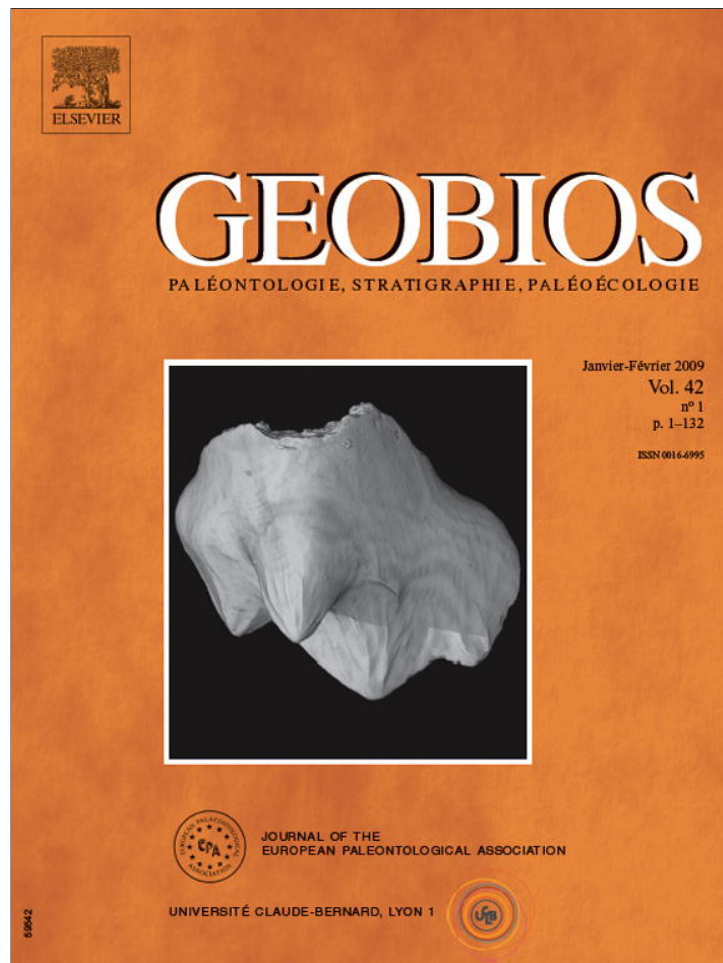


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Original article

# Lower Darriwilian radiolarians from the Argentine Precordillera<sup>☆</sup>

## Radiolaires du Darriwilien inférieur de la Précordillère argentine

Jörg Maletz<sup>a,\*</sup>, Guillermo Luis Albanesi<sup>b</sup>, Gustavo Gabriel Voldman<sup>b</sup>

<sup>a</sup> Department of Geology, University at Buffalo, Suny, 772 Natural Science Complex, Buffalo, 14260-3050 NY, USA

<sup>b</sup> CONICET – Museo de Paleontología, Universidad Nacional de Córdoba, Casilla de Correo 1598, 5000 Córdoba, Argentina

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### Abstract

The first radiolarians discovered in the Ordovician of the Argentinian Precordillera are reported. The material is associated with conodonts indicating the upper part of the *Lenodus variabilis* Biozone (Lower Darriwilian, Da1-2). The low diversity radiolarian fauna shows similarities with Middle Ordovician radiolarians from the Akzhal Mountains of Kazakhstan. However, a close comparison is difficult due to the poor preservation of the material, in which internal structures of the radiolarian tests are not preserved.

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### Résumé

Nous décrivons ici les premières radiolaires découvertes dans l'Ordovicien de la Précordillère argentine. Ce matériel est associé à des conodontes caractéristiques de la partie supérieure de la biozone à *Lenodus variabilis* (Darriwilien inférieur, Da1-2). La faible diversité de la faune de radiolaire la rapproche de celles de l'Ordovicien moyen des monts d'Akzhal, au Kazakhstan. Cependant, une comparaison précise est difficile du fait de la mauvaise préservation du matériel, pour lequel les structures internes des radiolaires ne sont pas conservées.

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**Keywords:** Ordovician; Darriwilian; Radiolaria; South America; Argentina; Precordillera

**Mots clés :** Ordovicien ; Darriwilien ; Radiolaire ; Amérique du Sud ; Argentine ; Précordillère

### 1. Introduction

Ordovician radiolarians have not previously been described from South America and their discovery in conodont samples from the Argentine Precordillera was quite a surprise (Voldman et al., 2008). In general, Palaeozoic radiolarians are more frequently mentioned in recent literature, but they have long been neglected (Maletz, 2007a). Ruedemann and Wilson (1936) described Ordovician radiolarians from thin sections of Normanskill Formation cherts, but provided very poor illustrations. Stürmer (1951, 1952, 1966) recorded abundant and well-preserved radiolarians from Silurian cherts of

Germany and provided excellent photographs of polished rock surfaces showing the delicate radiolarian structures in great detail. It was, however, the successful chemical isolation of radiolarians from limestones and cherts that boosted the research on Palaeozoic radiolarians. Fortey and Holdsworth (1971) documented what was then the oldest known radiolarian fauna recovered from limestones. The material from the Middle Ordovician of Spitsbergen is excellently preserved with fine details still visible, even though the material is recrystallized (Maletz and Bruton, 2005, 2007). The renewed interest in radiolarians from the Palaeozoic can be shown to provide an important tool for biostratigraphic purposes when studied in detail (Noble and Aitchison, 1995, 2000; Maletz, 2007a; Danelian and Popov, 2003). A number of radiolarian assemblages can be differentiated in the Ordovician, but biostratigraphic ranges of these faunas have not yet been documented (Maletz, 2007a). Several clearly distinct faunas

<sup>☆</sup> Corresponding editor: Fabienne Giraud.

