# First Ordovician Foraminifera from South America: A Darriwilian (Middle Ordovician) fauna from the San Juan Formation, Argentina

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ABSTRACT: The first Ordovician foraminifers in South America are described from Middle Ordovician (Darriwilian)strata of the upper part of the San Juan Formation, Argentina. The foraminifers are found together with conodonts of the *Eoplacognathus pseudoplanus /Dzikodus tablepointensis* Zone that enhances the stratigraphic significance of the foraminifers. The assemblage of foraminifers described includes the agglutinated genera *Lakites*, *Amphitremoida*, *Lavella*, *Ordovicina* and *Pelosina*. The distribution of the genera *Lakites* and *Lavella*, previously known only from the Lower Ordovician, Floian (*Tetragraptus phyllograptoides* graptolite Zone), now can be extended up into the Middle Ordovician (Darriwilian). The find of representatives of the xenophyophorean genus *Pelosina* extends the first appearance of this genus down into the Middle Ordovician.

## INTRODUCTION

The Precordillera terrane is located in western Argentina between the Cordillera Frontal to the west and the Sierras Pampeanas to the east. It consists of a thick succession of Paleozoic rocks of Cambrian, Ordovician, Silurian, Devonian and Carboniferous age. The Precordillera terrane has been subdivided into three morphostructural units based on stratigraphic and structural characteristics: the Eastern (Ortiz and Zambrano 1981), Central (Baldis and Chebli 1969) and Western Precordillera (Baldis et al. 1982). Recently, Astini (1992) based mostly on tectono-stratigraphic data distinguished an eastern tectofacies belt that includes the Eastern and Central Precordillera, and a western tectofacies belt represented by the Western Precordillera.

The Ordovician succession consists of carbonate rocks of the extensive platform that characterize the Precordillera, and are exposed in La Rioja, San Juan and Mendoza provinces. The carbonate sequence is represented by the La Silla and San Juan formations and is overlain by the Gualcamayo or Los Azules formations that consist of black shales with intercalated deep water calcareous mudstones (Baldis and Beresi 1981; Astini 1994).

The Cerro Viejo is a classical area for the study of the Ordovician in the Central Precordillera (Ortega et al. 2007 with references herein). There, the San Juan Formation (Dapingian and Darriwilian stages) forms the core of the Huaco anticline, on the western flank of which crops out the shaly succession of the Los Azules Formation (Harrington in Harrington and Leanza 1957) of Darriwilian age (Borrello and Gareca 1951; Cuerda and Furque 1975; Hünicken and Ortega 1987; Ortega 1987, 1995; Ortega and Rickards 2003; Ortega et al. 2007). The San Juan Formation bears a rich shelly fauna of brachiopods, trilobites, nautiloids, echinoderms, gastropods, sponges, conodonts, ostracods and foraminifers.

In the present paper we report the first discovery of Ordovician foraminifers from the upper part of the San Juan Formation. They also represent the oldest foraminifers found in South America.

## GEOLOGICAL SETTING AND STRATIGRAPHY

The area of this study is located in the San Juan province on the western flank of the Huaco anticline about 4km southeast from La Cienega village (text-fig. 1). There the San Juan Formation crops out in north-south belt with several well studied sections across this belt (text-fig. 1). The northernmost section, the source of foraminifers, is located on Del Aluvión creek (text-figs. 1, 2).

The San Juan Formation consists of 330m of carbonate strata (Keller 1999) interpreted as being deposited in a shallow to deep ramp setting. In the upper part, crinoidal barriers, hardgrounds, and several exposure surfaces are recognized (Cazas and Aguirre 2005 with references herein). A well-known hardground at the top of the unit is covered with nautiloids with giant phragmacones up to 60cm long (text-fig. 2). The Los Azules Formation overlies the San Juan Formation with a contact that has been interpreted as a paraconformity (Astini 1994). Ortega et al. (2007) reported conodonts of the Middle Ordovician (Darriwilian) *Lenodus variabilis* Zone from the upper part of the San Juan Formation. K-bentonites occur in the upper part of the San Juan Formation and the lower member of the Los Azules Formation in this section (Huff et al. 1995, 1997, 1998; Cingolani et al. 1997). U-Pb geochemistry of zircons indicates the associated eruption event as 464 ± 3m.y. which is consistent with the biostratigraphic data.

TABLE 1
Taxa described and illustrated in this study.

*Lakites*? sp.
Plate 1, figures 1-2
*Amphitremoida* sp. 1
Plate 1, figure 3-5; Plate 4, figure 1
*Amphitremoida* sp. 2
Plate 1, figure 7
*Lavella*? sp.
Plate 1, figure 6; Plate 4, figure 2
*Ordovicina* sp. 1
Plate 2, figures 1-2; Plate 4, figure 3
*Pelosina aspera* (Moremann 1930)
Plate 2, figures 6-11; Plate 4, figure 4
*Pelosina teschenhagensis* (Schallreuter 1983)
Plate 3, figures 1-3; Plate 4, figures 5-6

## BIOSTRATIGRAPHY

Numerous Ordovician conodonts and graptolites are mentioned from the Cerro Viejo area (all references in Ortega et al. 2007), and Ortega et al. (2007) defined several conodont biozones in the upper part of the San Juan Formation and the overlying Los Azules Formation: *Lenodus variabilis, Eoplacognathus suecicus, Pygodus serra* and *Pygodus anserinus*, in ascending order. Ortega et al. (2007) correlated the top of the San Juan Formation to the *Lenodus variabilis* Zone as that zone is defined in the Baltic region (Löfgren 1978, 2000) (text-fig. 3). In the present study, several conodont samples were taken from the uppermost part of the San Juan Formation to study the detailed biostratigraphy of this classical section (text-fig. 2). As result, a few elements of *Eoplacognathus pseudoplanus* Bergström were recovered from strata of the San Juan Formation, ca. 0.60m below the top, indicating a correlation with the *Eoplacognathus pseudoplanus/Dzikodus tablepointensis* Zone (Zhang 1998; Löfgren 2004), which overlies the *Lenodus variabilis* Zone in the biostratigraphic scheme proposed by Heredia et al. (2005) for the Central Precordillera (text-fig. 3). Foraminifers were discovered in the conodont residues along with ostracods, sponge spicules, trilobite remains, brachiopods, algal remains and crinoids.

## MATERIALS AND METHODS

The samples of wackestone, packstone and grainstone taken from the top of the San Juan Formation contain conodonts, crinoids, ostracods, sponge spicules, spines of trilobites, brachiopods and foraminifers. For isolating the microfossils, the samples were treated with a 10% formic acid solution following the method of Jeppsson and Anehus (1995). The preservation of conodonts is good, but the most foraminifers are preserved as external molds. This collection is housed in INGEO, Universidad Nacional de San Juan, under the code INGEO-MP.

## FORAMINIFERS

Ordovician foraminifers have been reported from only a few places in the world: Baltoscandia (Bykova 1956; Eisenack 1954, 1967, 1969; Schallreuter 1983, 1985; Reigraf and Niemeyer 1996; Nestell and Tolmacheva 2004), the Bohemian Massif in the Barrandian area (Bubík 1995, 1997; Holcová 1999), and North America (Moreman 1930, 1933; Conkin and Conkin 1965, 1977; Gutschick 1986). In these regions a few assemblages of foraminifers have been described from strata of most of the new global Ordovician stages (Bergström et al. 2006, Gradstein and Finney 2007, Ogg et al. 2008) except the Tremadocian and Hirnantian.

