Geologica Acta, Vol.1, N°1, 2003, 95-102
Available online at www.geologica-acta.com

geologica acta

El Alisal: A new locality with trace fossils of the Puncoviscana Formation (late Precambrian-early Cambrian) in Salta Province, Argentina

G. F. ACEÑOLAZA [1] **and M. F. TORTELLO** [2]

[1] **INSUGEO – Conicet, Facultad de Ciencias Naturales e IML**
Miguel Lillo 205, 4000 Tucumán, Argentina. E-mail: insugeo@unt.edu.ar

[2] **INSUGEO – Conicet, Museo de La Plata**
Paseo del Bosque s/n, 1900 La Plata, Argentina. E-mail: tortello@museo.fcnym.unlp.edu.ar

ABSTRACT

The Puncoviscana, Suncho and Las Aguaditas/Negro Peinado formations represent a thick siliciclastic folded succession that crops out on a strip about 800 km long and 150 km wide in northwestern Argentina (Jujuy, Salta, Tucumán, Catamarca and La Rioja provinces). These sequences are lithologically characterized by very low-grade metamorphic sediments grading from slates to schists; turbidites, pelagic clays, limestones and volcanic rocks. On the basis of paleoichnological data, these units have been assigned to the late Precambrian-early Cambrian. A new locality bearing well preserved trace fossils from the Puncoviscana Formation is described herein. The outcrop is located about 45 km west of Salta city (Salta Province), displaying an alternation of colored differentiated grayish-bluish slates and fine sandstones. Ichnofossils include *Cochlichnus anguineus* HITCHCOCK, *Helminthoidichnites tenuis* FITCH, *Helminthoida* isp., *Monomorphichnus lineatus* CRIMES, LEGG and MARCOS ARBOLEYA, *Planolites* isp. and *Torrowangea*? isp., as well as some limb marks and a few slightly bended smooth trails (indet.). An Early Cambrian age for the succession at El Alisal as well as some environmental considerations are allowed by the ichnological association. In addition, the ichnogenus *Planolites* is mentioned for the first time from the "red shales and conglomerate type" facies at the neighbor locality of Chorrillos.

KEYWORDS | **Trace fossils. Precambrian-Cambrian Puncoviscana Formation. Northwestern Argentina.**

INTRODUCTION

Highly folded metasedimentary sequences characterize the Upper Precambrian-Lower Cambrian of the Central Andean Basin of South America. The best developed sequences were described in northwestern Argentina (provinces of Jujuy, Salta, Tucumán, Catamarca and La Rioja) under the names of Puncoviscana, Suncho and Las Aguaditas/Negro Peinado formations (Aceñolaza et al., 1999 with references). In Southern Bolivia, close to the Argentinian border (Tarija Department), the succession is only represented by a small outcrop assigned to the San Cristobal Formation. These sequences reflect the Pampean Orogen evolution in the western margin of Gondwana.

The Puncoviscana Formation (s.l.) was originally considered non fossiliferous, as well as Precambrian in age. Nevertheless, the idea of a sterile "metamorphic basement" was abandoned in 1972 as the result of the first findings of trace fossils from the unit (Mirré and Aceñolaza, 1972; Aceñolaza and Durand, 1973). Since then, several new localities were found: Purmamarca (Jujuy Province), Campo Quijano, Cuesta Muñano, San Antonio de los Cobres (Salta Province) and Choromoro (Tucumán

