Comment on "Bilaterian Burrows and Grazing Behavior at >585 Million Years Ago"

Claudio Gaucher,[1]* Daniel G. Poiré,[2] Jorge Bossi,[3] Leda Sánchez Bettucci,[1] Ángeles Beri[1]

Pecoits *et al*. (Reports, 29 June 2012, p. 1693) describe bilaterian trace fossils and assign them an Ediacaran age based on the age of a granite interpreted as intrusive. We argue that the granite is not intrusive but in fact represents the basement of the sedimentary succession. Moreover, we show that identical trace fossils occur in nearby Carboniferous-Permian glacigenic rocks.

Pecoits *et al*. (*1*) report the occurrence of trace fossils from the Tacuarí Formation (Uruguay), which they claim represent the oldest bilaterian burrows so far described. Their age assignment is based on a U-Pb zircon age of 585 ± 3 million years (My) for a granitoid supposedly intruding the fossil-bearing succession, which would provide a minimum mid-Ediacaran age constraint for the fossils. However, the outcrops assigned to the Tacuarí Formation were traditionally assigned to the upper Carboniferous–early Permian San Gregorio Formation (Fig. 1A), which represents the Gondwanan Glaciation in Uruguay (*2*–*4*). Pollen and spores assigned to the *Cristatisporites inconstans*–*Vittatina saccata* Assemblage Zone (*3*) have been described from similar lithologies only 4 km to the southwest and 14 km to the northeast of the outcrops studied by Pecoits *et al*. (*5*, *6*). Thus, the critical piece of evidence is the stratigraphic relationship between the granite and the fossil-bearing rocks, which is not clear.

The geological map and the figures Pecoits *et al.* present to illustrate the nature of the contact are not convincing with respect to the granite being intrusive. Their figure S8 militates against this interpretation, because the rhythmites do not show recrystallization or metamorphism, and a small fault at the contact has reoriented clay minerals. It is not a "chilled margin" because the granite displays an abrupt, knife-sharp contact with the sedimentary rock. If the pluton is not intrusive with respect to the fossil-bearing succession, the age assignment and evolutionary conclusions of Pecoits *et al*. (*1*) are fundamentally flawed.

The granite has been traditionally interpreted as the basement of the succession (*2*, *7*). The contact near fossil site C (*1*) is through a thin, ferruginous basal sandstone layer (Fig. 1, B to E). About 1.5 km to the south (latitude 32.50945°S; longitude 54.11917°W), the same contact comprises a 5-m-thick glacial diamictite, which passes up-section into trace-fossil–bearing rhythmites. First, the diamictites include weathered, kaolinized granite clasts texturally identical to the underlying granite. Second, hematitization is better explained by low-temperature processes, because it is cryptocrystalline and stratabound or confined to joints (Fig. 1, C and E to F). Third, petrographic thin sections show no recrystallization or neoformation of metamorphic minerals at the contact (Fig. 1, D to F). On the contrary, there is excellent preservation of primary sedimentary structures (lamination, graded beds, and linsen structures), and clays are not recrystallized (Fig. 1F). Finally, the xenoliths in the granitoid were interpreted as derived from the Tacuarí Formation (*1*) but no evidence was presented to support this. In fact, the xenoliths shown in (*1*) look very different from the characteristic Tacuarí rhythmites and could instead be derived from nearby Neoproterozoic supracrustal successions, such as the Paso del Dragón Formation (*2*, *7*, *8*).

The interpretation of the granitoid as dykes (*1*) is not supported by previous observations (*2*, *7*). The rock is an equigranular (crystal size around 2 mm), predominantly isotropic quartz-diorite, but high-strain shear bands crosscutting the quartz-diorite and parallel to the strike of the Sierra Ballena Shear Zone (SBSZ) (Fig. 1A) were also observed. The geometry is of a relatively large pluton, as demonstrated by similar rocks cropping out 40 km to the northeast, which yielded U-Pb zircon ages of 580 ± 10 My (*8*), within error of the Tacuarí quartz-diorite. In the Tacuarí area, the granite is always kaolinized in its upper 10 m (paleoweathering surface), beneath the contact with overlying sedimentary rocks.