The foraminifers from the upper part of the San Juan Formation are represented by nine species belonging to the agglutinated genera *Amphitremoida*, *Ordovicina*, *Lakites*, *Lavella*, and *Pelosina*. Most of the foraminifers are preserved as casts; however, specific and generic identifications are based on the particular morphology of their tests. Species of the genera *Amphitremoida*, *Ordovicina*, *Lakites*, *Lavella* and two species of the genus *Pelosina* are placed in open nomenclature because they are casts. Two species of *Pelosina* could be assigned to the species *P. aspera* (Moreman) and *P. teschenhagensis* (Schallreuter); the first one is known from the Upper Ordovician Viola Limestone of the Arbuckle Mountains, Oklahoma, USA (Moreman 1930, Carlson and Newell 1997, Finney 1997), and the second one was described from Upper Ordovician erratic boulders of Germany (Schallreuter 1983). Several forms of uncertain identity are present in the assemblage and are referred to Incertae Sedis 1 and 2 (text-fig. 2; plate 2, 3). One specimen of *Tasmanites* or *Thuramminoides* was found in sample DA5. This specimen is brown in color and has a compressed discoidal shape. According to these features, the specimen reminds one of the algal genus *Tasmanites*, but it also is similar to the foraminiferal genus *Thuramminoides* because of the compressed discoidal shape. This recent find of Ordovician age foraminifers in Argentina expands their paleogeographical distribution and gives additional data for plate tectonic reconstructions.

## SYSTEMATIC DESCRIPTION

The authors use the system of higher protozoan taxa proposed by Cavalier-Smith (2002), higher agglutinated foraminifer taxa proposed by Kaminski (2004) and Mikhalevich (2004), and for xenophyophorean taxa proposed by Gooday and Tendal (2000) with addition of Mikhalevich and Voronova (1999).

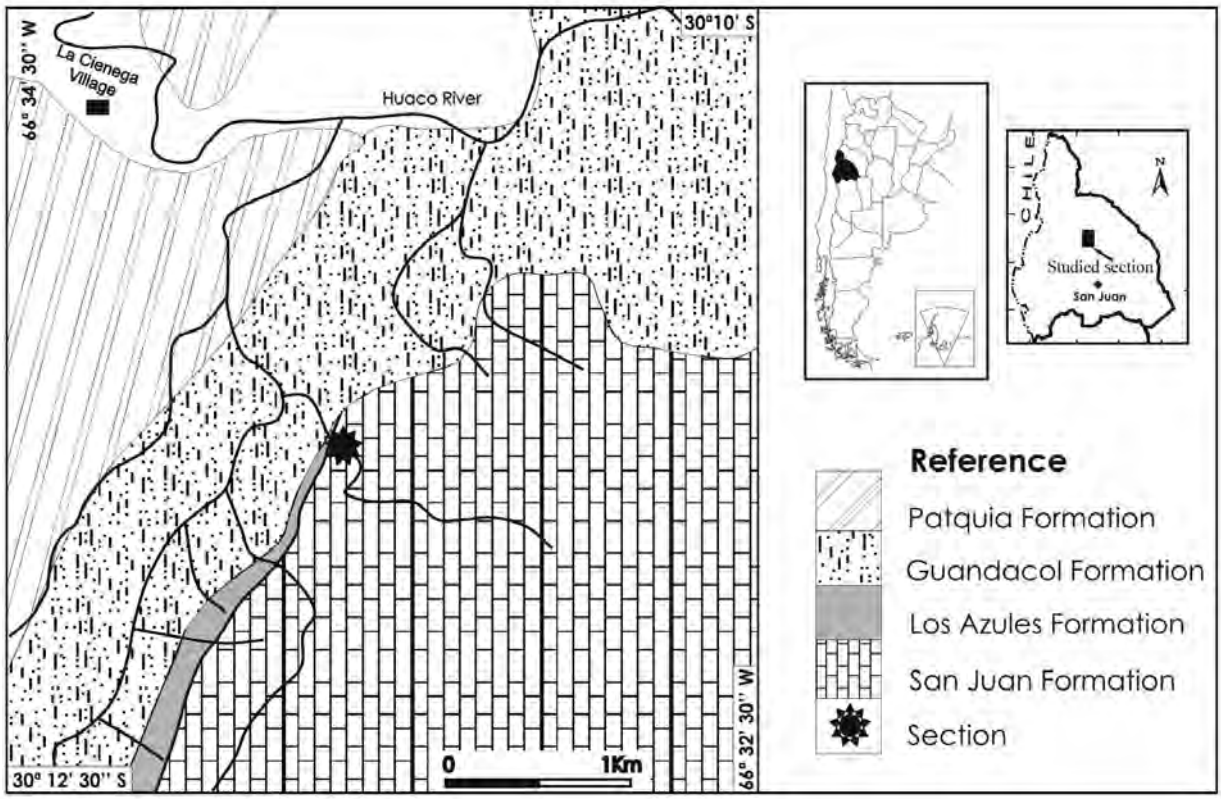
Kingdom PROTOZOA Goldfuss 1817; emend. Owen 1858
Subkingdom GYMNOMYXA Lankester 1878 stat. nov. emend. Cavalier-Smith 2002
Infrakingdom RHIZARIA Cavalier-Smith 2002
Phylum RETARIA Cavalier-Smith 1999 stat. nov. Cavalier-Smith 2002
Subphylum FORAMINIFERA (d'Orbigny 1826) Eichwald 1830 stat. nov. Margulis 1974; stat. emend. Cavalier-Smith 2002 [pro phylum Foraminifera]
Class ASTRORHIZATA Saidova 1981; emend. Mikhalevich 1995
Subclass ASTRORHIZANA Saidova 1981
Order ASTRORHIZIDA Lankester 1885 [nom. correct. Calkins 1909 pro order Astrorhizidea Lankester 1885; = Astrorhizida Fursenko 1958]
Family HIPPOCREPINELLIDAE Loeblich and Tappan 1984; emend. Mikhalevich 1995

Genus ***Lakites*** Nestell and Tolmacheva 2004
Type species: *Lakites ordovicus* Nestell and Tolmacheva 2004.

*Range* (emended herein): Lower Ordovician, Floian (*Tetragraptus phyllograptoides* graptolite Zone) – Middle Ordovician (Darriwilian).

***Lakites***? sp.
Plate 1, figures 1-2

*Description*: Test is free, monothalamous, stick-shaped, straight or curved, with two apertures, one at each end, one apertural end slightly wider than the other end, apertures plugged, but one can




TEXT-FIGURE 1
Location map of the Del Aluvión creek section, Cerro Viejo, San Juan Province, Argentina.

see that one aperture is rounded in shape (Plate 1, fig. 2b) and the other one is probably oval in shape (Plate 1, fig. 2c); wall was probably agglutinated, but specimens are casts, so the exact composition is unknown. Dimensions: test length (L) 0.87-1.2mm, width (W) 0.18-0.25mm, ratio L/W 4.7-6.0.

*Material*: One specimen from sample DA2, one – from sample DA3 and two - from sample DA4.

*Discussion*: We refer our specimens to the genus *Lakites* conditionally because of poor preservation. Based on the elongate test with two apertures, one at either end, *Lakites* sp. is very similar to *Lakites ordovicus* Nestell and Tolmacheva (2004, p. 257, pl. 1, fig. 1-4), but differs from it by larger size of the test, the absence of a collar at one aperture and constant width along the test.

*Occurrence*: Middle Ordovician, Darriwilian; Argentina, Cerro Viejo, Del Aluvión creek section, upper part of the San Juan Formation, *Eoplacognathus pseudoplanus/Dzikodus tablepointensis* conodont Zone.

Genus ***Amphitremoida*** Eisenack 1938; emend. Nestell and Tolmacheva 2004 [= *Croneisella* Dunn 1942; = *Pachyammina* Eisenack 1967]

Type species: *Amphitremoida citroniforma* Eisenack 1938.

*Range*: Lower Ordovician, Floian (*Tetragraptus phyllograptoides* graptolite Zone) – Carboniferous, Mississippian (Tournaisian).

***Amphitremoida*** sp. 1
Plate 1, figure 3-5; Plate 4, figure 1

*Description*: Test is free, monothalamous, large, fusiform, elongate, and white in color, with two apertures, one at each end. Apertures are located on small necks. One neck is narrower than the other. Wall was probably agglutinated, but specimens are casts, so the exact composition is unknown. Dimensions: test length (L) 0.69-1.23mm, width (W) 0.25-0.46, ratio L/W 2.67-2.76; width of the neck of one aperture 0.063-0.080mm, height 0.037-0.050mm; width of the neck of the other aperture 0.051-0.100mm, height 0.015-0.020mm.