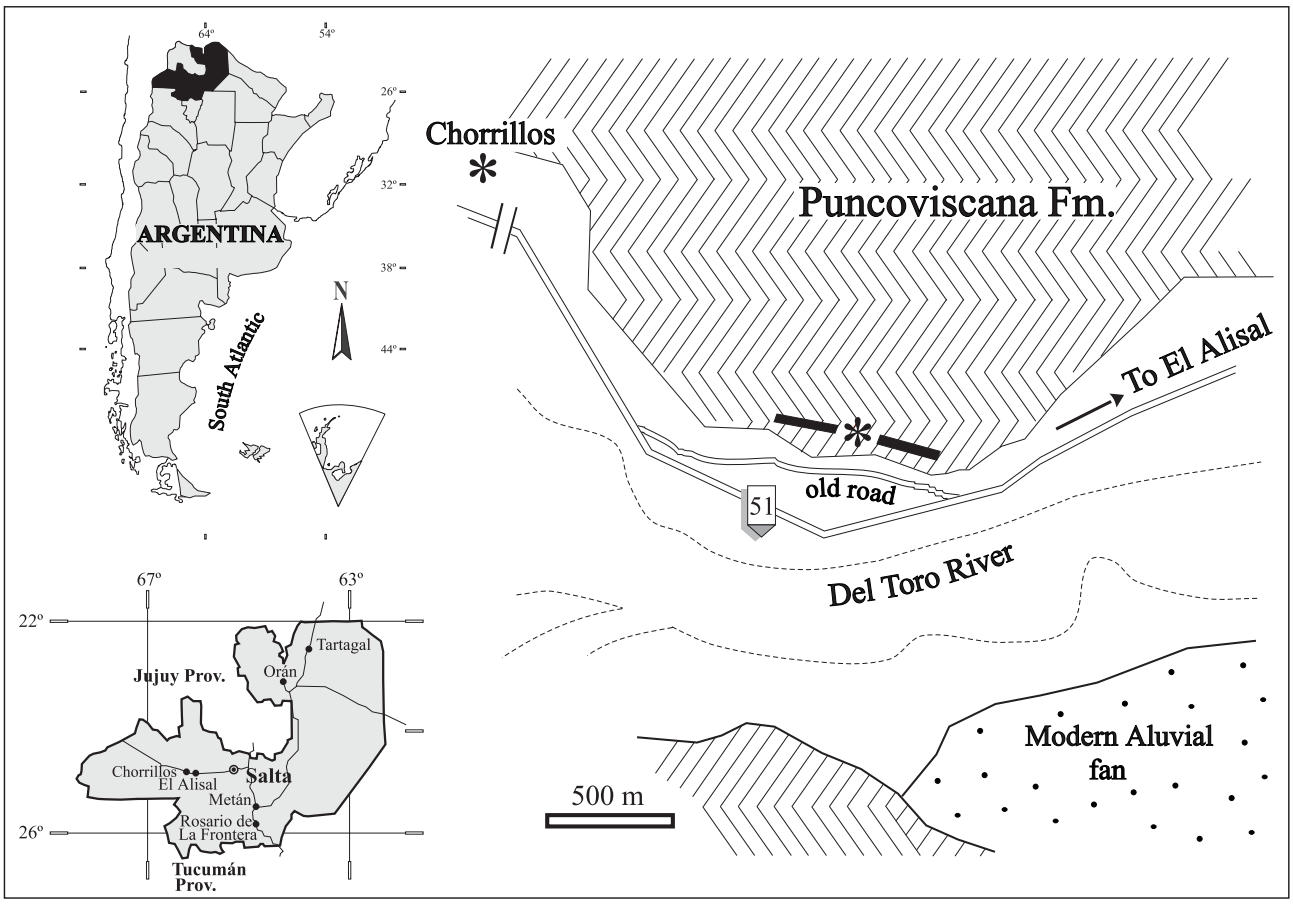

FIGURE 1 **Location of the ichnofossiliferous outcrops of the Puncoviscana Formation (Precambrian-Cambrian) close to El Alisal and Chorrillos localities, Salta Province, Argentina.**

Province). Nowadays, a highly diversified ichnological record is known from these sequences, including *Asaphoidichnus, Cochlichnus, Didymaulichnus, Dimorphichnus, Diplichnites, Glockeria, Helmintoida, Helminthopsis, Helminthorhape, Helminthoidichnites, Monomorphichnus, Multipodichnus, Neonereites, Nereites, Oldhamia, Phycodes, Planolites, Protichnites, Protopaleodictyon, Protovirgularia, Scolicia, Squamodictyon, Tasmanadia, Torrowangea, Treptichnus,* and some forms tentatively assigned to *Beltanelliformis, Paliella* and *Sekwia* (see Aceñolaza and Durand, 1973, 1982, 1984, 1986, 1987; Aceñolaza et al., 1999; Durand, 1992, 1993, 1994, 1996; Durand and Aceñolaza, 1990; Durand et al., 1993). Most of these ichnofossils belong to the *Nereites* ichnofacies, with some elements of the *Cruziana* ichnofacies (feeding, grazing and crawling types). On the basis of paleoichnological data, the Puncoviscana Formation and equivalents (Suncho and Las Aguaditas/Negro Peinado Formations) have been considered to be late Precambrian-early Cambrian in age (Aceñolaza and Durand, 1982, 1984, 1986; Aceñolaza et al., 1988; Durand, 1992, 1994; Durand and Aceñolaza, 1990).

The implications of ichnofossils from sequences where shelly fossils are either rare or absent have been pointed out by several authors (Seilacher 1967, 1970; Crimes, 1970; Baldwin, 1977 a.o.). In such cases, ichnofossils may provide the basis for age determination and environmental interpretration. Material from a new locality of the Puncoviscana Formation is herein described, adding new data to the stratigraphy and paleoenvironmental interpretation of the late Precambrian-early Cambrian of northwestern Argentina.

EL ALISAL SECTION

The studied outcrop is located in the northern flank of the Quebrada del Toro, 45 km west of Salta City, in the immediate vicinity of El Alisal Locality (Salta Province) (Fig. 1). The ichnofossiliferous section displays a highly folded alternation of grayish-bluish slates and green fine sandstones, about 500 m thick, assigned to the Puncoviscana Formation. The ichnofossils were recovered from the material exposed by the old national road number 51 to

San Antonio de Los Cobres. The sandstones and slates show some internal structures (e.g. normal gradation beds, low angle cross stratification, and turbidite wavy lamination) characterizing the section as heterolithic type. Because of the presence of tight folds and repetitions in the succession, a detailed description of a complete section is not possible.

Most of the trace fossils are distributed along the section. Despite of the high degree of deformation of the outcrop, trace fossils are more abundant in the upper part of the sequence. Ichnological forms occur together either in the base or the top of fine sandstone layers (Fig. 2).

