

# Late Capitanian (latest Guadalupian, Middle Permian) radiolarians from the Apache Mountains, West Texas

Galina P. Nestell<sup>1</sup> and Merlynd K. Nestell<sup>2</sup>

<sup>1</sup>Department of Earth and Environmental Sciences, University of Texas at Arlington, Arlington, Texas 76019, USA;  
Faculty of Geology, St. Petersburg State University, Russia  
e-mail: gnestell@uta.edu

<sup>2</sup>Department of Earth and Environmental Sciences, University of Texas at Arlington, Arlington, Texas 76019, USA;  
e-mail: nestell@uta.edu

---

**ABSTRACT:** A diverse radiolarian fauna is described from strata of a road cut section of the uppermost part of the Bell Canyon Formation (Capitanian, Guadalupian, Middle Permian), Apache Mountains, West Texas. Fifteen new species are described: *Campanulithus insuetus*, *Pseudoalbaillella apachensis*, *Astroentactinia capitanensis*, *Polyedroentactinia guadalupensis*, *Afanasievella apachensis*, *Copicyntra erinacea*, *Paracopicyntra snyderi*, *Klaengspongos planus*, *Copiellintra orbiculata*, *C. fastuosa*, *Shangella capitanensis*, *Rectortomentum wardlawi*, *Tetrortomentum ormistoni*, *Quadrilobata? blomei*, and *Nazarovispongos globosum*. The diagnoses of the species *Follicucullus sphaericus* Takemura in Takemura et al. 1999 and the genus *Raciditor* Sugiyama 2000 are emended. The rank of the subspecies *Raphidociclicus gemellus americanus* Nazarov and Ormiston 1985a is raised to species level. The genus *Nazarovispongos* Kozur 1980 is considered to be a valid genus and is reinstated. Established are one new genus, *Afanasievella* (assigned to the family Spongentactiniidae), one new subfamily Polyedroentactiniinae (in the composition of the family Orosphaeridae), and one new family Tetrortomentidae (in the composition of the order Pyramidata). The radiolarian assemblage from the described section in the Apache Mountains is at least partly coeval with the radiolarian assemblage from the Reef Trail Member of the Bell Canyon Formation in the Guadalupe Mountains, allowing a straight correlation of this age strata between the Apache and Guadalupe mountains. This correlation is supported by the conodont species that define the latest Guadalupian conodont zones and that occur together with radiolarians in both areas. The radiolarian species *Albaillella yamakitai* in sense of Xia et al. (2005) present in the late Guadalupian *J. altudaensis* conodont Zone cannot be a marker for the Guadalupian – Lopingian boundary as was proposed by Xia et al. (2005).

---

## INTRODUCTION

The only report of radiolarians in Middle Permian strata of the Apache Mountains in the southwestern part of the Delaware basin was by Babcock (1974; 1977) in connection with the study of conodonts and paleoenvironments of the Lamar Limestone Member of the uppermost part of the Bell Canyon Formation (Middle Permian, Guadalupian, upper Capitanian) in the nearby Guadalupe Mountains. The Lamar Limestone crops out in a nearly linear trend along the Lamar Cuesta on the western side of the Delaware basin from the north (Guadalupe Mountains) to the south (Apache Mountains) and Babcock (1977, fig. 1, sections H' and L') illustrated two sections from the Apache Mountains along the Texas Farm to Market road (FM) 2185. Later, Ormiston and Babcock (1979) described the new genus *Follicucullus* with two new species *F. scholasticus* and *F. ventricosus* from section H of Babcock (1974; 1977) in the Guadalupe Mountains along U. S. Highway 62/180, but they also mentioned that radiolarians were recovered from all sections including H' and L' in the northwestern part of the Apache Mountains.

In the Guadalupe Mountains, Capitanian age radiolarians have been described from the Lamar Limestone of the Bell Canyon Formation by several workers (Babcock 1977; Ormiston and Babcock 1979; Nazarov and Ormiston 1985a; Kozur 1993) and only illustrated from the Rader Member (Nestell et al. 2006a). In this paper, we describe radiolarians from the Apache Mountains for the first time from strata of partially coeval age to the Lamar Limestone and Reef Trail Members of the Guadalupe

Mountains. This study was initiated in 1997 as part of an ongoing project by the authors to document the foraminiferal and conodont successions by using bed by bed sampling in strata of the upper part of the Bell Canyon Formation in the general area of the northwestern part of the Apache Mountains. During the course of the sampling and subsequent processing for conodonts, abundant radiolarians were found at a number of levels in several sections of the uppermost Bell Canyon Formation. A few years ago Maldonado and Noble (this volume) independently started a study of the radiolarians from the Reef Trail Member of the Bell Canyon Formation in two Patterson Hills sections in the Guadalupe Mountains. As a number of species are common to the coeval strata exposed in the two areas, two separate papers have been written to document the radiolarian faunas as a cooperative effort among the four authors.

## STRATIGRAPHY

The radiolarians described in this paper were recovered from strata exposed in a road cut (EF section) located in the Apache Mountains along the Texas Farm to Market road (FM) 2185 about 30 miles northeast of Van Horn, Culberson County, West Texas (text-figs. 1, 2). In this continuous section the uppermost part of the Bell Canyon Formation of late Guadalupian age crops out in a road cut and is overlain by laminated strata of the basal part of the Castile Formation of early Late Permian age. During the course of this study, it quickly became apparent that the usage of member names of the Bell Canyon Formation originally described from the Guadalupe Mountains area could not

be directly applied to strata in the Apache Mountains area because of clear lithofacies differences (Nestell and Wardlaw 2009). Only the presence of key faunal elements in both areas such as conodonts and fusulinaceans permits biostratigraphic correlation between the two areas within the Delaware basin. The conodont data from the EF section document that strata of the uppermost part of the Bell Canyon Formation in the Apache Mountains are equivalent in age to the Lamar Limestone and Reef Trail Members of the Bell Canyon Formation in the Guadalupe Mountains area (Lambert et al. 2002; Nestell et al. 2006b; Nestell et al. 2007b; Wardlaw and Nestell this volume). The measured section studied is mostly exposed on the northwestern side of the road cut, but several additional meters of the lower part of the section can be seen on the southeastern side of the road cut where a small two meter thick block of thin bedded limestone is present (in a massive debris flow) that is clearly biostratigraphically equivalent in age to part of the Lamar Limestone (text-figs. 3, 4, 5, 6). The EF section is subdivided into five distinct lithologic units in ascending order: A, B, C, D and E (text-figs. 3, 6).

#### Unit A

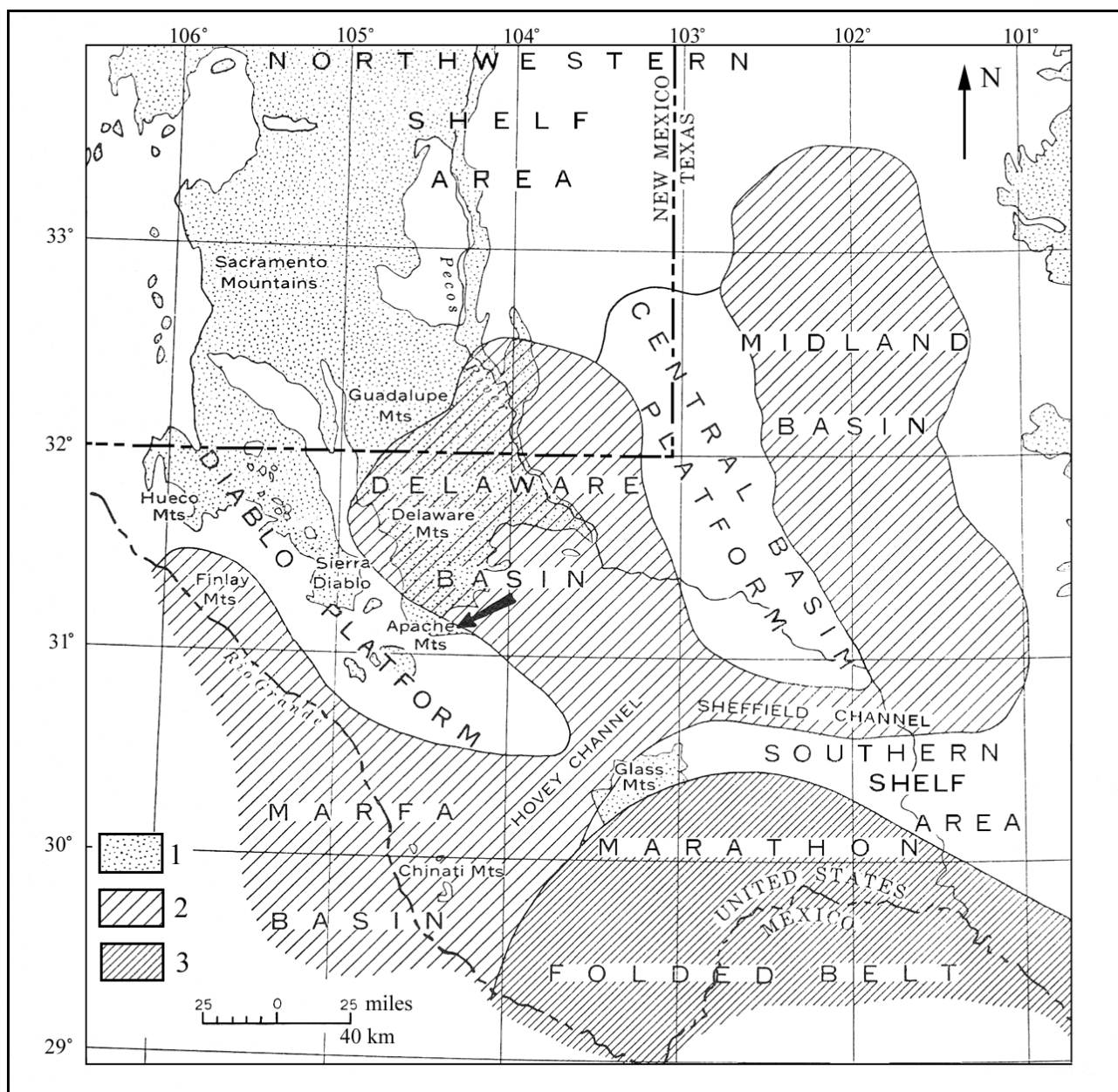
Unit A (thickness 7m) is a carbonate debris flow with coarse fossiliferous clasts in the lower part and laminated fine grained limestone in the upper part. Two small blocks of thin bedded limestone are present in the lower part of the debris flow (text-figs. 3, 4, 5). A large block approximately 2m thick, and bounded above and below by coarse debris is located on the east side of the road cut (text-fig. 4). It consists of an alternation of thin bedded dark gray carbonate mudstone/wackestone with several thin beds of brownish siltstone. Radiolarians are present at several levels throughout the block, but are not abundant. They are represented by 17 species, five of which are new (*Pseudoalbaillella apachensis*, *Copicyntra erinacea*, *Klaengspongos planus*, *Copielintra orbiculata*, and *C. fastuosa*) (text-fig. 7). Also present are the species: *Follicucullus scholasticus* Ormiston and Babcock, originally described from the Lamar Limestone in the Guadalupe Mountains (Ormiston and Babcock 1979), *Paratriposphaera cimelia* (Nazarov and Ormiston), *Hegleria mammiifera* Nazarov and Ormiston (= *Hegleria mamilla* in Noble and Jin this volume), *Tormentum sertulum* Nazarov and Ormiston, *Ruzhencevispongos girtyi* Nazarov and Ormiston, and *Nazarovispongos inflatum* (Nazarov and Ormiston) described from the Hegler, Rader and Lamar Limestone Members in the Guadalupe Mountains (Nazarov and Ormiston 1985a; Nestell et al. 2006a). The species *Entactinia itsukaichiensis* Sashida and Tonishi and *E. modesta* Sashida and Tonishi were originally described from a chert sequence of Guadalupian or younger age strata near Itsukaichi town, Tokyo Prefecture, Central Japan (Sashida and Tonishi 1985). The species *Pseudoalbaillella delawarensis* Maldonado and Noble is described from the Reef Trail Member in the Patterson Hills sections in the Guadalupe Mountains (Maldonado and Noble this volume). The conodont species *Jinogondolella shannoni* Wardlaw in Wardlaw and Mei 1998 and *J. postserrata* (Behnken) occur in the upper part of the succession of this block and designate a Lamar age (Wardlaw and Nestell this volume). The fusulinacean species *Paradoxiella pratti* Skinner and Wilde is also present together with the noted conodonts that also supports a Lamar age and is the index-species of the *Paradoxiella pratti* Zone established in the fore reef facies of the Lamar Limestone and originally described from near the mouth of McKittrick Canyon in the Guadalupe Mountains (Wilde and Rudine 2000; Nestell and Nestell 2006). The

presence of *Follicucullus scholasticus* also supports the fact that the block is not older than the Lamar Limestone.

A small second block of less than one meter in thickness consists of several thin beds of carbonate mudstone with a few interbeds of siltstone and occurs on the west side of the road cut approximately one meter below the top of debris flow (text-figs. 3, 5, 7). Poorly preserved radiolarians are found only in one sample (AHA-2). Nine species are present, six from which occur in strata equivalent to the Lamar Limestone of the Guadalupe Mountains, and three species are new for the Apache Mountains area: *Follicucullus japonicus* Ishiga, *Copicyntra irregularata* Maldonado and Noble and *Copicyntroides asteriformis* Nazarov and Ormiston. The first species is found together with *Follicucullus scholasticus* in sample 23 of Nabejiri-yama area, southwestern Japan (Ishiga et al. 1982; Ishiga 1991). *Copicyntra irregularata* is known from the Reef Trail Member in the Guadalupe Mountains area (Maldonado and Noble this volume). The third species *Copicyntroides asteriformis* is known from the Lamar Limestone of the Guadalupe Mountains area (Nazarov and Ormiston 1985a; Noble and Jin this volume). The conodont *Jinogondolella altudaensis* (Kozur) occurs with the radiolarians and supports the fact that this second small block can be referred to the *J. altudaensis* Zone, which is recognized in the Reef Trail Member of the Guadalupe Mountains area (Nestell et al. 2007a) and in the EF section (units B, C and D) of the Apache Mountains area (Lambert et al. 2002; Nestell et al. 2007b).

#### Unit B

Unit B (thickness 1.9m) is represented by brownish finely laminated siltstone with beds from 2cm to 13cm in thickness on average, sometimes up to 32cm with a few thin gray carbonate mudstone beds from 2cm to 12cm in thickness (text-fig. 3). The carbonate beds of this unit contain very abundant and well preserved radiolarians. The assemblage of the radiolarians consists of 43 species, 10 of which are new, and 11 species that are known in the strata of the Lamar Limestone in the Guadalupe Mountains area such as *Raphidociclicus americanus*, *Follicucullus scholasticus*, *Entactinia parapycnoclada* (= *Stigmospaerostylus parapycnocladus* in Noble and Jin this volume), *Paratriposphaera cimelia*, *Hegleria mammiifera*, *Copicyntroides asteriformis*, *Praedeflandrella densa* (Nazarov and Ormiston), *Tormentum sertulum*, *Tetragregnon japonicum* Sashida and Tonishi (= *T. sculpratus* Nazarov and Ormiston, see remarks in the section on taxonomy), *Ruzhencevispongos girtyi*, and *Nazarovispongos inflatum* (text-fig. 7). Nine species such as *Raphidociclicus scutum* Maldonado and Noble, *Camptolatus volaticus* Maldonado and Noble, *Pseudoalbaillella* sp. A, *Astroentactinia porosa* Maldonado and Noble, *Copicyntra cuspidata* Nazarov and Ormiston, *C. irregularata* Maldonado and Noble, *Copicyntroides nazarovi* Maldonado and Noble, *Copielintra* aff. *C. oviformis* (Kozur and Mostler), and *Praedeflandrella prolata* Maldonado and Noble are known from the Reef Trail Member in the Guadalupe Mountains area (Maldonado and Noble this volume). Also present are *Albaillella yamakitai* Kuwahara in sense of Xia et al. (2005), *Follicucullus orthogonus* Caridroit and De Wever, *F. sphaericus* Takemura and *Grandetortura nipponica* Sashida and Tonishi. The stratigraphic significance of these species is discussed below. The rest of species are known from Permian age strata in the different regions of the Tethyan Realm worldwide. The conodonts *Jinogondolella altudaensis* (Kozur) and *J.*



TEXT-FIGURE 1

Location of the Apache Mountains and structural features in Guadalupian time, West Texas and southeastern New Mexico (after Wilde and Todd 1968). 1 – Outcrops of Permian rocks, 2 – Basin areas, 3 – pre-Wolfcampian Paleozoic rocks of the Marathon folded belt.

*xuanhanensis* Mei and Wardlaw are found together with the radiolarians (Lambert et al. 2002).

#### Unit C

Unit C (thickness 3.6m) is represented by monotonous thin to medium bedded gray-blue carbonate mudstone with a few thin layers (0.5cm) of siltstone (text-fig. 3). Calcareous Radiolaria can be seen in the carbonate mudstone throughout the entire unit, but attempts to extract them were mostly unsuccessful and poorly preserved specimens were found in only three samples. The assemblage of radiolarians is represented by 20 species known from the underlying unit B (text-fig. 7). The conodonts

species found in the unit are the same as in unit B (Wardlaw and Nestell this volume).

#### Unit D

Unit D (thickness 1.2m) is represented by red-brownish thinly laminated siltstone beds of 4cm to 15cm in thickness alternating with several thin gray carbonate mudstone beds ranging from 4cm to 6cm in thickness, some of which are wavy bedded (text-fig. 3). Radiolarians are more diverse than in the unit C, and less diverse than in the unit B. The assemblage of radiolarians is represented by 23 species; all of the species occur in units B and C (text-fig. 7). The first carbonate mudstone at the base of



the unit contains conodont species that are the same as in the underlying unit C, and scarce fusulinaceans referred to *Paraboultonia splendens* Skinner and Wilde (Skinner and Wilde 1955; Nestell et al. 2006b).

### Unit E

Unit E at the base contains two beds of pinkish-gray limestone (11-15cm and 10cm, respectively) fining upwards (unit 5 of Nestell et al. 2006b) (text-fig. 6). The first bed (sample E-1) contains the fusulinacean *Paraboultonia splendens* Skinner and Wilde and the conodonts *Clarkina hongshuiensis* Henderson, Mei and Wardlaw (rank of the subspecies *Clarkina postbitteri hongshuiensis* was elevated to species level by Lambert et al. this volume), *Jinogondolella altudaensis* (Kozur) and *J. granti* (Mei and Wardlaw) (Lambert et al. 2002; Nestell et al. 2006b; Wardlaw and Nestell this volume). The upper bed (sample E-2) contains scarce conodonts. Abundant radiolarians occur in the upper part of the first limestone (sample E-1) and are represented by 25 species, four of which appeared for the first time in this unit (*Tetrapaurinella* sp. 1, *Copiellintra laurelae* Noble and Jin this volume, *Latentifistula* sp. 1, and *Nazarovispongus globosum* n. sp.). The rest of the species occur in units B, C, and D (text-fig. 7). Radiolarians from the second limestone bed (sample E-2) are represented by 24 species, 21 of which known from the underlying deposits of the units B, C and D, and two species, *Cauletella manica* (De Wever and Caridroit) and *Entactinia* sp. 1 appear for the first time in this unit.

Above these two limestone beds there are two gray thinly laminated limestone beds (20-30cm lower and 40cm upper) (unit 6 of Nestell et al. 2006b) (text-fig. 6). From the lowest 10cm limestone (sample E-3) abundant radiolarians (19 species) and some juvenile conodonts were recovered (text-fig. 7). The thicker upper limestone with small to large siliceous cavities (sample E-4) contains scarce juvenile conodonts in the basal part. Above the laminated limestone interval there is an approximately 20-30cm bed (thickness of this bed varies) of dark gray to pinkish limestone (lower part of unit 7 of Nestell et al. 2006b). This limestone (sample E-5) contains the conodonts *Clarkina hongshuiensis* Henderson, Mei and Wardlaw, *Jinogondolella crofti* (Kozur and Lucas), *J. altudaensis* (Kozur), and *J. xuanhanensis* Mei and Wardlaw (Lambert et al. 2002; Wardlaw and Nestell this volume). Poorly preserved radiolarians are present in this limestone and are represented by only seven species known from the underlying deposits (text-fig. 7). Above this pinkish limestone there is another 20-30cm black laminated limestone (sample E-6) with siliceous cavities that is barren of fossils and above it begins typical laminated strata of the Castile Formation. The interval above the two beds E-1 and E-2, from E-3 to E-6 is considered as the basal unit (Basal Limestone Member) of the Castile Formation (Anderson et al. 1972 with references; Nestell et al. 2009).

## BIOSTRATIGRAPHY

### The radiolarian assemblages described by Nazarov and Ormiston

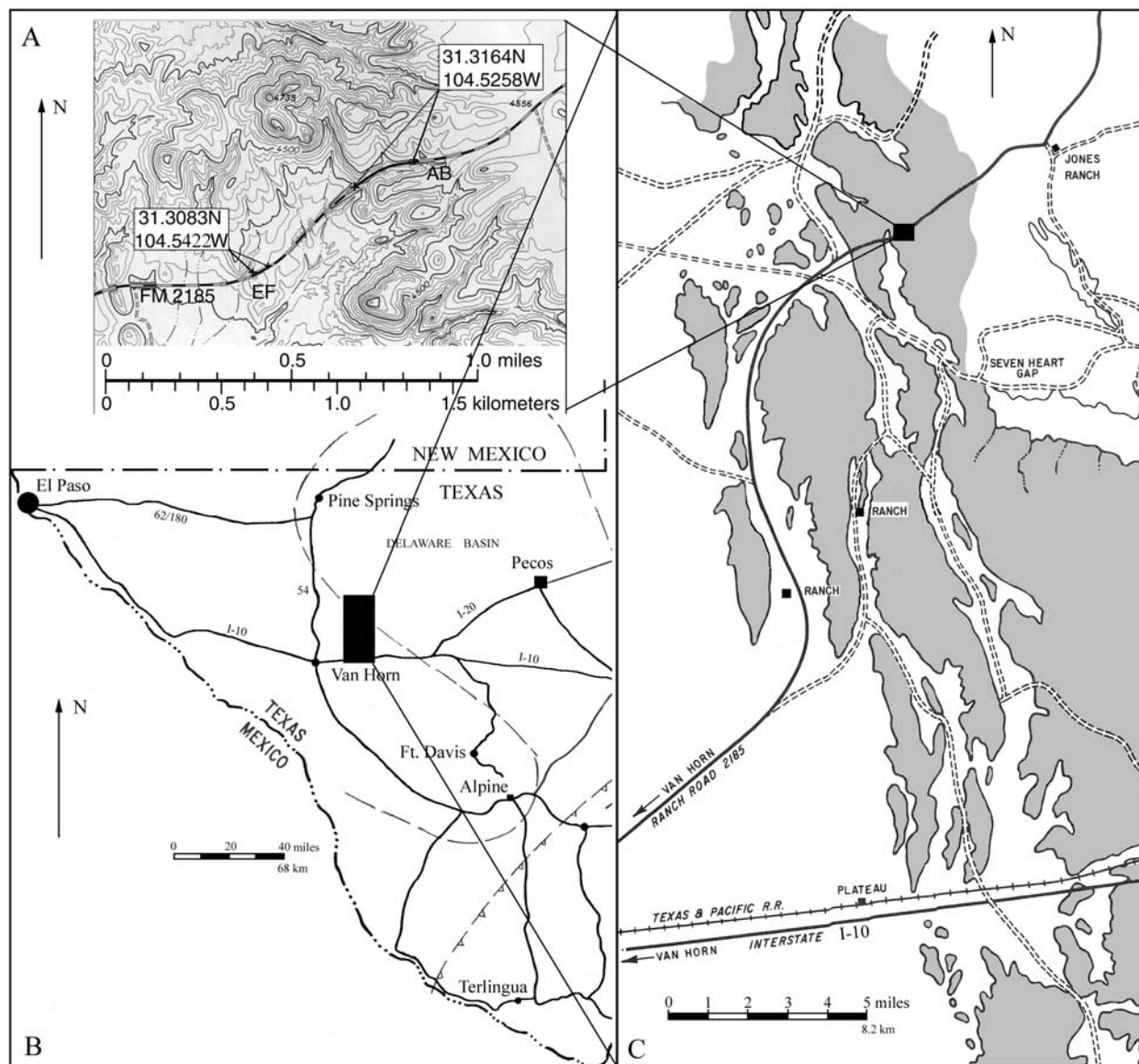
The first scheme of the distribution of radiolarian species and their assemblages in the Delaware basin, mostly in the Guadalupian Mountains area, was presented by Nazarov and Ormiston (1985a). They described many new species from the upper part of the Bone Spring Limestone of Leonardian age (strata now assigned to the Williams Ranch Member of the Cutoff Formation of Roadian, early Guadalupian age (Lambert et al.

2000)) from a prominent road cut on U. S. Highway 62/180, Culberson County in West Texas, a short distance east of its intersection with Texas FM 54. In this paper Nazarov and Ormiston also described several new species from the Hegler and Lamar Limestone Members of the Bell Canyon Formation. Based on the distribution of the radiolarian species, they established four radiolarian assemblages or faunal units (in ascending order): *Copicyntra? simulens*, *Octatormentum cornelli*, *Hegleria mammiifera*, *Follicucullus ventricosus*, and “*Copicyntra*” sp. (text-fig. 8). The *F. ventricosus* assemblage was based on the work of Ormiston and Babcock (1979) and Nazarov and Ormiston’s (1985a) further investigation of the Lamar Limestone. The first two faunal units they attributed to the entire Bone Spring Limestone of the Leonardian (Lower Permian), *Hegleria mammiifera* for the upper part of the Cherry Canyon and lower part of the Bell Canyon Formations, and *Follicucullus ventricosus* (the rank of this assemblage was raised up to zone by Nazarov and Ormiston in 1986a) for the upper part of the Bell Canyon Formation of the Guadalupian (Middle Permian), and “*Copicyntra*” sp. for the Castile Formation of the Ochoan Series (Upper Permian) (text-fig. 8) in spite of the fact that species of *Copicyntra* were found in the uppermost part of the Bell Canyon Formation (Anderson et al. 1972). Such a distribution of the faunal units was based on sparse radiolarian data in the Delaware basin. At the same time, Nazarov and Ormiston (1985b) published a scheme of the distribution of the radiolarian associations through entire Paleozoic in which, for the Upper Permian (Guadalupian and Ochoan), they listed three assemblages from the Delaware basin (*Hegleria mammiifera*, *Follicucullus ventricosus* and “*Copicyntra*” sp. assemblages). One year later, Nazarov and Ormiston (1986b) proposed a different scheme based on the distribution of stauraxon polycystines in which for the Guadalupian age strata the lower assemblage was named *Latentifistula texana*, the middle as *Latentifistula densa* and the upper as Unnamed (text-fig. 8). These names were never used again by Nazarov and Ormiston. Moreover, several years later Nazarov and Ormiston (1993) again returned to the scheme proposed in 1985b (text-fig. 8). In the present stratigraphic scheme of the Delaware basin, we place the radiolarian assemblages of Nazarov and Ormiston where they were originally described with a slight modification: *Hegleria mammiifera* - *Latentifistula texana* to the Hegler Member, *Follicucullus ventricosus* - *Latentifistula densa* to the Lamar Limestone, and “*Copicyntra*” sp. to the Reef Trail Member of the Bell Canyon Formation and the Basal Limestone Member of the Castile Formation (text-fig. 8).

### Correlation

In the Apache Mountains, many species of radiolarians found in the EF section were described by Nazarov and Ormiston (1985a) from the Lamar Limestone in the Guadalupe Mountains area. Based on such findings and also the presence of the conodont species *Jinogondolella shannoni*, we can correlate the strata of the first block in the lower part of unit A of the EF section to the Lamar Limestone and with the *Follicucullus ventricosus* Zone (Nestell et al. 2007a). Based on the presence of the conodont species *Jinogondolella altudaensis* in the upper part of unit A, units B, C and D of the EF section, we can correlate these strata to coeval strata of the Reef Trail Member in the Guadalupe Mountains area (Nestell et al. 2007a) (text-fig. 9).

The most stratigraphically important species present in unit B are *Albaillella yamakitai* Kuwahara in sense of Xia et al. (2005), *Follicucullus orthogonus* Caridroit and De Wever, and *Grande-*



TEXT-FIGURE 2

Location and topographic map showing studied EF section in West Texas. **A** – Topographic map showing the location of the EF and AB sections along Texas Farm to Market road (FM) 2185 (modified after Lambert et al. 2002). In the AB section, lower parts of the Bell Canyon Formation are present. **B** – Location of the studied area in West Texas (modified after Horak and Halsey 1983). **C** – Location of the EF section in the northwestern part of the Apache Mountains (indicated by gray color) (modified after Wilde and Todd 1968).

*tortura nipponica* Sashida and Tonishi because of the associated diagnostic conodont fauna. *Albaillella yamakitai* (= *Albaillella* sp. F of Kuwahara et al. 1998) was first described by Kuwahara (1999) from a pelagic cherty section in the Gujo-hachiman area, Mino Belt, southwestern Japan. In this section Kuwahara recognized four zones for the Upper Permian in ascending order: *Follicucullus scholasticus* - *F. ventricosus*, *F. charveti* – *Albaillella yamakitai*, *Neoalbaillella ornithoformis* and *N. optima* (text-fig. 9). Unfortunately, there is poor conodont control for this section. Yao et al. (2001) illustrate a number of broken and juvenile specimens of species of *Clarkina* and present a correlation chart of the conodont and radiolarian

zones between the Gujo-hachiman and Ryozen sections where the *Follicucullus charveti* – *Albaillella yamakitai* Zone corresponds to the upper part of the *Clarkina liangshanensis* and *C. orientalis* conodont zones of the upper Wuchiapingian. Yao et al. (2001) also correlate the *Follicucullus scholasticus* – *F. ventricosus* radiolarian Zone with the lower part of the *C. liangshanensis* Zone, of middle Wuchiapingian age. Later, Kuwahara et al. (2007, fig. 8) referred the *F. scholasticus* – *F. ventricosus* Zone to the uppermost Maokouan (or uppermost Capitanian in the international scale) of the uppermost Middle Permian, and the *F. charveti* – *A. yamakitai* Zone to the lowermost Wuchiapingian. Recently, Xia et al. (2004) restudied sev-

eral pelagic sections in China and southwestern Japan including the Gujo-hachiman section in connection with establishing a standard radiolarian zonation for the Upper Permian, Lopingian and correlating these zones to the standard conodont zones. They correlated the *F. charveti* – *A. yamakitai* zone of Kuwahara to the *Jinogondolella crofti* conodont Zone of the uppermost Guadalupian in China, established the *Albaillella postyamakitai* Zone above the *F. charveti* – *A. yamakitai* Zone and correlated the lower boundary of this zone with the lower boundary of the *Clarkina postbitteri postbitteri* conodont Zone of the lowest Wuchiapingian. The specimen of *A. postyamakitai* that Xia et al. (2004) illustrated in figure 5 is exactly the same specimen which in two following papers was identified as *Albaillella yamakitai* (Xia et al. 2005, pl. 3, fig. 10) and *Albaillella* sp. 1 (Sun and Xia 2006, pl. 3, fig. 1). Thus, it is not clear just what is meant by the species “*A. postyamakitai*” and furthermore, its precise range is not clear. We have specimens of the same species in the upper part of the Bell Canyon Formation (our unit B), and this part of the section correlates to the Reef Trail Member (uppermost Capitanian) in the Guadalupe Mountains based on the conodonts (Nestell et al. 2007a).

Later, Xia et al. (2005) corrected their misinterpretation of the Guadalupian – Lopingian boundary at the pelagic cherty section at Dachongling, near Qinzhou City, Guangxi, South China previously based on the misidentification of some radiolarian and conodont species (Sun and Xia 2004). It is interesting to note that the new Guadalupian – Lopingian boundary was transferred from the base of the bed Dch 46-C (Sun and Xia 2004) to the base of the bed Dch 45-21 (Xia et al. 2005). Xia et al. (2005) proposed a radiolarian zonation for the entire Guadalupian and Wuchiapingian based on the distribution of the radiolarians from the Dachongling section in South China and the Sasayama section (Tamba Belt) in southwestern Japan. They proposed three radiolarian zones for the Capitanian based on the distribution of the genus *Follicucullus* (in ascending order): *F. dilatatus*, *F. charveti*, and *F. falx* – *Foremanhelena triangula* (Xia et al. 2005, fig. 5, p. 225). The latter zone was correlated by Xia et al. (2005) to the *Jinogondolella granti* – *J. crofti* conodont Zone (text-fig. 9). Above this zone in the Dachongling section there is a conodont barren interval (about 40cm), and above the barren interval there is a 5cm interval with the conodont species *Clarkina postbitteri hongshuiensis* morphotype I. However, the conodont species *Clarkina postbitteri hongshuiensis* morphotype II is reported in the *Jinogondolella granti* – *J. crofti* conodont Zone (Xia et al. 2005, fig. 2). This entire interval with abundant radiolarians in the lower part and a reduced radiolarian assemblage in the upper part was assigned entirely to the *F. falx* – *Foremanhelena triangula* Zone by Xia et al. (2005, fig. 3). According to Xia et al. (2005), the first appearance of the species *Albaillella yamakitai* in sense of Xia et al. (2005) at the Dachongling section is in the *Clarkina postbitteri postbitteri* conodont Zone that defines the lower boundary of the Upper Permian, Lopingian or Wuchiapingian. These authors established the *A. yamakitai* Zone and correlated it with the *Albaillella postyamakitai* Zone of Xia et al. (2004), and state that this zone “was based on an erroneous interpretation of the two morphotypes of *A. yamakitai* as two different species” (Xia et al. 2005, p. 222). They also proposed to draw the Guadalupian – Lopingian boundary based on radiolarians on the first appearance of the species *A. yamakitai* in sample 45-21 at the Dachongling section where it occurs together with the conodont species *Clarkina postbitteri*

*postbitteri* (Xia et al. 2005, fig. 3, p. 221). As we mentioned above, the species *A. yamakitai* in sense of Xia et al. (2005) appears in unit B of our EF section (with the conodonts of the *Jinogondolella altudaensis* Zone) that is approximately 5m below the lower boundary of the *Clarkina hongshuiensis* conodont Zone in the Apache Mountains section. This radiolarian species also occurs in the Reef Trail Member of the Bell Canyon Formation in the Guadalupe Mountains (Maldonado and Noble this volume). Thus, the species *A. yamakitai* in sense of Xia et al. (2005) cannot be a species-index for the Guadalupian – Lopingian boundary because it ranges from the latest Guadalupian to the earliest Wuchiapingian. In the paper of Sun and Xia (2006), these authors published the distribution of conodonts and radiolarians on the Guadalupian – Lopingian boundary at the same section (Dachongling) with the Guadalupian – Lopingian boundary at the base of the bed Dch 46-C (Sun and Xia 2006, p. 278, fig. 3) which is much higher than in the paper of Xia et al. (2005, p. 219, fig. 2, G/L boundary is at the base of the bed Dch 45-21), and proposed different conodont and radiolarian zones (text-fig. 9). This time, in the uppermost Guadalupian they recognized two conodont zones: the lower *Jinogondolella granti* Zone and upper *Clarkina postbitteri hongshuiensis* Zone and correspondingly two radiolarian zones: the lower *Follicucullus scholasticus* Zone and upper *F. charveti* Zone. In the *F. scholasticus* Zone they found the following species: the nominal species, *F. ventricosus*, *F. porrectus*, *F. quadrataris* (which is probably a synonym of *F. dilatatus*), and *Hegleria mammilla* (= *Hegleria mammifera*). The presence of *F. ventricosus* indicates a correlation of this zone with the *F. ventricosus* Zone of the Lamar Limestone in the Guadalupe Mountains. Sun and Xia (2006) concluded that the *F. scholasticus* Zone defined by Ishiga (1986) “currently corresponds to the *F. ventricosus* – *F. scholasticus* and *F. charveti* – *A. yamakitai* zones” (Sun and Xia 2006, p. 278), although, according to them, the *F. scholasticus* Zone may range from the upper Roadian to the upper Capitanian. But, in the Dachongling section they recognized “the upper *F. scholasticus* Zone that belongs to Capitanian” (Sun and Xia 2006, p. 279). Thus, Sun and Xia could not correlate their *F. scholasticus* Zone with any conodont zone because of the absence of precise conodont data. Above the *F. scholasticus* Zone, Sun and Xia established the *F. charveti* Zone containing the species *Follicucullus orthogonus*, *F. bipartitus*, *Foremanhelena triangula*, *Ishigaum trifustis* and *Albaillella yamakitai* in sense of Xia et al. (2005). This *F. charveti* Zone was correlated by them to the *Jinogondolella granti* conodont Zone of late Capitanian age. They also infer “that the Guadalupian – Lopingian geochronostratigraphic boundary is at the lower part of the *A. levis* Zone” (Sun and Xia 2006, p. 281) (lowest Wuchiapingian zone in the sense of Sun and Xia 2006), which would place this boundary near the base of the *Clarkina postbitteri hongshuiensis* conodont Zone (Dachongling section, sample Dch46-1, Sun and Xia 2006, p. 278, fig. 3), and which is within the Capitanian or latest Guadalupian.