\* Corresponding author.

E-mail address: jorgm@buffalo.edu (J. Maletz).

with no biostratigraphic overlap of any faunal elements are differentiated and ranges have been established only from a few sections in western Newfoundland, crossing the Cambrian–Ordovician boundary (Won and Iams, 2002; Won et al., 2005). Nothing is known about biogeographic differentiation of radiolarian faunas. Thus, every new record adds important information to the knowledge on Palaeozoic radiolarian faunas and their usefulness.

## 2. Geological context

The Argentine Precordillera represents an eroded fold-and-thrust belt, mostly composed of Cambrian to Carboniferous strata, located in the foothills of the Andes, between 28 and 33° S (Ramos, 1988). There is a general agreement about the exotic nature of the lower Palaeozoic Precordillera to Gondwana. However, the debate continues over the original geographic position of the block or the timing of its rifting and collision (see recent reviews in Thomas and Astini, 2003; Ramos, 2004; Finney, 2007).

The Yerba Loca Formation (Furque, 1963) is a Darriwilian to Sandbian siliciclastic unit that crops out in the northern and central parts of the Western Precordillera, in the Yerba Loca, La Tranca, and El Tigre ranges. The strongly deformed unit is characterized by distal turbidites and hemipelagites, deposited in deep ocean basin to slope environments (Astini, 2003), and accompanied by subordinated concordant to subconcordant mafic to ultramafic rocks. Furque (1983) suggested a minimum thickness of 1500 m, based on lithostratigraphic correlations of sandstones, claystones, calcarenites and sparse conglomerates; although, the base and top are not well defined as yet.

First records of fossils from the Yerba Loca Formation correspond to Volkheimer (1962), who mentioned the appearance of *Climacograptus* sp. in the western flank of the Alto de Mayo Mountain. Later, Blasco and Ramos (1976) documented graptolites, indicative of the *Nemagraptus gracilis* Zone (Sandbian) from outcrops of the Yerba Loca Formation at the Cuesta del Viento locality. Subsequently, Ortega et al. (1991) extended the temporal range of this stratigraphic unit from mid Darriwilian to lower Sandbian (early Llanvirn to late Caradoc in the British timescale) through the record of specimens from the *Paraglossograptus tentaculatus* and *Nemagraptus gracilis* zones, respectively. At Ancaucha creek, the Yerba Loca Formation overlies in apparent conformity the Los Sombreros Formation, a lower Darriwilian olistostromal unit (Albanesi et al., 1995). The Yerba Loca Formation is one of the main stratigraphic units of the clastic wedge in the Western Precordillera and correlates with several Ordovician siliciclastic formations in the Precordillera (e.g., Sierra de la Invernada, Portezuelo del Tontal).

The study area involves two fossiliferous localities within the Yerba Loca Formation: the Puerta de Ancaucha (S30°6'20", W68°52'34") and El Salto (S30°5'41", W68°53'37"). It is located in the foothills of the Alto de Mayo Mountain, on the eastern border of the Western Precordillera, ca. 20 km north-west of Jáchal City, San Juan Province (Fig. 1).

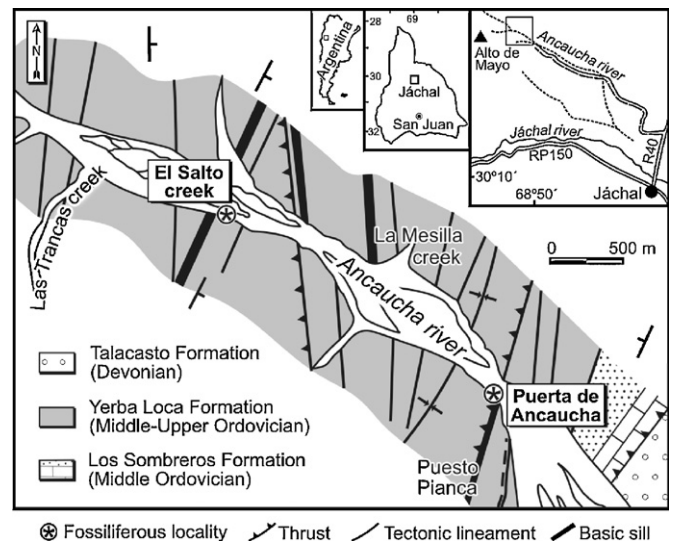


Fig. 1. Location map of the study area showing the radiolarian localities.

## 3. Conodont biostratigraphy

The radiolarians of the present study were recovered from the same samples of the Yerba Loca Formation that yielded conodonts, which are the objective of a major project on paleothermometry (Voldman et al., 2008). The samples come from two sections, Puerta de Ancaucha (sample P10) and El Salto (sample A17) (Fig. 1). The age of recorded radiolarians is constrained by the conodont biostratigraphy resulting from 44 calcarenite samples that produced ca. 1300 conodont elements, representing about 50 conodont species (Albanesi et al., 2006). These microfossils are housed in the Museo de Paleontología, Universidad Nacional de Córdoba, under repository code CORD-MP.

