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Gastropods Associated with Fossil Traces from Yacoraite Formation (Maastrichtian-Danian), and its Paleoenvironmental Significance, Jujuy, Northwestern Argentina

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Abstract: We present results tending to characterize the new records of invertebrates from the Yacoraite Formation (Maastrichtian-Danian). The fossils reported come from two stratigraphic sections exposed in the surroundings of Maimará and Jueya, province of Jujuy, northwestern Argentina. The selection was based on geological and paleontological evidence. The recovered fossils include gastropods and invertebrate fossil traces, including *Planolites*, *Skolitho*s and *Gastrochanoelites* ichnogenus. As result of our review, we discussed the possibility of assigning the analyzed gastropods to the family Zygopleuridae (gene. et. sp. indet.), as an approximation to the taxonomic resolution of this fossil fauna. The trace fossils were assigned to the archetypical *Glossifungites* ichnofacies. The study of the fossil assemblage allowed us to define a shallow depositional environment, characteristic of a marine context with high-energy conditions.

Key words: gastropod, *Glossifungites*, Yacoraite Formation

1 Introduction

The Yacoraite Formation (Turner, 1959) of the Salta Basin represents a carbonate deposit widely distributed in the northwest of Argentina (Marquillas et al., 2007). Its palaeontological record has been reviewed and discussed in many papers, and includes fishes (Cione et al., 1985; Arratia and Cione, 1996), reptiles (Gasparini y Buffetaut, 1980), gastropods, ostracods, bivalves, algaes, fossil plants and palinomorphs (Marquillas et al., 2005). It also contains dinosaur and bird tracks (Alonso, 1980; Alonso and Maraquillas, 1986; Marquillas and Salfity, 1994; Marquillas et al., 2007). Apart from ichnological researches performed on tracks of dinosaurs and birds, the invertebrate traces are poorly characterized. The possible Cretaceous/Cenozoic limit has been identified on a section of this unit in the surroundings of Metan, Salta (Marquillas et al., 2003). These contributions show shallow marine conditions, which are coincident with a rigorous isotopic analysis on its carbonates and its sedimentological framework (Marquillas et al., 2007). In the case of gastropods, the systematic knowledge of this fauna is outdated (Bonarelli, 1927, 1921), which has created a lack of consensus within the scientific community. The main purpose of the present paper is to discuss the diversity of gastropods and to describe, for the first time, the invertebrate trace fossils from the unit. At the conclusion of the paper, we discuss the environmental features for this fossil assemblage.

2 Geological Settings

The research area belongs to the Eastern Cordillera, Jujuy, in an extended area of northwestern Argentina (Marquillas and Salfity, 1989). The sedimentation began in a group of rift-type trenches that belong to the Salta Group (Turner, 1959) basins, which were initially isolated and then interconnected. Consequently, the development of the basins involved the territories of Bolivia, Paraguay and probably Chile. The geological history of the Salta Group began in Kimmeridgian?-Early Cretaceous (Salfity and Marquillas, 1981), probably as a result of Araucanian movements, and culminated during the Inca phase. The basin was entirely developed on Precambrian and Palaeozoic basement, where the units of the Salta Group lie either on pampean rocks, especially those of the Central

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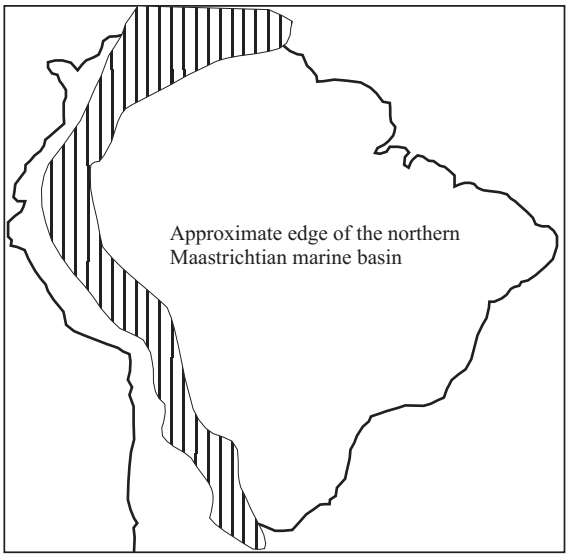

Fig. 1. Paleogeographic map of northern South America for the Maastrichtian. Modified from Gayet et al. (2001).