The difficulty of attempting to establish radiolarian and conodont zonations can be clearly seen from the comments above. Such zonations must be established with precise joint radiolarian and conodont data from carefully described sections in both pelagic cherty and shelfal settings because of the possible variable ranges of diagnostic radiolarian species within both depositional environments. Our tentative correlation of the late Guadalupian age strata in the Apache Mountains with coeval strata in China (and based on published data) is presented in





TEXT-FIGURE 3  
Panorama of the EF section on the northwestern side of the road FM 2185 showing debris flow at the base (unit A), and units B, C, D and E. Arrow shows the position of the small block illustrated in text-fig. 5. Open box shows the position of the strata illustrated in text-fig. 6.



text-fig. 9 where our data is from bed by bed sampling for radiolarians and conodonts.

## TAXONOMY AND DESCRIPTION OF TAXA

The authors use the revised classification of higher protozoan taxa in sense of Cavalier-Smith (2002), the suprageneric taxa of radiolarians proposed by Afanasieva et al. (2005), and have used the scope of some families accepted by De Wever et al. (2001). We use the terminology for the description of the new species given in Nazarov (1988), De Wever et al. (2001), Afanasieva and Amon (2006), and Jones and Noble (2006). All illustrated taxa including holotypes and paratypes of the new species are deposited in the collections of the U. S. National Museum in Washington D.C. as specimens USNM 538510 - 538725.

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 RADIOLARIA Müller 1858; emend. stat. nov. Cavalier-Smith 1993  
Superclass POLYCYSTINA Ehrenberg 1838  
Class ACULEARIA Afanasieva 1999; emend. Afanasieva and Amon 2003  
Order FASCICULATA Afanasieva and Amon 2003  
Family XIPHOCADIPELLIDAE Nazarov 1988 [nom. transl. Afanasieva and Amon 2003 ex Xiphocadiellinae Nazarov 1988]; emend. Afanasieva and Amon in Afanasieva et al. 2005

Genus *Campanulithus* Nazarov and Rudenko 1981; emend. Nazarov 1988  
Type species: *Campanulithus falcatus* Nazarov and Rudenko 1981.

**Diagnosis** (in sense of Nazarov 1988): Test consists of four spines intersecting at one point. Axial spine is long, and other three main (apical) spines curved and some have apophyses. The axial spine in the basal part has three-four additional spines perpendicular to it and sometimes intersecting with the three apical curved spines.

**Range** (updated here): Lower Permian, Cisuralian, Sakmarian – Middle Permian, Guadalupian, Capitanian.

*Campanulithus insuetus* Nestell and Nestell, n. sp.  
Plate 1, figures 1-6; Text-figure 10

**Diagnosis:** *Campanulithus* with three spines of different length intersecting in one point. Two lateral spines are complicated by additional lateral spines and axial spine by short apophyses (text-fig. 10).

**Description:** Test represented by three spines intersecting at one point. The axial spine is long with rare apophyses in the apical and basal parts. Apophyses are located perpendicular to or at a small angle to the axial spine. Sometimes the axial spine is bifurcated at the low end (pl. 1, fig. 4). One of the main apical (or lateral) spines is curved, and another one is relatively long and curved, or straight, some specimens have two-four addi-

tional curved lateral spines. In some tests the additional lateral spines are complicated by numerous short denticles (pl. 1, fig. 1).

**Measurements** ( $\mu\text{m}$ ): length of axial spine is 300-700, its diameter 15-20, the length of apophyses of the axial spine 30-70, the length of curved longest lateral spine 150 and the length of the shortest lateral spine 55-80, the length of additional curved lateral spines 120-170.

**Designation of types:** The specimen illustrated on plate 1, figure 3 (no. USNM 538512) is designated as the holotype, and specimens on plate 1, fig. 2 (no. USNM 538511) and fig. 5a (no. USNM 538514) as the paratypes. They are from West Texas, Apache Mountains, 50km north-east of Van Horn, Texas FM 2185, EF section, unit D, sample F-19, the upper part of the Bell Canyon Formation, age equivalent to the Reef Trail Member, upper Capitanian, Middle Permian.

**Etymology:** From the Latin *insuetus* – unusual.

**Material:** 12 specimens.

**Discussion:** Based on the spines intersecting at one point, *Campanulithus insuetus* n. sp. is similar to *C. falcatus* Nazarov and Rudenko (1981, p. 137, pl. 1, figs. 8-10), but differs from it by three and not four intersecting main spines, the presence of a bifurcation of the lower end of the axial spine, the presence of additional lateral spines on one of the apical main and longest lateral spine, and the absence of basal intersecting spines.

**Occurrence:** As the holotype, and also EF section, unit B, the upper part of the Bell Canyon Formation, age equivalent to the Reef Trail Member, Apache Mountains; Reef Trail Member, Guadalupe Mountains (Maldonado and Noble this volume), West Texas; Middle Permian, upper Capitanian.

Order TRIANGULATA Afanasieva and Amon 2003  
Family RAPHDOCICLICIDAE Afanasieva 1999 [nom. transl. Afanasieva and Amon 2003 ex Raphidociclicinae Afanasieva 1999]; emend. Afanasieva and Amon in Afanasieva et al. 2005

Genus *Raphidociclicus* Nazarov and Rudenko 1981  
Type species: *Raphidociclicus hiulcus* Nazarov and Rudenko 1981.

**Diagnosis:** Test characterized by a well developed main spine and weakly expressed two additional spines (*a* and *i* in Nazarov and Rudenko 1981, fig. b). All spines connected by a massive central ring and a spongy or reticulate meshwork. The connection of the patagium with the spines forms small rosettes or appears as two sheets of a semi-opened book.

**Range:** Lower Permian, Cisuralian, Sakmarian – Middle Permian, Guadalupian, Capitanian.

*Raphidociclicus americanus* Nazarov and Ormiston [nom. transl. herein ex *Raphidociclicus gemellus* Nazarov and Rudenko 1981 subsp. *americanus* Nazarov and Ormiston 1985a]  
Plate 1, figures 7-9

Radiolaria – BABCOCK 1977, fig. 11-10.  
*Raphidociclicus gemellus* Nazarov and Rudenko 1981 subsp. *americanus* NAZAROV and ORMISTON 1985a, p. 52, pl. 3, figs. 15-16.





TEXT-FIGURE 4

Position of the Lamar age equivalent block in the debris flow (unit A) on the southeastern side of the road FM 2185. Vertical maximal thickness of the block is approximately 2m. White lines delineate the block.

*Raphidociclicus gemellus americanus* NAZAROV and ORMISTON 1986a, pl. 7, fig. 10.

*Raphidociclicus gemellus americanus* NAZAROV and ORMISTON – NAZAROV 1988, pl. 32, fig. 4.

**Remarks:** We elevate the rank of the subspecies *Raphidociclicus gemellus americanus* to species because it differs from the species *Raphidociclicus gemellus* Nazarov and Rudenko (1981, p. 136, pl., figs. 2-4) by smaller size of the spines and diameter of the central ring, regularly developed rosettes in the patagium and a much younger stratigraphic interval (*R. gemellus* was described from the Lower Permian, Cisuralian, lower part of the Artinskian).

**Occurrence:** EF section, unit B, the upper part of the Bell Canyon Formation, Apache Mountains, age equivalent to the Reef Trail Member; also occurs in the Lamar Limestone (Nazarov and Ormiston 1985a, 1986a; Noble and Jin this volume) and Reef Trail (Maldonado and Noble this volume) Members, Guadalupe Mountains; West Texas; Middle Permian, upper Capitanian.

Order ALBAILLELLATA Deflandre 1953 [nom. transl. Holdsworth 1966 ex order Albaillellidea Deflandre 1953; nom. transl. Holdsworth 1969 ex suborder Albaillellina Deflandre 1953 in Holdsworth 1966; nom. transl. Afanasieva 1999 ex suborder Albaillellaria Deflandre 1953 in Holdsworth 1969; nom. correct. Afanasieva and Amon 2003 pro order Albaillellaria Deflandre 1953]; emend. Holdsworth 1969; emend. Afanasieva 1999; emend. Afanasieva and Amon 2003

Family FOLLICUCULLIDAE Ormiston and Babcock 1979 [in sense of Ormiston and Babcock 1979; non emend. Kozur and Mostler 1989]

Genus *Follicucullus* Ormiston and Babcock 1979; emend. Caridroit and De Wever 1986; non emend. Kozur and Mostler 1989 [= *Ishigaconus* Kozur and Mostler 1989; = *Cariver* Kozur 1993]

Type species: *Follicucullus ventricosus* Ormiston and Babcock 1979.



**Diagnosis** (in sense of Caridroit and De Wever 1986): Test is conical and imperforate, sometimes curved; with three parts: apical cone, pseudothorax and pseudoabdomen; with two spines prolonging the pseudoabdomen, their directions are oblique to the general axis of the test.

**Range:** Middle Permian, Guadalupian, uppermost Wordian – Upper Permian, Lopingian, Wuchiapingian.

Kuwahara et al. (1998) extended the range of the genus *Follicucullus* into the *Neobaillella optima* Zone of the Changhsingian. This extension of the range of the genus without conodont evidence is suspect. Bragin (in Bragin et al. 1999) illustrated a form that he referred to as *Follicucullus excelsior* Bragin from the Lower Triassic (Olenekian) of Sikhote-Alin in the Russian Far East. However, we question whether this form belongs to the genus *Follicucullus*.

**Remarks:** Ormiston and Babcock (1979) proposed the genus *Follicucullus* with type species *F. ventricosus* and the family Follicucullidae from the Guadalupian Bell Canyon Formation, Lamar Limestone Member in the Guadalupe Mountains, Delaware basin, West Texas. In addition to the type species they also described the species *F. scholasticus* characterized by a long narrow conical test. Later, Caridroit and De Wever (1984) described several new species of the genus *Follicucullus* from Upper Permian deposits of Kamigori, southwestern Japan: *Follicucullus bipartitus*, *F. charveti*, *F. falx*, *F. hamatus*, *F. hamatus uncinatus*, and *F. orthogonus*. Two years later, Caridroit and De Wever (1986) corrected the stratigraphic position of the previous locality and concluded that the section belongs to the Tatsuno Formation of the Maizuru Group. They proposed some terminology for the description of the genus *Follicucullus*, and redescribed previously described species and one new species (*Follicucullus furca*). They also presented a scheme for the development of species of *Follicucullus* in time. Kozur and Mostler (1989) emended the diagnosis of the genus *Follicucullus* including in its composition only tests with three well expressed subdivisions of the test: apical cone, inflated pseudothorax and short unsegmented pseudoabdomen, with no or only one pseudoabdominal spine developed (they included the species *Follicucullus ventricosus*, *F. monacanthus* Ishiga and Imoto in Ishiga et al. 1982, *F. charveti* Caridroit and De Wever 1984, *F. falx* Caridroit and De Wever 1984, and conditionally *F. orthogonus* Caridroit and De Wever 1984). The species *F. scholasticus* Ormiston and Babcock 1979, that was originally placed into the family Follicucullidae by Ormiston and Babcock, Kozur and Mostler (1989) proposed to consider as the type species for their new genus *Ishigaconus*, including in the composition of this genus the following species: *F. scholasticus*, *F. bipartitus*, *F. hamatus hamatus* and *F. hamatus uncinatus*, e. g., forms with a conical shape and two subdivisions of the test: “apical cone and a distal cylinder” (Kozur and Mostler 1989, p. 181). But, Caridroit and De Wever (1986) showed a transitional form between *F. scholasticus* and *F. ventricosus* with a slightly inflated pseudothorax (Caridroit and De Wever 1986, p. 72, fig. 15) in which the test was divided into three parts. Later, Ishiga (1991) established a new name, *Follicucullus japonicus*, for his *F. scholasticus* morphotype II, which has three subdivisions of the test and is interpreted by some workers as *F. ventricosus*. Later, Kozur (1993) added to the composition of his emended diagnosis of the genus *Follicucullus* the species *F. bispinosus* Kozur 1993, *F. dilatatus* Rudenko in Belyanskiy et al. 1984 and *F. porrectus* Rudenko in

Belyanskiy et al. 1984. He also established the new genus *Cariver* with the type species *F. orthogonus* and also described a new species *Cariver dorsoconvexus* from the Dzhulfian of the Sosio Valley area in western Sicily (Kozur 1993). Thus, all three genera, *Follicucullus* s. s. in sense of Kozur and Mostler (1989), *Ishigaconus* and *Cariver* have three subdivisions of the test that coincide with the original description of *Follicucullus*. Following the opinions of Blome and Reed (1992), Takemura et al. (1999), and De Wever et al. (2001), we consider the genera *Ishigaconus* and *Cariver* to be junior synonyms of the genus *Follicucullus* in the sense of the original description of Ormiston and Babcock (1979) and the expanded diagnosis of Caridroit and De Wever (1986). The stratigraphic range of the genus *Follicucullus* should be reevaluated because almost all known species have been described from chert or deposits without confirmation by conodonts.

***Follicucullus sphaericus*** Takemura in Takemura et al. 1999; emend. herein  
Plate 2, figures 17-22

*Follicucullus* sp. A - KUWAHARA 1997, pl. 2, fig. 8. – KUWAHARA and YAO 1998, pl. 1, fig. 22.

*Follicucullus* (?) sp. – TAKEMURA et al. 1998, pl. 1, fig. 13.

**Diagnosis** (after Takemura et al. 1999): Imperforate and smooth test with two parts: upper conical and lower flattened hemispherical and sometimes inflated. Two apertures present in the lower part: large subelliptical located ventrally and small teardrop-shape located at the distal end with small dorsal spine or flap. Tube-like ventral spine extends upwards from the center of the turned end of the wall.

**Emended diagnosis:** Test consists of three parts: apical cone with dorsally curved tip, very short and weakly inflated pseudothorax and semi-circular pseudoabdomen. The pseudoabdomen has a long and curved dorsal spine that starts from the lower end of a hollow sinus near the flap. Ventral spine is high and curved and projected above the test.

**Description:** Test lamellar, goose-shaped and consists of long thin apical cone with dorsally curved tip, pseudothorax very short and weakly inflated, and pseudoabdomen of semi-circular shape on the dorsal side and straight or slightly concave on the ventral side. The pseudoabdomen has a very long and curved, sometimes broken apertural dorsal spine. On the dorsal side of the pseudoabdomen and directly below the dorsal spine there is a narrow loop-shaped (teardrop-shape in sense of Takemura in Takemura et al. 1999) and hollow sinus (or small aperture in sense of Takemura in Takemura et al. 1999) with a small triangular flap. Aperture is oval or elliptical and located on the slightly concave ventral side with a short apertural or ventral in some cases curved spine. This ventral spine is projected above the apertural surface of the test at a height of 80-110µm.

**Measurements (µm):** length of the test 350-420, width (or diameter) of the test 180-230, length of the apical cone 160-210, height of the pseudoabdomen 160-180, length of the dorsal spine 180-220, length of the curved tip of the dorsal spine 20-50.

**Material:** 14 specimens from samples F-8 and F-15.

**Remarks:** Our specimens are very well preserved which enabled us to add descriptive information on some morphological fea-





TEXT-FIGURE 5  
Position of the small block of Reef Trail age equivalent strata in the upper part of the debris flow (unit A) on the northwestern side of the road FM 2185. Hammer handle is ruled in 5cm increments.

tures of the test, especially with regard to the development of dorsal and ventral spines.

**Occurrence:** Middle Permian, upper Capitanian, EF section, unit B, the upper part of the Bell Canyon Formation, age equivalent to the Reef Trail Member, Apache Mountains, West Texas; uppermost Middle Permian – lowest Upper Permian, Arrow Rocks, Waipapa Terrane, New Zealand; Upper Permian, Wuchiapingian, *Neoalibaillella ornitoformis* Zone, Gujohachiman area, Mino Belt, southwestern Japan.

Genus *Pseudoalibaillella* Holdsworth and Jones 1980

Synonymy

*Parafollicucullus* HOLDSWORTH and JONES 1980

*Haplodiacanthus* NAZAROV and RUDENKO 1981

*Holdsworthella* KOZUR 1981

*Longtanella* SHENG and WANG 1985

*Curvalbaillella* KOZUR and MOSTLER 1989

*Foremanconus* KOZUR and MOSTLER 1989

*Kitoconus* KOZUR and MOSTLER 1989

*Yaoconus* KOZUR and MOSTLER 1989

Type species: *Pseudoalibaillella scalprata* Holdsworth and Jones 1980.

**Diagnosis:** Test is conical shaped with three parts: apical cone segmented or not, inflated winged pseudothorax, and pseudoabdomen segmented or not with two basal spines of different shape and size.

**Remarks:** We agree with the discussion of some synonymy among the genera *Pseudoalibaillella*, *Parafollicucullus* and *Haplodiacanthus* presented in Ishiga et al. (1982), Blome and Reed (1992), and we also follow the synonymy of the genus *Pseudoalibaillella* of De Wever et al. (2001). We also consider that the genus *Holdsworthella* Kozur 1981 is a synonym of the genus *Pseudoalibaillella* based on the same morphology.

**Range:** Carboniferous, Middle Pennsylvanian – Middle Permian, Guadalupian.

Xia et al. (2004, p. 31, pl. 2, figs. 16, 22, 28) illustrated species of the genus *Pseudoalibaillella* from their *Alibaillella angusta* –



*A. flexa* Zone of the lowest Changhsingian in the Gujohachiman section of southwestern Japan. They stated that some species including *Pseudoalbaillella fusiformis* and *P. globosa* that disappeared in the underlying zone which is the *Neobalbaillella optima* – *Albaillella lauta* Zone (uppermost Wuchiapingian according to Xia et al. 2004), reappeared again in the *A. angusta* – *A. flexa* Zone of early Changhsingian age together with *Follicucullus monacanthus* (possible misidentification as this species is a Wordian form), *F. porrectus* and *F. scholasticus*, species which are characteristic for the upper Guadalupian. According to Kuwahara et al. (1998), the *Neobalbaillella optima* Zone is of Changhsingian age, and not Wuchiapingian based on their revised radiolarian zonation. However, no conodont data was available to support this conclusion and the presence of the genus *Pseudoalbaillella* in the Wuchiapingian or Changhsingian is questionable.

*Pseudoalbaillella apachensis* Nestell and Nestell, n. sp.  
Plate 3, figures 4-5

**Diagnosis:** *Pseudoalbaillella* with short and unsegmented apical cone, short and slightly inflated pseudothorax with two thin and long curved wings, and long unsegmented almost cylindrical to narrow conical shape imperforate pseudoabdomen.

**Description:** Test lamellar, an elongate cone, with three subdivisions of the test into an apical cone, pseudothorax and pseudoabdomen. The apical cone is relatively short, straight or insignificantly curved and unsegmented. The pseudothorax is small and slightly inflated with two thin and long curved wings. The pseudoabdomen is long, not segmented, with an almost cylindrical to narrow conical shape, and without any perforation. The basal part of the pseudoabdomen has two short basal spines curving to the ventral side. Each of the basal spines has a lateral apophysis at the junction of the end of the pseudoabdomen and basal spine. These apophyses connect with the wings.

**Measurements ( $\mu\text{m}$ ):** length of the test excluding basal spines 370-470, test width at the base of the pseudoabdomen 120-150, height of the apical cone 90-120 and width 40-50, height of the pseudothorax 40-50 and width 90-100, height of the pseudoabdomen 240-300, length of the basal spines 50-70, length of the apophysis 40-60.

**Designation of types:** The specimen illustrated on plate 3, figure 5 (no. USNM 538555) is designated as the holotype and the specimen on plate 3, figure 4 (no. USNM 538554) as the paratype. They are from West Texas, Apache Mountains, 50km north-east of Van Horn, Texas FM 2185, EF section, unit B, sample F-8; the upper part of the Bell Canyon Formation, age equivalent to the Reef Trail Member, upper Capitanian, Middle Permian.

**Etymology:** After the Apache Mountains, West Texas, USA.

**Material:** Very rare, 6 specimens.

**Discussion:** Based on the almost cylindrical shape of the pseudoabdomen and unsegmented apical cone and pseudoabdomen, *Pseudoalbaillella apachensis* n. sp. is similar to *P. rhombothoracata* Ishiga and Imoto (1980, p. 33, pl. 3, figs. 9-12), but differs from it by larger size of the test, smaller and slightly inflated pseudothorax, pseudoabdomen expanded to the base, and long wings connected with the apophyses of the basal spines.

**Occurrence:** As the holotype and paratypes, and also EF section, unit A, the upper part of the Bell Canyon Formation, age equivalent to the Lamar Limestone Member; Apache Mountains; Bell Canyon Formation, Reef Trail Member (Maldonado and Noble this volume), Guadalupe Mountains; West Texas; Middle Permian, upper Capitanian.

Class SPHAERELLARIA Haeckel 1881; emend. Afanasieva and Amon in Afanasieva et al. 2005

Order ENTACTINIATA Kozur and Mostler 1982 [nom. transl. De Wever et al. 2001 ex suborder Entactinaria Kozur and Mostler 1982; nom. correct. Afanasieva and Amon 2003 pro family Entactiniidae Riedel 1967]

Family ENTACTINIIDAE Riedel 1967; emend. Won 1997a; emend. Afanasieva 1999

Subfamily ENTACTINIINAE Riedel 1967; emend. Nazarov 1975; emend. Won 1997a; emend. Afanasieva 1999

Genus *Entactinia* Foreman 1963; emend. Won 1997a [= *Palaeoxyphostylus* Won 1983; = *Inaequalientactinia* Won 1991]

Type species: *Entactinia herculea* Foreman 1963.

**Diagnosis:** A spherical test with one porous shell, and with double six-rayed internal spicule with a median bar. The main three-bladed spines are the continuation of the rays of the spicule.

**Remarks:** Kozur and Mostler (1981) and Aitchison and Stratford (1997) considered the genus *Entactinia* as a junior synonym of the genus *Stigmosphaerostylus* Rüst 1892. De Wever et al. (2001) considered both of these genera to be valid. Recently, Afanasieva and Amon (2008) revised the taxonomic status of the genera *Entactinia* and *Stigmosphaerostylus* and supported the opinion of De Wever et al. (2001) about the validity of both genera. Moreover, based on different morphology of the test of the genus *Entactinia* and genus *Stigmosphaerostylus*, Afanasieva and Amon (2008) concluded that these two genera should be assigned to different families and correspondingly to different classes. They included the genus *Entactinia* in the family Entactiniidae of the class Sphaerellaria, and they assigned *Stigmosphaerostylus* to the family Haplentactiniidae of the class Spumellaria. We support the opinion of Afanasieva and Amon (2008) and follow their decision.

In the Middle Permian, upper Capitanian of West Texas we recognized the following species of the genus *Entactinia*: *E. parapycnoclada* Nazarov and Ormiston 1985a, *E. wildei* (Noble and Jin this volume), *E. itsukaichiensis* Sashida and Tonishi 1985, *E. modesta* Sashida and Tonishi 1985, ?*E. reticulata* Sashida and Tonishi 1985, *E. sp. 1*, and *E. sp. 2*.

**Range:** Middle Ordovician – Triassic.

Subfamily BIENTACTINOSPHERINAE Afanasieva 1999

Genus *Paratriposphaera* Kozur and Mostler 1989 [= *Sashidaella* Kozur 1999]

Type species: *Entactinosphaera strangulata* Nazarov and Ormiston 1985a.

**Diagnosis:** Test consists of two spherical shells with two to six main three-bladed spines rarely twisted. Mostly tests with two polar spines dominate, but forms with three, four, five and six spines also occur in less degree even among the one species.





TEXT-FIGURE 6

Enlarged view of the upper part of unit D and unit E. The boundary between the Bell Canyon Formation and the overlying Castile Formation is considered to be at the contact between beds E-2 and E-3.

Outer shell is segmented by narrow ridges arranged in a loose irregular polygonal manner. Each segment bears rounded or oval pores. The inner shell is small, porous, with numerous thin secondary rod-like spines that arise from the inner sphere and connect with the outer shell. They are often preserved. The internal framework is represented by a six-rayed spicule located eccentrically.

**Remarks:** The genus *Paratriposphaera*, with type species *Entactinosphaera strangulata* Nazarov and Ormiston 1985a, was introduced by Kozur and Mostler (1989) for Permian forms with two spherical shells, with a six-rayed spicule in the porous internal shell, with a polygonal structure of the external shell, and from two polar to six main spines. They included the following species in the composition of the new genus: the type species *Entactinosphaera strangulata*, *Entactinosphaera cimelia* Nazarov and Ormiston 1985a and *E. crassiclathrata* Nazarov and Ormiston 1985a. Kozur (1999) proposed a new genus *Sashidaella* with type species *Entactinosphaera pseudocimelia* Sashida and Tonishi 1988 that has two thick three-bladed spines (or tricarinate spines in the sense of Kozur) and

whose outer shell structure was similar to the external shell of the genus *Paratriposphaera*. He assigned the species *Entactinosphaera cimelia* to the genus *Sashidaella* which he earlier had assigned to the genus *Paratriposphaera*. Based on the presence of two thick three-bladed spines, Kozur (1999) compared the new genus with the genus *Triposphaera* Hinde 1890 which, according to Kozur and Mostler (1981), has priority in the use of the generic name compared with *Trilonche* Hinde 1899. The latter name was reinstated by Aitchison and Stratford (1997) and became accepted by many researchers. In any case, according to Kozur (1999), the genus *Sashidaella* differs from *Triposphaera* by having two main spines. In the material from the upper Capitanian in the Apache Mountains, we have abundant representatives of the species *Entactinosphaera cimelia*, whose tests have two, three or four three-bladed long spines. The number of spines and their length, in our opinion, is a specific feature for this species. Moreover, Kozur was inconsistent in the assignment of the species *E. cimelia*. Recently, Feng et al. (2007) assigned the species *Entactinosphaera cimelia*, *E. pseudocimelia* and *E. brevispinosa* to the genus *Trilonche* Hinde 1899 with no explanation. In this paper we ac-

cept the genus *Paratriposphaera* following De Wever et al. (2001) as a valid genus based on the presence of two spherical shells, the peculiar structure of the external shell, and the presence of the two or six three-bladed spines. We also consider that the genus *Sashidaella* is a junior synonym of the genus *Paratriposphaera* based on the description of the type species.

**Composition of the genus:** In the composition of the genus *Paratriposphaera* we include the following species: *Entactinosphaera strangulata* Nazarov and Ormiston 1985a, *E. cimelia* Nazarov and Ormiston 1985a, *E. crassiclathrata* Nazarov and Ormiston 1985a, *E. pseudocimelia* Sashida and Tonishi 1988, and *E. brevispinosa* Sashida and Tonishi 1988.

**Range:** Lower Permian, Cisuralian, Artinskian – Upper Permian, Lopingian.

Family ASTROENTACTINIIDAE Nazarov and Ormiston 1985a [nom. transl. Afanasieva 2000 ex Astroentactiniinae Nazarov and Ormiston 1985a]

Subfamily ASTROENTACTINIINAE Nazarov and Ormiston 1985a; emend. Afanasieva 1999

Genus *Astroentactinia* Nazarov 1975

Type species: *Astroentactinia stellata* Nazarov 1975.

**Diagnosis** (in sense of Nazarov 1988): Test is spherical with one latticed shell; with internal eccentrically located eight-rayed spicule with a median bar. The rays of the spicule have apophyses that continue as the additional main spines. The main spines of rod-shaped, conical or three-bladed shape are numerous.

**Remarks:** Won (1997a) placed the genus *Astroentactinia* as a synonym of the genus *Entactinia* Foreman 1963 because she doubted that the type species of the genus has apophyses. The type species *A. stellata* was reported by Nazarov and Ormiston (1983b) from the Upper Devonian Gogo Formation of Australia. Later, Won (1997a) restudied entactiniids from this formation and concluded that specimens assigned by Nazarov and Ormiston to *A. stellata* do not have apophyses. Based on this observation, Won placed the genus *Astroentactinia* in the synonymy of the genus *Entactinia*. In the EF section in the Apache Mountains there are forms that have eccentrically located spicules and rays that have apophyses. The features of these forms clearly coincide with the original diagnosis of the genus *Astroentactinia*. Afanasieva (2000) accepted the validity of the genus, and we follow her conclusion.

**Range:** Upper Devonian, Frasnian – Middle Permian, Guadalupian, Capitanian.

*Astroentactinia capitanensis* Nestell and Nestell, **n. sp.**

Plate 6, figures 4–8; Plate 7, figure 1

**Diagnosis:** *Astroentactinia* with small test, with longer thin three-bladed at the base and conical at the end, sometimes twisted main spines, and with numerous short conical secondary spines.

**Description:** Test spherical with one porous shell. Internal framework is represented by an eight-rayed spicule located eccentrically with a long median bar (length 55µm and thickness 4µm). The main spines are numerous (up to 12), and they are thin and three-bladed at the base, and conical at the end. In some tests the main spines are twisted. Numerous, short, conical

and thin secondary spines arise from interpore bars. Pores are subcircular with diameter 9–12µm. Apophyses can be seen at the end of rays of the spicule.

**Measurements (µm):** test diameter 150–270, wall thickness 6, length of main spines up to 120.

**Designation of types:** The specimen illustrated on plate 6, figure 8 (no. USNM 538587) is designated as the holotype, and specimens on plate 6, figure 7 (no. USNM 538586), and specimen on plate 7, figure 1 (no. USNM 538588) as the paratypes. They are from West Texas, Apache Mountains, 50km north-east of Van Horn, Texas FM 2185, EF section, unit B, sample F-13, the upper part of the Bell Canyon Formation, age equivalent to the Reef Trail Member, upper Capitanian, Middle Permian.

**Etymology:** After El Capitan Peak, Guadalupe Mountains, West Texas, USA.

**Material:** Abundant and 13 specimens have been photographed and measured.

**Discussion:** Based on the shape of the test, *Astroentactinia capitanensis* n. sp. is similar to *A. mendosa* Nazarov (in Isakova and Nazarov, 1986, p. 68, pl. 15, fig. 8), but differs from it by the smaller size of the test, thinner wall, smaller diameter of pores, and longer main spines.

**Occurrence:** As the holotype and paratype, and EF section, units D and E, the upper part of the Bell Canyon Formation, age equivalent to the Reef Trail Member, Apache Mountains; West Texas; Middle Permian, upper Capitanian.

Class SPUMELLARIA Ehrenberg 1875; emend. Afanasieva and Amon in Afanasieva et al. 2005

Order CANCELLIATA Afanasieva and Amon 2003

Family OROSPHAERIDAE Haeckel 1887

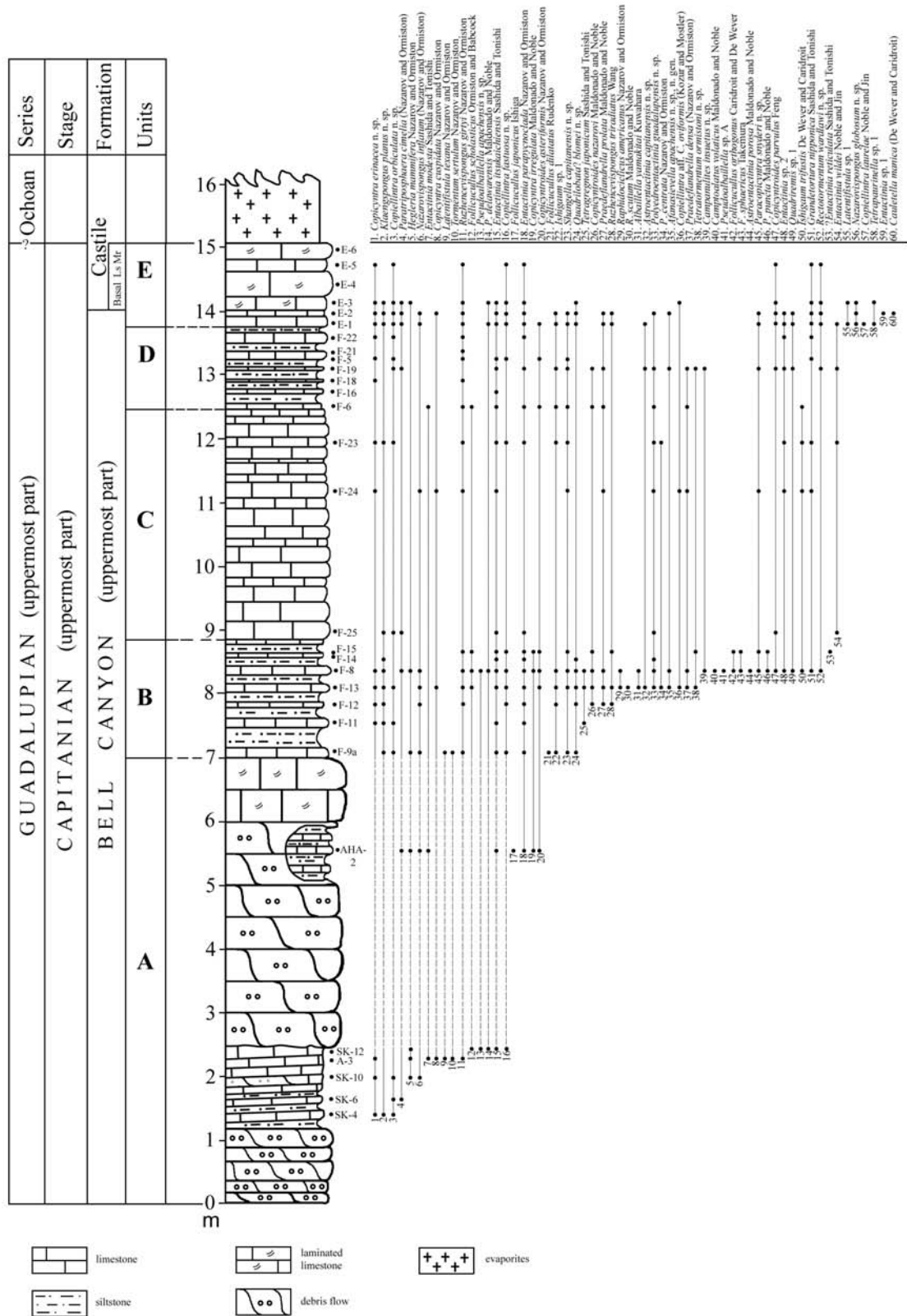
Subfamily POLYEDROENTACTINIINAE Nestell and Nestell, **n. subfam.**

**Diagnosis:** Tests reticular, of subspherical, irregular or regular polygonal shape, with one cortical shell with bar-centered seven to ten or more rayed spicule, rays of which continue as the main spines. Each ray has apophyses. On the surface of the test, the bases of all main spines unite by ridges which subdivide the cortical shell into polygonal segments of triangular, squared or polygonal shape. Each segment contains large pores of varied size and outline. Some specimens have secondary spines. The main spines are three-bladed.

**Composition:** *Polyedroentactinia* Kozur and Mostler 1989.

**Remarks:** We established a new subfamily Polyedroentactiniinae based on a recently published by Seo and Won (2009) revision of the genus *Polyentactinia* Foreman 1963 and correspondingly, the status of the family Polyentactiniidae Nazarov 1975. According to this revision, the type species of the genus *Polyentactinia*, *P. craticulata*, has “a very thin, layered, spongy shell with latticed base opened by a large pylome that has a rounded rim” (Seo and Won 2009, p. 66). This observation allowed these authors to reassign the genus *Polyentactinia* to the family Pylentonemidae Deflandre 1963. Correspondingly, the family Polyentactiniidae is the junior synonym of the family Pylentonemidae. Before this revision, De





TEXT-FIGURE 7  
 Distribution of stratigraphically important species of radiolarians in the EF section.

Wever et al. (2001) and Afanasieva et al. (2005) included in the family Polyentactiniidae, besides the genus *Polyentactinia*, the Cretaceous genera *Pyloctostylus* Dumitrica 1994 and *Cuboctostylus* Bragina 1999. Seo and Won (2009) pointed out that the genus *Pyloctostylus* with a pylome probably has a close relationship with the genus *Polyentactinia* that suggests a redefinition of the diagnoses of the family Pylentominidae and Polyentactiniidae in sense of De Wever et al. (2001). The Cretaceous genus *Cuboctostylus* differs from the genus *Pyloctostylus* by the absence of a pylome and centrally placed spicule (Bragina 1999) that is similar to the Paleozoic genus *Polyedroentactinia*. Such differences and similarities in the *Polyentactinia* – *Pyloctostylus* and *Polyedroentactinia* – *Cuboctostylus* probably can be explained by homeomorphy because no similar forms have been reported from the Upper Permian through the Jurassic. Thus, the genus *Polyedroentactinia* is probably a monotypic genus. We assign this genus to the new subfamily Polyedroentactiniinae of the family Orosphaeridae following Kozur and Mostler's opinion (Kozur and Mostler 1989) that the genus *Polyedroentactinia* is probably ancestor of the members of the family Orosphaeridae.

**Range:** Carboniferous, Middle Pennsylvanian – Middle Permian, Guadalupian.

Genus *Polyedroentactinia* Kozur and Mostler 1989

Type species: *Polyedroentactinia cisuralica* Kozur and Mostler 1989.

**Diagnosis:** Test with one external reticulate shell in a subspherical, irregular or regular polygonal shape; internal framework consists of a seven to ten or more rayed spicule with median bar located centrally. Rays of the spicule connected with the main three-bladed spines. On the distal end of the spicule rays there are apophyses connected with the spines or with the wall. The surface of the test consists of ridges that extend from the base of the main spines and which form a polygonal network that appear as segments of different shapes. Each segment consists of large pores of various shapes.

**Range:** Carboniferous, Middle Pennsylvanian – Middle Permian, Guadalupian.

*Polyedroentactinia guadalupensis* Nestell and Nestell, **n. sp.**  
Plate 7, figure 6; Plate 8, figures 1-3

**Diagnosis:** *Polyedroentactinia* with squarely box-shaped polyhedron test, long main spines, six to eight-rayed bar-centered spicule, and the same thickness of interpore bars.