Most representative conodont species, which have been illustrated in a previous work (Voldman et al., 2008), represent a diverse fauna that characterizes the *Paroistodus horridus* Subzone of the *Lenodus variabilis* Zone, following the biostratigraphic scheme developed for the Argentine Precordillera (Albanesi et al., 1998). In this scheme, the *L. variabilis* Zone correlates with the *Holmograptus lentus* and *Nicholsonograptus fasciculatus* graptolite zones, which represents the middle Darriwilian in the Baltoscandian biostratigraphy (Webby et al., 2004). The conodont biozonation for this region, as proposed by Löfgren (2003, 2004), includes the *Yangtzeplacognathus crassus* and *Eoplacognathus pseudoplanus* zones for this interval, which correlates with the upper part of the *L. variabilis* Zone and the *Eoplacognathus pseudoplanus*/*Dzikodus tablepointensis* zones of the Precordillera in the recent review for the Ordovician conodont biostratigraphy provided by Albanesi (2007) (Fig. 2). The *Histiodela holodentata* Zone of the North American midcontinent and Newfoundland (Harris et al., 1979; Stouge, 1984; Chen et al., 2006) and the *Dzikodus tablepointensis* Zone of the Yangtze Platform, in south-central China (Zhang, 1998) are other well-documented correlative units. Diverse formations of the Argentine Precordillera include this biostratigraphic interval as documented by the conodont records in different parts of the

Global Series Global Stages	GRAPTOLITES										CONODONTS	
	Australasia		North America		China		Great Britain		Baltoscandia		Argentine Precordillera	Baltoscandia
MIDDLE ORDOVICIAN	Darrivillan	riddellensis Da4	teretiusculus	teretiusculus	teretiusculus	teretiusculus	vagus	teretiusculus	serra	serra		
		decoratus Da3	elegans	jiangxiensis murchisoni elegans	murchisoni	distichus elegans	elegans	suecicus	suecicus			
		intersitus Da2	fasciculatus lentus dentatus	fasciculatus ellesae	artus	fasciculatus lentus	lentus	pseudoplanus / tablepointensis	pseudoplanus			
		austrodentatus Da1	austrodentatus	austro- dentatus	hirundo	dentatus	variabilis	horridus gladysi	crassus			
		Ya2 Ya1	morsus epsilon	Oncograptus	clavus	hirundo	austrodentatus	parva	norrlandicus			
	Ca4 Ca3	maximodiv. maximus	maximodivergens maximus	caduceus	gibberulus	maximus	navis	originalis navis				

Fig. 2. Biostratigraphic chart for conodonts and graptolites of the Argentine Precordillera and correlation with reference schemes (modified after Ortega et al., 2007; Albanesi, 2007). North America, based on Albani et al. (2001); *Dicellograptus vagus* Zone replaces *H. teretiusculus* Zone in Scandinavia (Maletz et al., 2007). The shaded band indicates the age of the radiolarian bearing levels.

San Juan, Los Azules, Las Chacritas, Gualcamayo, Las Aguaditas, and Sierra de La Invernada formations (see discussion on correlations in Ortega et al., 2007).

Regarding the paleoenvironmental setting, as represented by the conodont fauna, over 50% of the conodont assemblage is dominated by the genera *Periodon* and *Protopanderodus*, revealing a widespread biofacies that indicates deep-cold water conditions in the basin (Rasmussen, 1998). Following the palaeobiogeographic model of Zhen and Percival (2003), the conodont association of the Yerba Loca Formation is mostly integrated by pandemic pelagic forms of the Open-Sea Realm (> 200 m depth). The Precordilleran conodont faunas of this stage are represented by diverse forms from distant regions (Baltica, China, and North America), which reveal corridors for the migrations of these open sea faunas to colonize the temperate domain of the Precordillera.

#### 4. The radiolarians

Two samples with moderately abundant radiolarians have been found in the Yerba Loca Formation of the Argentine Precordillera. The material was dissolved out of limestones in the process to produce a conodont biostratigraphy:

- Puerta de Ancaucha (S30°6'20", W68°52'34"), sample P10, Middle part of Yerba Loca Formation, western Precordillera, San Juan Province, Argentina, upper part of *Lenodus variabilis* Conodont Zone. All specimens mounted on SEM stub JM 70;
- El Salto (S30°5'41", W68°53'37"), Yerba Loca Formation, sample A17, Upper *Lenodus variabilis* Conodont zone. Radiolarians and some sponge spicules are mounted on SEM stub JM 71. Further material remains on slides and includes phosphatic brachiopods.