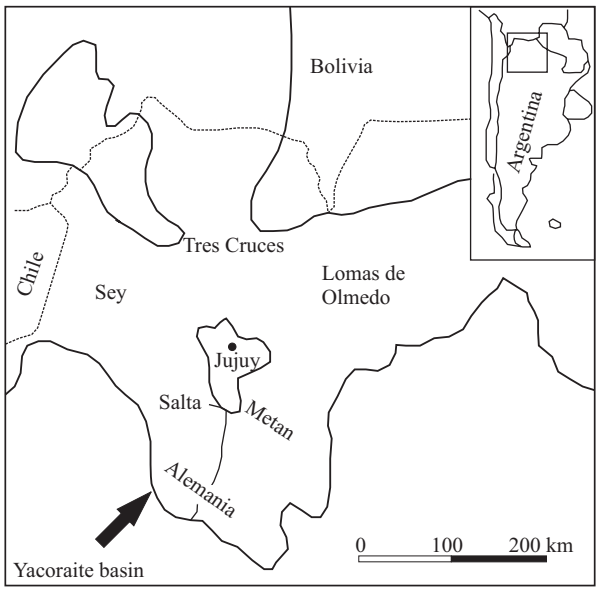

Fig. 2. Simplified palaeogeographic map with subbasins (Sey, Tres Cruces, Lomas de Olmedo, Metán y Alemanía). Modified from Salfity and Marquillas (1994).

Cratogen. The Pirgua Subgroup (Reyes and Salfity, 1973) belongs to the basal red banks. The Balbuena Subgroup (Moreno, 1970) is composed of sandstone, limestone and shale, and the Santa Barbara Subgroup (Moreno, 1970) is composed of shale with polychrome limestone and sandstone.

The Maastrichtian-Paleocene ingression in northern Argentina was linked to global changes equivalent to the Ranquel phase. The two pulses of the Ranquel phase indicate the beginning and end of the Balbuena Subgroup epiorogenic ingression, which occurred during a tectonic quietness stage (Salfity and Marquillas, 1999). The outstanding characteristic unit is the Yacoraite Formation, which overlies the previous one. It is a tabular (partly dolomitic) limestone deposit, with shale, sandstone and interbedded tuffs (Marquillas and Salfity, 1989).

The Yacoraite Formation is equivalent to the global transgressive deposition of the Late Cretaceous, which entered very deep into the South American continent (Gayet et al., 2001) (Fig. 1), and was interpreted as a shallow wide intracontinental restringed carbonate basin, with no direct influence from the open sea, therefore showing its own characteristics (Marquillas, 1985). The basins are known as Tres Cruces, Lomas de Olmedo, Metán, Alemanía, Cerro Hermoso, El Rey and El Charco or Sey (Fig. 2). The unit age is Maastrichtian-Danian (Marquillas et al., 1985), which implies that the Cretaceous-Cenozoic transition occurred during unit accumulation (Marquillas et al., 2007).

3 Materials and Methods

Gastropods and ichnofossils were recovered from several sedimentary levels in the study area. For this purpose, we built two stratigraphic sections in the surroundings of Maimará and Jueya, Tilcara district, Jujuy. The research material is stored in the invertebrate fossils collection of the Instituto Superior de Correlación Geológica/Facultad de Ciencias Naturales and Instituto Miguel Lillo (Universidad Nacional de Tucumán, Argentina), (YAC, Yacoraite Formation). The ichnological determinations in the laboratory were compared with field observations.

4 Systematic Paleontology

Subclass Caenogastropoda Cox, 1959
Superfamily Zygopleuroidea Wenz, 1938
Family Zygopleuridae Wenz, 1938
gen. et sp. indet.
Plate I, Figs. 1–7

Material: Seven specimens from Jueya, Jujuy. YAC I, II, III, IV, V, VI, VII.