**Description:** Test large, consists of one reticulate shell in the shape of an almost squarely box-shaped polyhedron. Internal framework is represented by a six- or eight-rayed spicule with a short median bar (length 10-12µm and thickness 5-6µm) and located centrally. Rays are connected with the base of the external main spines which are long and three-bladed in shape. Each ray has apophyses located distally and connected with the wall. The number of main spines is 6-8. The base of the main spines is connected with external thick ridges (thickness 8-10µm) that form squared polyhedral surfaces of different sizes. Secondary spines (or thorns) are numerous, small and cylindrical in shape, and are located at the corner of the intersection of the polyhedral surfaces and pores. Pores are of irregular shape: sub-circular, subsquared, and subrectangular of different sizes. Interpore bars are all of similar size (10-11µm).

**Measurements (µm):** test diameter 140-250, length of main spines up to 510, its width 30-50, length of the secondary spines (or thorns) 30-60, diameter of pores 18-25.

**Designation of types:** The specimen illustrated on plate 8, figure 1 (no. USNM 538594) is designated as the holotype, and the specimens on plate 8, figure 2 (no. USNM 538595) and figure 3 (no. USNM 538596) as the paratypes. They are from West Texas, Apache Mountains, 50km north-east of Van Horn, Texas FM 2185, EF section, unit B, sample F-8; the upper part of the Bell Canyon Formation, age equivalent to the Reef Trail Member, upper Capitanian, Middle Permian.

**Etymology:** After Guadalupe Peak, Guadalupian Mountains, West Texas, USA.

**Material:** Abundant and 15 specimens have been photographed and measured.

**Discussion:** Based on the polyhedral surface of the test and the centrally located internal spicule, *Polyedroentactinia guadalupensis* n. sp. is similar to *Polyedroentactinia centrata* (Nazarov and Ormiston) (Nazarov and Ormiston 1985a, p.43, pl. 2, figs. 6-8), but differs from it by smaller size of the test, larger length of the main spines, thicker main spines, location of the secondary spines (or thorns), the same thickness of the interpore bars, and bar-centered spicule.

**Occurrence:** As the holotype and paratypes, and also EF section, units C, D, E; the upper part of the Bell Canyon Formation, age equivalent to the Reef Trail Member, Apache Mountains; Bell Canyon Formation, Reef Trail Member (Maldonado and Noble this volume), Guadalupe Mountains; West Texas; Middle Permian, upper Capitanian.

Order SPONGIATA Afanasieva and Amon 2003

Family SPONGENTACTINIIDAE Nazarov 1975 [nom. transl.  
Afanasieva 1999 ex tribus Spongentactiniini Nazarov 1975]  
Subfamily PLURISTRATOENTACTINIINAE Afanasieva 1999

Genus *Afanasievella* Nestell and Nestell, **n. gen.**

Type species: *Afanasievella apachensis* Nestell and Nestell, **n. sp.**

**Diagnosis:** Test bipyramidal in shape, with three shells: spongy external shell, porous intermediate shell and microsphere. Between microsphere and intermediate shell six thin rod-like rays develop which continue outside of microsphere as primary three-bladed radial beams extending outside as main spines. Between intermediate and external shells, radial thin and rod-like beams and secondary small conical spines are developed. The ends of the radial beams are bifurcated as are the apophyses that connect with each other and form the internal or basal layer of the spongy external shell. Three rows of the linear apophyses are developed at the distal end of the primary three-bladed radial beams.

**Etymology:** After Dr. Marina Afanasieva, well known radiolarian worker.

**Discussion:** Based on the presence of apophyses arising from the radial beams and forming the basal layer of the spongy external shell, the new genus *Afanasievella* is similar to the genus *Spongospaera* Won 1997b, but differs from it by the presence of three shells of the test including microsphere, and six main



Nazarov and Ormiston, 1985a, 1985b				Nazarov and Ormiston, 1986b			Nazarov and Ormiston, 1993			Nazarov and Ormiston's radiolarian assemblages in the Recent scheme of the Delaware basin, West Texas, USA					
System	Series	Formation	Faunal units	System	Series	Radiolarian association	System	Series	Radiolarian	System	Series	Stage	Formation	Members	Radiolarian assemblages
Upper Permian	Ochoan	Castile	" <i>Copicyntra</i> " sp.	Upper Permian	Guadalupian	Unnamed	Upper Permian	Ochoan	" <i>Copicyntra</i> " sp.	Middle Permian	Guadalupian	Capitanian	Castile	Basal Limestone	" <i>Copicyntra</i> " sp.
	Bell Canyon	<i>Follicucullus ventricosus</i>	<i>Latentifistula densa</i>			<i>Follicucullus ventricosus</i>		Bell Canyon	Reef Trail						
		Cherry Canyon	<i>Hegleria mammiifera</i>			<i>Latentifistula texana</i>			<i>Hegleria mammiifera</i>				Lamar Limestone	<i>Follicucullus ventricosus</i> - <i>Latentifistula densa</i>	
					McCombs Rader Pinery										
					Hegler							<i>Hegleria mammiifera</i> - <i>Latentifistula texana</i>			
	Brushy Canyon	-----							Wordian			Cherry Canyon	Manzanita		
South Wells															
Getaway															
Lower Permian	Leonardian (u. p.)	Bone Spring Limestone (upper part)	<i>Octatormentum cornelli</i>								Roadian	Cutoff	Williams Ranch	<i>Octatormentum cornelli</i>	
			<i>Copicyntra simulens</i>										El Centro (upper part)	<i>Copicyntra simulens</i>	

TEXT-FIGURE 8

Position of Nazarov and Ormiston's radiolarian assemblages in the recent Guadalupian scheme of the Delaware basin.

spines. We cannot observe the internal structure of the microsphere, so we do not know if it contains a spicule inside, or represents a hollow microsphere by itself. From the genus *Meschedea* Won 1983 emend. Won 1997a with a multi-layered outer shell and numerous radial beams between shells, *Afanasievella* differs by the presence of apophyses at the end of the radial beams and primary radial beams, a tiny microsphere instead of a spicule and thin spongy external shell.

**Range:** Middle Permian, Guadalupian, upper Capitanian.

***Afanasievella apachensis*** Nestell and Nestell, **n. sp.**

Plate 8, figures 4, 6; Plate 9, figures 1-5

**Diagnosis:** Given in the diagnosis of the genus.

**Description:** Test consists of three shells: a thin spongy external shell, intermediate porous shell, and tiny microsphere. The external shell is bipyramidal in shape, with a two layered spongy shell. The external spongy layer consists of rounded to subrounded pores of different sizes, the internal or basal layer formed by the joining of the apophyses branching from the bifurcated ends of the thin rod-like radial beams arising from the intermediate shell. The intermediate shell is relatively large, latticed, with rounded pores and well developed thin secondary conical spines and radial beams. An internal framework appears

to be represented by a microsphere with six very thin rays arising from it and extending outside of the microsphere as relatively thick three-bladed beams which extend outside of the test as the main spines. There are six main spines that are thick and three-bladed at the beginning and become thinner toward the distal ends. The main spines have three rows of linear apophyses located close to the distal end of the main three-bladed beams that are located between the external and intermediate shells that connect to the external shell in a pyramidal manner, giving the test a somewhat squared or bipyramidal appearance.

**Measurements ( $\mu\text{m}$ ):** test diameter 190-270, length of main spines 210-390, width of main spines at the base 23-40 and at the distal end 10-15, diameter of intermediate shell 90-100, diameter of pores of the intermediate shell 6, diameter of pores of external layer of the shell 10-17 and of internal layer 15-20, diameter of the microsphere 13.

**Designation of types:** The specimen illustrated on plate 8, figure 6 (no. USNM 538599) is designated as the holotype, and specimens on plate 8, figure 4 (no. USNM 538598) and on plate 9, fig. 1 (no. USNM 538600) and fig. 5 (no. USNM 538604) as the paratypes. They are from West Texas, Apache Mountains, 50km north-east of Van Horn, Texas FM 2185, EF section, unit B, sample F-8, the upper part of the Bell Canyon Formation, age

equivalent to the Reef Trail Member, upper Capitanian, Middle Permian.

*Etymology*: After the Apache Mountains, West Texas, USA.

*Material*: Abundant and 20 specimens have been photographed and measured.

*Discussion*: Given in the description of the genus.

*Occurrence*: As the holotype and paratypes, and also EF section, units C, D, E, the upper part of the Bell Canyon Formation, age equivalent to the Reef Trail Member, Apache Mountains; West Texas; Middle Permian, upper Capitanian.

Family SPONGOPOLYENTACTINIIDAE Nazarov 1975 [nom. transl. Afanasieva 1999 ex tribus Spongopolyentactiniini Nazarov 1975]

Subfamily COPICYNTRINAE Kozur and Mostler 1989 [= Plenoentactiniinae Afanasieva 1999; = Copicyntridae Amon 1999]

Genus *Copicyntra* Nazarov and Ormiston 1985a; emend. Kozur and Mostler 1989

Type species: *Copicyntra cuspidata* Nazarov and Ormiston 1985a designated by Kozur and Mostler 1989.

*Diagnosis*: Spherical test with a spongy external shell and porous inner sphere, and with numerous (8-13) concentric shells between them. All shells are crossed by radial beams connected with the external numerous spines of various shape.

*Range*: Carboniferous, Upper Pennsylvanian, Gzhelian – Upper Permian, Lopingian, Changhsingian.

*Copicyntra erinacea* Nestell and Nestell, **n. sp.**

Plate 9, figures 6-8; Plate 10, figures 1-3, 5; Plate 18, figures 1-2

*Diagnosis*: Large *Copicyntra* with eight concentric shells and spines that are short thin and three-bladed at the base, and conical at the distal end.

*Description*: Test spherical, relatively large, with an external thin spongy shell and internal small porous sphere. Eight concentric shells (probably spirally coiled) are developed between the external shell and internal sphere. Internal sphere is penetrated by rounded small pores (diameter 3µm). Radial beams extend from the inner sphere and connect with relatively numerous short external spines. Spines are thin three-bladed at the base and are of conical shape toward the end. Spines are absent in some tests. Spongy external shell has a cellular surface.

*Measurements* (µm): test diameter 270-360, length of external spines 15-70, diameter pores of external shell 8-10, diameter of internal sphere 22.

*Designation of types*: The specimen illustrated on plate 9, figure 6 (no. USNM 538605) is designated as the holotype, and specimens illustrated on plate 9, figure 7 (no. USNM 538606) and figure 8 (no. USNM 538607), and plate 18, figure 1 (no. USNM 538715) and figure 2 (no. USNM 538716) as the paratypes. They are from West Texas, Apache Mountains, 50km north-east of Van Horn, Texas FM 2185, EF section, unit E: holotype and paratypes (pl. 9, fig. 8) and (pl. 18, figs. 1 and 2) from sample E-1, and paratype (pl. 9, fig. 7) from sample E-2;

the upper part of the Bell Canyon Formation, age equivalent to the Reef Trail Member, upper Capitanian, Middle Permian.

*Etymology*: From the Latin *erinacea* – hedgehog-shaped.

*Material*: Abundant and 13 specimens have been photographed and measured.

*Discussion*: Based on numerous short main spines, *Copicyntra erinacea* n. sp. is similar to *Copicyntra phymatodonta* Nazarov and Ormiston (1985a, p. 25, pl. 2, figs. 9-10), but differs by larger test, less number of internal concentric shells, less development of spines and their different shape and smaller size.

*Occurrence*: As the holotype and paratypes, and also EF section, units A, C, D, E, the upper part of the Bell Canyon Formation, age equivalent to the Reef Trail Member, Apache Mountains; Bell Canyon Formation, Lamar Limestone Member (Noble and Jin this volume) and Reef Trail Member (Maldonado and Noble this volume), Guadalupe Mountains; West Texas; Middle Permian, upper Capitanian.

Genus *Paracopicyntra* Feng in Feng et al. 2006b

Type species: *Copicyntra ziyunensis* Feng and Gu 2002.

*Diagnosis*: Test consists of a spongy external shell with small pores, large inner shell with centrally located initial spicule inside, and four to seven concentric shells between the outer and inner shells. Spines are numerous.

*Range*: Middle Permian, Guadalupian, Capitanian – Upper Permian, Lopingian, Changhsingian.

*Paracopicyntra snyderi* Nestell and Nestell, **n. sp.**

Plate 10, figures 6-10

*Diagnosis*: Small spongy test with seven concentric internal shells (probably spirally coiled), and 10 main spines that are narrow and relatively small three-bladed approximately up to 2/3 of the length, and conical at the distal end.

*Description*: Test spongy, consists of seven concentric shells (probably spirally coiled) penetrated by numerous thin rod-like radial beams. There are up to 10 main spines that are narrow three-bladed approximately up to 2/3 of the spine and then become of conical shape. In some tests the main spines can be twisted. Internal sphere is small and porous. Internal spicule not observed. The surface of the outer shell is shallow cellular with rounded and small pores and with tiny thorns developed along the surface that create the appearance of a rough wall.

*Measurements* (µm): test diameter 180 – 260, diameter of the internal sphere 30, the length of main spines 70-150, width of the main spines at the base 25-30, the diameter of pores of the outer shell is 6-7.

*Designation of types*: The specimen illustrated on plate 10, figure 6 (no. USNM 538613) is designated as the holotype, and specimens illustrated on plate 10, figure 7 (no. USNM 538614) and figure 10 (no. USNM 538617) as the paratypes. They are from West Texas, Apache Mountains, 50km north-east of Van Horn, Texas FM 2185, EF section, holotype is from unit B, sample F-8, and paratypes are from unit E, paratype (fig. 7) from sample E-1, and paratype (fig. 10) from sample E-2; the upper part of the Bell Canyon Formation, age equivalent to the Reef Trail Member, upper Capitanian, Middle Permian.



Standard Scale		Delaware basin, West Texas, USA				Kuwahara, 1999;		Xia et al., 2004			Xia et al., 2005			Sun and Xia, 2006															
System Series	Lopingian Stage	Wuchiapingian Stage	Ochoan Stage	Formation	Members (Guadalupian Mts.)	EF section, Apache Mts		System	Xia et al., 2004			Xia et al., 2005			Sun and Xia, 2006														
						Lambert et al. 2002; Wardlaw and Nestell	This study		Radiolarian zones	Series	Conodont zones	Radiolarian zones	Series	Conodont zones	Radiolarian zones	Series	Conodont zones	Radiolarian zones											
						Conodont zones	Radiolarian indices																						
Upper Permian	Lopingian	Wuchiapingian	Ochoan	Castle	Basal	evaporites		Neoalibaillella ornithoformis	Lopingian	Clarkina postbitteri postbitteri	A. postyamakitai	Lopingian	C. p. postbitteri	Albaillella yamakitai (lower part)	Lopingian	C. p. postbitteri	Albaillella levis												
Middle Permian	Guadalupian	Capitanian (upper part)	Guadalupian	Bell Canyon	Reef Trail	Limestone	E. B. A. (upper part)	Clarkina hongshuiensis (Jinogondolella granti, J. crofti)	Cauloteilla manica, Nazarovispongus globosum	Follicucullus charveti - Albaillella yamakitai	J. crofti	F. charveti - A. yamakitai	C. p. hongshuiensis morphotype I baren interval J. granti - J. crofti with C. p. hongshuiensis morphotype II	F. falx - Foremanhelena triangula	C. p. hongshuiensis	F. charveti (with F. bipartitus, F. orthogonus, F. scholasticus, Foremanhelena triangula, A. yamakitai, I. trifustus)													
																	A, B, C, D	J. altudaensis	F. orthogonus, A. yamakitai (F. sphaericus, F. scholasticus, Ishigaum trifustus)	F. charveti - F. bipartitus (with F. scholasticus, F. porrectus)	F. dilatatus	F. scholasticus							
																							A	J. shannoni	F. scholasticus, Tormentum sertulum	?	?	F. dilatatus	F. scholasticus (with F. ventricosus, F. porrectus, F. quadratus)

TEXT-FIGURE 9

Correlation of the Guadalupian/Lopingian boundary radiolarian and conodont zones between the EF section and two conodont bearing sections, one in the southwestern Japan and one in South China.

**Etymology:** After George Snyder, owner of the Jones Ranch, West Texas.

**Material:** Abundant and 10 specimens have been photographed and measured.

**Discussion:** Based on the presence of the three-bladed spines, *Paracopicyntia snyderi* n. sp. is similar to *Paracopicyntia ziyunensis* (Feng and Gu) (Feng and Gu 2002, p. 803, fig. 5.1-5.2 and 5.4-5.7), but differs from it by the smaller size of the test, less number of main spines, their shape and smaller length.

**Occurrence:** As the holotype and paratypes, and also EF section, unit C, D, E; QEF section, samples QEF-11; M section, sample M-18; the upper part of the Bell Canyon Formation, age equivalent to the Reef Trail Member, Apache Mountains; West Texas; Middle Permian, upper Capitanian.

Class STAURAXONARIA Afanasieva and Amon in Afanasieva et al. 2005

Order PALAEODISCATA Afanasieva and Amon in Afanasieva et al. 2005

Family PALAEOLITHOCYCLIIDAE Kozur and Mostler 1989 [= Palaeodiscalsidae Afanasieva 2008; nom. substit. Afanasieva 2008 pro Palaeodiscidae Afanasieva 2000]

Genus *Klaengspongos* Sashida in Sashida et al. 2000; emend. Feng and Gu 2002; emend. Maldonado and Noble this volume [= *Spongospaeradiscus* Wang in Wang and Shang 2001]

Type species: *Klaengspongos spinosus* Sashida in Sashida et al. 2000.

**Diagnosis:** Test large, discoidal, from lenticular to bi-convex in lateral view, consists of one spongy central sphere and a spongy discoidal margin. Short conical or three-bladed spines are developed in the equatorial plane.

**Remarks:** We consider that the genus *Spongospaeradiscus* described by Wang in Wang and Shang (2001) from the *Neoalibaillella ornithoformis* Zone of Guizhou, China to be a junior synonym of the genus *Klaengspongos* from the Upper Permian of eastern Thailand (Sashida et al. 2000) based on the almost identical generic diagnosis.

We included the genus *Klaengspongos* in the family Palaeolithocyclusidae following De Wever et al. (2001) and Feng et al. (2009), despite that our new species has discoidal test with only one spongy shell and not numerous shells as in palaeolithocyclusiids. But this difference may be due preservation. Sashida (in Sashida et al. 2000) referred the genus *Klaengspongos* to the Mesozoic family Orbiculiformidae Pessagno 1973 which is synonymized with the family Hagiastriidae Riedel by De Wever et al. (2001), who stated that the range of this family is from Late Triassic to Late Cretaceous. However, the members of the family Hagiastriidae have an initial shell and a system of girdles that the genus *Klaengspongos* does not have. We consider that family Palaeodiscalsidae is a junior synonym of the family Palaeolithocyclusidae based on the same generic composition of the families.

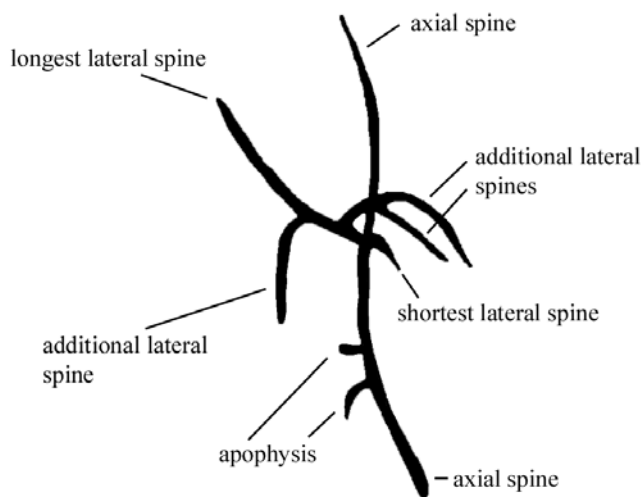
**Range** (updated herein): Middle Permian, Guadalupian, upper Capitanian – Upper Permian, Lopingian, Changhsingian.

***Klaengspongos planus*** Nestell and Nestell, n. sp.

Plate 11, figures 3-7; Plate 18, figures 3-4

**Diagnosis:** Test large, lenticular shape in the lateral view, without or with small conical spines.

**Description:** Test discoidal, of spherical shape in frontal view and lenticular in the lateral view; consists of one spongy internal relatively large sphere and one thick homogenous spongy shell surrounding the inner sphere. Numerous external short conical spines are developed along the equatorial margin in two rows.



TEXT-FIGURE 10  
Schematic view of *Campanulithus insuetus* n. sp. with terminology used in the description.

**Measurements ( $\mu\text{m}$ ):** test diameter 270-470, thickness 130-210, length of the spine 20-70.

**Variability:** The presence or absence of the spines on the equatorial margin of the tests.

**Designation of types:** The specimen illustrated on plate 11, figure 5 (no. USNM 538627) is designated as the holotype and specimens on plate 11, figure 4 (no. USNM 538626), figure 6 (no. USNM 538628) and figure 7 (no. USNM 538629), and on plate 18, figure 3 (no. USNM 538717) and figure 4 (no. USNM 538718) as the paratypes. They are from West Texas, Apache Mountains, 50km north-east of Van Horn, Texas FM 2185, EF section, unit B, sample F-8, the upper part of the Bell Canyon Formation, age equivalent to the Reef Trail Member, upper Capitanian, Middle Permian.

**Etymology:** From the Latin *planus* – flat.

**Material:** Abundant and 18 specimens have been photographed and measured.

**Discussion:** Based on the large size, discoidal test and development of spines in the equatorial plane, *Klaengspongius planus* n. sp. is similar to *K. spinosus* Sashida (Sashida et al. 2000, p. 256, pl. 3, figs. 7-8) and *K. shaiwaensis* (Wang in Wang and Shang 2001, p. 116, pl. 1, figs. 24-33). It differs from the first species by the lenticular shape of the test in lateral view, the absence of a flat and flanked depression around the prominent central sphere and thin conical spines. From *K. shaiwaensis*, the new species differs by its lenticular shape, not bi-convex, of the test in lateral view, larger size of the test and thin conical, not three-bladed, spines.

**Occurrence:** As the holotype, and also EF section, units A, C, D, E, the Bell Canyon Formation, age equivalent to the Reef Trail Member, Apache Mountains; Bell Canyon Formation,

Lamar Limestone Member (Noble and Jin this volume) and Reef Trail Member (Maldonado and Noble this volume), Guadalupe Mountains; West Texas; Middle Permian, upper Capitanian.

Order OVIFORMATA Afanasieva and Amon in Afanasieva et al. 2005

Family SPONGOLONCHIDAE Afanasieva and Amon in Afanasieva et al. 2005

Genus *Copiellintra* Nazarov and Ormiston 1985a [= *Ellipsocopicyntra* Kozur and Mostler 1989]

Type species: *Copiellintra diploacantha* Nazarov and Ormiston 1985a.

**Diagnosis** (after Nazarov 1988): Test consists of a spongy external shell and porous internal sphere with numerous ellipsoidal shells developed between the external and internal shells. Radial beams cross all of the shells, sometimes continued to external spines the number of which varies from two to six, or more.

**Remarks:** Nazarov and Ormiston (1985a) described a new genus *Copiellintra* with diagnosis mentioned above, but without noting the number of spines. Later, Nazarov (1988) added to the earlier diagnosis the number of spines (from two to six, or more). The type species of the genus, *C. diploacantha*, has only two spines developed in the poles. Later, Kozur and Mostler (1989) in their study of Early Permian radiolarians from the Urals discovered that in their material there are many forms that are elliptical with numerous internal shells and spines developed along the entire test. The structure of these forms coincided with the description of the genus *Copiellintra*, except for the presence of numerous spines in the entire test. Based on the description of the type species of *Copiellintra* with the presence of only two polar spines in the test, Kozur and Mostler (1989) included their forms in the new genus *Ellipsocopicyntra* that differs from *Copiellintra* by the presence of numerous spines along the entire test. But, Nazarov (1988) pointed out that the representatives of the latter genus have two to six spines, or more that was not taken under consideration by Kozur and Mostler. Thus, we consider that the genus *Ellipsocopicyntra* is a junior synonym of the genus *Copiellintra*.

**Range:** Carboniferous, Upper Pennsylvanian – Upper Permian, Lopingian, Changhsingian.

*Copiellintra orbiculata* Nestell and Nestell, n. sp.

Plate 11, figures 9-11; Plate 18, figures 5-6

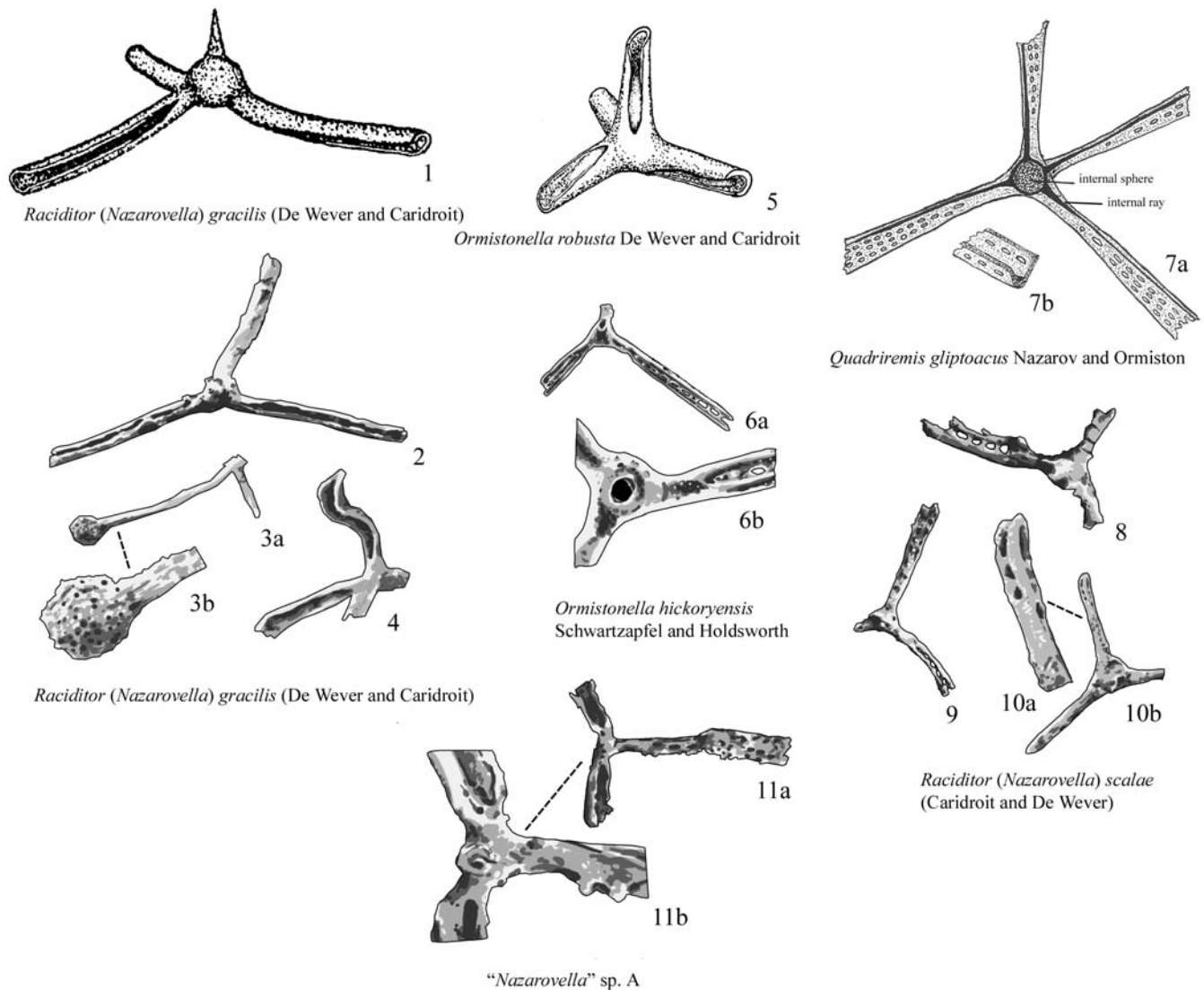
**Diagnosis:** Elliptical to oval *Copiellintra* with 10 internal shells and absence of spines.

**Description:** Test elliptical to oval, relatively large, consists of an external spongy shell and tiny inner sphere. More than 10 ellipsoidal shells are developed between them. Radial beams from the inner sphere cross all shells up to external shell. No external spines were seen.

**Measurements ( $\mu\text{m}$ ):** test length 200-370, test thickness 160-280, diameter of rounded pores of the external shell 4-6.

**Designation of types:** The specimen illustrated on plate 11, figure 10 (no. USNM 538632) is designated as the holotype and the specimen on plate 11, figure 9 (no. USNM 538631) and fig-





TEXT-FIGURE 11

Schematic views of some species of the family Ormistonellidae. Figs. 1 – 5, 8 – 10 – after Caridroit and De Wever 1986; fig. 6 – after Schwartzapfel and Holdsworth 1996; fig. 7 – after Nazarov and Ormiston 1985a.

ure 11 (no. USNM 538633), and on plate 18, figure 5 (no. USNM 538719) and figure 6 (no. USNM 538720) as the paratypes. They are from West Texas, Apache Mountains, 50km north-east of Van Horn, Texas FM 2185, EF section, unit E, holotype and paratypes (pl. 18, figs. 5 and 6) from sample E-1 and paratypes (pl. 11, fig. 11) from sample E-2, and paratype (pl. 11, fig. 9) from unit B, sample F-13; the upper part of the Bell Canyon Formation, age equivalent to the Reef Trail Member, upper Capitanian, Middle Permian.

**Etymology:** From the Latin *orbiculatus* – rounded.

**Material:** Abundant and 10 specimens have been photographed and measured.

**Discussion:** *Copiellintra orbiculata* n. sp. is similar to *Copiellintra elongata* Feng (in Feng et al. 2006b, p. 37, pl. 6,

figs. 15-24) based on the elliptical shape of the test, but differs from it by larger size and the absence of spines.

**Occurrence:** As the holotype and paratype, and also EF section, units A, C, D, E, the upper part of the Bell Canyon Formation, age equivalent to the Reef Trail Member, Apache Mountains; Bell Canyon Formation, Lamar Limestone Member (Noble and Jin this volume) and Reef Trail Member (Maldonado and Noble this volume), Guadalupe Mountains; West Texas; Middle Permian, upper Capitanian.

***Copiellintra fastuosa* Nestell and Nestell, n. sp.**

Plate 11, figures 12-15; Plate 12, figure 1

**Diagnosis:** Spongy and oval *Copiellintra* with 10 internal shells and rod-like main spines concentrated in the polar regions and numerous short secondary spines.

**Description:** Test oval with an external spongy shell and internal small porous internal shell. Ten internal shells are developed between the external shell and inner sphere. Numerous radial beams extend from the inner sphere, cross all shells and connect with the external main spines and secondary short conical spines of different length. The shape of main spines is rod-like and they are concentrated in the polar regions. Pores of the external shell are very small and rounded.

**Measurements ( $\mu\text{m}$ ):** test length 250-380, thickness 200-260, the length of main spines 110-130, secondary spines 30-40, and diameter of pores 3-5.

**Designation of types:** The specimen illustrated on plate 11, figure 13 (no. USNM 538635) is designated as the holotype and the specimens on plate 11, figure 12 (no. USNM 538634), figure 14 (no. USNM 538636) and figure 15 (no. USNM 538637), and on plate 12, figure 1 (no. USNM 538638) as the paratypes. They are from West Texas, Apache Mountains, 50km north-east of Van Horn, Texas FM 2185, EF section, unit B, holotype and paratype (pl.11, fig. 12) from sample F-8, paratypes (pl. 11, figs. 14 and 15) from sample F-13, and paratype (pl. 12, fig. 1) from unit E, sample E-1; the upper part of the Bell Canyon Formation, age equivalent to the Reef Trail Member, upper Capitanian, Middle Permian.

**Etymology:** From the Latin *fastuosus* – magnificent.

**Material:** Abundant and 11 specimens have been photographed and measured.

**Discussion:** Based on the developed numerous spines, *Copiellintra fastuosa* n. sp. is similar to *Copiellintra sakmarensis* (Kozur and Mostler) (Kozur and Mostler 1989, p. 219, pl. 2, fig. 4), but differs from it by the larger size of the test, longer main spines concentrated in the polar regions and different shape of the main spines.

**Occurrence:** As the holotype and paratype, and also EF section, units A, C, D, the upper part of the Bell Canyon Formation, age

equivalent to the Reef Trail Member, Apache Mountains; Bell Canyon Formation, Reef Trail Member (Maldonado and Noble this volume), Guadalupe Mountains; West Texas; Middle Permian, upper Capitanian.

Order LATENTIFISTULATA Caridroit, De Wever and Dumitrica 1999 [nom. correct. herein pro order Latentifistularia Caridroit, De Wever and Dumitrica 1999; = Stauraxonarida Amon 2000; = Radiiformata Afanasieva and Amon in Afanasieva et al. 2005]

Family LATENTIFISTULIDAE Nazarov and Ormiston 1983a  
Subfamily LATENTIFISTULINAE Nazarov and Ormiston 1983a

Genus *Latentifistula* Nazarov and Ormiston 1983a; emend. Kozur and Mostler 1989 [= *Wonella* Kozur and Mostler 1989; non *Wonella* Afanasieva 2000]

Type species: *Latentifistula crux* Nazarov and Ormiston 1983a.

**Diagnosis:** Test with internal porous or nonporous sphere with three hollow rays enclosing spongy single shell. Rays radiate from the inner sphere at angles of  $120^\circ$  and are connected with small terminal external spines.

**Remarks:** Nazarov and Ormiston (1983a) described a new genus *Latentifistula* (type species *Latentifistula crux*) with triradiate and lobate forms with a spongy and platy meshwork from strata of the Lower Permian, Asselian of Southern Urals. At the same time they established a new family Latentifistulidae and gave an outline of this family. In the composition of their genus *Latentifistula*, they included also the species *Paronaella impella* described by Ormiston and Lane (1976) based on reexamination of topotype specimens in transmitted light. This reexamination showed that the internal morphology of *P. impella* coincides with the generic affinity of the genus *Latentifistula*. Simultaneously with the publication of the paper of Nazarov and Ormiston (1983a), a monograph of Won (1983) was published, where she described several new genera from the Lower

## PLATE 1

Latest Capitanian (Guadalupian, Middle Permian) radiolarians from the EF section, Apache Mountains, West Texas.  
Scale bar is 100 $\mu\text{m}$ , except for figs. 5b, 6b–10 $\mu\text{m}$ .

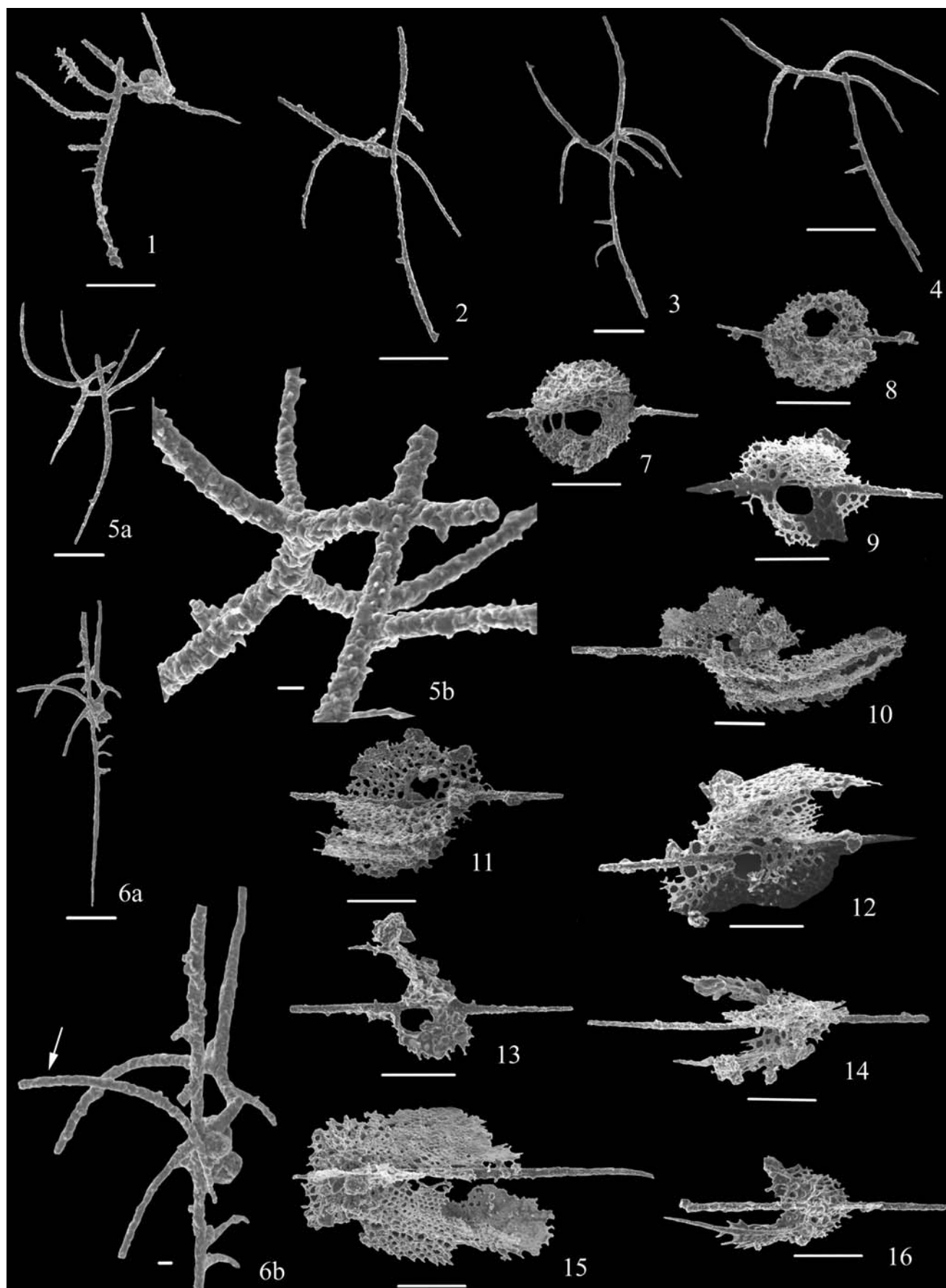
- 1-6 *Campanulithus insuetus* Nestell and Nestell, n. sp. 1 – no. USNM 538510, sample F-8, unit B; 2 – no. USNM 538511, paratype, sample F-19, unit D; 3 – no. USNM 538512, holotype, sample F-19, unit D; 4 – no. USNM 538513, sample F-19, unit D; 5a – no. USNM 538514, paratype, 5b – enlarged view of the intersection of the main spine and two lateral spines, right one is broken, sample F-19, unit D; 6a – no. USNM 538515, 6b – enlarged view of the intersection of the main spine and two lateral spines, the spine shown by arrow probably does not belong to this specimen; sample F-19, unit D.
- 7-9 *Raphidociclicus americanus* Nazarov and Ormiston. 7 – no. USNM 538516, sample F-8, 8 – no. USNM

538517, sample F-8, 9 – no. USNM 538518, sample F-13; unit B.