##### 4.1. Preservation

The radiolarians are in general poorly preserved and coarsely recrystallized (Fig. 3). Therefore, most of the detailed

structures of the original tests are destroyed. However, it is possible to recognize some details that help to identify the material. In many specimens, the mesh of the spherical test is still recognizable and mesh densities can be measured. Outer spines and beams (Maletz and Bruton, 2007 for differentiation) appear to be broken off in the majority of specimens, but in a few still reach a considerable length (Fig. 4). However, the beams on the outer surface of the tests are usually broken and not recognizable, even though they might have been present. These delicate fine structures are the first features to be lost during the recrystallization of the radiolarians. Indications of beams are present in few specimens only (Fig. 4(4, 6)). A number of specimens are preserved as spherical bodies without any definitive structure (Fig. 3(7, 10)). They are similar to the “clay balls” described by Maletz and Bruton (2007). There is no doubt that they represent radiolarians, but they are too strongly recrystallized to recognize any diagnostic features. This is supported by spherical objects still possessing some of the outer spines of the radiolarians (Fig. 3(6)). The material includes a few sponge spicules (Fig. 3(1, 3)), and a single specimen of *Konyrium* (Fig. 3(2)).

##### 4.2. Faunal composition

The faunas show a very low diversity that may, however, in part, be based on the small sample sizes. Sample A17 (132 specimens) include ca. 50% *Inanihella* sp. cf. *I. akzhala* and 25% of Archaeoentactiniid sp. indet., associated with a few sponge spicules and clay balls. The species ?*Triplococcus acanthicus* and *Inanihella bakanasensis* are represented by only one to two specimens each. A number of radiolarian specimens were so poorly preserved that their identification was impossible.

The P10 sample is very small with only 10 radiolarian specimens of which seven specimens can be assigned to *Inanihella* sp. cf. *I. akzhala*. The remaining specimens are fragments of spicular radiolarians, most probably belonging to the same taxon as was found in sample A17. The fauna appears to be identical to that of the A17 sample.