*Material*: Four specimens from sample DA1, one – from sample DA2, three – from sample DA3 (one specimen prepared as a thin section), and one specimen from sample DA4.

*Discussion*: *Amphitremoida* sp. 1 is similar to *Amphitremoida longa* Nestell and Tolmacheva (2004, p. 264, pl. 4, figs. 1-3, pl. 10, fig. 3) in having a fusiform and elongate test, but differs

from it by the larger size of the test, larger ratio L/W (in *A*. sp. 1 the ratio L/W is 2.67-2.76, in *A*. *longa* 1.9-2.5) and the presence of distinct necks on both apertural ends. Based on the presence of the apertural necks, *Amphitremoida* sp. 1 is similar to *A*. *fusiforma* Eisenack (1967, p. 253, pl. 25, figs. 3-4) and *A*. *tenuissima* Eisenack (1967, p. 254, pl. 25, figs. 9-10). From the first species, *A*. sp. 1 differs by its larger size and the fusiform and elongate shape of the test, and from *A*. *tenuissima* it differs also by its larger size of the test and shorter apertural necks.

*Occurrence*: Middle Ordovician, Darriwilian; Argentina, Cerro Viejo, Del Aluvión creek section, upper part of the San Juan Formation, *Eoplacognathus pseudoplanus/Dzikodus tablepointensis* conodont Zone.

***Amphitremoida*** sp. 2
Plate 1, figure 7

*Description*: Test is free, monothalamous, of pointed oval shape, of brownish color, with two apertures, one at each end, with one rounded apertural end and a projected neck on the other apertural end. Both apertures are plugged. The aperture on the neck is rounded in shape; the other aperture is of unknown shape. The surface of the test is bumpy (tuberculated). Wall was probably agglutinated, but specimens are casts, so the exact composition is unknown. Dimensions: test length (L) 0.94mm, width (W) 0.41mm, ratio L/W 2.29, width of the neck 0.09mm, height 0.05mm.

*Material*: One specimen from sample DA5.

*Discussion*: *Amphitremoida* sp. 2 is similar to *Amphitremoida asperella* Nestell and Tolmacheva (2004, p. 262, pl. 2, fig. 1) in the pointed oval shape of the test, but differs from it by the larger size of the test, larger ratio L/W (in *A*. *asperella* the ratio L/W is 1.8-1.9), and the presence of only one apertural neck.

*Occurrence*: Middle Ordovician, Darriwilian; Argentina, Cerro Viejo, Del Aluvión creek section, upper part of the San Juan Formation, *Eoplacognathus pseudoplanus/Dzikodus tablepointensis* conodont Zone.

Class NODOSARIATA Mikhalevich 1992
Subclass HORMOSINANA Mikhalevich 1992
Order SACCAMMINIDA Lankester 1885
Family SACCAMMINIDAE Brady 1884 [nom. transl. Cushman 1927 ex Saccammininae Brady 1884]
Subfamily SACCAMMININAE Brady 1884

Genus ***Lavella*** Nestell and Tolmacheva 2004
Type species: *Lavella cucumeriformis* Nestell and Tolmacheva 2004.

*Range* (emended herein): Lower Ordovician, Floian (*Tetragraptus phyllograptoides* graptolite Zone) – Middle Ordovician (Darriwilian).

***Lavella***? sp.
Plate 1, figure 6; Plate 4, figure 2

*Description*: Test is free, monothalamous, elongate oval in shape, of brownish color, with one aperture. Initial and apertural ends rounded. Some tests are expanded towards the apertural end. Surface of the test is bumpy. Aperture is terminal, simple, small and rounded. Wall was probably agglutinated, but specimens are casts, so the exact composition is unknown. Dimensions: test length (L) 1.05-1.12mm, width (W) 0.33-0.42mm, ratio L/W 2.66-3.18.

*Material*: Three specimens from sample DA1 (one specimen prepared as a thin section) and one - from sample DA3.

*Discussion*: Specimens are referred to the genus *Lavella* conditionally because of poor preservation. Based on the presence of one aperture and the elongate test, *Lavella*? sp. is similar to *Lavella cucumeriformis* Nestell and Tolmacheva (2004, p. 268, pl. 9, fig. 3), but differs from it by the much larger size of the test, larger ratio L/W (in *L*. *cucumeriformis* the ratio L/W is 1.7-1.85), and elongate oval shape of the test.

*Occurrence*: Middle Ordovician, Darriwilian; Argentina, Cerro Viejo, Del Aluvión creek section, upper part of the San Juan Formation, *Eoplacognathus pseudoplanus/Dzikodus tablepointensis* conodont Zone.

Subfamily THURAMMININAE A. Miklukho-Maklay 1963
Genus *Ordovicina* Eisenack 1938; emend. Eisenack 1954
Type species: *Ordovicina oligostoma* Eisenack 1938.

*Range*: Lower – Upper Ordovician.

***Ordovicina*** sp. 1
Plate 2, figures 1-2; plate 4, figure 3

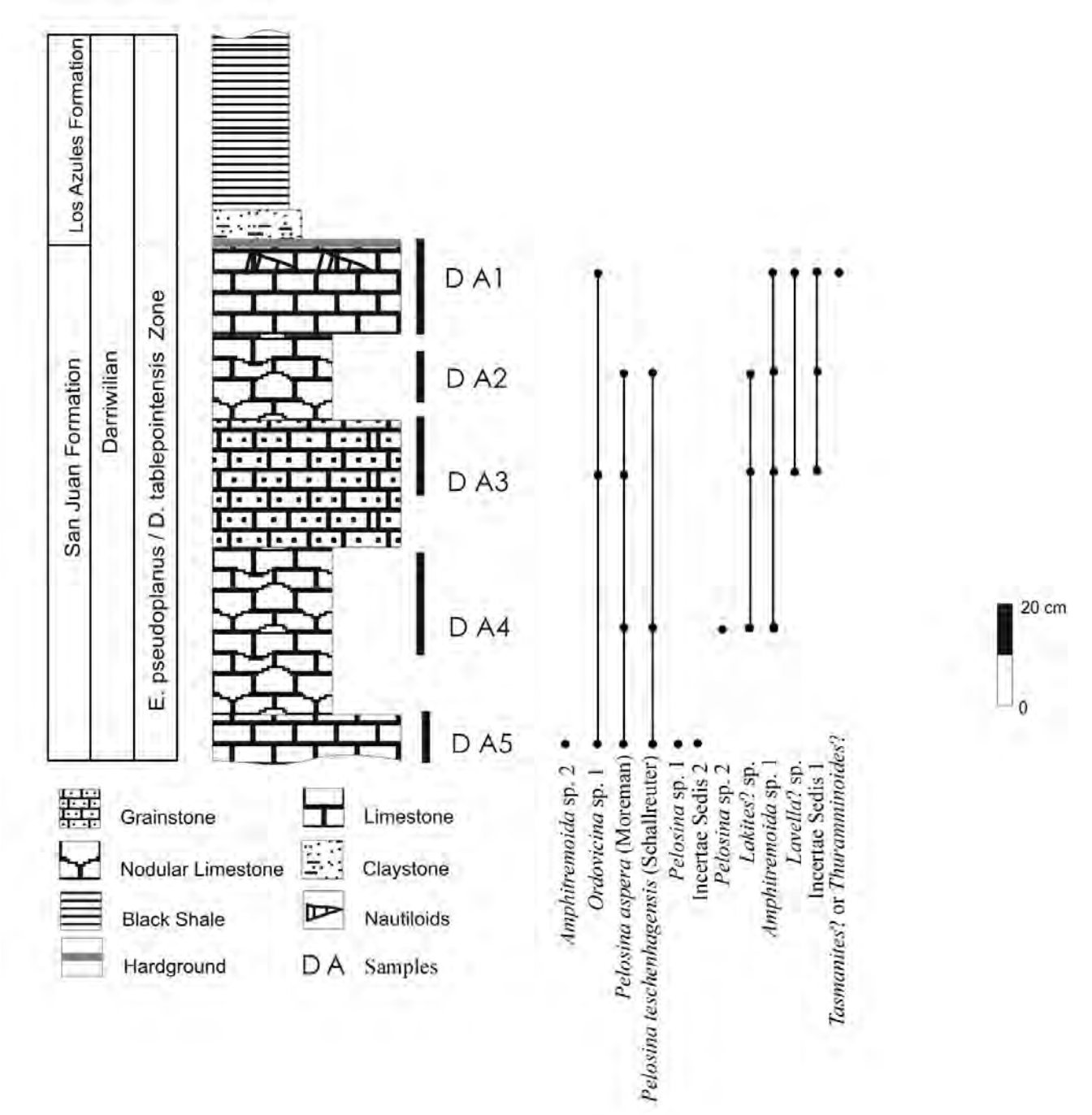
*Description*: Test is free, monothalamous, large, of white color, vase-shaped and slightly compressed, with one aperture on a short neck. Aperture is plugged. Wall is probably very thin but was likely dissolved during formic acid etching for the extraction of the foraminifers from limestone. The internal cavity is filled with partly sediment and possibly some organic? material (Plate 4, fig. 3). Dimensions: test length (L) with a neck 1.10-1.55mm, width (W) 0.49-0.51mm, ratio L/W 2.24-3.0; height of the neck 0.08-0.12mm, width 0.10-0.15mm.