10-14, 16 *Raphidociclicus scutum* Maldonado and Noble. 10 – no. USNM 538519, sample F-13, 11 – no. USNM 538520, sample F-13, 12 – no. USNM 538521, sample F-13, 13 – no. USNM 538522, sample F-8, 14 – no. USNM 538523, sample F-13, 16 – no. USNM 538524, sample F-13; unit B.

15 *Raphidociclicus* sp. 1, no. USNM 538525, sample F-13, unit B.





Carboniferous in Germany, including the genus *Scharfenbergia* (type species *Spongotropus concentricus* Rüst 1892) with a triangular spongy test composed of an internal sphere with three rays extended from it. Won (1983) included the species *Paronaella impella* in the composition of the genus *Scharfenbergia*, and also some species with absolutely different morphology (e.g., *Spongotropus rustae* Ormiston and Lane 1976, *Paronaella turgida* Ormiston and Lane 1976, and a new species *Scharfenbergia plenospongiosa*). On one hand, according to Cheng (1986), the genus *Scharfenbergia* represents a combined genus and thus, it is not valid. On the other hand, this genus was accepted by Holdsworth and Murchey (1988) and they described several new species under *Scharfenbergia*. They also assigned the species *Paronaella impella* to *Scharfenbergia*. Because of such contradictory data about the genus, Kozur and Mostler (1989) emended the diagnosis of the genus *Scharfenbergia* and included the following species in the composition of the genus: *Scharfenbergia concentrica* (Rüst 1892), *Spongotropus rustae* and *Scharfenbergia plenospongiosa*. They also established a new family Scharfenbergidae with the genera *Scharfenbergia*, *?Triactofenestrella* Nazarov and Ormiston 1984, and their new genus *Wonella* with the type species *Paronaella impella*. The species *Paronaella turgida*, Kozur and Mostler (1989) placed in the genus *Latentifistula* Nazarov and Ormiston 1983a. They also emended the description of the genus *Latentifistula* leaving in the composition of the genus forms only with triradiate and lobate tests with a spongy meshwork. They did not take into consideration that Nazarov and Ormiston (1983a) reexamined the topotypes of the species *Paronaella impella* and assigned it to the genus *Latentifistula*.

Thus, we agree with Nazarov and Ormiston about the generic assignment of the species *Paronaella impella* to the genus *Latentifistula*, and we consider that the genus *Wonella* of Kozur and Mostler is a junior synonym of the genus *Latentifistula*. We also agree with the opinion of Kozur and Mostler (1989) that the scope of the genus *Latentifistula* should be limited to forms with triradiate and lobate tests enclosed in a spongy shell. Forms with a platy-lattice shell we include in the genus *Praedelflandrella* Kozur and Mostler 1989 (type species *Latentifistula neotenica* Nazarov and Ormiston 1985a). Relative to the genus *Scharfenbergia*, we follow De Wever et al. (2001) who accepted this genus as a valid genus with the type species *Scharfenbergia concentrica* (Rüst 1892) sensu Won (1983). But we consider that this genus should be placed in the family Ruzhencevispongidae Kozur 1980, and not in the family Latentifistulidae Nazarov and Ormiston 1983a based on morphology of the type species.

*Range:* Carboniferous, Mississippian – Upper Permian, Lopingian, Changhsingian.

*Latentifistula texana* Nazarov and Ormiston 1985a

Plate 12, figure 6

*Latentifistula texana* NAZAROV and ORMISTON 1985a, p. 33, pl. 4, fig. 4. – NAZAROV and ORMISTON 1986b, fig. 2. – BLOME and REED 1992, p. 375, fig. 13- 6. – WANG and Li 1994, p. 204, pl. 1, figs. 15-16. – WANG et al. 1994, p. 189, pl. 3, fig. 26 with synonymy; DE WEVER et al. 2001, fig. 54-4. – WANG and YANG 2003, p. 335, pl. 1, figs. 1-5. – WANG et al. 2006, fig. 11FF, ZH.

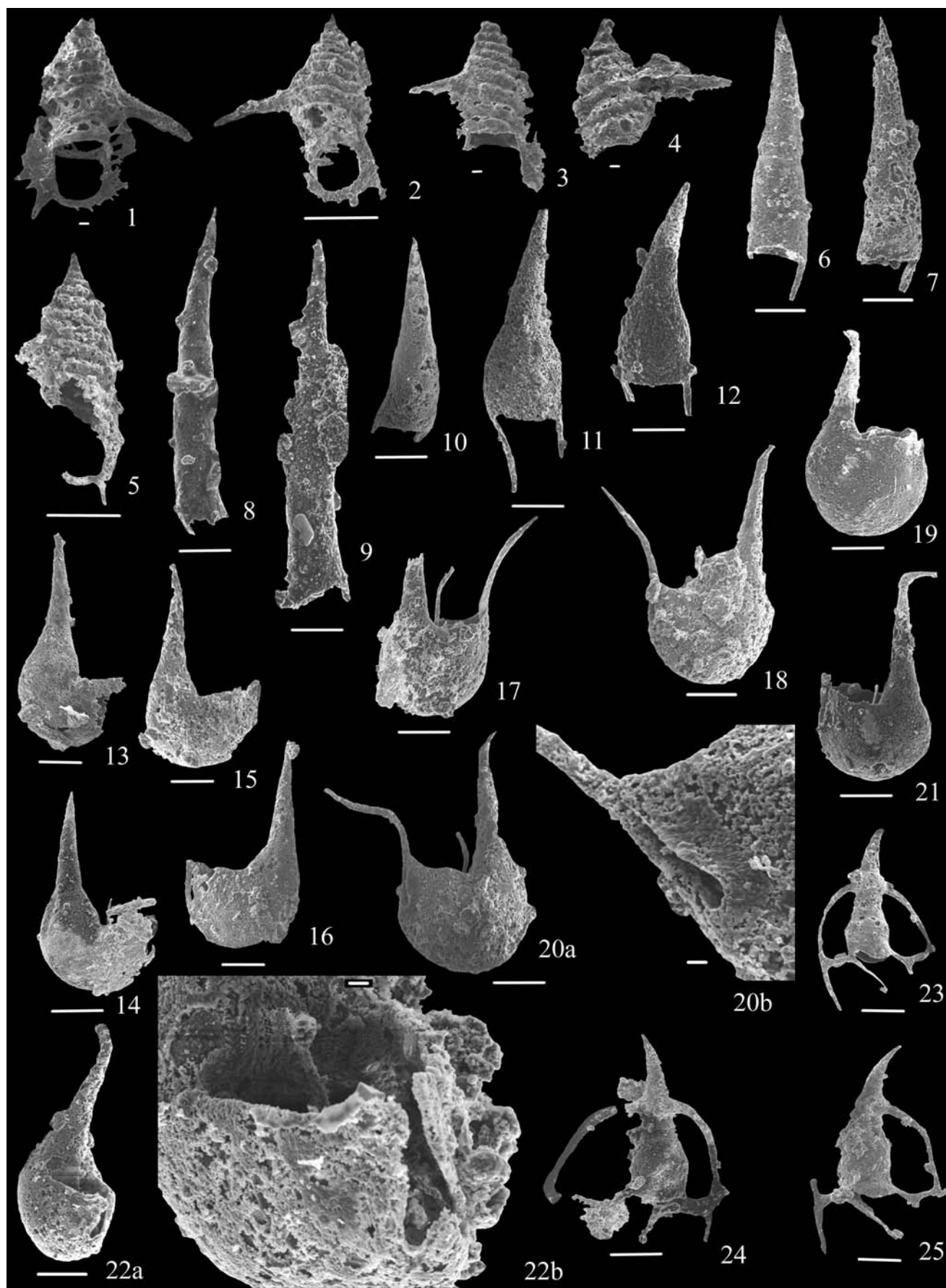
## PLATE 2

Latest Capitanian (Guadalupian, Middle Permian) radiolarians from the EF section, Apache Mountains, West Texas.

Scale bar is 100µm, except for figs. 1, 3, 4, 20b, 22b – 10µm.

- |   |   |
|---|---|
| <p>1-4 <i>Albaillella yamakitai</i> Kuwahara in the sense of Xia et al. 2005. 1 – no. USNM 538526, sample F-8, 2 – no. USNM 538527, sample F-8, 3 – no. USNM 538528, sample F-13, 4 – no. USNM 538529, sample F-13; unit B.</p> <p>5 <i>Albaillella</i> sp. 1, no. USNM 538530, sample F-8, unit B.</p> <p>6-9 <i>Follicucullus scholasticus</i> Ormiston and Babcock. 6 – no. USNM 538531, sample SK-12, unit A; 7 – no. USNM 538532, sample SK-12, unit A; 8 – no. USNM 538533, sample F-6, unit D; 9 – no. USNM 538534, sample F-8, unit B.</p> <p>10 <i>Follicucullus japonicus</i> Ishiga, no. USNM 538535, sample AHA-2, unit A.</p> <p>11-12 <i>Follicucullus dilatatus</i> Rudenko. 11 – no. USNM 538536, sample F-9A, base of unit B; 12 – no. USNM 538537, sample F-9A, base of unit B.</p> | <p>13-16 <i>Follicucullus orthogonus</i> Caridroit and De Wever. 13 – no. USNM 538538, sample F-8, unit B; 14 – no. USNM 538539, sample F-8, unit B; 15 – no. USNM 538540, sample F-8, unit B; 16 – no. USNM 538541, sample F-8, unit B.</p> <p>17-22 <i>Follicucullus sphaericus</i> Takemura in Takemura et al. 1999. 17 – no. USNM 538542, sample F-8, unit B; 18 – no. USNM 538543, sample F-8, unit B; 19 – no. USNM 538544, sample F-15, unit B; 20a – no. USNM 538545, 20b – enlarged view of hollow sinus, sample F-8, unit B; 21 – no. USNM 538546, sample F-8, unit B; 22a – no. USNM 538547, 22b – enlarged view showing the hollow sinus with a triangular flap, aperture, and ventral spine, sample F-8, unit B.</p> <p>23-25 <i>Pseudoalbaillella delawarensis</i> Maldonado and Noble. 23 – no. USNM 538548, sample SK-12, unit A; 24 – no. USNM 538549, sample F-8, unit B; 25 – no. USNM 538550, sample SK-12, unit A.</p> |
|---|---|





**Occurrence:** China, Dazong Range and Rock House, *Follicucullus bipartitus*-*F. charveti* Assemblage Zone; South China, *Follicucullus monacanthus* Zone, and Kuhfeng Formation, Guangdong Province; USA, Oregon, Blue Mountains, Grindstone terrane; West Texas, Guadalupe Mountains, the Bell Canyon Formation, the Hegler Limestone Member and Reef Trail Member (Maldonado and Noble this volume), and Apache Mountains, EF section, unit A and at the base of unit B, the upper part of the Bell Canyon Formation, analogous of the Lamar Limestone (unit A) and the Reef Trail (unit B) Members; Middle Permian, upper Wordian and Capitanian.

Family ORMISTONELLIDAE De Wever and Caridroit 1984; emend. Schwartzapfel and Holdsworth 1996; emend. De Wever et al. 2001 [= Paulianellidae Kozur and Mostler 1989; = Quadriremidae Afanasieva 2000]

**Remarks:** The family Ormistonellidae from the Upper Permian of southwestern Japan has been introduced by De Wever and Caridroit (1984) together with establishing two new genera: *Ormistonella* with type species *O. robusta* and *Nazarovella* with type species *N. gracilis* (text-fig. 11, 1-5). Both of these genera are characterized by four well developed gutter-shaped arms with a U-shaped cross section, but differences between them are in the unequal development of the fourth arm: *Ormistonella* has four equal arms, and *Nazarovella* has three equal arms and a fourth one that is very small compared with the other three. Later, Caridroit and De Wever (1986) gave expanded diagnoses of these two genera and correspondingly of their type species, and also described one new species, *Nazarovella scalae* (text-fig. 11, 8-10), and one form in open nomenclature under name *Nazarovella* sp. A (text-fig. 11, 11). The differences between *Ormistonella* and *Nazarovella* remained the same. Almost at the same time, Nazarov and Ormiston (1985a) described a new genus *Quadriremis* with type species *Q. gliptoacus* from the Lower Permian, Artinskian of

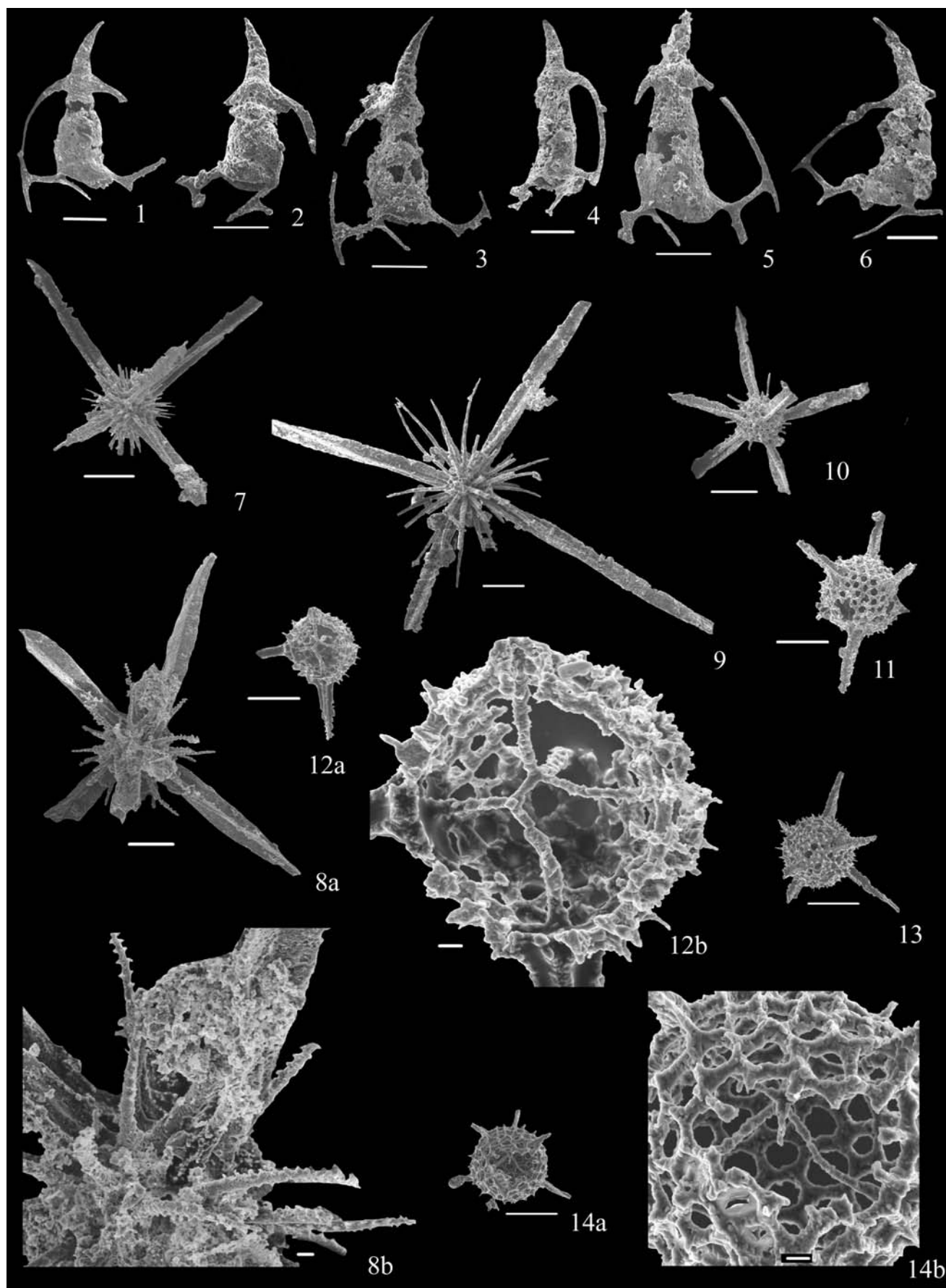
Southern Urals (text-fig. 11, 7). This genus is characterized by having four hollow rays (or arms), three of which emerge from the inner sphere at 120° and fourth one that is perpendicular to them. They also observed an “internal framework enclosed in platy or platy latticed or rarely in spongy shell” (Nazarov and Ormiston, 1985a, p. 36) with pores arrayed in two or three rows distally. Terminal spines are present in the distal part of the arms, and the proximal part of the arms has a deep furrow. Excluding the porous arms, the genus *Quadriremis* is similar in morphology to the genus *Ormistonella*, at least as it was described by De Wever and Caridroit. This fact permitted Kozur and Mostler (1989) to conclude that *Quadriremis* is a junior synonym of the genus *Ormistonella*. They also expanded the diagnosis of the family Ormistonellidae without official emendation, adding to it the description of the genus *Quadriremis*. Much later, Schwartzapfel and Holdsworth (1996) found forms that they considered similar in morphology to *Ormistonella* from the Mississippian of the Arbuckle Mountains in Oklahoma. They described a new species *Ormistonella hickoryensis* with test composed of an “imperforate globose tetrahedral central sphere surrounded by four extremely long rays which are near equal to equal in length; distal portion of each ray bearing a latticed meshwork formed by three longitudinal beams interconnected by numerous laterally transverse bars” (Schwartzapfel and Holdsworth 1996, p. 216) (text-fig. 11, 6). Based on this description and the illustration of this species, it is most likely that their new species should be assigned to the genus *Nazarovella*, and not to *Ormistonella*. Schwartzapfel and Holdsworth (1996) emended the diagnoses of the family Ormistonellidae and the genus *Ormistonella*. In this genus, Schwartzapfel and Holdsworth (1996) included tests with perforate (e.g., latticed) or imperforate (e.g., platy) gutter-shaped rays (or arms). Their opinion coincided with the opinion of Kozur and Mostler, but Schwartzapfel and Holdsworth (1996) did not make any conclusion about the genus *Quadriremis*. It is not clear that these authors consider the latter genus as a valid

### PLATE 3

Latest Capitanian (Guadalupian, Middle Permian) radiolarians from the EF section, Apache Mountains, West Texas.  
Scale bar is 100µm, except for figs. 8b, 12b, 14b – 10µm.

- 1-3 *Pseudoalbaillella delawarensis* Maldonado and Noble. 1 – no. USNM 538551, sample SK-12, unit A; 2 – no. USNM 538552, sample E-1, unit E; 3 – no. USNM 538553, sample SK-12, unit A.
- 4-5 *Pseudoalbaillella apachensis* Nestell and Nestell, n. sp. 4 – no. USNM 538554, paratype, sample F-8, 5 – no. USNM 538555, holotype, sample F-8; unit B.
- 6 *Pseudoalbaillella* sp. A, no. USNM 538556, sample F-8, unit B.
- 7,9-10 *Entactinia parapycnoclada* Nazarov and Ormiston. 7 – no. USNM 538557, sample F-19, unit D; 9 – no. USNM 538558, sample F-13, unit B; 10 – no. USNM 538559, sample F-19, unit D.
- 8 *Entactinia* sp. 1, 8a – no. USNM 538560, 8b – enlarged view of the cortical shell showing long secondary spines with small denticles, sample E-2, unit E.
- 11-14 *Entactinia wildei* (Noble and Jin). 11 – no. USNM 538561, sample F-19, unit D; 12a – no. USNM 538562, broken test showing internal structure, 12b – enlarged view of the cortical shell with an internal six-rayed bar-centered spicule located almost in the center of the test, sample F-19, unit D; 13 – no. USNM 538563, sample F-19, unit D; 14a – no. USNM 538564, broken specimen showing internal structure, 14b – enlarged view showing an internal spicule located close to the center of the test and small thorns or broken secondary spines formed on the intersections of the interpore bars; sample F-19, unit D.





genus or not. Recently, Feng et al. (2006a) described several new species under generic name *Ormistonella* from the Upper Permian (Changhsingian) of China. These forms have gutter-shaped porous arms and lace (probably seen due to good preservation) along each ventral side of the arms (species *Ormistonella adhaerensis*), three-bladed arms (three wide grooves and three rounded ridges) and hollow and porous distal part of the arms in shape of a flat sphere with terminal spines (species *O. elegans*). These authors did not give any remarks as to whose concept they followed, but their understanding of the genus *Ormistonella* seems to coincide with the opinion of Schwartzapfel and Holdsworth (1996).

The holotype of the type species of the genus *Ormistonella*, *O. robusta*, illustrated by De Wever and Caridroit (1984, pl. 2, figs. 8-9) and later repeated by Caridroit and De Wever (1986, pl. 4, figs. 7-8), clearly shows that the gutter-shaped structure on all four arms begins immediately from the central part and the arms rapidly expand. The presence of the gutter-shaped arms shows close similarity between the genera *Ormistonella* and *Nazarovella*, but the latter differs from the genus *Ormistonella* by an underdeveloped fourth short arm on the central spherical part compare to the others, globose tetrahedral central part and the presence of a well developed porous subspherical shell at the end of the arms (based on type species of *Nazarovella gracilis* emended by Caridroit and De Wever in 1986). Both genera, *Ormistonella* and *Nazarovella*, have U-shape cross sections of all arms.

From the time of establishment of the genera *Ormistonella* and *Nazarovella* and even to now, it is very confusing as to which genus such similar forms can be assigned, because, in our opinion, the type species of *Ormistonella* was described based on an incomplete specimen. Even the authors of these two genera seem to be confused. They described a new species *Nazarovella scalae* Caridroit and De Wever 1986 with morphology that is different from the original description of the genus *Nazarovella*. The new species has a globose tetrahedron imperforate central part with four arms, three of which are tubular proximally (without a gutter-shaped arm), and then in the distal part the tubular arm is subdivided onto two or three independent

rods connected by a porous meshwork. This meshwork forms a groove between two rods with subrectangular pores in one row that creates the impression of a porous or lattice shell. Such morphology is very similar to the genus *Quadriremis* Nazarov and Ormiston 1985a. Furthermore, Caridroit and De Wever (1986) described similar forms under the name *Nazarovella* sp. A with four arms arranged in a tetrahedral manner, one of which was short and perpendicular to the three others, and circular in cross section and not hollow, and possibly was a broken specimen. The other three arms are gutter-shaped with a U-shaped cross section in the proximal part, two of which have two rods joined together by a perforate shell and were also broken. The third arm has two opposite grooves in the proximal part and is distally "made up of longitudinal beams (or rods) and transverse bars" (Caridroit and De Wever 1986, p. 85). On one hand, *Nazarovella* sp. A resembles the genus *Ormistonella* in the central part and, on the other hand, the proximal part of the arm with two rods with a perforate meshwork on two arms inserts as stated in the emended diagnosis of the genus *Ormistonella* made by Schwartzapfel and Holdsworth (1996). According to them, *Nazarovella* sp. A of Caridroit and De Wever (1986) should be assigned to the genus *Ormistonella*. Moreover, Feng et al. (2006a, pl. 10, figs. 21 and 22) illustrated two specimens under the name *Ormistonella robusta* (type species of the genus *Ormistonella*). One (Feng et al. 2006a, fig. 22) is similar to the holotype, the second one (fig. 21) represents the broken distal part of the arm with a gutter-shaped structure and with a flat sphere of spongy meshwork that never was mentioned by De Wever and Caridroit in the original diagnosis of the species. If this broken distal part of the arm belongs to *Ormistonella robusta* or not, will not be known until complete specimens are found and the species is redescribed, and correspondingly, the diagnosis of the genus *Ormistonella* is emended. This broken arm with a flat spongy sphere resembles the species *Nazarovella gracilis*, whose expanded diagnosis was given by Caridroit and De Wever (1986), but in *N. gracilis* the terminal part of the arms has a rounded spongy meshwork. Furthermore, the species *Quadriremis gliptoacus* Nazarov and Ormiston 1985a (type species of the genus *Quadriremis*), *Q. minima* Nazarov and Ormiston 1985a, and *Q. nevadensis* Nazarov and Ormiston 1989 are similar in morphology with either of the gen-

#### PLATE 4

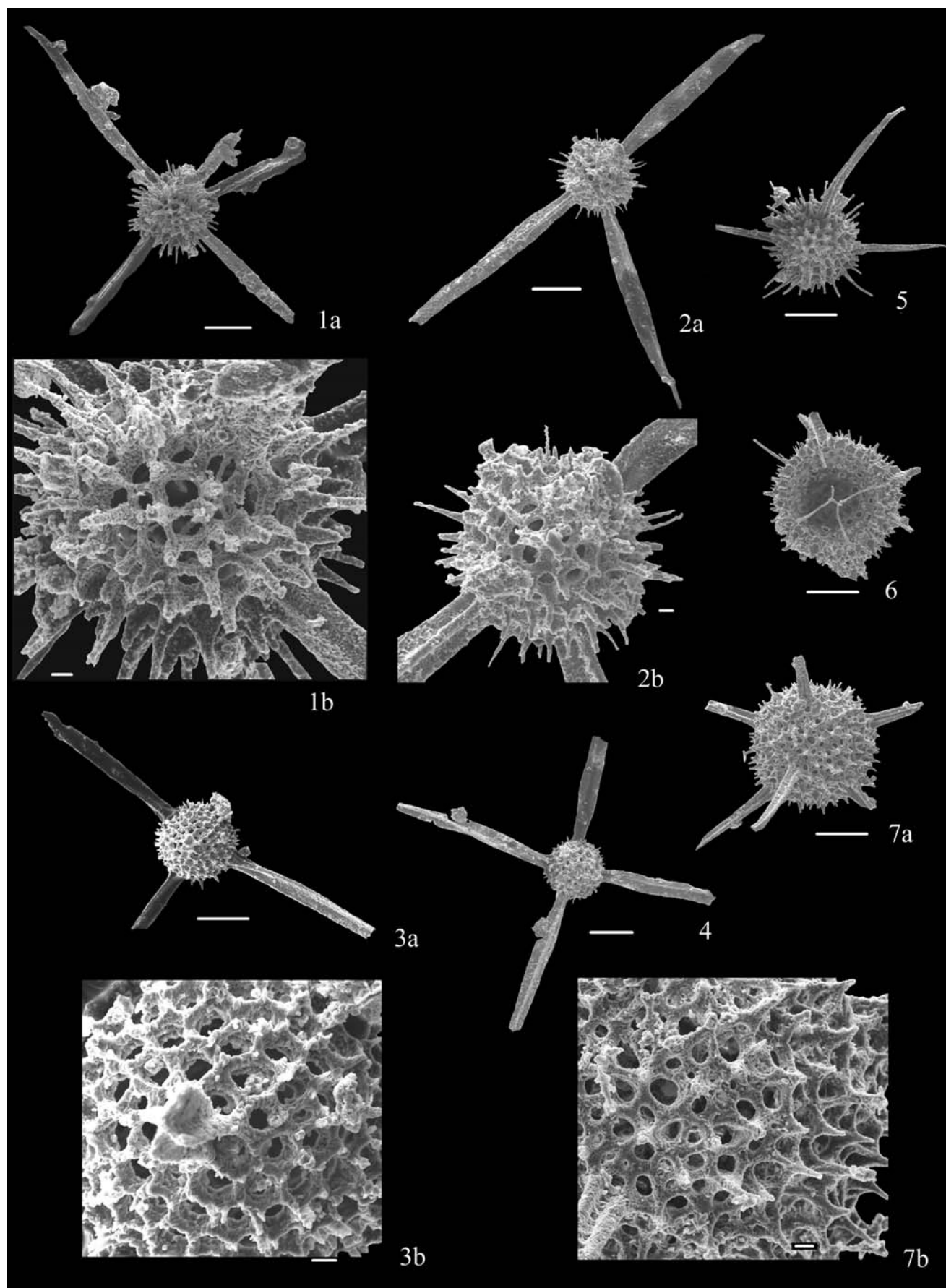
Latest Capitanian (Guadalupian, Middle Permian) radiolarians from the EF section, Apache Mountains, West Texas.  
Scale bar is 100µm, except for figs. 1b, 2b, 3b, 7b – 10µm.

- 1-4 *Entactinia itsukaichiensis* Sashida and Tonishi. 1a – no. USNM 538565, 1b – enlarged view of the porous cortical shell showing rounded pores and secondary conical spines on the intersections of the interpore bars, sample F-8, unit B; 2a – no. USNM 538566, 2b – enlarged view of the porous cortical shell showing rounded pores and numerous conical secondary spines, sample E-2, unit E; 3a – no. USNM 538567, 3b – enlarged view of the porous cortical shell with rounded pores and broken Y-shaped cross section of the one of the main spines located just to the left of the

center of the picture, sample F-8, unit B; 4 – no. USNM 538568, sample E-2, unit E.

- 5-7 *Entactinia* sp. 2. 5 – no. USNM 538569, sample E-1, unit E; 6 – no. USNM 538570, broken specimen showing internal bar-centered spicule located in the center of the test, sample E-1, unit E; 7a – no. USNM 538571, 7b – enlarged view of the porous cortical shell showing rounded pores and pointed conical thorns or broken secondary spines, sample E-1, unit E.





era *Nazarovella* or *Ormistonella*. Sashida and Tonishi (1986) and Blome and Reed (1992) all pointed out the similarity among the genera *Nazarovella*, *Quadriremis* and *Ormistonella*.

Summarizing the above comments, one can see that it is very difficult to distinguish the genera *Ormistonella*, *Nazarovella* and *Quadriremis*. De Wever et al. (2001) gave an emended diagnosis of the family Ormistonellidae and included the genus *Quadriremis* as a junior synonym of the genus *Nazarovella* without any explanation. The genus *Ormistonella* was considered by them as a valid genus with the inclusion of the genus *Paulianella* Kozur and Mostler 1989 as a junior synonym. In this paper we consider that the genus *Quadriremis* described on the basis of complete specimens is a valid genus, and the status of *Ormistonella* remains questionable until better preserved specimens are found and the generic status of the genus clarified. Here we include species only with globose central part in the genus *Nazarovella*. However, the name *Nazarovella* was used by Kozur and Mostler (1979) for spherical Triassic radiolarians. Thus, Sugiyama (2000) proposed a new generic name *Raciditor* for the genus *Nazarovella* of De Wever and Caridroit (1984).

We consider that the family Quadriremidae Afanasieva 2000 is a junior synonym of the family Ormistonellidae described by De Wever and Caridroit (1984) based on the almost identical diagnoses for the two families. According to Afanasieva (2000) and Afanasieva et al. (2005), the differences were in the description of the presence of a lamellar or platy shell in the representatives of the family Ormistonellidae and a porous or platy-porous shell in the family Quadriremidae which, in our opinion, depend on the preservation.

Genus *Raciditor* Sugiyama 2000 [nom. substit. Sugiyama 2000 pro *Nazarovella* De Wever and Caridroit 1984]; emend. Nestell and Nestell, herein

Type species: *Raciditor gracilis* (De Wever and Caridroit 1984) [nom. substit. Sugiyama 2000 pro *Nazarovella gracilis* De Wever and Caridroit 1984].

*Emended diagnosis*: Test consists of four rays extended from a distinctly expressed globose nonporous sphere. Three rays extend from the sphere at 120° or two rays at 130° and one at 100°, and a fourth underdeveloped ray is perpendicular to those three rays. They are tubular or gutter-shaped in the proximal part of the test, and distally remain gutter-shaped and imperforate (platy) or form a bundle of three rods connected with each other by bars which create the impression of perforate or porous shell. One of the rods continues as the terminal spine. In some species a spongy spherical or subspherical shell can be present at the terminal end of the rods.

*Composition of the genus*: *Raciditor gracilis* (De Wever and Caridroit 1984), *Raciditor scalae* (Caridroit and De Wever 1986), *Raciditor inflatus* (Sashida and Tonishi 1986), *Ormistonella hickoryensis* Schwartapfel and Holdsworth 1996, *Raciditor phlogides* (Wang and Li 1994), and *Quadriremis minima* Nazarov and Ormiston 1985a.

*Range*: Carboniferous, Upper Mississippian – Upper Permian, Lopingian, Changhsingian.

Family CAULETELLIDAE Caridroit, De Wever and Dumitrica 1999 [nom. substit. Caridroit et al. 1999 pro family Deflandrellidae De Wever and Caridroit 1984; = Kimagioridae Sugiyama 2000]

*Remarks*: Caridroit et al. (1999) substituted the previous name of the family Deflandrellidae De Wever and Caridroit 1984 as Cauletellidae and correspondingly the genus *Deflandrella* De Wever and Caridroit 1984 to *Cauletella* because the generic name is a homonym of *Deflandrella* Loeblich and Tappan 1961. One year later, Sugiyama (2000) proposed to change the generic name *Deflandrella*, to *Kimagior* and correspondingly, the name of the family to Kimagioridae, based on the same reason. But he probably did not see the paper of Caridroit et al. (1999) published one year before. Thus, the name of the family and correspondingly of the new genus of Sugiyama are junior synonyms of the family Cauletellidae and genus *Cauletella*. In 1989 Kozur and Mostler included the genera *Deflandrella* (now *Cauletella*) and their new genus *Praedeflandrella* in the composition of the

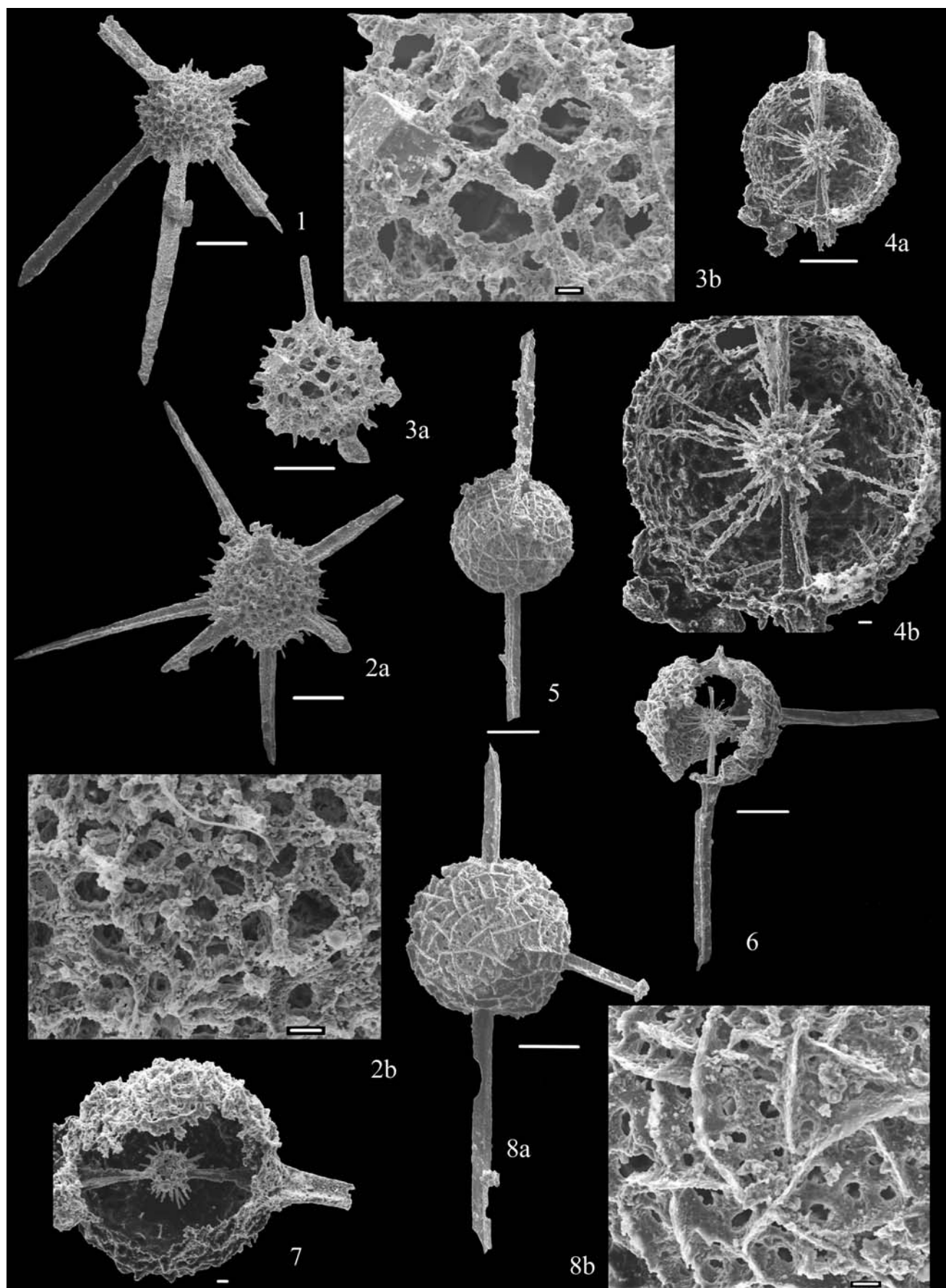
## PLATE 5

Latest Capitanian (Guadalupian, Middle Permian) radiolarians from the EF section, Apache Mountains, West Texas.  
Scale bar is 100µm, except for figs. 2b, 3b, 4b, 7, 8b – 10µm.