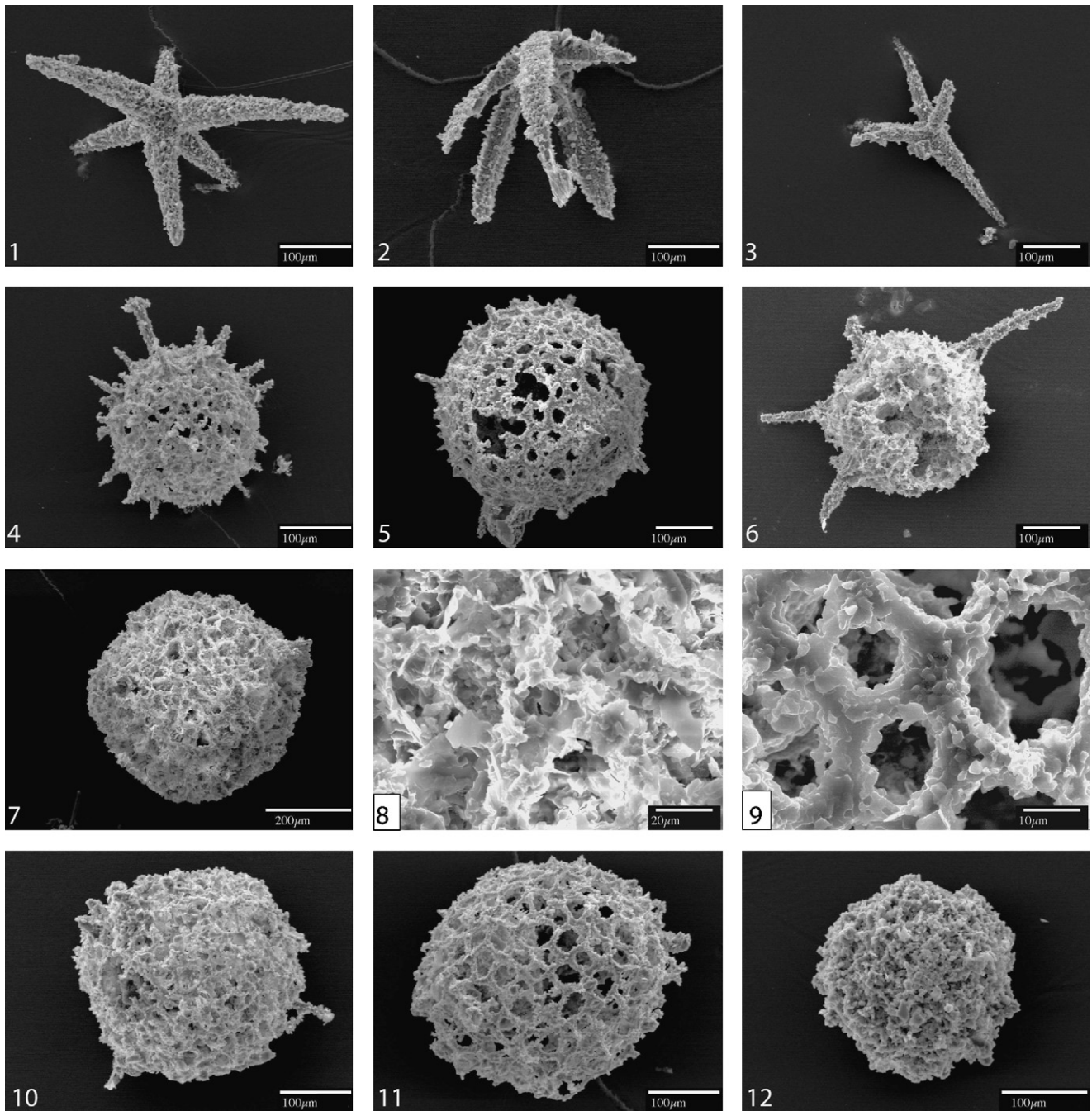


Fig. 3. Radiolarians and sponge spicules. 1. Sponge spicule, JM 71.83, CORD-MP 12480. 2. *Konyrium* sp., poor, incomplete specimen, JM 71.121, CORD-MP 12489. 3. Sponge spicule, JM 71.20, CORD-MP 12464. 4. ?*Triplococcus acanthicus* Danelian and Popov, JM 71.2, CORD-MP 12462. 5. *Inanihella* sp. cf. *Inanihella bakanasensis* (Nazarov, 1975), JM 71.98, CORD-MP 12485. 6. Radiolarian indet., showing outer spines, JM 70.2, CORD-MP 12459. 7, 8. Clay ball with few indications of radiolarian origin, JM 71.1, CORD-MP 12461. 9. *Inanihella* sp. cf. *I. akzhala* Danelian and Popov, detail showing coarse recrystallization of test, JM 70.13, CORD-MP 12460. 10. Clay ball, few details visible, see outer spines, JM 71.55, CORD-MP 12471. 11. *Inanihella* sp. cf. *Inanihella bakanasensis* (Nazarov, 1975), JM 71.102, CORD-MP 12486. 12. Clay ball, no details visible, JM 71.103, CORD-MP 12487.

## 5. Radiolarian biostratigraphy

Little is known of radiolarian biostratigraphy in the Ordovician, including Darriwilian faunas, but most faunas lack precise biostratigraphic dating (Maletz, 2007a). Maletz and Bruton (2005, 2007) and Maletz (2007a, 2007b) showed that Lower to Middle Ordovician radiolarian faunas from Spitsbergen and western Newfoundland, referred to the upper

Floian and lower Dapingian, differ considerably in their composition from Darriwilian faunas. Their material is precisely dated with cooccurring graptolite faunas and ranges in age from the *Didymograptellus bifidus* Zone (upper Floian) to the *Isograptus victoriae maximus* Zone (upper Dapingian).

Danelian and Popov (2003) introduced the *Inanihella bakanasensis*–*Inanihella* (?) *akzhala* assemblage from Kazakhstan and referred the assemblage to the Moridunian (Lower