Other lines of evidence also show that the fossil-bearing strata are younger than the quartz-diorite. The nearby SBSZ (Fig. 1A), which according to our observations does not affect the sedimentary succession, remained active until 551 to 537 million years ago (Ma) (*9*), suggesting a Cambrian or younger age for the trace fossils. Cleavage developed by nearby faults and tilting of the Tacuarí Formation (*7*) are clearly localized and brittle in nature—not widespread sinistral shearing and mylonitization at the SBSZ, which reached amphibolite facies or ~500°C (*9*). This is precluded by the excellent preservation of sedimentary structures and trace fossils.

The glacigenic San Gregorio Formation (Paraná Basin) crops out as a continuous band (*2*), with the area studied by Pecoits *et al.* located right within it (Fig. 1A). Trace fossils have been described from the unit and from its correlates in southern Brazil (*10*–*12*), which closely resemble the material figured by Pecoits *et al.* (*1*). They occur in dropstone-bearing shales indistinguishable from those of the Tacuarí Formation. Examples of trace fossils of the San Gregorio Formation in the Guazunambí-Cerro de las Cuentas area (site CCU 22; latitude 32.632484°S; longitude 54.462456°W) (Fig. 1A) include *Gordia* isp. (Fig. 2F) and bilobate burrows bearing striations oblique to the midline of the trace (Fig. 2, B and C) classified as *Cruziana problematica* (Schindewolf) in nearby outcrops in southern Brazil (*11*, *12*). These ichnofossils are identical to the Tacuarí material (*1*), which is shown here in Fig. 2, A, D, and E. At site CCU 22, the succession is undeformed, flat-lying, and unconformably overlies folded late Ediacaran carbonates and shales of the Arroyo del Soldado Group (*13*, *14*). It is in turn overlain by Early Permian sandstones of the Tres Islas Formation (*2*). The combination of the same taxa, the same preservation, and the same glacial environment suggests that trace fossils of the Tacuarí Formation are in fact Carboniferous-Permian and not Neoproterozoic in age.

Several authors have pointed out that postglacial transgressive units related to the Gondwanan glaciation were deposited in freshwater environments strongly affected by meltwater discharge (*6*, *12*, *15*). The impoverished ichnocoenosis found in the Tacuarí rhythmites, including *Gordia* and *Cruziana problematica*, is characteristic of these deposits (*12*, *15*). Freshwater conditions probably excluded marine macro- and microfossils, which occur higher up in the San Gregorio Formation (*4*). Furthermore, the extensive glacial cover of the continent that existed during this period may be responsible for the scarcity of spores and pollen in the rhythmites (*6*), which include reworked, older palynomorphs (*6*).

[1]Departamento de Geología, Facultad de Ciencias, Universidad de la República Iguá 4225, 11400 Montevideo, Uruguay. [2]Centro de Investigaciones Geológicas, Universidad Nacional de La Plata-CONICET, calle 1 Nr. 644, 1900 La Plata, Argentina. [3]Departamento de Suelos y Aguas, Facultad de Agronomía, Universidad de la República, Garzón 780, Montevideo, Uruguay.