- 1-2 *Entactinia modesta* Sashida and Tonishi. 1 – no. USNM 538572, sample F-9A, unit B; 2a – no. USNM 538573, 2b – enlarged view showing porous cortical shell with rounded pores, sample F-8, unit B.
- 3 *?Entactinia reticulata* Sashida and Tonishi, 3a – no. USNM 538574, 3b – enlarged view showing latticed cortical shell with large subquadrate pores, sample F-15, unit B.
- 4-8 *Paratriposphaera cimelia* (Nazarov and Ormiston). 4a – no. USNM 538575, broken test showing internal structure, 4b – enlarged view showing internal porous

sphere with numerous thin secondary spines and two primary thick radial beams, sample F-8, unit B; 5 – no. USNM 538576, sample E-2, unit E; 6 – no. USNM 538577, broken test showing small internal sphere with numerous secondary spines and four primary radial beams, sample E-2, unit E; 7 – no. USNM 538578, broken test showing internal sphere with numerous secondary spines and two polar primary radial beams, sample E-1, unit E; 8a – no. USNM 538579, 8b – enlarged view of the surface of the cortical shell showing ridges on the surface and small rounded pores between the ridges, sample E-2, unit E.





family Deflandrellidae (now Cauletellidae) with which Blome and Reed (1992) agreed. Later, De Wever et al. (2001) expanded the composition of the family Cauletellidae by adding the following genera: *Cauletellia*, *Foremanhelena* De Wever and Caridroit 1984 (with *Triplanospongia* Sashida and Tonishi 1988 as a junior synonym), *Ishigaum* De Wever and Caridroit 1984 and conditionally *Praedeflandrella* Kozur and Mostler 1989. Afanasieva et al. (2005) in their new classification of radiolarians accepted the family Deflandrellidae (now Cauletellidae) with only the genus *Deflandrella* (now *Cauletellia*) in its composition. In this paper we follow Kozur and Mostler (1989) and Blome and Reed (1992) about the scope of the family Cauletellidae with the genera *Cauletellia* and *Praedeflandrella* in its composition. We also consider that the genus *Shangella* Feng in Feng et al. (2006a) should be included in the composition of the family Cauletellidae based on similar morphology. The genera *Ishigaum* and *Pseudotormetus* De Wever and Caridroit 1984 should be included in the family Ishigaidae Kozur and Mostler 1989 as was proposed by Kozur and Mostler (1989) and supported by Blome and Reed (1992).

Genus *Praedeflandrella* Kozur and Mostler 1989

Type species: *Latentifistula neotenica* Nazarov and Ormiston 1985a.

**Remarks:** Kozur and Mostler (1989) proposed a new genus *Praedeflandrella* with type species *Latentifistula neotenica* Nazarov and Ormiston 1985a for forms with porous arms and not having a spongy shell around them as had been previously described in the genus *Latentifistula*. They include the following species in the composition of the new genus: *L. neotenica*, *L. densa* Nazarov and Ormiston and *Praedeflandrella?* n. sp. illustrated on pl. 10, fig. 3. Later, Feng et al. (2006a) include *Praedeflandrella?* n. sp. (= *Praedeflandrella* sp. in sense of Shang et al. 2001) in the synonymy of their new genus *Shangella*. We consider that *Praedeflandrella* is a valid genus as described by Kozur and Mostler (1989) and accepted by Blome and Reed (1992) based on the different morphological features such as the lack of a spongy shell.

In our Texas material we recognize two species: *Praedeflandrella densa* (Nazarov and Ormiston 1985a) and *P. prolata* Maldonado and Noble (this volume).

**Range:** Lower Permian, Cisuralian, Sakmarian – Middle Permian, Guadalupian, Capitanian.

Genus *Shangella* Feng in Feng et al. 2006a

Type species: *Shangella longa* Feng in Feng et al. 2006a.

**Diagnosis** (after Feng in Feng et al. 2006a, p. 828): Test consists of three coplanar hollow and tubular arms arranged at an angle of 120°. Central part with an internal small sphere is triangular in shape with some minute pores irregularly distributed. Arms are tubular with tiny pores in the proximal part and porous with regularly arranged pores in the rest of the arm. An inflated spongy structure is developed in the distal part of arms.

**Range:** Lower Permian, Cisuralian, Sakmarian – Upper Permian, Lopingian, Changhsingian.

*Shangella capitanensis* Nestell and Nestell, n. sp.

Plate 14, figures 4-6

**Diagnosis:** *Shangella* with long arms and the absence of the inflated spongy structure at the distal ends of the arms.

**Description:** Test consists of three coplanar tubular arms joined to the central part at angles of 110°, 120° and 130° to each other. Central part is of triangular shape with tiny rounded pores distributed irregularly. Arms are hollow with rare small pores in the proximal part, more pores in the middle part and with regular rows of pores forward to the distal part. Arms are straight or slightly curved; narrow in the proximal part and gradually expand to the distal part.

**Measurements** ( $\mu\text{m}$ ): length of arms (depend on preservation) reaches 590-920; width of the arms in proximal part 30-40, in the distal part - 50-70.

## PLATE 6

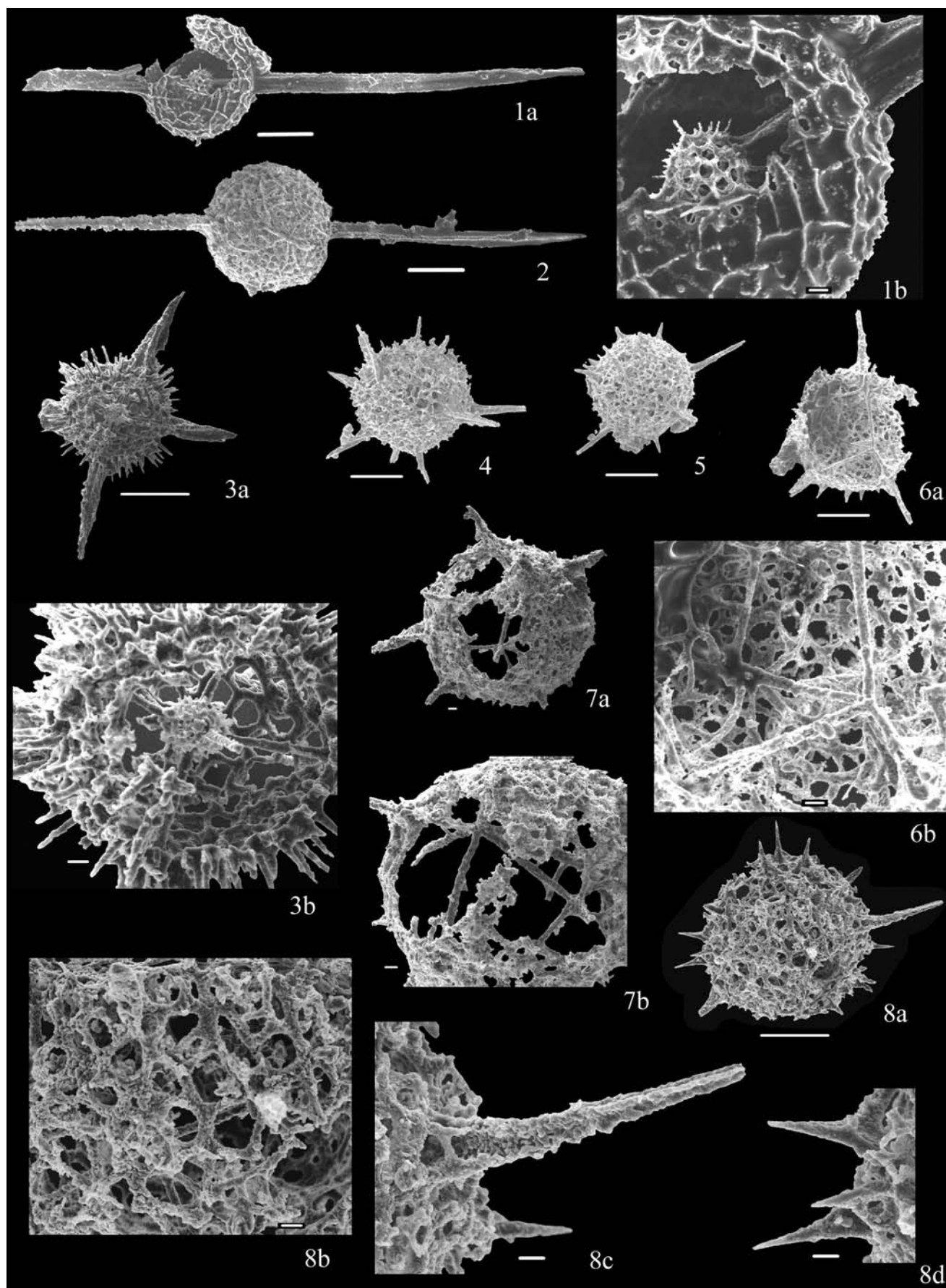
Latest Capitanian (Guadalupian, Middle Permian) radiolarians from the EF section, Apache Mountains, West Texas.

Scale bar is 100 $\mu\text{m}$ , except for figs. 1b, 3b, 6b, 7b, 8b, 8c, 8d – 10 $\mu\text{m}$ .

- 1-2 *Paratriposphaera cimelia* (Nazarov and Ormiston). 1a – no. USNM 538580, broken test showing internal structure, 1b – enlarged view showing porous internal sphere with secondary spines and ridges on the surface of the cortical shell, sample E-1, unit E; 2 – no. USNM 538581, sample F-8, unit B.
- 3 “*Entactinia*” *tyrrelli* Nazarov and Ormiston (see remarks in Noble and Jin this volume). 3a – no. USNM 538582, 3b – enlarged and rotated view showing small internal sphere with rod-like radial beams, sample F-13, unit B.
- 4-8 *Astroentactinia capitanensis* Nestell and Nestell, n. sp. 4 – no. USNM 538583, sample F-13, unit B; 5 – no.

USNM 538584, sample F-13, unit B; 6a – no. USNM 538585, broken test showing the eccentrically located spicule, 6b – enlarged view showing the four - (probably six) rayed spicule with apophyses, sample F-13, unit B; 7a – no. USNM 538586, paratype, 7b – enlarged and rotated view of the paratype showing the internal spicule, sample F-13, unit B; 8a – no. USNM 538587, holotype, 8b – enlarged view of the porous external shell with rounded polygonal pores, 8c – enlarged view of the primary narrow three-bladed spine, 8d – enlarged view of conical secondary spines, sample F-13, unit B.





**Designation of types:** The specimen illustrated on plate 14, figure 4 (no. USNM 538661) is designated as the holotype and the specimens on plate 14, figures 5 (no. USNM 538662) and figure 6 (no. USNM 538663) as the paratypes. They are from West Texas, Apache Mountains, 50km north-east of Van Horn, Texas FM 2185, EF section, unit E, holotype and paratype (fig. 6) from sample E-2, paratype (fig. 5) from sample E-1; the upper part of the Bell Canyon Formation, age equivalent to the Reef Trail Member, upper Capitanian, Middle Permian.

**Etymology:** After El Capitan Peak, Guadalupe Mountains, West Texas, USA.

**Material:** 16 specimens.

**Discussion:** Based on three long coplanar porous arms, *Shangella capitanensis* n. sp. is similar to *S. longa* Feng (in Feng et al. 2006a, p. 829, fig. 6.6, 6.7, 6.9-6.15), but differs from it by longer arms and the absence of an inflated spongy structure at the distal end of the arms.

**Occurrence:** As the holotype and paratypes, and also EF section, units C and D, the upper part of the Bell Canyon Formation, age equivalent to the Reef Trail Member, Apache Mountains; Bell Canyon Formation, Reef Trail Member (Maldonado and Noble this volume), Guadalupe Mountains; West Texas; Middle Permian, Capitanian.

Order PYRAMIDATA Afanasieva and Amon in Afanasieva et al. 2005

Family PSEUDOLITHELIIDAE Kozur and Mostler 1989; emend. De Wever et al. 2001 [= Grandetorturidae Sashida and Tonishi 1991]

**Remarks:** Kozur and Mostler (1989) established a new family Pseudolitheliidae for forms with a spiral growth of the test. Originally, they included in the composition of the family a new genus *Pseudolithelius* and an undescribed new genus in the sense of the species *Spironum haeckeli* Rüst. In the composition

of the new genus *Pseudolithelius*, Kozur and Mostler (1989) included the following species: *P. permicus* n. sp. (type species of the genus), *Lithelius difficilis* Rüst and conditionally *Octatormentum babcockae* Nazarov and Ormiston 1985a stating that the description of *O. babcockae* is based on poorly preserved specimens. Because the specimens of *Pseudolithelius permicus* were better preserved than the specimens of *O. babcockae*, Kozur and Mostler (1989) proposed a new genus *Pseudolithelius*. Later, De Wever et al. (2001) emended the description of the family Pseudolitheliidae including in its composition several genera characterized by spiral coiling of the test: *Grandetortura* Sashida and Tonishi 1991, conditionally *Hegleria* Nazarov and Ormiston 1985a, *Octatormentum* with *Pseudolithelius* as a synonym, *Staurentactinia* Schwartzapfel and Holdsworth 1996, *Tetragregnon* Ormiston and Lane 1976, conditionally *Tetraspongoactinia* Won 1998, and *Tetratormentum* Nazarov and Ormiston 1985a (this latter genus was actually listed as a member of both of the families Pseudolitheliidae and Latentifistulidae on p. 101 by De Wever et al. 2001). In our opinion, the genera *Hegleria*, *Tetragregnon* and *Tetratormentum* do not belong to the family Pseudolitheliidae because they do not have spiral coiling of the test. Afanasieva et al. (2005) did not accept the De Wever et al.'s concept of the composition of the family Pseudolitheliidae and assigned genera with spiral coiling to two different subfamilies of the family Tormentidae Nazarov and Ormiston 1983a (Afanasieva et al. 2005, p. S282). The solution of this taxonomic problem is beyond the scope of this paper. Herein we follow De Wever et al. (2001) and include the genera *Grandetortura* and *Octatormentum* (= *Pseudolithelius*) in the family Pseudolitheliidae.

Family TORMENTIDAE Nazarov and Ormiston 1983a

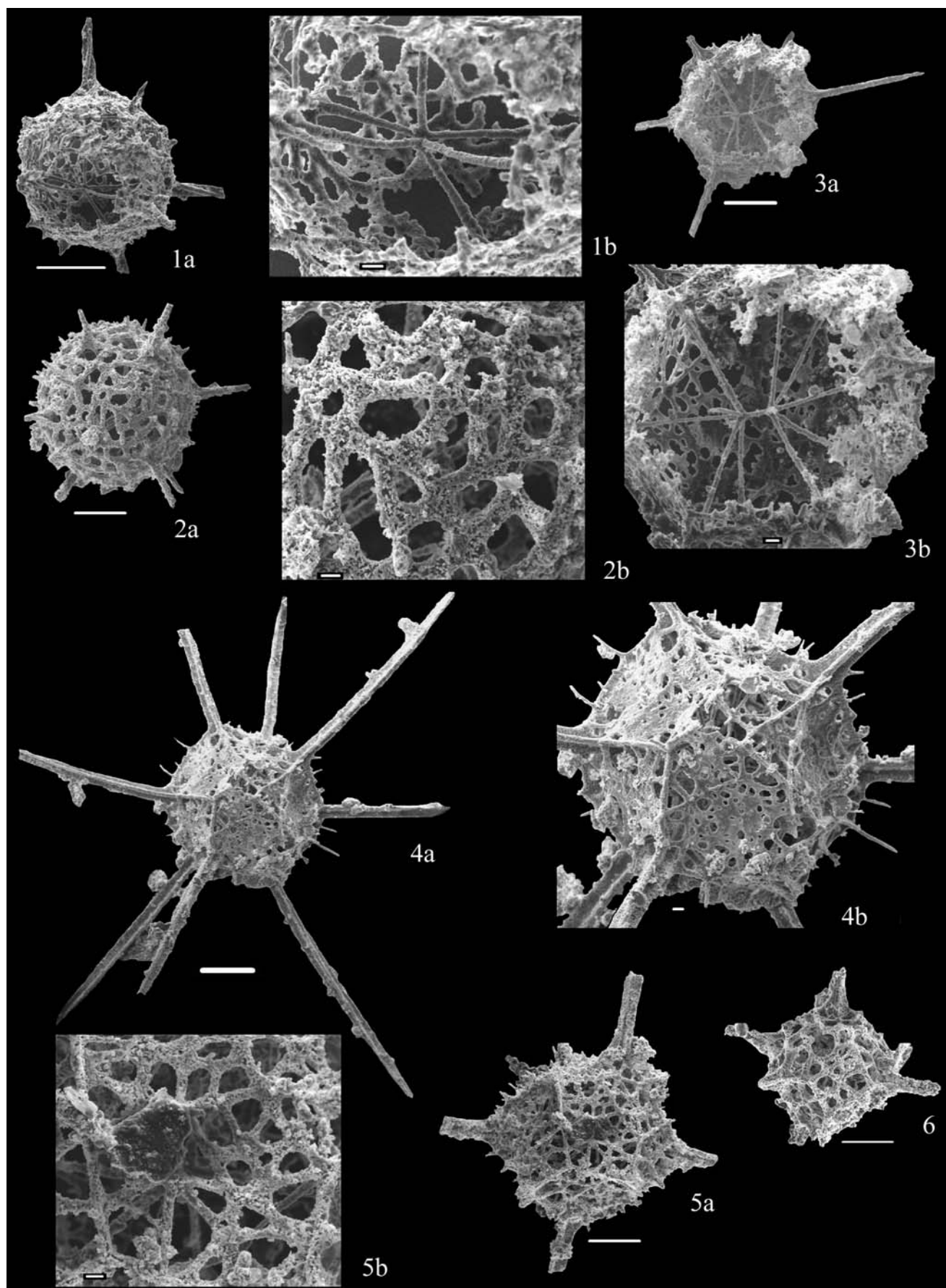
**Remarks:** The family Tormentidae was established by Nazarov and Ormiston (1983a) for forms with a discoidal, lensoid, triangular, and pyramidal external shape, and sometimes with a strongly inflated test; with an internal framework that appears as a hollow sphere with 3 to 4 hollow rays that are enclosed in a

## PLATE 7

Latest Capitanian (Guadalupian, Middle Permian) radiolarians from the EF section, Apache Mountains, West Texas.  
Scale bar is 100µm, except for figs. 1b, 2b, 3b, 4b, 5b – 10µm.

- 1 *Astroentactinia capitanensis* Nestell and Nestell, n. sp., 1a - no. USNM 538588, broken test of the paratype showing internal eccentrically located spicule and twisted primary spines, 1b – enlarged and rotated view showing internal seven-rayed spicule, sample F-13, unit B.
- 2 *Astroentactinia porosa* Maldonado and Noble, 2a - no. USNM 538589, 2b – enlarged view of porous cortical shell with rounded polygonal pores and thick interpore bars, sample F-8, unit B.
- 34 *Polyedroentactinia* sp. 1. 3a – no. USNM 538590, broken test showing centrally located internal spicule, 3b – enlarged view showing the ten-rayed bar-centered spicule, sample F-13, unit B; 4a – no. USNM 538591, 4b – enlarged view of reticular cortical shell with ridges on the surface, sample F-13, unit B.
- 5 *Polyedroentactinia* sp. 2, 5a – no. USNM 538592, 5b – enlarged view showing reticular surface of the cortical shell with polygonal pores, sample F-8, unit B.
- 6 *Polyedroentactinia guadalupensis* Nestell and Nestell, n. sp., no. USNM 538593, sample F-8, unit B.





solid or differentiated spongy meshwork. In the composition of the new family, Nazarov and Ormiston (1983a) included the new genus *Tormentum*, saying that the genus *Nazarovispongus* Kozur 1980 with a triangular and strongly inflated test probably belongs to this family, and not to Ruzhencevispongidae Kozur 1980. In the same paper, Nazarov and Ormiston (1983a) emended the diagnosis of the family Ruzhencevispongidae. Later, Nazarov and Ormiston (1985a) added the new genera *Rectotormentum*, *Tetratormentum* and *Octatormentum* to the family Tormentidae. As one can see, in the original description of the family Tormentidae, the tests with a triangular and strongly inflated external shell and, of course with the same internal structure, had in common features of the family Ruzhencevispongidae established by Kozur (1980). Such a description of the family Tormentidae permitted Kozur and Mostler (1989) later to conclude that Tormentidae is a junior synonym of the Ruzhencevispongidae. They also did not agree with Nazarov and Ormiston's emendation of the diagnosis of the family Ruzhencevispongidae. Moreover, Kozur and Mostler (1989) emended the description of the genus *Tormentum* (type species *T. protei* Nazarov and Ormiston 1983a) leaving in its composition only species with flattened spongy tests with rounded and wide blunt lobes without terminal spines. De Wever et al. (2001) agreed with the conclusion of Kozur and Mostler (1989) that the family Tormentidae is a junior synonym of the family Ruzhencevispongidae, but Afanasieva et al. (2005) accepted the mentioned above two families as separate families. In this paper we follow Afanasieva et al. (2005) and accept the family Tormentidae with two subfamilies: Tormentinae Nazarov and Ormiston 1983a (only with the genus *Tormentum* in the composition of the subfamily) and Rectotormentinae Afanasieva 2000 (only with the genus *Rectotormentum* in the composition). The genera *Grandetortura* and *Octatormentum* (= *Pseudolithelius*) which were placed by Afanasieva et al. (2005) in the composition of the family Tormentidae, are included by us in the family Pseudolitheliidae.

Based on an internal four-rayed spicule, the rays of which connect with four external main spines of different shape, and are enclosed in the spongy or platy shell, the genera *Tetrator-*

*mentum* Nazarov and Ormiston 1985a, *Staurentactinia* Schwartzapfel and Holdsworth 1996, *Tetraspongoactinia* Won 1998, and probably *Mostlerispongus* Kozur 1993 (with six main spines and unknown internal structure) should be referred to the new family Tetratormentidae. We also consider that the genus *Tetragregnon* should be included in this new family based on the four-rayed internal spicule enclosed in one loose spongy shell.

#### Subfamily RECTOTORMENTINAE Afanasieva 2000

Genus ***Rectotormentum*** Nazarov and Ormiston 1985a [= *Tormentidarium* Nazarov and Ormiston 1983a, *nomen nudum*]

Type species: *Rectotormentum fornicatum* Nazarov and Ormiston 1985a.

**Diagnosis:** Test lensoid, subtriangular or rounded with differentiated spongy shell with three short spines. Internal framework consists of a small spherical sphere with three thin rays diverging at an angle of 120° and ending externally in a short spine. From five to eight internal shells are developed between the internal sphere and external shell. All shells are connected with each other by irregularly located bars and by three rays of the internal framework.

**Range:** Lower Permian, Cisuralian, Artinskian – Middle Permian, Guadalupian, Capitanian.

***Rectotormentum wardlawi*** Nestell and Nestell, n. sp.

Plate 15, figures 3-6; Plate 18, figures 10-11

**Diagnosis:** *Rectotormentum* of subtriangular or rounded shape of the test, and the presence of bunch-shaped terminal spines at the corners.

**Description:** Test flattened, with a spongy meshwork, from subtriangular with convex sides to round in shape with blunt corners. Internal framework consists of a small rounded internal sphere (pl. 18, fig. 10) with three thin rays diverging from it at an angle of 120°. Externally these rays end with short bunch-shaped terminal spines. In some tests these spines are not

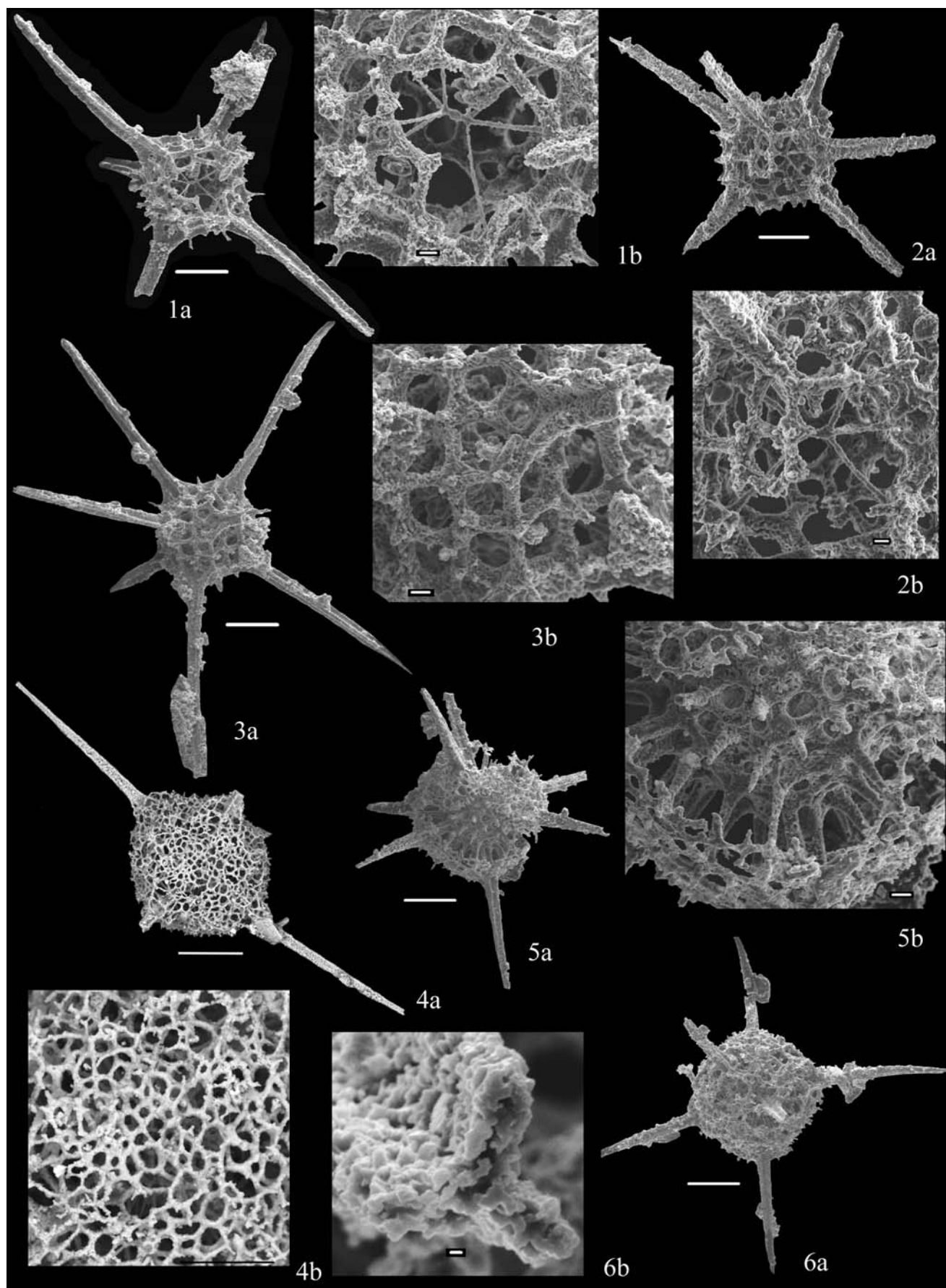
## PLATE 8

Latest Capitanian (Guadalupian, Middle Permian) radiolarians from the EF section, Apache Mountains, West Texas.  
Scale bar is 100µm, except for figs. 4b - 50µm, 1b, 2b, 3b, 5b - 10µm, 6b - 1µm.

- 1-3 *Polyedroentactinia guadalupensis* Nestell and Nestell, n. sp. 1a – no. USNM 538594, holotype, broken test showing internal centrally located spicule, 1b – enlarged view showing bar-centered eight-rayed spicule, sample F-8, unit B; 2a – no. USNM 538595, paratype, 2b – enlarged view showing bar-centered internal spicule, sample F-8, unit B; 3a – no. USNM 538596, paratype, 3b – enlarged view showing the base of three-bladed primary spine with ridges connected with rays of the spine and large pores at the base of the spine, sample F-8, unit B.

- 4,6 *Afanasievella apachensis* Nestell and Nestell, n. gen., n. sp. 4a – no. USNM 538598, paratype, 4b – enlarged view showing loose spongy wall on the surface of the test, sample F-8, unit B; 6a – no. USNM 538599, holotype, 6b – enlarged cross sectional view of one of the primary spines, sample F-8, unit B.
- 5 *Meschedea?* sp. A. 5a – no. USNM 538597, broken test showing two closely spaced concentric shells, 5b – enlarged view showing thin external shell and numerous radial beams between the external shell and the next interior shell, sample F-8, unit B.





preserved. About nine shells are developed between the external shell and the internal sphere.

*Measurements* ( $\mu\text{m}$ ): test diameter 210-360, thickness 104-156, diameter of the internal sphere 30, length of terminal spines 22.

*Designation of types*: The specimen illustrated on plate 15, figure 6 (no. USNM 538672) is designated as the holotype and the specimens on plate 15, figure 4 (no. USNM 538670) and figure 5 (no. USNM 538671), and on plate 18, figures 10 (no. USNM 538723) and 11 (no. USNM 538724) as the paratypes. They are from West Texas, Apache Mountains, 50km north-east of Van Horn, Texas FM 2185, EF section, Unit E, sample E-1; the upper part of the Bell Canyon Formation, age equivalent to the Reef Trail Member, upper Capitanian, Middle Permian.

*Etymology*: After B. R. Wardlaw, a well known conodont worker.

*Material*: Abundant and 6 specimens have been photographed and measured.

*Discussion*: Based on the many shells between the internal sphere and external shell, *Rectotortementum wardlawi* n. sp. is similar to the species *Rectotortementum fornicatum* Nazarov and Ormiston (1985a, p. 41, pl. 5, figs. 10-11), but differs by the subtriangular or round shape of the test, and the bunch-shaped terminal spines.

*Occurrence*: As the holotype and paratype, and also EF section, units B, C and D, the upper part of the Bell Canyon Formation, age equivalent to the Reef Trail Member, Apache Mountains; Bell Canyon Formation, Reef Trail Member (Maldonado and Noble this volume), Guadalupe Mountains; West Texas; Middle Permian, upper Capitanian.

Family **TETRATORMENTIDAE** Nestell and Nestell, n. fam.

*Diagnosis*: Test of pyramidal or bipyramidal shape consisting of an external shell and internal framework of four- or six-rayed spicules enclosed in an internal small sphere. Rays of the spicule are connected with four or six terminal spines of rod-like, conical or three-bladed spines of different length. Some genera have openings around the base of the spines. External shell is thick spongy or platy with small rounded pores.

*Composition*: The following genera are included in the family: *Tetratormentum* Nazarov and Ormiston 1985a, *Staurentactinia* Schwartzapfel and Holdsworth 1996, *Tetragregnon* Ormiston and Lane 1976 (with *Tetracircinata* Nazarov and Ormiston 1984, and *Tetraspongoactinia* Won 1998 as junior synonyms; see discussion below); *Mostlerispongus* Kozur 1993, and genus *Quadrilobata* Wang 1995 conditionally.

*Range*: Carboniferous, Mississippian, Tournaisian – Upper Permian, Lopingian, Changhsingian.

Genus ***Tetragregnon*** Ormiston and Lane 1976 [= *Tetracircinata* Nazarov and Ormiston 1984; = *Tetraspongoactinia* Won 1998]

Type species: *Tetragregnon sycamorensis* Ormiston and Lane 1976.

*Diagnosis*: Test subspherical or of rounded pyramidal shape, with a spongy meshwork; inner framework is represented by a four - rayed spicule, the distal ends of which are connected with four main external spines of rod-like, conical or three-bladed shape.

*Remarks*: Ormiston and Lane (1976) gave a very briefly diagnosis of their new genus *Tetragregnon* and did not note how many internal shells are present. They only mentioned a “spongy tetrahedral network” (Ormiston and Lane 1976, p. 23). In our broken specimens of *Tetragregnon*, the internal shells cannot be

## PLATE 9

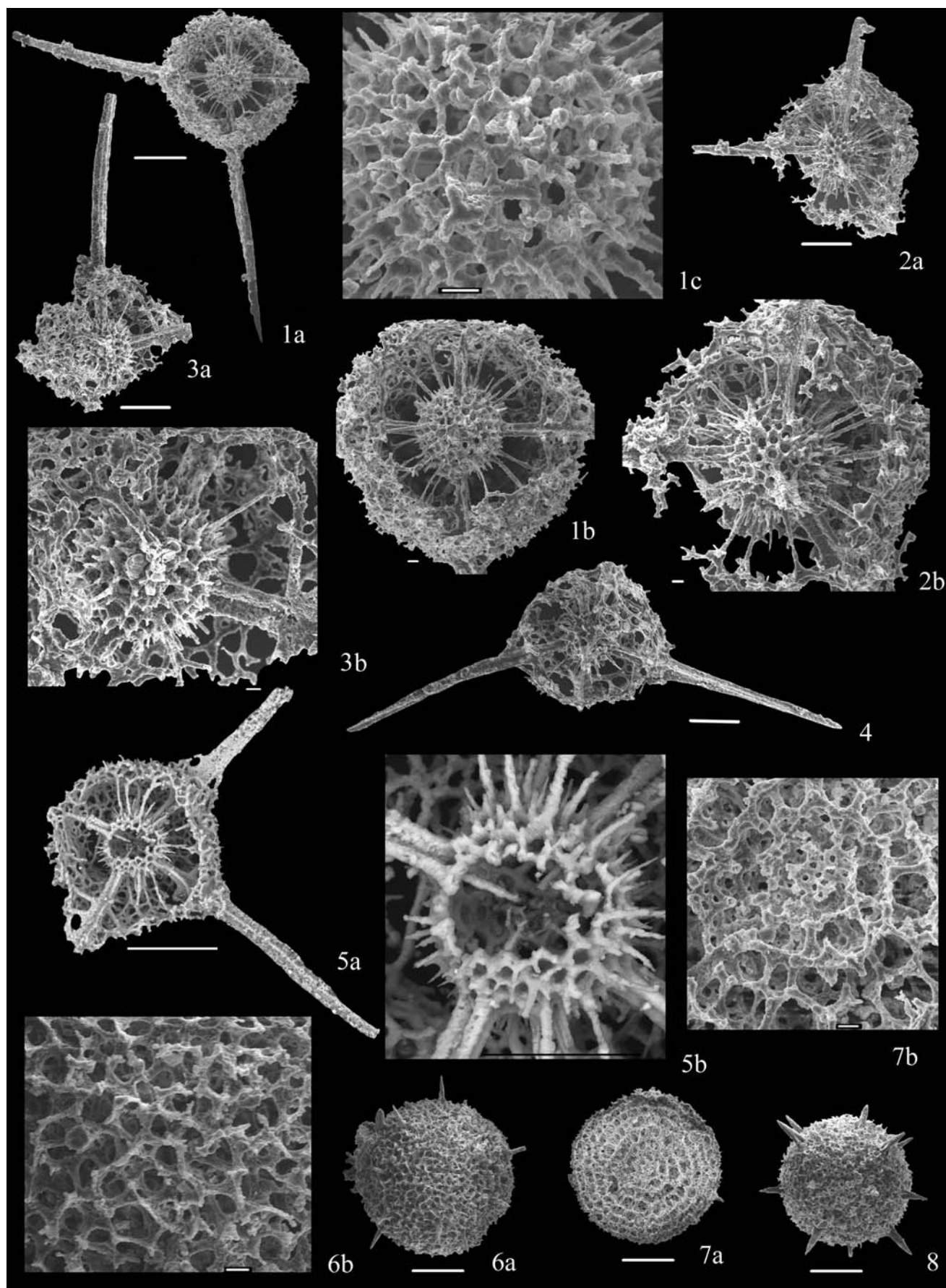
Latest Capitanian (Guadalupian, Middle Permian) radiolarians from the EF section, Apache Mountains, West Texas.  
Scale bar is 100 $\mu\text{m}$ , except for figs. 5b – 50 $\mu\text{m}$ , 1b, 1c, 2b, 3b, 6b, 7b – 10 $\mu\text{m}$ .

- 1-5 *Afanasievella apachensis* Nestell and Nestell, n. gen., n. sp. 1a – no. USNM 538600, paratype, broken test showing internal structure, 1b – enlarged view showing thick cortical shell and intermediate porous sphere with numerous thin radial beams and four primary rays with three rows of apophyses, 1c – enlarged view of the intermediate porous sphere, sample F-8, unit B; 2a – no. USNM 538601, broken test showing internal structure, 2b – enlarged view showing three primary radial rays with three rows of apophyses and porous intermediate sphere with thin rod-like radial beams, sample F-8, unit B; 3a – no. USNM 538602, broken test showing intermediate sphere, 3b – enlarged view showing porous intermediate sphere with two primary radial rays, sample F-8, unit B; 4 – no. USNM 538603, broken test showing internal structure, sample F-8,

unit B; 5a – no. USNM 538604, paratype, broken test showing internal structure, 5b – enlarged view showing broken intermediate sphere with broken microsphere with rod-like rays that extended as a primary three-bladed rays outside of intermediate sphere, sample F-8, unit B.