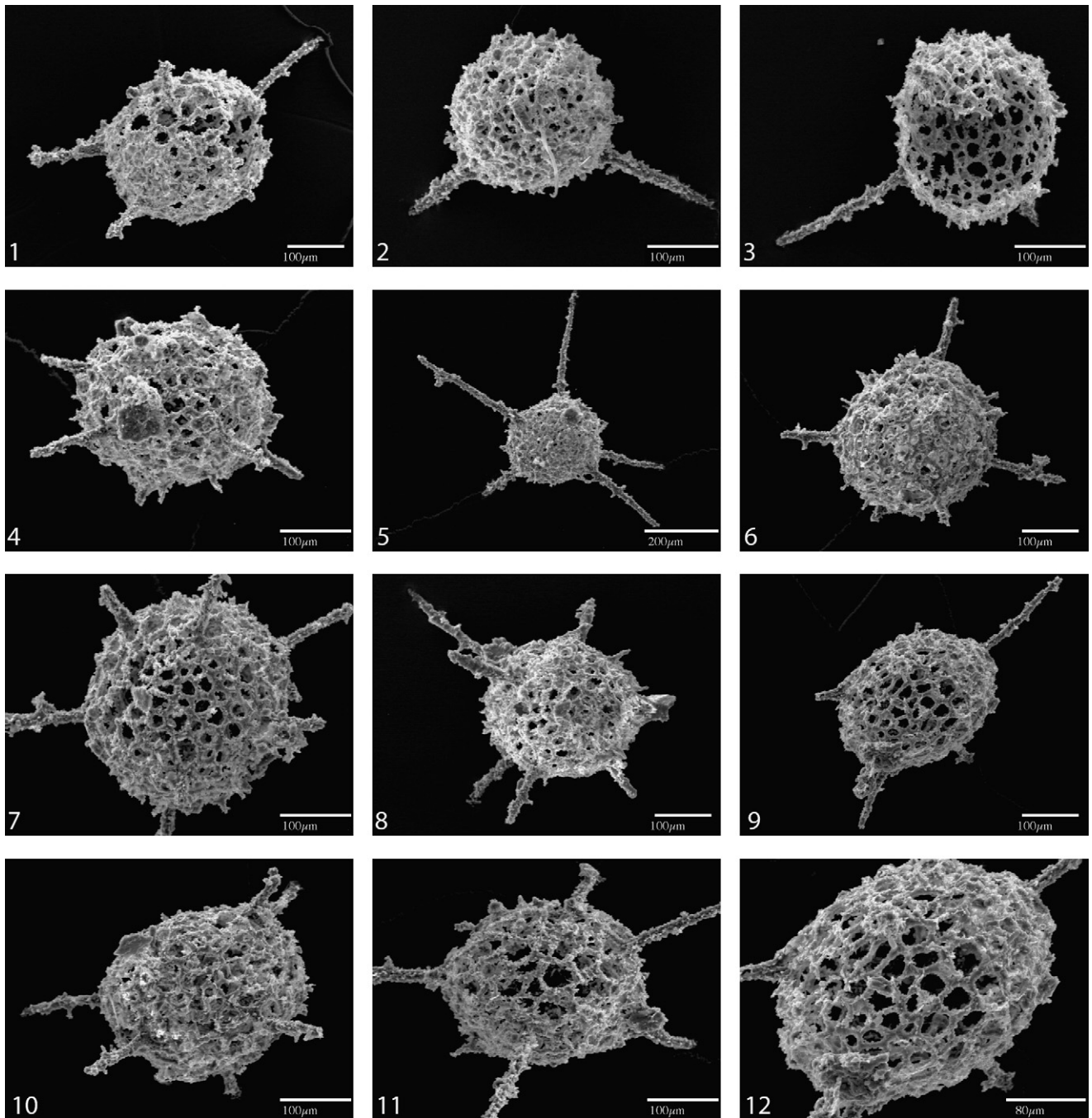


Fig. 4. *Inanihella (?) akzhala* Danelian and Popov. **1.** Slightly distorted specimen, JM 71.07, CORD-MP 12463. **2.** Complete outer sphere with two spines, JM 71.26, CORD-MP 12466. **3.** Broken sphere showing empty interior, JM 71.30, CORD-MP 12467. **4.** Slightly distorted specimen, JM 71.38, CORD-MP 12469. **5.** Specimen with long spines, JM 71.57, CORD-MP 12472. **6.** Specimen showing beams on outer surface, JM 71.96, CORD-MP 12484. **7.** Undistorted, spherical specimen, JM 71.109, CORD-MP 12488. **8.** Specimen with many robust spines, JM 71.50, CORD-MP 12470. **9, 12.** Strongly distorted specimen with partly preserved long spines, JM 71.65, CORD-MP 12474. **10.** Distorted specimen, JM 71.81, CORD-MP 12479. **11.** Distorted specimen with wide mesh, JM 71.91, CORD-MP 12483.

Ordovician, Arenig). Biostratigraphic assignment of this fauna is only supported by the presence of the conodont *Oistodus lanceolatus* in the generally unfossiliferous succession of the Akzhal Mountains. Younger faunas in the region include a trilobite fauna, tentatively referred to the Upper Arenig to Lower Llanvirn (Nikitin et al., 1980). A precise age, therefore, cannot be given for this fauna. Maletz (2007a: Fig. 1) suggested an assignment to the upper Dapingian.

Lower to Middle Darriwilian radiolarians have been described from Spitsbergen (Fortey and Holdsworth, 1971; Holdsworth, 1977), Scotland (Aitchison, 1998) and Kazakhstan (Nazarov and Popov, 1980). They are generally included in the *Proventocitum procerulum* assemblage; an interval previously considered to cover the entire Arenig (Nazarov, 1988; Noble and Aitchison, 2000) or the Floian to lower Darriwilian, but referred to the middle Arenig to lower Darriwilian by Danelian