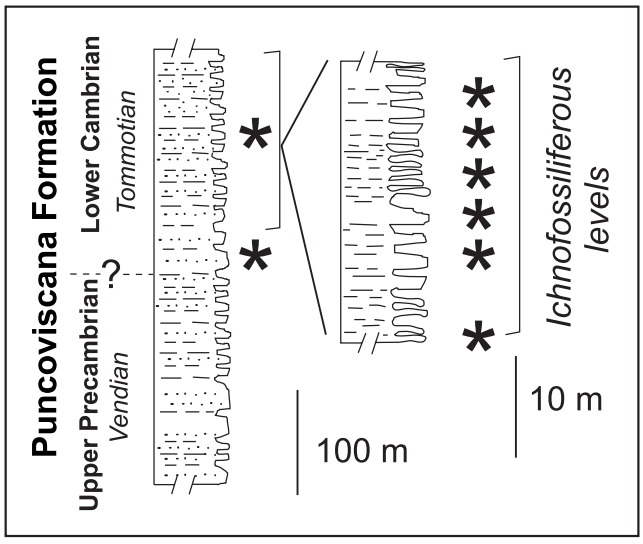

FIGURE 2 | **Schematic columnar section of the sequence cropping out at El Alisal locality, Salta Province. Relative distribution of ichnofossiliferous levels are shown by an asterisk.**

SYSTEMATIC ICHNOLOGY

The studied material is housed in the invertebrate paleontological collections of the Instituto Superior de Correlación Geológica / Facultad de Ciencias Naturales e Instituto Miguel Lillo (Universidad Nacional de Tucumán, Argentina) (PIL – Paleontología Instituto Lillo).

ICHNOGENUS ***Cochlichnus*** HITCHCOCK, 1858

Type ichnospecies: *Cochlichnus anguineus* HITCHCOCK, 1858

Cochlichnus anguineus HITCHCOCK, 1858
Figures 3.3, 3.5 and 3.7c

Material and repository: several specimens collected (PIL: 14.681, 14.685, 14.688).

Description: Simple, unbranched, bent trace with a sinuous general development characterized by a regularly meandering pattern. Smooth surface normally preserved as convex hyporelief. Regular meanders are seen by sectors of the same trace, changing into an irregular meandriform pattern. Width of trace regular, from 0.8 to 1 mm, length up to 34 mm. Amplitude of the sine curve is 3 to 4.2 mm. Wave length ranges from 5.5 to 6.5 mm.

Remarks: The material is well preserved, showing some variations on the regular pattern of the sinuosity. This irregularity on the trace is a frequent character of the ichnogenus. There is some confusion about the definition and differentiation of some ichnospecies of *Cochlichnus*, regarding whether it is a trail or a burrow. Nowadays, both are considered to be included in *C. anguineus* (see Fillion and Pickerill, 1990; Buatois et al., 1997 a.o.). The stratigraphic range of *Cochlichnus* is wide, having been recorded from the Precambrian to the Holocene. The genus is regarded as the trace of annelids feeding on the sea floor, locomotion trace of nematodes and insect larvae (Fillion and Pickerill, 1990; Metz, 1995).

ICHNOGENUS ***Helminthoidichnites*** FITCH, 1850

Type ichnospecies: *Helminthoidichnites tenuis* FITCH, 1850

Helminthoidichnites tenuis FITCH, 1850
Figs. 3.7a, 3.8 and 3.11

Material and repository: Six slabs bearing several well preserved samples (PIL:14.682, 14.683, 14.685, 14.686, 14.687, 14.688)

Description: Slender, slightly bent, non meandering and asymmetric traces of variable length, ranging from 5 mm up to 76 mm. Width between 0.7 to 1.3 mm. Height 0.3 to 0.4 mm. Outer surface smooth, with uniform thickness along the trace.

Remarks: The studied material fits perfectly within the description of material previously assigned to *Gordia* by Aceñolaza (1978) and Durand and Aceñolaza (1990). *Helminthoidichnites* differs from *Gordia* by showing less sinuosity along the trace and by lacking self-overcrossing. The ichnogenus ranges in age from Late Precambrian to Cenozoic.

ICHNOGENUS ***Helminthoida*** SCHAFHÄULT, 1851

Type ichnospecies: *Helminthoida labyrintica* HEER, 1865.

