemblage of terranes in Anglesey and the Llŷn Peninsula, the Monian Composite Terrane of McIlroy and Horak (2006). The system contains a series of steep NE-striking faults and shear zones, most significantly the Berw, Dinorwic and Aber–Dinlle faults (Fig. 2). The Arfon Basin largely lies within the MSFS, intervening between the Anglesey successions and the Lower Palaeozoic Welsh Basin. It contains a unique Neoproterozoic to Cambrian succession that has not been definitively linked to adjacent contemporary successions (Rushton and Molyneux, 2011b), but shares a Floian and younger cover with the adjoining Welsh Basin. The contrasting Cambrian succession in the Monian Composite Terrane to the NW is assigned to the Monian Supergroup (Muir et al., 1979; Phillips, 1991; McIlroy and Horak, 2006). It is significantly more deformed and metamorphosed than the Cambrian rocks to the south. However, it is unconformably overlain by a largely unmetamorphosed Ordovician succession that is generally correlated with the Welsh Basin (e.g., Brenchley et al., 2006).

In the following sections we consider the stratigraphy of these basins in turn. Note that in discussing the stratigraphic record of terrane interactions it is important to use a consistent timescale. Where possible, we use the timescales of Gradstein et al. (2012) throughout this paper. This includes a four-fold division of the Cambrian (Peng et al., 2012); we informally use 'lower Cambrian' to include Series 1 (Terreneuvian) and 2 (unnamed); 'middle Cambrian' to include Series 3 (unnamed); and 'upper Cambrian' to include Series 4 (Furongian).

2.2. Northern Welsh Basin

A thick succession of lower Cambrian to Tremadocian sedimentary rocks is exposed in the Harlech Dome in North Wales (Brenchley et al., 2006). The base of the Harlech Dome succession has been interpreted as an unconformity with the Bryn Teg Volcanic Formation, of presumed Precambrian age, proven in a British Geological Survey stratigraphic borehole (Allen and Jackson, 1978). The top is marked by a sub-Floian unconformity, which is also preserved in Pembrokeshire