*Material*: One specimen from sample DA1, one – from sample DA5 and one specimen from sample DA3 prepared as a thin section.

*Discussion*: Based on the vase-shaped test with a neck and the presence of one aperture, *Ordovicina* sp. 1 is similar to *O*. *monostoma* Eisenack (1954, p. 54, pl. 3, fig. 1), but differs from it by the much larger size of the test and higher stratigraphic interval. *Ordovicina monostoma* was described from the stage $B_2$ of the Baltic scheme that corresponds to the Dapingian Stage of the Ordovician (Ogg et al. 2008).

*Remarks*: We referred our specimens to the genus *Ordovicina* on the basis of similar morphology described by Eisenack (1938) and later emended by him (Eisenack 1954). In his emendation of the diagnosis of the genus, Eisenack noted that representatives of *Ordovicina* can have one or more extended apertures and a thin and delicate wall consisting of a red brown organic substance and sometimes with very fine foreign particles such as quartz fragments (Eisenack 1954, p. 53). Our specimens have an extremely thin wall as one can see on Plate 4, fig. 3 and a black brownish substance (organic?) inside of the test.

*Occurrence*: Middle Ordovician, Darriwilian; Argentina, Cerro Viejo, Del Aluvión creek section, upper part of the San Juan Formation, *Eoplacognathus pseudoplanus/Dzikodus tablepointensis* conodont Zone.




TEXT-FIGURE 2
Distribution of the foraminifers in the Del Aluvión creek section, upper part of the San Juan Formation, Cerro Viejo, Argentina.

Class **XENOPHYOPHOREA** Schulze 1904

*Remarks*: We consider the xenophyophores to be Foraminifera based on the investigation of Pawlowski et al. (2003) who analyzed the molecular data of living xenophyophorean species of the genus *Syringammina* Brady 1883. These authors showed that this species is closely related to representatives of the foraminiferan genus *Rhizammina* Brady 1879, *R. algaeformis* Brady 1879, and concluded that "the Xenophyophorea appear to be a highly specialized group of deep-sea Foraminifera" (Pawlowski et al. 2003, p. 483).

The time of the first appearance of xenophyophores is still a controversial matter. There are some proposals that this group of protozoans actually first appeared in the Precambrian (Tendal 1990) where their bodies were mistakenly accepted as a trace fossils because "their agglutinated walls consist of the same material as the sediment surrounding them" (Seilacher et al. 2003, p. 49).

Order STANNOMIDA Tendal 1972

Family **PELOSINIDAE** Cushman 1927 [nom. correct. here pro subfamily Pelosininae Cushman 1927; = Pelosinidae Mikhalevich in Mikhalevich and Voronova 1999; = Stegnamminidae Moreman 1930; = Thekammininae Dunn 1942]

*Remarks*: Cushman (1927) established a new subfamily Pelosininae within the composition of the family Saccamminidae Brady 1884 with a type genus *Pelosina* Brady 1879. Mikhalevich (in Mikhalevich and Voronova 1999) after revision of two species of the genus *Pelosina*, *P. variabilis* Brady 1879 (type species for the *Pelosina*) and *P. arborescens* Pearcey 1914 from the Holocene of Antarctic and sub-Antarctic, established a new family Pelosinidae. According to International Code of Zoological Nomenclature (1999, Chapter 11, Article 50), the authorship of the family belongs to Cushman and not Mikhalevich.

Genus ***Pelosina*** Brady 1879; emend. Mikhalevich and Voronova 1999 [= *Pelosinella* Parr 1950, = *Globosiphon* Avnimelech 1952; = *Stegnammina* Moreman 1930, = *Raibosammina* Moreman 1930; = *Thekammina* Dunn 1942]

Type species: *Pelosina variabilis* Brady 1879, earliest citation by Cushman 1910 (Carroll et al. 2006).

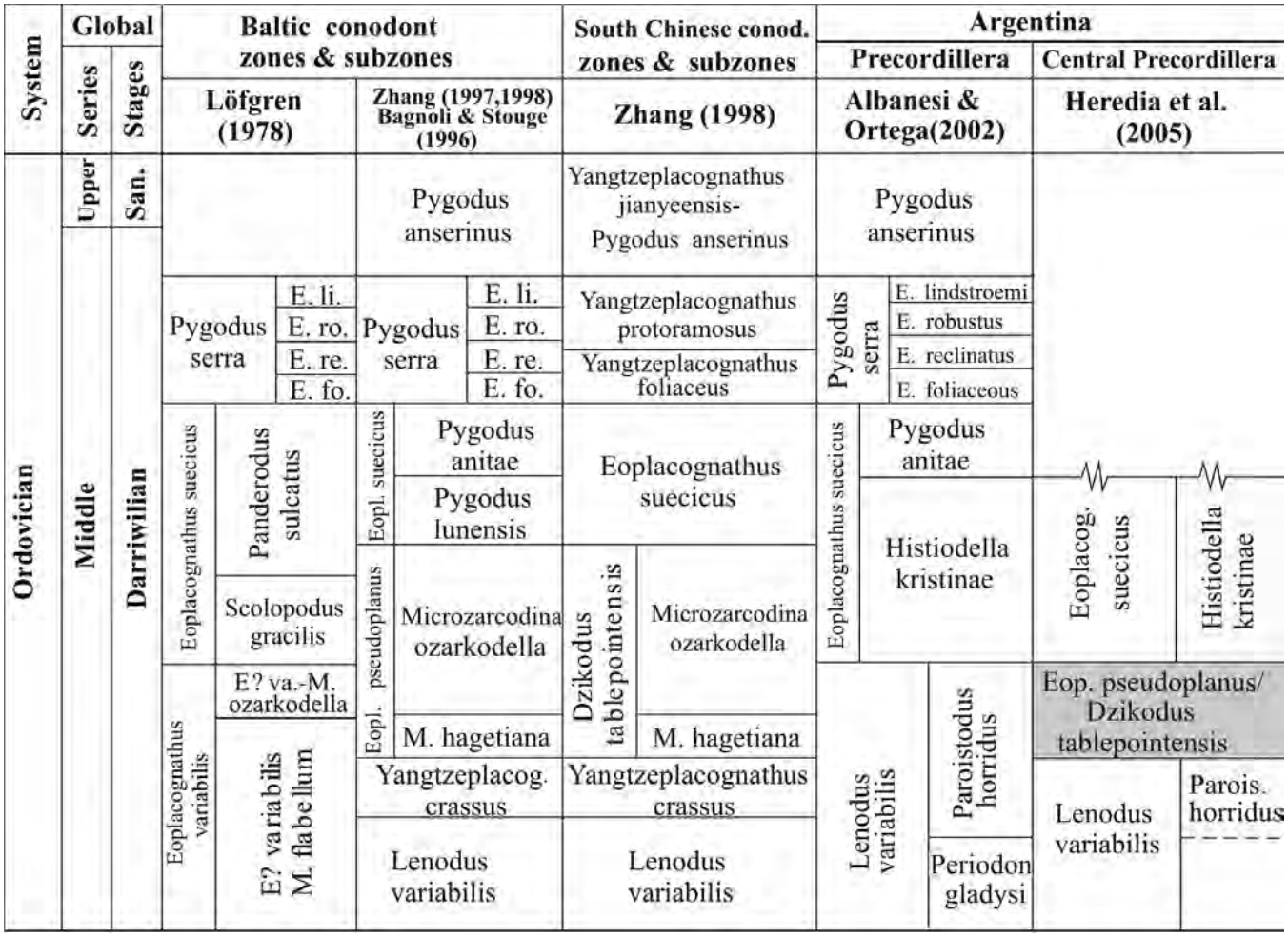
*Discussion*: The genus *Pelosina* was first described by Brady (1879) saying that "*Pelosina* should have a place very near to *Astrozhiza* in the zoological series", e.g., to the foraminifers. This statement was supported by many scientists, and later Cushman (1927) established a new subfamily Pelosininae within the composition of the family Saccamminidae Brady 1884. He included the genera *Pelosina*, *Technitella* and *Pilulina* in the new subfamily. Later, Cushman (1948) added the genus *Croneisella* (which is now a synonym of the genus *Amphitremoida*) to this subfamily. Galloway (1933) in his classification included the genus *Pelosina* into his new subfamily Proteonininae of the family Astrozhizidae Brady 1881. Bykova and Reitlinger (1959) referred *Pelosina* to the family Saccamminidae, subfamily Webbinellinae Cushman 1927. Loeblich and Tappan (1964) in their first classification of foraminifers included *Pelosina* in the subfamily Saccammininae Brady 1884 of the family Saccamminidae, and later they (Loeblich and Tappan 1987) placed *Pelosina* in the subfamily Astrozhizinae Brady 1881 of the family Astrozhizidae. The uncertain position of *Pelosina* was probably because of its peculiar morphology that it does not appear to fall easily into the descriptions of any of the foraminifer groups.

