

# Radiolaria from the Late Paleozoic of the Southern Urals, USSR and West Texas, USA

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**ABSTRACT:** The radiolarian succession from stratotypic sections for the Gzhelian Stage of the Late Carboniferous and the Asselian, Sakmarian and Artinskian stages of the Permian of the Southern Urals are described, as are the successions from the stratotype area for the Leonardian and Guadalupian stages of West Texas. The radiolarian ranges in the subject interval of the Southern Urals are used to identify twelve successive associations, whereas four radiolarian associations, one previously treated as a zone by other authors, are discriminated from the West Texas Leonardian and Guadalupian stages. We propose a broad correlation of the Bone Springs Formation with the Sakmarian to Artinskian interval of the Urals based on present knowledge of radiolarian ranges. Newly described taxa include ten new genera, forty-four new species, and one new subspecies.

## INTRODUCTION

Until the middle of the 1970s, information about Radiolaria of the Upper Carboniferous through Lower Permian was limited to the data of Rüst (1885, 1892) and of Parona and Roverto (1895). Since that time, Permian, primarily bilaterally symmetrical, Radiolaria from North America, Japan, and the Urals have been described by Ormiston and Babcock (1979), Holdsworth and Jones (1980), Ishiga and Imoto (1980), Takemura and Nakaseko (1981), Ishiga, Kito, and Imoto (1982a) and Nazarov and Rudenko (1981). Unfortunately, the majority of Late Paleozoic radiolarian associations have been recognized from sections of uncertain stratigraphic position, therefore the distribution of many taxa remains debatable.

It is evident that, in order to clarify the significance of the biostratigraphy of insufficiently known or new faunal groups, it is necessary to study them from strata, preferably stratotypic sections whose age is established by other fossils. Meeting this need requires a detailed description of the entire association, not just one arbitrarily chosen morphologic group like Radiolaria.

To a significant extent, the conditions listed above are met by the sections of Late Carboniferous to Early Permian of the Southern Urals and Late Carboniferous to Late Permian of West Texas that represent stratotype sections for the respective regions. In addition, these sections are well known paleontologically and are the subject of much research.

Unfortunately, in a single article, it is not possible to describe fully all Radiolaria of the Upper Carboniferous through Lower Permian, since the number of species is preliminarily calculated to be more than 300. The present work briefly reviews the systematics of the main morphologic groups of Late Paleozoic radiolarians and describes new taxa with emphasis on the most widely distributed species that, in our view, have real significance for stratigraphy. This approach leaves the impression of an inordinate number of new taxa, but it is a result of preferential description of new, short-ranged forms. Too many taxa are present in the sequences studied to allow us to treat the faunas comprehensively in one paper.

## STRATIGRAPHY

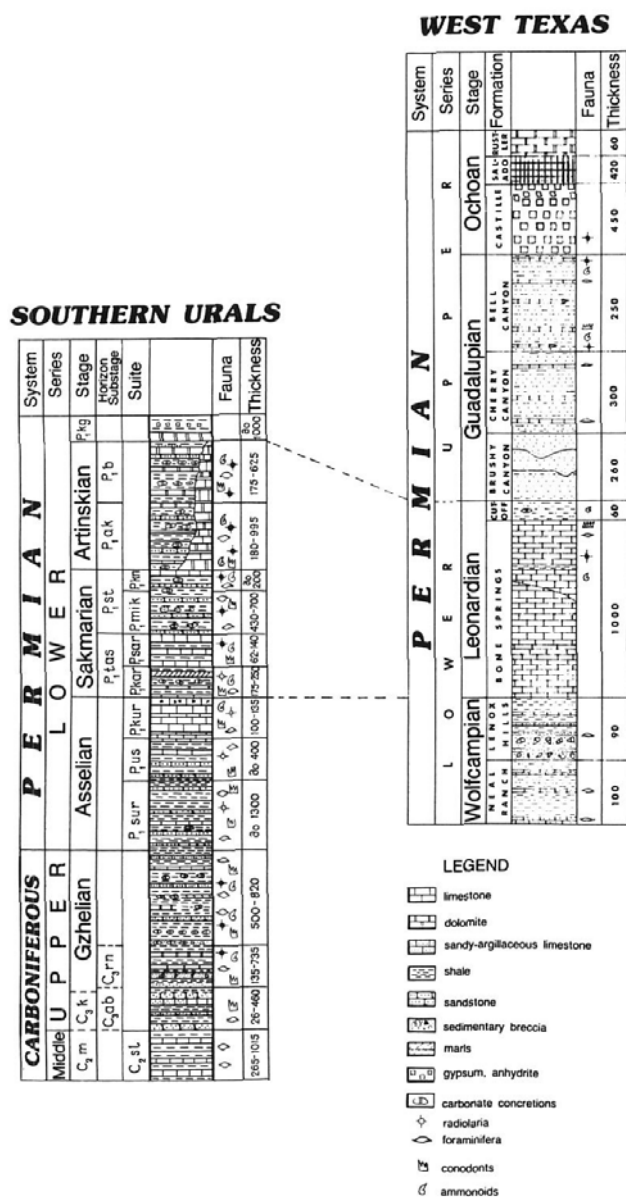
### Southern Urals

Carboniferous and Permian strata of the Southern Urals form an uninterrupted outcrop belt stretching for more than 400 km along the western slope. Paleontologically, they are superbly characterized by a variety of faunal groups. Natural changes of the fossil associations permit the identification here of all stages and, in a number of cases, of all zones of the Carboniferous and Permian systems. At the present time, Radiolaria are not known from the Early to Middle Carboniferous or the Kungurian, Ufimian, Kazanian or Tatarian stages of the Permian. The stratigraphy of these units is, therefore, not reviewed in this paper.

The tectonics, stratigraphy, lithology, and paleogeography of upper Carboniferous and lower Permian strata are treated in detail in many monographs (e.g. Ruzhencev 1950, 1951, 1956; Khvorova 1961). Therefore, they can be briefly described and summarized here in lithostratigraphic columns (text-fig. 1).

Because of the possibility of confusing certain Russian stratigraphic terms with North American stratigraphic terms of the same name which have a different meaning, it is important to briefly define what Soviet stratigraphers mean when they use these terms. The greatest possibility of confusion involves the term horizon, which in North American stratigraphy is not a stratigraphic unit but a traceable bedding plane contact between two beds. Thus, in North American usage it includes no rock. By contrast, Soviet stratigraphers use the term horizon to mean a lateral combination of several contemporaneous suites (stratigraphic units), which are known to be synchronous, but because of insufficient faunal study have not yet been distinguished as a zone.

In Soviet terminology, a suite is the basic unit of local stratigraphic subdivision. It is a subdivision of a series, whose lateral extent is limited by structural or facies changes and limited vertically by natural boundaries. A suite may be either conformable or unconformable with other suites, but it contains no angular unconformities within it. Typically, it cor-



TEXT-FIGURE 1

Generalized stratigraphic columns for the upper Carboniferous to Permian of the Southern Urals and the Permian of Texas with preliminary correlation by Radiolaria.

C<sub>2</sub>—Middle Carboniferous, Moscovian Stage; C<sub>2</sub>zl—Zlatogorov Suite; C<sub>3</sub>k—Upper Carboniferous, Kasimovian Stage; C<sub>3</sub>ab—Abzanov Horizon; C<sub>3</sub>zn—Ziyanchurin Horizon; P<sub>1</sub>sur—Lower Permian, Suren Suite; P<sub>1</sub>us—Uskalik Suite; P<sub>1</sub>kur or P<sub>1</sub>k—Kurmian Suite; P<sub>1</sub>sar or P<sub>1</sub>s—Sarabil Suite; P<sub>1</sub>mik—Maloik Suite; P<sub>1</sub>kn—Kandurov Suite; P<sub>1</sub>ak or P<sub>1</sub>akg—Aktastinian Substage; Bd<sub>1</sub>—Baigendzhinian Substage; P<sub>1</sub>kg or P<sub>1</sub>kn—Kungurian Stage; C<sub>3</sub>—Upper Carboniferous; P<sub>1</sub>—Lower Permian.

responds to part of a stage. Soviet stratigraphers use the term series to mean a thick succession of complex sedimentary, volcanic or metamorphic rocks often equivalent to a major sedimentary or tectonic cycle. The definitions given above have been paraphrased from a publication on stratigraphic classification and terminology by the Interdepartmental Stratigraphic Committee of the USSR (1959).

### Upper Carboniferous

In the Southern Urals, the lower part of the Late Carboniferous is represented by the Abzanov and Ziyantchurin horizons. The first of these belongs to the upper Kasimovian Stage, which is connected with a gradual transition from the carbonate-terrigenous development of the Zlatogorov Suite of the Middle Carboniferous. The Abzanov Horizon is represented by alternating greenish-gray argillites and platy sandstones forming a thin flysch. Rarely, there are layers of gravel and organodetrital limestones with fusulinids, bryozoans, crinoids and conodonts. The thickness varies from 26 to 460 m.

### Gzhelian Stage

The Ziyantchurian Horizon, comprising the lower part of this stage, has a variable and diverse lithologic composition. Subaqueous debris flow conglomerates and breccias, gravel-sand sequences, bituminous argillites, and discontinuous layers of limestone-dolomite concretions were deposited at this level. Typically, there are interbedded sandstones, argillites with biogenic limestones and fine-grained dolomites (carbonate flysch). The thickness is from 135 to 735 m. In the carbonate beds, fusulinids, ammonoids, conodonts, bryozoans, brachiopods, and corals are found.

Radiolaria were recovered from a few carbonate layers; they represent 30 species belonging to 12 genera. The radiolarian association is quite diverse. Most typical are large *Albaillella*, strongly curved *Haplodiacanthus*, numerous *Tormentidae* with an open central area and *Polyentactinia* having an octahedral form.

The strata of the upper part of the Gzhelian Stage were earlier treated as the lower and middle horizons of the Orenburgian Stage (Ruzhencev 1950). They represent a single complex of fine-grained sediments: argillites; shales, among which are developed discrete sand layers; and, less frequently, biogenic limestones and dolomites. Radiolaria observed in this part of the section are distinguished by great diversity. From a few horizons, 54 species belonging to 18 genera are known. Most characteristic are new species of the bilaterally symmetrical Radiolaria *Albaillella*, *Haplodiacanthus*, *Arrectoalatus*, and *Popofskyellum* along with species of *Latentifistula*, *Latentidiota*, and *Tormentum*, particularly numerous specimens of *T. protei* Nazarov and Ormiston 1983, which have an outline varying from rounded-triangular to star-shaped. Sixty-four species belonging to 18 genera are presently known from the Late Carboniferous Gzhelian Stage.

### LOWER PERMIAN

The Lower Permian of the west slope of the Southern Urals is divided into the Asselian, Sakmarian, Artinskian, and Kungurian stages, with stratotypic sections for the Asselian and Sakmarian stages situated there.

### Asselian Stage

This stage is represented by diverse sediments of variable facies which typically rest conformably on upper Carboniferous but rarely with erosive contact on older rocks. In the southern part, between the cities of Aktyubinsk and Ural,



these strata are dominantly terrigenous clastics and muddy rocks. Northward, they have a more diversified composition and are divided into three suites.

## SUREN, USKALIK, AND KURMAIN SUITES

### Suren Suite

This is a complex of sandy-shaly strata with interbedded sands, gravels and rare organodetrital limestones with fusulinids and conodonts. The thickness changes from 150 m in the south to 1330 m in the north.

### Uskalik Suite

This suite consists of well-developed argillites and shales with interbedded varied limestones and rare sands. Organic remains encountered include fusulinids, conodonts, bryozoans and rare ammonoids. The thickness of the suite is up to 400 m.

### Kurmain Suite

These rocks are represented by massive grey, thick-bedded micritic limestones with small chert concretions. Layers of platy siltstones or shaly organic limestones with fusulinids are sometimes developed between the micritic limestones. The thickness of the suite is from 100 to 135 m.

In the well-known section on the right bank of the Ural River at Nikol Village, the upper layers (from layer 40), which were earlier considered to be the uppermost part of the Orenburgian Stage, are here assigned to the Asselian. This part of the section has yielded a rich radiolarian complex. Thirty-four species belonging to 15 genera have been distinguished. By comparison with the older association from this same section, the impoverished species composition is noteworthy. Many species have disappeared, especially among the genera *Latentidiota*, *Camptolatus*, *Arrectoalatus*, *Popofskyellum* and others. At the same time, rare *Ruzhencevispongia*, *Copicyntra*, *Entactinia*, *Tormentum*, and ellipsoidal polycystines make an appearance. Their shapes and dimensions are more characteristic of Sakmarian and Artinskian Radiolaria. The characteristic index species for this part of the Asselian sequence are *Latentifistula crux* Nazarov and Ormiston 1983 with weakly differentiated spongy fabric and large pores (all specimens have only six to eight pores on the external shell) and *Entactinosphaera* with four massive three-bladed spines.

Radiolaria are also known from the upper parts of the Suren, Uskalik, and Kurmain suites. They are rare and poorly preserved, which makes identification, even to the genus level, difficult. The spherical polycystine *Copicyntra*?, subtriangular *Tormentum*? and possibly *Latentifistulidae* are present.

## SAKMARIAN STAGE

Strata assigned to the Sakmarian Stage are characterized by rapid facies changes, abrupt transitions from coarse detrital rocks to sandy, argillaceous flysch and terrigenous carbonate sediments. They conformably overlie the Asselian sequence and are, in turn, conformably overlain by Artinskian strata.

In the stratotype section on the right bank of the Sakmar River at Verkhnyaya Chernaya Rechka Village (= Kandurov-

ka Station) the Sakmarian Stage is subdivided into the Tastub and Sterlitimak horizons. The first of these consists of the Karamurun and Sarabil suites, the second of the Maloik and Kandurov suites.

The basal unit of the Karamurun Suite consists of argillites and interbedded platy, fine-grained sandstones, dark marls and fine-grained to micritic limestones. Thickness varies from 170 to 250 m.

The Sarabil Suite is represented by gray, primarily micritic limestones which form dense beds separated by thin layers of argillite, shales and marls. Occasionally, layers of bioclastic limestone are encountered. The thickness varies from 62 to 140 m.

The Maloik Suite is distinguished by the terrigenous composition of its rocks. These rocks consist of argillites with numerous interbeds of sandstones, siltstones and sometimes micritic limestones. The strata are characterized by intermittent horizons of spherical concretions of sandy composition. Rarely, there are layers of dolomitic limestone concretions. Thickness is from 430 to 700 m.

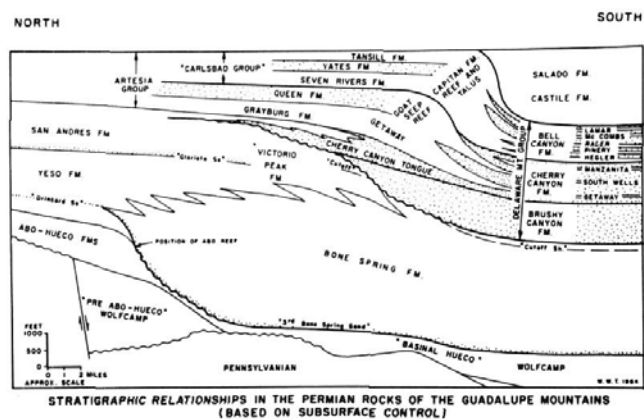
The Kandurov Suite consists of a complex of alternating beds of sandstones and argillites. There is an upward increase in the section in the number of beds of micritic, bioclastic, and clastic limestones. The thickness is up to 200 m.

The strata of the Sakmarian Stage are well characterized by different faunal groups, especially ammonoids and fusulinids, conodonts, bryozoans, brachiopods, corals and crinoids. We found Radiolaria at many levels in several sections enumerated in the higher suite. Based on preliminary data, the number of species is 80 or more. Unfortunately, they are almost all undescribed. The most widely distributed are bilaterally symmetrical segmented *Albaillella* [*A. tetrastiposa* (Kozur)], *Haplodiacanthus* [*H. permicus* (Kozur), *H. sakmarensis* (Kozur)], *Camptolatus* (*C. monopterygius* Nazarov and Rudenko) and extremely varied and abundant *Latentifistulidae*, among which, for the first time in the Sakmarian Stage, *Latentibifistula* with double walled rays appear. Among other taxa of the *Latentifistulidae*, note should be taken of the abundance of five-rayed *Quinqueremis* more than 2 mm in size. Among the *Tormentidae* there are forms with a differentiated spongy fabric. *Ruzhencevispongiae* often have a platy skeletal fabric in the central part of the shell. No less varied are spherical polycystines of porous-cellular kinds with two to five shells to multisphered, spongy *Copicyntra* with three-bladed spines. It is apparently possible to separate in the Sakmarian Stage several levels with characteristic radiolarian assemblages.

## ARTINSKIAN STAGE

The Artinskian strata of the western slope of the Southern Urals display sharp facies changes both within a section and from one section to another. There are coarse conglomeratic gravel sequences, sandy-shaly beds and sometimes even exclusively carbonate sections. The Artinskian of the subject region is divided into two substages: the Aktastinian and Baigendzhinian, which are sometimes treated as horizons.

Sandy-shaly sediments predominate in the Aktastinian sub-



TEXT-FIGURE 2

Stratigraphic relations among the Permian rocks of the Guadalupe Mountains, West Texas and New Mexico, showing the stratigraphic position of the Bone Springs Formation and the Hegler and Lamar limestones of the Bell Canyon Formation from which radiolarians are described.

stage, sometimes having flyschoid stratification. In some sections, there appear among the terrigenous rocks discontinuous, flattened carbonate concretions or beds of calcareous dolomite. To the south, not far from Aktyubinska, this substage contains a thick (up to 150 m) sequence of carbonate rocks—massive limestones, dolomites and calcareous dolomites. The thickness of these sediments is inconstant and varies from 180 to 1000 m.

The Baigendzhinian Substage is formed by strata of more variable facies than the underlying substage. Several sections are represented exclusively by coarse, terrigenous rocks—conglomerates, coarse-grained sandstones. Others consist of sandy-shaly sequences with concretions and beds of calcareous dolomite. Toward the south, sequences of massive calcareous dolomite and dolomitized limestones were originally deposited. The thickness of the substage varies from 175 to 625 m. In the Artinskian as in the Sakmarian Stage, abundant remains of ammonoids, radiolarians, conodonts, bryozoans, crinoids, and rarer fusulinids are found. Radiolaria are especially abundant in the Aktastinian Substage. From one small sample of about 1 kg in weight, typically more than 1000 specimens were recovered. By preliminary count, the number of Aktastinian radiolarian species is about 100. Most numerous are the spherical polycystines: *Entactinia*, *Entactinosphaera*, the *Stigmospaerinae* with four or five porous shells, and the spongy polycystine *Copicyntra*. There are up to 10 species of *Polyentactinia*, of which a few have elegant, lacy shells up to 1 mm in size. There are also diverse *Latentifistulidae* with three to five long arms. Among them appears the first *Polyfistula*, having 7 to 11 rays. Variable shapes are exhibited by the *Tormentidae*, including forms which sometimes approach a cube. Among the *Ruzhencevispongidae* there are many species with a triangular external outline. Bilaterally symmetrical Polycystina are represented by several species of *Albaillella*, *Haplodiacanthus*, *Raphidociclicus* and *Campanulithus*. In the upper part of the Artinskian Stage, the radiolarian complex is more uniform than in the lower. Spherical polycystines predominate with a few *Tormentidae*. Here appear for the first time bilaterally symmetrical forms

belonging to *Follicucullus*. Despite such diversity, only three species, *Haplodiacanthus anfractus* Nazarov and Rudenko, *Raphidociclicus gemellus* Nazarov and Rudenko, and *Campanulithus falcatus* Nazarov and Rudenko have been described at the present time. In the Artinskian Stage, it is also possible to separate a sequence of beds with characteristic radiolarian assemblages.

## WEST TEXAS

### Wolfcampian Stage

Rocks assigned to the Wolfcampian Stage vary considerably in facies in the West Texas region (text-fig. 2). In the stratotype area of the Glass Mountains in Brewster County, Texas, the stage is made up of the Neal Ranch Formation and the overlying Lenox Hills Formation, which are 90 and 100 m thick, respectively. The Neal Ranch Formation, which includes a good proportion of dark grey shale with interbedded carbonate units, has not yielded identifiable radiolarians. The basal part of the overlying Lenox Hills Formation consists of 47 m of conglomerate, which is overlain by alternating thick shale units and thin conglomerates and coarse calcarenite beds. This unit has also failed to yield Radiolaria in its type region. Similarly, a series of samples from a well-exposed section on the west side of Leonard Mountain (see Ross 1963) failed to yield radiolarians.

In the Hueco Mountains, the base of the Wolfcampian Stage is marked by the Powwow conglomerate, a polymict conglomerate containing limestone and other cobbles and commonly having a matrix of red, argillaceous carbonate, which rests on an unconformity. Little of the latest Carboniferous (Virgilian in North American nomenclature) appears to be missing beneath this unconformity in Hueco Canyon as judged by comparing the fusulinid sequence with that in the type Virgil of Kansas. Regionally, however, this unconformity cuts deeply into older rocks. The Powwow varies in thickness from 10 to 30 m. Overlying the Powwow are a series of bedded shelf carbonates of the Hueco Group. These shallow-water limestones exhibit numerous shallowing upward cycles (James 1978) which characteristically culminate in phylloid algal beds, which may be planar or form small mounds, but are typically traceable for long distances. These strata contain a well-developed fusulinid fauna. The Hueco Group is up to 330 m thick and is overlain by Leonardian red beds which change facies toward the Delaware Basin into the dark carbonates of the Bone Springs Formation. To date, no structurally preserved Wolfcampian Radiolaria have been recovered from the sequence in the Hueco Mountains.

We have examined Radiolaria from Mill Canyon, Nevada, from collections made by Susan Laule of Amoco Denver, which are apparently of Wolfcampian age. Since these fossils come from structurally complex terrane and poorly dated sequences, we elect not to consider them in order to maintain consistency with the objectives established in the introduction to this paper.

### Leonardian Stage

In the type area (Leonard Hills), strata of this age are developed as shelf carbonates with a rich benthic fauna and occasional lensoid mounds or bioherms. Toward the Dela-

ware Basin, these rapidly change facies into the thick Bone Springs Formation which consists of dark, laminated basinal limestones with few benthic fossils but a rich nekto-planktic fauna of ammonoids, conodonts, fish and radiolarians. This unit is nowhere completely exposed in outcrop, but is known to attain a thickness of nearly 1000 m in the nearby subsurface. Exposures of the upper part of the unit in the vicinity of Bone Springs Canyon, Guadalupe Mountains, become less laminated and more cherty upward. Thin stringers of allochthonous fossil fragmental debris are also more common in the upper part. The lithic and faunal characteristics of the unit point to a basinal, oxygen-poor environment of deposition. The presence of Radiolaria in the Bone Springs Limestone has been known for many years (Newell et al. 1953) but well-preserved material has only recently been described by Cornell (1983). This important fauna permits interesting comparisons with certain radiolarian associations in the Sakmarian and lower Artinskian of the Urals which are discussed in the section on biostratigraphy. We have recovered reasonably well-preserved Radiolaria from a road cut on U.S. Highway 180 at latitude 31°40'45"N, longitude 104°49'30"W, Culberson County, Texas.

#### Guadalupian Stage

In the type area of the Delaware Mountains, the Delaware Mountain Group represents the Guadalupian Stage. It consists, in ascending order, of the Brushy Canyon, Cherry Canyon, and Bell Canyon formations. All these units are dominated by terrigenous clastics, fine-grained sandstone, siltstones and shales. Excellent examples of channels and other features of density flow deposits are seen, especially in the Brushy Canyon, but also in the overlying units. The upper two units each have a number of limestone tongues representing detrital carbonate material from the nearby Guadalupian carbonate shelf (see Tyrrell 1969). Some of these carbonates, such as the Rader and McKittrick members, show dramatic signs of having been limestone boulder debris deposits from the shelf. Attempts have been made to recover Radiolaria from all these tongues, but only those of the Bell Canyon Formation have so far yielded structurally preserved material. Radiolarians from the youngest of these carbonate tongues, the Lamar Limestone, were illustrated and described by Ormiston and Babcock (1979), and further material from this unit is incorporated into the present paper. Radiolarians which were also recovered from the slightly older Hegler Limestone (see text-fig. 1) are described in this paper.

#### Ochoan Stage

At the end of Guadalupian time, the Delaware Basin began to fill with evaporites. These begin with a Castille Formation, which is finely laminated "varved" anhydrite in the subsurface (gypsum in outcrop) consisting of couplets of white evaporites and thin layers of dark carbonate. The presence of Radiolaria in strata of Ochoan Age can be inferred from material illustrated by Anderson et al. (1972, fig. 3C) from the Castille Formation. The Castille Formation is up to 600 m thick. In the basin center, the Castille is succeeded by the salts of the Salado Formation. The final deposits of the Ochoan Stage are dolomites of the Rustler Formation that carry a limited benthic fauna dominated by mollusks and are prob-

ably indicative of still elevated salinities. Attempts to recover structurally preserved Ochoan Radiolaria from the thin carbonate lentils within the Castille Formation have not proved successful.

#### SOME REMARKS ABOUT PALEOZOIC RADIOLARIA

The Paleozoic, especially the Late Paleozoic, radiolarian fauna, despite its apparent diversity, represents distribution of only two distinctly separate groups—Polycystina (Spumellaria?) of diverse external morphology and bilaterally symmetrical Radiolaria?. Whether the latter group actually belongs to the radiolarians or represents a peculiar group of Protozoa with a siliceous skeleton cannot be simply decided. Beginning with the research of Deflandre (1952), they have been treated as Radiolaria incertae sedis (Riedel 1967 et seq.) or have been placed in Polycystina (Holdsworth 1977 et seq.). Information presented in some papers (Chediya 1964; Tappan and Loeblich 1973) about the distribution of Nassellaria in the Paleozoic, and especially in the Late Paleozoic, was insufficiently substantiated and has not been confirmed by subsequent research.

Among the polycystines (Spumellaria?) presently known from the Ordovician, Silurian, Devonian, Carboniferous, and Permian strata (e.g. Deflandre 1952, 1960, 1972a, 1972b, 1973; Foreman 1963; Holdsworth 1969, 1973, 1977; Nazarov 1973, 1975, 1981a, 1981b; Ormiston and Lane 1976), the distinctive forms possess an internal framework. From the same rock sample after its dissolution in acid, one recovers, associated with these forms, Polycystina lacking an internal framework, but otherwise indistinguishable in morphology and dimensions from those in which an internal framework is seen. The resultant dilemma could suggest that, among the plankton of Paleozoic basinal seas, there were Polycystina with an internal framework (for example, Entactiniidae sensu lato) and those without (Actinommidae Riedel or "palaeoactinommids" Holdsworth). The systematics of the two fundamental groups of polycystines described above are based on completely different principles and, naturally, biostratigraphic research requires two independent schemes for the classification of fossil Radiolaria.

In the works of protozoologists (e.g. Riedel 1959; Berger 1968; Petrushevskaya 1971; Kruglikova 1981) attention has been paid to the preservation of Radiolaria in bottom deposits and the correlation of this with taxonomic composition of plankton and sediment composition. From observations by Petrushevskaya (1971, p. 282), it is known that the skeletons of different species of Nassellaria showed changes in the degree of preservation in passing from suspension through deeper water into bottom deposits. Similar changes account for peculiarities in ontogenetic stages. Factors that promote the dissolution, or a selective dissolution, of separate parts of the radiolarian skeleton have been confirmed in the works of Riedel (1959), Berger (1968), Moore (1969), Kruglikova (1969, 1981) and other investigators. The most widespread changes occurring during sedimentation involve thinning of the shell wall, smoothing of the external surface, dissolution of the internal sphere, a partial cephalis and terminal (basal) segments. In addition, the climatic belt may have an influence



on the preservation of the radiolarian skeleton. Those from temperate and tropical latitudes have been reported to be less well preserved than those of the subpolar and polar regions (Petrushevskaya 1966, 1971; Kruglikova 1981). However, the reverse may also be the case (Riedel personal communication).

Thus, the degree of preservation of modern radiolarian skeletons reflects the hydrodynamic and physical-chemical peculiarities of the water column through which they move and of the sediments in which they are buried, climatic belts and the peculiarities of skeletal structure in different taxonomic groups.

It is likely analogous factors influencing the preservation of radiolarian skeletons could have existed in the equatorial seas of the geologic past. In addition, the intensity of the post-sedimentary process and the characteristics of the diagenetic conversion were closely associated with the depositional environment and structurally with the mineralogical peculiarities of the sedimentary deposits. According to Patrunov (1980), diagenetic recrystallization modifies and significantly changes the original structure of the rock, and in the process many skeletal remains deteriorate or even completely disappear. Moreover, after lithification, organic remains are subject to destruction as a result of chemical and physical alteration. As we already know, but it bears repeating, the less the original rock changes through secondary processes, the better the preservation of the fossil fauna. For example, the preservation of Radiolaria from strata exposed in natural outcrops is significantly worse than that of those collected from the same beds where they were artificially exposed during the construction of a highway. Solution and loss of separate parts of the skeleton also occur during chemical and especially mechanical disintegration of samples to separate the microfauna.

As is evident from the preceding remarks, there are significantly more negative influences on the preservation of fossil organic remains than positive ones. It is surprising that in a certain portion of ancient Radiolaria such fine and fragile microstructures as the internal framework have been preserved. The discovery of Radiolaria with such internal skeletal structure is much more a fortunate happenstance than a regular occurrence.

The absence of one or another skeletal element, apparently, does not represent a sufficient basis for the assignment of one or another specimen to a different taxonomic group. Actually, it is simpler and easier to describe and record what has been observed, and in this way investigators cannot later be accused of subjectivity. ("At the outset, observe and describe.") What this can lead to is evident from the following example. After dissolving a sample of early Artinskian concretions, more than 100 specimens of Radiolaria were picked from the residue. They possessed one simple spherical shell measuring from 275 to 305  $\mu\text{m}$ , six long, three-bladed spines, and numerous secondary spines. On study in transmitted light, one-third of them were observed to have an eccentrically situated internal spicule. Other specimens had fragmentary thin rods from the base of the spines and were generally devoid of any indication of an internal skeleton. Unless some degree of subjective interpretation is employed,

the Radiolaria with an internal spicule must be assigned to *Entactinia* (Entactiniidae), the remainder to, for instance, *Hexalonychidium* (Actinommidae) or some genus of the Cubosphaeridae if we take into account the varying lengths of the separate fragile spine. In this manner it is possible to artificially create the appearance of taxonomic diversity.

It is more probable that Paleozoic Polycystina possessed diverse internal frameworks that are preserved in relatively few specimens for reasons of depositional, diagenetic, and postdepositional changes. Since this distinctive character is the most important for Paleozoic Radiolaria, their systematics must be based, above all, on a consideration of the structure of the internal framework. The first efforts in this direction were carried out by Foreman (1963), Nazarov (1975, 1981a), and in part by Holdsworth (1977).

As recounted above, the Late Paleozoic radiolarians represent two groups—bilaterally symmetrical Radiolaria and diverse Polycystina. Among the Polycystina one can distinguish polyaxon spherical forms and stauraxon discoidal-lobate Radiolaria. That is to say, there are three distinctly separable, large groups of Late Paleozoic Radiolaria: 1) bilaterally symmetrical incertae sedis; 2) spherical Polycystina; and 3) discoidal-lobate Polycystina.

We will consider and expand on the systematics of these three groups. It may seem that this kind of problem is far removed from stratigraphy. However, it turns out that no biostratigraphic or even geologic problem can be decided on material that has been investigated by antiquated methods using contradictory, unstable systematics. By placing Radiolaria in consistent, satisfactory systematics, it is possible to use them for the subdivision of strata and for correlation between even distant regions, in the present case West Texas and the Southern Urals.

#### SPHERICAL POLYCYSTINA

Radiolaria having a spherical form are probably the oldest representatives of the Sarcodina with a siliceous skeleton. The external morphology of Paleozoic spherical polycystines is quite uniform—porous or spongy shells with four to six, rarely fewer or more, external radial spines. Analogous or even identical outlines are present in many Mesozoic-Cenozoic and modern Spumellaria. Therefore, the discovery in Paleozoic sediments (e.g. Hinde 1890; Rüst 1892; Ruedemann and Wilson 1936; Bykova and Polenova 1955) of spheroids similar to those traditionally assigned to one or another taxon in the radiolarian classification of Haeckel (1881, 1887), led to the idea of the exclusive conservatism of Radiolaria. Besides, antiquated methods of study, usually in thin section, did not allow for the clarification of the unique structure of the fossil forms and led to a substantiation of the comparison of the Paleozoic and modern polycystines. A clarification became possible only in recent years with the discovery of well-preserved Radiolaria, extracted by chemical means from lithified rocks of Ordovician through Permian age.

As recounted above, an internal framework is developed in practically all groups of Paleozoic Sphaeroida. It occupies a central or eccentric position in the internal cavity and has the form of a hollow, nonporous sphere, gently multi-faceted, or of a spicule with four to six or more rays. Rays arising



from this sphere or from the central bar of the spicule unite with, or cross to, the external radial spines. Typically, the rays display branching apophyses. These unite with each other to produce the development of a spherical or other form of skeleton (text-fig. 3). Thus, we observe that the number of shells and number and orientation of major spines has a definite dependence on the structural peculiarities of the internal framework. This is most clearly expressed in two laws: 1) The number of major radial spines depends on the number of rays of the internal spicule or sphere (polyhedron). 2) The number of external and internal shells (spheres) depends on the number of groups of apophyses developed along the rays of the internal framework. Such unique Paleozoic spherical polycystines are distinctly different from modern and similar spheroids and cannot be placed in any taxa of the existing scheme in the classification of Radiolaria.