Diagnosis: Shell, medium or large, conical or highly conical, slender. The protoconch remains unknown. Siphonal canal is absent. The teleoconch has convex whorls that increase rapidly in width. The suture is moderately incised and undulated. No spiral ornament. The teleoconch is ornamented by 6–8 strong axial ribs throughout ontogeny.

Discussion: These gastropods were located by Bonarelli (1927, 1921) in the Zygopleuridae Family. Many species have also been described for this sedimentary sequence

(Console Gonella and Aceñolaza, 2008). It is possible that many of them belong to the same genus. Unfortunately, the fossil preservation is diverse. The taphonomic conditions in some sections only allow the identification at family level. In this preliminary paper, we believe that it is possible to solve the taxonomic affinities. Some elements allow us to assign the gastropods to Zygopleuridae *s.l.*: habitus zygopleuroid and teleoconch ornament; with high spirals with ornament of wavy axial ribs, and absence of siphonal canal. However, in the future, we hope to provide new evidence to enhance this analysis.

5 Systematic Ichnology

Ichnogenus *Skolithos* Haldeman, 1840
Type ichnospecies: *Fucoides*? *linearis* Haldeman, 1840
Skolithos linearis Haldeman, 1840
Plate II, Figs. 1–3.

Material and repository: Specimens collected in Maimará and Jueya. YAC 1, YAC 2 and material in locus.

Description: Vertical to subvertical, straight, simple, cylindrical structures showing more or less uniform diameter, ranging from 10 to 35 mm. Length 30–100 mm, mostly approximately 90 mm, filled with structureless, medium sand, similar to the host rock.

Remarks: Dense occurrences were recognized in the field. The rock contains an ichnofabric index of 3 Bottjer and Droser (1991), "pipe rock" type. *Skolithos* Haldeman 1840 is a simple, non-branching, undecorated, straight or gently curved, shaft-like burrow, generally orientated perpendicular to, but in some instances steeply inclined to bedding. *Skolithos* trace fossils can be found in a variety of depositional environments, from deep-sea to non-marine, and have been found in tidal channels, tidal flats, deltas, estuaries and storm deposits (Droser, 1991).

Ichnogenus *Planolites* Nicholson, 1873
Type ichnospecies: *Planolites vulgaris* Nicholson and Hinde, 1875;
by subsequent designation (Miller, 1889).
Planolites isp.
Plate II, Figs. 4–5.

Material and repository: Specimen collected in Jueya. YAC 3.

Description: Straight or moderately curved, smooth, exceptionally branching tunnels of circular outline, parallel to bedding, filled with material differing from the surrounding rock. Preserved as full reliefs. The diameter of the tunnels commonly ranges from 3 to 10 mm, and the length of the preserved sections are greater than 20 mm.

Remarks: Since its original definition, the ichnogenus was discussed extensively, and different diagnostic criteria were focused for the outlining of the traces (Aceñolaza and Tortello, 2003). The details of the reviews were presented by Alpert (1975), Benton and Trewin (1978), Pemberton and Frey (1982) and Fillion (1989). *Planolites* differs from *Paleophycus* as a result of the existence of an unlined wall and a different filling from the host rock in the former (Pemberton and Frey, 1982; Fillion and Pickerill, 1990; Keighley and Pickerill, 1995).

Ichnogenus *Gastrochaenolites* Leymerie, 1842
Plate II, Figs. 6–7.

Material and repository: Specimen collected in Jueya. YAC 4.

Description: Clavate borings in stromatolitic substrate. The opening section of the borings is narrower than the main chamber, and its form is mainly circular or dumbbell shaped. The opening is separated from the main region by a neck. Two sizes of superposed borings are observed: small diameter orifices (3 mm) and large diameter orifices (20 to 30 mm). The main chamber may vary from subspherical to elongated.

