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Review Article

Geological and geochemical evolution of the Trincheira Complex, a Mesoproterozoic ophiolite in the southwestern Amazon craton, Brazil

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ABSTRACT

We document the first-known Mesoproterozoic ophiolite from the southwestern part of the Amazon craton, corresponding to the Trincheira Complex of Calymmian age, and propose a tectonic model that explains many previously enigmatic features of the Precambrian history of this key craton, and discuss its role in the reconstruction of the Columbia supercontinent. The complex comprises extrusive rocks (fine-grained amphibolites derived from massive and pillowed basalts), mafic–ultramafic intrusive rocks, chert, banded iron formation (BIFs), pelites, psammitic and a smaller proportion of calc-silicate rocks. This sequence was deformed, metasomatized and metamorphosed during the development of the Alto Guaporé Belt, a Mesoproterozoic accretionary orogen. The rocks were deformed by a single tectonic event, which included isoclinal folding and metamorphism of the granulite–amphibolite facies. Layered magmatic structures were preserved in areas of low strain, including amygdaloidal and cumulate structures. Metamorphism was pervasive and reached temperatures of 780–853 °C in mafic granulites and 680–720 °C in amphibolites under an overall pressure of 6.8 kbar.

The geochemical composition of the extrusive and intrusive rocks indicates that all noncumulus mafic–ultramafic rocks are tholeiitic basalts. The mafic–ultramafic rocks display moderate to strong fractionation of light rare earth elements (LREE), near-flat heavy rare earth element (HREE) patterns and moderate to strong negative high field strength element (HFSE) anomalies (especially Nb), a geochemical signature typical of subduction zones. The lowest units of mafic granulites and porphyroblastic amphibolites in the Trincheira ophiolite are similar to the modern mid-ocean ridge basalt (MORB), although they locally display small Ta, Ti and Nb negative anomalies, indicating a small subduction influence. This behavior changes to an island arc tholeiite (IAT) signature in the upper units of fine-grained amphibolites and amphibole rich-amphibolites, characterized by progressive depletion in the incompatible elements and more pronounced negative Ta and Nb anomalies, as well as common Ti and Zr negative anomalies. Tectono-magmatic variation diagrams and chondrite-normalized REE and primitive mantle normalized patterns suggest a back-arc to intra-oceanic island arc tectonic regime for the eruption of these rocks. Therefore, the Trincheira ophiolite appears to have originated in an intraoceanic supra-subduction setting composed of an arc-back-arc system. Accordingly, the Trincheira Complex is a record of oceanic crust relics obducted during the collision of the Amazon craton and the Paraguá block during the Middle Mesoproterozoic. Thus, the recognition of the Trincheira ophiolite and suture significantly changes views on the evolution of the southern margin of the Amazon craton, and how it can influence the global tectonics and the reconstruction of the continents.

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1. Introduction

The paleogeographic continental reconstructions of the Mesoproterozoic commonly propose a link between eastern Laurentia and the western margin of the Amazon craton (Cawood et al., 2007; Dalziel, 1991; Hoffman, 1991; Keppie et al., 2001; Santos et al., 2008; Tohver et al., 2004a,b; Weil et al., 1998). The link between Amazonia and Laurentia is a key issue for the reconstruction of the Mesoproterozoic paleogeography. Over the past decade, different scenarios have been proposed for the evolution of the SW margin of the Amazon craton, primarily based on geochronological data (Bettencourt et al., 2010; Boger et al., 2005; Cordani and Teixeira, 2007; D'Agrella-Filho et al., 2008; Litherland et al., 1989; Sadowski and Bettencourt, 1996; Santos et al., 2000, 2008; Teixeira and Tassinari, 1984; Tohver et al., 2002, 2004a,b). All these previous investigations were conducted on a regional scale, without detailed field information or petrological, geochemical and structural data, limiting their interpretation of tectonic environments involved in the crustal growth of the southwestern Amazon craton. Several tectonic environments have been suggested and are related to the amalgamation of intra-oceanic magmatic arcs or back-arc and Wilson Cycle processes of ocean opening and closing (accretionary orogens). However, thus far, only Tohver et al. (2004a, 2006) have indicated the location of a suture zone between the adjoining Amazonia and Laurentia. In this work, we provide detailed field information and geochemical data which allow advancements in understanding the tectonic setting of the southwestern margin of the Amazon craton.