- 6-8 *Copicyntra erinacea* Nestell and Nestell, n. sp. 6a – no. USNM 538605, holotype, 6b – enlarged view of the spongy surface of the cortical shell, sample E-2, unit E; 7a – no. USNM 538606, paratype, broken test showing numerous internal concentric shells, 7b – enlarged view of the center of the test, sample E-2, unit E; 8 – no. USNM 538607, paratype, sample E-1, unit E.





distinguished and only an internal spongy meshwork is present. In the diagnosis of the new genus *Tetracircinata*, Nazarov and Ormiston (1984) noted that it has internally a four - rayed spicule, each of whose rays extend into a spine with an uneven arrangement of the apophyses. Based on their additional branching and connection with each other, Nazarov and Ormiston stated that the apophyses “form somewhat closed or semi-closed internal shells” (Nazarov and Ormiston 1984, p. 74). Based on the stated presence of several shells, Afanasieva et al. (2005) and Afanasieva and Amon (2006) assigned *Tetracircinata* to the subfamily Haplotaeniinae Afanasieva and Amon in Afanasieva et al. 2005 of the family Haplentactiniidae Nazarov in Nazarov and Popov 1980, in spite of the fact that members of this family include genera with a six - rayed spicule whose rays are connected with six main external spines and have a lattice meshwork. We consider that *Tetracircinata* has affinity with the genus *Tetragregnon* based on the presence of a four - rayed internal spicule and a spongy meshwork in the entire test that does not appear to be subdivided into extra shells. The genus *Tetracircinata* could be considered as a junior synonym of the genus *Tetragregnon* as was proposed by De Wever et al. (2001). We propose that the genus *Tetraspongoactinia* with the type species *T. holdsworthi* described by Won (1998) also is a junior synonym of the genus *Tetragregnon* based on the similarity of the small openings at the base of main spines present in both genera (Ormiston and Lane 1976, pl. 2, fig. 6 and Won 1998, pl. 4, fig. 12), the similarity of the spongy shell, and presence of apophyses whose branches connect to the meshwork of the test. Moreover, the species *Tetraedroclathrum cabrierense* Deflandre 1960 (*nomen nudum*) was included by Ormiston and Lane into the type species of the genus *Tetragregnon*, and Won also included it in the type species of the genus *Tetraspongoactinia*.

**Range:** Carboniferous, Mississippian, Tournaisian – Upper Permian, Lopingian, Changhsingian.

***Tetragregnon japonicum*** Sashida and Tonishi  
Plate 15, figures 7-9

*Tetragregnon japonicum* SASHIDA and TONISHI 1985, p. 13, pl. 4, figs. 5-9.

*Tetragregnon scalpratus* NAZAROV and ORMISTON 1985a, p. 23, pl. 2, fig. 17.

**Remarks:** Kozur and Mostler (1989) pointed out the similarity of the species *Tetragregnon japonicum* Sashida and Tonishi (1985) that was published in March and *Tetragregnon scalpratus* Nazarov and Ormiston (1985a), that was published in April, but they did not write any kind of conclusion about this matter. Indeed, the descriptions of both species *Tetragregnon japonicum* and *Tetragregnon scalpratus* are almost identical, and they were published in the same year. But, because the paper of Sashida and Tonishi (1985) was published in March, and paper of Nazarov and Ormiston (1985a) in April, the priority in the name of the species is *Tetragregnon japonicum*, and *Tetragregnon scalpratus* is considered to be a junior synonym of the former species.

**Occurrence:** USA, West Texas; Guadalupian Mountains, the Bell Canyon Formation, Lamar Limestone Member (Nazarov and Ormiston 1985a) and Reef Trail Member (Maldonado and Noble this volume); Apache Mountains, EF section, unit B, the upper part of the Bell Canyon Formation, age equivalent to the Reef Trail Member; Middle Permian, Guadalupian, upper Capitanian; Central, Japan, Tokyo Prefecture, Itsukaichi, Guadalupian or younger rocks.

## PLATE 10

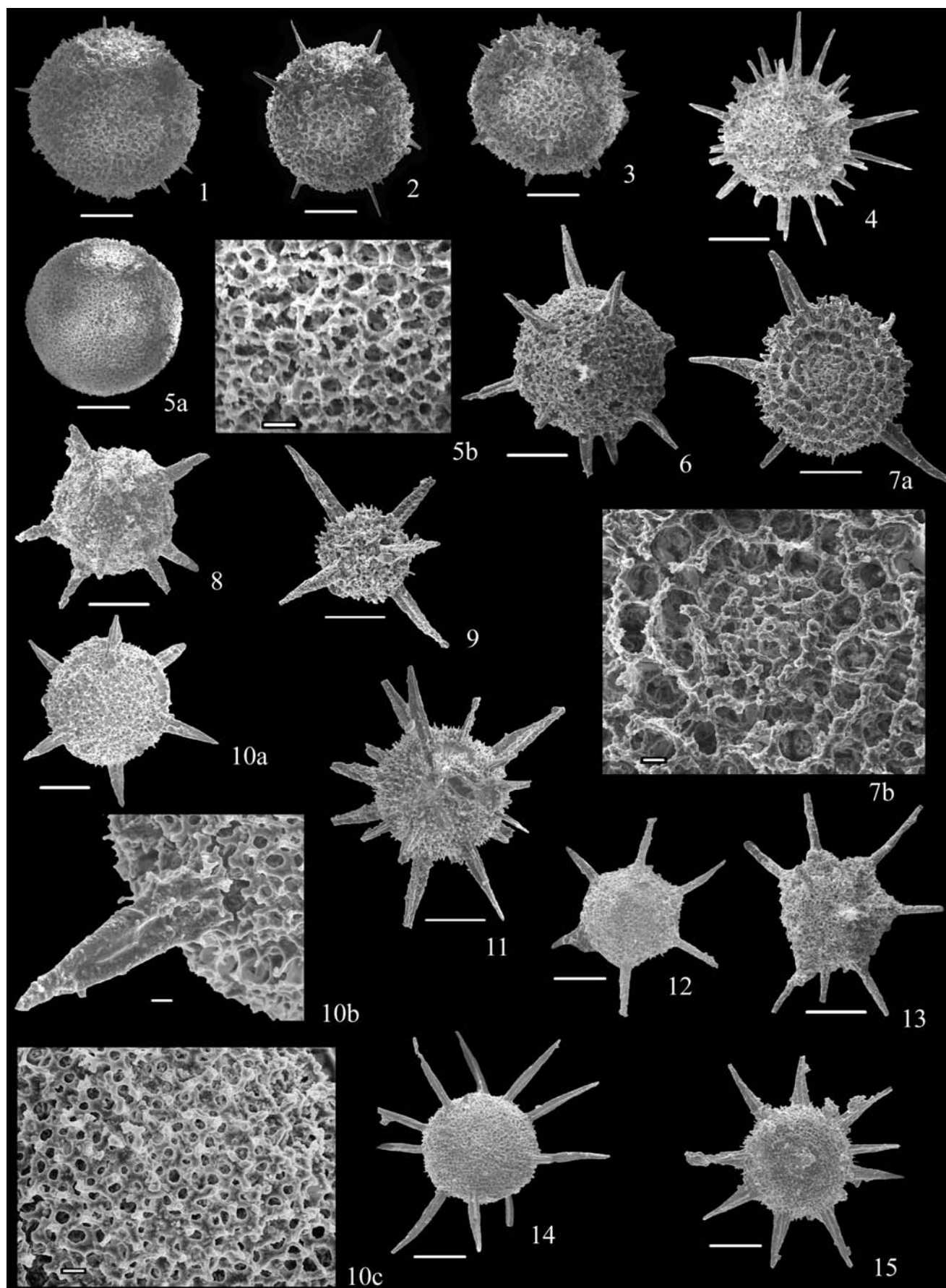
Latest Capitanian (Guadalupian, Middle Permian) radiolarians from the EF section, Apache Mountains, West Texas.  
Scale bar is 100µm, except for figs. 5b, 7b, 10b, 10c – 10µm.

- 1-3,5 *Copicyntra erinacea* Nestell and Nestell, n. sp. 1 – no. USNM 538608, sample E-1, unit E; 2 – no. USNM 538609, sample E-2, unit E; 3 – no. USNM 538610, sample E-2, unit E; 5a – no. USNM 538611, 5b – enlarged view of the spongy surface of the cortical shell, sample E-1, unit E.
- 4 *Copicyntra cuspidata* Nazarov and Ormiston, no. USNM 538612, sample F-13, unit B.
- 6-10 *Paracopicyntra snyderi* Nestell and Nestell, n. sp. 6 – no. USNM 538613, holotype, sample F-8, unit B; 7a – no. USNM 538614, paratype, broken test showing internal concentric shells, 7b – enlarged view of the center of the test showing small internal sphere, sample E-1, unit E; 8 – no. USNM 538615, sample F-15, unit B; 9 – no. USNM 538616, sample F-8, unit B; 10a – no. USNM 538617, paratype, 10b – enlarged view of

the one of the primary three-bladed spines, 10c – enlarged view of the spongy surface of the cortical shell, sample E-2, unit E.

- 11 *Paracopicyntra puncta* Maldonado and Noble, no. USNM 538618, sample F-8, unit B.
- 12 *Copicyntroides nazarovi* Maldonado and Noble, no. USNM 538619, sample F-8, unit B.
- 13 *Copicyntra irregularata* Maldonado and Noble, no. USNM 538620, sample F-15, unit B.
- 14 *Copicyntroides asteriformis* Nazarov and Ormiston, no. USNM 538621, sample E-2, unit E.
- 15 *Copicyntroides parvulus* Feng, no. USNM 538622, sample E-2, unit E.





Genus *Tetratormentum* Nazarov and Ormiston 1985a

Type species: *Tetratormentum narthecium* Nazarov and Ormiston 1985a.

**Diagnosis:** Test mostly pyramidal or rounded pyramidal, with a four-rayed internal spicule enclosed in a thick spongy or platy shell. Four rays connected with external four spines of different shape.

**Range:** Carboniferous, Upper Pennsylvanian, Gzhelian – Upper Permian, Lopingian, Wuchiapingian.

*Tetratormentum ormistoni* Nestell and Nestell, n. sp.

Plate 15, figures 10-13; Plate 16, figure 1

**Diagnosis:** *Tetratormentum* with thin platy shell and four conical or rod-like spines, and short apophyses on the internal rays.

**Description:** Test rounded pyramidal, almost subspherical, with four external main spines. The three conical or rod-like spines are located at an angle of 120° to each other and a fourth one of the same shape is perpendicular to them. External shell is platy, thin, penetrated by small rounded pores, and connected directly with the base of the spines or with a small projection in the shape of a truncated cone (pl. 15, fig. 10). There are about five large openings at the base of each spine. Internal framework is represented by a four-rayed spicule (in the shape of a triangle with two straight sides and one slightly curved side), with three rays in one plane and a fourth ray perpendicular to the three rays of the spicule and located in the middle of the rounded side of the spicule. Each internal ray has short apophyses internally, and outside these rays are connected with the external spines.

**Measurements (μm):** height of the test without spines 180-230, test width of the base without spines 160-250, diameter of triangular spicule 30, thickness of the internal rays 7-10, diameter pores 6, thickness of the external shell 8, the length of the external spines 50-110.

**Designation of types:** The specimen illustrated on plate 15, figure 12 (no. USNM 538678) is designated as the holotype and the specimens on plate 15, figure 10 (no. USNM 538676), figure 11 (no. USNM 538677) and figure 13 (no. USNM 538679), and on plate 16, figure 1 (no. USNM 538680) as the paratypes. They are from West Texas, Apache Mountains, 50km north-east of Van Horn, Texas FM 2185, EF section, holotype and paratype (pl. 15, fig. 6) and paratype (pl. 16, fig. 1) from unit D, sample F-19, paratypes (pl. 15, figs. 10 and 11) from unit B, sample F-13; the upper part of the Bell Canyon Formation, age equivalent to the Reef Trail Member, upper Capitanian, Middle Permian.

**Etymology:** After A. R. Ormiston.

**Material:** 6 specimens have been photographed and measured.

**Discussion:** Based on the almost subspherical test, *Tetratormentum ormistoni* n. sp. is similar to *Tetratormentum condensum* Nazarov (in Isakova and Nazarov 1986, p. 104, pl. 24, fig. 4) but differs from it by the larger size of the test, the presence of an internal triangular – shaped spicule, and presence of short apophyses in the internal rays.

**Occurrence:** As the holotype and paratypes, and also EF section, unit C, the upper part of the Bell Canyon Formation, age equivalent to the Reef Trail Member, Apache Mountains; Bell Canyon Formation, Reef Trail Member (Maldonado and Noble this volume), Guadalupe Mountains; West Texas; Middle Permian, upper Capitanian.

Genus *Quadrilobata* Wang 1995

Type species: *Quadrilobata ephippiomorpha* Wang 1995.

**Diagnosis** (after Wang 1995): Test spongy, of subquadrate shape with four lobes and concave sides between the lobes. Lobes are located at 90° to each other. Each lobe becomes nar-

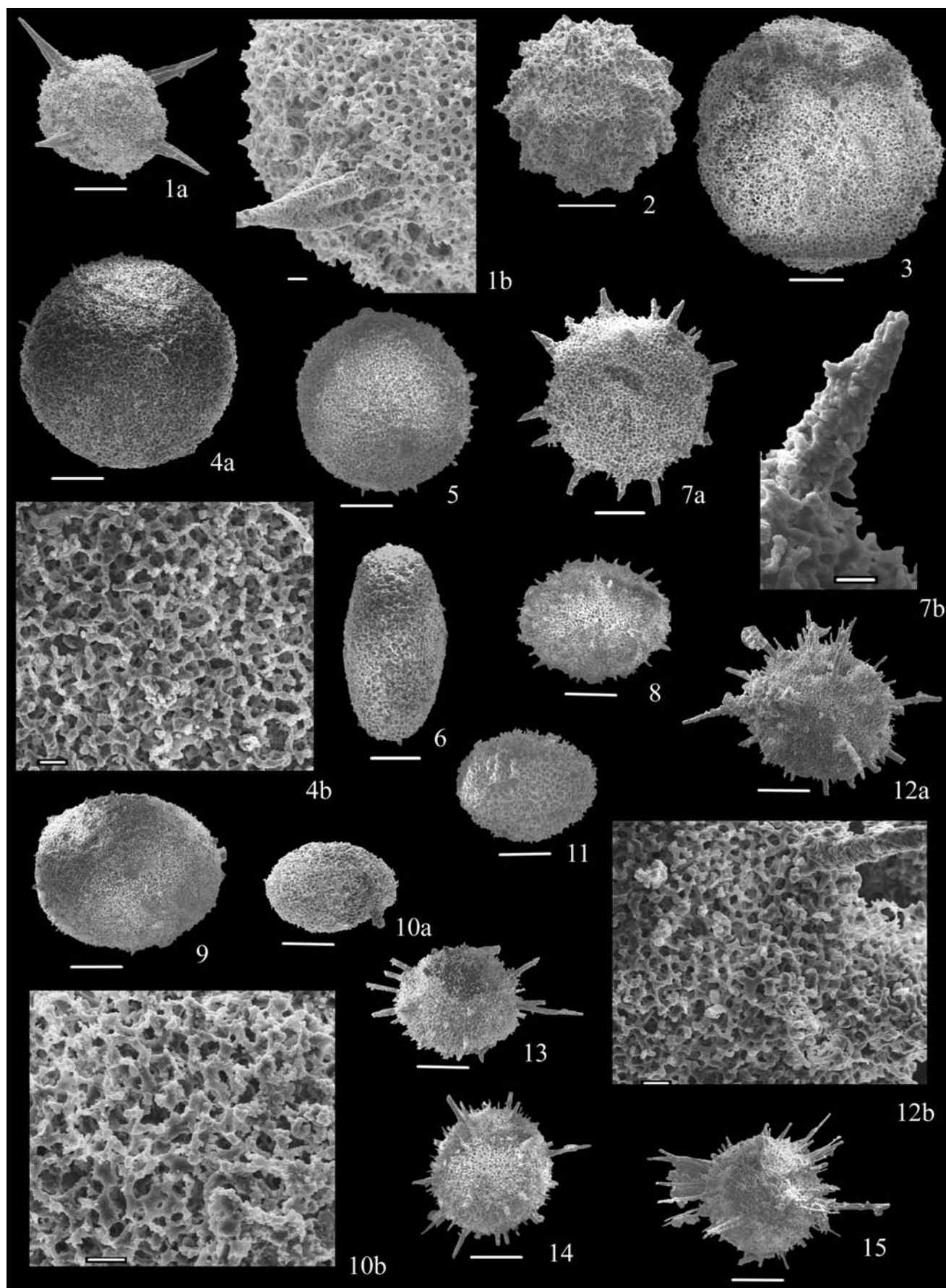
## PLATE 11

Latest Capitanian (Guadalupian, Middle Permian) radiolarians from the EF section, Apache Mountains, West Texas.

Scale bar is 100μm, except for figs. 1b, 4b, 7b, 10b, 12b – 10μm.

- 1 *Tetrapaurinella* sp. 1, 1a - no. USNM 538623, 1b – enlarged view showing spongy surface of the cortical shell and one of the three-bladed primary spines, sample E-1, unit E.
- 2 *Hegleria mammifera* Nazarov and Ormiston, no. USNM 538624, sample AHA-2, unit A.
- 3-7 *Klaengspongos planus* Nestell and Nestell, n. sp. 3 – no. USNM 538625, sample F-2, unit E; 4a – no. USNM 538626, paratype, 4b – enlarged view of the spongy surface of the cortical shell, sample F-8, unit B; 5 – no. USNM 538627, holotype, sample F-8, unit B; 6 – no. USNM 538628, paratype, lateral view, sample F-8, unit B; 7a – no. USNM 538629, paratype, 7b – enlarged view of the one of the primary conical spines, sample F-8, unit B.
- 8 *Copiellintra* aff. *C. oviformis* (Kozur and Mostler), no. USNM 538630, sample F-13, unit B.
- 9-11 *Copiellintra orbiculata* Nestell and Nestell, n. sp. 9 – no. USNM 538631, paratype, sample F-13, unit B; 10a – no. USNM 538632, holotype, 10b – enlarged view of the spongy surface of the cortical shell, sample E-1, unit E; 11 – no. USNM 538633, paratype, sample E-2, unit E.
- 12-15 *Copiellintra fastuosa* Nestell and Nestell, n. sp. 12a – no. USNM 538634, paratype, 12b – enlarged view of the spongy surface of the cortical shell, sample F-8, unit B; 13 – no. USNM 538635, holotype, sample F-8, unit B; 14 – no. USNM 538636, paratype, sample F-13, unit B; 15 – no. USNM 538637, paratype, sample F-13, unit B.





row to the distal part; two opposite lobes are bent down and two bent up.

**Remarks:** Wang (1995) gave a very brief description of a new genus *Quadrilobata* based on one specimen with a peculiar shape of the test and without a description of the internal structure. Furthermore, he illustrated only one specimen as the type species. In our Texas material we have a number of specimens of similar morphology to *Quadrilobata*, but the shapes of our forms vary widely from squared to squared with shallow concave sides, to squared with deep concave sides, to squared bipyramidal, and even to specimens with five - six lobes in a bipyramidal outline. Thus, we refer our specimens to the genus *Quadrilobata* conditionally until this genus is described properly. Possibly, the species *Octatormentum? floriferum*, *Tetratormentum acutum* and *Octatormentum? sp.* from Itsukaichi of Central Japan (Sashida and Tonishi 1988), and *Octatormentum? floriferum* Sashida and Tonishi 1988 illustrated from the Changhsingian of southern Guangxi in China by Feng et al. (2006a) belong to the genus *Quadrilobata*. Our new species, *Q? blomei* is possibly a transitional form between *Q. ephippiomorpha* and *O? floriferum* because the new species has a spongy squared test as in the former species and a bipyramidal spongy test as in the latter species.

**Range:** Middle Permian, Guadalupian, Roadian – Upper Permian, Lopingian, Changhsingian.

***Quadrilobata? blomei*** Nestell and Nestell, n. sp.  
Plate 16, figures 2-12; Plate 18, figures 7-8

**Diagnosis:** *Quadrilobata?* with different shape of the test (from squared to bipyramidal), with four (sometimes five – six) conical or rod-like main spines and some short secondary spines.

**Description:** Test varies from a squared shape with straight sides or with shallow or deep concave sides to a bipyramidal shape to star-shaped that creates a test with arms (or lobes) from widely rounded to narrow acute shape, each lobe ending in a short or long conical or rod-like spine. In some specimens with five or six arms (star-shaped, pl. 16, fig. 12), the arms are somewhat inflated just before the main spines. In some tests there are many very short and thin secondary spines along the exterior margin of the test. The internal framework consists of a small porous sphere from which the external main spines radiate (pl. 16, fig. 11). The main test consists of a single finely meshed spongy shell.

**Measurements ( $\mu\text{m}$ ):** the height of squared specimens with straight sides – 260-290, width – 360, diagonal length without spines – 360; height of squared specimens with shallow concave sides – 220-330, width – 200-330, diagonal length without spines – 270-450; height and width of specimens with deep concave sides – 330-370, diagonal length without spines – 350-460; height and width of star-shaped specimens – 360-370, their thickness 220, diagonal length without spines – 320-460; the length of main spines – 30-80; the diameter of internal sphere 40 (based on 14 specimens).

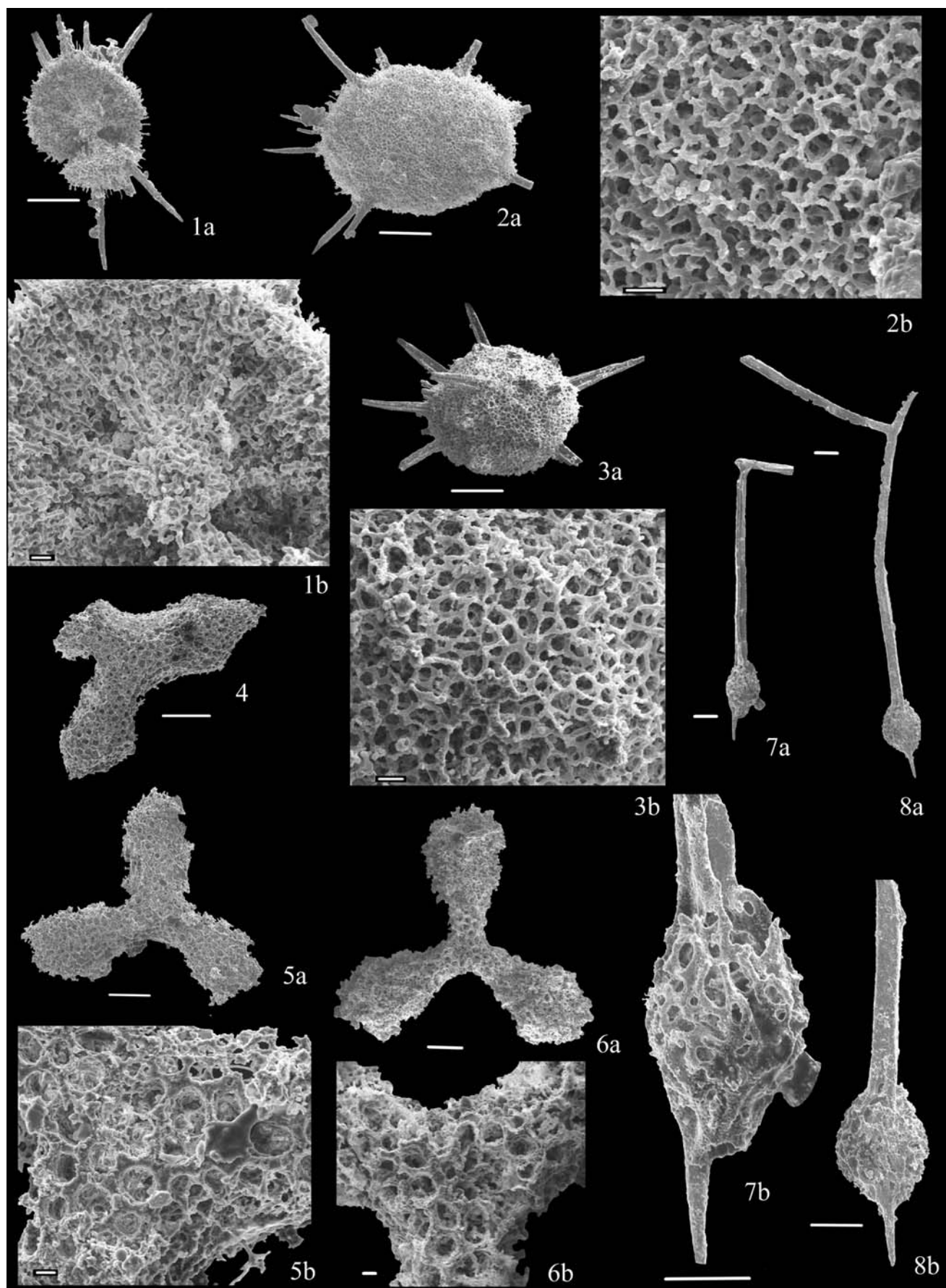
**Designation of types:** The specimen illustrated on plate 16, figure 3 (no. USNM 538682) is designated as the holotype and the specimens on plate 16, figure 2 (no. USNM 538681), figure 7 (no. USNM 538686), figure 9 (no. USNM 538688), figure 10 (no. USNM 538689), and on plate 18, figure 7 (no. USNM 538721) as the paratypes. They are from West Texas, Apache Mountains, 50km north-east of Van Horn, Texas FM 2185, EF section, unit E, holotype and and paratype (pl. 18, fig. 7) is from sample E-2, paratypes (pl. 16, figs. 9 and 10) from sample E-1; paratypes (pl. 16, fig. 2 and 7) from unit B, sample F-12; the up-

## PLATE 12

Latest Capitanian (Guadalupian, Middle Permian) radiolarians from the EF section, Apache Mountains, West Texas.  
Scale bar is 100 $\mu\text{m}$ , except for figs. 1b, 2b, 3b, 5b, 6b, 7b, 8b – 10 $\mu\text{m}$ .

- 1 *Copiellintra fastuosa* Nestell and Nestell, n. sp. 1a – no. USNM 538638, paratype, broken test showing internal structure, 1b – enlarged view showing the internal porous sphere and numerous radial beams in a spongy meshwork, sample E-1, unit E.
- 2 *Copiellintra ferula* Noble and Jin, no. USNM 538639, 2b – enlarged view of the spongy surface of the cortical shell, sample E-2, unit E.
- 3 *Copiellintra laurelae* Noble and Jin, 3a - no. USNM 538640, specimen with three-bladed primary spines, 3b – enlarged view of the spongy surface of the cortical shell, sample E-1, unit E.
- 4-5 *Latentifistula* sp. 1. 4 – no. USNM 538641, sample E-2, unit E; 5a – no. USNM 538642, 5b – enlarged view of the central part of the test showing the spongy surface with large rounded pores, sample E-2, unit E.
- 6 *Latentifistula texana* Nazarov and Ormiston, 6a – no. USNM 538643, 6b – enlarged view of the central part of the test showing the spongy surface with rounded pores, sample A-3, unit A.
- 7-8 *Quadriremis?* sp. 1. 7a – no. USNM 538644, 7b - enlarged view of the terminal part on the nonporous arm with elliptical shell and long terminal spine, sample E-2, unit E; 8a – no. USNM 538645, 8b – enlarged view of the terminal part of the nonporous arm with elliptical spongy shell and long terminal spine, sample E-2, unit E.





per part of the Bell Canyon Formation, age equivalent to the Reef Trail Member, upper Capitanian, Middle Permian.

*Etymology:* After C. Blome, a well known radiolarian worker.

*Material:* 40 specimens.

*Discussion:* Based on the squared shape of the test, *Qudri-lobata? blomei* n. sp. is similar to *Q. ephippiomorpha* (Wang 1995, p. 144, pl. 2, fig. 16), but differs from it by the variety of shapes, even distribution of all arms (in *Q. ephippiomorpha* two arms are bent down and two arms are bent up), the presence of main and secondary spines, and higher stratigraphic interval.

*Occurrence:* As the holotype and paratypes.

Family RUZHENCEVISPOGIDAE Kozur 1980; emend. Nazarov and Ormiston 1983a; emend. Nazarov and Ormiston 1985a [= Patrickellidae Kozur and Mostler 1989]

*Remarks:* The family Ruzhencevispongidae was introduced by Kozur (1980) when he described two new genera: *Ruzhencevispongius* and *Nazarovispongius*. According to Kozur, the genus *Ruzhencevispongius* has a triangular test with straight to slightly concave sides, with or without spines on the corners of the triangle, and with a spongy meshwork as an external layer. Moreover, this spongy layer becomes sparse in the center of the test. The inner framework consists of an imperforate, sub-spherical to subtriangular sphere from which three hollow rays radiate and connect with three main spines. The genus *Nazarovispongius* differs from *Ruzhencevispongius* by having an inflated triangular test with convex sides, sharp or rounded corners with short three-bladed (tricarinate in the sense of Kozur) spines, and part of the test between the external spongy shell and the initial imperforate sphere is not filled with a spongy meshwork and is empty. Later, Nazarov and Ormiston (1983a) emended the diagnoses of the family Ruzhencevispongidae and

the genus *Ruzhencevispongius* given by Kozur (1980) adding to them the description of new forms with flat triangular latticed-porous tests with an internal triangle that enclosed a hollow sphere with three rays connected with the terminal spines and with a distinct marginal border. These forms were described later by Nazarov and Ormiston (1985a) as the species *Ruzhencevispongius cataphractus*. Kozur and Mostler (1989) did not agree with Nazarov and Ormiston's emendation based on the fact that original *Ruzhencevispongius* does not have such an internal triangle and marginal border and is more inflated than *R. cataphractus*. They proposed a new generic name for the latter species, *Patrickella*, and even a new family Patrickellidae. We consider that the genus *Patrickella* is probably a valid genus because in our Texas material there are a number of specimens of representatives of the genus *Ruzhencevispongius* in sense of Kozur and Mostler (1989), and none of these specimens have an internal triangle and marginal border. We support De Wever et al. (2001) who included the genus *Patrickella* in the composition of the family Ruzhencevispongidae. We also consider that in this case the emendation of the family Ruzhencevispongidae by Nazarov and Ormiston (1983a) is valid, and the family Patrickellidae is a junior synonym of the family Ruzhencevispongidae.

At the same time with the emendation of the family Ruzhencevispongidae, Nazarov and Ormiston (1983a) established a new family Tormentidae and described a new genus *Tormentum* with the type species *T. protei*. This species is characterized by a large flattened test highly variable in shape with a spongy meshwork and without terminal spines. The internal framework is represented by a nonporous internal sphere with three hollow rays diverging at angles of about 120°. In the family Tormentidae Nazarov and Ormiston (1983a) included the genus *Tormentum* and also three new genera that they described later (Nazarov and Ormiston 1985a) under names *Rectortormentum*, *Tetrortormentum* and *Octortormentum*. Nazarov and Ormiston (1983a) wrote that the genus *Nazarovispongius* established by

### PLATE 13

Latest Capitanian (Guadalupian, Middle Permian) radiolarians from the EF section, Apache Mountains, West Texas.  
Scale bar is 100µm, except for figs. 1a, 7b, 7c, 9b, 9c, 9d, 10b–10µm.

- 1 *Quadriremis?* sp. 1. 1b – no. USNM 538646, test with broken terminal ends of the arms, 1a – enlarged view of the central part of the test, sample E-2, unit E.
- 2 *Cauletella manica* (De Wever and Caridroit), no. USNM 538647, sample E-2, unit E.
- 3 *Praedeflandrella densa* (Nazarov and Ormiston), no. USNM 538648, sample F-8, unit B.
- 46 *Ishigaum trifustis* De Wever and Caridroit. 4 – no. USNM 538649, sample F-8, unit B; 5 – no. USNM 538650, sample F-8, unit B; 6 – no. USNM 538651, sample F-8, unit B.
- 7-11 *Praedeflandrella prolata* Maldonado and Noble. 7a – no. USNM 538652, 7b – enlarged view of the left arm showing three beams with grooves between them, 7c – enlarged view of the upper arm showing porous structure, sample E-2, unit E; 8 – no. USNM 538653, sample F-8, unit B; 9a – no. USNM 538654, 9b – enlarged view of the center of the test showing nonporous initial sphere, 9c – enlarged view of the upper arm showing porous meshwork, 9d – enlarged view of the broken right arm with elongate pores, sample F-8, unit B; 10a – no. USNM 538655, 10b – enlarged view of the upper arm showing porous meshwork, sample F-8, unit B; 11 – no. USNM 538656, sample F-13, unit B.
- 12 *Praedeflandrella* sp. 1, no. USNM 538657, sample F-8, unit B.





Kozur (1980) “probably belongs to this family and could be assigned to the category of satellite genus” (Nazarov and Ormiston 1983a, p. 366). Kozur and Mostler (1989) disagreed with such a conclusion and showed that species described as *Tormentum* by Nazarov and Ormiston (1985a) belongs to the two different genera: *Tormentum s. s.* and *Nazarovispongus*. Kozur and Mostler (1989) emended the diagnosis of the genus *Tormentum* leaving in its composition only species similar in morphology with the type species. Species with inflated tests such as *Nazarovispongus pavlovi* Kozur 1980, *Tormentum delicatum* Nazarov and Ormiston 1985a and *T. inflatum* Nazarov and Ormiston 1985a they included into the composition of the genus *Nazarovispongus*. We concur with the opinion of Kozur and Mostler, and consider that the genus *Nazarovispongus* is a valid genus in spite of the opinion of Dumitrica (1984) that *Nazarovispongus* is a junior synonym of the genus *Ruzhencevispongus*. In our Texas material there are many forms clearly showing the same morphology with the genus *Nazarovispongus*: inflated subtriangular tests with an internal nonporous sphere with three hollow rays diverging from a nonporous internal sphere at an angle of 120° and connected with three-bladed terminal spines, surrounded by a thick spongy meshwork and having empty space between the internal sphere and one spongy shell. We think that the subdivision of the family Ruzhencevispongidae into two subfamilies Latentidiotinae (with one shell) and Ruzhencevisponginae (with two shells) proposed by Afanasieva (2000), Afanasieva et al. (2005) and Afanasieva and Amon (2006) needs to be redefined because representatives of the genus *Ruzhencevispongus* have only one shell.

Genus *Ruzhencevispongus* Kozur 1980

Type species: *Ruzhencevispongus uralicus* Kozur 1980.

**Diagnosis:** Test compressed to some degree, triangular in outline with straight or slightly convex or concave sides, with terminal short spines or without them at the corners of the triangle. The internal sphere is nonporous with three rays radiating from

it and enclosed in a spongy meshwork that becomes sparse in the middle part of the test.

**Range:** Lower Permian, Cisuralian, Kungurian – Upper Permian, Lopingian, Changhsingian.

*Ruzhencevispongus girtyi* Nazarov and Ormiston 1985a

Plate 16, figures 13-18

*Ruzhencevispongus girtyi* NAZAROV and ORMISTON 1985a, p. 32, pl. 3, fig. 3. – NAZAROV and ORMISTON 1986a, pl. 7, fig. 11. – NAZAROV and ORMISTON 1986b, fig. 2. – WANG and QI 1995, pl. 3, figs. 8-10. – NESTELL et al. 2006a, pl. 10, figs. 5-9.

*Ruzhencevispongus uralicus* morphotype *uralicus* WANG 1993, p. 47, pl. 1, figs. 13-16.

**Discussion:** *Ruzhencevispongus girtyi* differs from *R. uralicus* Kozur (1980, p. 237, pl. 1, figs. 1-3) by larger size of the test, three straight or slightly concave sides, even development of the spongy meshwork along the entire test and the presence of short cylindrical spines.

**Occurrence:** Middle Permian; USA, West Texas; Guadalupe Mountains, Bell Canyon Formation, Hegler, Rader, Lamar Limestone and Reef Trail (Maldonado and Noble this volume; Noble and Jin this volume) Members; Apache Mountains, EF section, units A, B, C, D, E, Bell Canyon Formation, age equivalent to the Reef Trail Member; China, Jiangsu and Anhui provinces, Kuhfeng (= Gufeng) Formation.

*Ruzhencevispongus triradiatus* Wang 1993

Plate 17, figures 1-6; Plate 18, figure 12

*Ruzhencevispongus uralicus* morphotype *triradiatus* WANG 1993, p. 9, pl. 1, figs. 1-4.

*Ruzhencevispongus uralicus* morphotype *subtriangulus* WANG 1993, p. 9, pl. 1, figs. 5-12.

*Ruzhencevispongus uralicus* Kozur – WANG and QI 1995, pl. 3, figs. 5-7.

*Ruzhencevispongus uralicus* morphotype A - WANG 1995, p. 144, pl. 2, figs. 11-12.

## PLATE 14

Latest Capitanian (Guadalupian, Middle Permian) radiolarians from the EF section, Apache Mountains, West Texas.

