Reviews

Early Paleozoic Peri-Gondwanan Terranes: New Insights from Tectonics and Biogeography

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Reviewed by J. Brendan Murphy
Department of Earth Sciences
St. Francis Xavier University
P.O. Box 5000
Antigonish, NS, Canada, B2G 2W5
E-mail: bmurphy@stfx.ca

During the late Neoproterozoic and Early Cambrian, fundamental changes to global plate motions were accompanied by the final breakup of Rodinia and the amalgamation of Gondwana. The ancient margins of Gondwana record a highly varied evolution during the Paleozoic. Some parts of that margin were severed and displaced, were incorporated into younger Paleozoic orogens and were further dispersed by the breakup of Pangaea. Other parts of the margin, although tectonically active, remained either attached or proximal to that margin. The term 'peri-Gondwanan terranes' was originally introduced as a collective term to describe terranes along the northern margin of Gondwana, but in this special publication, the term is used more generally to include all Paleozoic terranes that originated along the periphery of Gondwana.

This special publication is an outcome of a 1-day symposium at the 2007 Lyell Meeting, held at the Geological Society of London, and was jointly organized with the Paleontological Association. There are twelve original papers in the publication, and a wide range of topics are covered, ranging from global-scale syntheses of paleogeography (e.g. Torsvik and Cocks) and climate (Cherns and Wheeley) to updates in the description of individual microcontinents or terranes (e.g. Fatka and Mergl; Popov et al.). Most of the papers focus on terranes that originated either along the northern margin or the proto-Andean margin of Gondwana. The limited time between the conference and publication of the book indicates that the papers are up-to-date syntheses. As implied in the title of the volume, most of the papers focus on the establishment and significance of biogeographical provinces and their application to paleogeography. With the exception of one article, all figures are in black-and-white. The production is up to the usual high quality expected of a Geological Society Special Publication.

Beginning in the Late Cambrian – Early Ordovician, several terranes located along the northern margin of Gondwana drifted from that margin, and subsequently accreted to other continents (e.g. Laurentia, Baltica) prior to the collision between Laurussia and Gondwana and the amalgamation of Pangaea. In North America, these terranes (Avalonia, Ganderia) are incorporated into the Appalachian Orogen and accreted to Laurentia prior to the amalgamation of Pangaea. These terranes underlie much of continental Europe and have played critical roles in the development of the Caledonian and Variscan orogens. All aspects of the evolution of these terranes are controversial, including their relative positions along the northern Gondwanan margin prior to separation, the timing and mechanisms of separation, their odyssey prior to accretion, the nature of their accretion to Laurentia or Baltica and their post-accretionary history before, and during, the amalgamation of Pangaea. Several papers in this volume (Fatka and Mergl; Servais and Sintubin; Álvaro and Van Vliet-Lanoë; Cocks and Fortey; Harper, Owen and Bruton) provide up-to-date syntheses on various aspects of these terranes.

Although the classic tectonostratigraphic zonation of the Variscan Orogen in Europe (Franke 1989) provides a first-order overview of the orogen, it masks the controversies and complexities in interpreting the tectonic significance of the peri-Gondwanan terranes. A bewildering and impenetrable array of terminology has arisen, which a few papers in this special publication attempt to clarify. Fatka and Mergl provide an overview of the complex evolution of terrane terminology, and argue, largely on the basis of faunal evidence, for the existence of Perunica as a microcontinent that is separate from the Armorican Terrane Assemblage throughout the Ordovician. They also evaluate the migration of faunas in response to Ordovician climatic changes. The contribution of Servais and Sintubin also tries to clarify the relative roles of Avalonia, Armorica and Perunica, noting that some terranes are called microcontinents, a paleogeographic term, and others have been called microplates, a plate tectonic term. They begin with a review of basic terminology in paleogeography, plate tectonics and paleobiogeography (very useful for students) and then apply that terminology to Avalonia, Armorica and Perunica. Their analysis, underpinned by faunal and paleomagnetic evidence, indicates that i) only Avalonia should be considered a separate microcontinent on a separate plate; ii) Armorica is composed of several terranes, and iii) Perunica should be considered only as a separate biogeographical province.