Distinguishing between accreted-terrane and terrane boundaries and sutures that separate different cratons or orogens involved in continent–continent collisions may be difficult because the distinction depends on identifying juxtaposed terranes that had significantly different magmatic and lithotectonic histories prior to collision but share a common history afterwards. Accretionary orogens may also be referred to as non-collisional, exterior orogens or zones of type-B subduction formed at intraoceanic and continental margin convergent plate boundaries. They form at sites of subduction of the oceanic lithosphere and include the supra-subduction zone forearc, magmatic arc and back-arc components (ophiolites) (Cawood et al., 2009). A large proportion of juvenile mafic to silicic calc-alkaline igneous rocks are involved, as well as their volcanosedimentary products. Large volumes of rocks from accretionary belts exhibit typical juvenile isotopic signatures, indicating essentially mantle-derived parental magmas. Ophiolites can be part of these environments as remnants of an allochthonous or autochthonous ancient oceanic crust and upper mantle incorporated into an orogenic belt. Thus, ophiolites are of prime importance to an understanding of orogens and are essential to the definition of a suture zone. One of the difficulties in the study of ophiolite complexes in deformed regions is that they are generally emplaced early and undergo considerable deformation and alteration during subsequent orogenic events.

Therefore, the identification of oceanic crust relicts in ophiolites along a suture zone at which the Amazon craton collided with the Laurentia or Paraguá block to form a supercontinent has remained enigmatic for many years, despite intense study of the poorly exposed SW portion of the Amazon craton. Tohver et al. (2004a) believe that the E–W trending Nova Brasilândia belt marks the limit between the Amazon and Paraguá cratons and formed during the late Mesoproterozoic. However, the Nova Brasilândia belt has no petrotectonic association compatible with a suture zone and was interpreted as a rift-passive margin (Rizzotto, 1999). To date, there are no known ophiolites in the southwestern margin of the Amazon craton.

Most modern ophiolites have subduction zone chemical characteristics, indicating their magmatic and tectonic association with supra-subduction zone processes (Dilek et al., 1999; Ishikawa et al., 2002; Shervais, 2001; Stern and Bloomer, 1992). The well-studied Tethyan ophiolites show a common geochemical progression in their magmatic evolution from initially MORB-like to IAT to boninites. In general, these ophiolitic complexes show an internal stratigraphy and chemical composition represented by a lower suite of relatively evolved IAT lavas, a middle suite of depleted arc tholeiite rocks, and a stratigraphically higher suite of highly depleted boninitic rocks (Dilek and Furnes, 2009). The evolution in the geochemical behavior of magma from MORB-type to IAT is characterized by a progressive depletion of the incompatible elements and more pronounced negative Ta and Nb anomalies, as well as negative anomalies of Ti and Zr.

The recognition of ancient tectonic environments based on only their geochemical characteristics is restricted by chemical similarity and alteration. The uncertainty about the tectonic setting where such ophiolites formed is due to the common occurrence of MORB-like lavas, in addition to those more indicative of a suprasubduction zone setting (IAT). Likewise, several examples in the literature show us that the geochemical characteristics of Archean mafic–ultramafic volcanic rocks provide important information for understanding the evolution of the initial mantle–crust system (Arndt et al., 1997; Jochum et al., 1991; Polat et al., 1998; Puchtel et al., 1998; Sun, 1987). Similarly, the geochemical characteristics of modern volcanic rocks of different tectonic environment are distinct in terms of the behavior of HFSE, LFSE and REE (Pearce and Cann, 1973; Sun and McDonough, 1989).