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

G. F. ACEÑOLAZA and M. F. TORTELLO

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.


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 (Mirre 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...
Province). Nowadays, a highly diversified ichnological record is known from these sequences, including Asaphoidichnus, Cochlichnus, Didymaichnus, Dimorphichnus, Diplichnites, Glockeria, Heliomithoida, Helminthopsis, Helminthorhapes, Helminthoidichnites, Monomorphichnus, Multipodichnus, Neonereites, Nereites, Oldhamia, Phycodes, Planolites, Protichnites, Protopaleodictyon, Protovirgularia, Scolicia, Squamodictyon, Tasmanadua, 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 Aguarditas/Negro Peinado Formations) have been considered to be late Precambrian-early Cambrian in age (Aceñolaza and Durand, 1973, 1982, 1984, 1986; Aceñolaza et al., 1988; Durand and Aceñolaza, 1990; Durand et al., 1993). 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 interpretation. 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-blush 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).

**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).

**ICNOGENUS 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 meandric form 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).

**ICNOGENUS 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.

**ICNOGENUS Helminthoida** Schafhault, 1851

Type ichnospecies: *Helminthoida labyrintica* Heer, 1865.
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: Hantzschel (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.

ICHOGENUS 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 Monomorphichnus and Diplichnites. Jensin (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.

ICNOGENUS Planolites NICHOLSON, 1873

Type ichnospecies: Planolites vulgaris NICHOLSON and HINDE, 1874; by subsequent designation (Miller, 1889).
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 turbidites. 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 – sub-horizontal traces, as a result of the particular paleo-environmental conditions of the basin. Turbidites attest to changes between low-energy and high-energy deposition-al 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. Ichnotaxonomic 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 Patle, 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

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.


Manuscript received October 2001; revision accepted July 2002.