At the present time, several variants of radiolarian classification are known. In most common use is the classification of Haeckel (1887) which is based primarily on the morphology and symmetry of skeletal development. There also exist several modifications introduced by Deflandre (1953), Campbell (1954), Khabakov et al. (1959), Zhamoida and Kozlova (1970), and Lipman (1975). The attitude of investigators to this particular system is paradoxical. In most cases, this system, although used by protozoologists and paleontologists, has been noted by both as imperfect. Actually, by now enough evidence has been amassed to contradict the views of Haeckel. The basic objection is the fact that Haeckel's system does not take into account evidence of ontogenesis, peculiarities of structure, and symmetry of the nucleus and central capsule. It also pays no attention to phylogenetic interrelationships. In addition, the separation of even large taxa is based not on the complex of features but on the expression of one selected character, with the result that often analogous rather than truly homologous development is used. Electron microscopic study of the cytology of modern Radiolaria and discovery of exceptionally well-preserved, unique fossil radiolarian faunas demonstrate even more clearly the imperfection of this Haeckelian classification.

A rational revision of the systematics of Radiolaria was undertaken by Riedel (1967). Nassellaria and Spumellaria were united within one group, Polycystina Ehrenberg. The Spumellaria were subdivided into 11 families. All spherical Radiolaria were placed in two families—Entactiniidae and Actinommidae. The classification proposed by Riedel was based on morphologic criteria with attention to stratigraphic distribution, that is, their possible phylogeny.

Polycystines with an internal framework were placed in the Entactiniidae, which Riedel postulated existed only from the Late Devonian to the Early Carboniferous. Contemporaneous with the Entactiniidae and persisting afterwards, even to the present, were the Actinommidae. However, new information (Fortey and Holdsworth 1971; Nazarov 1975, 1981a, 1981b; Ormiston and Lane 1976) provides evidence for the development of polycystines with an internal framework from the Early Ordovician to the Late Permian. The Polycystina proposed by Riedel appears mainly to be large taxa. These lack diagnoses and the temporal distribution of lesser known genera is unknown, which somewhat restricts the use of this

system in practical research. Recently, protozoologists have shown a preference for a radiolarian system worked out by Hollande (Hollande and Enjume 1960) and Cachon and Cachon (1970, 1972a, 1972b, 1976). The system created by them is based on the morphology and development of the nucleus, axopodial apparatus and ontogenetic evidence. They separated several new types of structure of the nucleoxopodial complex typical for Spumellaria and Nassellaria. Among spherical Radiolaria, three groups are distinguished: Periaxoplastides, Centroaxoplastides, and Cryptoaxoplastides, which are taxa of the highest systematic rank. Cachon and Cachon especially emphasized the association of axopodia and axopodial apparatuses with the formation of the skeleton. According to these authors, the axopodial system plays a direct role in the formation of the skeleton. In the opinion of some investigators (Petrushevskaya 1969; Nazarov 1975), the radiolarian systems reviewed above are not compatible with one another; according to other investigators (Zhamoida 1975; Kozur and Mostler 1981), they complement one another. The acceptance of different schemes of classification for fossil Radiolaria and the resultant taxonomic confusion naturally has an effect on biostratigraphic conclusions. Certain published works create the impression that fossil Radiolaria are unique and endemic. However, direct study of the actual fossil material demonstrates that new names were given to earlier known species. On the basis of formal characters of Haeckelian classification, differing forms of the same species have been assigned to different genera and families. Such works stress a nonstratigraphic approach to Radiolaria, hinder the determination of age and, even more, correlation of strata in different regions.

It has turned out that the comparative-morphologic studies carried out by Petrushevskaya, Cachon and Cachon (1976) on Cenozoic Radiolaria have been the most insightful. They established a definite dependence on the arrangement of the central skeletal spheres (shells) on the nucleoxopodial complex, which in the central-cryptoperiaxoplastic Sphaerellaria have constant dimensions. The demonstration of a correlation between the skeletal structure and the nucleoxopodial apparatus allows the use in systematics not only of peculiarities of euplasmatic development but also of those of the skeletal morphology. The first variant of a system for polycystines taking these characters into account was proposed by Petrushevskaya (1979). However, as in the Riedel system for the polycystines, diagnoses are given for orders and families and a list of genera belonging to them. Further investigation in this direction, combined with a classification of the true phylogeny of the polycystines and the establishment of clear-cut criteria for separation of taxa of generic rank, apparently could lead to the creation of a "synthetic" classification of Radiolaria satisfactory to both protozoologists and paleontologists. Until such a system is finished, one should use, for the solution of any concrete stratigraphic problems, a system or classification which objectively reflects modern knowledge of the group involved and which is suitable for a practical application. This is especially true for the Paleozoic spherical polycystines having an internal framework.

The first systematic arrangement for fossil Sphaeroidea was proposed by Nazarov (1975) based on a study of Late Devonian Radiolaria of the Southern Urals, taking account of

the work of Foreman (1963). Internal structure was the basic criterion for the separation of taxonomic entities. All sphaeroids having an internal frame were placed in the family Entactiniidae Riedel. The subfamilies Entactiniinae and Polyentactiniinae were set off on the basis of the number of rays of the internal spicule. The structure of the external shell permits the distinction within each subfamily of the tribes Entactiniini and Polyentactiniini with a porous-latticed shell and the Spongactiniini and Spongpolyentactiniini with a spongy external shell. The separation of genera was based on the number of spherical shells.

Later (see Nazarov and Popov 1980), two subfamilies, Pylentonemiinae and Haplentactiniinae, were added to the Entactiniidae. The development of a pylome and a seven-rayed internal spicule is characteristic of the former. The Haplentactiniinae possess a massive rodlike, six-rayed spicule. On these rays are developed dense apophyses, the fusion of which forms one, rarely two, isometric, coarsely spongy shells.

This formal classification was used for the descriptions published in 1975 of Radiolaria from the Ordovician of Kazakhstan and the Late Devonian of the Southern Urals and Byelorussia. As pointed out by the authors Nazarov (1975, pp. 33–34) and Nazarov and Popov (1980, p. 24), this system for the Sphaeroidea represents only a working scheme and is to a certain degree artificial, as its founding principle is the separation of taxonomic entities purely by morphologic characters and based on the number of rays on the internal spicule and the number of radial spines plus the number and structure of the shells. The composition of the Entactiniidae was left as it had been, although it was already clear that it was by no means a homogeneous group. Attention has not been paid in this classification to the position of the internal framework, the size of the outer sphere and the fine structure of the spongy fabric, and it does not reflect the interrelationship of Ordovician-Silurian polycystines with Devonian to Permian ones.

Actually, there are numerous entactiniids in Ordovician and Devonian strata which have identical-sized single, porous shells with six basic spines. However, the Ordovician examples have a centrally situated internal framework in the form of an empty sphere (or rounded polyhedron) with massive rays emerging from it and passing into rodlike major spines. Devonian single-shelled forms have an eccentrically situated, slender, six-rayed spicule, whose rays unite with the bases of three-bladed spines. Also typical for the Ordovician and Devonian are Entactiniidae with double spherical shells. The internal spicule is situated eccentrically within the smallest sphere. Its rays unite with the six main radial crossbeams connecting the spheres, which continue on to connect with the rodlike radial spines of Ordovician forms or the three-bladed radial spines of Devonian forms. However, the dimensions of the internal sphere in Ordovician entactiniids are 92 to 110  $\mu\text{m}$  and 35 to 50  $\mu\text{m}$  in Devonian ones. Despite such differences, all these forms have been placed in either the genus *Entactinia* (one sphere) or *Entactinosphaera* (two spheres). The facts reviewed above strongly suggest that the systematics of Paleozoic spherical Radiolaria should be based not only on the number of rays in the internal framework and the number of shells in their structure but also on the

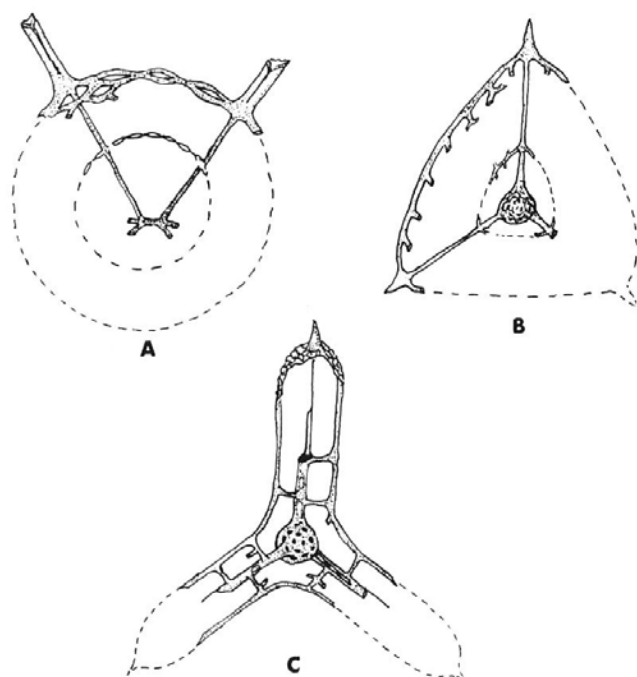
position of the internal framework and the size of spheres and form of the radial spines. However, in order to clarify the actual relationships, it is necessary to understand the evolution through the Paleozoic of spherical polycystines as a whole, as well as of the individual parts of the skeleton. The general outline of radiolarian evolution during the Paleozoic was surveyed by Nazarov (1981a). It reflected changes through time of the internal framework, radial spines, form and size of the shell and skeletal fabric. Three levels of major changes in radiolarian associations were noted, the most marked occurring in the Early Devonian, apparently at about the Lower/Middle Devonian boundary which involved diversification of the internal framework, the appearance of spongy shell structures and the development of three-bladed spines. It should be noted that this change was so sharp that, if the general plan of construction were not kept in mind, one would note a complete absence of connection between Lower and Middle Devonian Radiolaria. Spherical Radiolaria of the Late Paleozoic, that is Middle Devonian through Late Permian, represent quite a unified group despite an appearance of diversity in the structure and number of shells. Almost all have an eccentric internal spicule and an internal sphere with a consistent diameter of 35 to 55  $\mu\text{m}$  and predominantly three-bladed spines. Taken together they can be treated as one huge taxon. Moreover, all the diverse forms fit into the scheme of classification for the Entactiniidae (Nazarov 1975, 1981a). The exceptions are some spongy sphaeroids which have six or more (up to several tens) of external spines and several concentric shells. These shells are closely set and connected by thin crossbeams positioned between the internal porous sphere and the external spongy layer. It is unlikely that they are formed centripetally, gradually increasing in number as a result of regular fusion of apophyses of secondary spines arising from the corners of the pore frames. In actuality, their development probably proceeded in the manner shown on text-figure 4.

Spongy Entactiniidae were widely distributed in the Late Devonian. The spongy layer distributed over a porous sphere probably arose as a result of random fusion of apophyses from the major and secondary spines and the indistinct expression of radial elements (spines). A similar structure is typical of *Somphoentactinia somphozona* (Foreman), *S. teuchestes* (Foreman) having numerous spines (see text-figs. 4a, 4e), and some *Spongactinia*. Continuing, further differentiated spongy fabric arises from more distinctly expressed original radial parts of the skeleton (spines) in the manner shown in text-figures 4b–d, thereafter tangential fabric arises as shown on text-figures 4b and 4e. Spongy entactiniids having the structure illustrated on text-figures 4b, f are known from mid-Carboniferous sediments of the Kolyma River Basin, and the types shown on text-figures 4b–e are known from the Late Carboniferous of the Southern Urals. Similar polycystines from the Early Permian (Sakmarian and Artinskian stages of the Southern Urals) and the Late Permian of West Texas are typical representatives of radiolarian associations of this period. They are described in this paper as the genus *Copicyntra*. Differentiated spongy fabric probably also arose analogously among discoidal, flattened polycystines (text-figs. 4k, 4l), which are reviewed below and among the Spongactiniini with six major spines. The new genus *Plurostra-*

*toentactinia* of the tribe Spongentactiniini was described from the late Famennian of the Kolyma River Basin (Nazarov et al. 1981). As is the case with *Copicyntia*, the Spongentactiniini with spongy layers are widely distributed in the Permian of the Urals and West Texas. Multisphered, spongy Entactiniidae with numerous external spines should be assigned to the subfamily Polyentactiniinae, the type genus of which is *Polyentactinia* Foreman 1963. But this subfamily requires renaming in view of the fact that *Polyentactinia* has more diagnostic characteristics of the Orosphaeridae than of the Entactiniidae. We will consider this question in more detail.

In the mid-1970s, *Polyentactinia* was known only from Late Devonian to Early Carboniferous strata in many regions of the globe. Later these forms were observed in the Ordovician and Silurian as highly varied elements of the Late Paleozoic of the northeastern Soviet Union (mid-Carboniferous), and in the Southern Urals and West Texas (Late Carboniferous to Late Permian). For a long time, more than 200 m.y., the subject genus persisted essentially without change. The general evolutionary tendencies of Paleozoic Radiolaria are well traced in the genus *Polyentactinia*. The progressive covering over of the internal framework, transformation of rodlike into three-bladed spines, the thinning and lightening of the shell, and the concomitant development of thin external crossbeams for greater stability (rigidity) are the trends observed. At the same time *Polyentactinia* is basically distinguished from the Entactiniidae sensu lato by the stable central position in the shell of the internal framework and the structure of the skeletal fabric of the single latticed shell. Among Entactiniidae sensu lato the internal framework is as a rule situated eccentrically and the structure of the shell is more varied (spongy, porous, latticed) with the number of shells varying from one to four or more. Overall, these observations suggest that *Polyentactinia* is nearer to the Orosphaeridae Haeckel (Collodaria). This has been pointed out by Friend and Riedel (1967), Petrushevskaya (1969, 1971) and Nazarov (1975). Friend and Riedel considered the absence of *Polyentactinia* from the Late Paleozoic and Mesozoic and the small dimensions of Devonian *Polyentactinia* as the basic arguments preventing the inclusion of *Polyentactinia* in the family Orosphaeridae.

*Polyentactinia* is now known from Permian strata and, moreover, has dimensions near those of modern Orosphaeridae up to 1 mm. It is more difficult to explain the absence of *Polyentactinia* or Orosphaeridae from the Mesozoic. In part, this may depend on methods of recovery. *Polyentactinia* is easily destroyed during extraction with hydrofluoric acid as well as by mechanical disintegration. Whatever the case, polyentactiniids are an isolated group of mid-Paleozoic polycystines morphologically near the Orosphaeridae to which *Polyentactinia* may be provisionally assigned. The earlier established subfamily, Polyentactiniinae, is more expediently renamed Astroentactiniinae, n. subfam. with the Astroentactiniini, n. tribe (porous-latticed) and Somphoentactiniini (spongy) as proposed by Kozur and Mostler (1981), who included taxa of generic rank that were formerly assigned to the Polyentactiniinae. Kozur and Mostler also proposed the renaming of the family Entactiniidae on the basis of priority of Triposphaeridae Vinassa deRegny. Such a replacement is not warranted, since the family Triposphaeridae consists of

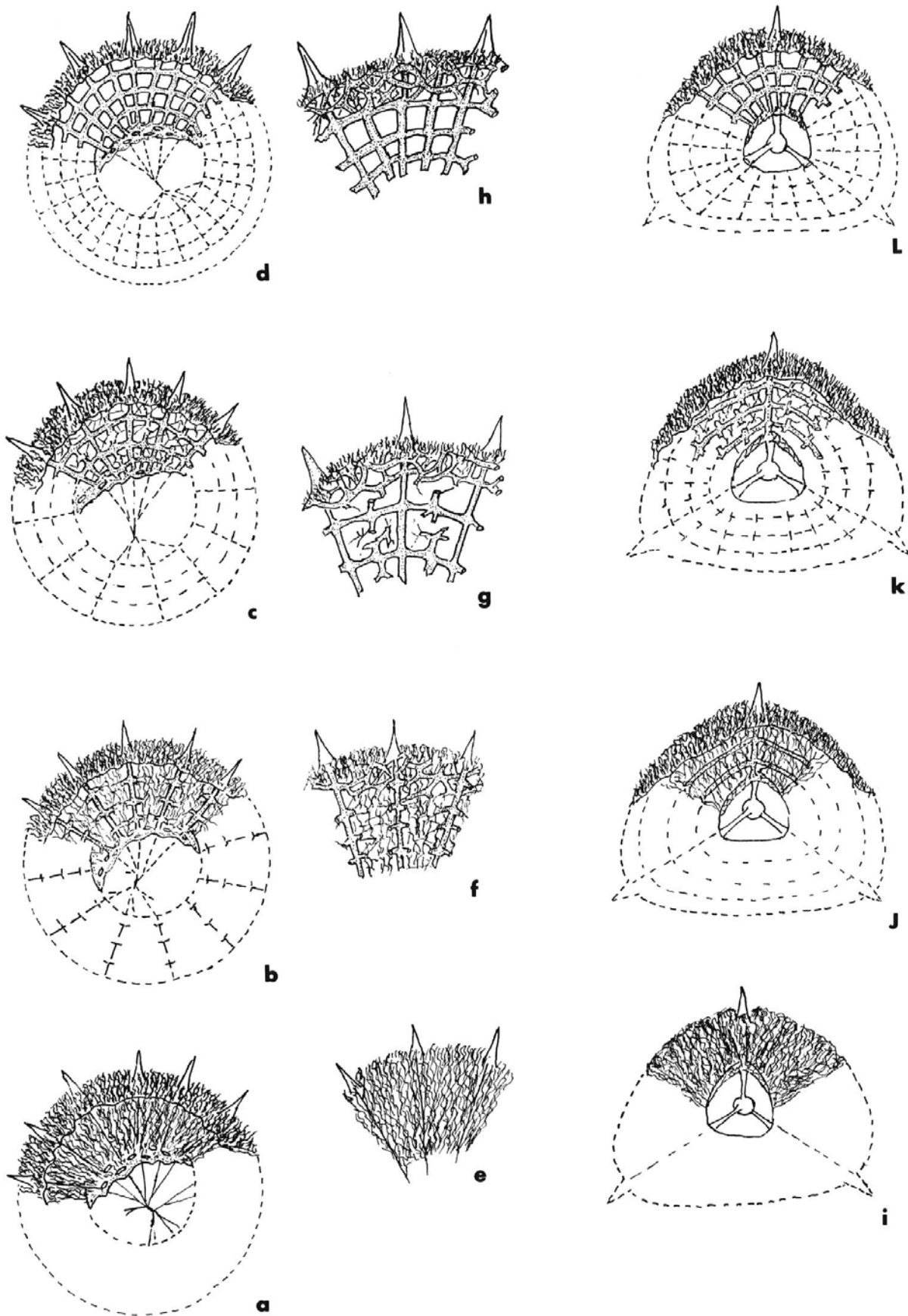


TEXT-FIGURE 3

Hypothetical scheme of the development of tangential parts of the skeleton (e.g. sphere, shells) of A, Entactiniidae; B, Ruzhencevispongidae; C, Latentistulidae.

spheroids with three spines and lacking an internal framework. Moreover, the Triposphaeridae has for a long time remained unused by paleontologists, so that it can be regarded as an "abandoned name." As presently understood, a generalized classification for the Paleozoic spherical Polycystina can be represented as follows:

- Order Polycystina Ehrenberg 1838, emend. Riedel 1967
  - Suborder Spumellaria Ehrenberg 1875
    - Family Entactiniidae Riedel 1967
      - Subfamily Entactiniinae Riedel 1967, emend. Nazarov 1975
        - Tribe Entactiniini Nazarov 1975
          - Entactinia* Foreman 1963
          - Entactinosphaera* Foreman 1963
          - Thecoentactinia* Nazarov 1975
        - Tribe Spongentactiniini Nazarov 1975
          - Spongentactinia* Nazarov 1975
          - Phuristratoentactinia* Nazarov 1981
          - Hegleria*, n. gen.
        - Tribe Tetrentactiniini Kozur and Mostler 1979
          - Tetrentactinia* Foreman 1963
          - Tetragregnon* Ormiston and Lane 1976
      - Subfamily Astroentactiniinae, n. subfam.
        - Tribe Astroentactiniini, n. tribe
          - Astroentactinia* Nazarov 1975
          - Helioentactinia* Nazarov 1975
        - Tribe Somphoentactiniini Kozur and Mostler 1981
          - Somphoentactinia* Nazarov 1975
          - Spongentactinella* Nazarov 1975
          - Copicyntia*, n. gen.
          - Eostylodictya* Ormiston and Lane 1976
          - Copicyntroides*, n. gen.





Subfamily Pylentonemiinae Deflandre 1972

*Pylentonema* Deflandre 1964

*Archocyrtium* Deflandre 1972

Subfamily Haplentactiniinae Nazarov 1980

*Haplentactinia* Foreman 1963

*Syntagentactinia* Nazarov 1980

It should be noted that the classification given, like those proposed earlier (Nazarov 1975, 1981a; Kozur and Mostler 1981) is only a working scheme under which spherical polycystines of the Late Paleozoic can be described. No doubt the present scheme will be changed and refined as a result of new information revising the systematics of the Spumellaria on the basis of comparative morphologic studies and new data about Paleozoic radiolarian faunas.

### STAUAXON POLYCYSTINA

The stauraxon polycystines, which are widely distributed in the Carboniferous and Permian, are peculiar to the Late Paleozoic radiolarian fauna. They have diverse skeletal forms—triangular, oval, subtriangular, discoidal, or crosslike, with three to five, or even more, rays (arms). However, despite the significant variety in external outline, all have a similar internal framework formed like an imperforate (rarely perforate), hollow sphere from which hollow rays extend (text-fig. 3C). A comparable structure of the internal framework is not known among Devonian polycystines, but appears as a cryptogen in the Early Carboniferous (*Latentifistula impella*). It is therefore difficult even to conjecture as to which concrete group of Polycystina (Entactiniidae?) they might be genetically close. It is not impossible that the present case may be an instance of one of the varieties of cladogenesis-iteration. As Krasilov noted (1977, p. 88), "During iteration or successive phylogenetic branching, after a branching off, the original group continues to exist without physical change. After some time, another branch arises from it developing in the very same direction as the initial one and paralleling it. This process can be repeated several times. Although the branching interval is to be estimated at hundreds of thousands or even many millions of years, the stability of the gene pool in the conservative mainline provides for a genetic closeness of all branches."

Naturally, the preceding account is only an assumption, since presently there are no other facts to explain the appearance in the Late Paleozoic of polycystines with this kind of internal structure. Among stauraxons, as among spherical polycystines, there is observed a clearly expressed connection between the internal framework and the external shell (text-fig. 3).

The development of apophyses at the ends of the rays or all along the length of the rays of the internal framework and their continued branching and joining leads to the formation of various skeletal forms (text-fig. 3). Depending on the geometric form, symmetry and degree of compression, three basic groups can be separated: 1) subtriangular, flattened; 2) oval, lensoid, subtriangular, discoidal-inflated; 3) cruciform, consisting of three to five and more subcylindrical rays.

The identical internal structure of all three groups permits them to be united in a higher rank taxon—a superfamily—and these natural subdivisions to be treated as families. The names and systematics given the stauraxon Paleozoic polycystines are shown in the following hierarchy:

#### Order Polycystina

##### Suborder Spumellaria

Superfamily Latentifistulidae Nazarov and Ormiston 1983

Family Latentifistulidae Nazarov and Ormiston 1983

(cruciform, 3-rayed)

Family Tormentidae Nazarov and Ormiston 1983

(oval, discoidal, inflated)

Family Ruzhencevispongidae Kozur 1980, emend. Nazarov and Ormiston 1983

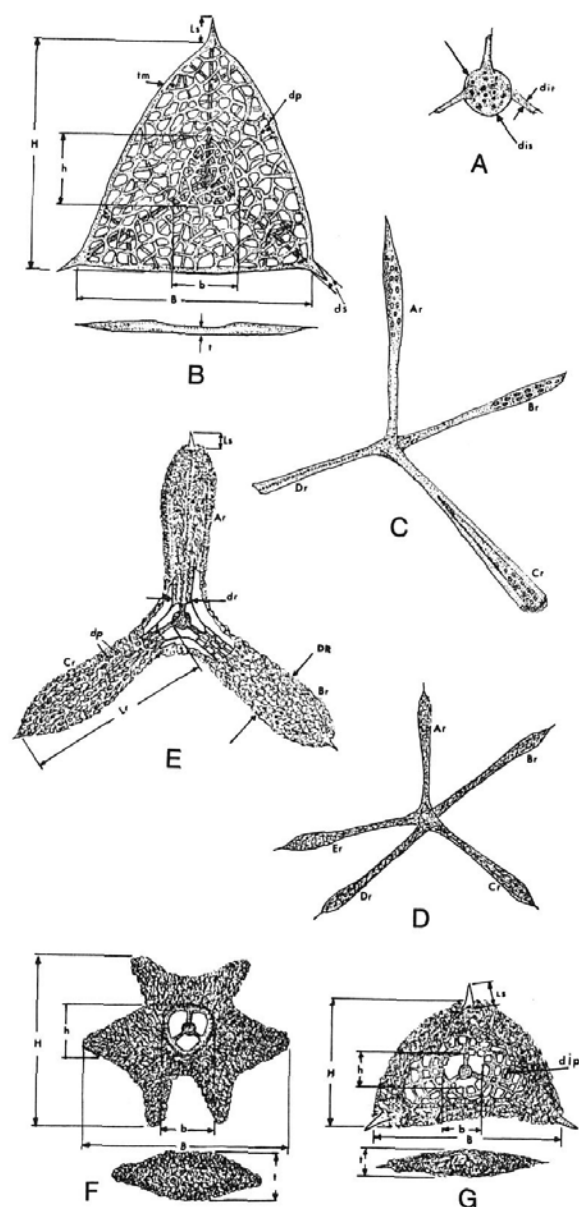
(subtriangular, flattened)

A form of the proposed classification was outlined in Eurorad News by Nazarov complete with illustrations (1980, pp. 47–56, pl.). A short time later, by the end of the year, Kozur (1980) published a short article in which a new family, Ruzhencevispongidae, was described with two new genera, *Ruzhencevispongia* and *Nazarovispongia*, from Early Permian strata of the Southern Urals (material donated by E. V. Movshovich from collections of V. P. Pnev made for extraction and study of conodonts). Radiolaria of this new family have a flattened or inflated subtriangular form of a spongy shell with a small internal sphere, although the dimensions of the shell, internal sphere, and other skeletal parts were not indicated. Judging from illustrations, individuals assigned to *R. uralicus* Kozur include both those with a flattened and those with an inflated skeleton, although the latter possess differentiated spongy fabric. In *Nazarovispongia pavlovi* Kozur, the junction of the internal rays with the external spines and the spongy layer is unclear, as is its structure. The structure of the central part of *N. permicus* Kozur was not indicated. It is not understood whether the spongy development of this form is finely porous or platy skeletal fabric, or is generally absent.

The assignments in Kozur (1980) are highly inconsistent. From Kozur's descriptions it is entirely unclear what prin-

### TEXT-FIGURE 4

Hypothetical scheme of development of multi-layered skeletons of spheroid (a–h) and stauraxon (i–l) polycystines. a, e, schematic illustration of spongy *Somphoentactinia* from the Late Devonian with weakly expressed radial parts (spines) of the skeleton; b, f, spongy *Somphoentactiniini* of the mid-Carboniferous (Moscovian Stage, Kolyma River) with well-developed radial parts of the skeleton, i.e. radially differentiated spongy layers; c, g, spongy *Somphoentactiniini* with distinct radial and weakly expressed tangentially differentiated spongy layers—a hypothetical form; d, h, *Copicyntia* s.l. from the Late Carboniferous to Permian of the Southern Urals. Differentiated spongy layer ending in development of perfectly spherical shell (concentric spheres encased in one another beneath spongy layer); i, spongy Tormentidae of Late Carboniferous to Early Permian (Asselian Stage) of Southern Urals with undifferentiated spongy layers; j, k, Tormentidae with different degrees of tangential differentiation of the spongy layer—a hypothetical form; l, *Rectotormentum* s.l. from Sakmarian and Artinskian stages of Southern Urals showing differentiated spongy layer ending in formation of several isometric shells.



TEXT-FIGURE 5

Schematically illustrated and measured parts of Latentifistulidea Nazarov and Ormiston 1983 and their letter indices.

**Abbreviations:** Latentifistulidea (A): dis—diameter of internal sphere; dir—diameter of rays emanating from internal sphere. Ruzhencevispongidae (B): B—maximum breadth; H—maximum height; t—thickness; b—breadth of internal triangle; h—height of internal triangle; Ls—length of terminal spine, proximally; ds—diameter of spine; tm—breadth of external margin; dp—diameter of pore. Latentifistula and Latentibifistula (E): Ar, Br, Cr—arm indices, lettered clockwise; Lr—length of ray from internal sphere; DR—diameter of external arm; dr—diameter of internal ray; Ls—length of terminal spine; dp—pore diameter or cell of spongy fabric. Quadriremis (C): Ar, Br, Cr, Dr—arm indices, lettered clockwise. Quinqueremis (D): Ar, Br, Cr, Dr, Er—arm indices, lettered clockwise. Tormentum (F): Designations as for Latentifistula. Rectortormentum (G): Designations as for Latentifistula.

ciples are being used to separate taxa of family, genus, and species rank, the criteria being patently eclectic. In addition, the inaccurate assignment of samples to strata in which they were allegedly found should be noted. Thus, strata cited as Kungurian are in reality Artinskian while other samples come from various parts of the Sarabil Suite. These inaccuracies lead directly to serious biostratigraphic errors that result from the fact that Kozur had no conception of the actual stratigraphy of the Southern Urals, as he had not conducted field investigations in this region.

In each of the three families, the separation of genera is based on the quantity of shells surrounding the internal framework. The flattened, subtriangular Ruzhencevispongidae Kozur 1980, emended herein, have a small internal triangle (text-fig. 5B); in the Latentifistulidae are included forms with two shells on each ray, with the recognition that such structure (text-fig. 5E) is typical only for three-rayed varieties. Four- to five-rayed Latentifistulidae primarily have only a single shell layer. In the Tormentidae as in spherical polycystines, there is a characteristic differentiated, spongy layer (text-figs. 4i-l, 5G) with distinctively regular pores beneath a spongy layer, as a consequence of which the test appears to consist of several coalescent shells.

The structure of the skeletal fabric, external outline, form and structure of external (terminal) spines, and combinations of these characters represent the criteria for the separation of species in each of the genera of these three families. The present systematics of stauraxon polycystines can be represented in the following way:

Superfamily Latentifistulidea Nazarov and Ormiston 1983

Family Latentifistulidae Nazarov and Ormiston 1983

*Latentifistula* Nazarov and Ormiston 1983

(3-rayed, spongy with one shell)

*Latentibifistula* Nazarov and Ormiston 1983

(3-rayed, spongy and spongy-porous with two shells)

*Quadriremis* Nazarov and Ormiston, n. gen.

(4-rayed, spongy and latticed)

*Quinqueremis* Nazarov and Ormiston 1983

(5-rayed, predominantly spongy)

Family Ruzhencevispongidae Kozur 1980, emended herein

*Ruzhencevispongius* Kozur 1980, emended herein

(spongy, latticed with small internal triangle)

*Latentidiota* Nazarov and Ormiston, n. gen.

(predominantly spongy, triangular and sublobate)

Family Tormentidae Nazarov and Ormiston 1983

*Tormentum* Nazarov and Ormiston 1983

(spongy, triangular, oval, lensoidal)

*Rectortormentum* Nazarov and Ormiston, n. gen.

(triangular, lensoidal, discoidal with differentiated spongy layer)

*Tetratormentum* Nazarov and Ormiston

(pyramidal, spongy, rarely porous)

*Octatormentum* Nazarov and Ormiston, n. gen.

(bipyramidal, 3-shelled)

*Nazarovispongius* Kozur 1980 probably belongs to the Tormentidae and could be assigned to the category of a satellite genus according to the suggestion of Meien (1975). The systematic position of the following genera is unclear because of insufficient study. Two undescribed genera from the Late Paleozoic of the Urals are conditionally assigned to the Latentifistulidae: The first of these genera consists of large, up

to 2 mm, triradiate forms with a large, latticed sphere up to 120  $\mu$ m and double-shelled rays. The second is multi-rayed, platy and small-pored.

A more objective evaluation requires the inclusion of other individual parts of the skeleton such as the diameter of the internal sphere and of the rays emanating from it, the breadth and height of the test, the length of the arms and their diameter. These parts of the skeleton can be measured for essential inclusion in the description. Numerical data can subsequently be used for statistics of variation.

Designations for essential characters of stauraxon polycystines are listed in the explanation of text-figure 5.