The paper by Cocks and Fortey provide a review and a partial re-interpretation of Avalonia during the Lower Paleozoic, with emphasis on the distribution of marine faunas, and the relationships of those faunas to adjacent terranes. They persuasively argue for a unified existence of Avalonia as a single terrane during the Ordovician, rather than as independent West and East Avalonian terranes. Most Avalonian workers agree with this conclusion, but reserve the terms West and East Avalonia as convenient descriptors for the portions of Avalonia that ended up in North America and Europe (respectively) when Avalonia was sundered by the opening of the Atlantic (Murphy and Nance 2002). More controversially, Cocks and Fortey re-open the debate, principally with Landing (1996, 2005) about the relationship between Avalonia and Gondwana in the late Neoproterozoic and Cambrian. Cocks and Fortey follow McKerrow et al. (1992) in maintaining that Avalonia was part of Gondwana throughout this time interval until the Early Ordovician, whereas Landing and co-workers maintain that Avalonia was a separate microcontinent at different paleolatitudes during the late Neoproterozoic and Cambrian. This is an important debate and it is unfortunate that there is no contribution from Landing and co-workers in this volume.

Harper et al. provide a welcome clarification on the mysterious concept of the Celtic faunas. They point out that between the Early and Middle Ordovician, there was an unprecedented increase in marine life diversity (species, genus and family levels). During that same time period, a group of microcontinents and island arcs had distinctive shelly faunas. They show that these Celtic faunas include a large number of endemic brachiopod taxa, whereas associated trilobite faunas are predominantly composed of wide-ranging genera. Using spatial and temporal cluster analyses of brachiopod distribution data, they argue for the integrity of the Celtic province as a discrete and widespread biogeographic unit that was located north of the Gondwanan margin and included areas of central Andes, Famatina, Atlantic Canada, Ireland, NW Wales and the southern Urals.

The Paleozoic passive margin sequence preserved in Iberia provides first-order constraints for the evolution of the southern flank of the Rheic Ocean (Quesada 1990). The paper by Álvaro and Van Vliet-Lanoë focuses on the crucial Late Ordovician interval, when evidence of Hirnantian glaciation is widespread in northern Gondwana. The paper examines the relationship between carbonate productivity and the glaciomarine record in a stable inner platform as well as a platform undergoing heterogeneous subsidence.

On the basis of faunal evidence, Fortey and Cocks (2003) show the Early Paleozoic terranes in Kazakhstan as a collage of microplates located adjacent to the northern Gondwanan margin. Popov et al. provide a very detailed tectonostratigraphic and faunal analysis from strata in two terranes in Kazakhstan, the Chu-Il and Karatau-Naryn terranes. Their paper includes several useful maps, lithostratigraphic correlation diagrams, field photographs and basin subsidence history diagrams. They use paleogeographic affinities with Gondwana to refute earlier models involving accretionary tectonics and provide global paleogeographic reconstructions implying that the Kazakh terranes resided at sub-equatorial latitudes between the Middle Ordovician and Early Silurian.

At the same time as terranes drifted from northern Gondwana to Laurentia and Baltica, the Precordillera separated from the Ouachita embayment of southeastern Laurentia and drifted toward the South American margin of Gondwana. Recently, we have learned that subduction occurring beneath the proto-Andean margin of West Gondwana continued throughout most of the late Neoproterozoic and Paleozoic, and that peri-Gondwanan terranes formed along that margin, but re-accreted to it. Pankhust and Vaughan provide a brief overview of the tectonic context of the Early Paleozoic southern margin of Gondwana, which stretched for more than 18 000 km from South America to Australia. These authors point out that it was one of the longest and longest-lived active continental margins, with subduction initiating in the late Neoproterozoic, and eventually evolving into the Terra Australis Orogen (Cawood 2005; Vaughan and Pankhurst 2008).