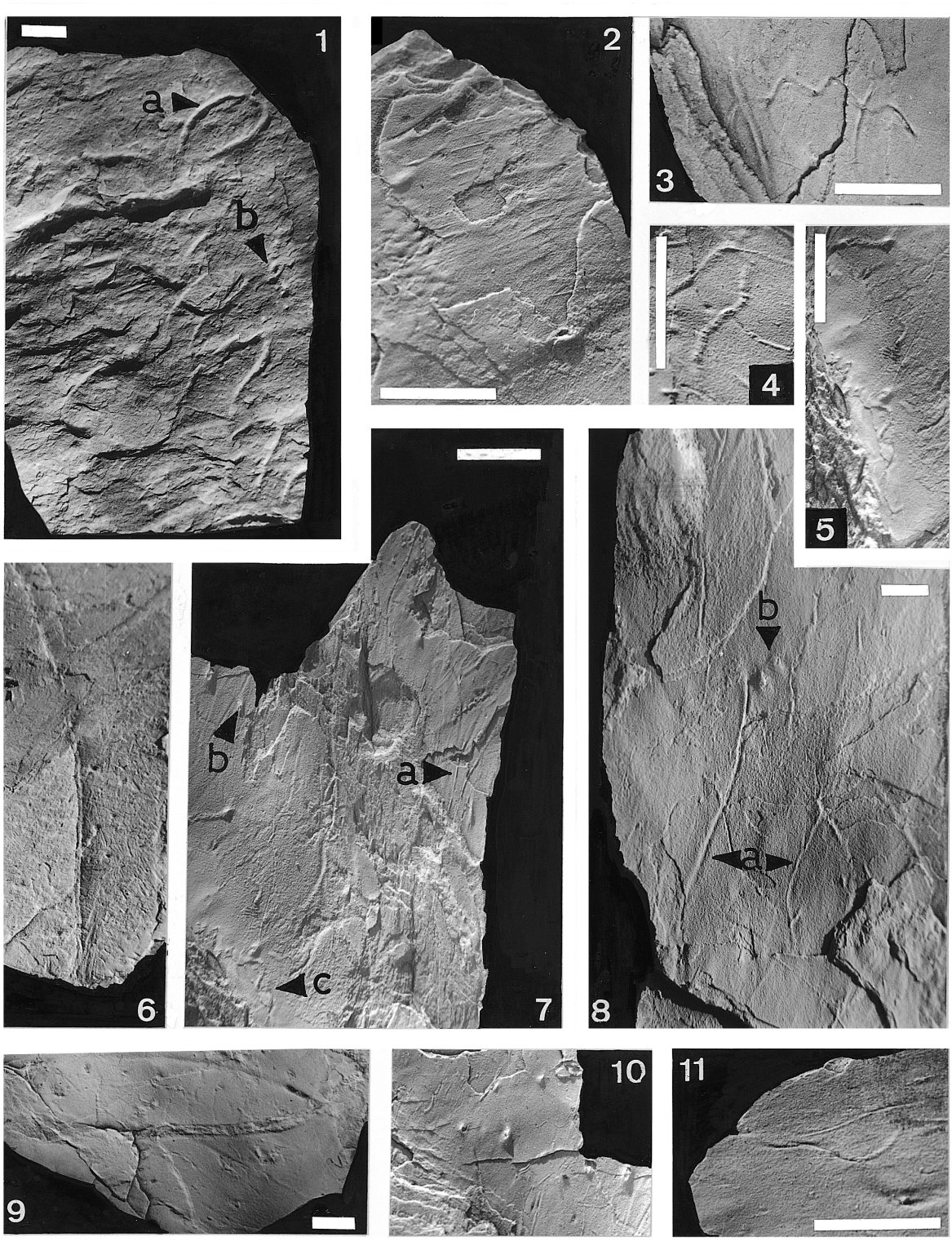

FIGURE 3 | **Trace fossils from the Puncoviscana Formation at El Alisal locality. Scale bar is one centimeter long. 1a, *Helminthoida* isp., fairly large and well preserved sample on sole of a fine sandstone, PIL 14.684. 2, *Monomorphichnus lineatus* CRIMES, LEGG and MARCOS ARBOLEYA, 1977, fine ridges preserved as hyporeliefs arranged in separated sets, PIL 14.681. 3. 5. 7c, *Cochlichnus anguineus* HITCHCOCK, sinuous simple unbranched trace. Intraspecific variations can be observed, PIL 14.681, 14.685, 14.688. 4. *Torrowangea*? WEBBY, 1970, epirelief of unique sample assigned to this ichnospecie PIL 14.687. 6. 9, *Planolites* isp. number 6 comes from El Alisal outcrop, while 9 was recovered in the neighbor locality of Chorrillos, PIL 14.682, 14.689. 7a. 8a. 11, *Helminthoidichnites tenuis* FITCH, 1850. Slender non meandering traces in several samples, PIL, 14.686, 14.687, 14.688. 10. 1b. 7b. 8b, Undetermined scratch marks. Isolated imprints and single scratches from El Alisal locality, PIL 14.682, 14.684, 14.687, 14.688.**

Helminthoida isp.
Fig. 3.1a

Material and repository: one slab containing a single well preserved specimen (PIL 14.684)

Description: Small trails resembling wide meanders. Width of trails ranges from 2 to 5 mm, length up to 20 cm. Spacing between meanders variable, from 7 to 12 mm.

Remarks: Häntzschel (1975) clearly stated the variability of this ichnogenus. Our material does not present a regular meandering pattern, resembling very much those specimens figured by Crimes and Anderson (1985, fig. 7.4, 7.5) and Durand and Aceñolaza (1990, pl. 2, fig. 7). *Helminthoida* isp. differs from *Cochlichnus anguineus* because the latter shows a regular meandering pattern. In addition, the material described here is larger than the specimens of *C. anguineus*.

ICHNOGENUS ***Monomorphichnus*** CRIMES, 1970

Type ichnospecies: *Monomorphichnus bilinearis* CRIMES, 1970.

Monomorphichnus lineatus CRIMES, LEGG and MARCOS ARBOLEYA, 1977
Fig. 3.2

Material and repository: one slab containing several specimens (PIL: 14.681).

Description: Two individual sets composed of two to five parallel, straight to very slightly bent ridges preserved as convex hyporeliefs. Each ridge of uneven length (1-7 mm) and 0.2-0.3 mm wide. 1.2 – 1.9 mm is the distance between ridges. Width of each individual set is 3 mm, and length up to 9 mm.