#### BILATERALLY SYMMETRICAL RADIOLARIA

The earliest information about bilaterally symmetrical Radiolaria should be attributed to Hinde (1899). Hinde described, under the generic names *Plagiacantha* and *Plagoniscus* (Plectoidea, Nassellaria), five species from Middle Devonian strata of New South Wales that have threadlike, sometimes curved spines with apophyses which are attached to each other.

Subsequently, similar Radiolaria, also assigned to the Plectoidea, were discovered in Upper Devonian (Frasnian) limestones of the Northern Urals (Bykova and Polenova 1955). Since the studies of Hinde and Bykova were only on thin sections, it is difficult to judge whether these spiny skeletons described as Plectoidea (Nassellaria) really belong to the Radiolaria or to sponge spicules or some other kind of organism. Further study of bilaterally symmetrical Radiolaria is associated with the name of Deflandre (1952, 1953, 1960, 1964, 1973), who first separated Paleozoic Radiolaria from lithified rocks by chemical means. Later, a great number of taxa of similar radiolarians were described from primarily Upper Devonian to Lower Carboniferous strata. Based on peculiarities of skeletal structure, they were assigned to the suborder Albaillellaria (Spumellaria?), Collodaria?, and the families Popofskyellidae and Corythoecidae (incertae sedis).

We will briefly examine the morphology of the above enumerated taxa of bilaterally symmetrical Radiolaria and dwell on some questions of systematics. Among the Ceratoikiscidae, probably the most ancient Albaillellaria, the skeletal plan consists of three spines, whose intersection forms an internal triangle often surrounded by spongy or latticed fabric, the patagium.

Two other families, Albaillellidae and Lapidopiscidae, possess a subconical shell. Holdsworth (1969, 1977) suggested that such a shell form represents a transformation and reduction of the interior triangle enclosed by the individual spines. The fusion of skeletal fabric developed on these spines and hollow ribs probably led to the formation of a subconical shell with an open aperture (or foramen) in the basal part. Homologous skeletal construction in the Ceratoikiscidae, Lapidopiscidae and Albaillellidae is quite logical and well-grounded, although at the present time no intermediate transitional form is known between the Ceratoikiscidae and Albaillellidae. By the mid-70s the following genera had been established among Albaillellaria: Ceratoikiscidae—*Ceratoikiscum* Deflandre 1952, *Holoeciscus* Foreman 1963, *Neo-*

*holoeciscus* Ormiston and Lane 1976; Lapidopiscidae—*Lapidopiscum* Deflandre 1958; Albaillellidae—*Albaillella* Deflandre 1952.

Later, the genus *Follicucullus* Ormiston and Babcock 1979 was described from the upper Permian of North America, and the new family, Follicucullidae, was established. An insignificantly curved subconical shell without lateral wings, in whose interior are two opposing columellae almost fused with a shell wall, are characteristic for species of this genus. The columellae unite in the apical part and end freely at the base, sometimes extended as long, threadlike appendicular spines. These characteristics allow this family to be placed in the Albaillellaria. In recent years there have appeared publications about bilaterally symmetrical Radiolaria from the Southern Urals, Japan, and Alaska in which significant attention is devoted to Albaillellaria. Holdsworth and Jones (1980) described two new genera, *Pseudoalbaillella* and *Parafollicucullus*, while pointing out that they belong to the "Albaillellidae or Follicucullidae" (Holdsworth and Jones 1980, p. 285). They did not explain the reasons for this dualism. In addition, the described species have lateral wings. In the diagnosis of *Follicucullus* this characteristic, important diagnostic feature is not reflected, since the type material from the Lamar limestone shows no specimens having even fragments or traces of the development of lateral spines in the apical or central part of the shell.

Ishiga and Imoto (1980) and Ishiga, Kito and Imoto (1982a) followed Holdsworth and Jones in assigning subconical, straight or curved shells with winglike developments to Albaillellidae/Follicucullidae; and other specimens lacking lateral wings were assigned to the Follicucullidae. In light of these publications there quite naturally arises the question of how to present a hierarchy of higher taxa. Are they really Albaillellaria or do they belong to another group of bilaterally symmetrical polycystines? However, neither Holdsworth and Jones (1980) nor Ishiga and Imoto (1980) clarified the internal structure of the new taxa they described. Apparently, this was not possible, as the material is not adequately preserved. It should be noted that, judging by the descriptions of Holdsworth and Jones as well as by their accompanying illustrations, the difference between *Pseudoalbaillella* and *Parafollicucullus* is insignificant. It is not inconceivable that they are species of the same genus.

In the stratigraphic sections of Upper Carboniferous through Lower Permian age of the Southern Urals there are found both typical *Albaillella* and *Ceratoikiscum* as well as forms that are morphologically close to them. The genus *Haplodiacanthus* Nazarov and Rudenko 1981 was assigned to the Albaillellidae. This genus is close to *Albaillella* in the conical form of its imperforate test and the development of two opposing columellae which sometimes have trabeculae, but *Haplodiacanthus* has these trabeculae continuing in the interior of the lateral wings and lacks the H-frame in the basal part, although it can be inferred in the distinct junction of the basal prolongations.

*Raphidocyclicus* Nazarov and Rudenko, whose skeleton consists of a massive, elongated spine and weakly developed secondary ones enclosing spongy or latticed fabric in the central part, has been provisionally assigned to the Ceratoi-

kiscidae. In its external outline, *Haplodiakanthus* is somewhat similar to *Pseudoalbaillella* and possibly *Parafollicucullus*. However, it is impossible to resolve whether *Haplodiakanthus* really represents a synonym of either of these two genera, since the species described from siliceous sequences of Alaska and Japan have unknown internal structure.

In 1981, Kozur published a small article on Early Permian Albaillellaria from the Southern Urals. He established two new families, Spinodeflandrellidae and Holdsworthellidae. The principles for separation of these two taxa are not at all clear. It is unclear why typical *Albaillella* should be assigned to a new family, Spinodeflandrellidae. Is this solely on the basis of the two spines developed on its basal part?

Similar albaillellids close to this species are known from both the Early Carboniferous of North America and Late Permian of Japan (Ishiga and Imoto 1980, pp. 340–341, pl. 5, figs. 1–16) where they were described as *Albaillella*. Identical specimens in different states of preservation are assigned to different families. If the skeleton is incomplete or somewhat deformed, it is assigned to the Parafollicucullidae/Follicucullidae; if complete and well-preserved, to the Holdsworthellidae. In our opinion, it is probably necessary to carry out a detailed study of the internal structure of the taxa established by Kozur in order to avoid creating redundant taxa.

Takemura and Nakaseko (1981) described the new genus *Neoalbaillella* from the Permian of Japan and assigned it to the Albaillellidae. A conical shell with rows of pores and two paired columellae on the external side of the shell are characteristic for *Neoalbaillella*. The establishment of this genus appears well grounded; it is a pity that the internal structure is not illustrated either by line drawing or by transmitted light photographs.

Thus, the Albaillellaria presently represent one of the most widely distributed groups of Paleozoic Radiolaria. In external appearance the Popofskyellidae are close to the Albaillellaria. They share with them a subconical shell, but, in contrast to the majority of albaillellids, they often have a perforated shell wall. In addition, *Popofskyellum* Deflandre, *Tuscaritellum* Deflandre and *Cyrtentactinia* Foreman have an internal framework in the apical part of the shell that is similar to the internal spicule of entactinoid Radiolaria. It is as though the Popofskyellidae occupy an intermediate position between the Spumellaria and Nassellaria. Deflandre (1972a, 1972b, 1973), accepting the hypothesis of Petrushevskaya (1969), suggested that they might be associated with the Nassellaria [Sphaeroidea (periaxoplastides)-Pylentone-miidae-Popofskyellidae-Cyrtoidea sensu stricto].

*Corythoecia* Foreman and *Camptoolatus* Nazarov and Rudenko are somewhat similar to the Albaillellaria and Popofskyellidae in the subconical, largely perforated shell. These unique Radiolaria have two columellae on the unclosed side of the conical shell. Between them is a large platy wing whose lobes extend parallel to the columellae on the outer side of the shell. Foreman (1963) noted that no known group of fossils or modern Radiolaria have a similar skeletal structure. Such Radiolaria were formerly known only from the Late Devonian of Ohio (Foreman 1963). Morphologically similar

or nearly identical Radiolaria have subsequently been found in the Late Carboniferous to Early Permian strata of the Southern Urals (Nazarov and Rudenko 1981). They have been set off as the new family Corythoecidae in which are included the two genera *Corythoecia* Foreman and *Camptoolatus*. A new genus from the Late Carboniferous, *Arrectoolatus*, for which an elongate, conical shell with an aperture in the apical part below which is situated a two-lobed wing are typical morphologic characters, is assigned to this family. The shell of *Arrectoolatus*, reminiscent in outline of a typical cyrtid, usually has a varying number of segments each bearing one or two rows of pores. A peculiar group is constituted by those bilaterally symmetrical Radiolaria that consist of a varying number of coalescent spines (from 1 to 8 or more). The most widely distributed genus, *Palaeoscenidium* Deflandre (Middle Devonian to Early Carboniferous), has a skeleton of six to eight spines from which crossbars arise. Usually three or four spines, called basal spines, ornamented with apophyses of various lengths, are surmounted by apical spines which, for the most part, are smooth. The site of the junction of the spines is sometimes covered by platy fabric in the form of a cup. A series of genera of similar Radiolaria, whose skeletons consist of various numbers of spines, was established by Deflandre (1960, 1972a, 1973), but almost all of these are undescribed and have been represented only by illustrations. Two related genera, *Bissylentactinia* Nazarov and *Campanulithus* Nazarov and Rudenko 1981, were described later. Originally, Radiolaria consisting only of spines were assigned to incertae sedis (Riedel 1967). Holdsworth provisionally included the Palaeoscenidiidae in the superfamily Entactiniaceae? (Spumellaria). Dumitrica (1978) also regarded this family as part of the Spumellaria, accepting a point of view about the possible affinity of *Palaeoscenidium* sensu stricto with the Haplentactiniidae (Entactiniaceae). Dumitrica (1978) also assigned the new subfamily Pentactinocarpinae to the Palaeoscenidiidae. The presence of a massive spicule enclosed in the inner of the two spheres is characteristic of the latter family. In the diagnosis of the Palaeoscenidiidae (Riedel 1967; Holdsworth 1977), the number of spheres was not indicated, especially as the development of one or two of them associated with an internal spicule is one fundamental taxonomic character for the separation of genera in the family Entactiniidae (Foreman 1963; Riedel 1967; Nazarov 1975, 1981a; Holdsworth 1977). A more logical view was presented by Kozur and Mostler (1981), who assigned the Pentactinocarpinae to the Hexastylacea Haekel. Petrushevskaya (1969, 1979) and Deflandre (1973) noted the similarity of the Palaeoscenidiidae and other acicular radiolarians as well with certain Thalassothamnidae (Collodaria). Kozur and Mostler (1981) assigned genera illustrated and named (but not diagnosed) by Deflandre (1973) to two subfamilies, Palhindeolithinae and Palacantholithinae, but assigned the Palaeoscenidiidae to the Hexastylacea. If the separation of these subfamilies is to any extent well grounded, then the assignment of the Palaeoscenidiidae sensu lato to the typical spumellarians is apparently premature, since morphologically palaeoscenidiids are much nearer to Collodaria than to Spumellaria. It is more likely that *Palaeoscenidium* belongs to a separate family among acicular Paleozoic Radiolaria that can be provisionally assigned to the Collodaria.



All the groups of bilaterally symmetrical Radiolaria discussed above are heteropolar, and it is an attractive idea to unite them in one higher taxonomic group. However, a similar type of symmetry could have arisen independently among different groups of Radiolaria. A characteristic example is the heteropolarity of many spherical Paleozoic Entactiniidae. Therefore, it is apparently premature to consider them as a single order. The fundamental reason is the vagueness of their phylogenetic connections. Since homology of skeletal development has been made clear for only a few bilaterally symmetrical Radiolaria, they ought, as proposed earlier, to be separated into the suborder Albaillellaria which is provisionally assigned to the polycystines with others provisionally assigned to the Collodaria, and the remainder treated as Radiolaria incertae sedis. A generalized classification scheme for heteropolar bilaterally symmetrical Radiolaria can be represented in the following way:

Order Polycystina? Ehrenberg 1838, emend. Riedel 1967

Suborder Albaillellaria Deflandre 1953, emend. Holdsworth 1969

Family Ceratohiscidae Holdsworth 1969

*Ceratohiscus* Deflandre 1953

*Holoeiscus* Foreman 1963

*Neoholoeiscus* Ormiston and Lane 1976

Family Ceratohiscidae? Holdsworth, 1969

*Rhaphidociclicus* Nazarov and Rudenko 1981

*Helenifore* Nazarov and Ormiston 1983

Family Lapidopiscidae Deflandre 1958

*Lapidopiscus* Deflandre 1958

Family Albaillellidae Deflandre 1953, emend. Holdsworth 1969

*Albaillella* Deflandre 1953

*Haplodicanthus* Nazarov and Rudenko 1981

*Neobaillella* Takemura and Nakaseko 1981

Family Albaillellidae? Deflandre 1953, emend. Holdsworth 1969

*Pseudoalaillella* Holdsworth and Jones 1980

Family Follicucullidae Ormiston and Babcock 1979

*Follicucullus* Ormiston and Babcock 1979

Family Follicucullidae? Ormiston and Babcock 1979

*Parafollicucullus* Holdsworth and Jones 1980

Suborder Collodaria? Haeckel 1881

Family Palaeoscenidiidae Riedel 1967

Subfamily Palaeoscenidiinae Riedel 1967, emend. Nazarov 1981

*Palaeoscenidium* Deflandre 1953

Subfamily Palhindeolithinae Kozur and Mostler 1981

*Palhindeolithus* Deflandre 1973

*Xiphocabrium* Deflandre 1973

*Xiphocadiella* Deflandre 1973

*Xiphochistrella* Deflandre 1973

*Bissylentactinia* Nazarov 1975

*Campanulithus* Nazarov and Rudenko 1981

*Arrhinella* Kozur and Mostler 1981

Subfamily Palacantholithinae Kozur and Mostler 1981

*Palacantholithus* Deflandre 1973

*Palaeothalomus* Deflandre 1973

Suborder Radiolaria incertae sedis

Family Popofskyellidae Deflandre 1964

*Tuscaritellum* Deflandre 1972

*Cyrtentactinia* Foreman 1963

*Popofskyellum* Deflandre 1964

Family Corythoecidae Nazarov 1981

*Corythoecia* Foreman 1963

*Camptoolatus* Nazarov and Rudenko 1981

*Arrectoalatus*, n. gen.

## RADIOLARIAN ASSEMBLAGES OF THE LATE CARBONIFEROUS TO PERMIAN OF THE SOUTHERN URALS AND WEST TEXAS

Analysis of the distribution of Radiolaria in the paleontologically characterized strata of the Upper Carboniferous to Permian of the Southern Urals and West Texas with consideration of earlier published data (Ormiston and Babcock 1979; Kozur 1980, 1981; Nazarov and Rudenko 1981) permits the identification of a series of characteristic radiolarian associations which sequentially replace one another. It should be noted that this information is preliminary, since the greater part of the radiolarian association of the Late Paleozoic is not yet described, with the exception of some stauraxon polycystines from the Southern Urals (Nazarov and Ormiston 1983a). Therefore, details of the separation, interrelationship, appropriate subdivisions, and their content may be significantly changed in further studies. Nevertheless, the account below of data on the radiolarian assemblages will, in our opinion, have significance for the clarification of the age of the strata that contain only Radiolaria and their better-grounded correlation as well as for decisions on many other geological problems.

As noted above, in the Southern Urals and West Texas, radiolarians are not known from strata of the middle and lower parts of the Upper Carboniferous. The first occurrence of Radiolaria in Late Paleozoic sections of these regions is in the lower horizons of the Gzhelian Stage (Zianchurin Horizon, see text-fig. 1). In overlying strata in the Southern Urals a series of assemblages of Radiolaria is encountered (numbered from bottom to top, text-fig. 13).

### I. *Tormentum pervagatum* Nazarov and Ormiston, n. sp.

This radiolarian assemblage characterizes the lower part of the Gzhelian Stage, but its lower limit cannot be established with sufficient certainty. Well-preserved Radiolaria were found in a series of sections from which 30 species belonging to 12 genera are known. The most typical are large, slightly compressed *Albaillella*, curled-up *Haplodicanthus*, numerous *Tormentidae* with an open central area, and *Polyentactinia* which have the shape of an almost perfect octahedron with a finely celled shell wall.

Characteristic species are: *Albaillella amplificata*, n. sp., *Tormentum pervagatum*, n. sp., *Tetratormentum narthecium*, n. sp., and *Haplodicanthus circinatus*, n. sp.

### II. *Tormentum protei* Nazarov and Ormiston 1983

The designated assemblage is known from the top of the Gzhelian Stage or the lower and middle parts of the Orenburgian Stage. The lower boundary is quite clearly marked by the appearance of variable *Tormentum protei*, *Arrectoalatus cernuus*, n. sp. and many other new species not known from lower strata. Radiolaria of this assemblage are distinguished by exceptional diversity. Presently, 54 species of 18 genera have been identified. The most widely distributed and abundant are *Tormentum protei*, *Latentidiota visenda*, n. sp., *Arrectoalatus cernuus*, as well as a series of new species of *Albaillella* (small, unsegmented forms with two massive basal spines), *Camptoolatus*, *Popofskyellum*, *Latentifistula*, *Entac-*

*tinia*, *Polyentactinia*, *Latentidiota*, *Tormentum* and *Entactinosphaera*.

### III. *Latentifistula crux* Nazarov and Ormiston 1983

The subject radiolarian assemblage is known from the lower beds of the Asselian Stage at several sections. The most representative assemblage has been identified from strata on the right bank of the Ural River at Nikol Village, which were previously assigned to the upper part of the Orenburgian Stage. As compared with other, older radiolarian assemblages from the same section and other sections, the impoverished taxonomic composition is noteworthy. Many species of the genera *Latentidiota*, *Camptolatus*, *Arrectolatus*, *Popofskyellum*, *Entactinosphaera*, *Entactinia*, *Tormentum*, and others which occur widely in older strata have disappeared. At the same time *Ruzhencevispongidae*, *Copicyntra*, and *Copiellintra* appear, as do several forms of *Latentidiota*, *Entactinia*, *Tormentidae*, and *Latentifistulidae*. *Latentifistula crux* is the most characteristic species of this assemblage with weakly differentiated spongy fabric and occurs with unique, large-pored *Entactinosphaera* which have six to eight pores on the external sphere and four massive three-bladed spines.

According to recent data based on the study of foraminifera and conodonts (Barskov, Isakova and Schastlivtseva 1981) it is exactly at the base of this assemblage III that the Permian-Carboniferous boundary should be drawn in the Southern Urals. The radiolarian assemblage is characterized by a combination of older forms (widely distributed *Tormentidae*, *Latentifistulidae* with differentiated spongy fabric, compressed *Albaillella*, and others) as well as the appearance of *Copicyntra*, *Copiellintra*, *Entactinia* cf. *E. pycnoclada*, n. sp., *Latentidiota*, and a series of other taxa of Permian aspect. Thus, changes in the radiolarian assemblage do not contradict the opinion based on the study of foraminifera and conodonts. Instead, a gradual replacement of one radiolarian assemblage by another is observed at this time and consequently there is a quite "peaceful" boundary. Since one also notes a gradual change of assemblage composition among ammonoids at the Carboniferous-Permian boundary, it is apparent that this should be the proposed location of this boundary.

In the uppermost horizons of the Asselian Stage, Radiolaria are rarely encountered. They are poorly preserved, which makes their identification even to genus difficult.

Somewhat conditionally, the following can be separated.

### IV. Beds with *Tormentidae*

These characterize the Suren and lower part of the Uskalik suites. At a number of levels, abundant subtriangular specimens lacking terminal spines and also lacking terminal spines on spherical varieties were observed.

### V. Beds with *Copicyntra* sp.

These beds correspond with the Uskalik and Kurmain suites of the Asselian Stage and the Karamurun Suite of the Sakmarian Stage. In carbonate layers of these strata there are sometimes encountered large and small spherical forms, some of which occasionally contain a concentric structure in the

internal cavity. These apparently belong to *Copicyntra* and possibly also to *Copiellintra*. Rare subtriangular forms and fragments of rays in this interval apparently belong to the *Latentifistulidae*.

### VI. *Haplodiacanthus perforatus* (Kozur)-*Helioentactinia* sp.

This complex is characteristic of the upper part of the Sarabils Suite, but the lower boundary is conditional. Most abundant in this assemblage are large, spherical *Helioentactinia* (pl. 1, fig. 10) with 8 to 12 short, three-bladed spines and a doubled, pseudospongy outer shell. Appearing for the first time are *Latentibifistula* with clearly differentiated spongy layers, *Entactinia* aff. *E. pycnoclada* with long, three-bladed spines and short apophyses, *Ruzhencevispongidae*, distinctly segmented *Albaillella* and *Haplodiacanthus*. Typical species are *Haplodiacanthus perforatus*, *Albaillella permica* (Kozur), *Helioentactinia* sp. (pl. 1, fig. 10) and others.

### VII. *Tormentum circumfusus*, n. sp.-*Entactinia pycnoclada*, n. sp.

The subject assemblage is known from the lower and middle parts of the Maloik Suite. The lower boundary is marked by the appearance of new species of *Latentibifistula*, *Entactinia* with apophyses on massive spines, and rounded triangular *Tormentum* with an open central area. Also quite abundant in this assemblage are *Copicyntra*, *Copiellintra* with two polar spines and large *Entactinia*. The most widely distributed and dominant elements are *Tormentum circumfusus*, *Entactinia pycnoclada*, *Latentibifistula triacanthophora* Nazarov and Ormiston 1983, and *Latentifistula valdeinepta*, n. sp.

### VIII. *Camptolatus monopterygius* Nazarov and Rudenko

This assemblage is typical of the upper part of the Maloik and Kandurov suites. The lower boundary may be drawn on the appearance of new species of *Camptolatus*, *Ruzhencevispongius*, and *Entactinosphaera*. The assemblage includes abundant *Camptolatus*; *Ruzhencevispongidae* with platy fabric in the center; partitioned, finely-latticed, large *Entactinosphaera* and other species of this genus that also possess partitions but thin-shelled walls and primarily have two spines; *Tetratormentum* with spongy and platy outer shells; and latticed *Raphidociclicus*. The most characteristic species of this complex are *Camptolatus monopterygius*, *Raphidociclicus hiulcus* Nazarov and Rudenko, *Entactinosphaera strangulata*, n. sp., *Ruzhencevispongius plumatus*, n. sp., *Helioentactinia* sp. and others.

### IX. *Rectotormentum fornicatum*, n. sp.

In a single section on the right bank of the Ural River at Don Village, consisting of a lithologically monotonous sequence of terrigenous rocks with beds and lenses of limestone and dolomite, it is possible to clearly see the replacement of one radiolarian assemblage by another. The boundary between the Sakmarian and Artinskian stages has been delineated by conodonts in this same section. Moreover, in the underlying strata (beds with *Camptolatus monopterygius*) ammonoids are known in the uppermost part of the Sakmarian Stage: *Propopanoceras* aff. *P. postsimense* Ruzhencev, *Uraloceras*

*burtiense* (Voin), *Marathonites* sp., and others. The lower boundary of the assemblage is drawn on the appearance of abundant *Rectotortum* having an external form varying from oval, triangular, lensoid to subcubic and distinctly expressed terminal spines of conical form. In addition to the dominant *Rectotortum*, there are encountered varied, but not so abundant *Latentifistulidae*, *Tortentidae*, *Entactiniinae*, *Spongactiniinae*, and *Polyentactinia*. Characteristic species are *Rectotortum fornicatum*, *Tortum? pavlovi*, *Latentifistula sakmarica* (in part) with long, densely spongy rays, two of which are strongly curved.

X. *Quinqueremis arundinea* Nazarov and Ormiston 1983-  
*Entactinosphaera crassilathrata*, n. sp.

This assemblage is known from the lower and middle parts of the Aktastinian Substage and is distinguished by exceptionally diverse Radiolaria. By preliminary identification, there are no fewer than seventy species. In this association there are abundant *Entactinia* possessing large shells with long major and secondary spines, *Entactinia* with a small shell and six massive spines with apophyses at two levels, *Entactinosphaera* which also have significant dimensions and a varied structure of the exterior shell wall—latticed, cellular, partitioned, and porous. The appearance of *Astroentactinia* with apophyses on each spine; *Spongactiniinae* with four or five medullary shells between the porous internal sphere and the external spongy layer; *Copiellintra* with a swollen spine at one pole; *Ruzhencevispongus* (approximately 10 species with a distinct internal triangle and differentiated wall structure); *Polyentactinia* (also about 10 species), some with thin, large-celled shell and others with thick, spongy walls; diverse and exotic *Latentifistula*; *Latentibifistula*; *Quinqueremis*; *Quadrirremis*; and *Polyfistula* with long (up to 1500  $\mu$ m) rays. Bilaterally symmetrical Radiolaria are represented by *Raphidociclicus*, *Campanulithus*, segmented *Albaillella*, and *Haplodiacanthus* among which are developed long spines curved toward the base. The most characteristic species are *Entactinia densissima*, n. sp., *Astroentactinia luxuria*, n. sp., *Entactinosphaera crassilathrata*, n. sp., *Ruzhencevispongus cataphractus*, n. sp., *Quinqueremis arundinea*, and *Albaillella apporrecta*, n. sp.

XI. *Tetragregnon* sp.

This assemblage is provisionally recognized in the upper part of the Aktastinian Substage, as Radiolaria were discovered there only recently and have not yet been sufficiently studied. It should be noted that abundant, large (up to 400  $\mu$ m) *Tetragregnon*, in which three of four internal layers are developed forming several isometric shells, occur here. More rarely encountered are *Entactinia*, *Astroentactinia*, *Latentifistulidae*, rare *Tortentidae*, and *Ruzhencevispongidae*, while bilaterally symmetrical forms have not been observed. Characteristic species of this assemblage apparently will be *Tetragregnon* and *Astroentactinia*.

XII. *Polyentactinia lautitia*, n. sp.

This assemblage is identified in the upper part of the Baigendzhinan Substage by the appearance of large, fine-celled *Polyentactinia*, *Copicyntra* with quite long, three-bladed

spines and *Latentidiota* which have beveled rays on which short but massive terminal spines are developed. By comparison with radiolarian associations of the Aktastinian Substage, the impoverishment in diversity and quantity of many taxonomic groups is notable especially among *Latentifistulidae*, *Tortentidae* and *Entactiniinae*. At the same time, the number of specimens of single species, for example *Copicyntra cuspidata* and others, is great. Dominant in this assemblage are *Polyentactinia*, *Entactinia*, *Latentidiota*, *Copicyntra*, *Copiellintra*. Genera only rarely met with are *Quadrirremis*, *Quinqueremis*, *Raphidociclicus*, and *Campanulithus*.

At the top of the Artinskian Stage, in a section at Upper Lake Village, individual specimens of *Follicucullus* were observed together with a unique *Haplodiacanthus*. This represents the first appearance of the genus *Follicucullus* in the Permian of the Soviet Union. The most widely distributed species of the assemblage are *Polyentactinia lautitia*, *Copicyntra cuspidata*, n. sp., *Copicyntra phymatodonta*, n. sp., *Haplodiacanthus anfractus* Nazarov and Rudenko, and *Follicucullus* sp.

Thus, in the Late Paleozoic strata of the west slope of the Urals are developed a series of radiolarian assemblages which have been traced through many sections. Of course, the scope and paleontologic characterization of each of these is highly variable as a result of insufficient study of radiolarians. It is apparent that it will be possible in the future to break out more fundamental local stratigraphic subdivisions on the basis of radiolarian distributions. For now, Radiolaria of the Upper Carboniferous to Lower Permian are unknown from many regions in which strata of this age are developed, except for North America. In West Texas, a diverse radiolarian assemblage has been identified from the Bone Springs Limestone which was correlated with the Artinskian Stage by Furnish (1973, p. 533) and represents more than 20 species. *Entactinia*, *Polyentactinia*, *Tortum*, *Albaillella*, *Haplodiacanthus*, *Latentifistula*, and *Quadrirremis* (see text-fig. 14) are present. This assemblage is peculiar. If these Radiolaria actually come from an equivalent of the upper part of the Artinskian Stage then attention should be drawn to the wide distribution, especially of *Latentifistulidae* and *Tortentidae*, which have a rather relict (Asselian-Sakmarian) aspect. In addition, Bone Springs spongy polycystines with abundant radial spines are practically identical externally with the Ural *Copicyntra* but lack medullary shells between the internal sphere and outer spongy layer. Such structure is also characteristic of older *Spongactiniinae*. At the same time, a number of species present in the Bone Springs Limestone—*Latentifistula neotenica*, n. sp., *Latentifistula* sp. (pl. 4, figs. 3-4), *Haplodiacanthus anfractus* and species of *Quadrirremis*, *Quinqueremis*, and *Albaillella*—are near to and even identical with some yet undescribed forms from the Artinskian and sometimes the Sakmarian of the Southern Urals. On the basis of fusulinids, Ross (1963, p. 1) correlated the lower part of the Leonardian including part of the Bone Springs Formation with the Sakmarian Stage.

*Ociatortum cornelli*, n. sp. is a characteristic taxon for the Bone Springs Limestone, individual specimens of which have been encountered in the Artinskian Stage of the Southern Urals. From strata assigned to the Leonardian Stage in



West Texas, only two localities are known to yield structurally preserved Radiolaria which, of course, means an incomplete representation of the radiolarian assemblage and its composition. This circumstance, for the present, somewhat complicates correlations, that is, direct correlation of the Urals with West Texas. Therefore, until new assemblages of Radiolaria are found from other levels in the Bone Springs Formation and, allowing for the peculiarity already known, the entire Bone Springs Limestone is equated with the Sakmarian and Artinskian stages of the west slope of the Southern Urals as is shown on text-figure 1. The failure to recover Radiolaria from the Wolfcampian strata of West Texas prevents us from using these fossils to correlate Lower Permian strata between North America and the Soviet Union. Documentation of Wolfcampian Radiolaria from the stratotype area is a logical area for future radiolarian research.

Radiolarian assemblages from Japan inferred to be upper Wolfcampian or lower Leonardian on their conodont faunas (Ishiga, Kito and Imoto 1982b, p. 20) contain the *Haplo-diacanthus rhombothoracata* (Ishiga and Imoto) assemblage which includes the upper range of *H. sakmarensis* (Ishiga, Kito and Imoto 1982b, fig. 5). The underlying *H. lomentaria* assemblage which includes the lower range of *H. sakmarensis* was also inferred to be probably Wolfcampian. In the Soviet Union, *H. sakmarensis* is confined to the Tastubian Substage of the lower Sakmarian (text-fig. 13, Faunal Assemblage VI).

Four radiolarian assemblages are recognized in the upper Permian of West Texas (text-fig. 14) in this paper and probably will be greatly augmented by future study. The lowest documented Guadalupian assemblage is found in the Hegler Limestone of the Bell Canyon Formation and is characterized by *Hegleria mammiifera*, n. gen., n. sp. in association with *Tormentum sertulum*, n. sp., *Latentifistula texana*, n. sp. and *Entactinia tyrrelli*, n. sp. This assemblage is succeeded by the *Follicucullus ventricosus* assemblage (Ormiston and Babcock 1979) in the latest Guadalupian Lamar Limestone. It is characterized by the overlap of the name bearer with a number of newly appearing species: *Ruzhencevispongius girtyi*, n. sp., *Copicyntrides asteriformis*, n. sp., *Latentifistula densa*, n. sp., *Raphidociclicus gemellus americanus*, n. subsp., *Octatormentum babcockae*, n. sp. and *Follicucullus scholasticus* Ormiston and Babcock. There appears to be a rather marked change in the radiolarian succession within the Guadalupian of West Texas. One further assemblage is provisionally recognized marked by the persistence of "*Copicyntra*" sp. from the Lamar Limestone upward into the evaporitic Castille Formation, perhaps more noteworthy as a feat of survivorship than as a biostratigraphic entity. Direct correlation of the Guadalupian Radiolaria with the Soviet Union is impeded by the inappropriate facies represented in the stratotypic Upper Permian of the Soviet Union and the lack of documentation of Late Permian assemblages elsewhere within the Soviet Union. However, sequences with numerous species of *Follicucullus* are present in the far eastern part of the Soviet Union near Magadan (undescribed collections of Nazarov) and are probably broadly correlative with the Guadalupian. A more direct correlation can be made with the *Follicucullus scholasticus* assemblage zone represented in the Sasayama area of Japan (Ishiga, Kito and Imoto 1982b, p. 19) which includes *F. ventricosus* Ormiston and Babcock.

The Japanese occurrences have been inferred to be of Guadalupian age, based on species composition and stratigraphic position above the assemblages previously discussed. One possibly complicating factor is that the Japanese sequences appear to be quite condensed and could conceivably include some reworking of radiolarians, which makes it difficult to sort out true ranges. The youngest assemblage zones documented by Ishiga, Kito and Imoto (1982b), which consist of species of *Neobaillella*, have not yet been recognized in West Texas and may well be post-Guadalupian in age.

## SYSTEMATIC PALEONTOLOGY

The collections of Late Carboniferous and Permian Radiolaria described below are repositied in the Geological Institute of the Soviet Academy of Sciences, Moscow (GIN) and the United States National Museum, Washington (USNM).