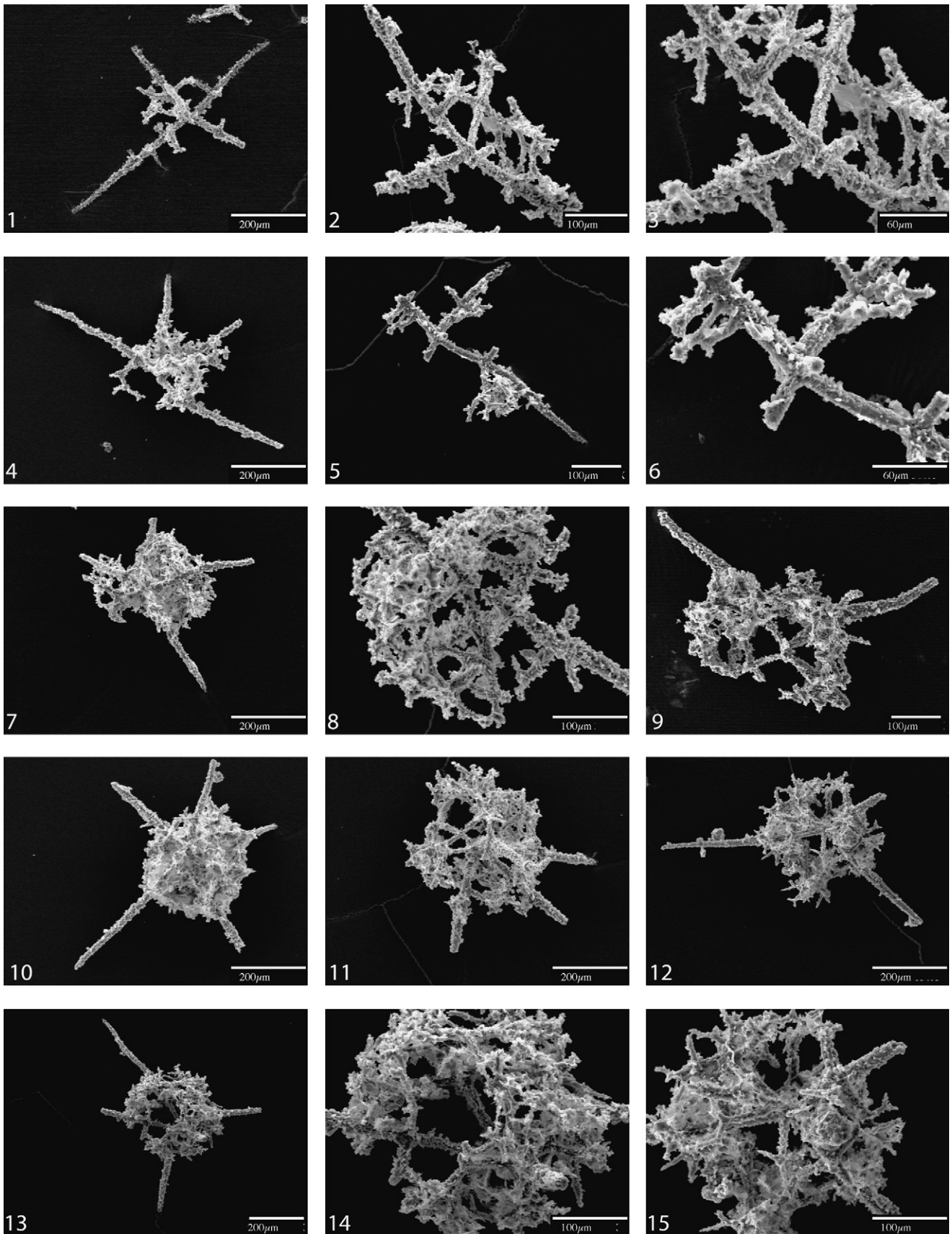


Fig. 5. Archaeoentactiniid? indet. **1.** Juvenile spicule with little evidence of the spherical test, JM 71.132, CORD-MP 12490. **2, 3.** Juvenile showing the spicule, JM 71.87, CORD-MP 12482. **4.** Fragment with several long spines, JM 71.73, CORD-MP 12477. **5, 6.** Specimen showing the point-centered, six-rayed spicule, JM 71.24, CORD-MP 12465. **7.** Possibly asymmetrical placing of spicule, JM 71.36, CORD-MP 12468. **8.** Poor specimen showing mesh, JM 71.63, CORD-

and Popov (2003). Maletz (2007a: Fig. 1) reported the *Proventocitum procerulum* assemblage from the upper Dapignian to lower Darriwilian. The lower limit is based on a single poor specimen of possible *Proventocitum* in the *Inanihella bakanasensis*–*Inanihella* (?) *akzhala* assemblage of Kazakhstan (Danelian and Popov, 2003: Fig. 5s). Younger Darriwilian radiolarians are present in the Table Head Formation of western Newfoundland (e.g., Maletz, 2007a: *Nicholsonograptus fasciculatus* to *Pterograptus elegans* zones) and in the *Hustedograptus teretiusculus* Zone in Kazakhstan (Nazarov and Popov, 1980).

The faunas from the Yerba Loca Formation show closest similarities to the *Inanihella bakanasensis*–*Inanihella* (?) *akzhala* assemblage from Kazakhstan. None of the indicative elements of older or younger radiolarian faunas is present in the samples. However, the poor preservation prevents a detailed analysis. The age of this fauna is best defined by the conodonts associated with the radiolarians. If the comparison of the Argentinian material with the *Inanihella bakanasensis*–*Inanihella* (?) *akzhala* assemblage of Kazakhstan is correct, we have gained a more precise biostratigraphic control on this radiolarian assemblage as a further step to establish a radiolarian biostratigraphy for the Ordovician.

## 6. Systematic palaeontology

All specimens are housed in the Museo de Paleontología, FCEfyN, Universidad Nacional de Córdoba, Argentina under repository code CORD-MP. Some of the material is mounted on SEM stubs JM 70–JM 71. Additional material is preserved on microscope slides.

### Subclass RADIOLARIA Müller, 1858

Family INANIGUTTIDAE Nazarov and Ormiston, 1984 (emend. Danelian and Popov, 2003)

Genus *Inanihella* Nazarov and Ormiston, 1984

**Type species:** *Helioentactinia? bakanasensis* Nazarov, 1975; original designation.

*Inanihella* sp. cf. *Inanihella bakanasensis* (Nazarov, 1975)

Fig. 3(5, 11)

cf. 1975. *Helioentactinia? bakanasensis* n. sp. – Nazarov, p. 89, Pl. 19, Figs 9–13.

cf. 1980. *Helioentactinia bakanasensis* Nazarov – Nazarov and Popov, p. 48, Text-Fig. 26; Pl. 16, Figs 7, 8.

cf. 2003. *Inanihella bakanasensis* (Nazarov) – Danelian and Popov, p. 332, Fig. 5a–f.

**Material:** Two poorly preserved specimens from sample A17.

**Description:** The material shows tests with a diameter of 350 to 420 µm in diameter. They show a fine mesh with irregular meshes, measuring 35 to 40 µm in diameter. The bars are about 10 µm in diameter and sometimes appear to be

flattened. Only the outermost shell is preserved and internal details are not available in this material.

**Remarks:** The material is poorly preserved and shows little detail. Identifications are based on surface features and the size of the material only. The specimens are similar to *Inanihella bakanasensis* as described by Danelian and Popov (2003), but differ in a slightly larger outer test. They show fine and short outer spines (beams) arising from the surface of the outer sphere, but these may be lacking due to poor preservation.