Remarks: *Monomorphichnus* is defined by sets of elongated, narrow ridges which could have been made by sideways-swimming or raking arthropods. Seilacher (1985, 1990) regards the ichnogenus as a synonymous of *Dimorphichnus*. Fillion and Pickerill (1990) have provided a deep discussion on the morphological characters of *Dimorphichnus*, relating it to *Monomorpichnus* and *Diplichnites*. Jensen (1997) states that both ichnogenera may represent different behaviors of a same producer. Our material is very similar to some frequent forms in the Lower Ordovician of northwestern Argentina.

ICHNOGENUS ***Planolites*** NICHOLSON, 1873

Type ichnospecies: *Planolites vulgaris* NICHOLSON and HINDE, 1874; by subsequent designation (Miller, 1889).

Planolites isp
Fig. 3.6 and 3.9

Material and repository: two rock slabs containing a couple of specimens (PIL: 14.682 and 14.689). Additional material was obtained from the neighbor locality of Chorrillos.

Description: Unlined, straight to slightly sinuous burrows. Horizontal to slightly inclined development with elliptical cross-section and massive filling. Non bifurcated. Length ranges from 8 mm to 76 mm. Width is 0.7-3.8 mm.

Remarks: Since its original establishment, the ichnogenus has been a topic of considerable discussion. Different diagnostic criteria were focused on the filling and lining of the traces. Detailed summaries have been presented by Alpert (1975); Benton and Trewin (1978); Pemberton and Frey (1982) and Fillion (1989). The present material is most similar to that from other outcrops of the Puncoviscana Formation (Aceñolaza, 1978; Durand and Aceñolaza, 1990, a.o.).

ICHNOGENUS ***Torrowangea*** WEBBY, 1970

Type ichnospecies: *Torrowangea rosei* WEBBY, 1970

Torrowangea? isp. WEBBY, 1970
Fig. 3.4

Material and repository: one fairly well preserved specimen (PIL 14.687).

Description: Single, slightly bent to straight traces showing an irregular transverse annulation. Preserved mainly as epirelief. Width is 0.7 to 1 mm; length 3 to 13 mm. The thickness of each annulation ranges from 0.3 to 0.8 mm.

Remarks: The specimen differs from the type material by having smoother annulations. It clearly differs from the material assigned to *Torrowangea* by Durand and Aceñolaza (1990). The material from El Alisal is most similar, in shape and size, to *Torrowangea rosei* from Coria (Cáceres, Spain) (Liñán and Palacios, 1987).

Undetermined scratch marks
Fig. 3.1b, 3.7b, 3.8b and 3.10

Isolated imprints of different shapes, from circular to elongated, comma type and single scratches, have also been identified in the outcrop. Many of them can be regarded as arthropod trackways.

FINAL CONSIDERATIONS AND CONCLUSIONS

The sediments of the Puncoviscana Formation (s.l.) were deposited on an elongated basin placed between the

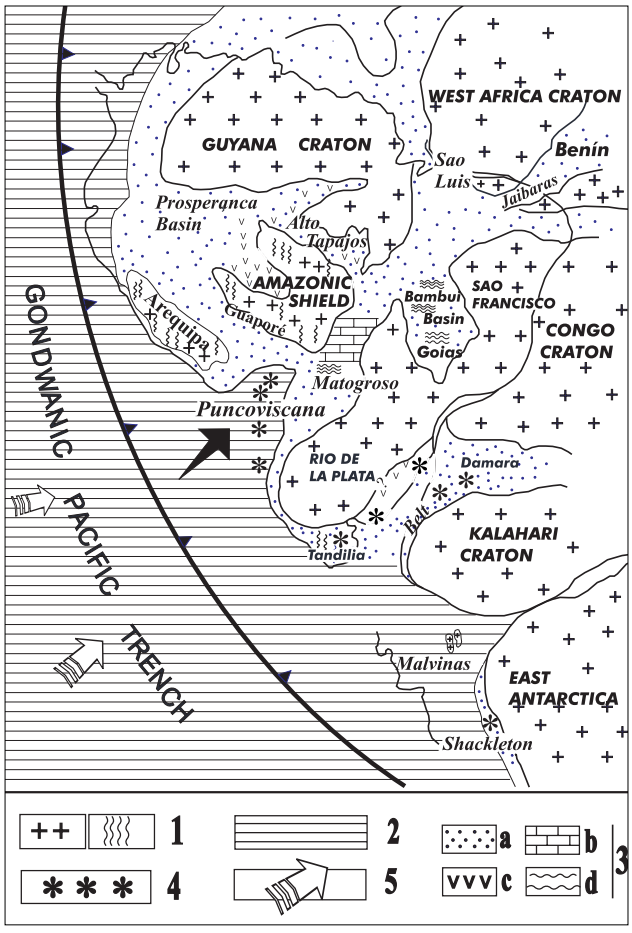

FIGURE 4 | **Paleogeographical sketch of the western Gondwanan border for the Precambrian - Cambrian transition. South America, the western margin of Africa and East Antarctic are figured. Main marginal and intracratonic sedimentary basins are displayed, highlighting the Puncoviscana basin of northern Argentina and Southern Bolivia. 1. Craton areas; 2. Open seas; 3a. Siliciclastic shelf areas; 3b. Carbonate deposition; 3c. Volcanic zones; 3d. Stromatolites; 4. Ichnofossiliferous localities; 5. Plate motion.**