Diagnoses of families, subfamilies, and genera published earlier in readily accessible works are not repeated. Detailed descriptions are given only for new taxa.

Order POLYCYSTINA Ehrenberg 1838, emend. Riedel 1967  
Suborder SPUMELLARIA Ehrenberg 1875  
Family ENTACTINIIDAE Riedel 1967  
Subfamily ENTACTINIINAE Riedel 1967, emend. Nazarov 1975  
Genus ENTACTINIA Foreman 1963

*Entactinia densissima* Nazarov and Ormiston, n. sp.  
Plate 1, figures 1-2

*Derivation of name:* densissima—Latin, very dense.

*Holotype:* GIN 4673/1, Lower Permian, Artinskian Stage, Aktastinian Substage, Southern Urals, Ural River, Don Village.

*Description:* Shell large, spherical, with six massive major and numerous secondary spines. Internal framework consisting of an eccentrically placed six-rayed spicule. Median crossbar and basal part of rays of the spicule are threadlike but toward the periphery the rays are already acquiring a three-bladed form, while small protuberances are developed on the blades. Rays of the internal spicule imperceptibly passing into long main spines with massive blades. Secondary spines arising from corners of interpore lattice have diverse form and dimensions. They are threadlike, long, straight or curved, branched in the distal part, either with numerous short spinules on the individual spines or wavy. Shell wall quite thick, penetrated by predominantly rounded, sometimes funnel-like pores.

*Dimensions (in  $\mu\text{m}$ ):* Shell diameter 150-285, majority 250; wall thickness 10-20; length of main spine up to 1670, diameter at base 35-100, majority 50-65; length of secondary spines up to 275; pore diameter 8-32, average 16-20.

*Comparison:* From presently known species of the genus, *E. densissima* is distinguished by the unique combination of massive sphere with massive long major spines and development of secondary spines of variable shape and size.

*Distribution:* Lower Permian, Artinskian Stage, Aktastinian Substage, Southern Urals.

*Material:* More than 100 specimens.



*Entactinia pycnoclada* Nazarov and Ormiston, n. sp.  
Plate 1, figures 3, 5–6

*Derivation of name:* pycnocladus—Latin, densely branched.

*Holotype:* GIN 4672/2, Lower Permian, Sakmarian Stage, Sarabil Suite, Southern Urals, Ural River, Verkhne-Ozernoe Village.

*Description:* Shell small, spherical, with six long, massive spines. Internal six-rayed spicule eccentrically situated in shell cavity, its rays joining with bases of three-bladed spines. At a distance of about 100  $\mu\text{m}$  from their bases all main spines have one or two groups of apophyses which in turn have prolongations of various lengths bearing small spinules. The contact of these apophyses with neighboring spines creates the impression of the development of an additional, isometric shell. Secondary spines numerous, of varied form. They are rodlike or with fine spinules in their distal part, as if serrated. Thick shell wall penetrated by rounded, funnel-like pores.

*Dimensions (in  $\mu\text{m}$ ):* Shell diameter 50–85; wall thickness 5–20, average 15; length of main spines up to 1165, majority up to 700; diameter at their base 25–50; length of secondary spines up to 270, average 55–80; pore diameter in nearly all cases 10, rarely 5–8.

*Comparison:* The small sphere and long, massive spines with two groups of apophyses clearly distinguish *E. pycnoclada*, n. sp. from other species of the genus.

*Remarks:* Species of *Entactinia* having a small shell and massive three-bladed spines are characteristic for the Middle Carboniferous to Permian of many regions. In the mid-Carboniferous of the northeastern Soviet Union, *Entactinia* with strongly branched apophyses on the major spines occur, but they have a larger sphere (up to 160  $\mu\text{m}$ ) and small secondary spines. In the Late Carboniferous of the Urals, species without apophyses on the main spines dominate. In Artinskian strata, similar *Entactinia* have long, branched apophyses and dilated main spines which almost fuse with each other whereas often only two spines are developed.

Specimens of related *Entactinia* from the Bone Springs Formation of West Texas have spines without apophyses, a smaller-pored shell, and uniform secondary spines.

From the Triassic of Austria (Kozur and Mostler 1981) comes a species described as *Triplosphaera? cordevolica* Kozur and Mostler which has a small shell and long major spines with apophyses. This species is distinguished from Late Paleozoic ones by the bigger, fine-pored shell with small secondary spines and, most importantly, by the development of an internal sphere.

*Distribution:* Lower Permian, Sakmarian Stage (upper part), Southern Urals.

*Material:* More than 100 specimens.

*Entactinia parapycnoclada* Nazarov and Ormiston, n. sp.  
Plate 1, figure 13

*Derivation of name:* para—Latin, near—combined with pycnoclada.

*Holotype:* USNM 257599, Lower Permian, Leonardian Stage, Bone Springs Formation, West Texas.

*Description:* Shell small, spherical, with six long, three-bladed main spines. Internal spicule massive, six-rayed, without apparent branches and eccentrically situated in shell. Its rays unite with the bases of the six three-bladed external spines. All main spines about 500  $\mu\text{m}$  in length, some show a slight torsion along their length. These spines lack apophyses. There are numerous secondary spines of varied form, mostly cylindrical but of varied length and diameter. The shell wall is thick and penetrated by numerous rounded-oval pores.

*Dimensions (in  $\mu\text{m}$ ):* Diameter of shell 80–100, spine length up to 600, secondary spines up to 15; pores of shell 4–8; diameter of main spines at their base 15–22.

*Comparison:* *Entactinia parapycnoclada* closely resembles *E. pycnoclada*, n. sp. from the Sakmarian of the Southern Urals, but differs principally in lacking the prominent cross branches of the main spines exhibited by that species and in having shorter secondary spines and smaller pores penetrating the shell. *Entactinia tortispina* (Ormiston and Lane 1976) differs in having a larger shell diameter (Ormiston and Lane 1976, p. 166) and four to six major spines with a more markedly eccentric internal spicule.

*Distribution:* Lower to Upper Permian, Leonardian to Guadalupian stages, Bone Springs Limestone and Lamar Limestone, West Texas.

*Material:* More than 15 specimens.

*Entactinia tyrrelli* Nazarov and Ormiston, n. sp.  
Plate 1, figure 12

*Derivation of name:* In honor of Willis Tyrrell, author of an important summary paper on the Lamar Limestone.

*Holotype:* USNM 257600, Upper Permian, Guadalupian Stage, Lamar Limestone, West Texas.

*Description:* Shell of moderate size, spherical, with six (rarely 12) main spines of three-bladed form and numerous secondary spines. The internal spicule is six-rayed and eccentrically situated. The central bar and proximal parts of rays are rodlike, but the distal parts of the rays become three-bladed before joining the external spine. The external spines are three-bladed and taper rapidly to an acuminate tip. Their length is only slightly greater than the shell radius. Numerous, short, cylindrical secondary spines arise from the interpore framework of the shell. Pores are circular to oval. Shell wall not especially thick.

*Dimensions (in  $\mu\text{m}$ ):* Shell diameter 110–140, pore diameter 3–9, wall thickness 6; length of main spines 90–150, diameter at base 20–25; maximum length of secondary spines 20, diameter at base 4–6.

*Comparison:* The smaller shell diameter and shorter and thinner main and secondary spines distinguish *E. tyrrelli* from the Soviet species *E. densissima*, n. sp. from the Artinskian of the Urals.

*Remarks:* The secondary spines are exceedingly thin and may easily be broken. The observed lengths may thus be substantially less than the original length.

**Distribution:** Upper Permian, Guadalupian Stage, Hegler and Lamar limestones, West Texas and New Mexico.

**Material:** Twelve specimens.

Genus ENTACTINOSPHAERA Foreman 1963

*Entactinosphaera crassiclathrata* Nazarov and Ormiston, n. sp.  
Plate 1, figures 4, 7–8

**Derivation of name:** crassi—Latin, thick; clathratus—Latin, latticed.

**Holotype:** GIN 4673/4, Lower Permian, Artinskian Stage, Aktastinian Substage, Southern Urals, Ural River, Don Village.

**Description:** Shell spherical, with two to six major three-bladed spines. Internal sphere small, thick-walled, penetrated by predominantly rounded pores. Internal framework represented by six-rayed spicule situated eccentrically, its threadlike rays uniting with the bases of the three-bladed crossbeams between the inner and outer spheres, which in turn directly connect with the external major spines. The outer sphere consists of thin strips arising from the spines and interlacing irregularly with each other, as a result of which the external appearance somewhat resembles a ball of thread. The space between these strips was probably occupied by thin skeletal fabric not now preserved. Major spines three-bladed, sometimes twisted. Their number is inconstant.

Specimens with two opposing spines dominate, but forms with three, six, and rarely five spines are also encountered. Secondary spines are lacking from the external surface of the shell, but the inner sphere has numerous additional spines, some of which unite with the outer shell.

**Dimensions (in  $\mu\text{m}$ ):** Diameter of outer sphere 225–250, thickness of wall 15; diameter of pore-cells 10–50; diameter of internal sphere 45, thickness of wall 5–12, pore diameter 8–10; length of main spines up to 300.

**Comparison:** The unique structure of the external sphere consisting of interlacing strips distinguishes this species from other presently known taxa of *Entactinosphaera*.

**Distribution:** Lower Permian, Artinskian Stage, Aktastinian Substage, Southern Urals.

**Material:** More than 50 specimens.

*Entactinosphaera strangulata* Nazarov and Ormiston, n. sp.  
Plate 2, figures 1–2

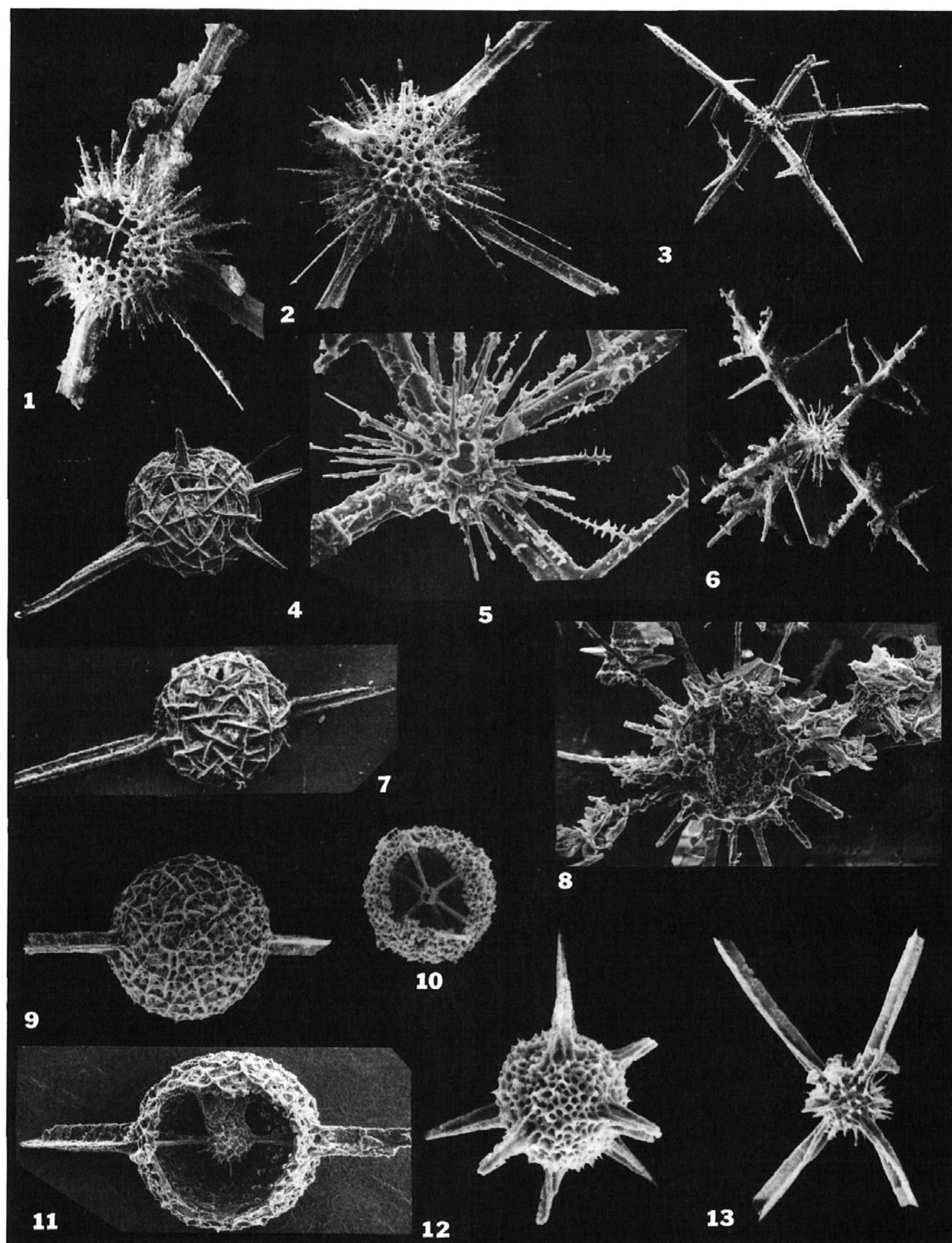
**Derivation of name:** strangulatus—Latin, drawn in.

**Holotype:** GIN 4673/15, Lower Permian, Artinskian Stage, Aktastinian Substage, Southern Urals, Ural River, Don Village.

**Description:** Shell spherical with two to six major spines. Inner sphere small, fine, with rounded-oval pores. Internal

#### PLATE 1

- 1–2 *Entactinia densissima* Nazarov and Ormiston, n. sp.  
Lower Permian, Artinskian Stage, Aktastinian Substage, Southern Urals, Ural River, Don Village. 1, paratype, GIN 4673/2, external view of shell with three-bladed main and diverse secondary spines,  $\times 95$ ; 2, paratype, GIN 4673/3, internal structure showing eccentric position of internal spicule,  $\times 100$ .
- 3, 5–6 *Entactinia pycnoclada* Nazarov and Ormiston, n. sp.  
Lower Permian, Sakmarian Stage, Sarabil Suite, Southern Urals, Ural River, Upper Lake Village. 3, paratype, GIN 4672/4,  $\times 80$ ; 5, holotype, GIN 4672/2, showing structure of diverse secondary spines,  $\times 235$ ; 6, paratype, GIN 4672/3,  $\times 100$ . 3, 6, external views of specimens with two equally long apophyses on three-bladed main spines.
- 4, 7–8 *Entactinosphaera crassiclathrata* Nazarov and Ormiston, n. sp.  
Lower Permian, Artinskian Stage, Aktastinian Substage, Southern Urals, Ural River, Don Village. 4, 7, external views of specimens with differing numbers of main spines; 4, paratype, GIN 4673/6, with six spines, one longer than the five others,  $\times 95$ ; 7, paratype, GIN 4673/5, with two spines,  $\times 95$ ; 8, GIN 4673/7, structure of internal sphere, view of ray fragments of internal spicule,  $\times 475$ .
- 9, 11 *Entactinosphaera cimelia* Nazarov and Ormiston, n. sp.  
Upper Permian, Guadalupian Stage, Lamar Limestone, West Texas. 9, external view of holotype, USNM 257601,  $\times 170$ ; 11, view of interior of topotype,  $\times 200$ .
- 10 *Helioentactinia* sp.  
View of undescribed species from Lower Permian, Sakmarian Stage, Sarabil Suite, Southern Urals, showing thin lattice shell (upper left) resting on thick spongy layer and stout internal beams uniting with medullary shell,  $\times 110$ .
- 12 *Entactinia tyrrelli* Nazarov and Ormiston, n. sp.  
Upper Permian, Guadalupian Stage, Lamar Limestone, West Texas. Holotype, USNM 257600, showing rapidly tapering spines,  $\times 240$ .
- 13 *Entactinia parapycnoclada* Nazarov and Ormiston, n. sp.  
Upper Permian, Guadalupian Stage, Lamar and Hegler limestones, West Texas. Holotype, USNM 257599,  $\times 140$ .



framework represented by a six-rayed spicule occupying an eccentric position in the internal sphere. Threadlike spicular rays which arise from the median crossbar, uniting with the three-bladed crossbeams between the inner and outer spheres connecting with the external spines. These crossbeams are massive, but if two to four spines are not developed, they are finer, with weakly expressed blades. Besides the major crossbeams, the inner sphere is also united with the outer by thin rods arising from the corners of the interpore lattice of the inner sphere. Outer sphere thin, partitioned into segments by narrow ridges irregularly interlaced with one another. Each segment is penetrated by a different number of rounded angular pores. Major spines three-bladed, rarely twisted. Majority of specimens have two oppositely directed spines, but sometimes there are encountered forms with three, four and, rarely, more spines. Secondary spines absent.

**Dimensions (in  $\mu\text{m}$ ):** Diameter of the external sphere 224–256, wall thickness 7–10, pore diameter 4–9; diameter of inner sphere 45–55, wall thickness 4–6, pore diameter 4–6; length of major spines up to 270, possibly larger.

**Comparison:** Segmentation of the outer shell by numerous fine ridges distinguishes *E. strangulata* from all presently known species of the genus except for *E. cimelia*, n. sp., which is distinguished by having more numerous partitions on the external surface.

**Distribution:** Lower Permian, Sakmarian and Artinskian stages, Southern Urals.

**Remarks:** In the Sakmarian Stage, similar *Entactinosphaera* are rarely encountered. They are weakly segmented and usually have two spines. *Entactinosphaera strangulata* is abundant in the lower layers of the Artinskian strata. Individual specimens are encountered at the top of the Aktastinian Sub-stage.

**Material:** More than 100 specimens.

*Entactinosphaera cimelia* Nazarov and Ormiston, n. sp.  
Plate 1, figures 9, 11

**Derivation of name:** cimelius—Latin, beautiful.

**Holotype:** USNM 257601, Upper Permian, Guadalupian Stage, Lamar Limestone, road cut on Highway 162, West Texas.

**Description:** Shell spherical with two to six major spines. Internal sphere much smaller than outer one, with rounded, oval pores. Internal framework within inner sphere is not preserved in available material. The inner and outer spheres are united by a pair of massive, three-bladed crossbeams (pl. 1, fig. 11) which thicken rapidly away from the inner sphere and unite with the two major external spines, which the vast majority of available specimens show. Numerous, thin, rod-like spines arising from the internal sphere also connect to the external sphere, but these are rarely entirely preserved. Wall of external sphere thin. Shell surface bears numerous arcuate ridges or partitions intersecting in a disorganized manner to form polygonal (often triangular) cells. These cells separate groups of pores ranging in number from one to five, with two pores per cell the most frequent. Major spines are bladed-triangular in cross section, thin bladed and long, not

twisted. Two-spined forms represent about 90% of all specimens seen, but four- and six-spined forms exist and are probably ecologic variants.

**Dimensions (in  $\mu\text{m}$ ):** Diameter of external sphere 160–230, wall thickness 5–6, pore diameter 4–5; diameter of internal sphere 35–40, pore diameter 3–4; length of main spines up to 240 or more.

**Comparison:** In the compartmentalization of the surface of the external sphere by raised ridges or partitions and the presence of two massive, three-bladed crossbeams between inner and outer spheres, this taxon closely resembles *E. strangulata*, n. sp. *Entactinosphaera cimelia* is distinguished from the Soviet taxon in having more numerous partitions on the external surface, dividing the surface into smaller "cells" which consequently contain fewer pores.

**Distribution:** Upper Permian, Guadalupian Stage, Hegler and Lamar limestones of the Bell Canyon Formation, West Texas and New Mexico.

**Material:** More than 40 specimens.

Tribe SPONGENTACTINIINI Nazarov 1975

*Hegleria* Nazarov and Ormiston, n. gen.

**Derivation of generic name:** Named for the Hegler Limestone, Bell Canyon Formation.

**Type species:** *Hegleria mammiifera*, n. sp.

**Diagnosis:** Spongentactiniines with three spongy shells, of which the outer bears numerous orderly arranged, raised mammae with hairlike cylindrical central spinules. Multiple internal rays (at least 12) connect the shells. Internal spicule not presently known.

**Remarks:** The genus *Rikivatella* Kozur and Mostler (1981, p. 51) from Triassic strata somewhat resembles *Hegleria* in having a mammillose external surface, but these mammae have a triangular central spine in *Rikivatella*, and the internal structure of that genus is not known.

*Hegleria mammiifera* Nazarov and Ormiston, n. sp.  
Plate 6, figures 3–5

**Derivation of name:** mammatum—Latin, breast; ferus—Latin, to carry.

**Holotype:** USNM 257602, Upper Permian, Guadalupian Stage, Lamar Limestone, West Texas.

**Description:** Outer shell large with prominent, large nodes of spongy fabric, between which is porous shell with many small pores separated by thick pore bars. Centers of nodes are short, thin hairlike spinules of circular cross section. Nodes number 50–60. Internally, there are two spheres of spongy composition. These are usually poorly preserved. The central sphere has multiple (at least 12) rays which connect it with the second inner shell at which position branching of these rays appears to occur. The branches then connect the second shell with the outer. All rays are cylindrical in form. Internal spicule not seen.

**Dimensions (in  $\mu\text{m}$ ):** Diameter of outer sphere 330–410, second sphere 250–260, and inner sphere 70–80. Diameter of



external nodes 40, diameter of spinules at node center 1–2, diameter of pores in outer sphere 6–8.

**Comparison:** *Rikivatella nodospinosa* Kozur and Mostler (1981, p. 52, pl. 1, fig. 1) from the Anisian and Ladinian of Italy is superficially similar but has no organized pores between the nodes and has spines of triangular form emerging from the nodes. The internal structure of *R. nodospinosa* is not known, and it may only be externally homeomorphic with *H. mammifera*.

**Distribution:** Upper Permian, Guadalupian Stage, Lamar and Hegler limestones of the Bell Canyon Formation, West Texas and New Mexico.

**Material:** More than 40 specimens.

Tribe TETRENTACTINIINI Kozur and Mostler 1979

Genus TETRAGREGNON Ormiston and Lane 1976

***Tetragregon nitidus*** Nazarov and Ormiston, n. sp.

Plate 6, figure 12

**Derivation of name:** nitidus—Latin, neat.

**Holotype:** USNM 257603, Lower Permian, Leonardian Stage, Bone Springs Limestone, West Texas.

**Description:** Large pyramidal shell of spongy fabric with spines at the apices. Internal sphere eccentrically situated with four major rays continuing externally as the terminal spines. Internal sphere porous. The spongy fabric surrounding the sphere is almost touching it and consists of fine, hairlike threads less than 1  $\mu$ m thick. The external spines are as long as the height of the shell where they are fully preserved. At their base, spines are three-bladed in form but become rodlike distally. Form of outer shell varies from distinctly pyramidal to subpyramidal with inflated sides.

**Dimensions (in  $\mu$ m):** Shell height 260–360, length of side 200–320; diameter of sphere 110; length of spines up to 350; diameter of spongy “cells” 6–8.

**Comparison:** The subject species resembles *T. pyramidale* Nazarov (in press) from the Upper Carboniferous of the Southern Urals in shape. It differs from that species in its slightly larger size, finer spongy fabric and the three-bladed basal cross section of the apical spines. Still undescribed species of *Tetragregon* from the Artinskian of the Southern Urals in the collections of B. Nazarov also have fine spongy fabric but are distinguished by the tendency of this fabric to form concentric layers about the inner sphere.

**Distribution:** Lower Permian, Leonardian Stage, Bone Springs Limestone, West Texas.

**Material:** More than 15 specimens.

***Tetragregon scalpratus*** Nazarov and Ormiston, n. sp.

Plate 2, figure 17

**Derivation of name:** scalpratus—Latin, having a sharp edge.

**Holotype:** USNM 257604, Upper Permian, Guadalupian Stage, Lamar Limestone, West Texas.

**Description:** A small *Tetragregon* with cells of two orders

in the spongy fabric, the larger four times the diameter of the smaller. Shell outline subpyramidal to subspherical with long, sharp-edged, three-bladed spines at the apices. Internal sphere porous, central. The three-bladed form of the spines persists to their acuminate tip, and spines have a length equal to or greater than shell diameter.

**Dimensions (in  $\mu$ m):** Shell diameter 110–164; spine length 125–165; spine diameter at base 28–34; large cells of spongy fabric 15–20; small cells 5–7.

**Comparison:** *Tetragregon scalpratus*, n. sp. is distinguished from *T. nitidus*, n. sp. from the Bone Springs Limestone by its smaller size, more strongly bladed spines and spongy fabric with two orders of cells.

**Distribution:** Upper Permian, Guadalupian Stage, Lamar Limestone, West Texas.

**Material:** Six specimens.

Subfamily ASTROENTACTINIINAE Nazarov and Ormiston, n. subfam.

Genus ASTROENTACTINIA Nazarov 1975

***Astroentactinia luxuria*** Nazarov and Ormiston, n. sp.

Plate 6, figure 13

**Derivation of name:** luxuria—Latin, splendid verdure, splendid growth.

**Holotype:** GIN 4673/1, Lower Permian, Artinskian Stage, Aktastinian Substage, Southern Urals, Ural River, Don Village.

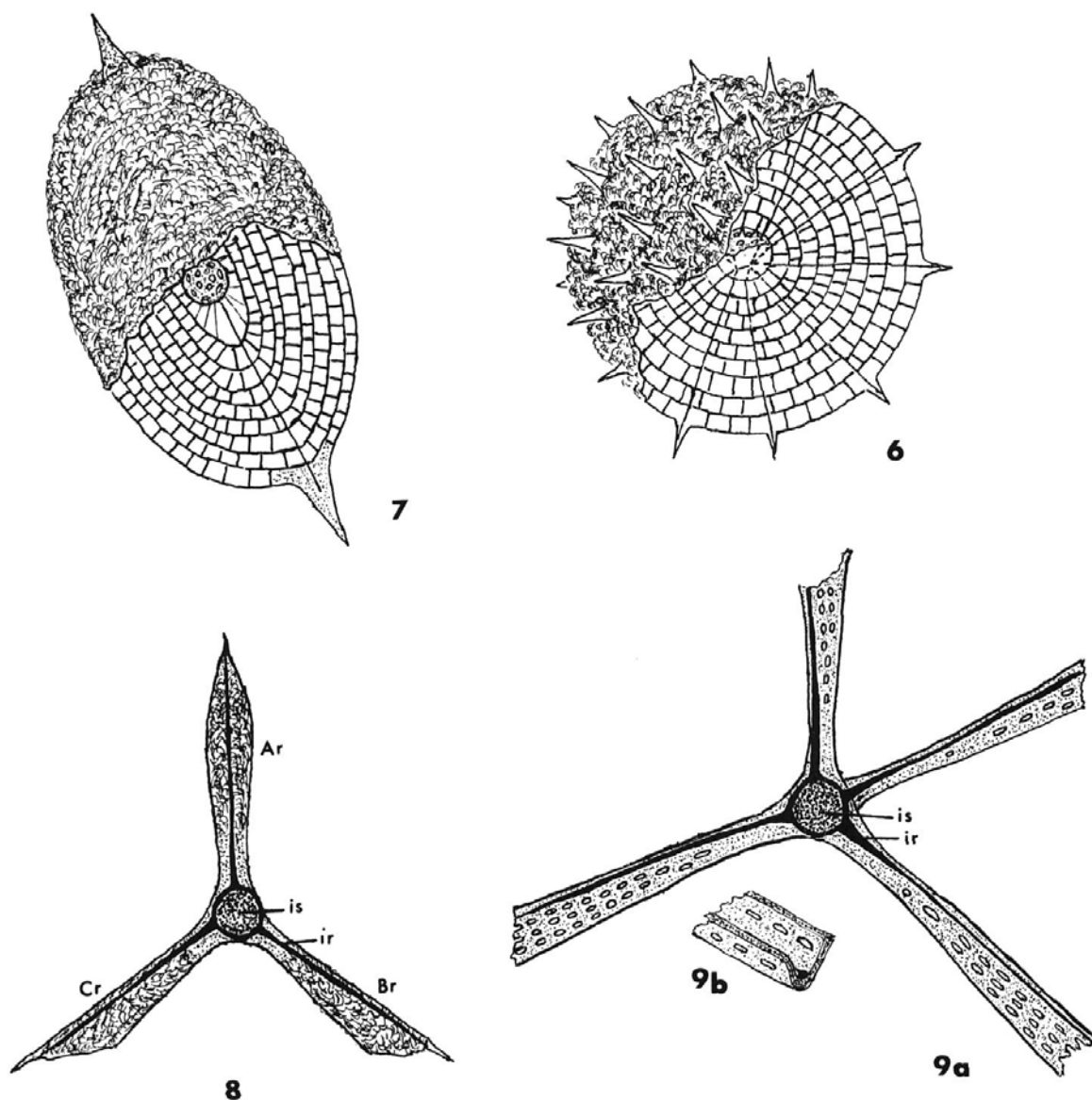
**Description:** Shell small, spherical, with numerous external spines. Internal framework represented by multi-rayed spicule situated eccentrically sometimes near the outer sphere. Number of rays arising from the small crossbar (2–4  $\mu$ m long) is from eight to ten. These fine rays are often curved and typically have from one to three apophyses which connect also with the spine bases. The number of major spines is 20–24. They are long, three-bladed, acuminate in the distal part. Shell wall penetrated by pores of hexagonal form. From the angles of the interpore lattice arise secondary spines branched in their distal part. Union of the apophyses of neighboring secondary spines and apophyses of major spines creates the impression of the development of an additional external shell.

**Dimensions (in  $\mu$ m):** Shell diameter 135–150; wall thickness 15, pore diameter 10–14; length of main spines up to 340, diameter at base 35, length of secondary spines 75–80, rarely up to 120.

**Comparison:** From all species of the genus found in Carboniferous through Permian strata, *A. luxuria* is distinguished by the development of apophyses on the main and secondary spines that unite with each other to form a second lattice shell at a distance of 75 to 80  $\mu$ m from the inner shell surface.

**Distribution:** Lower Permian, Artinskian Stage, Aktastinian Substage, Southern Urals.

**Material:** Tens of specimens.



TEXT-FIGURES 6-9b

6, schematic illustration of *Copicyntra*, n. gen. showing external form and internal structure. 7, schematic illustration of internal structure and external outline of *Copellintra*, n. gen. 8, schematic illustration of structure of internal sphere and rays of *Latentifistula neotenica*, n. sp., letter indices defined on text-figure 5. 9a, schematic illustration of structure of internal sphere and rays of *Quadriremis gliptoacus*, n. sp., is—internal sphere; ir—internal ray. 9b, schematic cross section of arm of this species, showing arm groove.

Tribe SOMPHOENTACTINIINI Kozur and Mostler 1981

*Copicyntra* Nazarov and Ormiston, n. gen.

*Derivation of generic name:* copia—Latin, abundance; cyclis—Latin, circular; intra—Latin, inner.

*Type species:* *Copicyntra acilaxa*. Upper Carboniferous, Gzhelian Stage, Southern Urals, Ural River, Nikol Village.

*Diagnosis:* Astroentactiniinae with a spongy outer layer and porous inner sphere. Among them are developed 8-13, rarely more, thin concentric shells, which are nested. These shells probably represent differentiated spongy layers (see text-fig.

4d, h). All spheres are crossed by radial crossbeams joining with the bases of outer spines of varied form.

*Comparison:* From all spongy, spherical polycystines of the Late Paleozoic, the subject genus is distinguished by the development of multiple intercalated shells (pl. 2, fig. 11) between the outer spongy layer and the porous inner sphere. *Eostylodictya eccentrica* Ormiston and Lane 1976, from the Mississippian of North America and the new genus *Copellintra* from the Late Carboniferous to Early Permian of the Southern Urals also possess intercalated shells, but these genera characteristically have a lensoid or ellipsoidal external shell form. Middle Triassic Oertlispongidae (*Oertlispongius*

Dumitrica, Kozur and Mostler, *Gombergellus* Dumitrica, Kozur and Mostler, *Tamonaella* Dumitrica, Kozur and Mostler 1980) have a similar outline, but among them, as among all ellipsoidal polycystines, the external spines are not so numerous.

**Remarks:** It is probable that the radial crossbeams arising from the internal sphere, directly linking with the external spines, are associated with an internal framework. Among some species there are sometimes visible thin, threadlike rays proceeding inward from the radial crossbeams. Judging by their orientation, an internal spicule could have been situated eccentrically (text-fig. 6). Thus, it is not excluded that branches of its rays were developed (text-fig. 6).

**Generic composition:** Three species of this genus from Permian strata of the Southern Urals and West Texas are described in this paper: *C. cuspidata*, n. sp. ( $P_1$ ), *C. phymatodonta*, n. sp. ( $P_1$ ) and *C. simulens*, n. sp. ( $P_2$ ). Other species assignable to this genus also exist, since *Copicyntra* is also distributed in the Late Carboniferous, and Sakmarian Stage of the Southern Urals. These species are not described in the present article.

**Distribution:** Late Carboniferous to Late Permian, Southern Urals, West Texas and eastern Soviet Union.

***Copicyntra cuspidata*** Nazarov and Ormiston, n. sp.  
Plate 2, figure 14

**Derivation of name:** *cuspidatus*—Latin, elongate-pointed.

**Holotype:** GIN 4673/11, Lower Permian, Artinskian Stage, Baigendzhinskian Substage, Southern Urals, Aktyubinsk Region, Aktasti River.