Danelian and Popov (2003) discussed the problems with the material previously described by Nazarov (1975) and Nazarov and Popov (1980) and suggested that the material from both publications may represent different species.

### Genus *Triplococcus* Danelian and Popov, 2003

**Type species:** *Triplococcus acanthicus* Danelian and Popov, 2003; by monotypy.

?*Triplococcus acanthicus* Danelian and Popov, 2003

Fig. 3(4)

**Material:** Two specimens from sample A17.

**Description:** Spherical test with a diameter of 200 µm, provided with numerous short and blunt spines or beams. The spines are about 20 µm long and have a diameter of ca. 5 µm. The meshes of the sphere are about 10 to 15 µm in diameter.

**Remarks:** The material is very similar to *Triplococcus acanthicus*, based on the external appearance and size of the test. The presence of inner spheres cannot be confirmed in this material. Therefore, the identification remains uncertain. Alternatively, it could represent an inner sphere of *Inanihella* sp. cf. *Inanihella bakanasensis*.

?*Inanihella* (?) *akzhala* Danelian and Popov, 2003

Fig. 4(1–12)

?2003. *Inanihella* (?) *akzhala* n. sp. – Danelian and Popov, p. 333, Fig. 5n–r.

**Material:** 70 specimens from SEM stubs JM 70 and JM 71.

**Diagnosis:** Radiolarian with a spherical shell bearing at least six to eight long spines, the origin of which is uncertain; shell shows a dense mesh of bars; short beams present in some specimens.

**Description:** The spherical shell or test has a diameter of ca. 220 to 300 µm and is formed from thin bars forming meshes with a diameter of 15 to 30 µm. The shell is provided with six to eight long and slender spines. The spines have an initial diameter of ca. 10 to 15 µm and taper slowly towards the tip. They are up to 300 µm long, but more commonly around 200 µm. However, spines are broken off in many specimens. Internal details are not available as the few broken specimens show only an empty shell (Fig. 4(3)). Many specimens are strongly distorted and show an oval shape (Fig. 4(9–12)), but do not differ in any details from the spherical forms. They are, thus, referred to the same species.



**Remarks:** Danelian and Popov (2003) described *Inanihella* (?) *akzhala* from the Akzhal Mountains of Kazakhstan. Their specimens show distinct beams on the surface of the test as well as a number (ca. 8–10 according to the authors) of longer, more robust spines. None of the illustrated material from Kazakhstan, however, shows long spines. The long spines present in the Argentinian material may indicate a more complete preservation of the material. Even in this material, many spines are broken and only their bases are visible. Thus, this character is not taken as an indication that the material might be a different species.

The Argentinian material of ?*Inanihella* (?) *akzhala* is a good example of distortion of radiolarian material. Specimens vary from spherical to strongly oval, but all other available features are identical. Thus, the material is considered to represent a single species. Some specimens may be modified through partial compaction of the surrounding sediment. Alternatively, the material may be tectonically modified. However, in this case, all specimens should be distorted in the same way.

Variably distorted fossil specimens occur frequently in graptolite faunas found in limestone nodules, clearly showing that the partial compaction of the calcareous material is responsible for the distortion. Maletz (2003) described specimens of *Normalograptus scalaris* from a limestone nodule collected in the Kallholn Shale of Dalarna. Specimens range from fully three-dimensional in preservation to completely flattened. Even though graptolite periderm is made from organic material and radiolarians are composed of amorphous silica (opal), it appears to be reasonable to attribute the oval shape of some of the here described radiolarian material to partial compaction of the test during diagenetic compaction of the sediment. A recrystallization or replacement of the original material may also have happened at the same time.

?Archaeoentactiniid species indet.

Fig. 5(1–15)

**Material:** 35 specimens from SEM stubs JM 70 and JM 71.

**Diagnosis:** Large spherical radiolarian with a point-centered spicule and six long primary rays; sphere formed as three-dimensional body with empty inner cavity.

**Description:** The point-centered inner spicule has six primary spines or rays on all available specimens, reaching a length of more than 400  $\mu\text{m}$ . The spines are ca. 10  $\mu\text{m}$  wide at the base and slowly taper to the tip. The apophyses on the primary rays start at about 60 to 100  $\mu\text{m}$  from the center of the spicule (Fig. 5(6)). They form a distinct three-dimensionally shell around an empty inner cavity with a diameter of 170 to 200  $\mu\text{m}$  (Fig. 5(2, 14, 15)). The sphere is initially about 200 to 230  $\mu\text{m}$  in diameter, but reaches up to 350  $\mu\text{m}$  in the largest specimens. It is formed from irregularly placed apophyses and bars that have a diameter of ca. 5–8  $\mu\text{m}$ . Further spines are not present on the outside of the sphere. The spicule may be placed somewhat irregularly and not in the center of the sphere.

**Remarks:** The species is fairly characteristic and, with its point-centered central spicule, appears to be very similar to members of the Archaeoentactiniidae Won in Won and Below,

1999. These are known, however, only from the Upper Cambrian to basal Ordovician (Lower Tremadocian) and, at the moment, a phylogenetic relationship is uncertain. Similar forms are unknown from younger Ordovician strata. A number of specimens are strongly altered and little of their spherical shell remains, leaving a spherical body with outer spines (Fig. 5(6)). Due to the poor preservation and uncertainty of structural details, this form is not named here.

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