Recently, Mikhalevich and Voronova (1999) revised two species of living *Pelosina*, *P. variabilis* and *P. arborescens*. After the investigation of their morphology and cytology, these authors concluded that the genus *Pelosina* is not a foraminifer and "should be refer to the Class Xenophyophorea, Order Stannomida…on the basis of its leaf-like rolled up body with the linellae built by tubes of the granellare plasmodium and stercomare" (Mikhalevich and Voronova 1999, p. 141). They also emended the description of the genus, and gave new diagnosis of the two above mentioned species. We support Mikhalevich and Voronova's opinion to include *Pelosina* within the xenophyophores.

Based on the shape of the body of *Pelosina* there are two groups of species within the concept of this genus: a group with elongate and nearly cylindrical shape sometimes with constrictions in which we can include the species – *Pelosina variabilis*, *P. arborescens*, *P. variabilis* var. *constricta* Earland 1933, *P. cylindrica* Brady 1884, probably *P. longula* Bulatova 1964, *P. parva* Rhumbler 1913, *P. plana* Wiesner 1931, *P. recta* Cushman 1918, probably *P. spiculotesta* Egger 1893 and *P. elongata* Wiesner 1931. A second group is characterized by a fusiform shape of the body in which we can include following species – *Pelosina variabilis* var. *sphaeriloculum* Höglund 1947 (type species for the genus *Globosiphon* Avnimelech 1952, a junior synonym of the genus *Pelosina*), two species were described under the genus *Pelosinella* Parr 1950, which is a junior synonym of the genus *Pelosina*: *P. bicaudata* Parr 1950 and *P. didera* Loeblich and Tappan 1953, *Pelosina fusiformis* Earland 1933 and probably, *P.* (?) *arctica* Awerinzew 1911. All of these species have been described from the Holocene excluding the Late Cretaceous form *Pelosina longula*. But, in the fossil record, there are several species that are very similar in description to the genus *Pelosina* and some of them were described even under this name. Some of these taxa are *Nodosaria* (?) *mediana* Bykova 1956 from the Silurian of the Lithuania; *Saccamminopsis* (?) *teschenhagensis* Schallreuter 1983, and *S.* (?) *camelopardalis* Schallreuter 1985 from the Ordovician of Germany; *Pelosina grandaeva* Bell 1996 from the Devonian of Australia; and *Pelosina zoetgeneugdensis* McMillan 2003 from the Cretaceous of South Africa.

In North America forms similar to *Pelosina* were described by Moreman (1930) under the new names of *Stegnammina* and *Raibosammina* from the Upper Ordovician in Oklahoma. These forms are characterized by cylindrical or subcylindrical shape of the "chambers", frequently of not uniform diameter, straight or irregularly branched test, often unequal thickness of the agglutinated wall and an indefinite aperture. Also Dunn (1942) described the new genus *Thekammina* from the Silurian of the Mississippi basin that was very similar to Moreman's genera *Stegnammina* and *Raibosammina* but differs from them by a box-shaped test and poorly cemented wall. Later, McClellan (1966) revised these three genera and, following Loeblich and Tappan (1964), concluded that all of them possessed the same features, and thus, *Raibosammina* and *Thekammina* are junior synonyms of the genus *Stegnammina*. But in the last foraminiferal classification of Loeblich and Tappan (1987) they again reinstated all three genera with no explanation. We agree with the opinion of McClellan (1966) that the genera *Stegnammina*, *Raibosammina* and *Thekammina* are congeneric. But these genera seem to have been described based on separate pieces which all probably belong to *Pelosina* because they do not have apertures, and true chambers. Even in thin sections one can see a solid mass that looks like a cast as is shown in the species *Stegnammina moremani* Eisenack (1954, pl. 2, fig. 13, pl. 3, fig. 20) and Plate 4, figs. 4-6 illustrated herein. So, the genus *Stegnammina*, with *Raibosammina* and *Thekammina* considered as its junior synonyms should be included into the concept of *Pelosina*. Moreover, in the species *Saccamminopsis* (?) *camelopardalis* illustrated by Schallreuter (1985, pl. 1, fig. 3) one can see an internal structure as an internal cast that resembles a densely coiled leaf in the shape of the tube.

In the material from the San Juan Formation there are four varieties of forms that are considered to belong to *Pelosina*. One of them, *Pelosina aspera* (Moreman 1930) is illustrated on Plate 2, figs. 6-11 and Plate 4, fig. 4, and referred to the species de-




TEXT-FIGURE 3
Correlation of the conodont zones in Baltoscandia, south-central China and the Precordillera (after Heredia et al. 2005). Shaded in grey is the *Eoplacognathus pseudoplanus/Dzikodus tablepointensis* conodont Zone.

scribed by Moreman (1930, p. 50, pl. 6, figs. 13-15) as *Raibosammina aspera* from the Viola Limestone (Upper Ordovician) of Oklahoma on the basis of an irregularly branching "test" and "chambers" of uneven diameter. A second variety is listed under a name in open nomenclature as *Pelosina* sp.1 and is illustrated on Plate 2, figs. 12a and 12b. This form resembles the species *Pelosina variabilis* var. *constricta* with an elongate shape of "chambers" and the presence of a constriction between the two present "chambers". Several layers of the wall are shown on the Plate 2, fig. 12b. A third type of form, identified as *Pelosina teschenhagensis* and described originally as *Saccaminopsis* (?) by Schallreuter (1983), is shown on Plate 3, figs. 1-3 and Plate 4, figs. 5-6. A fourth type is characterized by a fusiform test with narrower ends in the shape of short tubes and illustrated on the Plate 3, fig. 4 under the name *Pelosina* sp. 2. This form resembles representatives of the genus *Amphitremoida* based on the presence of bipolar tubes or necks, but the illustrated form has several layers of the wall as is shown on the Plate 3, fig. 4d.