**Description:** Shell spherical with numerous three-bladed spines. The number of concentric spheres between the outer shell and inner porous sphere is usually eight, rarely up to 10. Inner sphere small with rounded pores. Radial crossbeams arising from the inner sphere have a three-bladed form. External spines long with three sharp blades, spine acuminate in distal part. Outer spongy layer represented by disorganized interweaving of thin skeletal fibers forming small cells.

**Dimensions (in  $\mu\text{m}$ ):** Shell diameter 240–280, thickness of spongy layer 5–15; diameter of inner sphere 30–35, intercalated shells have diameters proceeding inward from spongy layer of 275, 250, 175, 150, 125, 100, 75 and 50; spine length 76–130.

**Comparison:** From the majority of species of the genus and also from *C. phymatodonta* with which it occurs, *C. cuspidata*, n. sp. is distinguished by long, three-bladed spines.

**Distribution:** Lower Permian, Artinskian Stage, Baigendzhinskian Substage, Southern Urals.

**Material:** Approximately 100 specimens.

***Copicyntra phymatodonta*** Nazarov and Ormiston, n. sp.  
Plate 2, figures 9–10

**Derivation of name:** *phymatodontus*—Latin, swollen toothed.

**Holotype:** GIN 4673/19, Lower Permian, Artinskian Stage,

Baigendzhinskian Substage, Southern Urals, Aktyubinsk Region, Aktasti River.

**Description:** Shell spherical or slightly ellipsoidal, with spongy spines. The number of concentric internal spheres is from eight to 10, rarely 11. Innermost sphere has a thin wall penetrated by rounded oval pores. Radial crossbeams arising from it are thin, sub-bladed. Numerous external spines are subconical, strongly expanded at their base; as a result, the outer surface of the shell is uneven and bumpy. Spongy layer is quite thick, dense with tiny cells.

**Dimensions (in  $\mu\text{m}$ ):** Shell diameter 274–308, thickness of spongy layer up to 30, diameter of inner sphere 35–38; pore diameter 4–6; intercalated shells diameters 275, 250, 225, etc., spine length 20–28.

**Comparison:** From the majority of species of the genus, *C. phymatodonta*, n. sp. is distinguished by the spongy external spines.

**Distribution:** Southern Urals, Lower Permian, Artinskian Stage, Baigendzhinskian Substage.

**Material:** Tens of specimens.

***Copicyntra? simulens*** Nazarov and Ormiston, n. sp.  
Plate 2, figures 15–16

**Derivation of name:** *simulens*—Latin, resembling, an allusion to its external resemblance to other *Copicyntra* species.

**Holotype:** USNM 257605, Lower Permian, Leonardian Stage, Bone Springs Limestone, West Texas.

**Description:** Shell spherical, spongy, with short, three-bladed spines that taper rapidly from their base. From 90 to 110 spines on outer surface. Internal sphere is thin-walled, penetrated by pores; surrounded by spongy fabric with good radial persistence of rays but only rare development of clear concentric layers. Numerous radial rays. Shell surface finely spongy.

**Dimensions:** Shell diameter 190–240; diameter of internal sphere 45–50, spine length 17–20.

**Comparison and remarks:** The absence of development of multiple concentric rings of spongy fabric around the internal sphere does not seem to be an effect of poor preservation but part of the original structure. It is not possible, therefore, to be certain that this species belongs in *Copicyntra*. Externally it does resemble fairly closely *C. phymatodonta*, n. sp. from the Artinskian of the Urals from which it is externally distinguished by a slightly smaller size and more acuminate spines.

**Distribution:** Lower Permian, Leonardian Stage, Bone Springs Limestone, West Texas.

**Material:** Thirty-five specimens.

***Copiellintra*** Nazarov and Ormiston, n. gen.  
Text-figure 7

**Derivation of generic name:** *copia*—Latin, abundance; *ellipsodeus*—Latin, ellipsoidal; *intra*—Latin, inner.

**Type species:** *Copiellintra diploacantha*. Lower Permian,

Sakmarian Stage, Kandurov Suite, Southern Urals, Ural River, Don Village.

**Diagnosis:** Ellipsoidal Astroentactiniinae with spongy outer layer and porous inner sphere. Between these more than 10 ellipsoidal, thin shells developed, nested in each other. Radial crossbeams crossing all shells, sometimes continuing to external spines.

**Comparison:** The ellipsoidal external form of the shell distinguishes this genus from all spongy Paleozoic polycystines. It is distinguished from *Copicyntra* in having numerous internal shells. From *Eostylodictya* Ormiston and Lane for which a lensoid form and few intercalated shells are typical, the described species is distinguished by the development of two, rarely several, polar spines. In *Eostylodictya* there are numerous longer spines in an equatorial belt around the shell.

**Generic composition:** Only the type species is described in

this paper. Some new species from the Permian of the Southern Urals and West Texas may also belong to this genus.

**Distribution:** Middle Carboniferous to Late Permian of Southern Urals, North America, and eastern Soviet Union. It should be noted that *Copiellintra* is more typical of Permian strata. In the Southern Urals, *Copiellintra* appears only at the base of the Asselian Stage.

*Copiellintra diploacantha* Nazarov and Ormiston, n. sp.  
Plate 2, figure 5

**Derivation of name:** diplos—Greek, two; acanthus—Latin, spiny.

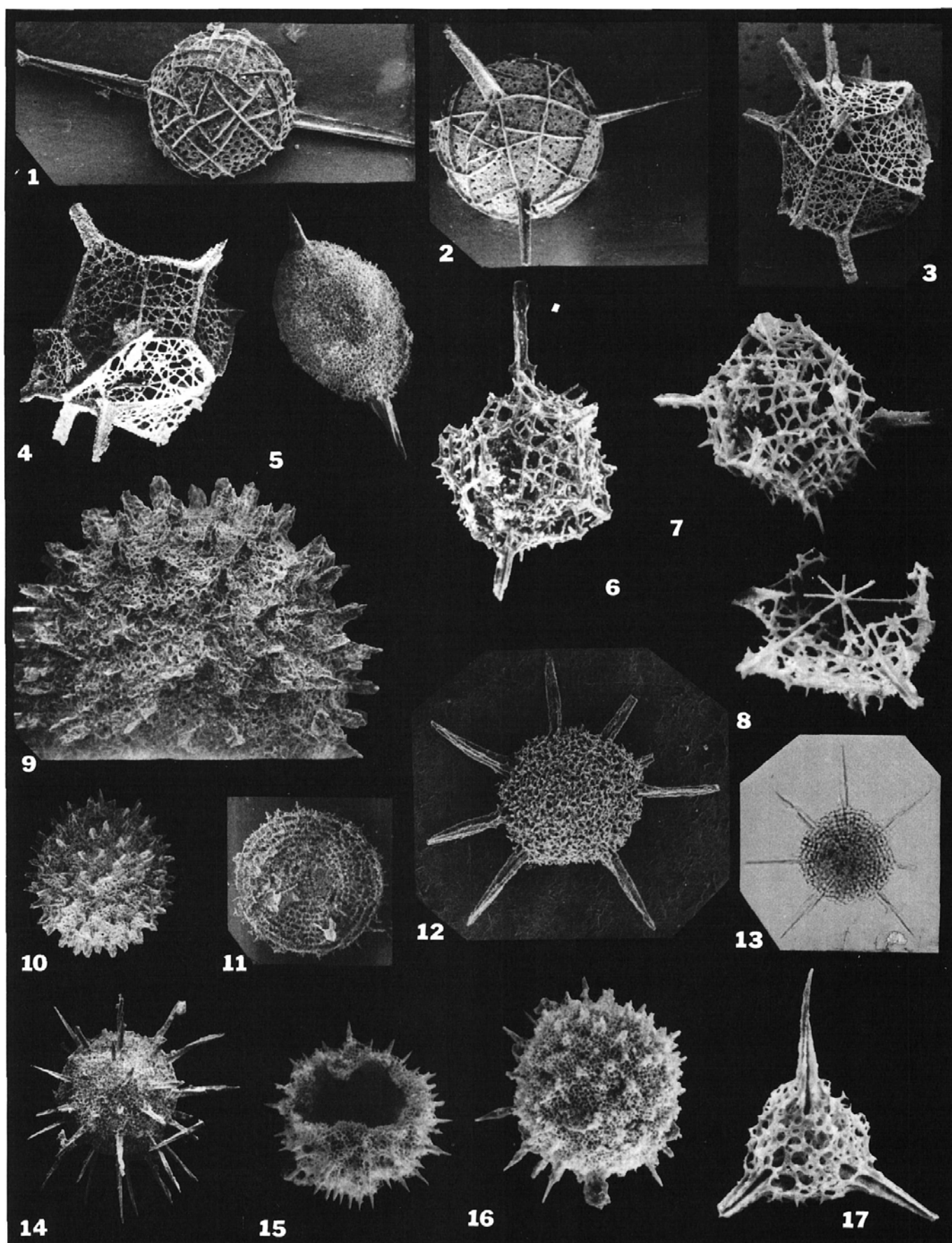
**Holotype:** GIN 4672/5, Lower Permian, Sakmarian Stage, Kandurov Suite, Southern Urals, Ural River, Don Village.

**Description:** Shell elliptical, with two opposing spines. The number of shells between the spongy layer and the internal

## PLATE 2

- 1–2 *Entactinosphaera strangulata* Nazarov and Ormiston, n. sp.  
Lower Permian, Artinskian Stage, Aktastinian Substage, Southern Urals, Ural River, Don Village. 1, paratype, GIN 4673/17, external view of shell with two massive spines,  $\times 95$ ; 2, paratype, GIN 4463/16, external view of shell with three main spines of different lengths,  $\times 95$ .
- 3–4 *Polyentactinia lautitia* Nazarov and Ormiston, n. sp.  
Lower Permian, Artinskian Stage, Baigendzhinskian Substage, Southern Urals, Aktyubinsk Region, Aktasti River. External view of shells with differing numbers of main three-bladed spines; 3, paratype, GIN 4673/9,  $\times 48$ ; 4, paratype, GIN 4673/10,  $\times 53$ .
- 5 *Copiellintra diploacantha* Nazarov and Ormiston, n. gen., n. sp.  
Lower Permian, Sakmarian Stage, Kandurov Suite, Southern Urals, Ural River, Don Village. Paratype, GIN 4672/6, external view of shell with two oppositely situated (polar), three-bladed spines,  $\times 125$ .
- 6–8 *Polyentactinia centrata* Nazarov and Ormiston, n. sp.  
Lower Permian, Leonardian Stage, Bone Springs Limestone, West Texas. 6, holotype, USNM 249799,  $\times 200$ ; 7, external view,  $\times 170$ ; 8, specimen showing central, internal spicule,  $\times 210$ .
- 9–10 *Copicyntra phymatodonta* Nazarov and Ormiston, n. gen., n. sp.  
Lower Permian, Artinskian Stage, Baigendzhinskian Substage, Southern Urals, Aktyubinsk Region, Aktasti River. 9, enlarged fragment of external surface of shell; the structure of the spongy layer and subconical spongy spines are visible,  $\times 230$ ; 10, paratype, GIN 4673/2a, external view of shell with spongy spines,  $\times 95$ .
- 11 *Copicyntra* sp.  
Lower Permian, Artinskian Stage, Southern Urals, Assel River, GIN 4673/18, partially broken specimen, view of internal sphere and concentric medullary shells (specimen not described),  $\times 100$ .
- 12–13 *Copicyntroides asteriformis* Nazarov and Ormiston, n. gen., n. sp.  
Upper Permian, Guadalupian Stage, Lamar Limestone, West Texas. 12, holotype, USNM 257606, showing bladed peripheral spines and bilateral symmetry,  $\times 210$ ; 13, transmitted light photograph showing internal structure,  $\times 120$ .
- 14 *Copicyntra cuspidata* Nazarov and Ormiston, n. gen., n. sp.  
Lower Permian, Artinskian Stage, Baigendzhinskian Substage, Southern Urals, Aktyubinsk Region, Aktasti River. Paratype, GIN 4673/12, external view of shell with numerous three-bladed, long, main spines,  $\times 90$ .
- 15–16 *Copicyntra? simulens* Nazarov and Ormiston, n. sp.  
Lower Permian, Leonardian Stage, Bone Springs Limestone, West Texas. 15, specimen showing central cavity and numerous short spines,  $\times 110$ ; 16, holotype, USNM 257605, exterior view,  $\times 210$ .
- 17 *Tetragregnon scalpratus* Nazarov and Ormiston, n. sp.  
Upper Permian, Guadalupian Stage, Lamar Limestone, West Texas. Holotype, USNM 257604, showing two orders of external pores,  $\times 200$ .





sphere is inconstant. In the same sample are found specimens with 10, 11, 12, 13, and 14 intercalated shells, the majority with 11 or 12. Internal shell, as a rule, is represented by a sphere penetrated by rounded pores. Radial crossbeams arising from it are indistinctly expressed with the exception of two, which join with the spine bases. Spines three-bladed, short, acuminate in their distal part. They sometimes appear twisted, rarely one spine can be split into two. Spongy layer thin, represented by disorganized fibers of skeletal fabric. Cells in the spongy layer are small.

*Dimensions (in  $\mu\text{m}$ ):* Shell diameter from 160 by 190 to 190 by 300, thickness of spongy layer 12–27, diameter of the internal sphere 35–40, pore diameter 4–8; spacing between intercalated shells 20–25; spine length 100–115.

Comparisons with other species of the genus will be found in a subsequent publication.

*Distribution:* Lower Permian, upper part of the Sakmarian Stage, Southern Urals.

*Material:* Tens of specimens.

*Copicyntroides* Nazarov and Ormiston, n. gen.

*Derivation of generic name:* From *Copicyntro* plus *oides*, a diminutive.

*Type species:* *Copicyntroides asteriformis*, n. sp.

*Diagnosis:* Shell inflated, discoidal, consisting of finely cellular spongy outer layer and nine or ten concentric inner shells with a central spherical shell. Periphery with six to nine three-bladed spines with a gap in their radial arrangement, which marks a plane of bilateral symmetry.

*Remarks:* *Copicyntroides* is closest to *Eostylodictya* Ormiston and Lane 1976, from which it differs in lacking an eccentric prominence on the disk, having fewer longer equatorial spines and a spongy rather than solid outer layer.

*Copicyntroides asteriformis* Nazarov and Ormiston, n. sp.  
Plate 2, figures 12–13

*Derivation of name:* aster—Latin, star; formis—Latin, form.

*Holotype:* USNM 257606, Upper Permian, Guadalupian Stage, Lamar Limestone of Bell Canyon Formation, West Texas.

*Description:* Shell inflated, discoidal, with six to nine (typically 7) three-bladed spines around equatorial belt. Shell consisting of nine or ten concentric disks around spherical inner shell. Internal sphere small, presence of pores not determinable. Major crossbeams connect the inner sphere with the external spines. There is a distinct bilaterality in the arrangement of the external spines with a gap where no spine is developed, interrupting the radial arrangement. External spines are not in a horizontal plane, but diverging from it by up to 30°. Outer spongy layer consists of fine skeletal threads in an unorganized pattern. Cells minute.

*Dimensions (in  $\mu\text{m}$ ):* Maximum diameter of outer shell 130–155, minimum diameter of outer shell 45–90; diameter of inner sphere 42, length of spines 70–90, cells of outer layers 2–3.

*Comparison:* *Eostylodictya eccentrica* Ormiston and Lane (1976, p. 171, pl. 4, figs. 1–6) from the Mississippian of Oklahoma somewhat resembles *C. asteriformis* but lacks a spongy outer layer, has more numerous, short, conical equatorial spines, and an eccentric prominence.

*Remarks:* Undescribed discoidal forms from the Artinskian Stage examined in Nazarov's collections are generally similar to *C. asteriformis* except that they have rodlike peripheral spines and not three-bladed ones.

*Distribution:* Upper Permian, Guadalupian Stage, Lamar Limestone of West Texas.

*Material:* More than 20 specimens.

Superfamily *Latentifistulidea* Nazarov and Ormiston 1983

*Diagnosis:* Paleozoic, predominantly stauraxon Polycystina with internal framework in the form of a hollow sphere with four to five, rarely more, rays arising from it. Internal framework covered by porous or spongy fabric which forms subtriangular, discoidal, lobed (cruciform) or other shell shapes (text-fig. 5).

*Comparison:* From Paleozoic Polycystina (Entactiniidae sensu lato) and bilaterally symmetrical Radiolaria, representatives of this superfamily are distinguished by the stauraxon symmetry of the skeleton. The massive internal framework and larger dimensions distinguish Latentifistulidea from Mesozoic-Cenozoic Discoidea sensu lato.

*Remarks:* Mesozoic Discoidea-Hagiastriidae, Pseudoaulophacidae and others have an external skeletal outline identical with that of Latentifistulidea. Peculiarities of the internal structure of Mesozoic Discoidea have not presently been clarified, therefore it is not possible to evaluate the inclusion of Paleozoic with younger crossed axon polycystines. One cannot exclude the possibility of a phylogenetic connection.

At the end of the last century, Rüst (1892) described Discoidea from the Carboniferous to Permian? strata of various European regions, assigning them to various Haeckelian taxa. Since his studies were carried out only on thin sections, it is difficult to determine whether the material he described really belongs to the Latentifistulidea. According to the illustrations and descriptions given, several of them could be accommodated in separate genera of this superfamily.

### Superfamily Composition

Superfamily LATENTIFISTULIDEA Nazarov and Ormiston 1983  
Family LATENTIFISTULIDAE Nazarov and Ormiston 1983  
Family RUZHENCEVISPONGIDAE Kozur 1980, emend. Nazarov and Ormiston 1983  
Family TORMENTIDAE Nazarov and Ormiston 1983

*Distribution:* Late Paleozoic (Carboniferous to Permian), Europe, Asia and North America.

*Dimensions:* Letter indices employed for the measured parts of members of the Latentifistulidea in the following descriptions are defined on text-figure 5.

Family Ruzhencevispongidae Kozur 1980, emend.

*Emended diagnosis:* Flattened Latentifistulidea of predominantly subtriangular form. Internal framework represented

by hollow sphere with three rays. Internal structures enclosed in spongy, cellular or partly platy skeletal material. Rays of internal framework united with base of terminal spines by narrow, threadlike laminae forming external (marginally, see text-fig. 5B) border which becomes outer margin between spongy and latticed parts of shell.

**Comparison:** From other families of the Latentifistulidea the Ruzhencevispongidae are distinguished by the flattened, subtriangular form of the skeleton. From subtriangular Tormentidae, Ruzhencevispongidae are distinguished further by the development of a border that separates different types of skeletal fabric on the outer surface of the shell.

**Family composition:** Two genera are presently known: *Latentidiota*, n. gen. of Late Carboniferous age and *Ruzhencevisponus* Kozur of Permian age.

**Distribution:** Late Paleozoic (Carboniferous to Permian) of the Urals, eastern Soviet Union and North America.

***Latentidiota* Nazarov and Ormiston, n. gen.**

**Derivation of generic name:** latens—Latin, hidden; diota—Latin, vessel.

**Type species:** *Latentidiota visenda*, n. sp. Upper Carboniferous, Gzhelian Stage, Southern Urals, Ural River, Nikol Village.

**Diagnosis:** Triangular or lobate-triangular Ruzhencevispongidae. Hollow rays of internal framework emerging at 120° angles from sphere, crossing directly to terminal spines. External shell spongy, rarely lattice laminar. Marginal border distinct in some species, weakly expressed in others.

**Comparison:** From *Ruzhencevisponus*, which occurs in Sakmarian and Artinskian strata, *Latentidiota* is distinguished by a more varied form of the skeleton. However, the fundamental distinction is the presence in *Ruzhencevisponus* of an internal lattice shell within which the internal sphere is enclosed (see text-fig. 5B).

**Remarks:** Some species of this genus have outlines that are shared by a number *Latentifistula* species. However, in *Latentifistula*, the cross-sectional shape of the rays (lobes) is circular, whereas it is elongate-oval in *Latentidiota*. Such shape convergences can be the result of ecologic factors. On the other hand, the external form of the skeleton apparently reflects the genetic proximity of two probably recently diverged groups.

**Generic composition:** Ten species are known from strata of the Gzhelian Stage and the lower part of the Asselian. In this paper, only the type species is described.

**Distribution:** Upper Carboniferous to Lower Permian (basal layers) of the Southern Urals.

***Latentidiota visenda* Nazarov and Ormiston, n. sp.**  
Plate 3, figure 7

**Derivation of name:** visendus—Latin, remarkable.

**Holotype:** GIN 4488/50a, Upper Carboniferous, Gzhelian Stage, Southern Urals, Ural River, Don Village.

**Description:** A *Latentidiota* having a variable outline, equal-

sided, rarely a right triangle, often with curved sides. Internal sphere occupies a central position. Typically two rays that emerge are indistinctly curved at the base, then run straight as a ray toward the exterior. Among individual specimens it is distinctly visible that in their upper third (as measured from the sphere), rays have branches in the form of fine threads. These threads unite with the marginal border and thereby reinforce or bulge it out, conferring an inflation or convexity to the sides of the shell. The outer layer is spongy with fine cells apparently developed from a thin, latticed layer which is visible in partially etched specimens. The marginal border is thin, visible in transmitted light in specimens which have a loose, spongy layer. The terminal spine is short, subconical, acuminate.

**Dimensions (in  $\mu\text{m}$ ):** H 325–490; B 325–400; t 44–50; dis 37–40; dir 10–12; Ls 14–35; tm 3–8.

**Comparison:** *Latentidiota visenda*, n. sp. is distinguished from most species of the genus by the variably triangular outline of the exterior. The more concrete distinction of *L. visenda* from other Late Carboniferous species of this genus will be presented during a description of the latter in another paper.

**Distribution:** Upper Carboniferous, Gzhelian Stage, Southern Urals.

**Material:** Tens of specimens.

Genus *Ruzhencevisponus* Kozur 1980, emend. Nazarov and Ormiston 1983

*Ruzhencevisponus* KOZUR 1980, p. 237.

**Type species:** *Ruzhencevisponus uralicus* Kozur. Lower Permian, Kungurian?? Stage, Southern Urals, Bashkiria, Ai River, Alagazovo Village.

**Diagnosis:** Triangular or triangular-rounded Ruzhencevispongidae with internal triangle enclosing hollow sphere and basal parts of rays. Rays of internal framework diverging at angles of 120°, connecting internal and external shells and connecting directly with terminal spines. External shell latticed-porous, rarely partially platy, marginal border narrow, clearly expressed.

**Comparison:** The development of a small internal shell surrounding the internal sphere and the rounded-triangular external form of the skeleton distinguish this genus from *Latentidiota*, n. gen.

**Generic composition:** More than ten species. In this paper, several new species are described from the Early Permian of the Southern Urals and the Late Permian of North America.

**Distribution:** Permian of the Southern Urals and West Texas.

***Ruzhencevisponus cataphractus* Nazarov and Ormiston, n. sp.**  
Plate 3, figures 1–2

*Ruzhencevisponus*, n. sp. NAZAROV and ORMISTON 1983, p. 370, pl. 1, figs. 8–9.

**Derivation of name:** cataphractus—Greek, dressed in platy armour, coat of mail.

**Holotype:** GIN 4673/23, Lower Permian, Artinskian Stage, Aktastinian Substage, Southern Urals, Ural River, Don Village.



**Description:** Test rounded-triangular with inflated sides. Internal sphere occupies a central position. The internal triangle bordering it is developed of thin rods which are formed from the internal rays. It is fine-latticed, sometimes a kind of subplaty fabric. External shell of the test latticed-porous, with larger pores situated at the marginal border gradually diminishing in size toward the shell center, marginal border quite massive, clearly expressed. Terminal spines usually absent, hence vertices of the shell are rounded and at this position there is observed a narrow, oval opening (pl. 3, fig. 1).

**Dimensions (in  $\mu\text{m}$ ):** H 520–630; B 590–682; h 150–180; b 150–200; t 38–54; dis 35–44; dir 8–12; tm 12–14.

**Comparison:** *Ruzhencevispongos cataphractus* is distinguished from most species of the genus by the smooth, rounded outline of the shell and an absence of terminal spines in most specimens.

**Distribution:** Lower Permian, Artinskian Stage, Aktastinian Substage, Southern Urals.

**Material:** Tens of specimens.

***Ruzhencevispongos? plumatus* Nazarov and Ormiston, n. sp.**  
Plate 3, figures 4–5

**Derivation of name:** plumatus—Latin, feathered, plumed.

**Holotype:** GIN 4672/7, Lower Permian, Sakmarian Stage, Kandurov Suite, Southern Urals, Ural River, Don Village.

**Description:** Shell has the outline of an equilateral triangle. Internal sphere occupies a central position. The internal triangle that surrounds it is not clearly expressed. On both sides, the larger part of the shell test, especially in the center, consists of imperforate, platy fabric, whose outline is circular. The remaining part of the test is porous-latticed. Marginal border narrow, distinct, merging with the base of the terminal spines. Terminal spines small, rodlike, acuminate in distal part.

**Dimensions (in  $\mu\text{m}$ ):** H 318–350; B 418–465; h 90–124; b 120–140; t 40–45; dis 38–43; dir 8–10; Ls 45–50; tm 8–10.

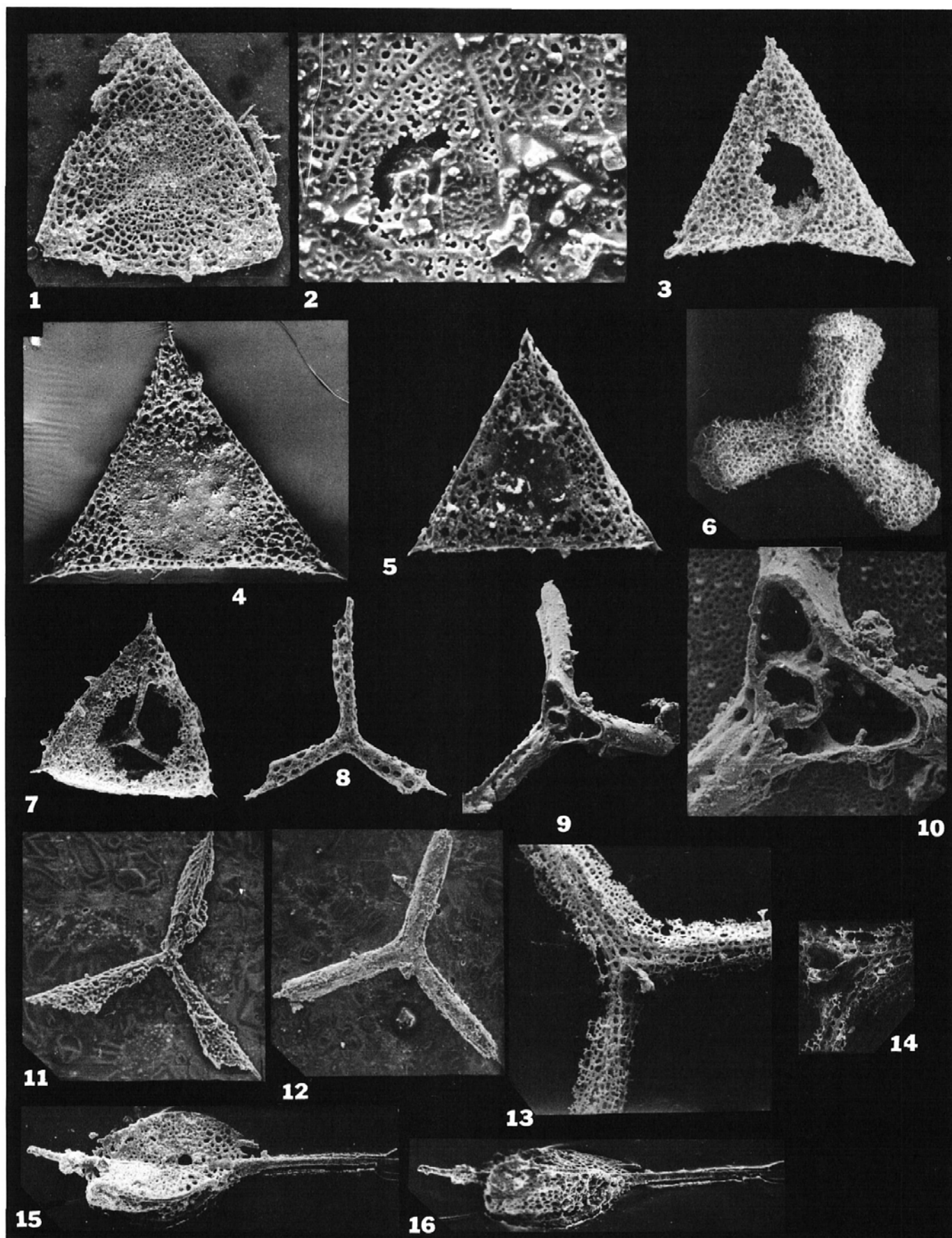
**Comparison:** From most species of this genus, *R.? plumatus* is distinguished by the development of platy skeletal fabric

# PLATE 3

- 1–2 *Ruzhencevispongos cataphractus* Nazarov and Ormiston, n. sp.  
Lower Permian, Artinskian Stage, Aktastinian Substage, Southern Urals, Ural River, Don Village. 1, paratype, GIN 4673/24, external view of porous-latticed shell,  $\times 70$ ; 2, paratype, GIN 4673/25, internal triangle in whose interior internal sphere is faintly visible,  $\times 300$ .
- 3 *Ruzhencevispongos girtyi* Nazarov and Ormiston, n. sp.  
Upper Permian, Guadalupian Stage, Lamar Limestone, West Texas. Holotype, USNM 257607,  $\times 163$ .
- 4–5 *Ruzhencevispongos? plumatus* Nazarov and Ormiston, n. sp.  
Lower Permian, Sakmarian Stage, Kandurov Suite, Southern Urals, Ural River, Don Village. Paratype, GIN 4472/10, external view of a specimen with platy skeletal fabric in the center which is, in effect, surrounded by latticed-porous fabric peripherally. 4,  $\times 125$ ; 5,  $\times 120$ .
- 6 *Latentifistula crux* Nazarov and Ormiston 1983  
Lower Permian, Asselian Stage, Southern Urals, Ural River, Nikol Village. Holotype, GIN 4488/92a, external view of spongy, small shell with arms rounded in distal part,  $\times 95$ .
- 7 *Latentidiota visenda* Nazarov and Ormiston, n. gen., n. sp.  
Upper Carboniferous, Gzhelian Stage, Southern Urals, Ural River, Don Village. Holotype, GIN 4488/50a, external outline and structure of internal framework,  $\times 100$ .

- 8 *Latentifistula densa* Nazarov and Ormiston, n. sp.  
Upper Permian, Guadalupian Stage, Lamar Limestone, West Texas. Holotype, USNM 257610,  $\times 140$ .
- 9–10 *Latentifistula valdeinepta* Nazarov and Ormiston, n. sp.  
Lower Permian, Sakmarian Stage, Kandurov Suite, Southern Urals, Sakmar River, Old Upper Black Creek. Paratype, GIN 4672/10, external view of platy shell with open internal cavity in which the entire internal sphere is visible. 9,  $\times 100$ , 10,  $\times 285$ .
- 11 *Latentifistula neotenica* Nazarov and Ormiston, n. sp.  
Lower Permian, Artinskian Stage, Aktastinian Substage, Southern Urals, Ural River, Don Village. Paratype, GIN 4673/22, external view,  $\times 80$ .
- 12–14 *Latentifistula triacanthophora* Nazarov and Ormiston 1983  
Lower Permian, Sakmarian Stage, Maloik Suite, Southern Urals, Ural River, Don Village. 12, paratype, GIN 4672/12, external view,  $\times 40$ ; 13, paratype, GIN 4672/13, structure of spongy fabric in central part of shell beneath which is developed an intercalated shell (not clearly visible),  $\times 95$ ; 14, paratype, GIN 4672/14, structure of rays with two shells, as is typical for this genus,  $\times 110$ .
- 15–16 *Raphidociclicus gemellus americanus* Nazarov and Ormiston, n. subsp.  
Upper Permian, Guadalupian Stage, Lamar Limestone, West Texas. 15, holotype, lateral view, USNM 249934,  $\times 100$ ; 16, lower view of same specimen,  $\times 100$ .





in the center of the shell and in having an external outline in the form of an equilateral triangle.

**Remarks:** The described species occupies a somewhat intermediate position between *Latentidiota* and *Ruzhencevispon-gus*. It is assigned with some doubt to the latter, since it has an indistinctly expressed internal triangle. However, *R. ? plu-matus* has the partial development of a porous-latticed fabric and a distinct marginal border—characteristic features for *Ruzhencevispon-gus*. At the same time, this species has a central area of imperforate, platy skeletal fabric. This kind of structure is present in Late Carboniferous *Latentidiota*. It is entirely possible that it is a new genus in the family Ruzhencevispon-gidae which can be separated with further study.

**Distribution:** Lower Permian, Sakmarian Stage, Southern Urals.

**Material:** About 150 specimens, possibly more.

*Ruzhencevispon-gus girtyi* Nazarov and Ormiston, n. sp.  
Plate 3, figure 3

**Derivation of name:** In honor of George Girty, pioneer student of West Texas Permian paleontology.

**Holotype:** USNM 257607, Upper Permian, Guadalupian Stage, Lamar Limestone, West Texas and New Mexico.

**Description:** Shell triangular, varying from equilateral to an isosceles triangle, with weakly inflated sides. An internal sphere occupies the central position. External shell cellular with diameter of cells 5–6  $\mu\text{m}$  near the periphery but distinctly smaller over the central triangle where the shell appears almost platy. A marginal border is not distinguishable. The three terminal spines are short and cylindrical in cross section.