Remarks: The constriction in the opening section immediately distinguishes it from *Trypanites,* and a typical *Gastrochaenolites* varies in size of diameter from 2 to 45 mm, and in length from 3 to 100 mm (Kelly and Bromley, 1984). As suggested by the etymology, the ichnotaxon is typically a product of boring bivalves. Although Bromley (1970) and Kelly and Bromley (1984) indicated that *G. torpedo* could also be produced by polychaetes and sipunculids, preservation of the indeterminate bivalve within the analyzed specimen indicates this not to be the case here, also discussed by Pickerill et al. (2002).

6 Discussion

It is understood that Zygopleuridae has been characterized for shallow marine environments (*s.l.*) and it is noted that the gastropod communities which lived on Jurassic carbonate platforms differ significantly from those found in recent shallow water environments (see Grundel and Klaim, 2006). This model can be accepted in our preliminary study, given its environmental and taxonomic similarities, and could explain the absence of related fauna in similar modern environments.

Ichnofossils are useful tools for making geologic interpretations of paleoenvironmental conditions, because they are less likely to be transported, and are more likely to have modern analogue than body fossils (Seilacher, 1967). *Skolithos* commonly occurs in shallow marine

environments (Fillion and Pickerill, 1990), but also can be found in continental environments (Bromley and Asgaard, 1979; Schlirf et al., 2001; Gregory et al., 2006). Dense occurrences of *Skolithos* are referred to "pipe-rock" ichnofabric (Droser, 1991). Marine *Skolithos* is mainly interpreted as a domichnion structure made by phoronids or annelids (Sokoloski, 2005). *Planolites* is interpreted as a feeding structure of deposit feeder, mainly worms (Pemberton and Frey, 1982), or possibly larval insects in continental deposits (Buatois and Mangano, 1993; Kim et al. 2002; Singh et al. 2008). *Planolites* is usually defined as "facies-crossing trace" and appears in the main diverse facies (Buatois and Lopez Angriman, 1991). The fluctuating water conditions in these nearshore environments favor the preservation of primary sedimentary structures, such as crossbedding, and are characterized by abundant "domichnia" (or "dwelling") type trace fossils, which includes *Skolithos* and other burrows and tubes that are predominantly vertically oriented (Ekdale et al., 1984). Many of the organisms that produce clavate borings today, partly or completely line their borings with calcareous deposits, and this is particulary the case among boring bivalves (Kelly and Bromley, 1984). In contrast, *Gastrochaenolites* has been interpreted as part of shallow waters, which indicates a few meters of water column, (Kleemann, 1973; Bromley, 1992, 1994) also indicating high energy, a very diminished or null sedimentation rate, and a good availability of nutrients (Verde, 2002). Seilacher (1964) originally described the *Glossifungites* ichnofacies as a mainly littoral assemblage of trace fossils emplaced in cohesive substrates. These are markedly different from the *Skolithos* ichnofacies that characterize settings with shifting substrates. Frey and Seilacher (1980) restricted the *Glossifungites* ichnofacies to firmgrounds in marine environments, though the essential components of Seilacher's original (1964) definition remained intact. *Glossifungites* are an Ichnofacies, which represents an assemblage of burrows (vertical, U-shaped, or sparsely branched) that occur in firm, but not lithified siliciclastic and/or carbonate muds and silts of the intertidal and shallow marine where scouring has often removed the unconsolidated layers at the sediment surface (Pemberton and Frey, 1985).

7 Conclusions

Given the characteristics of the analyzed association and its relation with sedimentary and paleoenvironmental characteristics, a coastal brackish marine environment with some tidal influence is interpreted in concordance with previous sedimentological studies. The trace fossils are assigned to the archetypical *Glossifungites* ichnofacies.

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Plate I

Figures 1–7 Zygopleuridae Wenz, 1938 gen. et sp. indet. Apertural view. YAC I, II, III, IV, V, VI and VII. Bar, 1 cm.

Plate II

Fossil traces from Yacoraite Formation. Bar, 1 cm.

1, *Skolithos isp.* Haldeman, 1840. Horizon showing piperock ichnofabric.

2, *Skolithos linearis* Haldeman, 1840, YAC 1.

3, *Skolithos linearis* Haldeman, 1840, YAC 2.

