Editorial

Foreword

This special issue of the JSAES aims to summarize the present state of knowledge concerning events of Grenvillian age in Central and South America, and to outline ties with coeval processes in Laurentia. The papers presented here should be of interest to a broad audience of scientists working in Earth Sciences because of the many implications these ties have on paleogeographical reconstructions of continents and on consequent effects, for example on paleoclimatology and ore resources.

The Grenville Province was first recognized along the eastern border of the Canadian shield, where early K–Ar dating of gneisses and igneous rocks gave much younger ages (ca. 1000 Ma) than those that characterise the Archaean and earlier Proterozoic provinces that form the greater part of the shield, with a rather sharp boundary zone known as the Grenville Front. Decades of intense study, including more advanced dating, showed that the province did indeed contain older rocks, reworked during a major collisional orogeny. The structure shows large-scale north-westward thrusting, and evidence of long-lived plate convergence, always directed towards the Laurentian cratonic core. Older (parautochthonous) rocks are found near the base of the thrust stack in the west, attributed to the Paleoproterozoic Labradorian (ca. 1650 Ma) and the Mesoproterozoic Pinwarian (ca. 1400 Ma) orogenies. The Grenville orogeny itself is now recognized as a complex and extended series of igneous, deformational and metamorphic episodes related to terrane accretion events on the eastern side of the province; in some classifications the overall time span extends from about 1300 Ma to 950 Ma. The southward extension of the orogenic belt is progressively buried by Paleozoic and younger rocks, and was involved, together with part of this cover, in the Appalachian orogenies. Nevertheless, it has been traced continuously into the Ouachita belt of Mexico.

The further discovery of Mesoproterozoic–Neoproterozoic orogenic belts of similar ages surrounding or cross-cutting older cratons elsewhere in the world, notably in Africa, Australia and Antarctica, led to their integration into global plate tectonic models that attempted to join them up (Dalziel, 1991; Hoffman, 1991). For many authors, the Grenville-age collisional belts marked a major stage of amalgamation of the continental masses into a hypothetical supercontinent, Rodinia, towards the close of the Mesoproterozoic. The nature (or even the existence) of Rodinia has sometimes been challenged, but it would have disappeared during the mid-Neoproterozoic era through the opening of new ocean basins. Eventual collisions between many of the dispersing continental fragments, and others not previously involved in Rodinia, resulted in a new grouping by Cambrian times: the supercontinent of Gondwana.

It is widely considered that Eastern Laurentia and the Amazonian cratons were juxtaposed within Rodinia. Relics of Mesoproterozoic processes are well preserved in Central and South America, although the outcrops are dispersed over very long distances, rendering correlations difficult. This explains why the Mesoproterozoic evolution of different parts of Central and South America still remains poorly known, as does correlation with coeval processes along the Appalachian margin of Laurentia. In South America, the record of Grenvillian-age processes is found in the Sunsás–Aguapeí belt along the southern margin of the Amazonian craton. This orogen overprints an older orogenic belt (the Rondonian–San Ignacio belt) that is considered an immediate precursor. In addition, Grenville-age processes are recorded in scattered basement outcrops within the Andean region from Mexico (Oaxaquia) to southern Peru and northern Chile (Arequipa–Antofalla block), in the foreland of the southern Central Andes (Sierras Pampeanas of Argentina), as relics within the Brasiliano–Panafrican Borborema province in NE Brazil (Cariris-Velhos), and as remnants of intra-plate tectonic events scattered through the Amazonian and São Francisco cratons. The initial relative locations of the different South and Central American segments of this major orogenic belt and their internal structures are subject to very large uncertainties.

There have been many outstanding and comprehensive reviews of the Grenville province and the Grenvillian orogeny (e.g., Davidson, 1995; Hynes and Ludden, 2000; Tollo et al., 2004; Rivers, 2008; see also Canadian Journal of Earth Sciences, vol. 37, 2000, and The Grenville Instructional Web Server http://www.instruct.uwo.ca/earth-sci/300b-001/grenv.htm). The present collection of papers begins with a review of the Grenvillian collisional belt in northeastern North America, along the Appalachian margin of Laurentia, by Bartholomew and Hatcher. This article reviews the successive episodes of plate convergence from about 1250 Ma to 1000 Ma (the Elzevirian orogeny, and the Shawanigan, Ottawan and Rigolet phases of the Grenville orogeny). Particular emphasis is placed on the use of magnetic anomaly mapping in order to define the form of discrete tectonic units and to locate the trace of the sutures between them and their intersections with the rifted margin. Such details should provide potential piercing points that could help to orient separated fragments of the originally continuous belt now occurring outside North America.

Further context is set by Keppie and Ortega-Gutierrez, who review the late Mesoproterozoic igneous and metamorphic rocks of the Oaxaquia belt of Mexico. They conclude that the isolated Grenville-age outcrop fragments were parts of a single juvenile arc/back-arc terrane. The distribution and timing of tectono-metamorphic events and the pattern of Neoproterozoic exhumation are used to constrain the possible fit of North and Central America to the Amazonian craton of South America within Rodinia.

The subsequent contributions concentrate on South America and include reviews and research papers that address different geodynamic scenarios.

The immediate precursor of the Grenvillian orogeny is the Rondonian–San Ignacio belt of southwestern Amazonia, described by Bettencourt and co-workers, who fix its timing as between 1.56 and 1.3 Ga, correlative with the Pinwarian, and to some extent the Elzevirian, orogeny of North America. The belt resulted from oblique collision of the Paraguá microcontinental block with the Amazonian craton, and consists of juvenile intra-oceanic as well as continental magmatic arcs. The authors distinguish a number of discrete orogenic episodes and terranes of different ages and geotectonic significance, thus providing an up-to-date overview of this complex orogenic belt.