*To whom correspondence should be addressed. E-mail: gaucher@chasque.net

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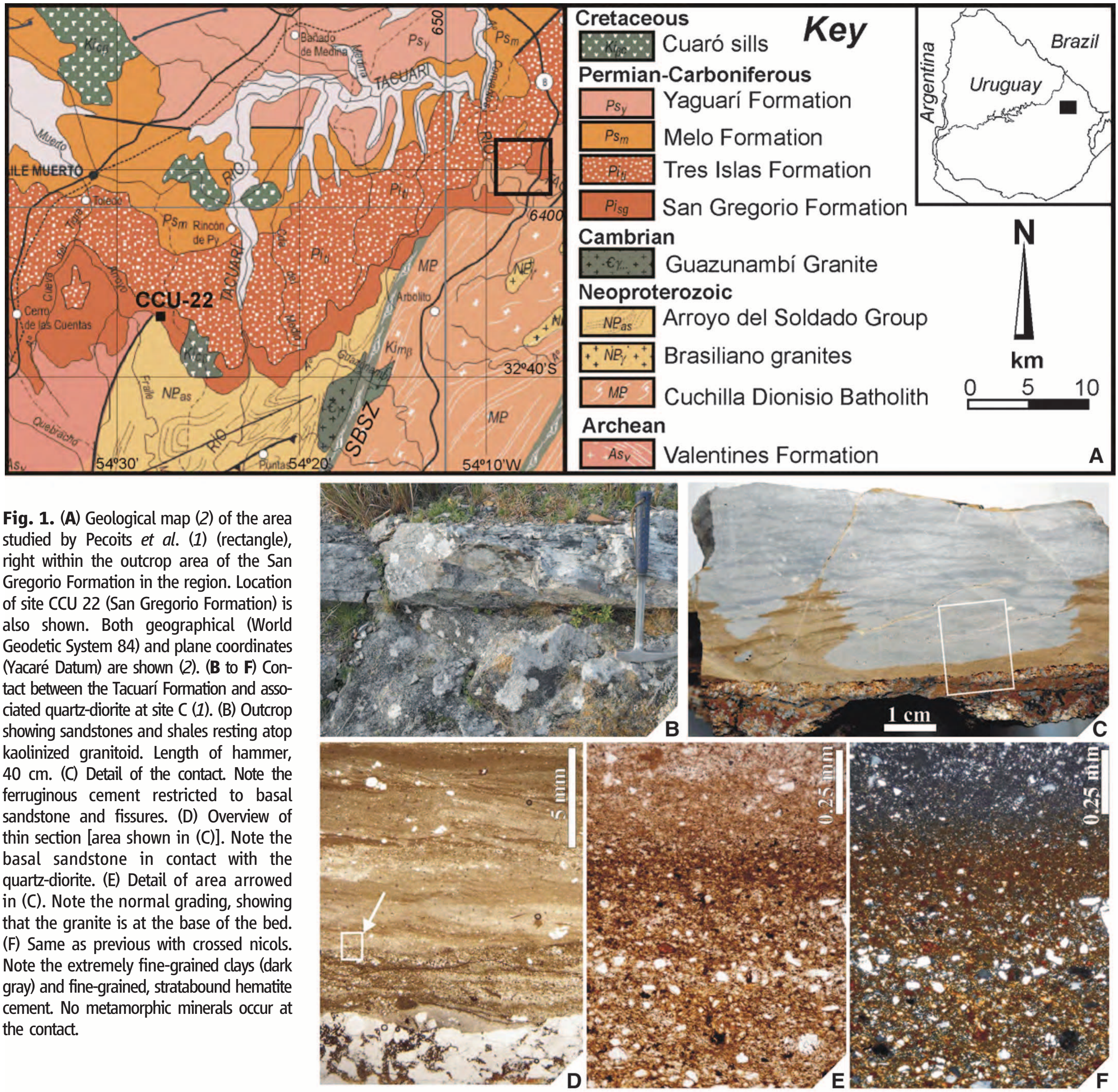

Fig. 1. (**A**) Geological map (*2*) of the area studied by Pecoits *et al*. (*1*) (rectangle), right within the outcrop area of the San Gregorio Formation in the region. Location of site CCU 22 (San Gregorio Formation) is also shown. Both geographical (World Geodetic System 84) and plane coordinates (Yacaré Datum) are shown (*2*). (**B** to **F**) Contact between the Tacuarí Formation and associated quartz-diorite at site C (*1*). (B) Outcrop showing sandstones and shales resting atop kaolinized granitoid. Length of hammer, 40 cm. (C) Detail of the contact. Note the ferruginous cement restricted to basal sandstone and fissures. (D) Overview of thin section [area shown in (C)]. Note the basal sandstone in contact with the quartz-diorite. (E) Detail of area arrowed in (C). Note the normal grading, showing that the granite is at the base of the bed. (F) Same as previous with crossed nicols. Note the extremely fine-grained clays (dark gray) and fine-grained, stratabound hematite cement. No metamorphic minerals occur at the contact.