Arequipa-Antofalla massif to the west and the Pampean Craton to the east. The basin was connected with the intracratonic, shallower basins of Bambuí and Goias to the NE, and with the Alto Paraguay and Pacaas basins to the north and east (Fig. 4). O´Connor and Welde (1986) recorded similar ichnofaunas from the Tucavaca Belt of eastern Bolivia and western Paraguay, displaying some environmental continuity to the north. Several new ideas about the geotectonic setting of the Puncoviscana basin have been recently considered (see Omarini et al., 1999; Sureda and Omarini, 1999; and references included). These discussions go beyond the focus of this paper.

The Puncoviscana Formation is characterized by very low-grade metamorphic sediments grading into schists. Classically, the unit has been assigned to an off-shore setting (e.g. distal sectors of coalescent submarine fans). Jezek (1990) distinguished a sedimentary complex composed of six facies: conglomerates, proximal, intermediate and distal turbidites, red pelites, and carbonates. Analysis of paleocurrents indicate a provenance area from the east and southeast, changing to North-South directions in the most distal parts of the basin (Cachi area, Salta Province) (Jezek, 1990).

Recently, Buatois et al. (2000), in concordance with some interpretations about the record of Late Precambrian-Early Cambrian trace fossils (e.g. Crimes, 1992), considered the possibility of assigning part of the Puncoviscana Formation to a shallower, nearshore setting. We consider this hypothesis as possible, mentioning that much additional sedimentological work must be done in order to improve the knowledge on the environments represented in the unit.

The ichnological distribution displays a remarkable alignment in bands within the Puncoviscana basin. Until now three ichnoassociations have been recognized: *Beltanelliformis* to the east, *Nereites* placed in the middle, and *Oldhamia* to the west (Aceñolaza and Alonso, 2001, with references). Outcrops at El Alisal fall into the *Nereites* ichnoassociation, fitting in the proximal turbiditic system of Jezek (1990). The occurrence of *Monomorphichnus lineatus* CRIMES, LEGG and MARCOS ARBOLEYA in the ichnoassociation, restricts the age of this sequence at El Alisal to the earliest Cambrian, probably Tommotian.

Trace fossils are related to specific lithologies. *Helminthoidichnites*, *Cochlichnus* and *Monomorphichnus* are associated with thin layers of fine sandstones (up to 3 cm thick) representing deposition of low energy turbidites. On the other hand, *Helminthoida*, *Planolites* and *Torrowangea*? are frequent in thicker sandstone levels (up to 20 cm) that are interpreted as produced by higher energy turdidites. This situation is interpreted as a consequence of a relatively fast colonization by infaunal organisms, that resulted after the deposition of successive sedimentary impulses. Each impulse supplied oxygen and organic matter at once.

Ichnossils studied are restricted to horizontal – subhorizontal traces, as a result of the particular paleo-environmental conditions of the basin. Turbidites attest to changes between low-energy and high-energy depositional regimes that are also recorded by their ichnological record. These changes cause the formation of a flysch-type pattern related to oxygen content. In a general sense, only single layer colonizers are distinguished within the succession at El Alisal, lacking on the presence of deeper bioturbators.

It is known that trace fossils are significantly diverse in Vendian shallow water seas. Ichnogeneric diversity in deep ocean settings was low in Cambrian times, increasing gradually towards the Ordovician-early Silurian (Crimes, 1992). According to Crimes (1974), this relative delay in animal penetration could be the result of the limited oxygen content and organic supplies in deep oceans. Typical "deep water" traces recorded from muddy, quiet settings assignable to the late Precambrian-Early Cambrian do provide relevant information on these subjects (Crimes and Anderson, 1985; Narbonne et al., 1987; Fedonkin, 1988; Hofmann and Patel, 1989).

ACKNOWLEDGEMENTS

We kindly thank Drs. F. Aceñolaza, S. Esteban, L. Cabrera and J. De Gibert for the critical reading of the manuscript. The drawings were done by D. Ruiz Holgado, who is also thanked.

REFERENCES

Aceñolaza, F.G., 1978. El Paleozoico inferior de Argentina según sus trazas fósiles. Ameghiniana, 15(1-2), 15-64.

Aceñolaza, F.G., Alonso, R., 2001. Icnoasociaciones de la transición Precámbrico-Cámbrico en el noroeste de Argentina. Cuadernos de Geología Ibérica (in press). Madrid.

Aceñolaza, F.G., Durand, F.R., 1973. Trazas fósiles del basamento cristalino del noroeste argentino. Boletín de la Asociación Geológica de Córdoba, 2, 45-55.

Aceñolaza, F.G., Durand, F.R., 1982. El icnogénero *Oldhamia* (traza fósil) en Argentina, carácteres morfológicos e importancia estratigráfica en formaciones del Cámbrico Inferior. V Congreso Geológico Latinoamericano, 1, 705-720.

Aceñolaza, F.G., Durand, F.R., 1984. The trace fossil *Oldhamia*: Its interpretation and occurrence in the Lower Cambrian of Argentina. Neues Jahrbuch für Geologie und Paläontologie Monatshefte, 12, 728-740.

