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Discussion

Comment on "Provenance of the Arroyo del Soldado Group (Ediacaran to Cambrian, Uruguay): Implications for the palaeogeographic evolution of southwestern Gondwana" by Blanco et al. [Precambrian Res. 171 (2009) 57–73]

Leda Sánchez Bettucci[a,*], Enrique Masquelin[a], Elena Peel[a], Pedro Oyhantçabal[a], Rossana Muzio[a], Juan J. Ledesma[a], Fernando Preciozzi[b]

[a] Instituto de Ciencias Geológicas, Facultad de Ciencias, Iguá 4225, CP 11400, Montevideo, Uruguay
[b] Dirección Nacional de Minería y Geología, Hervidero 2861, CP 11800, Montevideo, Uruguay

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> "Thus, it is truly tectonics which governs stratigraphy, and the two branches of the geological sciences are inseparable. A structural geologists who is not a stratigrapher is only a geometer, not a geologist; for he reasons about abstract surfaces and volumes, emptied of their history; and a stratigrapher who never concerned himself with tectonics would produce only a dead stratigraphy," (Gignoux, 1950, p. 3).

The paper "Provenance of the Arroyo del Soldado Group (Ediacaran to Cambrian, Uruguay): Implications for the palaeogeographic evolution of southwestern Gondwana" (Blanco et al., 2009) presented new U–Pb (SHRIMP), Sm–Nd and geochemical data of some units of Arroyo del Soldado Group (ASG), in order to better constraining the evolution of sedimentary protoliths and therefore to justify a rift tectonic setting for deposition of those units. Unfortunately, the data presented are incapable of answering the tectonic evolution of Neoproterozoic–Lower Paleozoic Brasiliano units located at the east of the Uruguayan territory. We point out that the authors' interpretation is not substantiated on the data. The scarcity of geological and isotopic data obtained for Dom Feliciano belt (DFB) determines a wide span of geotectonic models. Blanco et al. (2009) use, force, and adapt the available isotopic data to sustain their tectonic model. Other plausible models can also explain the geologic history of the DFB. We found in their hypothesis significant conceptual mistakes and omissions related to the metamorphic and deformational evolution of this region. In this comment we support a different view for the evolution of the Neoproterozoic-Cambrian basins in Uruguay and analyze these sequence based on a multidisciplinary approach.

1. Stratigraphical considerations

We cannot agree with the sentence "*one of the best studied Ediacaran to Lower Cambrian basins of SW-Gondwana* (*the Arroyo del Soldado Group sensu* Gaucher, 2000)" due to the scarcity of field geological information, geochemical, structural and isotopic data, as well as the controversial stratigraphical value of microfossils with problematic taxonomy. In fact, the stratigraphy proposed originally by Gaucher (2000) for the Arroyo del Soldado Group (ASG) is very controversial due to: (1) the lack of stratigraphic evidence of continuous deposition between the formations of the ASG; (2) relationships with igneous rocks, in terms of basement of the sequence or intrusive contacts, are not well documented; (3) the thickness of the sequences of the ASG sustained by Blanco et al. (2009), originally proposed by Gaucher (2000), are not based on structural (and stratigraphic) data. The complex deformational history, as well as the tectonic repetitions and refolded structures, suggest that the proposed values, without balanced cross-sections and palimpastic restoration, are at least doubtful (Rapalini and Sánchez Bettucci, 2008); (4) the Barriga Negra Group was first defined by Preciozzi et al. (1979) formalized by Preciozzi and Fay (1990) and divided into three units from bottom to top in: (i) the Polanco Formation,

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* Corresponding author at: Facultad de Ciencias, Departamento de Geología, Area Geofísica-Geotectónica, Iguá 4225, Montevideo 11400, Uruguay.
Tel.: +598 2 5258619; fax: +598 2 5258617.
E-mail address: leda@fcien.edu.uy (L.S. Bettucci).

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represented by interstratified meta-calcareous, meta-sandstones and meta-calcpelites, folded and intruded by granitoids; (ii) the Arroyo del Soldado Formation represented by meta-sandstones and meta-arkoses (probably an equivalent of the Cerro the San Francisco Formation from Gaucher, 2000), and (iii) the Paso de los Talas Formation constituted by conglomerates without regional deformation. The Paso de los Talas Formation may be considered as a northern equivalent of Las Ventanas Formation (Midot, 1984). These units are considered as late Brasiliano molassic deposits (Preciozzi et al., 1979; Preciozzi and Fay, 1990; Sánchez Bettucci, 1998; Fambrini et al., 2005; among others). Blanco et al. (2009) discard and do not discuss the original definition of these units. For the Barriga Negra Formation Fambrini et al. (2005) suggested a fluvial sedimentation (alluvial fan) in an active tectonic environment (relaxation phase) developed in arid climatic conditions suggested by the presence of marble clasts of Polanco Formation. We consider that the immature conglomerates of Barriga Negra Formation, suggest the deposition of later molassic allosequence (post-orogenic deposits from Piquiri (Rio Grande do Sul, Brazil) to Playa Hermosa (Uruguay) *sensu* Paim et al., 2000). In contrast, Blanco et al. (2009) consider Barriga Negra deposits as recording only a fall in the sea level. Locally, this succession is underlying by medium grade metamorphic rocks (basement), and the overlying sequence is at least tilted and folded. Also, the Barriga Negra Formation (earlier molassic allosequence) is affected by low-grade metamorphic conditions and ductile deformation (slaty cleavage).