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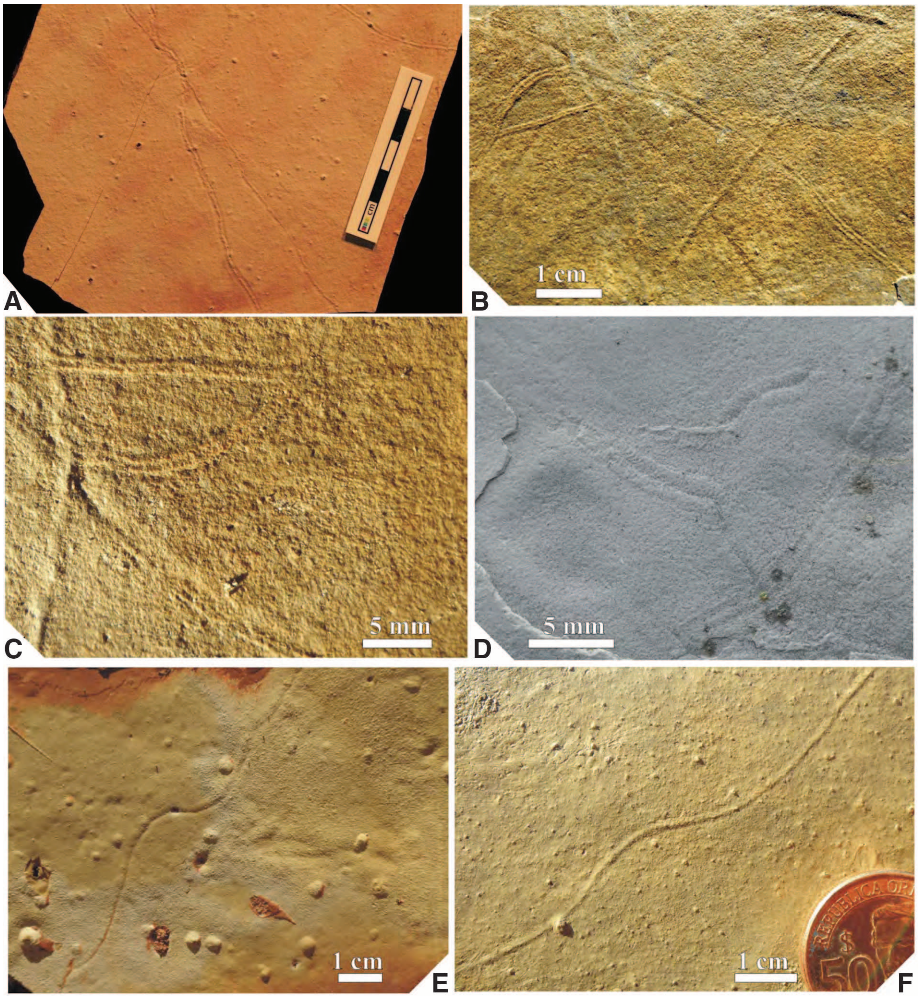

Fig. 2. Trace fossils of the Carboniferous San Gregorio Formation at site CCU 22 and of the Tacuarí Formation. (**A**) Bilobate trace fossils of the Tacuarí Formation from (*1*). (**B**) Bilobate burrows of the San Gregorio Formation, possibly poorly preserved *Cruziana problematica*. Note the X-shaped crossing. (**C**) Detail of previous specimen, showing crossing and poorly preserved striations. (**D**) *Cruziana problematica* from fine siltstones of the Tacuarí Formation at its type area (latitude 32.50087°S; longitude 54.12827°W) showing fine striations oblique to the midline of the trace. (**E**) Sinusoidal trace fossil (*Gordia* isp.) from the Tacuarí Formation at site A of Pecoits *et al*. (*1*, *7*), with scattered dropstones. (**F**) Identical *Gordia* isp. from the San Gregorio Formation, also with scattered dropstones.

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