*Range*: Middle Ordovician, Darriwilian – Holocene.

***Pelosina aspera*** (Moreman 1930)
Plate 2, figures 6-11; Plate 4, figure 4

*Raibosammina aspera* MOREMAN 1930, p. 50, pl. 6, figs. 13-14.
*Raibosammina mica* MOREMAN 1930, p. 50, pl. 6, figs. 7, 11.

*Remarks*: Conkin and Conkin (1977) considered without explanation that *Raibosammina aspera* is a junior synonym of the species *R. mica*. Our opinion is that *R. mica* must be a junior synonym of *R. aspera* because Moreman (1930) illustrated specimens of *R. aspera* showing the branching of the test (Ibid., pl. 6, fig. 15) and two "chambers" of uneven growth (Ibid., pl. 6, fig. 13), whereas only two small fragments of the test were illustrated as *R. mica*.

*Occurrence*: Upper Ordovician, USA, Oklahoma, Arbuckle Mountains, Viola Limestone; Middle Ordovician, Darriwilian, Argentina, Cerro Viejo, Del Aluvión creek section, upper part of the San Juan Formation, *Eoplacognathus pseudoplanus/ Dzikodus tablepointensis* conodont Zone.

***Pelosina teschenhagensis*** (Schallreuter 1983)
Plate 3, figures 1-3; Plate 4, figures 5-6

*Saccamminopsis* (?) *teschenhagensis* SCHALLREUTER 1983, p. 4, pl. 2, figs. 1-5.

*Remarks*: Schallreuter (1983) described the species *teschenhagensis* referring it to the calcareous foraminiferal genus *Saccamminopsis* Sollas 1921 and relying upon the fact that his specimens have an originally calcareous wall and similar morphology. But he noted that the specimens have a smaller size of the test then the usual representatives of *Saccamminopsis*. First, we consider that this species of Schallreuter cannot belong to *Saccamminopsis* because the forms probably do not have a calcareous wall. Perhaps the acid techniques (HF dissolution) used by Schallreuter destroyed any evidence of agglutinated wall structure. Second, *Saccamminopsis* is not a foraminifer according to Vachard and Cózar (2003) who interpreted it as a probable udoteacean algal gametophyte. They analyzed all species described under the name of *Saccaminopsis* and concluded that the Ordovician species of Schallreuter do not belong to this genus. We consider that they belong to the genus *Pelosina* based on similar morphology.

*Occurrence*: Middle Ordovician, Darriwilian, Argentina, Cerro Viejo, Del Aluvión creek section, upper part of the San Juan Formation, *Eoplacognathus pseudoplanus/Dzikodus tablepointensis* conodont Zone; Upper Ordovician, Germany, erratic boulders.

## CONCLUSIONS

The first Middle Ordovician (Darriwilian) foraminifers in Argentina are described in this paper from strata of the upper part of the San Juan Formation and represent the first find of Ordovician foraminifers in South America. The foraminifers are found together with conodonts of the *Eoplacognathus pseudoplanus/Dzikodus tablepointensis* Zone that enhances the stratigraphic significance of the foraminifers. It is unfortunate that the acid techniques used (formic acid) to recover these foraminifers probably destroyed any wall structure that might have been present so the specimens are preserved only as casts. In spite of this problem, some genera are clearly identified such as *Lakites*, *Lavella*, and *Amphitremoida*.

The assemblage of foraminifers described includes the agglutinated genera *Lakites*, *Amphitremoida*, *Lavella*, *Ordovicina* and *Pelosina*. The distribution of the genera *Lakites* and *Lavella*, previously known only from the Lower Ordovician, Floian (*Tetragraptus phyllograptoides* graptolite Zone), now can be extended up into the Middle Ordovician (Darriwilian).

The find of representatives of the xenophyophorean genus *Pelosina* extends the first appearance of this genus down into the Middle Ordovician.

## ACKNOWLEDGMENTS

We thank Dr. Merlynd Nestell (Arlington, USA) for his comments and checking English, Dr. Stanley Finney (Long Beach, USA), Dr. Graciela Sarmiento (Madrid, Spain), and Dr. Michael Kaminski (London, UK) for suggestions and help that improve the manuscript.

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## PLATE 1

All foraminifers are from the Del Aluvión creek section, upper part of the San Juan Formation, Cerro Viejo, Argentina; Middle Ordovician, Darriwilian, *Eoplacognathus pseudoplanus/Dzikodus tablepointensis* conodont Zone. Scale bar: figs. 1, 2a, 3, 4, 5a, 6a, 7a – 100µm, figs. 2b, 2c, 5b, 5c, 6b, 6c, 7b, 7c, 7d – 10µm.

1-2 *Lakites*? sp.

1 INGEO-MP no. 385, sample DA2.

2 INGEO-MP no. 338, 2b – view of the upper apertural end, 2c – view of the lower apertural end, sample DA4.

3-5 *Amphitremoida* sp. 1

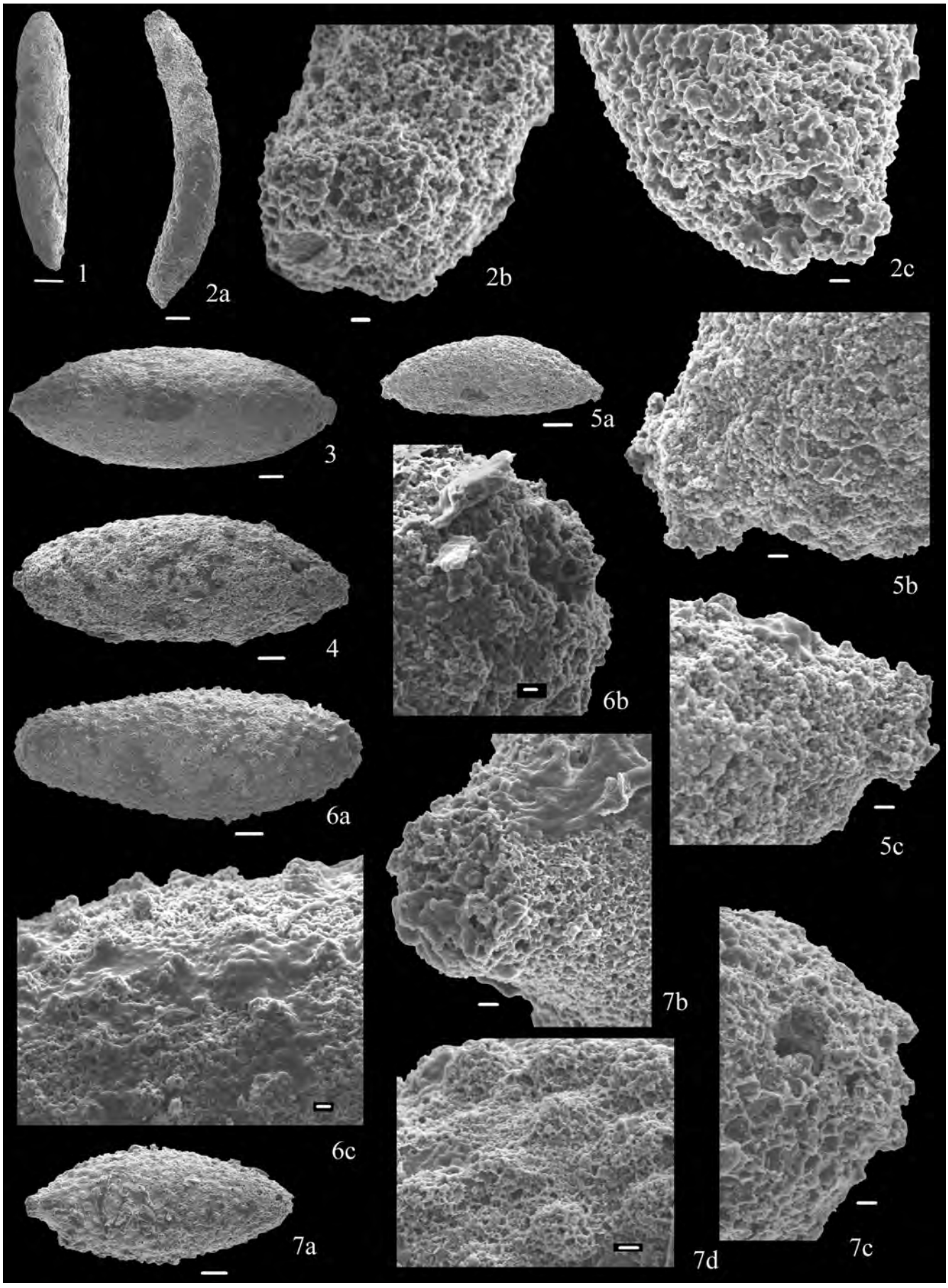
3 INGEO-MP no. 407, sample DA1.