2. Structural evidence

The regional heterogeneous strain and the partitioning of deformation in the DFB, as well as the timing of the different phases related to the orogenic deformation have been documented and exemplified (Midot, 1984; Preciozzi, 1989; Masquelin, 1990; Sánchez Bettucci et al., 2001, 2003a, 2004; Oyhantçabal, 2005; Oyhantçabal et al., 2007; among others). The supracrustal sequences involved in this discussion are tectonically imbricated with the basement (e.g. Campanero Unit) in the southern portion (Sánchez Bettucci et al., 2001, 2003a), and both are intruded by granitic batholiths (arc and post-orogenic magmatism, see Fig. 1a). These deformational features are in agreement with the proposal of a lithospheric evolution from back-arc/foreland basin to orogenic deformation as a consequence of tectonic collision (Sánchez Bettucci et al., 2001, 2003a, 2004; Oyhantçabal, 2005). The tectonic transposition, repetition and imbrication of tens of meters thick fault-bounded stratigraphic intervals, provide evidence for an important compressional regime. Also, the sinistral transpressional Sierra Ballena shear zone, affects the supracrustal rocks of Lavalleja Group, the ASG (*sensu* Gaucher, 2000; Blanco et al., 2009) and the molassic sequences like Las Ventanas, San Carlos, Barriga Negra and Sierra de Aguirre Formations (Oyhantçabal, 2005 and references therein). The Sierra Ballena shear zone would correspond to an intra-continental shear belt (Silva et al., 2005; Oyhantçabal, 2005; among others). This shear zone is responsible for the lateral juxtaposition of different crustal levels (Oyhantçabal, 2005). Blanco et al. (2009) mention that the ASG is folded and faulted, but do not discuss their genesis. A structural analysis, made in some key-areas, shows that the ASG succession is affected by ductile and heterogeneous deformation (Figs. 1 and 2). A stronger deformation was recorded in some lithologic types leading to metamorphic foliation, tight and isoclinal folds and, in marbles and pelites passive flow-folds (Fig. 1). Some rhythmic metapelites from Barriga Negra Formation show recumbent folding. Finally, the marbles (see Figs. 1 and 2), although preserving some primary structures, show passive folding and they are affected by ductile shearing. These structural features are compatible with P–T conditions reaching, at least, greenschist facies. But, the most important fact is that structural analysis affects the result of lithostratigraphical interpretation, as well as the stratigraphic thickness of the successions. Surprisingly, Blanco et al. (2009) does not consider the orogenic deformation that took place in the DFB suggesting rifting at ca. 615–580 Ma and tectonic inversion (see Fig. 12, Blanco et al., 2009) ca. 535 Ma.

3. Metamorphism

The ductile regional deformation for the DFB implies P–T conditions where recrystallization processes occur. In other way, Blanco et al. (2009) misinterpreted the petrological description made by Rapalini and Sánchez Bettucci (2008) where theses authors had described a low-grade metamorphic paragenesis. Following Gaucher (2000), Blanco et al. (2009) suggest that ASG is not affected by metamorphism, and the maximum temperature reached 200 °C. This affirmation is either the first report of unmetamorphosed BIF (Cerro Espuelitas Formation) or inconsistent with the well know fact that "*Generally*, *BIFs are invariably metamorphosed even if weakly*, *and their primary minerals have been replaced by other phases*" (Mücke and Annor, 1993, p. 137). On the other hand, the mineral assemblages suggest a very low to low metamorphic grade (see Fig. 2), and structural features observed show complex ductile deformation.

4. Geochronology

Blanco et al. (2009) in order to sustain their hypothesis forced the scarce geochronologic data that exist in Proterozoic units of Uruguay. For example, when we analyze the Uruguayan data showed in Table 1 (Blanco et al., 2009, pp. 61 and 62) we observe different kind of errors.

Sánchez Bettucci (1998) defined the Campanero Unit as the basement of Lavalleja Group with an age of 1.7 Ga (Sánchez Bettucci et al., 2003b). This basement is intruded by granites (Carapé Complex *sensu* Sánchez Bettucci et al., 2003b). Mallmann et al. (2007) does not use the nomenclature proposed by Sánchez Bettucci (1998), even though the data presented by this author 1754 ± 7 Ma corresponds to Campanero Unit.

Gómez Rifas (1995, p. 72) in his Ph.D. thesis presents four K–Ar data for a metabasalt (*sic*) outcrop of the Lavalleja Group. The ages are 626 ± 47 Ma, 736 ± 116 Ma, 761 ± 60 Ma and 1203 ± 65 Ma. We consider highly speculative and unsubstantiated to choose the older one without even mentioning and discussing the other results.

In Table 1 (Blanco et al., 2009, pp. 61–62) point out an age >600 Ma for the Lavalleja Group atributed to Almeida et al. (2005), but this work describes the Brasiliano post-orogenic vulcanism and the Lavalleja Group is not mentioned. Also, is importan to remark that Mallmann et al. (2007, Table 3) assume for Lavalleja Group's metabasalts and amphibolites a crystalization age of 600 Ma.

The Arroyo Mangacha (583 ± 7 Ma) Granite cut the supracrustal rocks (marbles and siltstones). The field relation clearly shows an intrusive contact generating a contact aureole.

The so called "Puntas del Santa Lucía granodiorite" (with ages from 640 to 600 Ma, Hartmann et al., 2002) is not the basement of ASG. This pluton intrudes into this succession developing contact metamorphism in the Polanco Formation (see Fig. 2f).

The Sm–Nd and Rb–Sr data presented in the Table 1 for the Sierra de Las Animas Complex (Pan de Azúcar Syenite) does not fit Bossi et al. (1993a) reference. Bossi et al. (1993b) present a Rb–Sr age of 520 ± 5 Ma. The samples analyzed (see Table 3 and Fig. 9 *in* Bossi et al., 1993b) were four rhyolites and one trachytoid. An Ar–Ar (on amphibole) age of ~579 Ma was recently obtained from Pan de Azú-