4, 5, *Planolites isp,* Nicholson, 1873, YAC 3.

6, *Gastrochaenolites isp.* Leymerie, 1842, YAC 4.

7, *Gastrochaenolites isp.* Leymerie, 1842, YAC 4 with small bivalve *in situ*.

Plate I

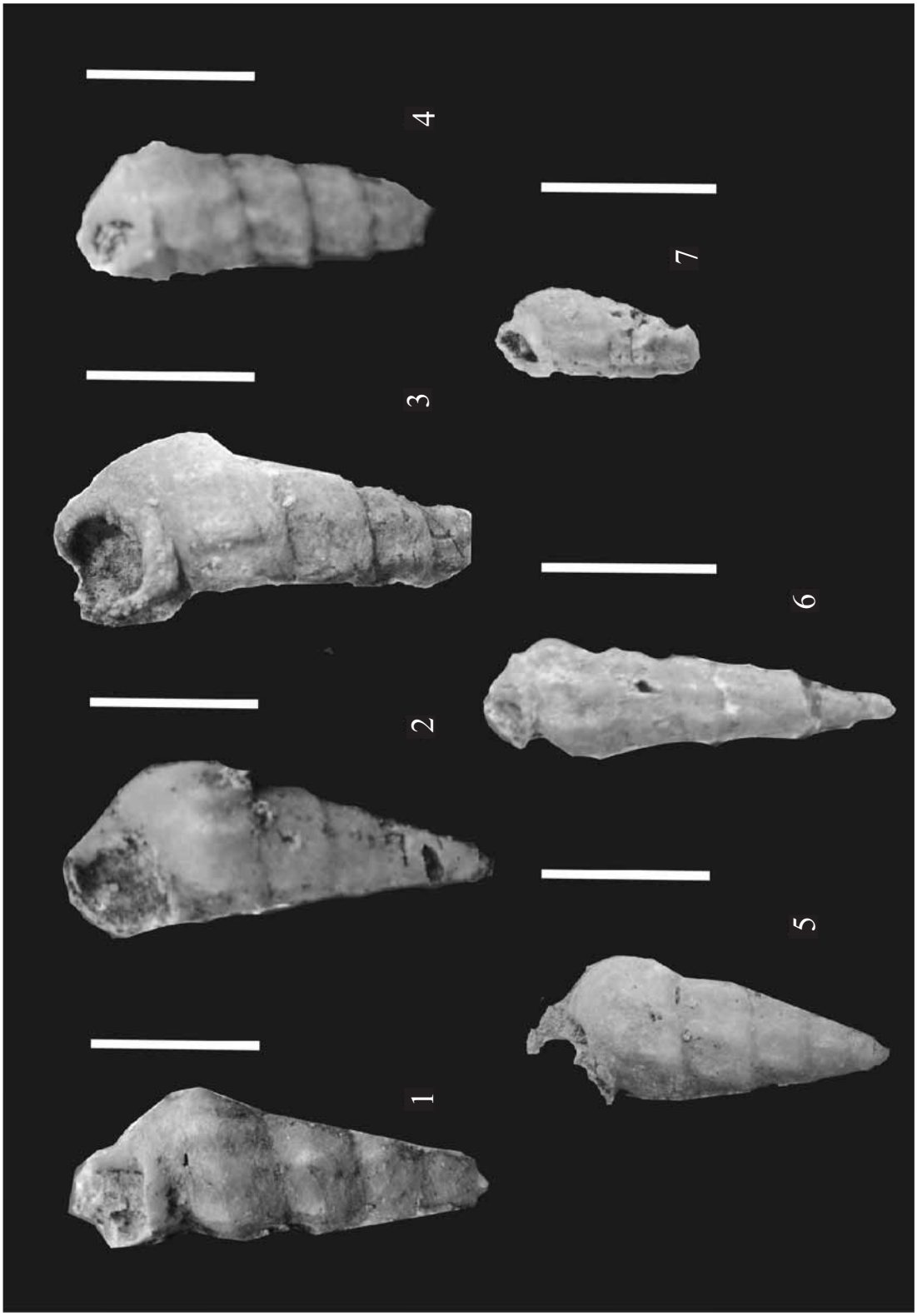
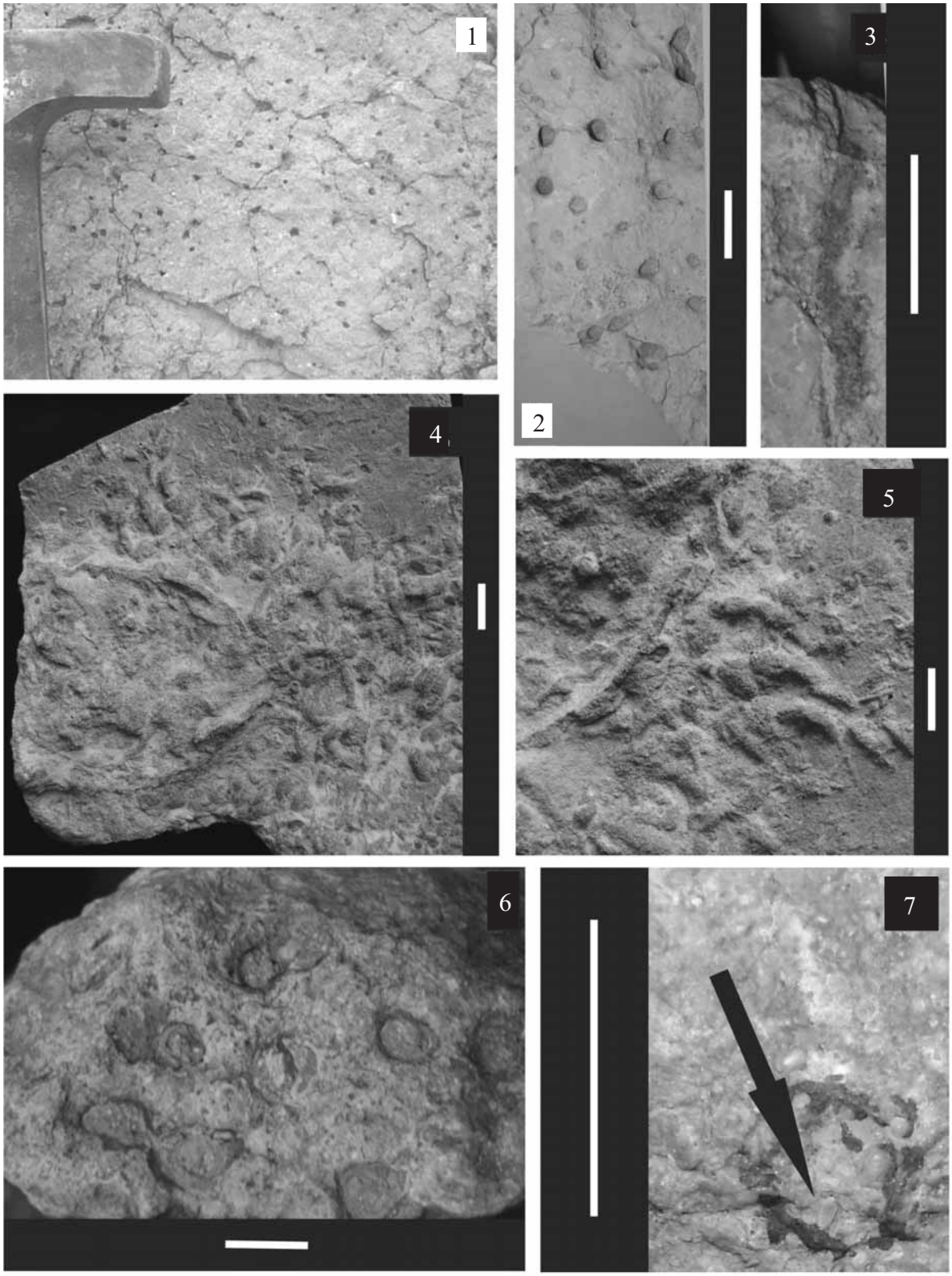
Plate II