**Dimensions (in  $\mu\text{m}$ ):** H 250–700; B 280–750; t 150–170; dt near margin 5–6; Ls 15–20.

**Comparison:** *Ruzhencevispon-gus girtyi* differs from the majority of Permian species in lacking a marginal border set off by contrasting cellular fabric. The terminal spines are short, but their presence distinguishes *R. girtyi* from *R. cataphractus*, n. sp. from the Artinskian Stage of the Southern Urals.

**Distribution:** Upper Permian, Guadalupian Stage, Hegler and Lamar limestones, Bell Canyon Formation, West Texas and New Mexico.

**Material:** Nine specimens.

Family LATENTIFISTULIDAE Nazarov and Ormiston 1983

**Diagnosis:** Latentifistulidea with internal framework in the form of hollow sphere with three to five, rarely more, hollow rays. Rays emerge from sphere at various angles, thereby determining similarly varied symmetry of external shell outline. External skeleton consisting of three, four, five or more subcylindrical rays (lobes) radiating from central area.

**Comparison:** From the two other families, Ruzhencevispon-gidae and Tormentidae, this family is distinguished by its rayed (lobate) form of the outer skeleton. Some *Latentidiota* from the Late Carboniferous have outlines close to that of

some *Latentifistula*. However, *Latentidiota* has arms (rays or false rays) of depressed ellipsoidal cross sections whereas those of *Latentifistula* are rounded.

**Composition of family:** *Latentifistula* Nazarov and Ormiston 1983; *Latentibifistula* Nazarov and Ormiston 1983; *Quadrirremis*, n. gen.; *Quinqueremis* Nazarov and Ormiston 1983. Two undescribed genera are also present in the Ural material, and are provisionally included in this family. The first genus is characterized by a large (up to 120  $\mu\text{m}$ ), porous, internal sphere and long (up to 2.5 mm) two-layered rays. The second has long, platy and, apparently, nonporous rays of a sort not typical for this family.

**Distribution:** Late Paleozoic (Carboniferous to Permian) of the Urals, North America and eastern Soviet Union.

Genus *Latentifistula* Nazarov and Ormiston 1983

*Paronaella* ORMISTON and LANE 1976, pp. 168–169.

**Type species:** *Latentifistula crux* Nazarov and Ormiston 1983. Upper Carboniferous, Gzhelian Stage, Southern Urals, Ural River, Nikol Village.

**Diagnosis:** Latentifistulidae having internal framework of nonporous sphere with three hollow, short rays. Rays usually radiating from sphere at angles of 120°, producing same cruciform arrangement of skeleton. Internal framework enclosed by spongy-porous or platy shell. Terminal spines connected by thin rods to internal hollow rays, well expressed in one species and lacking in others.

**Comparison:** From all other genera of the family, with the exception of *Latentibifistula*, this genus is distinguished by the cruciform skeletal shape consisting only of three rays. From *Latentibifistula* which has the same external outline, it is distinguished by the single-layered shell of the rays, whereas *Latentibifistula* has a second internal shell of latticed fabric developed in each ray.

**Generic composition:** There are about 20 species. In the present work several new species are described from Carboniferous to Permian strata of the Southern Urals and North America.

**Remarks:** Ormiston (Ormiston and Lane 1976, p. 169) noted that three-rayed polycystines from the Carboniferous Sycamore Limestone of Oklahoma were similar in external form to some species of *Paronaella* Pessagno (Pessagno 1971) from Cretaceous strata of California, but differed in their larger dimensions and structure of the spongy layer. Originally, the internal framework of the Mississippian forms was not observed because of infill of the internal cavity of most shells by opaline material. Therefore, relying on external form, they were provisionally assigned to *Paronaella*. Study of additional material has shown that these triradial forms from the Sycamore Limestone have an internal framework in the form of a hollow sphere from which three rays radiate. This permits them to be regarded as the earliest presently known representatives of *Latentifistula*.

**Distribution:** Lower Carboniferous of North America, Upper Carboniferous of the Southern Urals, Lower Permian of the Southern Urals and West Texas.

***Latentifistula crux* Nazarov and Ormiston 1983**

Plate 3, figure 6

*Latentifistula crux* NAZAROV and ORMISTON 1983, p. 372, pl. 1, fig. 1.**Holotype:** GIN 4488/92a, Lower Permian, lower part of Asselian Stage, Southern Urals, Ural River, Nikol Village.**Comparison:** From most species of the genus known in the Carboniferous strata of the Southern Urals, the described species is distinguished by the differentiated spongy layer and weak development of terminal spines. From lower Permian species, *L. crux* is distinguished by smaller dimensions, a smoother, spongy layer, and short, thick rays.**Distribution:** Lower Permian, Asselian Stage, Southern Urals.**Material:** Tens of specimens.***Latentifistula valdeinepta* Nazarov and Ormiston, n. sp.**

Plate 3, figures 9–10

**Derivation of name:** valde—Latin, very; ineptus—Latin, ridiculous.**Holotype:** GIN 4672/9, Lower Permian, Sakmarian Stage, Kandurov Suite, Southern Urals, Sakmar River, Verkhnyaya Chernaya Rechka Village.**Description:** Shell small, platy with rounded arms of a single form. Internal framework represented by a nonporous sphere with three hollow rays. However, the rays do not extend within the external arms as they do in most species of the genus. They are, instead, practically perpendicular to those arms and merge with the platy wall (pl. 3, figs. 9–10). The internal rays have a rounded opening near the sphere. External arms densely platy, with a depression continuing almost their entire length. In this depression are six or seven rounded pores. The distal part of the arms is rounded, lacking a terminal spine.**Dimensions (in  $\mu\text{m}$ ):** LAr 190–205; LBr 196–215; LCr 210–236; Dr 80–94; dis 42–45; dir 18–22; dp (ir) 8–10; dp (Ar, Br, Cr) 4–6.**Comparison:** This is a distinctive species clearly distinguished from all others of the genus by the orientation of the internal rays of the framework. In addition, the linear arrangement of the pores in a narrow depression on the outer arms is characteristic, and unknown in other representatives of the genus.**Distribution:** Lower Permian, upper part of Sakmarian Stage, Southern Urals.**Material:** Seven specimens.***Latentifistula neotenica* Nazarov and Ormiston, n. sp.**

Plate 3, figure 11; text-figure 8

**Derivation of name:** neotenicus—Latin, new form.**Holotype:** GIN 4673/21, Lower Permian, Artinskian Stage, Aktastinian Substage, Southern Urals, Ural River, Don Village.**Description:** Shell small, platy-porous with small arms of different forms. Internal framework represented by an imperforate sphere whose wall almost merges with the platy

fabric of the external arms. As a consequence, it is indistinctly expressed. Internal rays fine, also merging with the platy fabric of the external arms and extending for their entire length, passing into the terminal spine. The external arms have different forms. One of them (Ar, text-figs. 5E, 8) is subtriangular, gradually expanding from the center to its distal part where it is sharply constricted; and as a result, the termination of the arm is acuminate. The two other arms (Br, Cr, text-fig. 8) gradually expand from the center to the periphery and have their greatest diameter in the distal part. Skeletal fabric of the arms is platy, nonporous centrally but porous in the proximal and distal areas. Terminal spines short, rodlike; they are always developed on arm Ar and may be absent either on arms Br or Cr (text-figs. 5E, 8).

**Dimensions (in  $\mu\text{m}$ ):** LAr 325–360; LBr 310–345; LCr 310–354; Dr min. 25, max. 100; dis 40; dir 10; Ls 20–60; dp 4–13.**Comparison:** *Latentifistula neotenica* is distinguished from most species of the genus by the structure of the arms, which have different forms, and the merging of the wall of the internal sphere with the platy fabric of the external arm.**Distribution:** Lower Permian, Sakmarian and Artinskian stages, Southern Urals; Leonardian Stage of West Texas.**Material:** Approximately 20 specimens.***Latentifistula texana* Nazarov and Ormiston, n. sp.**

Plate 4, figure 2

**Derivation of name:** From the state name, Texas.**Holotype:** USNM 257608, Upper Permian, Guadalupian Stage, Hegler Limestone, West Texas.**Description:** A *Latentifistula* having one arm with a blunt terminus, two other arms less blunt, all diverging at 120°. Shell wall platy-porous and quite thick showing some regularity of the arrangement of pores in a radial pattern. Terminal spines are not preserved in the available material. All arms expanded terminally. The one arm which is blunter than the others also expands more rapidly at its terminus and thus is somewhat club-shaped.**Dimensions (in  $\mu\text{m}$ ):** LAr 245–290; LBr 280–320; LCr 280–320; H 420–475; Dr min. 70, max. 150; dp 8–15.**Comparison:** This species is distinguished from the somewhat similar *L. crux* from the Lower Permian Asselian Stage of the Southern Urals in having less compact arms and less dense spongy fabric and in lacking even, short terminal spines.**Distribution:** Hegler Limestone, Upper Permian, Guadalupian Stage, West Texas.**Material:** Four specimens.***Latentifistula patagilateriala* Nazarov and Ormiston, n. sp.**

Plate 4, figure 1

**Derivation of name:** patagium plus lateralis—Latin, in allusion to development of lateral patagial tissue.**Holotype:** USNM 257609, Lower Permian, Leonardian Stage, Bone Springs Limestone, West Texas.**Description:** Triradiate shell small, spongy, with rays of the



same size and shape. Internal sphere nonporous and giving rise to three slender rays which persist as thin rods sometimes merging with spongy fabric of the distal part of the arms but rarely continuing as a fine, terminal spine external to the ray. A thick, spongy cover is developed over the internal skeleton. The rays characteristically expand slightly from the point of junction and have a lanceolate terminus. Spongy layer fairly coarse in middle of arm becoming fine laterally and sometimes forming a patagial wedge that is thinner than the thickness of the rays. Spongy fabric is partly organized pores 10–15  $\mu\text{m}$  in diameter. Wall layer quite thick.

*Dimensions (in  $\mu\text{m}$ ):* H 400–520; Dr 100–120; LAr 190–310; LBr 220–320; LCr 220–320; dp 10–15; dis 40–45.

*Comparison:* *Latentifistula patagilaterala* is most similar to *L. crux* from the Lower Permian of the Southern Urals. It is distinguished from that species by its larger dimensions, more lanceolate arm terminus and the tendency to develop a lateral patagial wedge.

*Distribution:* Lower Permian, Leonardian Stage, Bone Springs Formation, Highway 180, Culberson County, Texas.

*Material:* More than 50 specimens.

*Latentifistula densa* Nazarov and Ormiston, n. sp.  
Plate 3, figure 8

*Derivation of name:* densa—Latin, dense, an allusion to the solidity of much of the wall.

*Holotype:* USNM 257610, Upper Permian, Guadalupian, Lamar Limestone, West Texas and New Mexico.

*Description:* Shell small, solid, with relatively few pores. Having short rays of unequal form, each arm forming 120° angle with adjacent ones, one arm distinctly longer; a terminal spine developed from one edge of each arm is the continuation of the internal rays which are appressed to the outer wall. Internal shell a nonporous sphere which almost touches the external wall on all sides. Three internal rays are thin. Two of the external arms expand progressively from point of junction and have larger diameter at their ends than the third arm, which is the longer one. A few, relatively large, oval pores penetrate the outer shell. These are arrayed in a pair of rows on each surface of each arm and increase in size distally. A few small pores are present on the small central disk.

*Dimensions (in  $\mu\text{m}$ ):* H 220; Dr 22–33; LAr 150; LBr 168; LCr 170; dp 2–9, Ls 30–35.

*Comparison:* *Latentifistula densa* most closely resembles *Latentifistula neontenica*, n. sp. from the Sakmarian and Artinskian of the Southern Urals and the Leonardian of Texas. *Latentifistula densa* is distinguished by its more solid outer shell with fewer large pores and smaller overall dimensions.

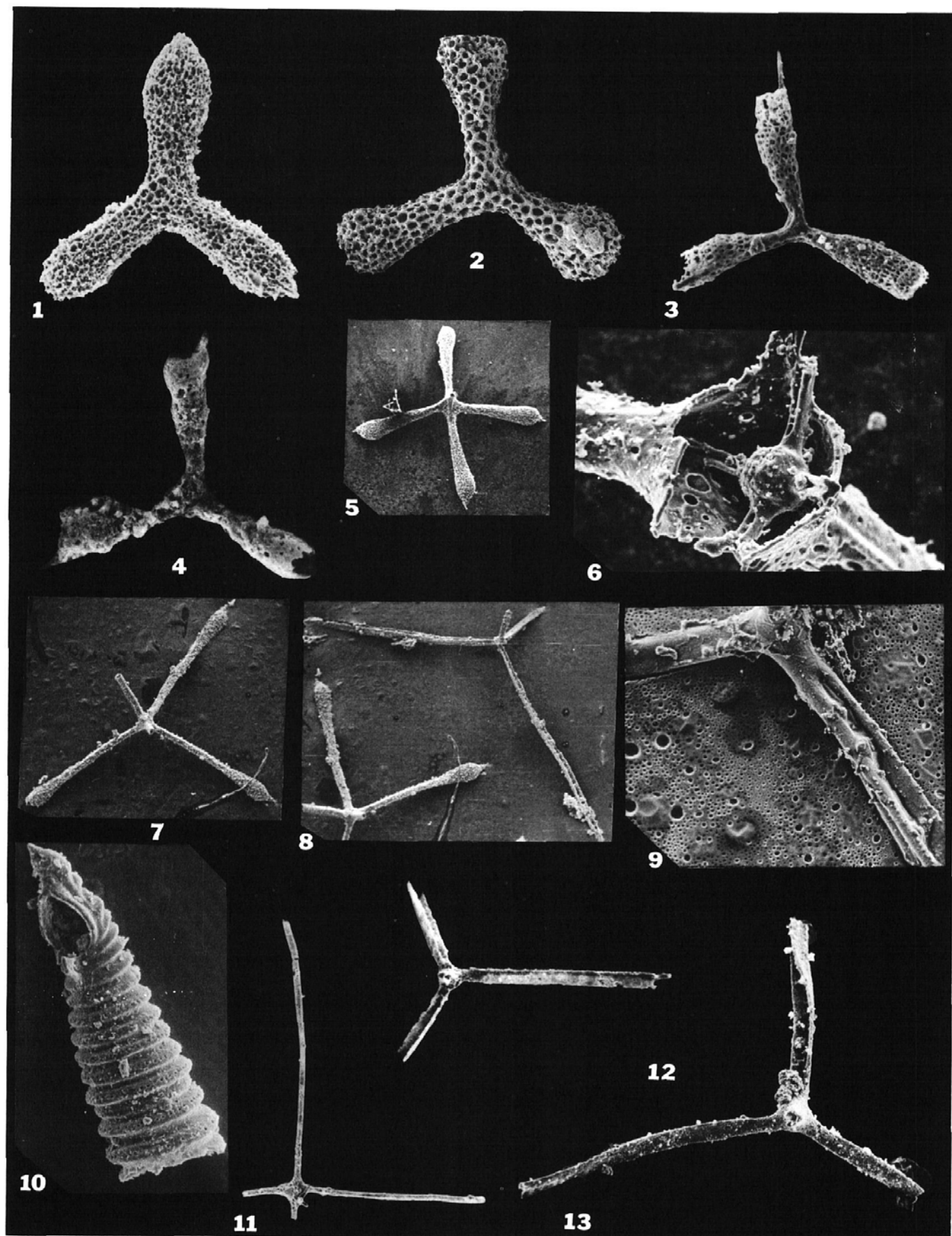
*Distribution:* Upper Permian, Guadalupian Stage, Lamar Limestone, West Texas and New Mexico.

*Material:* Three specimens.

#### PLATE 4

- 1 *Latentifistula patagilaterala* Nazarov and Ormiston, n. sp.  
Lower Permian, Leonardian Stage, Bone Springs Formation, West Texas. Holotype, USNM 257609,  $\times 100$ .
- 2 *Latentifistula texana* Nazarov and Ormiston, n. sp.  
Upper Permian, Guadalupian Stage, Hegler Limestone, West Texas. Holotype, USNM 257608,  $\times 125$ .
- 3–4 *Latentifistula* sp.  
3, Lower Permian, Leonardian Stage, Bone Springs Formation, West Texas,  $\times 120$ ; 4, Lower Permian, Artinskian Stage, Baigendzhinskian Substage, Southern Urals,  $\times 240$ .
- 5–7 *Quinqueremis arundinea* Nazarov and Ormiston 1983  
Lower Permian, Artinskian Stage, Aktastinian Substage, Southern Urals, Bashkiria, Little Suren River. 5–7, external outline of specimens with arms broken off; 7, paratype, GIN 4673/27,  $\times 20$ ; 5, paratype, GIN 4673/28,  $\times 23$ ; 6, paratype, GIN 4673/29, structure of internal cavity, with internal sphere and fragments of rays visible,  $\times 250$ .
- 8–9 *Quadriremis gliptoacus* Nazarov and Ormiston, n. gen., n. sp.  
Lower Permian, Artinskian Stage, Aktastinian Substage, Southern Urals, Ural River, Don Village. 8, paratype, GIN 4673/31 (upper right), external outline of a form with two complete and two broken-off arms,  $\times 20$ ; 9, structure of central part of one arm with well-preserved furrow base,  $\times 250$ .
- 10 *Arrectoalatus cernuus* Nazarov and Ormiston, n. gen., n. sp.  
Upper Carboniferous, Gzhelian Stage, Southern Urals, Ural River, Nikol Village. Holotype, GIN 4488/29a, external view of a specimen with multiple porous segments and a broken two-lobed wing,  $\times 225$ .
- 11 *Quinqueremis robusta* Nazarov and Ormiston, n. sp.  
Lower Permian, Leonardian Stage, Bone Springs Formation, West Texas. Holotype, USNM 257612, obverse view showing four arms, the fifth being normal to this plane,  $\times 53$ .
- 12 *Quadriremis* sp.  
Upper Permian, Guadalupian Stage, Lamar Limestone, West Texas, showing furrowed arms,  $\times 110$ .
- 13 *Quadriremis minima* Nazarov and Ormiston, n. sp.  
Lower Permian, Leonardian Stage, Bone Springs Formation, West Texas. Holotype, USNM 257611, showing arms furrowed only proximally,  $\times 160$ .





Genus *Latentifistula* Nazarov and Ormiston 1983

*Type species: Latentifistula triacanthophora* Nazarov and Ormiston 1983. Lower Permian, Sakmarian Stage, Maloik Suite, Southern Urals, Ural River, Don Village.

*Diagnosis:* Latentifistulidae with internal framework forming an imperforate sphere with three hollow rays, radiating at angles of about 120°. Internal framework enclosed in two-layered, spongy or porous skeletal fabric.

*Comparison:* From other genera of the family, the subject genus is distinguished by the cruciform arrangement of the skeleton consisting of three rays. From *Latentifistula* it is distinguished by its two-layered shell.

*Generic composition:* Approximately 10 species. In the present paper the type species alone is described.

*Distribution:* Lower Permian, Sakmarian and basal part of Artinskian stages, Southern Urals.

*Latentifistula triacanthophora* Nazarov and Ormiston 1983  
Plate 3, figures 12–14

*Latentifistula triacanthophora* NAZAROV and ORMISTON 1983,  
p. 374, pl. 1, figs. 4–5.

*Holotype:* GIN 4672/11, Lower Permian, Sakmarian Stage, Maloik Suite, Southern Urals, Ural River, Don Village.

*Description:* Shell spongy with long arms of one form. Internal framework has the typical structure for the genus. Internal rays hollow, sometimes with small pores in the sphere. Toward the periphery they gradually become thin and pass into fine rods which join the base of the terminal spines. Internal layer of skeletal fabric on each arm is rounded, porous. The outer, spongy layer is smooth, represented by irregularly interwoven fine fibers. Many specimens have narrow depressions along the whole length of the arms in which the spongy layer is finer. In the distal part, the arms are tapered or bluntly rounded. Terminal spines are small, conical, absent from some specimens.

*Dimensions (in  $\mu\text{m}$ ):* LAr, LBr, LCr 760–1267; Dr 75–125; dr 45–95; dis 35–45; dir 10–14; Ls 35–64.

*Comparison:* From other species of this genus *L. triacanthophora* differs in the development of narrow depressions on the arms as a result of which their cross sections resemble that of a gear wheel, and also by the uniformity of the subcylindrical arms.

*Distribution:* Lower Permian, upper part of the Sakmarian Stage, Southern Urals.

*Material:* More than 50 specimens.

*Quadriremis* Nazarov and Ormiston, n. gen.

*Derivation of name:* quadriremis—Latin, four-oared.

*Type species: Quadriremis gliptoacus*, n. sp. Lower Permian, Artinskian Stage, Aktastinian Substage, Southern Urals.

*Diagnosis:* Latentifistulidae with internal framework forming a nonporous sphere with four hollow rays. Three rays usually emerging from sphere at 120° with fourth ray perpendicular to that grouping. Internal framework enclosed in platy, platy-

lattice or, rarely, a spongy shell. Terminal spines connected with rays of internal framework by thin rods.

*Comparison:* This genus is distinguished from other genera of the family Latentifistulidae by the development of four arms and also by the dominance of species with platy-porous skeletal fabric in all arms.

*Remarks:* Individual *Quadriremis* are encountered in Late Carboniferous strata. They have short arms with a thick spongy layer. They are not known at the present time from the Asselian or from the lower part of the Sakmarian Stage of the Southern Urals, but are quite diverse and numerous in the Artinskian. Spongy forms are encountered extremely rarely, whereas forms with long, platy-porous arms are dominant.

*Generic composition:* There are probably about 10 species. In this paper the type species and one from the West Texas Permian are described.

*Distribution:* Late Carboniferous (rare), Southern Urals; Permian of Southern Urals, West Texas, and Nevada.

*Quadriremis gliptoacus* Nazarov and Ormiston, n. sp.  
Plate 4, figures 8–9; text-figures 9a–b

*Derivation of name:* glipt—Greek, furrowed; acus—Latin, spine.

*Holotype:* GIN 4673/30, Lower Permian, Artinskian Stage, Aktastinian Substage, Southern Urals, Ural River, Don Village.

*Description:* *Quadriremis* with long, platy-porous arms. Internal framework represented by nonporous sphere whose wall practically merges with the platy fabric that joins the base of the outer arm. At this location the central part of the shell is more inflated. The rays emanating from the sphere persist to the terminal spines in the form of fine rods. External arm rounded, imperforate in the basal part for a distance of 30 to 40  $\mu\text{m}$ . Beyond this, arms are partly open having a semicircular cross section. For up to half their length, the arms mostly lack pores. The remaining part of the arm is porous, and the diameter of the pores increases toward the terminal spine where these pores are sometimes arrayed in two or three rows. Terminal spines conical, acuminate in the distal part.

*Dimensions (in  $\mu\text{m}$ ):* LAr, LBr, LCr, LDr 840–2135; Dr min. 35, max. 40–65; dis 45–50; dir max. 16, min. 7–11; Ls 30–74; dp 4–12.

*Comparison:* From most species of the genus, *Q. gliptoacus* differs in the partly open form of the arms and in the presence of a small number of pores on each arm.

*Distribution:* Lower Permian, Artinskian Stage of the Southern Urals.

*Material:* Tens of specimens.

*Quadriremis minima* Nazarov and Ormiston, n. sp.  
Plate 4, figure 13

*Derivation of name:* minimus—Latin, least.

*Holotype:* USNM 257611, Lower Permian, Leonardian Stage, Bone Springs Limestone, West Texas.

**Description:** A *Quadriremis* having slender, elongate arms which at their junction form a slightly inflated boss. Internal sphere nonporous, touching the outer wall. Internal rays slender, not seen to form terminal spines. Proximal third of outer shell platy, nonporous; distally shell becomes porous with up to three rows of pores on each arm. Proximal part of arms with a deep furrow, distal part cylindrical.

**Dimensions (in  $\mu\text{m}$ ):** LAr, LBr, LCr, LDr up to 400; Dr 30–42; dis 30, dir 7–10.

**Comparison:** *Quadriremis minima*, n. sp. differs from the type species, *Q. gliptocacus*, from the Artinskian of the Southern Urals, in its very small size and in having the proximal part of the arms furrowed.

**Distribution:** Lower Permian, Leonardian Stage, Bone Springs Limestone, West Texas.

**Material:** Four specimens.

Genus *Quinqueremis* Nazarov and Ormiston 1983

**Type species:** *Quinqueremis arundinea* Nazarov and Ormiston 1983 (p. 375, pl. 1, figs. 6–7). Lower Permian, Artinskian Stage, Aktastinian Substage, Southern Urals, Little Suren River.

**Diagnosis:** Latentifistulidae having internal framework in the form of a nonporous sphere with five hollow rays. Four rays usually radiating from the sphere at angles of 90°, the fifth perpendicular to them. Internal frame enclosed primarily in spongy shell. External form of skeleton—five subcylindrical arms radiating from a rounded central area.

**Comparison:** From other genera of the family, *Quinqueremis* differs in the five-armed skeletal form.

**Generic composition:** There are several species. In the present paper the type species and a Permian species from Texas are described.

**Remarks:** The first representatives of this genus were known from the Gzhelian Stage of the Upper Carboniferous. They are not abundant and, as a rule, are poorly preserved. This prevents a clarification of their structural peculiarities. Also, individual specimens were encountered in the lower part of the Asselian and Sakmarian stages of the Southern Urals. Only at the base of the Artinskian does *Quinqueremis* become more abundant and varied. However, they were not found at the top of the Baigendzhinian Substage.

**Distribution:** Upper Carboniferous (rare) to Lower Permian of the Southern Urals, Upper Permian of West Texas.

*Quinqueremis arundinea* Nazarov and Ormiston 1983  
Plate 4, figures 5–7

*Quinqueremis arundinea* NAZAROV and ORMISTON 1983, p. 375, pl. 1, figs. 6–7.

**Holotype:** GIN 4673/26, Lower Permian, Artinskian Stage, Aktastinian Substage, Southern Urals, Little Suren River (Bashkiria).

**Description:** *Quinqueremis* with long, spongy arms and short terminal spines. Internal sphere situated at some distance from the shell which unites with the base of the external arm.

Hollow rays emanating from the sphere are half open in their basal part or appear cut by a deep furrow. Gradually they transform to a rodlike beam which unites with the base of the terminal spine. External arms differentiated in the basal part, spongy, more rarely platy. In their central area, the arms gradually expand and their greatest diameter is observed in the distal part. Here the arms are strongly inflated (swollen) or inflated for only half of the arm, therefore, they have the form of lobes. Terminal spines conical, sometimes enclosed in a spongy mass. The skeletal fabric of all arms is represented by irregularly interwoven fine fibers.

**Dimensions (in  $\mu\text{m}$ ):** LAr, LBr, LCr, LDr, LEr 760–1408; Dr min. 50–60, max. 180; dis 45–55; dir max. 24, min. 8–10; Ls 14–55.

**Comparison:** From other species of the genus, *Q. arundinea* is distinguished by the similar structure and dimensions of all rays and the clear expression of terminal spines.

**Distribution:** Lower Permian, Artinskian Stage, Aktastinian Substage of the Southern Urals.

**Material:** More than 100 specimens, almost all with partially broken-off arms.

*Quinqueremis robusta* Nazarov and Ormiston, n. sp.  
Plate 4, figure 11

**Derivation of name:** robusta—Latin, in allusion to robust central disk.

**Holotype:** USNM 257612, Lower Permian, Leonardian Stage, Bone Springs Limestone, West Texas.

**Description:** Shell with arms arrayed so that four intersect at 90° in one plane and the fifth is normal to that plane. Central disc flattened on opposite side of fifth spine and inflated around base of that spine. Arms elongate, slender, platy and without pores in proximal part. Internal sphere at some distance from wall of central disc, slightly eccentrically situated, rays from central sphere very fine, eccentric and adhering to one side of wall of outer shell. Arms elongate and incompletely preserved. Beyond 200  $\mu\text{m}$  from the central disc, arms bear minute pores in a single row. Arms cylindrical proximally but appear polygonal in distal cross section.

**Dimensions (in  $\mu\text{m}$ ):** LAr, LBr, LCr, LDr, LEr 340–500+; Dr 25–30; dr 2; dis 40–45; dp to 4, diameter central disc 85.

**Comparison:** *Quinqueremis arundinea* from the Artinskian of the Southern Urals is easily distinguished from *Q. robusta*, n. sp. by its distally expanding arms and terminal spines.

**Distribution:** Lower Permian, Leonardian Stage, Bone Springs Limestone, West Texas.

**Material:** Six specimens.

Family *Tormentidae* Nazarov and Ormiston 1983

**Diagnosis:** Latentifistulidea having varied external form—discoidal, lensoid, triangular, pyramidal, though skeleton is strongly inflated. Internal framework usually represented by hollow sphere with three or four hollow rays enclosed in solid or differentiated spongy fabric.

**Comparison:** In the *Tormentidae*, the armed (cruciform)

skeleton, typical of the Latentifistulidae, is characteristically absent. The dominant skeletal form for the Ruzhencevispongidae is triangular. The Tormentidae with the same outline are distinguished by their greater inflation, differentiated spongy fabric of certain genera and the absence of a marginal border, such as frames the external skeleton of Ruzhencevispongidae.

**Composition of the family:** Four genera are presently known: *Tormentum* Nazarov and Ormiston 1983; *Rectotormentum*, n. gen.; *Tetratormentum*, n. gen.; and *Octatormentum*, n. gen. It is probable that the family has more representatives, since many associations of Radiolaria in the Late Paleozoic have not yet been studied in any detail.

**Distribution:** Late Paleozoic (Carboniferous to Permian), Urals, North America and eastern Soviet Union.

Genus *Tormentum* Nazarov and Ormiston 1983

*Spongotropus?* ORMISTON and LANE 1976, p. 168.

Type species: *Tormentum protei* Nazarov and Ormiston 1983

(p. 376, pl. 1, fig. 3). Upper Carboniferous, Gzhelian Stage, Southern Urals, Ural River.

**Diagnosis:** Subtriangular, oval, lensoid Tormentidae with a three-rayed internal frame that is partially or completely enclosed in a thick, sometimes weakly differentiated, spongy layer. External terminal spines connected with rays of the internal frame are developed in one species and absent in others.

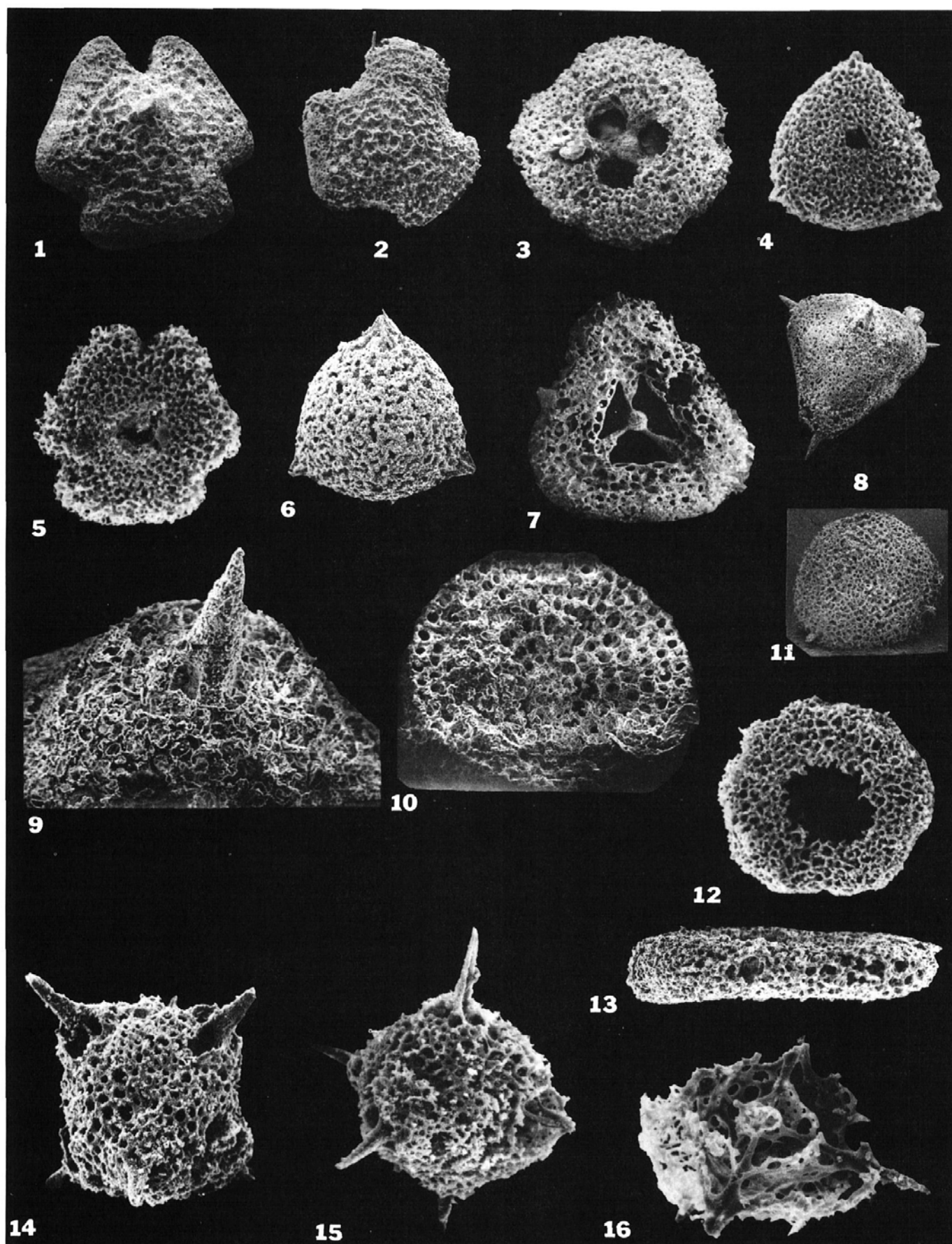
**Comparison:** This genus differs from *Tetratormentum*, n. gen. in having a smaller number of rays emanating from the internal sphere, which in *Tetratormentum* number four. Species of *Rectotormentum*, n. gen. have an outline analogous to that of *Tormentum*, but the former has a differentiated spongy layer, and between the internal sphere and the outer surface of the test there are several intermediate shells (text-fig. 4L).