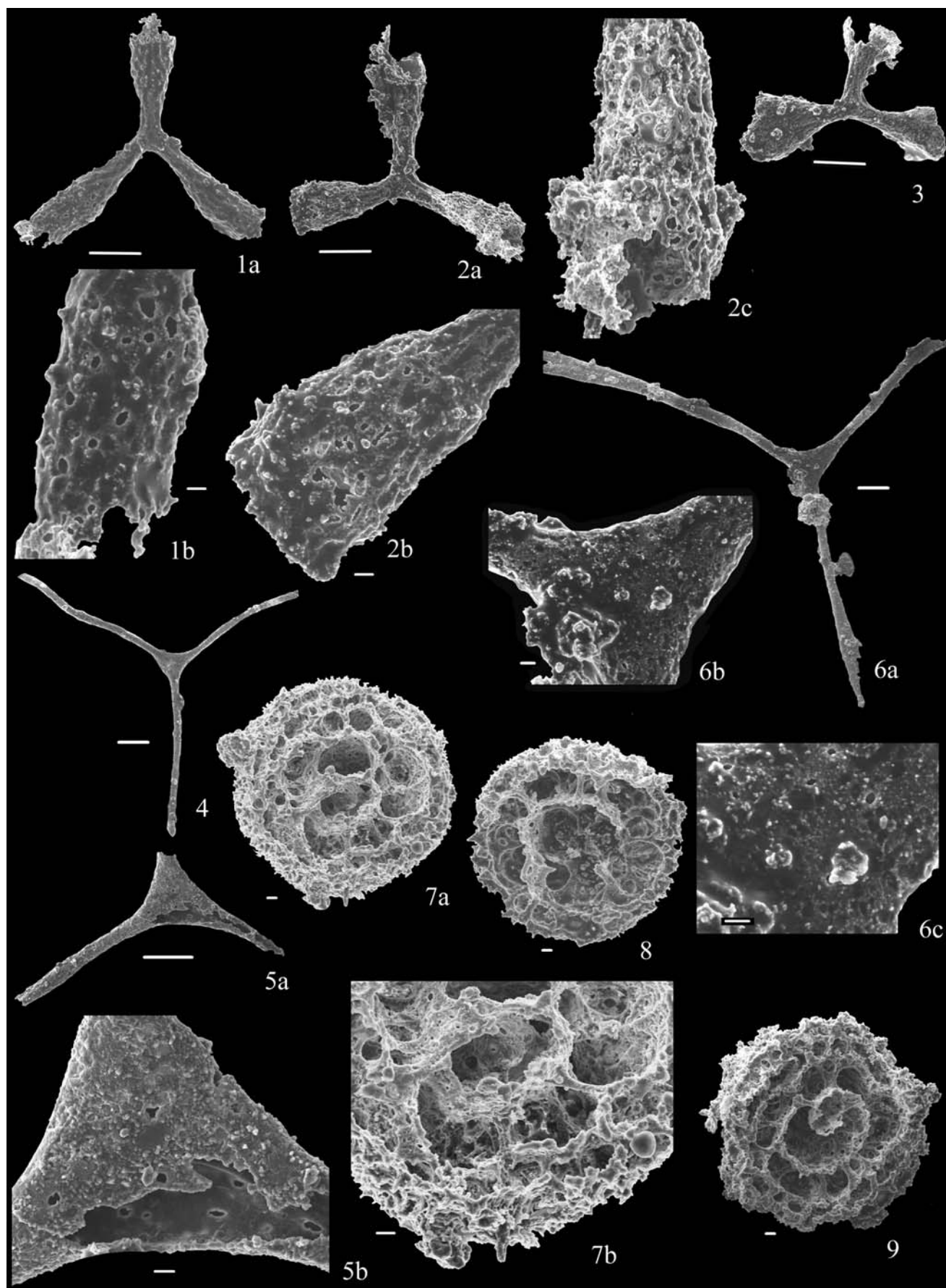
Scale bar is 100µm, except for figs. 1b, 2b, 2c, 5b, 6b, 6c, 7a, 7b, 8, 9 – 10µm.

- 1-2 *Ishigaum* sp. 1. 1a – no. USNM 538658, 1b – enlarged view of the left arm showing porous surface, sample E-2, unit E; 2a – no. USNM 538659, 2b – enlarged view of the left arm showing porous surface, 2c – enlarged view of the right arm showing spongy? structure, sample F-4, unit E.
- 3 *Ishigaum?* sp. 2, no. USNM 538660, sample F-4, unit E.
- 4-6 *Shangella capitanensis* Nestell and Nestell, n. sp. 4 – no. USNM 538661, holotype, sample E-2, unit E; 5a – no. USNM 538662, broken test of the paratype, 5b – enlarged view showing rare oval pores and hollow in-

ternal part, sample E-1, unit E; 6a – no. USNM 538663, paratype, 6b – enlarged view of the central part of the test, 6c – enlarged view of the central part of the test showing rare oval pores, sample E-2, unit E.

- 7-9 *Grandetortura nipponica* Sashida and Tonishi. 7a – no. USNM 538664, broken test showing spiral coiling, 7b – enlarged view of part of spiral coiling, sample E-1, unit E; 8 – no. USNM 538665, broken test showing spiral coiling, sample E-2, unit E; 9 – no. USNM 538666, broken test showing spiral coiling, sample F-22, unit D.





*Ruzhencevispongos uralicus* morphotype B – WANG 1995, p. 144, pl. 2, figs. 13-14.

**Remarks:** Wang (1993) described three new morphotypes of the species *Ruzhencevispongos uralicus* Kozur: *R. u. uralicus*, *R. u. triradiatus* and *R. u. subtriangulus* from the Kuhfeng (= Gufeng) Formation of Jiangsu and Anhui provinces in China. The morphotype *uralicus* is characterized by a triangular shape of the test with three straight sides, morphotype *subtriangulus* by a triangular shape of the test with three sides moderately concave, and morphotype *triradiatus* is characterized by a triangular shape of the test with three sides strongly concave. In our opinion, *Ruzhencevispongos uralicus* described by Kozur (1980, p. 237, pl. 1, figs. 1-3) from the Kungurian of Southern Urals differs from the *R. uralicus uralicus* Wang (1993, p. 9, pl. 1, figs. 13-16) by two slightly concave sides and one straight side, and a loose spongy meshwork in the central area of the test. Wang's *R. uralicus uralicus* is very similar in shape to the species *Ruzhencevispongos girtyi* described by Nazarov and Ormiston (1985a).

We consider that Wang's *Ruzhencevispongos uralicus* morphotype *triradiatus* and *R. u.* morphotype *subtriangulus* represent variability of the shape of the test from moderate concave sides to strongly concave sides. Moreover, the age of the Gufeng Formation is assigned to the Middle Permian, Kuhfengian stage of China that corresponds to the conodont *Jinogondolella nankingensis* to *J. postserrata* zones (Kuwahara et al. 2007) of the Guadalupian in the recent scale. In our Texas material we have tests with a gradual transition from one shape to another. Thus, we consider that *R. u. triradiatus* and *R. u. subtriangulus* are the same species. We raise the rank of the morphotypes to the specific level under the name *Ruzhencevispongos triradiatus* Wang.

**Variability:** Tests illustrated on plate 17, figures 1-6 show the gradual changing of the shape from a subtriangular test with widely rounded corners and slightly convex two sides and slightly concave third side (fig. 1) to strongly concave two sides and slightly concave third side and narrow rounded corners (fig. 6). Some specimens have short conical terminal spines at the corners of the triangular test.

**Discussion:** *Ruzhencevispongos triradiatus* Wang differs from *R. girtyi* Nazarov and Ormiston by the subtriangular shape of the test, different degree of concave sides, widely rounded or narrow rounded corners (in *R. girtyi* the corners are pointed), and conical spines (in *R. girtyi* the spines are cylindrical).

**Occurrence:** Middle Permian; China, Kuhfengian, Gufeng Formation; USA, West Texas, Capitanian, Apache Mountains, EF section, units B, D, E, Bell Canyon Formation, equivalent age of the Reef Trail Member, Guadalupe Mountains, Bell Canyon Formation, Reef Trail Member (as *Ruzhencevispongos* cf. *R. uralicus* Kozur in Maldonado and Noble this volume).

**Genus** *Nazarovispongos* Kozur 1980; reinstated herein  
Type species: *Nazarovispongos pavlovi* Kozur 1980.

**Diagnosis:** Test from triangular shape to almost spherical, inflated, with convex sides, and with sharp or rounded corners. Internal framework is represented by a small nonporous sphere enclosed in a dense spongy meshwork. Three internal rays diverge from the sphere at an angle of 120° and connect with external short three-bladed spines. The central part of the test between the external spongy shell and initial nonporous sphere is not filled with a spongy meshwork and is empty.

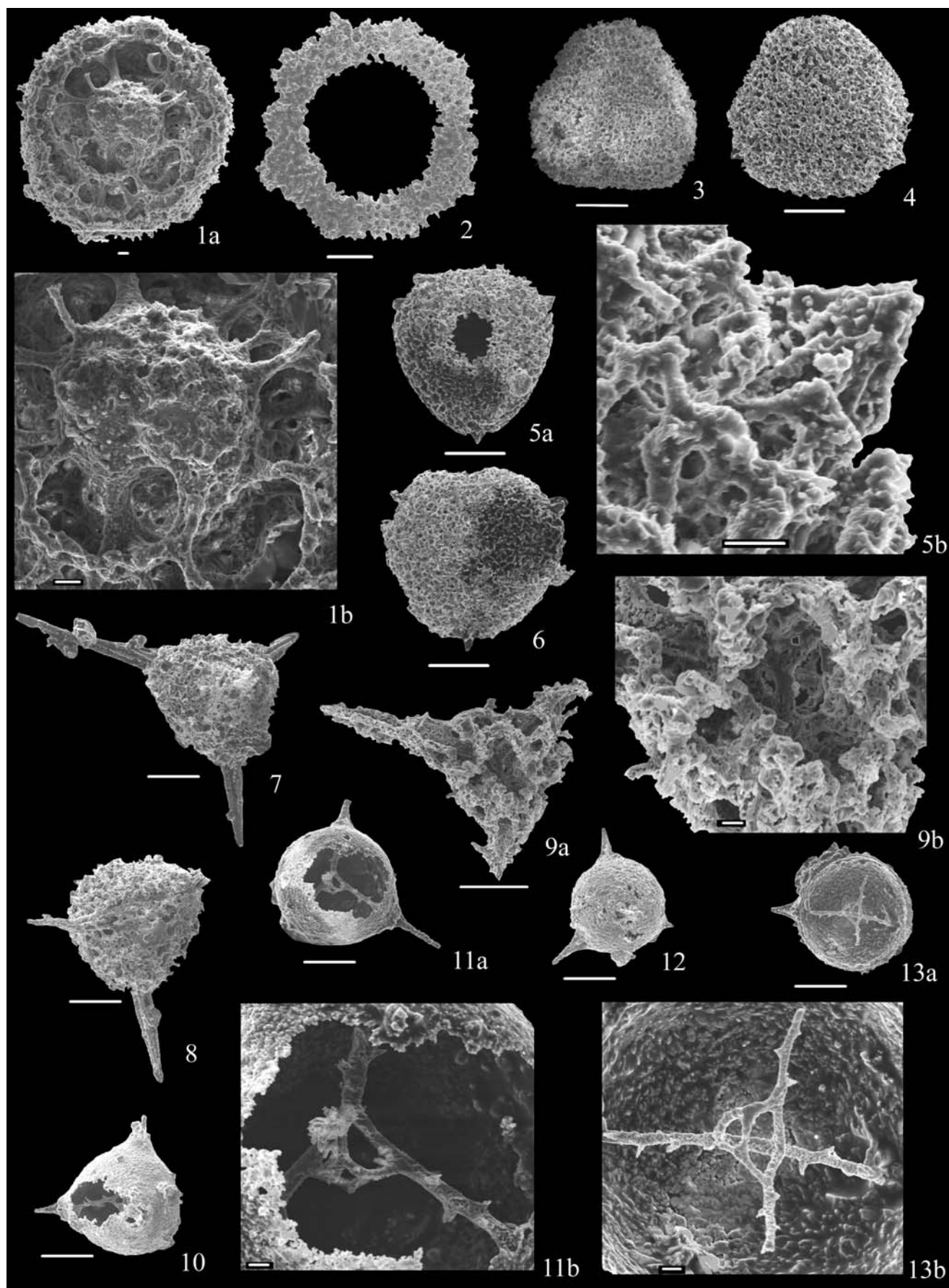
**Range:** Carboniferous, Upper Pennsylvanian, Gzhelian – Middle Permian, Guadalupian, Capitanian.

## PLATE 15

Latest Capitanian (Guadalupian, Middle Permian) radiolarians from the EF section, Apache Mountains, West Texas. Scale bar is 100µm, except for figs. 1a, 1b, 5b, 9b, 11b, 13b – 10µm.

- 1 *Grandetortura nipponica* Sashida and Tonishi, 1a – no. USNM 538667, broken test showing the spiral coiling, 1b – enlarged view showing one of the internal porous shells, sample E-2, unit E.
- 2 *Tormentum sertulum* Nazarov and Ormiston, no. USNM 538668, sample F-9A, base of unit B.
- 3-6 *Rectotortum wardlawi* Nestell and Nestell, n. sp. 3 – no. USNM 538669, sample F-13, unit B; 4 – no. USNM 538670, paratype, sample E-1, unit E; 5a – no. USNM 538671, paratype, 5b – enlarged view of one of the short spines, sample E-1, unit E; 6 – no. USNM 538672, holotype, sample E-1, unit E.
- 7-9 *Tetragregnon japonicum* Sashida and Tonishi. 7 – no. USNM 538673, sample F-8, unit B; 8 – no. USNM 538674, sample F-8, unit B; 9a – no. USNM 538675, broken test showing internal structure, 9b – enlarged view showing thick internal spicule, sample F-13, unit B.
- 10-13 *Tetratormentum ormistoni* Nestell and Nestell, n. sp. 10 – no. USNM 538676, paratype, broken specimen showing internal ray, sample F-13, unit B; 11a – no. USNM 538677, paratype, broken specimen showing internal structure, 11b – enlarged view showing four-rayed internal spicule and rays with short apophyses, sample F-13, unit B; 12 – no. USNM 538678, holotype, sample F-19, unit D; 13a – no. USNM 538679, paratype, broken test showing internal structure, 13b – enlarged view showing four-rayed internal spicule with short apophyses on the rays, sample F-19, unit D.





*Nazarovispongos globosum* Nestell and Nestell, n. sp.  
Plate 17, figures 14-17

**Diagnosis:** *Nazarovispongos* with strongly inflated almost globose or spherical test, oblong or rounded shape of the internal sphere, and short three-bladed pyramidal spines.

**Description:** Test strongly inflated almost globose with one thick spongy shell. Internal framework consists of a slightly oblong or rounded nonporous internal sphere with a bumpy surface. Three very thin internal rays diverge from it at an angle of 120°. Each ray ends externally as a short three-bladed pyramidal spine. There is empty space between the internal sphere and external thick spongy shell. The internal layer of the external shell is sparsely porous with rounded to oval pores, closer to the external surface the spongy shell is denser with tiny rounded pores.

**Measurements (µm):** test diameter 260-360, thickness of the spongy shell 50, diameter of rounded internal sphere 40; the length of the oblong internal sphere 50, the width 40; the height of the spines 22-40; the diameter pore of the internal layer of the shell 10-18, external layer 4-6.

**Designation of types:** The specimen illustrated on plate 17, figure 16 (no. USNM 538713) is designated as the holotype and the specimens on plate 17, figures 14 (no. USNM 538711) and 17 (no. USNM 538714) as the paratypes. They are from West Texas, Apache Mountains, 50km north-east of Van Horn, Texas FM 2185, EF section, unit E, sample E-2; the upper part of the Bell Canyon Formation, age equivalent to the Reef Trail Member, upper Capitanian, Middle Permian.

**Etymology:** After the Latin *globosus* – round.

**Material:** 6 specimens.

**Discussion:** Based on the inflated test, *Nazarovispongos globosum* n. sp. is similar to *N. inflatum* (Nazarov and Ormiston) (Nazarov and Ormiston 1985a, p. 41, pl. 5, fig. 6), but differs from it by a spherical test, oblong or rounded shape of the internal sphere (in *N. inflatum* the internal sphere is subtriangular, see pl. 17, fig. 7b in this paper), and different shape of the spines.

**Occurrence:** As holotype and paratypes.

## CONCLUSIONS

Diverse radiolarians from strata partially the age equivalent of the Reef Trail Member of the Bell Canyon Formation (Capitanian, Guadalupian, Middle Permian) from the EF section in the Apache Mountains are described for the first time. The assemblage consists of 68 species belonging to 32 genera, 22 families, 10 orders and 4 classes in sense of classification of Afanasieva et al. (2005). Fifteen new species are described: *Campanulithus insuetus*, *Pseudobailiella apachensis*, *Astroentactinia capitanensis*, *Polyedroentactinia guadalupensis*, *Afanasievella apachensis*, *Copicyntra erinacea*, *Paracopicyntra snyderi*, *Klaengspongos planus*, *Copellintra orbiculata*, *C. fastuosa*, *Shangella capitanensis*, *Rectotortum wardlawi*, *Tetratortum ormistoni*, *Quadrilobata? blomei*, and *Nazarovispongos globosum*.

The diagnoses of the species *Follicucullus sphaericus* Takemura in Takemura et al. 1999 and the genus *Raciditor* Sugiyama 2000 are emended. The rank of the subspecies *Raphidociclicus gemellus americanus* Nazarov and Ormiston 1985a is raised to species level. The genus *Nazarovispongos* Kozur 1980 is considered to be a valid genus and is reinstated herein.

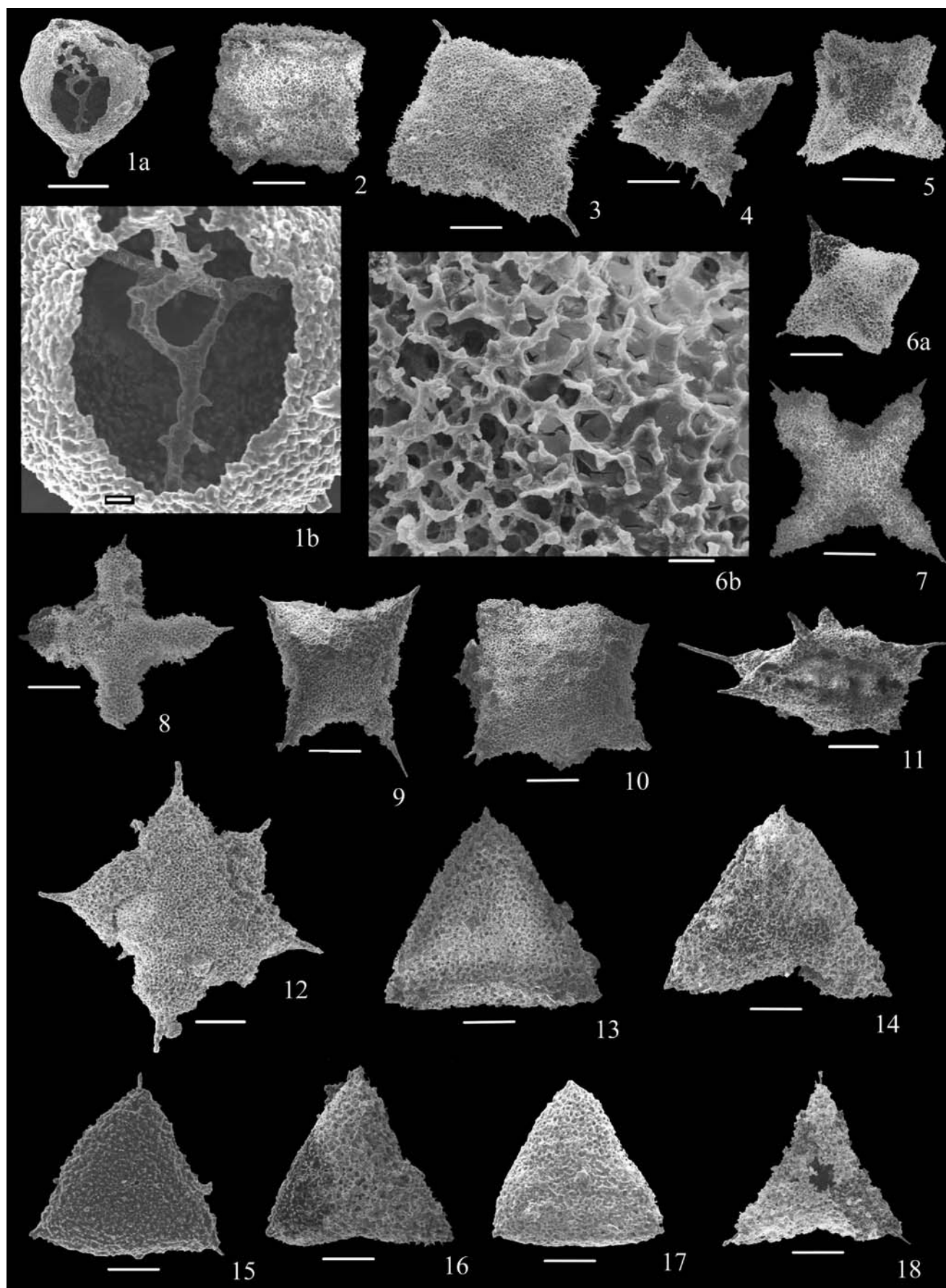
Established are one new genus, *Afanasievella* (assigned to the family Spongentactiniidae), one new subfamily Polyedro-

## PLATE 16

Latest Capitanian (Guadalupian, Middle Permian) radiolarians from the EF section, Apache Mountains, West Texas.  
Scale bar is 100µm, except for figs. 1b, 6b – 10µm.

- 1 *Tetratortum ormistoni* Nestell and Nestell, n. sp., 1a - no. USNM 538680, paratype, broken test showing internal structure, 1b – enlarged view showing four-rayed internal spicule and short apophyses on the ray, sample F-19, unit D.
- 2-12 *Quadrilobata? blomei* Nestell and Nestell, n. sp. 2 – no. USNM 538681, paratype, sample F-12, unit B; 3 – no. USNM 538682, holotype, sample E-2, unit E; 4 – no. USNM 5386843, sample F-8, unit B; 5 – no. USNM 538684, sample F-12, unit B; 6a – no. USNM 538685, 6b – enlarged view of the spongy surface of the shell, sample F-8, unit B; 7 – no. USNM 538686, paratype, sample F-12, unit B; 8 – no. USNM 538687, sample F-13, unit B; 9 – no. USNM 538688, paratype, sample E-1, unit E; 10 – no. USNM 538689, paratype, sample E-1, unit E; 11 – no. USNM 538690, lateral view of the broken test showing internal sphere enclosed in a spongy meshwork, sample E-1, unit E; 12 – no. USNM 538691, sample F-8, unit B.
- 13-18 *Ruzhencevispongos girtyi* Nazarov and Ormiston. 13 – no. USNM 538692, sample F-23, unit C; 14 – no. USNM 538693, sample F-23, unit C; 15 – no. USNM 538694, sample F-9A, base of unit B; 16 – no. USNM 538695, sample E-2, unit E; 17 – no. USNM 538696, sample F-12, unit B; 18 – no. USNM 538697, sample F-12, unit B.





entactiniinae (in the composition of the family Orosphaeridae), and one new family Tetratormentidae (in the composition of the order Pyramidata).

The radiolarian assemblage from the EF section in the Apache Mountains is coeval with the radiolarian assemblage from the Reef Trail Member of the Bell Canyon Formation in the Guadalupe Mountains, allowing a clear correlation between these units. This correlation is supported by the conodont species that define the latest Guadalupian conodont zones and that occur together with radiolarians in both areas. In the EF section, four conodont zones were recognized by Lambert et al. (2002) and Wardlaw and Nestell (this volume) (in ascending order): *Jinogondolella postserrata*, *J. shannoni* (Lamar Limestone), and *J. altudaensis* and *Clarkina hongshuiensis* (Reef Trail Member). As far as the radiolarian zone succession is concerned, one very interesting observation can be made. The species *Albaillella yamakitai* in sense of Xia et al. 2005 is found in the *J. altudaensis* conodont zone in both the Apache and Guadalupe Mountains. The first appearance of this species was considered as a marker for the Guadalupian – Lopingian boundary by Xia et al. (2005). Clearly the species *A. yamakitai* in sense of Xia et al. 2005 is not a reliable marker for this boundary.

#### ACKNOWLEDGMENTS

The authors thank Dr. Robert Scott (University of Tulsa, Tulsa, Oklahoma) for the use of some radiolarian materials and literature of A. Ormiston, to Dr. Charles Blome (U. S. Geological Survey, Denver, Colorado) who provided Permian radiolarian

literature and lively discussions about the taxonomy of late Paleozoic Radiolaria, to Dr. Cliff Nestell (Shawnee Mission Hospital library, Shawnee, Kansas) who assisted in obtaining rare literature, to Dr. Marina Afanasieva (Paleontological Institute, Moscow, Russia) for her helpful comments about the classification of Radiolaria, to Amy Maldonado, Ivy Jin and Dr. Paula Noble from the University of Nevada at Reno for discussions about radiolarian species and their taxonomy from the Lamar Limestone and Reef Trail Members of the Bell Canyon Formation in the Guadalupe Mountains, Martha Gracey (University of Texas at Arlington, Texas) for providing useful advice about using the SEM and photographing radiolarians, and to Alexei Dukov for the drawings of some representatives of the family Ormistonellidae. We are grateful to Dr. Emile Pessagno (University of Texas at Dallas, Texas), Dr. Katsuo Sashida (University of Tsukuba, Ibaraki, Japan), and Dr. Bruce Wardlaw for their critical reviews that improved the manuscript. All SEM photographs were taken using the facilities of the Department of Biology at the University of Texas at Arlington. Mr. George Snyder, owner of the Jones Ranch in the Apache Mountains very kindly provided us warm hospitality and access to very interesting Middle Permian (Guadalupian) strata exposed on his ranch.

#### REFERENCES

- AFANASIEVA, M. S., 1999. Novyy variant systematiki paleozoyskikh radiolyariy [New variant of systematics of Paleozoic radiolarians]. In: Yushkin, N. P., Ed., *13<sup>th</sup> Geological Congress of the Komi Republic on Geology and Mineral Resources of northeastern European Russia: New results and new prospects*, 253-256. Syktyvkar: Institut

#### PLATE 17

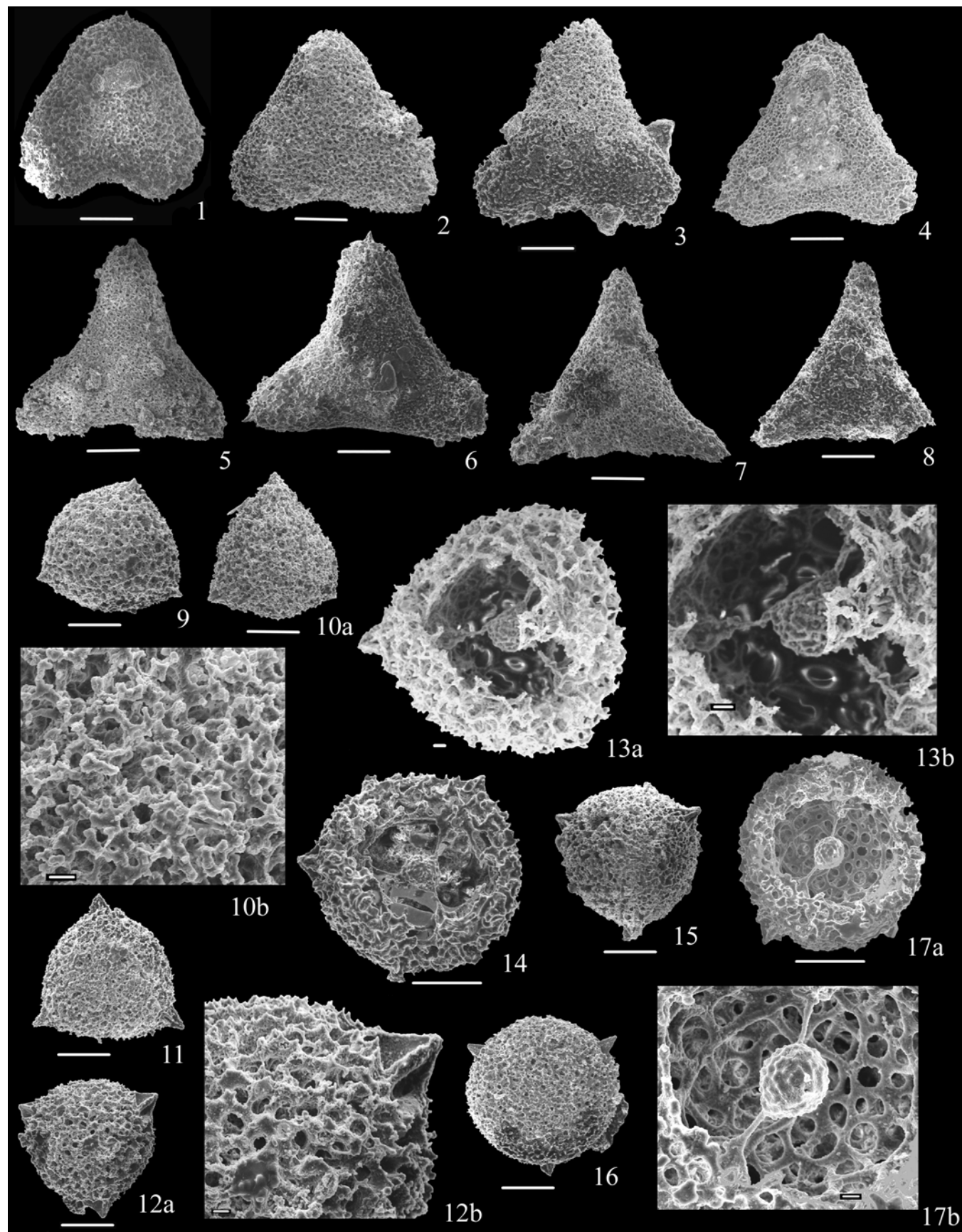
Latest Capitanian (Guadalupian, Middle Permian) radiolarians from the EF section, Apache Mountains, West Texas.  
Scale bar is 100µm, except for figs. 10b, 12b, 13a, 13b, 17b – 10µm.

- 1-6 *Ruzhencevispongia triradiatus* Wang. 1 – no. USNM 538698, sample F-8, unit B; 2 – no. USNM 538699, sample F-8, unit B; 3 – no. USNM 538700, sample F-9A, base of unit B; 4 – no. USNM 538701, sample F-13, unit B; 5 – no. USNM 538702, sample F-8, unit B; 6 – no. USNM 538703, sample E-2, unit E.
- 7-8 *Ruzhencevispongia?* sp. 1. 7 – no. USNM 538704, sample E-1, unit E; 8 – no. USNM 538705, sample E-1, unit E.
- 9-13 *Nazarovispongia inflatum* (Nazarov and Ormiston). 9 – no. USNM 538706, sample E-2, unit E; 10a – no. USNM 538707, 10b – enlarged view of the spongy surface of the test, sample F-8, unit B; 11 – no. USNM 538708, sample E-1, unit E; 12a – no. USNM 538709, 12b – enlarged view showing the spongy surface of

the test and one of the short three-bladed spines, sample E-1, unit E; 13a – no. USNM 538710, broken test showing internal structure, 13b – enlarged view showing the subtriangular nonporous sphere with thin rod-like beams, sample F-13, unit B.

- 14-17 *Nazarovispongia globosum* Nestell and Nestell, n. sp. 14 – no. USNM 538711, paratype, broken test showing the sphere with three beams, sample E-2, unit E; 15 – no. USNM 538712, sample E-2, unit E; 16 – no. USNM 538713, holotype, sample E-2, unit E; 17a – no. USNM 538714, paratype, broken test showing the internal structure, 17b – enlarged view of the internal structure showing the oval nonporous sphere and two preserved thin beams. Note porous internal wall of the spongy shell, sample E-2, unit E.





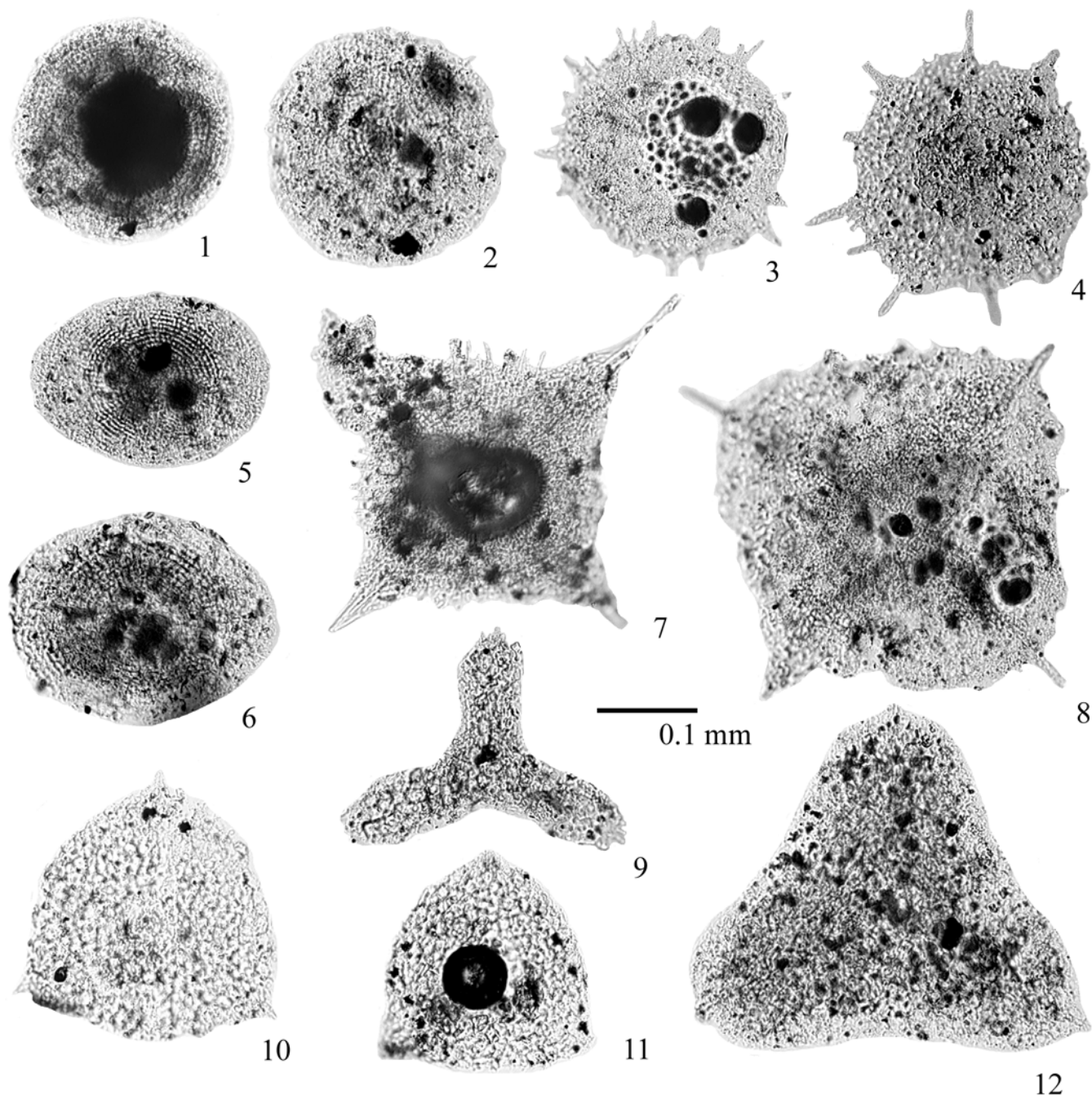
- Geologii, Komi nauchno-tsentral'noe Ural'skoe otделение Rossiyskoy Akademii Nauk, 2. (In Russian)
- , 2000. *Atlas radiolyariy paleozoya Russkoy Platformy* [Atlas of Paleozoic Radiolaria of the Russian Platform]. Moscow: Scientific World, 480 pp. (In Russian)
- , 2008. New replacement names for the genus *Palaeodiscus* Afanasieva, 2000 and the family Palaeodiscidae Afanasieva, 2000 (Radiolaria). *Paleontological Journal*, 42: 440.
- AFANASIEVA, M. S. and AMON, E. O., 2003. A new classification of the Radiolaria. *Paleontological Journal*, 37(6): 630-645.
- , 2006. *Radiolyarii* [Radiolaria]. Moscow: PIN RAS, 320 pp. (In Russian)
- , 2008. Taxonomic status of the genera *Entactinia* Foreman, 1963 and *Stigmosphaerostylus* Rüst, 1892 (Radiolaria of the Paleozoic). *Paleontological Journal*, 42(4): 343-349.
- AFANASIEVA, M. S., AMON, E. O., AGARKOV, Yu. V. and BOLTOVSKOY, D. S., 2005. Radiolarians in the Geological record. *Paleontological Journal, Supplement*, 39: 392 pp.
- AITCHISON, J. C. and STRATFORD, M. C., 1997. Middle Devonian (Givetian) Radiolaria from eastern New South Wales, Australia: a reassessment of the Hinde (1899) fauna. *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen*, 203: 369-390.
- AMON, E. O., 1999. Sistematika sferellyariy (radiolyarii) paleozoya Urala [Systematics of Sphaerellarian radiolarians from the Paleozoic of the Urals]. *Materialy po stratigrafii i paleontologii Urala*, 2: 187-196. (In Russian)
- , 2000. Sistema vysschikh taksonov stauroksonnykh radiolyariy paleozoya [System of Paleozoic higher radiolarian stauroxon taxa]. *Ezhgodnik 1999, Institut geologii i geokhimii, Ural'skoe otделение Rossiyskoy Akademii Nauk*: 3-11. (In Russian)
- ANDERSON, R. Y., DEAN, W. E., KIRKLAND, D. W. and SNIDER, H. I., 1972. Permian Castile varved evaporite sequence, West Texas and New Mexico. *Geological Society of America Bulletin*, 83: 59-86.
- BABCOCK, L. C., 1974. "Statistical approaches to the conodont paleobiology of the Lamar Limestone, Permian Reef Complex, West Texas". Ph.D. dissertation, University Wisconsin, Madison, 175 pp.
- , 1977. Life in the Delaware Basin: the paleoecology of the Lamar Limestone. In: Hileman, M. E. and Mazzullo, S. J., Eds, *Upper Guadalupian facies, Permian Reef Complex, Guadalupe Mountains, New Mexico and West Texas*, 357-389. Tulsa, OK: SEPM (Society of Sedimentary Geology). Publication 77-16
- BELYANSKIY, G. S., NIKITINA, A. P. and RUDENKO, V. S., 1984. O sebucharskoy svite Primor'ya [On the Sebuchar Formation of the Primorye]. In: Poyarkova, Z. N., Ed., *Novye dannye po detal'noy biostratigrafii fanerozoya Dal'nego Vostoka*, 43-57. Vladivostok: DVNC Akademii Nauk SSSR. (In Russian)
- BLOME, C. D. and REED, K. M., 1992. Permian and Early (?) Triassic radiolarian faunas from the Grindstone terrane, Central Oregon. *Journal of Paleontology*, 66: 351-383.
- BRAGIN, N. Yu., VISHNEVSKAYA, V. S., ZHAMOYDA, A. I. and KAZINTSOVA, L. I., 1999. *Prakticheskoe rukovodstvo po mikrofaune. T. 6. Radiolarii mezozoya* [Practical manual on microfauna. V. 6. Mesozoic radiolarians.] St. Petersburg: VSEGEI, 272 pp. (In Russian)

## PLATE 18

Pictures of Latest Capitanian (Guadalupian, Middle Permian) radiolarians from the EF section, Apache Mountains, West Texas taken in transmitted light excluding fig. 8 (QEF section, next to EF section). Scale bar is 0.1mm.