Aceñolaza, F.G., Durand, F.R., 1986. Upper Precambrian – Lower Cambrian biota from the northwest of Argentina. Geological Magazine, 123, 367-375.

Aceñolaza, F.G., Durand, F.R., 1987. Paleontología del límite Precámbrico-Cámbrico de Argentina. X Congreso Geológico Argentino, 1, 315-320.

Aceñolaza, F.G., Miller, H., Toselli, A.J., 1988. The Puncoviscana Formation (Late Precambrian – Early Cambrian). Sedimentology, tectonometamorphic history and age of the oldest rocks of NW Argentina. In: Bahlburg, H., Breitkreuz, Ch., Giese, P. (eds.). The Southern Central Andes. Lecture Notes in Earth Sciences, 17, 25-37.

Aceñolaza, F.G., Aceñolaza, G.F., Esteban, S., 1999. Bioestratigrafía de la Formación Puncoviscana y unidades equivalentes en el NOA. In: González Bonorino, G., Omarini, R., Viramonte, J. (eds.). Geología del Noroeste Argentino, Relatorio XIV Congreso Geológico Argentino, 1, 91-114.

Alpert, S.P., 1975. *Planolites* and *Skolithos* from the Upper Precambrian – Lower Cambrian White-Inyo Mountains, California. Journal of Paleontology, 49, 508-521.

Baldwin, C.T., 1977. The stratigraphy and facies associations of trace fossils in some cambrian and Ordovician rocks of north western Spain. In:. Crimes, T.P., Harper, J.C. (eds). Trace fossils 2. Geological Journal, Special Issue, 9, 9-40.

Benton, M.J., Trewin, N.H., 1978. Discussion and comments on Nicholson´s 1872 manuscript "Contributions to the study of errant annelides of the older Paleozoic rocks" University of Aberdeen, Department of Geology and Mineralogy. Publication 1, 1-16.

Buatois, L.A., Jalfin, G., Aceñolaza, F.G., 1997. Permian nonmarine invertebrate trace fossils from southern Patagonia, Argentina: Ichnologic signatures of substrate consolidation and colonization sequences. Journal of Paleontology, 71(2), 324-336.

Buatois, L.A., Mángano, M.G., Aceñolaza, F.G., Esteban, S.B., 2000. The Puncoviscana ichnofauna of northwest Argentina: a glimpse into the ecology of the Precambrian-Cambrian transition. In: Aceñolaza, G.F., Peralta, S. (eds.). Cambrian from the Southern Edge. Instituto Superior de Correlación Geológica, Miscelánea, 6, 82-84.

Crimes, T.P., 1970. Trilobite tracks and other trace fossils from the Upper Cambrian of North Wales. Geological Journal, 7, 47-68.

Crimes, T.P., 1974. Colonization of the early ocean floor. Nature, 248 (5446), 328-330.

Crimes, T.P., 1992. Changes in the trace fossil biota across the Proterozoic-Phanerozoic boundary. Journal of the Geological Society, London,149, 637-646.

Crimes, T.P., Anderson, M.M., 1985. Trace fossils from Late Precambrian-Early Cambrian of southeastern Newfoundland (Canada): Temporal and environmental implications. Journal of Paleontology, 59, 310-343.

Durand, F.R., 1992. Avances y problemas en la definición del límite Precámbrico-Cámbrico en el Noroeste Argentino. Instituto Superior de Correlación Geológica, Serie Correlación Geológica, 9, 127-138.

Durand, F.R., 1993. Las icnofacies del basamento metasedimentario en el Noroeste Argentino: Significado cronológico y aspectos paleogeográficos. XII Congreso Geológico Argentino, 2, 260-267.

Durand, F.R., 1994. Síntesis sobre el conocimiento icnológico del basamento Precámbrico-Cámbrico del noroeste argentino. Acta Geológica Leopoldensia, 17, 733-746.

Durand, F.R., 1996. La transición Precámbrico-Cámbrico en el sur de Sudamérica. In: Baldis, B.A., Aceñolaza, F.G. (eds.). Early Paleozoic Evolution in Northwest Gondwana. Instituto Superior de Correlación Geológica, Serie Correlación Geológica, 12, 195-206.

Durand, F.R., Aceñolaza, F.G., 1990. Carácteres biofaunísticos, paleoecológicos y paleogeográficos de la Formación Puncoviscana (Precámbrico Superior – Cámbrico Inferior) del noroeste argentino. In: Aceñolaza, F.G., Miller, H., Toselli,

A.J. (eds.). El Ciclo Pampeano en el Noroeste Argentino. Instituto Superior de Correlación Geológica, Serie Correlación Geológica, 4, 71-112.

Durand, F.R., Lech, R.R., Tortello, M.F., 1993. Nuevas evidencias paleontológicas en el basamento Precámbrico-Cámbrico del noroeste argentino. Acta Geológica Leopoldensia, 17, 691-701.

Fedonkin, M.A., 1988. Paleoichnology of the Precambrian-Cambrian Transition in the Russian Platform and Siberia. In: Landing, E., Narbonne, G.M., Myrow, P. (eds.). Trace Fossils, Small Shelly Fossils and the Precambrian-Cambrian Boundary. Proceedings. New York State Museum Bulletin, 463, 12.