**Generic composition:** The exact number of species which may belong to this genus is unknown. By preliminary count there are no more than 20. In the present paper, several species

## PLATE 5

- 1-2 *Tormentum protei* Nazarov and Ormiston 1983  
Upper Carboniferous, Gzhelian Stage (bed 28), Southern Urals, Ural River, Nikol Village. Illustrating the most widely occurring outlines of this variable species; 1, holotype, GIN 4488/1a,  $\times 125$ ; 2, paratype, GIN 4488/1b,  $\times 100$ .
- 3 *Tormentum pervagatum* Nazarov and Ormiston, n. sp.  
Upper Carboniferous, Gzhelian Stage, Southern Urals, Ural River, Nikol Village. Paratype, GIN 4488/40a, external view of specimen with exposed internal sphere,  $\times 120$ .
- 4-5 *Tormentum delicatum* Nazarov and Ormiston, n. sp.  
Lower Permian, Leonardian Stage, Bone Springs Limestone, West Texas. 4, holotype, USNM 257613, triangular form,  $\times 140$ ; 5, clover-leaf shaped form,  $\times 130$ .
- 6 *Tormentum? inflatum* Nazarov and Ormiston, n. sp.  
Upper Permian, Guadalupian Stage, Hegler Limestone, West Texas. Holotype, USNM 257614, exterior view,  $\times 150$ .
- 7 *Tormentum circumfusum* Nazarov and Ormiston, n. sp.  
Lower Permian, Sakmarian Stage, Maloik Suite, Southern Urals, Ural River, Don Village. Paratype, GIN 4672/16, external view showing open central area,  $\times 95$ .
- 8-9 *Tetratormentum narthecium* Nazarov and Ormiston, n. gen., n. sp.  
Lower Permian, Artinskian Stage, Aktastinian Substage, Southern Urals, Ural River, Don Village. Paratype, GIN 4673/40; 8, external outline,  $\times 95$ ; 9, structure of spines and spongy layer,  $\times 450$ .
- 10-11 *Rectotormentum fornicatum* Nazarov and Ormiston, n. gen., n. sp.  
Lower Permian, Artinskian Stage, Aktastinian Substage, Southern Urals, Ural River, Don Village. 10, paratype, GIN 4673/37, structure of internal cavity with differentiated spongy fabric,  $\times 225$ ; 11, paratype, GIN 4673/36, external view of specimen with two small spines,  $\times 100$ .
- 12-13 *Tormentum sertulum* Nazarov and Ormiston, n. sp.  
Upper Permian, Guadalupian Stage, Hegler Limestone, West Texas. 12, holotype, USNM 249763, showing central cavity and scalloped outline,  $\times 110$ ; 13, lateral view to show thickness and spine bases on periphery,  $\times 179$ .
- 14-16 *Octatormentum cornelli* Nazarov and Ormiston, n. gen., n. sp.  
Lower Permian, Leonardian Stage, Bone Springs Limestone, West Texas. 14, oblique apical view showing bipyramidal shape,  $\times 200$ ; 15, lateral view showing two apical and four equatorial spines,  $\times 160$ ; 16, view showing shell interior and ovoid inner shell,  $\times 260$ .





are described from the Upper Paleozoic strata of the Southern Urals and West Texas.

**Distribution:** Lower to Upper Carboniferous of the Southern Urals, Severnaya Zemlya, Oklahoma, eastern Soviet Union; Lower Permian of Southern Urals and West Texas.

*Tormentum protei* Nazarov and Ormiston 1983

Plate 5, figures 1–2

*Tormentum protei* NAZAROV and ORMISTON 1983, p. 376, pl. 1, fig. 3.

**Holotype:** GIN 4488/1a, Upper Carboniferous, Gzhelian Stage, Southern Urals, Ural River, Nikol Village (pl. 5, fig. 1).

**Description:** Shell large, highly variable, external outline without terminal spines. Nonporous, quite thick-walled internal sphere, usually situated in the center. Hollow rays emanating from it at angles of approximately 120° to each other. Internal framework bordered by a fine, rodlike bolster which forms from the bent back edges of the rays at a distance of 25 to 35  $\mu\text{m}$  from the sphere. The form of the bolster is subtriangular with the apex directed at the expanded part of the shell (the base). Probably the internal cavity bordering the bolster was covered by fine latticed fabric which almost came in contact with the internal sphere. On the outer sides, the subtriangular bolster is encircled by a thick, spongy layer. It is not impossible that this layer was formed as a result of irregular interweaving and uniting of rodlike prolongations arising from the bolster and their further branches. In addition, on the rodlike, elongate, hollow rays are developed apophyses with spinules that also interweave with the branch prolongations arising from the subtriangular bolster. Thus, the internal sphere and basal part of the rays are surrounded by a fine, latticed fabric and a thick, spongy layer. This kind of structure is characteristic for almost all Late Carboniferous species of the genus. The external form of this species is distinguished by great variability. Specimens are encountered displaying star, pitcher-like, shieldlike, and other outlines. In all, there are 17 forms. But the internal structure and structures of the spongy layer are the same in all.

**Dimensions (in  $\mu\text{m}$ ):** H 260–345; B 250–345; h 75–100; b 75–100; dis 40–45; dir 20–35; t 170–210.

**Comparison:** The subject species differs from most species of the genus known from Carboniferous strata in the varied external form and absence of terminal spines. Terminal spines are also unknown in *T. pervagatum*, n. sp., but this species has partial absence of spongy fabric in the central area of the shell as a result of which it has a clearly visible central sphere.

**Distribution:** Upper Carboniferous, upper part of the Gzhelian Stage, Southern Urals.

**Material:** Hundreds of specimens.

*Tormentum pervagatum* Nazarov and Ormiston, n. sp.

Plate 5, figure 3

**Derivation of name:** pervagatus—Latin, widely distributed.

**Holotype:** GIN 4488/10, Upper Carboniferous, Gzhelian Stage, Southern Urals, Ural River, Nikol Village.

**Description:** Shell large, quite varied in external form, lacking

terminal spines and having an open central cavity. As in *T. protei*, hollow rays arise from the sphere at angles of 120°, and at a distance of 25–35  $\mu\text{m}$  along them there is a subtriangular bolster. A thick spongy layer develops from the bolster, which does not close the central part of the shell. This portion of the shell was probably occupied by thin, latticed fabric, which is not preserved in the fossil form. The external form is dominantly lensoid, subtriangular, sometimes star-shaped. Cells of the spongy layer are small.

**Dimensions (in  $\mu\text{m}$ ):** H 260–400; B 275–450; h 115–160; b 110–160; dis 40–47; dir min. 20–25, max. 35–50; t 150–180.

**Comparison:** *Tormentum pervagatum* is distinguished from almost all species of the genus by the absence of a spongy layer in the central portion of the shell. The spongy layer is absent in the center in *T. circumfusum*, n. sp., described below, but *T. pervagatum* has a more varied external form and a more platy, spongy layer than *T. circumfusum*.

**Distribution:** Upper Carboniferous, Gzhelian Stage, Southern Urals.

**Material:** Tens of specimens.

*Tormentum circumfusum* Nazarov and Ormiston, n. sp.

Plate 5, figure 7

*Tormentum* n. sp. NAZAROV and ORMISTON 1983, pl. 1, fig. 2.

**Derivation of name:** circumfundo—Latin, to pour around.

**Holotype:** GIN 4672/15, Lower Permian, Sakmarian Stage, Maloik Suite, Southern Urals, Ural River, Don Village.

**Description:** Shell rounded-triangular with open central cavity. Internal framework represented by a hollow sphere with rays arising at angles of about 120°. The rays are cylindrical in their basal part, thereafter they strongly expand, and in this part have several rounded openings. All rays join the subtriangular bolster, which is developed from the edges of their walls. A quite loose, spongy fabric from this bordering structure is developed, immediately adjacent to the bolster which is almost porous. From the distal part of the rays there also arise fine rods joining with the terminal spines. The spines are short and pyramidal in form. Their bases are encased in spongy masses of the external shell.

**Dimensions (in  $\mu\text{m}$ ):** H 380–405; B 375–415; h 150–160; b 145–160; dis 40; dir min. 15–20, max. 40–45; t 160–180; Ls 30–50.

**Comparison:** From *T. pervagatum*, which also lacks spongy fabric in the center of the shell, this species is distinguished by the less varied external outline of the skeleton. *Tormentum circumfusum* has a primarily triangular-rounded external form. In addition, the subject species shows many specimens having terminal spines that are absent in *T. pervagatum*.

**Distribution:** Lower Permian, upper part of the Sakmarian Stage, Southern Urals.

**Material:** More than 60 specimens.

*Tormentum delicatum* Nazarov and Ormiston, n. sp.

Plate 5, figures 4–5

**Derivation of name:** delicatus—Latin, luxurious, an allusion to the fine, spongy fabric.

**Holotype:** USNM 257613, Lower Permian, Leonardian Stage, Bone Springs Limestone, West Texas.

**Description:** A *Tormentum* bearing short terminal spines, shell-shaped, ranging from rounded-triangular to clover-leaf. Shell inflated. Internal sphere centrally situated. Terminal spines short, blunt and conical. Internal sphere porous. Spongy fabric consists of fine "cells." In the central area of the shell, the spongy fabric is distinctly thinner, and therefore often broken out into a circular pattern. A few specimens have the shell intact centrally.

**Dimensions (in  $\mu\text{m}$ ):** H 210–370; B 200–320; t 150–270; dp 4–6; Ls 15–20; dis 40–50.

**Comparison:** *Tormentum delicatum* is similar to *T. protei* from the Upper Carboniferous of the Urals, especially in the plasticity of the external form and dimensions. It differs from that taxon only in the presence of terminal spines and, possibly, in the marked central thinning of the spongy fabric.

**Distribution:** Lower Permian, Leonardian Stage, Bone Springs Limestone, West Texas.

**Material:** More than 30 specimens.

***Tormentum? inflatum*** Nazarov and Ormiston, n. sp.  
Plate 5, figure 6

**Derivation of name:** inflatus—Latin, swollen, inflated.

**Holotype:** USNM 257614, Upper Permian, Guadalupian Stage, Hegler and Lamar limestones, West Texas.

**Description:** Shell inflated, triangular, with ratio of thickness to height approximately 0.8. Short, blunt spines at the apices are distinctly three-bladed and from 20 to 25  $\mu\text{m}$  in length. Shell wall thick (up to 35  $\mu\text{m}$ ), consisting of dense, spongy layer on a thin, inner lattice network. Internally, thin rays connecting with the three apical spines are poorly preserved and not observed to connect with an inner sphere.

**Dimensions (in  $\mu\text{m}$ ):** H 170–245; t 140–200; Ls 20–25.

**Comparison:** *Spongotropus ruestae* Ormiston and Lane 1976 (p. 168, pl. 3, figs. 8–9) from the Mississippian of Oklahoma is also conceivably a *Tormentum* but lacks preserved internal structure. It resembles *T. inflatum*, n. sp. in its inflated, triangular shape but has longer apical spines.

**Distribution:** Upper Permian, Guadalupian Stage, Hegler and Lamar limestones, West Texas.

**Material:** Fourteen specimens.

***Tormentum sertulum*** Nazarov and Ormiston, n. sp.  
Plate 5, figures 12–13

**Derivation of name:** sertula—Latin, a wreath, an allusion to the shape of the shell.

**Holotype:** USNM 249763, Upper Permian, Guadalupian Stage, Hegler Limestone, West Texas.

**Description:** Shell large, discoidal, with an open central area probably possessing marginal spines as indicated by the presence of hollow indentations at the bases of the slight extensions of the margin. Shell shaped like a wreath with a scal-

loped margin. Shell consists of disorganized, spongy fabric. In cross section, the lateral edge is sharply rounded; the thickness of the shell is  $\frac{1}{4}$  its diameter. Central sphere and rays are not preserved in available specimens but are presumed to have existed.

**Dimensions (in  $\mu\text{m}$ ):** H 275–295; t 75–85; h 120–125; dp 8–17.

**Comparison:** *Tormentum sertulum* most closely resembles *T. delicatum*, n. sp. from the Bone Springs Limestone, from which it is distinguished by its larger central opening, the presence of marginal spines and proportionally greater shell thickness.

**Distribution:** Upper Permian, Guadalupian Stage, Lamar and Hegler limestones, West Texas.

**Material:** Forty-three specimens.

***Rectotormentum*** Nazarov and Ormiston, n. gen.  
Text-figure 4L

**Derivation of name:** rectus—Latin, correct, in good order; tormentum—Latin, missile stone.

**Type species:** *Rectotormentum fornicatum*, n. sp. Lower Permian, Artinskian Stage, Aktastinian Substage, Southern Urals.

**Diagnosis:** Tormentidae with a spongy outer layer and varied structure of the internal framework. Among them are developed several intercalated shells whose outlines duplicate the external outline. The shells are connected to one another by irregularly positioned beams and three, rarely more, rays arising from the internal framework. The structure of the internal framework is not adequately known. In one species it is represented by a nonporous sphere with rays emanating at angles of  $120^\circ$ ; among others, it gives the impression of the presence of a three-rayed spicule. Terminal spines developed in some species, but they also may be absent.

**Comparison:** In external outline, species of this genus are similar to those of *Tormentum*, but they differ in the development of intercalated shells. From *Tetratormentum*, the subject genus is distinguished by the number of rays of the internal framework, which is primarily three in *Rectotormentum*, but always four in *Tetratormentum*.

**Generic composition:** The exact number of species in this genus is unknown, since similar Tormentidae have not yet been studied in detail. In this paper, only the type species is described.

**Distribution:** Lower Permian of the Southern Urals.

***Rectotormentum fornicatum*** Nazarov and Ormiston, n. sp.  
Plate 5, figures 10–11

**Derivation of name:** fornicatus—Latin, arched, vaulted.

**Holotype:** GIN 4673/35, Lower Permian, Artinskian Stage, Aktastinian Substage, Southern Urals, Ural River, Don Village.

**Description:** Shell lensoid with three small spines. Five to eight intercalating shells between thin, spongy layer and in-

ternal framework. Internal framework sphere-shaped, with three fine rays. Sometimes the sphere is slightly separated from the first internal shell. All intercalated shells are united by rodlike crossbeams. A thin, spongy layer on the surface consists of disorganized, interwoven, thin skeletal fibers which form small cells. Terminal spines short, subconical, bluntly rounded in their distal part.

*Dimensions (in  $\mu\text{m}$ ):* Shell diameter 210–300 by 250–320, thickness of spongy layer 15–20; diameter of internal sphere 40; intercalated shells spaced at a distance of 20 to 25; length of terminal spines 60–75.

*Comparison:* It is difficult to conduct a comparison with still undescribed species. Judging from available material, species of this genus differ from one another in external outline and internal structure. Distinctive of the type species is the development of six to eight internal shells in combination with relatively long spines.

*Distribution:* Lower Permian, Artinskian Stage, Southern Urals.

*Material:* Tens of specimens.

*Tetratormentum* Nazarov and Ormiston, n. gen.

*Derivation of name:* tetra—Greek, four, combined with generic name *Tormentum*.

*Type species:* *Tetratormentum narthecium*, n. sp. Upper Carboniferous, Gzhelian Stage, Southern Urals, Ural River.

*Diagnosis:* Mainly pyramidal Tormentidae with four-rayed internal framework enclosed in quite thick spongy or platy shell. External terminal spines connected with rays of internal framework well developed in all species of the genus.

*Comparison:* From *Tormentum*, the subject genus is distinguished by the larger number (4) of rays of the internal framework, of which there are only three in *Tormentum*.

*Generic composition:* Four species are known from the Late Carboniferous (Gzhelian Stage), and the lower part of the Asselian Stage. The generic composition is probably more extensive, since *Tetratormentum* species are not yet described, except for that described below.

*Distribution:* Upper Carboniferous to Lower Permian of the Urals.

*Tetratormentum narthecium* Nazarov and Ormiston, n. sp.  
Plate 5, figures 8–9

*Derivation of name:* narthecium—Latin, small box.

*Holotype:* GIN 4488/44, Upper Carboniferous, Gzhelian Stage, Southern Urals, Ural River, Nikol Village.

*Description:* Large *Tetratormentum* which have an equant outline, three-sided pyramids with short, subconical terminal spines. Internal framework represented by a nonporous sphere somewhat shifted toward the base. Three hollow rays arise from it at angles of  $120^\circ$  from one another and a fourth perpendicular to the other three. In some specimens there is observed a small internal pyramid of latticed fabric in which the sphere is enclosed, as well as the proximal part of the

rays. External spongy layer thick, sometimes creating the impression that it is divided into several layers. Terminal spines conical; some forms have a shallow opening in the basal part (pl. 5, fig. 9).

In the subject genus the height of the pyramid, its basal width, the diameter of the internal sphere, diameter of the rays, length and diameter of the terminal spines are all measurable. As in *Tormentum* these parameters are assigned letter indices.

*Dimensions (in  $\mu\text{m}$ ):* H 175–250; B 175–265; h 110–115; b 110–120; dis 40; dir 16–20; Ls 40–67; ds 25–30.

*Comparison:* From the majority of species of the genus, *T. narthecium* is distinguished by the perfect pyramidal form and structure of the spines.

*Remarks:* In external form, measured specimens of the subject species from Permian strata are practically identical with the holotype from the Gzhelian Stage. However, these may represent another species or even genus, since in the Permian form there is observed a differentiated spongy layer with a development of several intercalated shells between the internal sphere and the outer spongy layer.

*Distribution:* Upper Carboniferous to Lower Permian of the Southern Urals.

*Material:* About 100 specimens.

*Octatormentum* Nazarov and Ormiston, n. gen.

*Derivation of name:* octa—Latin, eight combined with the genus *Tormentum*, alluding to eight-sided member of Tormentidae.

*Type species:* *Octatormentum cornelli*, n. sp.

*Diagnosis:* Tormentidae with three shells, innermost nonporous, outermost with bipyramidal outline, six major spines, four emerging at the corners of the equatorial plane, the other two at the apices of each pyramid. These external spines are continuations of the six internal rays. Outer shell spongy, but sometimes differentiated into a discrete cellular fabric.

*Remarks:* This genus is distinguished from *Tormentum* by its greater number of internal rays and three shells. From *Tetratormentum*, it differs in the greater number of rays as well as its bipyramidal form.

*Octatormentum cornelli* Nazarov and Ormiston, n. sp.  
Plate 5, figures 14–16

*Derivation of name:* In honor of Professor W. W. Cornell of the University of Texas at El Paso, student of Permian Radiolaria.

*Holotype:* USNM 249932, Lower Permian, Leonardian Stage, Bone Springs Limestone, West Texas.

*Description:* Large outer shell has the form of an unequal double pyramid with terminal spines emerging at the four equatorial corners and the two apices. This outer shell is a spongy fabric, but is usually differentiated into cells with pore rosettes of large pores developed at the points of emergence of the terminal spines. External spines are three-bladed. There



is considerable variability in the shape of the outer shell with the pyramidal faces sometimes inflated so that an irregular, subspherical form is produced. Internally there is a subspherical, nonporous inner shell from which six rays emerge. The junction of these rays cannot be seen within this sphere. This inner sphere is eccentrically situated within a second internal shell, this one porous and eccentric with respect to the outer bipyramid. The rays of the innermost shell are connected to the second shell and continue on to pass into the base of the main external spines. These rays are rodlike. The basal part of the external spines is coarsely three-bladed, but their distal part becomes faintly so or even conical. External spines of moderate and equal length.

**Dimensions (in  $\mu\text{m}$ ):** Maximum height of outer shell 300–420; maximum diameter of outer shell 180–340; maximum diameter of second shell 110–220; maximum diameter of inner shell 50; cells in outer shell 8–25; cells in second shell 5–20; length of outer spine 90; diameter at base 10.

**Comparison:** The bipyramidal outer form combined with the presence of three shells and six spines easily distinguishes this species from other presently known taxa. There are variants of this species which approach an irregularly spherical outer form. Their internal structure clearly shows they represent the same taxon.

**Distribution:** Lower Permian, Leonardian Stage, Bone Springs Limestone, West Texas.

**Material:** More than 20 specimens.

***Octatormentum babcockae* Nazarov and Ormiston, n. sp.**  
Plate 6, figures 1–2

**Derivation of name:** After Dr. Laurel C. Babcock, colleague and author of Lamar Limestone studies.

**Holotype:** USNM 249933, Upper Permian, Guadalupian Stage, Lamar Limestone, West Texas.

**Description:** Outer shell polyhedral to subspherical with six, rarely eight, rapidly tapering cylindrical spines which have rosettes of enlarged pores around their bases; shell platy, penetrated by sparse, small circular pores. Inner shell ellipsoidal, connected by cylindrical crossbeams to outer shell; these beams are continuous with major spines. The solid inner sphere seen in the type species is not preserved in available material of *O. babcockae*. Attached to the outer shell are preserved remnants of a thin, outer spongy layer which may have covered the outer shell originally.

**Dimensions (in  $\mu\text{m}$ ):** Dimensions of outer shell 175 by 180 to 180 by 200; diameter of inner shell 90 by 120 to 100 by 150; pore diameter of outer shell 5–9, pores in rosettes around spines 25; diameter of pores in inner shell 4–6; length of outer spines up to 60.

**Comparison:** *Octatormentum babcockae*, n. sp. closely resembles the type species, *O. cornelli*, n. sp., from the Bone Springs Limestone but differs in having a more subspherical outer shell, with a platy composition, smaller pores, slightly shorter spines, and smaller overall dimensions than *O. cornelli*.

**Distribution:** Upper Permian, Guadalupian Stage, Lamar Limestone, West Texas.

**Material:** Ten specimens.

Order COLLODARIA? Haeckel 1887  
Family OROSPHAERIDAE? Haeckel 1887  
Genus POLYENTACTINIA Foreman 1963

***Polyentactinia lautitia* Nazarov and Ormiston, n. sp.**  
Plate 2, figures 3–4

**Derivation of name:** *lautitia*—Latin, splendor, magnificence.

**Holotype:** GIN 4683/8, Lower Permian, Artinskian Stage, Baigendzhinian Substage, Southern Urals, Aktasti River, Aktyubinsk Region.

**Description:** Shell has the outline of an irregular polygon. Internal spicule with seven to ten rays arising from a short, median crossbar occupying a central position. Rays of the spicule merge directly with the main radial spines. In addition, each ray has three apophyses in its distal part which also merge with the supplementary spines or join with the wall. The bases of all spines are joined by fine ridges (pl. 2, fig. 3), hence the shell is divided into segments (polygonal areas) of different shapes. Each segment is crisscrossed by fine bars which form the latticed wall of the shell with the cells having a varied outline. Main spines are three-bladed with distinctly expressed blades. Secondary spines are lacking.

**Dimensions (in  $\mu\text{m}$ ):** Shell diameter 520–710; wall thickness 10–16; cell diameter 4–35; length of main spines up to 240.

**Comparison:** *Polyentactinia lautitia* differs from all Paleozoic species of the genus in the delicate open work of the shell, distinctly expressed crossbars joining with the bases of all spines and larger dimensions.

**Distribution:** Lower Permian, Artinskian Stage, Baigendzhinian Substage, Southern Urals.

**Material:** Tens of specimens.

***Polyentactinia centrata* Nazarov and Ormiston, n. sp.**  
Plate 2, figures 6–8

**Derivation of name:** An allusion to the central position of the internal spicule.

**Holotype:** USNM 249799, Lower Permian, Leonardian Stage, Bone Springs Limestone, West Texas.

**Description:** Shell an irregular polygon with centrally situated internal spicule which is bar-centered and apparently had 12 rays. These rays continue without expansion to unite with the bases of the external spines. External spines 8 to 12 in number and three-bladed. Numerous secondary spines are rodlike with occasional irregular apophyses. The bases of the main spines unite with surface ridges which partition the shell into polygonal faces. The fabric covering these faces appears lacy and consists of varied cell outlines, many triangular of varied sizes.

**Dimensions (in  $\mu\text{m}$ ):** Shell diameter 120–340, length of main spines up to 180, secondary spines to 25; pore diameter 2–11; diameter of main spines at base 12–15.

**Comparison:** The subject species differs from *P. lautitia* from the Artinskian Stage of the Southern Urals in the presence

of secondary spines and less finely cellular texture. From an undescribed species of *Polyentactinia* known in the Lamar Limestone, it differs in lacking regular transverse apophyses on the secondary spines.

*Distribution:* Lower Permian, Leonardian Stage, Bone Springs Limestone, West Texas.

*Material:* Ten specimens.

Order POLYCYSTINA? Ehrenburg 1838, emend. Riedel 1967  
Suborder ALBAILLELLARIA Deflandre 1953, emend. Holdsworth 1969

Family ALBAILLELLIDAE Deflandre 1953, emend. Holdsworth 1969

Genus *Albaillella* Deflandre 1952

*Type species:* *Albaillella paradoxa* Deflandre 1952 (p. 873, text-figs. 1-3, 5). Lower Carboniferous, Montagne Noire, France.

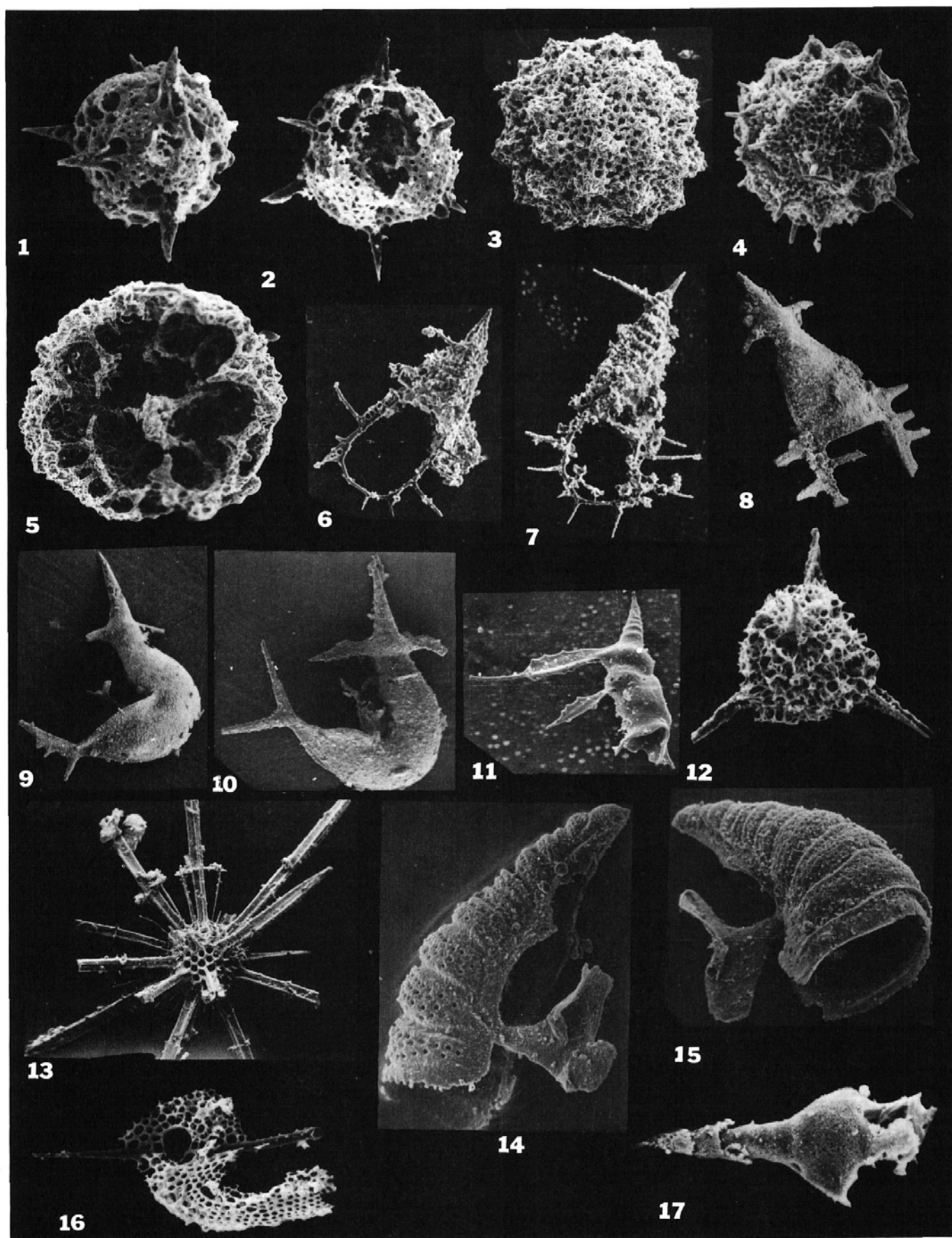
*Diagnosis:* The most complete description is that given by Holdsworth (1966, p. 321). This was supplemented by Ormiston (Ormiston and Lane 1976, p. 171). The diagnosis of Holdsworth modified by Ormiston can be augmented for Late Carboniferous and Permian *Albaillella* which have a continuation of trabeculae in the lateral wings, a segmented apical and central part of the shell and sometimes have perforations in the individual segments.

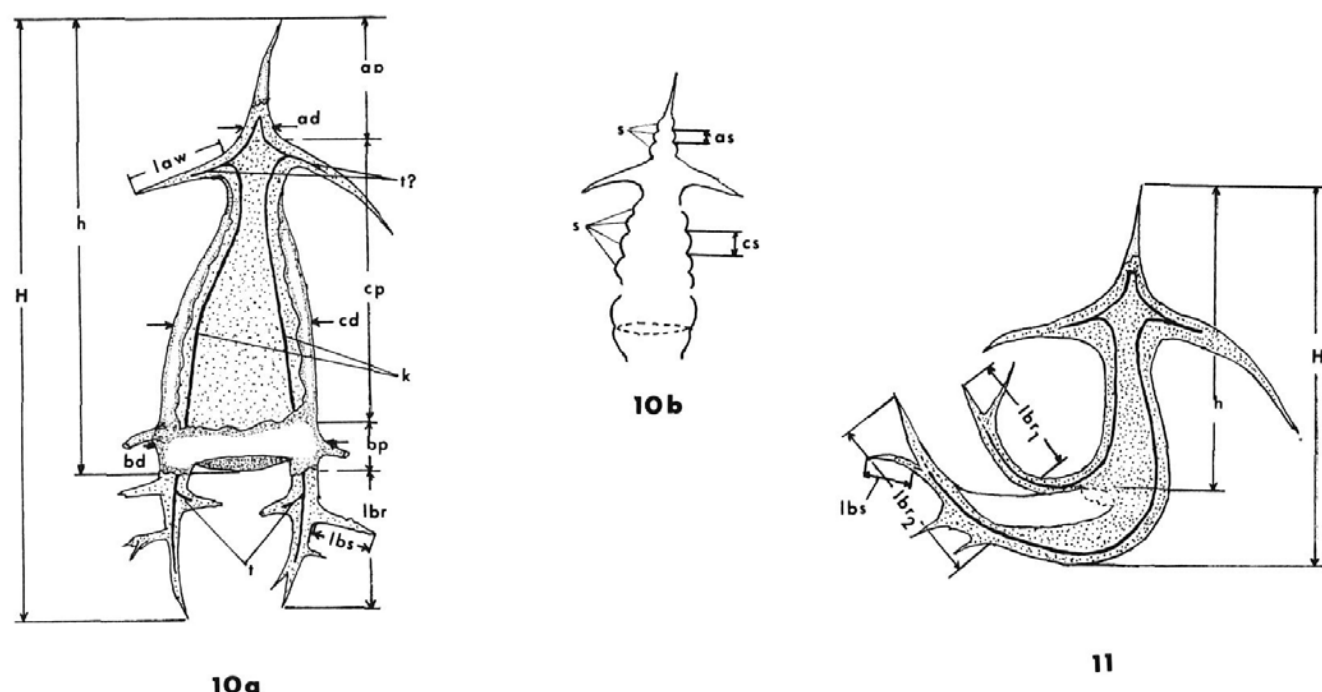
*Comparison:* *Albaillella* is distinguished from the morphologically similar *Haplodiacanthus* by the columellar structure. Whereas columellae are straight in the central and basal part in *Albaillella*, in *Haplodiacanthus* they are curved, causing the shell to be somewhat curled up.