- 1-2 *Copicyntra erinacea* Nestell and Nestell, n. sp. 1 – no. USNM 538715, paratype, section showing numerous concentric shells, sample E-1, unit E; 2 – no. USNM 538716, paratype, section showing numerous concentric shells, sample E-1, unit E.
- 3-4 *Klaengspongos planus* Nestell and Nestell, n. sp. 3 – no. USNM 538717, paratype, section showing non subdivided spongy meshwork surrounding central part, sample F-8, unit B; 4 – no. USNM 538718, paratype, section showing spongy meshwork, sample F-8, unit B.
- 5-6 *Copiellintra orbiculata* Nestell and Nestell, n. sp. 5 – no. USNM 538719, paratype, section showing numerous elliptical shells, sample E-1, unit E; 6 – no. USNM 538720, paratype, section showing numerous elliptical shells, sample E-1, unit E.
- 7-8 *Quadrilobata? blomei* Nestell and Nestell, n. sp. 7 – no. USNM 538721, paratype, section showing small sphere enclosed in spongy meshwork, sample E-2, unit E; 8 – specimen showing spongy meshwork, sample QEF-3.
- 9 *Latentifistula* sp. 1, no. USNM 538722, sample E-1, unit E.
- 10-11 *Rectotortum wardlawi* Nestell and Nestell, n. sp. 10 – no. USNM 538723, paratype, section showing small sphere and numerous not well expressed intercalated shells, sample E-1, unit E; 11 – no. USNM 538724, paratype, section showing several not well expressed intercalated shells whose outlines duplicate the outlines of the external shell. Black circle in the middle of the section is a bubble, sample E-1, unit E.
- 12 *Ruzhencevispongos triradiatus* Wang, no. USNM 538725, section showing spongy meshwork with obscure internal rays; sample F-8, unit B.





- BRAGINA, L. G., 1999. *Cuboctostylus* n. gen., a new Late Cretaceous spicule-bearing spumellarian Radiolaria from southern Sakhalin (Russia). In: De Wever, P. and Caulet, J. P., Eds., *InterRad VIII, Paris/Bierville 8-13 septembre 1997. Geodiversitas*, 21: 571-580.
- CARIDROIT, M. and DE WEVER, P., 1984. Description de quelques nouvelles espèces de Follicucullidae et d'Entactinidae (radiolaires polycystines) du Permien du Japon. *Geobios*, 17: 639-644.
- , 1986. Some Late Permian radiolarians from pelitic rocks of the Tatsuno Formation (Hyogo Prefecture), southwest Japan. *Marine Micropaleontology*, 11: 55-90.
- CARIDROIT, M., DE WEVER, P. and DUMITRICA, P., 1999. Un nouvel ordre, une nouvelle famille et un nouveau genre de Radiolaires du Paléozoïque: Latentifistularia, Cauletellidae et Caulella. *Comptes Rendus de l'Académie des sciences, Sciences de la terre et des planètes*, 329: 603-608.
- CAVALIER-SMITH, T., 1993. Kingdom Protozoa and its 18 phyla. *Microbiological Review*, 57: 953-994.
- , 1999. Principles of protein and lipid targeting in secondary symbiogenesis: euglenoid, dinoflagellate, and sporozoan plastid origins and the eukaryote tree. *Journal of Eukaryotic Microbiology*, 46: 347-366.
- , 2002. The phagotrophic origin of eukaryotes and phylogenetic classification of Protozoa. *International Journal of Systematic and Evolutionary Microbiology*, 52: 297-354.
- CHENG, Y., 1986. *Taxonomic studies on Upper Paleozoic Radiolaria*. Beijing: National Museum of Natural Science. Special Publication 1, 311 pp.
- DEFLANDRE, G., 1953. Actinopodes –Radiolaires fossils. *Titres et travaux scientifiques de Georges Deflandre (Supplément, 1949-53)*, 1-17.
- , 1960. A propos du développement des recherches sur les radiolaires fossils. *Revue de Micropaléontologie*, 2: 212-218.
- , 1963. *Pylentonema*, nouveau genre de Radiolaire du Viséen: Sphaerellaire ou Nassellaire? *Comptes Rendus de l'Académie des Sciences*, 257: 3981-3984.
- DE WEVER, P. and CARIDROIT, M., 1984. Description de quelques nouveaux Latentifistulidea (Radiolaires polycystines) Paléozoïques du Japon. *Revue de Micropaléontologie*, 27: 98-106.
- DE WEVER, P., DUMITRICA, P., CAULET, J. P., NIGRINI, C. and CARIDROIT, M., 2001. *Radiolarians in the Sedimentary Record*. Amsterdam: Gordon and Breach Science Publishers, 533 pp.
- DUMITRICA, P., 1984. Sistematika radiolyariy Sphaerellaria [Systematics of Sphaerellarian radiolarians]. In: Petrushevskaya, M. G. and Stepanjants, S. D., Eds., *Morfologiya, ekologiya i evolyutsiya radiolyariy [Radiolarian morphology, ecology and evolution]*, 91-102. Leningrad: Nauka. Materialy IY simpoziuma evropeyskikh radiolyaristov [Materials of the IY Symposium of European radiolarists – EURARAD 4]. (In Russian)
- , 1994. *Pyloctostylus* n. gen., a Cretaceous Spumellarian Radiolarian genus with initial spicule. *Revue de Micropaléontologie*, 37: 235-244.
- EHRENBERG, Ch. G., 1838. Über die Bildung der Kreidefelsen und des Kreidemergels durch unsichtbare Organismen. *Königliche Akademie der Wissenschaften zu Berlin, Abhandlungen*, Jahre 1838: 59-147.
- , 1875. Fortsetzung der mikrogeologischen Studien als Gesamt-Uebersicht der mikroskopischen Paläontologie gleichartig analysirter Gebirgsarten der Erde, mit specieller Rücksicht auf den Polycystinen Mergel von Barbados. *Königliche Akademie der Wissenschaften zu Berlin, Abhandlungen*, 1875: 1-226.
- FENG, Q. and GU, S., 2002. Uppermost Changxingian (Permian) radiolarian fauna from southern Guizhou, southwestern China. *Journal of Paleontology*, 76: 797-809.
- FENG, Q., GU, S., HE, W. and JIN, Y., 2007. Latest Permian Entactinaria (Radiolaria) from southern Guangxi, China. *Journal of Micropalaeontology*, 26: 19-37.
- FENG, Q., HE, W., ZHANG, S. and GU, S., 2006a. Taxonomy of order Latentifistularia (Radiolaria) from the Latest Permian in southern Guangxi, China. *Journal of Paleontology*, 80: 826-848.
- FENG, Q., HE, W., GU, S., JIN, Y. and MENG, Y., 2006b. Latest Permian Spumellaria and Entactinaria (Radiolaria) from south China. *Revue de Micropaléontologie*, 49: 21-43.
- FENG, Q., MEI, Y. and CRASQUIN, S., 2009. Latest Permian Palaeolithocycliidae (Radiolaria) from South China. *Revue de Micropaléontologie*, 52: 141-148.
- FOREMAN, H. P., 1963. Upper Devonian Radiolaria from the Huron member of the Ohio shale. *Micropaleontology*, 9: 267-304.
- GOLDFUSS, G. A., 1817. *Über die Entwicklungshefer der Thiere*. Nürnberg: L. Schrag, 58 pp.
- HAECKEL, E., 1881. Entwurf eines Radiolarien-Systems auf Grund von Studien der Challenger-Radiolarien. *Jenaische Zeitschrift für Naturwissenschaft*, 15: 418-472.
- , 1887. Report on the Radiolaria collected by H.M.S. "Challenger" during the years 1873-1876. *Report on the Scientific Results of the Voyage of the H. M. S. "Challenger"*. Zoology, 18: 1-1803.
- HINDE, G. J., 1890. Notes on Radiolaria from the Lower Palaeozoic rocks (Llandeilo – Caradoc) of the south of Scotland. *Annals and Magazine of Natural History*, 6(31): 40-59.
- , 1899. On the Radiolaria in the Devonian rocks of New South Wales. *Quarterly Journal of the Geological Society of London*, 55: 38-64.
- HOLDSWORTH, B. K., 1966. Radiolaria from the Namurian of Derbyshire. *Palaeontology*, 9: 319-329.
- , 1969. Namurian Radiolaria of the genus *Ceratoikiscus* from Staffordshire and Derbyshire, England. *Micropaleontology*, 15: 221-229.
- HOLDSWORTH, B. K. and JONES, D. L., 1980. Preliminary radiolarian zonation for Late Devonian through Permian time. *Geology*, 8: 281-285.
- HOLDSWORTH, B. K. and MURCHEY, B. L., 1988. Paleozoic radiolarian biostratigraphy of the northern Brooks Range, Alaska. In: Gryc, G., Ed., *Geology and exploration of the National Petroleum Reserve in Alaska, 1974 to 1982*, 777-796. Reston, VA: U. S. Geological Survey. Professional Paper 1399.
- HORAK, R. L. and HALSEY, J. H., 1983. *Geological field trip to El Paso, Texas, Carlsbad, New Mexico, Alpine, Texas, Big Bend National Park, Midland/Odessa, Texas, August 22-27, 1983*. Dallas, TX: Mobil Exploration and Producing Services, Inc., 65 pp.



- ISAKOVA, T. N. and NAZAROV, B. B., 1986. *Stratigrafiya i mikrofauna pozdnego karbona-ranney permi yuzhnogo Urala* [Late Carboniferous – Early Permian stratigraphy and microfauna of Southern Urals]. Moscow: Nauka, 184 pp. (In Russian)
- ISHIGA, H., 1986. Late Carboniferous and Permian Radiolarian Biostratigraphy of southwest Japan. *Journal of Geosciences, Osaka City University*, 29: 89-100.
- , 1991. Description of a new *Follicucullus* species from southwest Japan. *Memoirs of the Faculty of Science, Shimane University*, 25: 107-118.
- ISHIGA, H. and IMOTO, N., 1980. Some Permian radiolarians in the Tamba District, southwest Japan. *Earth Science: Journal of the Association for the Geological Collaboration in Japan*, 34: 333-345.
- ISHIGA, H., KITO, T. and IMOTO, N., 1982. Middle Permian radiolarian assemblages in the Tamba District and an adjacent area, southwest Japan. *Earth Science: Journal of the Association for the Geological Collaboration in Japan*, 36(5): 272-281.
- JONES, M. K. and NOBLE, P. J., 2006. Sheinwoodian (uppermost Lower Silurian) Radiolaria from the Cape Phillips Formation, Nunavut, Canada. *Micropaleontology*, 52: 289-315.
- KOZUR, H., 1980. Ruzhencevispongidae, eine neue Spumellaria-Familie aus dem oberen Kungurian (Leonardian) und Sakmarian des Vorurals. *Geologisch-Paläontologische Mitteilungen Innsbruck*, 10: 235-242.
- , 1981. Albaillellidea (Radiolaria) aus dem Unterperm des Vorurals. *Geologisch-Paläontologische Mitteilungen Innsbruck*, 10: 263-274.
- , 1993. Upper Permian radiolarians from the Sosio Valley area, western Sicily (Italy) and from uppermost Lamar Limestone of West Texas. *Jahrbuch für Geologie. B. –A.*, 136: 99-123.
- , 1999. Permian development in the western Tethys. *Proceedings of the International Symposium on Shallow Tethys (ST)*, 5: 101-135.
- KOZUR, H. and MOSTLER, H., 1979. Beiträge zur Erforschung der mesozoischen Radiolarien. Teil III: Die Oberfamilien Actinommacea Haeckel 1862 emend., Artiscacea Haeckel 1882, Multiarcusellacea nov. der Spumellaria und triassische Nassellaria. *Geologisch-Paläontologische Mitteilungen Innsbruck*, 9: 1-132.
- , 1981. Beiträge zur Erforschung der mesozoischen Radiolarien. Teil IV: Thalassosphaeracea Haeckel, 1862, Hexastylacea Haeckel, 1882 emend. Petruševskaja, 1979, Sponguracea Haeckel, 1862 emend. und weitere triassische Lithocycliacea, Trematodiscacea, Actinommacea und Nassellaria. *Geologisch-Paläontologische Mitteilungen Innsbruck Sonderband 1*, 208 pp.
- , 1982. Entactinaria subordo nov., a new radiolarian suborder. *Geologisch-Paläontologische Mitteilungen Innsbruck*, 11/12: 399-414.
- , 1989. Radiolarien und schwammskleren aus dem Unterperm des Vorurals. *Geologisch-Paläontologische Mitteilungen Innsbruck, Sonderband 2*: 147-275.
- KUWAHARA, K., 1997. Upper Permian radiolarian biostratigraphy: abundance zones of *Albaillella*, 55-75. Osaka: News of Osaka Micropaleontologists. Special volume, 10.
- , 1999. Phylogenetic lineage of Late Permian *Albaillella* (Albaillellaria, Radiolaria). *Journal of Geoscience, Osaka City University*, 42: 85-101.
- KUWAHARA, K. and YAO, A., 1998. Diversity of Late Permian radiolarian assemblages. In: Matsuoka, A., Ed., *Proceedings of the Six Radiolarian Symposium*, 33-46. Osaka: News of Osaka Micropaleontologists. Special volume 11.
- KUWAHARA, K., YAO, A. and YAMAKITA, S., 1998. Reexamination of Upper Permian radiolarian biostratigraphy. *Earth Science (Chikyū Kagaku)*, 52: 391-404.
- KUWAHARA, K., YAO, A., YAO, J. and WANG, X., 2007. Permian radiolarians from the Gufeng Formation of the Tongling area, Anhui Province, China. *Journal of Geosciences, Osaka City University*, 50: 35-54.
- LAMBERT, L. L., BELL, G. L., Jr., FRONIMOS, J. A., WARDLAW, B. R. and YISA, M. O., (this volume). Conodont biostratigraphy of a more complete Reef Trail Member section near the type section, latest Guadalupian Series type region. *Micropaleontology*, 56: 233-253.
- LAMBERT, L. L., LEHRMANN, D. J. and HARRIS, M. T., 2000. Correlation of the Road Canyon and Cutoff Formations, West Texas, and its relevance to establishing an International Middle Permian (Guadalupian) Series. In: Wardlaw, B. R., Grant, R. E. and Rohr, D. M., Eds., *The Guadalupian Symposium*, 154–184. Washington, DC: Smithsonian Institution. Contributions to the Earth Sciences, 32.
- LAMBERT, L. L., WARDLAW, B. R., NESTELL, M. K. and NESTELL, G. P., 2002. Latest Guadalupian (Middle Permian) conodonts and foraminifers from West Texas. *Micropaleontology*, 48: 343-364.
- LANKESTER, E. R., 1878. Preface to the English translation of the 2<sup>nd</sup> edition. *Gegenbaur's Elements of Anatomy*. London: Macmillan.
- LOEBLICH, A. R. and TAPPAN, H., 1961. Remarks on the systematics of the Sarcodina (Protozoa), renamed homonyms and new and validated genera. *Proceedings of the Biological Society of Washington*, 74: 21-234.
- MALDONADO, A. and NOBLE, P. J., (this volume). Radiolarians from the upper Guadalupian (Middle Permian) Reef Trail Member of the Bell Canyon Formation, West Texas and their biostratigraphic implications. *Micropaleontology*, 56: 69-115.
- MÜLLER, J., 1858. Über die Thalassicollen, Polycystinen und Acanthometren des Mittelmeers. *Königliche Preussische Akademie der Wissenschaften zu Berlin, Abhandlungen, Jahre 1858*: 1-62.
- NAZAROV, B. B., 1975. *Radiolyarii nizhnego-srednego paleozoya Kazakhstana* [Lower and Middle Paleozoic radiolarians of Kazakhstan]. Moscow: Nauka, 202 pp. (In Russian)
- , 1988. *Prakticheskoe rukovodstvo po mikrofaune SSSR. T. 2. Radiolyarii paleozoya* [Practical manual on microfauna of USSR. Vol. 2. Paleozoic Radiolaria]. Leningrad: Nedra, 232 pp. (In Russian)
- NAZAROV, B. B. and ORMISTON, A. R., 1983a. A new superfamily of stauraxon polycystine Radiolaria from the Late Paleozoic of the Soviet Union and North America. *Senckenbergiana Lethaea*, 64: 363-379.
- , 1983b. Upper Devonian (Frasnian) radiolarian fauna from the Gogo Formation, Western Australia. *Micropaleontology*, 29(4): 454-466.
- , 1984. Vozmozhnaya sistema radiolyariy paleozoya [Tentative system of Paleozoic Radiolaria]. In: Petrushevskaya, M. G. and Stepanjants, S. D., Eds., *Morfologiya, ekologiya i evolyutsiya radiolyariy* [Radiolarian morphology, ecology and evolution]. Materialy

- IY simpoziuma evropeyskikh radiolyaristov [Materials of the IY Symposium of European radiolarists – EURARAD 4], Leningrad, Nauka: 64–87. (In Russian)
- , 1985a. Radiolaria from the Late Paleozoic of the Southern Urals, USSR and West Texas, USA. *Micropaleontology*, 31: 1-54.
- , 1985b. Evolution of Radiolaria in the Paleozoic and its correlation with the development of other marine fossil groups. *Senckenbergiana Lethaea*, 66: 203-215.
- , 1986a. Trends in the development of Paleozoic Radiolaria. *Marine Micropaleontology*, 11: 3-32.
- , 1986b. Origin and biostratigraphic potential of the stauraxon polycystine Radiolaria. *Marine Micropaleontology*, 11: 33-54.
- , 1989. Novye vidy radiolyarii iz permi yuga Urala i Nevady [New radiolarian species from the Permian of the Southern Urals and Nevada]. *Paleontologicheskii Zhurnal*, 2: 13-21. (In Russian)
- , 1993. New biostratigraphically important Paleozoic Radiolaria of Eurasia and North America. In: Blueford, J. and Murchey, B., Eds., *Radiolaria of giant and subgiant fields in Asia. Nazarov Memorial Volume*, 22-60. New York: Micropaleontology Press. Micropaleontology Special Publication, 6.
- NAZAROV, B. B. and POPOV, L. E., 1980. *Stratigrafiya i fauna kremnisto-karbonatnykh tolshch ordovika Kazakhstana (radiolyarii i bezzamkovye brachiopody)* [Stratigraphy and fauna of Ordovician siliceous-carbonate deposits of Kazakhstan (radiolarians and inarticulate brachiopods)]. Moscow: Nauka, 190 pp. (In Russian)
- NAZAROV, B. B. and RUDENKO, V. S., 1981. Nekotorye bilateral'no - simmetrichnye radiolyarii pozdnego paleozoya yuzhnogo Urala [Some bilaterally-symmetrical Late Paleozoic radiolarians of the South Urals]. *Voprosy mikropaleontologii*, 24: 129-139. (In Russian)
- NESTELL, G. P. and NESTELL, M. K., 2006. Middle Permian (Late Guadalupian) foraminifers from Dark Canyon, Guadalupe Mountains, New Mexico. *Micropaleontology*, 52: 1-50.
- NESTELL, M. K. and WARDLAW, B. R., 2009. The Bell Canyon Formation (Wordian - Capitanian) of the Guadalupian Series (Middle Permian): correlation problems from the Guadalupe Mountains to the Apache Mountains. In: *2009 Meeting, Abstracts with Programs*, 20. Midland, TX: Southwest Section, American Association of Petroleum Geologists.
- NESTELL, M. K., BELL, G. L. Jr., WARDLAW, B. R., NESTELL, G. P., LAMBERT, L. L., MALDONADO, A. L. and NOBLE, P. J., 2007a. Biostratigraphic significance of a new potential key reference section for the latest Guadalupian Reef Trail Member of the Bell Canyon Formation (Middle Permian), West Texas. *Geological Society of America Abstracts with Programs*, 39: 68.
- NESTELL, M. K., NESTELL, G. P., WARDLAW, B. R. and SWEATT, M. J., 2006a. Integrated biostratigraphy of foraminifers, radiolarians and conodonts in shallow and deep water Middle Permian (Capitanian) deposits of the “Rader Slide”, Guadalupe Mountains, West Texas. *Stratigraphy*, 3: 161-194.
- NESTELL, M. K., NESTELL, G. P. and BELL, G. L., Jr., 2006b. Road Log – Day 2. Van Horn to Apache Mountains to southern Delaware Mountains, Texas. Permian (Late Guadalupian – Lopingian). In: Hinterlong, G., Ed., *Basinal facies of the uppermost Guadalupian: applicability to Exploration and development Projects. Field Trip Guidebook Permian Basin Section (Field trip leaders: Trentham, R. and Bell, G.)*, 1-18. Tulsa, OK: SEPM (Society of Sedimentary Geology). Publication 2006-46.
- NESTELL, G. P., NESTELL, M. K., WARDLAW, B. R., BELL, G. L. Jr. and YERMOLAYEV, J. B., 2007b. Integrated biostratigraphy of conodonts, foraminifers and radiolarians from the uppermost Guadalupian (Middle Permian) in the Apache Mountains, West Texas. *Geological Society of America Abstracts with Programs*, 39: 68.
- NESTELL, M. K., NESTELL, G. P., WARDLAW, B. R., LAMBERT, L. L. and BELL, G. L. Jr., 2009. The Bell Canyon/Castile formational contact: implications for the Guadalupian/Lopingian Series boundary (Middle/Upper Permian) in the Apache Mountains, West Texas. South–Central Section, *Geological Society of America, Abstracts with Programs*, 41: 29.
- NOBLE, P. J. and JIN, Y., (this volume). Radiolarians from the Lamar Limestone, Guadalupe Mountains, West Texas. *Micropaleontology*. 56: 117-147.
- ORMISTON, A. and BABCOCK, L., 1979. *Follicucullus*, new radiolarian genus from the Guadalupian (Permian) Lamar Limestone of the Delaware Basin. *Journal of Paleontology*, 53: 328-334.
- ORMISTON, A. R. and LANE, H. R., 1976. A unique radiolarian fauna from the Sycamore Limestone (Mississippian) and its biostratigraphic significance. *Palaeontographica, Abt. A*, 154: 158-180.
- OWEN, R., 1858. Palaeontology. In: Traill, T. S., *Encyclopaedia Britannica (8<sup>th</sup> Edition)*, Volume 17, 91-176. Edinburgh: Encyclopaedia Britannica.
- PESSAGNO, E. A., Jr., 1973. Upper Cretaceous Spumellariina from the Great Valley Sequence, California Coast Ranges. *Bulletins of American Paleontology*, 63(276): 102 pp.
- RIEDEL, W. R., 1967. Some new families of Radiolaria. *Proceedings of the Geological Society of London*, 1640: 148-149.
- RÜST, D., 1892. Beiträge zur Kenntnis der fossilen Radiolarien aus Gesteinen der Trias und der palaeozoischen Schichten. *Palaeontographica*, 38: 107-192.
- SASHIDA, K. and TONISHI, K., 1985. Permian radiolarians from the Kanto Mountains, Central Japan – Some Upper Permian Spumellaria from Itsukaichi, western part of Tokyo Prefecture. *Science Reports of the Institute of Geoscience, University of Tsukuba, Section B = Geological Sciences*, 6: 1-19.
- , 1986. Upper Permian stauraxon polycystine Radiolaria from Itsukaichi, western part of Tokyo Prefecture. *Science Reports of the Institute of Geoscience, University of Tsukuba, Section B = Geological Sciences*, 7: 1-13.
- , 1988. Additional note on Upper Permian radiolarian fauna from Itsukaichi, western part of Tokyo Prefecture, Central Japan. *Transactions, Proceedings of Palaeontological Society of Japan, N. S.*, 151: 523-542.
- , 1991. An Upper Permian coiled radiolarian from Itsukaichi, Central Japan. *Micropaleontology*, 37: 86-94.
- SASHIDA, K., SALYAPONGSE, S. and NAKORNSRI, N., 2000. Latest Permian radiolarian fauna from Klaeng, eastern Thailand. *Micropaleontology*, 46: 245-263.
- SHANG, Q., CARIDROIT, M. and WANG, Y., 2001. Radiolarians from the uppermost Permian Changhsingian of southern Guangxi. *Acta Micropalaeontologica Sinica*, 18: 229-240.
- SCHWARTZAPFEL, J. A. and HOLDSWORTH, B. K., 1996. *Upper Devonian and Mississippian radiolarian zonation and biostratigraphy of the Woodford, Sycamore, Caney and Goddard formations*,



- Oklahoma. Washington, DC: Cushman Foundation for Foraminiferal Research. Special Publication, 33, 273 pp.
- SEO, E.-H. and WON, M.-Z., 2009. Review of the genus *Polyentactinia* and the family Polyentactiniidae. *Micropaleontology*, 55: 61-74.
- SHENG J. and WANG, Y., 1985. Fossil Radiolaria from Kufeng Formation at Longtan, Nanjing. *Acta Palaeontologica Sinica*, 24: 171-183. (In Chinese with English abstract)
- SKINNER, J. W. and WILDE, G. L., 1955. New fusulinids from the Permian of West Texas. *Journal of Paleontology*, 29: 927-940.
- SUGIYAMA, K., 2000. Replacement names for Permian stauraxon radiolarians. *Paleontological Research*, 4: 227-228.
- SUN, D. and XIA, W., 2004. Zonation of conodonts and characteristics of the conodont fauna from the Guadalupian-Lopingian boundary strata in pelagic chert sequences in Guangxi and the basal boundary of the Lopingian Series. *Acta Micropaleontologica Sinica*, 21: 100-106. (In Chinese with English abstract)
- , 2006. Identification of the Guadalupian-Lopingian boundary in the Permian in a bedded chert sequence, South China. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 236: 272-289.
- TAKEMURA, A., AITA, Y., HORI, R. S., HIGUCHI, Y., SPÖRLI, K. B., CAMPBELL, H., KODAMA, K. and SAKAI, T., 1998. Preliminary report on the lithostratigraphy of the Arrow Rocks, and geologic age of the northern part of the Waipapa Terrane, New Zealand. In: Matsuoka, A., Ed., *Proceedings of the Six Radiolarian Symposium*, 47-57. Osaka: News of Osaka Micropaleontologists. Special volume 11.
- TAKEMURA, A., MORIMOTO, T., AITA, Y., HORI, R. S., HIGUCHI, Y., SPÖRLI, K. B., CAMPBELL, H. J., KODAMA, K. and SAKAI, T., 1999. Permian Alabaillellaria (Radiolaria) from a limestone lens at the Arrow Rocks in the Waipapa Terrane (Northland, New Zealand). *Geodiversitas*, 21: 751-765.
- WANG, R., 1993. Morphological change of the *Ruzhencevispongos uralicus* in Gufeng Formation (Lower Permian) from Jiangsu and Anhui provinces. *Shanghai Geology*, 4: 5-12. (In Chinese with English abstract)
- , 1995. Radiolarian fauna from Gufeng Formation (Lower Permian) in Hushan area of Nanjing, Jiangsu Province. *Scientia Geologica Sinica*, 30: 139-148. (In Chinese with English abstract)
- WANG, Y. and LI, J., 1994. Discovery of the *Follicucullus bipartitus* – *F. charveti* radiolarian assemblage zone and its geological significance. *Acta Micropalaeontologica Sinica*, 11: 201-212.
- WANG, Y. and QI, D., 1995. Radiolarian fauna of the Kuhfeng Formation in southern part of Jiangsu and Anhui provinces. *Acta Micropalaeontologica Sinica*, 12: 374-387.
- WANG, Y. and SHANG, Q., 2001. Discovery of the *Neoalabaillella* radiolarian fauna in the Shaiwa Group of Ziyun District, Guizhou. *Acta Micropalaeontologica Sinica*, 18: 111-121. (In Chinese with English abstract)
- WANG, Y. and YANG, Q., 2003. Radiolarians from the Middle Permian Kuhfeng Formation of the Renhua area, Shaoguan, Guangdong Province. *Acta Micropalaeontologica Sinica*, 20: 333-341. (In Chinese with English abstract)
- WANG, Y., CHENG, Y. and YANG, Q., 1994. Biostratigraphy and Systematics of Permian radiolarians in China. *Palaeoworld*, 4: 172-202.
- WANG, Y., YANG, Q., CHENG, Y. and LI, J., 2006. Lopingian (Upper Permian) radiolarian biostratigraphy of South China. *Palaeoworld*, 15: 31-53.
- WARDLAW, B. R. and MEI, S. L., 1998. A discussion of the early reported species of *Clarkina* (Permian Conodonta) and the possible origin of the genus. In: Jin, Y. G., Wardlaw, B. R. and Wang, Y., Eds., *Permian stratigraphy, environments and resources, Volume 2: Stratigraphy and environments*, 33-52. Beijing: Palaeoworld, vol. 9.
- WARDLAW, B. R. and NESTELL, M. K., (this volume). Latest Middle Permian conodonts from the Apache Mountains, West Texas. *Micropaleontology*, 56: 149-183.
- WILDE, G. L. and TODD, R. G., 1968. Guadalupian Biostratigraphy and Sedimentation in the Apache Mountains Region, West Texas. In: *Guadalupian facies, Apache Mountains area, West Texas. Symposium and Guidebook 1968 Field Trip, Permian Basin Section*, 10-31. Tulsa, OK: SEPM (Society of Sedimentary Geology) Publication 68-11.
- WILDE, G. L. and RUDINE, S. F., 2000. Late Guadalupian biostratigraphy and fusulinid faunas, Altuda Formation, Brewster County, Texas. In: Wardlaw, B. R., Grant, R. E. and Rohr, D. M., Eds., *The Guadalupian Symposium*, 343-371. Washington, DC: Smithsonian Institution. Contributions to the Earth Sciences, 32.
- WON, M.-Z., 1983. Radiolaren aus dem Unterkarbon des Rheinischen Schiefergebirges (Deutschland). *Palaeontographica, Abt. A*, 182: 116-175.
- , 1991. Lower Carboniferous radiolarians from siliceous boulders in western Germany. *Journal of Paleontological Society of Korea*, 7: 77-106.
- , 1997a. Review of family Entactiniidae (Radiolaria), and taxonomy and morphology of Entactiniidae in the late Devonian (Frasnian) Gogo Formation, Australia. *Micropaleontology*, 43: 333-369.
- , 1997b. The proposed new radiolarian subfamily Retentactiniinae (Entactiniidae) from the late Devonian (Frasnian) Gogo Formation, Australia. *Micropaleontology*, 43: 371-418.
- , 1998. A Tournaisian (Lower Carboniferous) radiolarian zonation and radiolarians of the *A. pseudoparadoxa* Zone from Oese (Rheinische Schiefergebirge), Germany. *Journal of Paleontological Society of Korea*, 19: 216-259.
- XIA, W., ZHANG, N., KAKUWA, Y. and ZHANG, L., 2005. Radiolarian and conodonts biozonation in the pelagic Guadalupian-Lopingian boundary interval at Dachongling, Guangxi, South China, and mid-upper Permian global correlation. *Stratigraphy*, 2: 217-238.
- XIA, W., ZHANG, N., WANG, G. and KAKUWA, Y., 2004. Pelagic radiolarian and conodonts biozonation in the Permo-Triassic boundary interval and correlation to the Meishan GSSP. *Micropaleontology*, 50: 27-44.
- YAO, J., YAO, A. and KUWAHARA, K., 2001. Upper Permian biostratigraphic correlation between conodont and radiolarian zones in the Tamba-Mino Terrane, Southwest Japan. *Journal of Geosciences, Osaka City University*, 44: 97-119.

## APPENDIX 1

### List of described taxa

*Campanulithus insuetus* Nestell and Nestell, **n. sp.**

Plate 1, figs. 1-6

*Raphidocyclicus americanus* Nazarov and Ormiston 1985

Plate 1, figs. 7-9

*Follicucullus sphaericus* Takemura in Takemura et al. 1999;  
emend. herein

Plate 2, figs. 17-22

*Pseudoalbaillella apachensis* Nestell and Nestell, **n. sp.**

Plate 3, figs. 4-5

*Astroentactinia capitanensis* Nestell and Nestell, **n. sp.**

Plate 6, figs. 4-8; Plate 7, fig. 1

**Polyedroentactiniinae** Nestell and Nestell, **n. subfam.**

*Polyedroentactinia guadalupensis* Nestell and Nestell, **n. sp.**

Plate 7, fig. 6; Plate 8, figs. 1-3

*Afanasievella* Nestell and Nestell, **n. gen.**

*Afanasievella apachensis* Nestell and Nestell, **n. sp.**

Plate 8, figs. 4, 6; Plate 9, figs. 1-5

*Copicyntra erinacea* Nestell and Nestell, **n. sp.**

Plate 9, figs. 6-8; Plate 10, figs. 1-3, 5; Plate 18, figs. 1-2

*Paracopicyntra snyderi* Nestell and Nestell, **n. sp.**

Plate 10, figs. 6-10

*Klaengspongos planus* Nestell and Nestell, **n. sp.**

Plate 11, figs. 3-7; Plate 18, figs. 3-4

*Copiellintra orbiculata* Nestell and Nestell, **n. sp.**

Plate 11, figs. 9-11; Plate 18, figs. 5-6

*Copiellintra fastuosa* Nestell and Nestell, **n. sp.**

Plate 11, figs. 12-15; Plate 12, figs. 1

*Raciditor* Sugiyama 2000; emend. herein

*Shangella capitanensis* Nestell and Nestell, **n. sp.**

Plate 14, figs. 4-6

*Rectotortementum wardlawi* Nestell and Nestell, **n. sp.**

Plate 15, figs. 3-6; Plate 18, figs. 10-11

**Tetratormentidae** Nestell and Nestell, **n. fam.**

*Tetratormentum ormistoni* Nestell and Nestell, **n. sp.**

Plate 15, figs. 10-13; Plate 16, fig. 1

*Quadrilobata? blomei* Nestell and Nestell, **n. sp.**

Plate 16, figs. 2-12; Plate 18, figs. 7-8

*Ruzhencevispongos girtyi* Nazarov and Ormiston 1985

Plate 16, figs. 13-18

*Ruzhencevispongos triradiatus* Wang 1993

Plate 17, figs. 1-6; Plate 18, fig. 12

*Nazarovispongos globosum* Nestell and Nestell, **n. sp.**

Plate 17, figs. 14-17

## APPENDIX 2

Because of the unclear taxonomic position of the radiolarian species *Hegleria mammiifera* Nazarov and Ormiston 1985a, we add some comments about the problems associated with its status.

Nazarov and Ormiston (1985a) described a new genus *Hegleria* with the type species *Hegleria mammiifera* from the Bell Canyon Formation, Hegler and Lamar Limestone Members in the Guadalupe Mountains. This paper was published on April 18, 1985. One month earlier, in March 1985, Sheng and Wang published a paper where they described a new species *Phaenicosphaera mamilla* from the Kufeng Formation at Longtan, Nanjing, China. Their description was based only on the external features of the test without any information given on the internal structures.

In 1992 Blome and Reed published a paper where they stated that in their opinion *Phaenicosphaera mamilla* and *Hegleria mammiifera* are the same species despite the fact that the specimens of the tests illustrated by Sheng and Wang (1985) of *P. mamilla* are “poorly preserved” (Blome and Reed 1992, p. 369). Because the paper of Sheng and Wang was published one month earlier than that of Nazarov and Ormiston, Blome and Reed concluded that the name *mamilla* has priority before *mammiifera* and thus the name *mammiifera* is a junior synonym and must be changed to *mamilla* with the generic name *Hegleria* adopted by Blome and Reed for such Paleozoic forms, because the genus *Phaenicosphaera* was used originally for the description of modern forms (Blome and Reed 1992).

From that time and even to the present many radiolarian workers use the generic name *Hegleria*, but the specific name *mamilla* for similar forms. We consider that Blome and Reed’s discussion is incorrect because according to International Code of Zoological Nomenclature (1999), Chapter 15, Article 67.1.2 “The name of a type species remains unchanged even when it is a junior synonym or homonym, or suppressed name.”

Summarizing the above comments, in this paper we use the original name *Hegleria mammiifera* (type species of the genus) instead of *H. mamilla*, which might be a junior synonym of *H. mammiifera* or a valid different species. This problem will not be resolved until the species *H. mamilla* is redescribed based on specimens from the original type area in China.