4 INGEO-MP no. 363, sample DA3.

5 INGEO-MP no. 408, 5b – view of the left apertural end, 5c – view of the right apertural end, sample DA1.

6 *Lavella*? sp., INGEO-MP no. 409, 6b – view of the aperture, 6c – view of the external surface of the test, sample DA1.

7 *Amphitremoida* sp. 2, INGEO-MP no. 301, 7b – view of the left apertural end, 7c – view of the right apertural end, 7d – view of the external surface of the test, sample DA5.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2a
2b
2c
3
5a
5b
4
6b
6a
5c
7b
6c
7a
7d
7c

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**PLATE 2**

All foraminifers are from the Del Aluvión creek section, upper part of the San Juan Formation, Cerro Viejo, Argentina; Middle Ordovician, Darriwilian, *Eoplacognathus pseudoplanus /Dzikodus tablepointensis* conodont Zone.
Scale bar: figs. 1a, 2a, 4 - 10, 12a – 100µm, figs. 1b, 2b, 2c, 12b – 10µm.

1-2 *Ordovicina* sp. 1

1 INGEO-MP no. 410, 1b – view of the left apertural end, sample DA1.

2 INGEO-MP no. 302, 2b – view of the left apertural end, 2c – view of the right end, sample DA5.

3-5 Incertae Sedis 1

3 INGEO-MP no. 364, sample DA3.

4 INGEO-MP no. 386, sample DA2.

5 INGEO-MP no. 387, sample DA2.

6-11 *Pelosina aspera* (Moreman 1930)

6 INGEO-MP no. 365, sample DA3.

7 INGEO-MP no. 339, sample DA4.

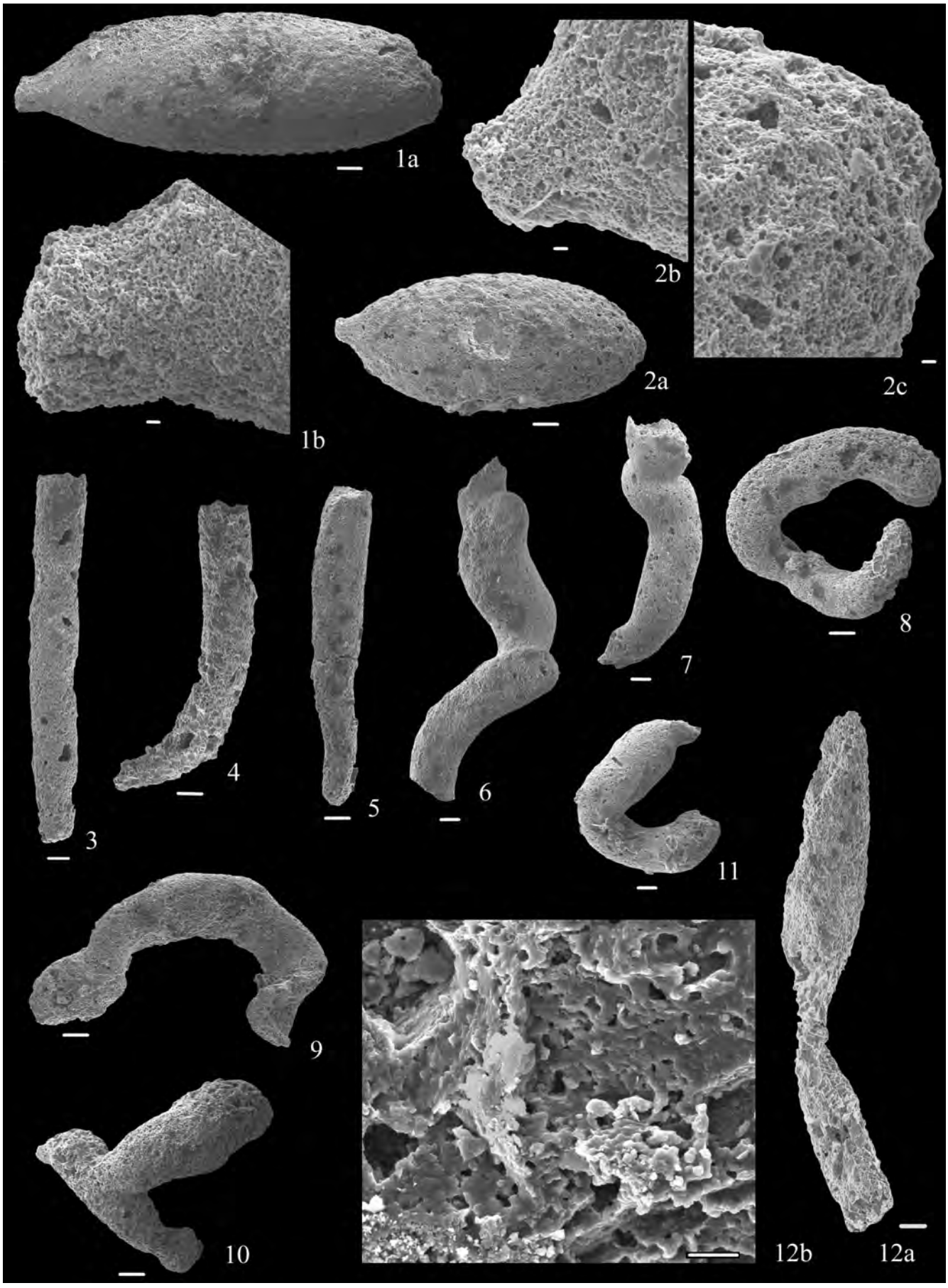
8 INGEO-MP no. 340, sample DA4.

9 INGEO-MP no. 388, sample DA2.

10 INGEO-MP no. 341, sample DA4.

11 INGEO-MP no. 342, sample DA4.

12 *Pelosina* sp. 1, INGEO-MP no. 303, 12b – view of the surface of the test, sample DA5.


1a
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2b
2c
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12b

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## PLATE 3

All foraminifers are from the Del Aluvión creek section, upper part of the San Juan Formation, Cerro Viejo, Argentina; Middle Ordovician, Darriwilian, *Eoplacognathus pseudoplanus/Dzikodus tablepointensis* conodont Zone.
Scale bar: figs. 1a, 2, 3, 4a, 5, 6a – 100μm, figs. 1b, 4b, 4c, 4d, 6b – 10μm.