The subject genus is distinguished from *Neoalbaillella* in the less perforated wall of the shell and the absence of supplementary skeletal fabric below the lateral wings.

## PLATE 6

- 1-2 *Octatormentum babcockae* Nazarov and Ormiston, n. gen., n. sp.  
Upper Permian, Guadalupian Stage, Lamar Limestone, West Texas. 1, holotype, USNM 249933, showing polyhedral shell and enlarged pores at spine bases,  $\times 160$ ; 2, view showing ellipsoidal inner shell,  $\times 160$ .
- 3-5 *Hegleria mammiifera* Nazarov and Ormiston, n. gen., n. sp.  
Upper Permian, Guadalupian Stage, Lamar Limestone, West Texas. 3, holotype, USNM 257602, showing mammate exterior,  $\times 180$ ; 4, specimen showing well-preserved cylindrical spines emerging from apices of mammae,  $\times 140$ ; 5, specimen showing internal structure,  $\times 250$ .
- 6-7 *Albaillella apporrecta* Nazarov and Ormiston, n. sp.  
Lower Permian, Artinskian Stage, Aktastinian Substage, Southern Urals, Ural River, Don Village. External views of specimens with rounded basal frames bearing apophyses; 6, paratype, GIN 4673/33,  $\times 100$ ; 7, paratype, GIN 4673/34,  $\times 125$ .
- 8 *Albaillella amplificata* Nazarov and Ormiston, n. sp.  
Upper Carboniferous, Gzhelian Stage, Southern Urals, Ural River, Nikol Village. Holotype, GIN 4488/51a, external aspect of specimen with short lateral spines,  $\times 100$ .
- 9-10 *Haplodiacanthus circinatus* Nazarov and Ormiston, n. sp.  
Upper Carboniferous, Gzhelian Stage, Southern Urals, Ural River, Nikol Village. External views of specimens with differing curvature and with well-developed basal prolongations; 9, holotype, GIN 4488/15a,  $\times 95$ ; 10, paratype, GIN 4488/15b,  $\times 100$ .
- 11 *Haplodiacanthus* sp.  
Lower Permian, Artinskian Stage, Aktastinian Substage, Southern Urals, Ural River, Don Village. GIN 4673/38, external view of specimen with well-developed segments and supplementary spines in central part,  $\times 100$ .
- 12 *Tetragregnon nitidus* Nazarov and Ormiston, n. sp.  
Lower Permian, Leonardian Stage, Bone Springs Limestone, West Texas. Holotype, USNM 257603,  $\times 100$ .
- 13 *Astroentactinia luxuria* Nazarov and Ormiston, n. sp.  
Lower Permian, Artinskian Stage, Aktastinian Substage, Southern Urals, Ural River, Don Village. Paratype, GIN 4673/42, external view of specimen with numerous three-bladed spines,  $\times 95$ .
- 14-15 *Camptolatus benignus* Nazarov and Ormiston, n. sp.  
Upper Carboniferous, Gzhelian Stage, Southern Urals, Ural River, Nikol Village. External aspect from different sides; 14, paratype, GIN 4488/27b,  $\times 210$ ; 15, holotype, GIN 4488/27a,  $\times 175$ .
- 16 *Raphidociclicus gemellus americanus* Nazarov and Ormiston, n. subsp.  
Upper Permian, Guadalupian Stage, Lamar Limestone, West Texas, lateral view,  $\times 160$ .
- 17 *Haplodiacanthus* cf. *H. rhombothoracata* (Ishiga and Imoto 1980)  
Imperfect specimen from Lower Permian, Sakmarian Stage, Sarabil Suite, Southern Urals, Ural River,  $\times 280$ .





TEXT-FIGURES 10a-11

10a, b, schematic illustration of structure of skeleton of *Albaillella amplificata*, n. sp. and letter indices for measured skeletal parts. 11, schematic illustration of structure of skeleton of *Haplodicanthus circinatus*, n. sp. and indices for measured skeletal parts.

**Abbreviations:** H—maximum height of shell; h—shell height from pylome; ap—height of apical part; ad—maximum diameter of apical part; as—height of segment in apical part; cs—height of segment in central part; cd—diameter of segment in central part; cp—overall height of central part; bp—overall height of basal part; bd—diameter of basal part; bs—height of segment of basal part; law—maximum length of lateral wings; lbs—maximum length of basal apophyses (lateral); lbr—length of basal prolongations below pylome; k—columellae; t—trabeculae.

**Species composition:** *Albaillella paradoxa paradoxa* Deflandre, *A. paradoxa gibbosa* Deflandre, *A. cornuata* Deflandre, *A. undulata* Deflandre (lower Carboniferous, Montagne Noir and Turkey), *A. pennata* Holdsworth, *A. aff. pennata* Holdsworth (Namurian of England), *A. cartalla* Ormiston and Lane (Mississippian of North America), *Albaillella* sp. A, *A. sp. B*, *A. sp. C* (Upper Permian of Japan). Several new species are presently known from the Late Carboniferous to Permian strata of the Southern Urals and West Texas.

*Albaillella tetraspinosa* was described by Kozur (1980). In the present paper two new species are described: *Albaillella amplificata* and *A. apporrecta*.

**Distribution:** Late Paleozoic (Carboniferous to Permian), Europe, Asia and North America.

**Remarks:** Above all, to effect a description of Late Paleozoic *Albaillella* it is necessary to have descriptive terms for the parts of the skeleton in order to define those parts. The measured parts of the skeleton and their letter indices are indicated on text-figures 10a-b and are used in designating dimensions in the descriptions which follow.

In articles by Holdsworth (1966, 1969, 1977), Ishiga and Imoto (1980) and several others the expressions "dorsal and ventral sides" are used or implied. This is apparently a highly arbitrary concept, since nothing is known of the cytoplasmic

organization of the organisms involved and the life orientation they maintained in Paleozoic seas. We do not use this terminology in the present work.

***Albaillella amplificata* Nazarov and Ormiston, n. sp.**  
Plate 6, figure 8; text-figure 10a

**Derivation of name:** *amplificata*—Latin, expanded.

**Holotype:** GIN 4488/51a, Upper Carboniferous, Gzhelian Stage, Southern Urals, Ural River, Nikol Village.

**Description:** Large *Albaillella* possessing unsegmented and imperforate, subconical, slightly flattened shell. Internal framework represented by two quite massive columellae, one straight, the other curved. Trabeculae excluding those at the base are not expressed. At the same time, thin rods lead from the columellae to the upper part of the shell and form the foundation (internal) of the lateral wings (spines). Lateral spines small, acuminate in their distal part. Usually, one spine is straight and the other bent so that its free end is directed toward the shell base. Apical part of shell smooth, steadily tapering from the wings to the acuminate or rounded apex. Basal part typically has well-expressed prolongations (pl. 6, fig. 8). On them and also on the basal part of the basal segment there are typically developed lateral apophyses irregularly distributed or more rarely symmetrical. Typically, such apophyses number 2-5, sometimes even more, on each side.



**Dimensions (in  $\mu\text{m}$ ):** H 515–680; h 400–480; ap 105–125; ad 35–54; cp 225–300; cd 135–190; bp 40–100; bd 150–200; law 65–80, max. 200; lds 54–75, max. 140; lbr 95–150.

**Comparison:** The described species is distinguished from Lower Carboniferous *Albaillella* by the curvature of one of the trabeculae, the almost three-bladed form of the lateral wings and its larger dimensions. The unsegmented shell distinguishes this species from Permian ones of this genus.

**Remarks:** Practically all specimens present in our collection possess a curved interior, but the basal rods do not join one another. This creates the impression that the H-frame typical of *Albaillella* is generally absent from this species. However, in three available specimens there were basal rods observed strongly curved toward each other; as a result they almost joined one another. This kind of structure of the basal rods permits the assumption that the subject species developed a semicircular junction of these rods much as in *Albaillella cartalla* and *A. apporrecta*, n. sp., described below.

**Distribution:** Upper Carboniferous, Gzhelian Stage, Southern Urals.

**Material:** Tens of specimens.

*Albaillella apporrecta* Nazarov and Ormiston, n. sp.  
Plate 6, figures 6–7

**Derivation of name:** apporrectus—Latin, extended, elongated.

**Holotype:** GIN 4673/32, Lower Permian, Artinskian Stage, Aktastinian Substage, Southern Urals, Ural River, Don Village.

**Description:** Shell elongated, of conical form, segmented. Columellae straight, sometimes somewhat undulose, merging with the shell wall or separated from it at a distance of 4 to 5  $\mu\text{m}$ . Columellae are especially clearly seen in the basal part (pl. 6, fig. 7) where they are curved so as to unite with each other. Trabeculae are clearly expressed. Their junction delineates segments in the central and basal parts of the shell. In the majority of specimens the apical part is smooth, conical, having a spinelike termination; more rarely it is weakly segmented. Beneath the apical part are developed two spine-like wings, one straight and shorter than the other. Often specimens have only one rodlike spine. Central part of the shell is divided into 7 to 12 imperforate segments. In the basal area there is developed on the outer side of the shell a supplementary layer of skeletal fabric (a kind of patagium), penetrated by rounded openings (pores?). Below the basal segment the rounded, connecting columellae have rodlike apophyses of different lengths (pl. 6, fig. 7).

**Dimensions (in  $\mu\text{m}$ ):** H 310–395; h 240–310; ap 45–64; ad 20–40; cp 130–210; cd 100–140; hs 15–25; bp 18–35; bd 105–150; law 40–75, max. 150; lds 40–83, max. 105.

**Comparison:** The described species is distinguished from Carboniferous species of this genus by the distinct segmentation of the central parts of the shell and the development of supplementary skeletal fabric on the external side of the basal area.

**Distribution:** Lower Permian, Artinskian Stage of the Southern Urals.

**Material:** About 30 specimens.

Genus *Haplodiacanthus* Nazarov and Rudenko 1981

*Haplodiacanthus* NAZAROV and RUDENKO 1981, p. 133.

**Type species:** *Haplodiacanthus anfractus* Nazarov and Rudenko 1981. Lower Permian, Artinskian Stage, Southern Urals, Ural River, Don Village.

**Diagnosis:** Albaillellidae having conical, imperforate shell with two lateral spines in upper third. Internal framework represented by two rodlike columellae uniting in apical segment. Typically, columellae conformable, curved, with different degrees of curvature discernible in central or basal parts. Basal segment typically with different number of prolongations (spines).

**Comparison:** In the form of the conical shell with two lateral spines, and orientation of the columellae, the subject genus is similar to the type genus of the family, *Haplodiacanthus*, however, does not have the H type junction of the columellae at the base typical of *Albaillella*, although one may assume their junction (compare Nazarov and Rudenko 1981, text-fig. on p. 134, fig. E). In addition, while the shell of both genera mentioned can be divided into segments, in *Albaillella* the segments are small and of uniform dimensions, whereas in *Haplodiacanthus* one observes heterogeneous segmentation, small segments developing in the apical area and larger ones in the distal areas.

**Genus composition:** Several species are presently known: *H. anfractus* Nazarov and Rudenko 1981; *H. permicus* (Kozur), *H. sakmarensis* (Kozur), *H. perforatus* (Kozur), and *H. nazarovi* (Kozur). In this paper two species are described from the Late Carboniferous and Artinskian strata of the Southern Urals.

**Remarks:** The platy, imperforate shell of conical external outline with prominent segments in the basal area and somewhat curved skeleton on the whole somewhat allies *Haplodiacanthus* with *Follicucullus* Ormiston and Babcock, but in the subject genus two lateral spines are always developed which are lacking in *Follicucullus*.

**Distribution:** Upper Carboniferous to Lower Permian, Southern Urals, North America and eastern Soviet Union.

*Haplodiacanthus circinatus* Nazarov and Ormiston, n. sp.  
Plate 6, figures 9–10; text-figure 11

**Derivation of name:** circinatus—Latin, curled up.

**Holotype:** GIN 4488/15a, Upper Carboniferous, Gzhelian Stage, Southern Urals, Ural River, Nikol Village.

**Description:** If a metal or polyethylene cone were bent in two, drawing the ends together, it would form the outline of this species. In other words, an elongate, conical shell is so bent that its apical and basal parts are drawn together while rodlike basal prolongations are contiguous with, or cross, the lateral spines. The internal framework is represented by massive, bent columellae which sometimes merge with the shell wall. In the upper third of the shell, thin rods continue the colu-

mellae into the interior of the lateral spines. Lateral spines are short, rodlike, sometimes with indistinct blades, often so curved that their free ends are directed toward the shell base. Apical part of the shell conical, acuminate. Central part inflated at the position of the lateral wings and gradually expanding toward the point of shell inflection. Following this quite abrupt bend, the central part is directed almost upward where a pylome of varying outline is situated. Basal part with two, long, rodlike prolongations (pl. 6, fig. 9), the more proximal one often dichotomously branched, the other bearing apophyses or supplementary spines of various lengths. Shell wall platy, imperforate. It should be noted that all parts of the shell are unsegmented.

**Dimensions (in  $\mu\text{m}$ ):** Dimensional properties are an important aspect of this species. *Haplodiaceanthus* has virtually the same measurable skeletal features as are present in *Albaillella*, the designations for which are almost identical (text-fig. 11). A few new letter indices are introduced on this figure. The following are the dimensions of *H. circinatus*: H 335–420; h 225–325; ap 100–135; ad 35–50; cp 135–204; cd 75–100; bp 75–175; bd 75–110; law max. 135; Lbr 175–176; Lbr2 50–185; Lbs 32–100.

**Comparison:** An apparently similar species is *Haplodiaceanthus bulbosus* (Ishiga 1982) from Maruyama, Hyogo Prefecture, Japan (Ishiga 1982, p. 335, pl. 1, figs. 8–13, 16–17) which occurs in association with Late Carboniferous conodonts. Although the internal structure of *H. bulbosus* is not described, it appears (Ishiga 1982, pl. 1, fig. 17) to have a distal, basal prolongation as in *H. circinatus*, n. sp. The type material of *H. bulbosus* is not well enough preserved to establish the presence of a proximal basal prolongation. The reflexing of the shell is like that in *H. circinatus* and lacks the U-shaped depression of *Pseudoalbaillella uforma* Holdsworth and Jones. The "pseudoabdomen" (reflexed part of the shell) of *H. bulbosus* differs from that of *H. circinatus* in forming a more nearly semicircular curvature, and the shell is more constricted beneath the lateral wings in *H. bulbosus*.

*H. circinatus* is distinguished from Permian species of the genus by its lack of segmentation on all parts of the shell.

**Remarks:** In external form, this species is somewhat reminiscent of *Pseudoalbaillella uforma* (Holdsworth and Jones 1980, p. 285, figs. C, F), which is curved in the lower third. It is difficult to carry out a meaningful comparison, since *P. uforma* is not well preserved and the description is sketchy. In addition, the internal structure of *P. uforma* is totally unclear.

**Distribution:** Found only in the upper Carboniferous, Gzhelian Stage, Southern Urals.

**Material:** Hundreds of specimens.

*Haplodiaceanthus* sp.

Plate 6, figure 11

**Description:** Shell elongate, curved in opposite directions in apical and basal parts. Internal framework represented by two curved columellae, well developed only in the central part. Apically and basally it is practically not expressed. Apical part of shell consisting of four to six small segments, central part of three, of which the lowest is prominent and

significantly bigger than the other two. In the basal part there is only one expanded segment with short prolongations. Two opposing lateral spines have distinct facets along their full length, except for the distal part where they are rodlike. Below these spines on the middle segment of the central area there is developed a three-bladed spine with short spinules on one of its edges. Shell wall is platy, imperforate.

**Dimensions (in  $\mu\text{m}$ ):** H 305; h 260; ap 100; ad 40; cd 100; cp 160; bp 45; bd 105; law max. 210; law<sub>2</sub> 110; lbr max. 40.

**Comparison:** The described species is distinguished from all others of the genus by the development of an additional spine beneath the two lateral ones.

**Remarks:** The two specimens present in the collection do not permit the clarification of all structural peculiarities of this species. Therefore, it is described in open nomenclature. It is entirely possible that the development of a supplementary spine is not characteristic of this taxon, but is a unique abnormality.

**Distribution:** Lower Permian, Artinskian Stage, Aktastinian Substage, Southern Urals, Ural River, Don Village.

**Material:** Two specimens.

**Radiolaria Incertae Sedis**

Family CORYTHOECIDAE Nazarov 1981

**Type genus:** *Corythoecia* Foreman 1963.

**Diagnosis:** Paleozoic bilaterally symmetrical Radiolaria with two adjacent columellae on one side of a conical shell, between which is situated a bilobed wing extending parallel to the columellae. Shell may be partly open or have a conical form with a pylome (equals foramen) in the upper third.

**Generic composition:** *Corythoecia* Foreman 1963 (Upper Devonian, Famennian Stage of Ohio); *Camptoalatus* Nazarov and Rudenko 1981 (Upper Carboniferous to Lower Permian, Southern Urals). In the present paper, the new genus *Arrectoalatus* is described from the Late Carboniferous of the Southern Urals.

**Remarks:** Helen Foreman (1963, p. 300) noted that there was no homology between *Corythoecia* and other known radiolarians. Actually, the unique form of *Corythoecia* with its one massive bilobed wing is not known either among modern or fossil polycystines or among bilaterally symmetrical Radiolaria. Many Albaillellidae and Popofskyellidae possess a conical shell, but they have symmetrically disposed columellae opposite one another and not adjacent to each other as in the majority of representatives of the subject family. Segmented, perforate shells such as *Camptoalatus* and *Arrectoalatus* have shapes typical of Popofskyellidae, but the latter have a completely different pore distribution, more typical for a nassellarian than for Paleozoic Radiolaria sensu stricto. However, the basic distinguishing character for the taxa described below is the development in all of them of a massive bilobed wing.

Genus *Camptoalatus* Nazarov and Rudenko 1981

**Type species:** *Camptoalatus monopterygius* Nazarov and Rudenko 1981. Lower Permian, Sakmarian Stage, Maloik Suite, Southern Urals, Ural River, Don Village.

**Diagnosis:** Shell segmented, perforate, half open. Massive columellae uniting apically and in central part of shell. From site of union of columellae in central part of shell arises a massive, bilobed, platy wing. Shell segments, except for apical segment, are perforated by pores.

**Comparison:** In the form of the conical, unclosed shell with a bilobed wing, *Camptoalatus* is allied with *Corythoecia*. But a distinctly segmented shell and porous central and basal segments are characteristic of *Camptoalatus* while *Corythoecia* Foreman has a solid shell wall.

**Species composition:** Five species are known. The type species was described from the Early Permian and in the present paper *C. benignus*, n. sp. is described. Descriptions of the remaining three species will be published later.

**Distribution:** Upper Carboniferous to Lower Permian of the Southern Urals.

*Camptoalatus benignus* Nazarov and Ormiston, n. sp.  
Plate 6, figures 14–15

**Derivation of name:** *benignus*—Latin, abundant.

**Holotype:** GIN 4488/27a, Upper Carboniferous, Gzhelian Stage, Southern Urals, Ural River, Nikol Village.

**Description:** Shell subconical, somewhat truncated on one side. From the apex of this rather incomplete cone proceed two rodlike columellae diverging at 30–45°. Near their mid-length in the upper or lower third, they are united by a transverse crossbeam from which arises the massive bilobed wing. This wing has a varied form and may be straight, twisted like a propeller, or curved. Shell segmented. The number of segments is not constant but varies from 7 to 16. The interior of each segment is restricted by fine arched rods, which at their ends are united with the columellae. Excluding the three or four at the apex, all segments are perforated by small, rounded pores distributed irregularly or rarely aligned in two to three rows. Basal segments are thin, not porous, with an uneven lower edge. Sometimes the same kind of fabric is developed laterally beneath the wings.

**Dimensions (in  $\mu\text{m}$ ):** Shell height 240–400; maximum diameter 92–145; segment heights—apical 10–15, remaining segments 35–45; diameter of pores in segments 2–4; length of wing 104–145; breadth 75–100, rarely up to 150.

**Comparison:** *Camptoalatus benignus* is distinguished from the type species by irregularly distributed pores that pierce the segments and by a lesser curvature.

**Distribution:** Upper Carboniferous, Gzhelian Stage, Southern Urals.

**Material:** More than 50 specimens.

*Arrectoalatus* Nazarov and Ormiston, n. gen.

**Derivation of name:** *arrectus*—Latin, upraised; *alatus*—Latin, winged.

**Type species:** *Arrectoalatus cernuus*, n. sp. Upper Carboniferous, Gzhelian Stage, Southern Urals, Ural River, Nikol Village.

**Diagnosis:** Segmented corythoeciid possessing segmented,



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TEXT-FIGURE 12

Schematic illustration of external structure of *Arrectoalatus cernuus*, n. sp.

porous shell. Archlike curve of the columellae developed only in the apical part. Junction with each other forming oval pylome (foramen) in upper part of shell beneath which the bilobed wing is developed.

**Comparison:** Species of the subject genus are distinguished from the corythoeciid *Camptoalatus* by the closed cylindrical form of the central and basal parts of the shell. Moreover, the described genus is distinguished from *Corythoecia* by the porous shell wall, and from *Camptoalatus* by the straight, uncurved shell.

**Remarks:** If the wing were broken off and the pylome not visible, *Arrectoalatus* could, on the basis of its external form, be assigned with certainty to the Cyrtidina (Nassellaria). It is entirely likely that the section of such forms also would be accepted as nassellarians.

**Species composition:** There are three species, of which only the type is described here.

**Distribution:** Species of this genus are presently known only from strata of the Upper Gzhelian Stage, highest Carboniferous of the Southern Urals.

*Arrectoalatus cernuus* Nazarov and Ormiston, n. sp.  
Plate 4, figure 10; text-figure 12

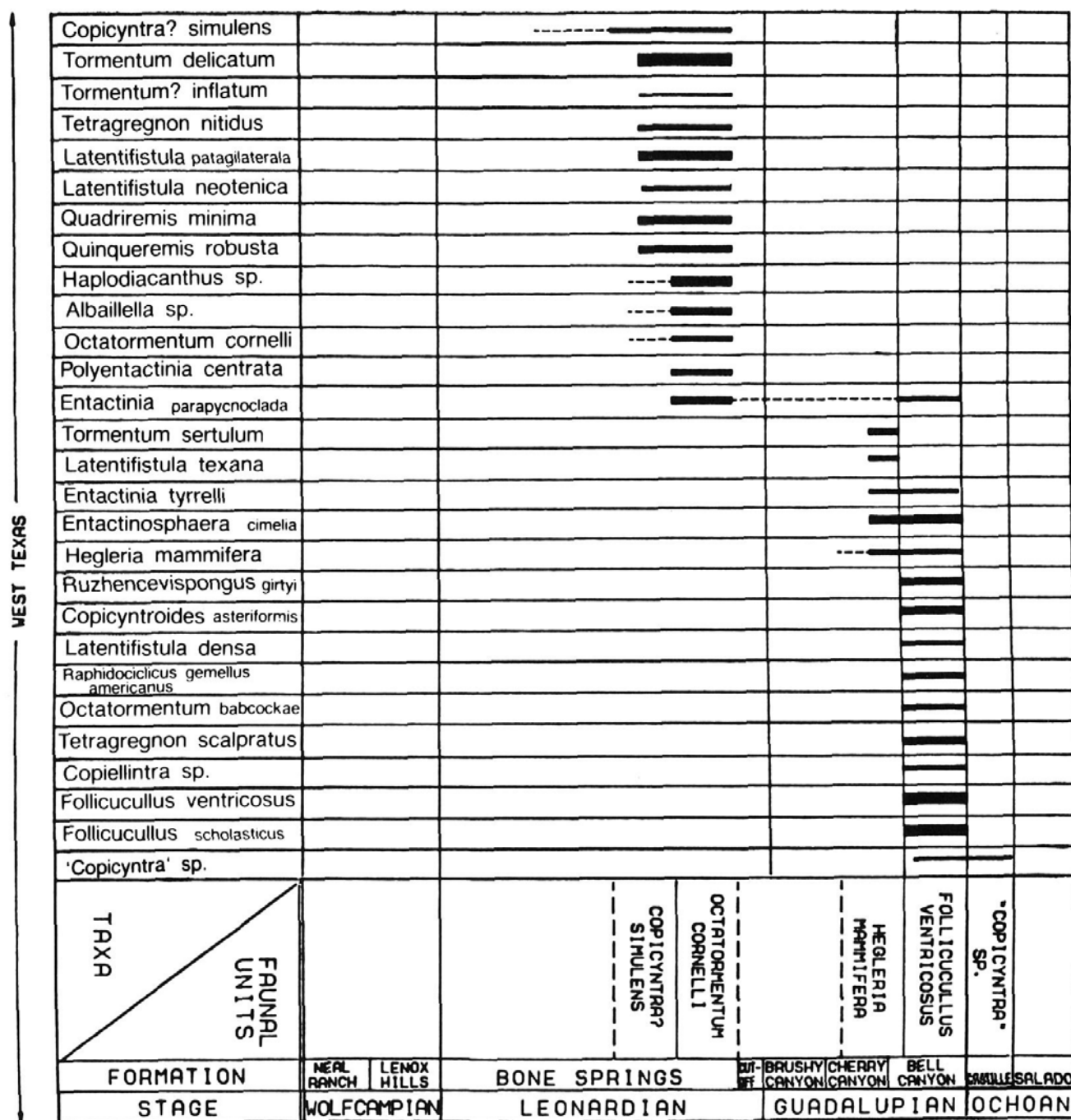
**Derivation of name:** *cernuus*—Latin, falling down.

**Holotype:** GIN 4488/29a, Upper Carboniferous, Gzhelian Stage, Southern Urals, Ural River, Nikol Village.

**Description:** Shell elongate, conico-cylindrical in form. It expands smoothly from the apex approximately to its mid-length beyond which it is cylindrical, sometimes a bit tapered at the base. In the upper part on one side are visible two curved rods (columellae) leading away from the apical spines or the rounded apex. Thereafter, they curve and join again, forming an oval pylome. Beneath the pylome is situated a small wing. It is bilobed and platy. Sometimes a fine seam extends from the base of the wing to the middle of the shell or its basal part as though it were dividing the shell into two halves. The shell has a varying number of segments devel-

SYSTEM		CARBONIFEROUS			P E R M I A N											
SERIES		C <sub>2</sub>	C <sub>3</sub>		P <sub>1</sub>											
STAGE		C <sub>2m</sub>	C <sub>3k</sub>	C <sub>3g</sub>	P <sub>1as</sub>			P <sub>1s</sub>			P <sub>1a</sub>		P <sub>1kn</sub>			
SUBSTAGE			C <sub>3ab</sub>	C <sub>3zn</sub>				P <sub>1tas</sub>	P <sub>1st</sub>	P <sub>1akt</sub>	P <sub>1b</sub>					
SUITE					P <sub>1sur</sub>	P <sub>1us</sub>	P <sub>1k</sub>	P <sub>1kr</sub>	P <sub>1s</sub>	P <sub>1mk</sub>	P <sub>1kn</sub>					
TAXA	ASSEMBLAGE	No.														
			Tormentum pervagatum	Tormentum protei	Latentifistula crux	Tormentidae	Copicynta spp.	Haplodicanthus perforatus	Helioentactinia sp.	Tormentum circumfusum	E. pycnoclada	Camptolatus monopterygius	Rectotormentum fornicatum	Quinqueremis arundinea	E. crassiclathrata	Tetragregnon spp.
			I	II	III	IV	V		VI	VII	VIII	IX	X	XI	XII	
Tetratormentum narthecium n. sp.																
Tormentum pervagatum n. sp.																
Tormentum protei Naz. & Orm																
Haplodicanthus circinatus n. sp.																
Albaillella amplificata n. sp.																
Camptolatus benignus n. sp.																
Latentidiota visenda n. sp.																
Arrectolatus cernuus n. sp.																
Latentifistula crux Naz. & Orm.																
Tormentidae gen. & sp. indet.																
Copicynta spp.																
Helioentactinia sp.																
Haplodicanthus sakmarensis (Kozur)																
Haplodicanthus nazarovi (Kozur)																
Haplodicanthus perforatus (Kozur)																
Albaillella permica (Kozur)																
Nazarovispongia pavlovi (Kozur)																
[ = Tormentum?pavlovi (Kozur) ]																
Nazarovispongia permica Kozur																
[ = Tormentum?permica (Kozur) ]																
Tormentum circumfusum n. sp.																
Entactinia pycnoclada n. sp.																
Latentifistula valdeinepta n. sp.																
Raphidociclicus hiulus Nazarov et Rudenko																
Camptolatus monopterygius Nazarov et Rudenko																
Entactinosphaera strangulata n. sp.																
Ruzhencevispongia plumatus n. sp.																
Latentifistula aff. neotenica n. sp.																
Latentifistula triacanthophora Naz. & Orm																
Rectotormentum fornicatum n. sp.																
Entactinia densissima n. sp.																
Entactinosphaera crassiclathrata n. sp.																
Astroentactinia luxuria n. sp.																
Ruzhencevispongia cataphractus n. sp.																
Latentifistula neotenica n. sp.																
Quadrimeris gliptocetus n. sp.																
Quinqueremis arundinea Naz. & Orm.																
Albaillella apporrecta n. sp.																
Haplodicanthus anfractus Nazarov et Rudenko																
Raphidociclicus gemellus Nazarov et Rudenko																
Campanulithus falcatus Nazarov et Rudenko																
Tetragregnon spp.																
Copicynta cuspidata n. sp.																
Copicynta phymatodonta n. sp.																
Polyentactinia lautitia n. sp.																
Ruzhencevispongia uralicus Kozur																
Follicuculus sp.																





TEXT-FIGURE 14  
Distribution of Radiolaria in the Permian of the Delaware Basin, West Texas.

oped along its whole length, from 6 to 13. With the exclusion of the apical ones, they are perforated by one or two rows of small, rounded pores. The lower edge of the shell is usually imperforate.

**Dimensions (in  $\mu\text{m}$ ):** Shell height 200–351; maximum diameter 80–95, rarely up to 134; segment height 15–20; diameter of pores 2–4; pylome diameter on average  $30 \times 50$ ; wing length 60; breadth of wing 20–35.

TEXT-FIGURE 13  
Distribution of Radiolaria in Upper Carboniferous to Lower Permian of Southern Urals. Named stratigraphic subdivisions are the same as those in text-figure 1.

**Comparison:** From all species of the genus, *A. cernuus*, n. sp. is distinguished by a clearly segmented shell and its subcylindrical form beneath the wing.

**Distribution:** Upper Carboniferous, Gzhelian Stage, Southern Urals.

**Material:** Twenty-two specimens.

Family CERATOIKISCIDAE? Holdsworth 1969

Genus *Raphidociclicus* Nazarov and Rudenko 1981

**Type species:** *Raphidociclicus hiulcus* Nazarov and Rudenko 1981 (p. 135, fig. 1).

**Diagnosis:** The diagnosis of Nazarov and Rudenko (1981, p. 135) is accepted here without modification. Characterized by well differentiated spine "b" and weakly expressed spines "a" and "i." All spines unite with a massive ring (rib C<sub>1</sub>) from which there arise paired apophyses. All skeletal elements are united by porous or spongy fabric, not evenly developed. The junction of the patagium with these spines forms small rosettes, or their junction forms a structure with the appearance of two pages of a half-open book.

**Remarks:** Radiolarian Genus B of Foreman 1963 was placed in synonymy with *Raphidociclicus* by Nazarov and Rudenko (1981). Foreman's material is now assigned to the Devonian genus *Helenifore* Nazarov and Ormiston 1983 and is excluded from the concept of *Raphidociclicus*.

*Raphidociclicus gemellus* Nazarov and Rudenko 1981 *americanus* Nazarov and Ormiston, n. subsp.

Plate 3, figures 15–16; plate 6, figure 16

**Derivation of subspecies name:** *americanus*, in allusion to the origin of the type material of the subspecies.

**Holotype:** USNM 249934, Upper Permian, Guadalupian Stage, Lamar Limestone, West Texas and New Mexico.

**Description:** Spines a and i (Holdsworth 1969, text-fig. 1) are almost entirely reduced, thin and imbedded in the patagial fabric. Spine b is long, rodlike and gradually tapering distally. It is interrupted medially and continued by patagial tissue "beneath" the central subcircular ring. Patagium "above" central ring a single layer but "below" it forms a two-walled downwardly expanding wedge whose base bears three rods parallel to spine b continuing for the length of the patagium. The patagial tissue consists of regularly developed rosettes which are smallest proximally and increase slightly in size distally.

**Dimensions (in  $\mu\text{m}$ ):** Maximum length of spine b 450–500; diameter of ring 32; diameter of cells of the patagium 2–12.

**Comparison:** *Raphidociclicus gemellus americanus*, n. subsp. is similar to the nominate subspecies, *R. gemellus gemellus* from the Lower Artinskian Stage of the Southern Urals (Nazarov and Rudenko 1981, p. 136, fig. 1a) from which it is distinguished by having a distinctly more orderly arrangement of the rosettes of the patagium and less disordered patagial tissue combined with a fainter expression of ribs a and i.

**Distribution:** Upper Permian, Guadalupian Stage, Lamar Limestone, West Texas and New Mexico.

**Material:** Seven specimens.

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