Benedetto et al. provide a synthesis of the wealth of recent faunal data from Paleozoic rocks along the South American margin. The main tectonostratigraphic domains are defined: i) Autochthonous South America with internal and peripheral basins; ii) volcano-sedimentary basins that are marginal to Gondwana (Famatina and Puna); and iii) exotic crustal blocks (e.g. Precordillera). Their analysis shows that faunas in the marginal volcano-sedimentary basins have linkages to Celtic faunas, thereby providing constraints for continental reconstructions. Additional and updated faunal evidence is provided to show that the Precordillera is indeed Laurentian-derived (cf. Astini and Thomas 1999).

The early history of land plants is a controversial subject from evolutionary and phytogeographical perspectives. Edwards et al. describe plant assemblages in the Devonian strata of the Argentine Precordillera. Paleocontinental reconstructions indicate that the Precordillera was located at high latitude at that time. The much lower grades of floral organization in the Precordillera compared with coeval assemblages on other continents is interpreted by the authors as evidence for a global latitudinal gradient in vegetation. In a second contribution, Edwards et al. provide a detailed study of enigmatic fossils in Upper Silurian sequences of Bolivia and conclude that they indicate high productivity at high paleolatitudes in Late Silurian epicontinental seas.

The contribution of Torsvik and Cocks provides a welcome update of their influential paper (Cocks and Torsvik 2002) and extends the analysis to include peri-Gondwanan terranes along the northeastern and eastern segments of the Gondwanan margin, which today are found in Turkey, the Middle East, north of the Indian subcontinent, southern China, southeastern Asia, Australia and New Zealand.

Some of these regions, they argue, were passive margins for much of the Paleozoic. Others became separate terranes. They delve into the important debate on the origin and timing of the Paleotethys Ocean, which is linked to the putative drift of the Hun superterrane from the northern Gondwanan margin (compare Stampfli and Borel 2002).

Cherns and Wheeler provide a provocative synthesis of climate change in the early to middle Paleozoic in which they examine the relationship between facies, faunas, and isotopic data from the peri-Gondwanan terranes of Europe. In contrast to previous syntheses, they interpret Late Ordovician carbonate deposits in high paleolatitudes to reflect cool carbonate deposition, indicating an interval of global cooling rather than warming. They view the Late Ordovician Hirnantian glaciation as the most pronounced expression of episodic cooling of any event between the Middle Cambrian and Late Silurian, and propose that it may have been orbitally controlled.

The editor is congratulated for putting together a very attractive collection of papers that provide up-to-date syntheses on the current state of knowledge, as well as the lack of knowledge, on the Paleozoic distribution of these important terranes. As a non-practitioner of paleontology, I initially was apprehensive about reviewing a publication that I anticipated might contain abundant systematic paleontology. Instead, this publication is clearly intended to reach a broader readership and I think it will be successful in attaining this goal. I would certainly recommend it to research students who are working on any aspect of Paleozoic paleogeography and the methodologies involved. For the more experienced researcher, it is certainly worthwhile having a copy of this volume on your library shelf. It will be on mine, and I anticipate that I will refer to it often.

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The Legacy of Mike Coward: The Deformation of the Continental Crust

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Reviewed by Adrian F. Park
Department of Geology
University of New Brunswick
PO Box 4400
Fredericton, NB, Canada, E3B 5A3
E-mail: apark@unb.ca

Mike Coward cast a long shadow in the world of geology in general, and it was not just the 'structural geology' community who mourned his premature death at 59 in 2003. This volume of papers contributed and edited by colleagues and former graduate and undergraduate students, is a fitting memorial. The scope of topics covered reflects the breadth of Mike Coward's own interests and influence – simply saying he was a 'structural geologist' does not do justice – he was equally at home analyzing outcrop-scale strain as attempting a traverse through a modern orogenic belt; indulging in theoretical aspects of natural strain as applying his knowledge and analytical skills to seismic reflection profiles. A 'details' man: he never lost sight of the big picture, so appositely placed in the title to this volume – 'the deformation of the continental crust.'

In an age when 'field work' is practically a term of abuse, and university bean-counters are employing every method they can to cut field school and excursion budgets (the latest ploy being concerns over liability issues and potential costs) Mike Coward's teaching and research emphasized the primacy of sound observation. All good geology begins in the field and any model that is not so firmly grounded, for all its numerical elegance or flood of colourful print-out, remains an exercise in wishful thinking.