1-3 *Pelosina teschenhagensis* (Schallreuter 1983)

1 INGEO-MP no. 304, 1b – view of the surface of the test, sample DA5.

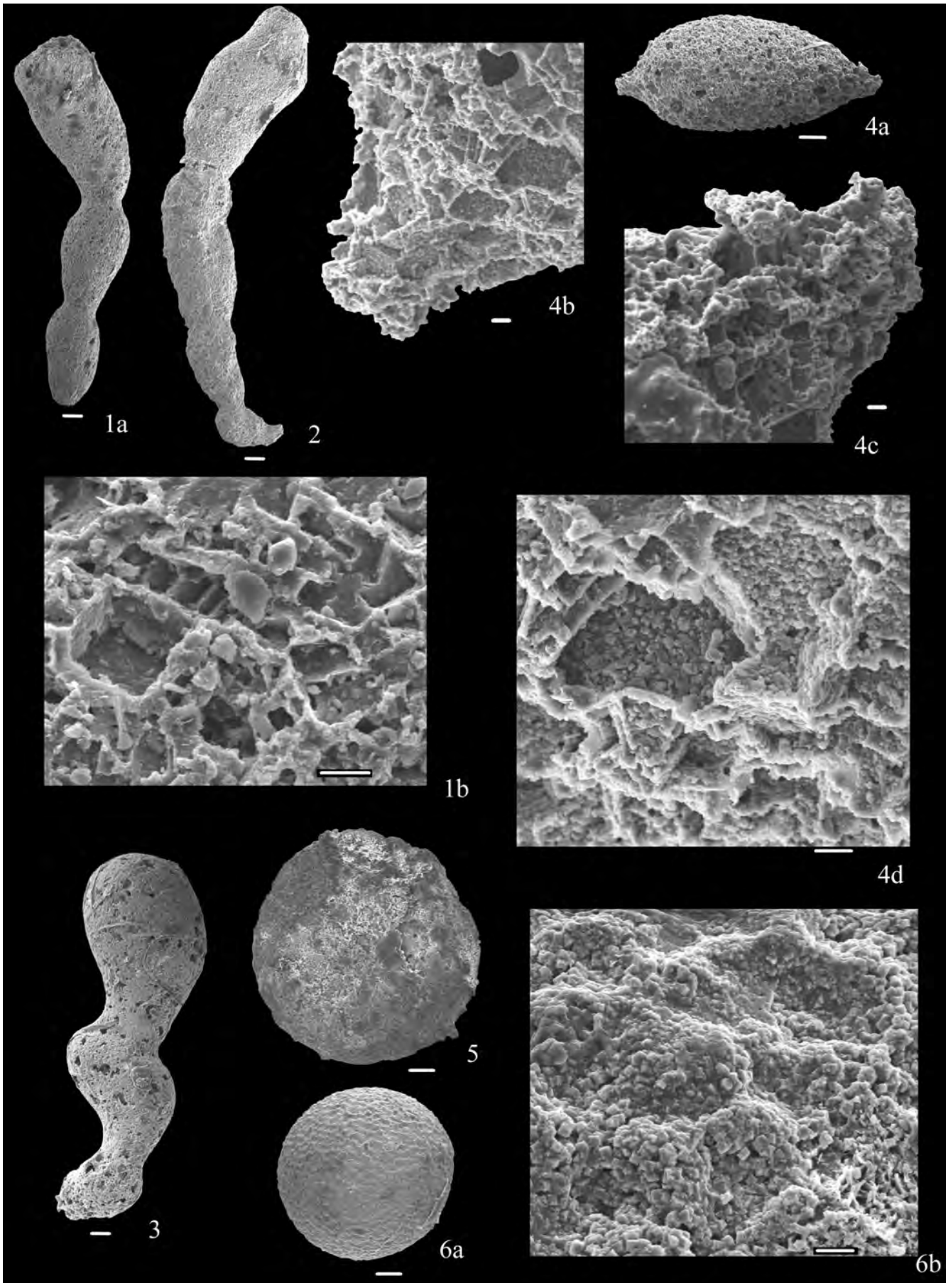
2 INGEO-MP no. 305, sample DA5.

3 INGEO-MP no. 306, sample DA5.

4 *Pelosina* sp. 2, INGEO-MP no. 343, 4b – view of the left end of the test, 4c – view of the right end of the test, 4d – view of the surface of the test, sample DA4.

5 *Tasmanites*? or *Thuramminoides*? sp., INGEO-MP no. 411, sample DA1.

6 Incertae Sedis 2, INGEO-MP no. 307, 6b – view of the surface, sample DA5.


1a
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4a
4c
1b
4d
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6a
6b

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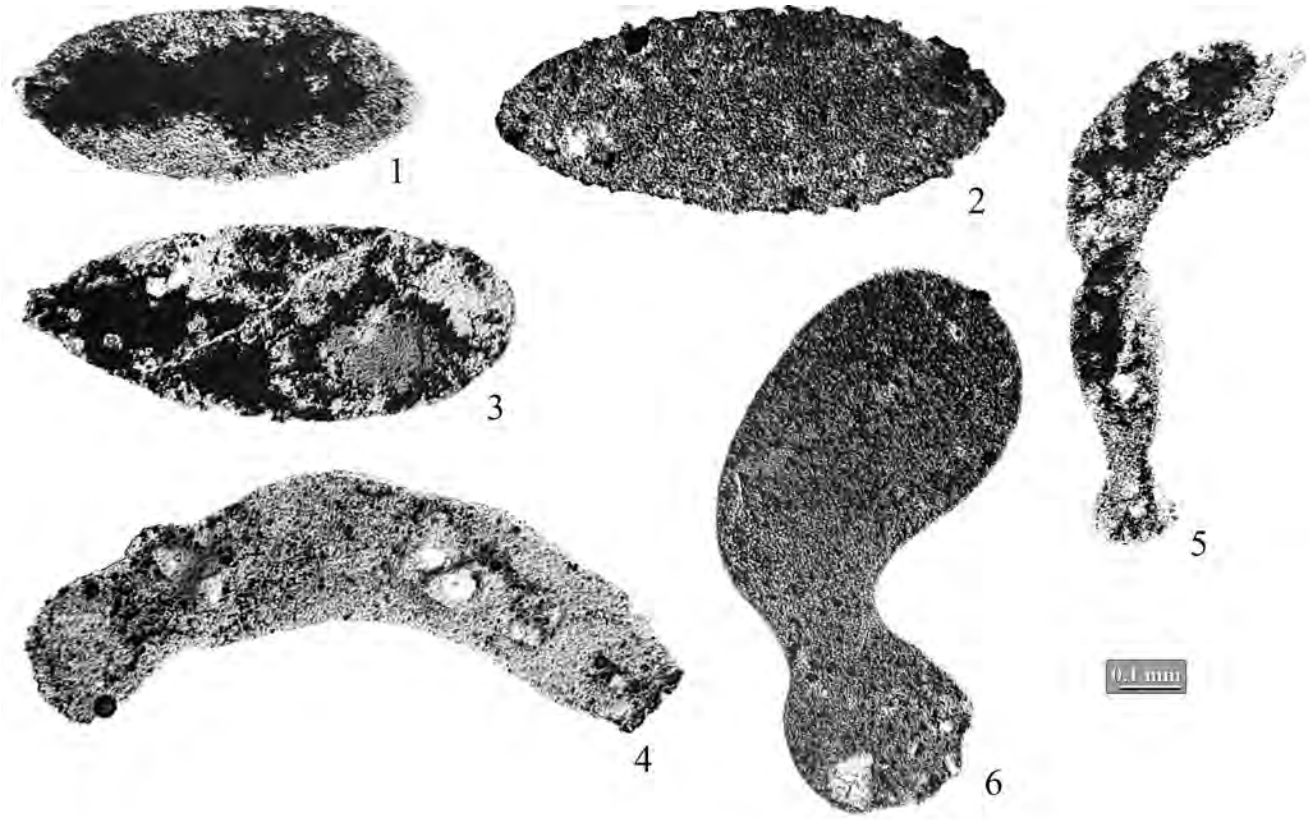


**PLATE 4**

All thin sections of foraminifers are from the Del Aluvión creek section, upper part of the San Juan Formation, Cerro Viejo, Argentina; Middle Ordovician, Darriwilian, *Eoplacognathus pseudoplanus /Dzikodus tablepointensis* conodont Zone.
All magnification - x100.

1 *Amphitremoida* sp. 1, INGEO-MP no. 366, sample DA3.

2 *Lavella*? sp., INGEO-MP no. 412, sample DA1.

3 *Ordovicina* sp. 1, INGEO-MP no. 367, sample DA3.

4 *Pelosina aspera* (Moreman 1930), INGEO-MP no. 399, sample DA2.

5-6 *Pelosina teschenhagensis* (Schallreuter 1983)

5 INGEO-MP no. 308, sample DA5.

6 INGEO-MP no. 309, sample DA5.

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