The Sunsás–Aguapeí belt, described by Teixeira and co-workers, has long been considered the true equivalent of the Grenville orogeny in South America and is a keystone in all proposed reconstructions of Rodinia. The orogeny took place between 1.2 and 0.91 Ga, thus embracing the Ottawan and Rigolet orogenies of the Grenville province of Canada. The orogeny overprints the already cratonized Rondonian–San Ignacio belt and the Paraguá block, and consists of an earlier extensional stage that led to passive-margin sedimentation and to the formation of rifted basins in the foreland, either floored by oceanic crust (Nova Brasilanda) or intracratonic (Huanchaca-Aguapeí). This stage was followed by deformation and metamorphism within an overall transpressional setting related to propagation of collision into the foreland and producing shear zones with sinistral offsets and coeval closure of the rifted basins. Orogenic-collapse magmatism took place between 1.08 and 0.98. The authors note the similarities to the Grenville orogeny of Laurentia.

Santos and co-workers deal with the tectonic events of the Cariris-Velhos belt, a late Grenville-age tectonic unit which is found as a relict within the Neoproterozoic Borborema tectonic province of northeastern Brazil. Tonian (1.0–0.9 Ga) orogenic assemblages within the Borborema province have been found recently. They are restricted to some shear-bounded domains within the tectonic province and underwent strong reworking during the late Neoproterozoic Brasiliano cycle tectonic events. The age of Cariris-Velhos is however uncommon in the Rodinia–Gondwana Grenvillian realm. The authors evaluate possible correlations, suggesting likely counterparts in the Tuareg shield and in the Sahara regions in Western and Central Africa.

Grenvillian ages are encountered in several basement inliers within the Mesozoic–Cenozoic tectonic structures of the Andean Cordillera. Ramos presents an overview of outcrops of Grenville-age rocks from Colombia to Patagonia, concluding that they participated in the amalgamation of the Rodinian supercontinent between 1.2 and 1.0 Ga. Some Grenvillian terranes were left on the Gondwanan side after Rodinia break-up, but others are allochthonous and were accreted much later at various times during the Paleozoic (e.g., Cuyania). The author thus envisages a complex history of terrane transfer between Laurentia and Gondwana that involved displacements, detachments and amalgamations.

Cardona and co-workers report on a comprehensive geochronological and isotope geochemical study of the northern Andes. Grenville-type ages were obtained from: (1) direct dating of basement inliers in Colombia, Ecuador and Peru, and (2) U–Pb detrital zircon dating from Paleozoic sequences in the Eastern Peruvian Andes. The studied basement inliers exhibit a quite different isotopic pattern from either the Sunsás belt or the Grenvillian sequences of Canada, and the authors suggest their derivation through arc and back-arc magmatic processes. Their conclusion is that the inliers formed a separate composite orogen within an active continental margin, possibly as a parautochthonous domain close to the margin of the Amazonian craton.

Rapela and co-workers combined geochemical and isotopic analyses with a few robust Grenville-type U–Pb zircon ages from a key area within the Sierras Pampeanas in Argentina. The geodynamic evolution of the region, dominated by convergent tectonics, is shown to have been a complex one, related to the accretionary stacking of a juvenile oceanic arc (Sierra de Pie de Palo) with an active continental margin developed on a Paleoproterozoic crust (Sierra de Maz). A medium- to high-grade regional metamorphic event is detected by dating of zircon overgrowths. A later extensional magmatic episode affecting the continental crust of Sierra de Maz, still within the Grenvillian age interval, formed an important AMCG complex, and resulted in a widespread regional thermal overprint.

The Arequipa block in Peru, where Paleoproterozoic to Paleozoic ages were already available, is a key area for Laurentia–Amazonia ties within Rodinia reconstructions. Casquet and co-workers provide significant additional geochronological constraints from U–Pb SHRIMP zircon dating. The oldest units are Paleoproterozoic and include UHT-type metamorphic rocks. Grenville-age low-P metamorphism is widespread, also affecting the older rocks. In the early Paleozoic, an important magmatic process affected the Arequipa massif, resulting in the formation of anorthositic rocks that were formerly believed to be Grenvillian. The authors indicate that the different age domains recognized could have been tectonically juxtaposed, and also suggest that extensional processes may have produced the Grenville-age metamorphic event associated with Laurentia–Amazonia collision.

Intra-plate tectonic events of Grenvillian age, not directly related to active margins, are discussed by Cordani and co-workers for the Amazonian and São Francisco cratons. The authors explore the relationships of intra-plate deformation, magmatism and metamorphism with processes at the active margins and argue that a relationship exists in the case of the K'Mudku events in Amazonia. The latter involved shearing, extensional anorogenic magmatism, and significant regional heating. The authors conclude that rifting processes were at work within Amazonia and São Francisco–Congo cratons at the time of Rodinia amalgamation.

As a concluding remark this special issue on the Grenvillian orogeny in central and southern South America presents up-to-date information on many key regions. Review papers contribute overviews that synthesize a wealth of dispersed information from complex and often inaccessible regions. Research papers in turn add new valuable data that contribute to better constraints on geotectonic processes in some key regions of South America with Grenville-age rocks. Reviews and new data contained in this special issue will thus be of much interest to all those working in geotectonics as well as in paleogeographical correlations of continents during amalgamation and break-up of Rodinia, opening the way for future work on many different issues.

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