Fitch, A., 1850. A historical, topographical and agricultural survey of the county of Washington. Pt. 2-5 New York Agricultural Society. Transactions 9, 753-994.

Fillion, D., 1989. Les critères discriminants à l`intérieur du triptyque Palaeophycus-Planolites-Macaronichnus. Essai de synthèse d`un usage critique. C.R. Academie Sciences du Paris, 309(2), 169-172.

Fillion D., Pickerill R.K., 1990. Ichnology of the Upper Cambrian? to Lower Ordovician Bell Island and Wabana Groups of eastern Newfoundland, Canada. Palaeontographica Canadiana, 7, 1-119.

Häntzschel, W., 1975. Trace fossils and problematica. In: Teichert, F.C. (ed.). Treatise on Invertebrate Paleontology. Part W, Miscelánea (Supplement 1), 1-2.

Hitchcock, E., 1858. Ichnology of New England. A Report on the Sandstone of the Connecticut Valley, Especially its footprints. White (Boston), 220 pp.

Hofmann, H.J., Patel, I.M., 1989. Trace fossils from the type "Etchemunian Series" (Lower Cambrian Ratcliffe Brook Formation). Saint John area, New Brunswick, Canada. Geological Magazine, 126, 139-157.

Jensen, S., 1997. Trace fossils from the Lower Cambrian Mickwitzia sandstone, south-central Sweden. Fossils and Strata, 42, 1-110.

Jezek, P., 1990. Análisis sedimentológico de la Formación Puncoviscana entre Tucumán y Salta. In: Aceñolaza, F.G., Miller, H., Toselli, A.J. (eds.). El Ciclo Pampeano en el Noroeste Argentino. Instituto Superior de Correlación Geológica, Serie Correlación Geológica, 4, 9-36.

Liñán, E., Palacios, T., 1987. Asociaciones de pistas fósiles y microorganismos de pared orgánica del Proterozoico, en las facies esquisto-grauváquicas del norte de Cáceres. Consecuencias regionales. Boletín de la Real Sociedad Española de Historia Natural (Geología), 82(1-4), 211-232.

Metz, R., 1995. Sinusoidal trail formed by a recent biting midge (Family Ceratopogonidae): trace fossil implications. Journal of Paleontology, 62, 330-348.

Miller, S.A., 1889. North American geology and palaeontology for the use of amateurs, students and scientists. Western Methodist Book Concern. Cincinnati, 664 pp.

Mirré, J.C., Aceñolaza, F.G., 1972. El Hallazgo de *Oldhamia* sp. (traza fósil) y su valor como evidencia de edad cámbrica para el supuesto Precámbrico del borde occidental del Aconquija. Provincia de Catamarca. Ameghiniana, 9(1), 72-78.

Narbonne, G. M., Myrow, P. Landing, E., Anderson, M.M., 1987. A candidate stratotype for the Precambrian-Cambrian boundary. Fortune Head, Burin Peninsula, southeastern Newfoundland. Canadian Journal of Earth Sciences, 24, 1277-1293.

Nicholson, H.A., 1873. Contributions to the study of the errant annelides of the older Paleozoic rocks, Royal Society of London. Proceedings, 21, 288-310.

Nicholson, H.A., Hinde, G.J., 1871. Notes on the fossils of the Clinton, Niagara and Guelph formations of Ontario, with descriptions of new species. Canadian Journal Sci. Lit. History, 14, 137-160.

O`Connor, E., Welde, D., 1986. Recognition of Eocambrian progenic cycle in SW Brazil and SE Bolivia. Zentralblatt für Geolgie und Paläontologie, 1441-1456.

Omarini, R.H., Sureda, R.J., Götze, J.-H., Seilacher, A., Pflüger, F., 1999. Pucoviscana folded belt in northwestern Argentina: Testimony of Late Proterozoic Rodinia fragmentation and pre-Gondwana collisional episodes. International Journal of Earth Sciences, 88, 76-97.

Pemberton S.G., Frey, R.W., 1982. Trace fossil nomenclature and the *Planolites-Palaeophycus* dilemma. Journal of Paleontology, 56(4), 843-881.

Seilacher, A., 1967. Bathymetry of Trace fossils. Marine Geology, 5, 413-428.

Seilacher, A., 1970.Cruziana stratigraphy of "non fossiliferous" Palaeozoic sandstones. In: Crimes, T.P., Harper, J.C. (eds.). Trace Fossils, Geological Journal, Special Issue 3, 447-476.

Seilacher, A., 1985. Trilobite palaeobiology and substrate relationship. Transactions of the Royal Society of Edinburgh, 76, 231-237.

Seilacher, A., 1990. Paleozoic trace fossils. In: Said, R. (ed.). The Geology of Egypt. Balkema, 649-670.

Sureda, R. J., Omarini, R. H., 1999. Evolución geológica y nomenclatura pre-Gondwánica en el Noroeste de Argentina (1800-160 Ma). Acta Geologica Hispanica, 34(2-3), 197-225.

Webby, B.D., 1970. Late Precambrian trace fossils from New South Wales. Lethaia, 3, 79-109.

Manuscript received October 2001;
revision accepted July 2002.