



**Upper Permian Radiolarians
from the Sosio Valley Area, Western Sicily (Italy)
and from the Uppermost Lamar Limestone of West Texas**

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With 4 Text-Figures, 1 Table and 3 Plates

*Italien
Sizilien
USA
Texas
Radiolaria
Systematik
Stratigraphie
Paleogeographie*

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**Oberpermische Radiolarien
aus dem Sosiotal (West-Sizilien, Italien)
und aus dem obersten Lamar-Kalk (West-Texas, USA)**

Zusammenfassung

Eine der reichsten oberpermischen Radiolarienfaunen der Welt wurde in roten Tiefwassertonen im Sosiotal (West-Sizilien) nachgewiesen. 4 neue Gattungen und 4 neue Arten werden aus dieser Fauna beschrieben. Conodonten aus einer Kalkarenit-Einlagerung nahe der reichsten Radiolarien-führenden Probe erlauben eine Zuordnung zur Dzhulfa-Stufe. Die biostratigraphische und paläogeographische Bedeutung dieser Radiolarienfaunen wird diskutiert.

Für Vergleiche mit der oberpermischen Radiolarienfauna von Sizilien wurde die Radiolarienfauna des obersten Lamar-Kalksteins von West-Texas neu untersucht. Im Gegensatz zu früheren Altersbestimmungen gehört diese Fauna nicht zur oberen Capitan-Stufe, sondern zur Dzhulfa-Stufe. *Follicucullus bispinosus* n.sp. wird aus dieser Fauna beschrieben.

Abstract

Red deep-water clays from the Sosio Valley area in Western Sicily contain one of the richest Upper Permian radiolarian faunas of the world. 4 new genera and 4 new species are described from this fauna. Conodonts from a calcarenite intercalation near the richest radiolarian-bearing sample indicate a Dzhulfian age. The stratigraphic and paleogeographic importance of this deep-water radiolarian fauna is discussed.

For comparison with the Sicilian Upper Permian radiolarian fauna, the radiolarian fauna of the uppermost Lamar Limestone of West Texas was re-investigated. In contrast to the previous age determinations this fauna is not of Late Capitanian, but of Dzhulfian age. *Follicucullus bispinosus* n.sp. has been described from this fauna.

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1. Introduction

Permian radiolarians have been so far described above all from the Circum-Pacific area (Japan, South China, Philippines, Alaska, Western North America, Chile), from the Cis-Urals, and from Texas.

KOZUR & KRAHL (1987) discovered the first Permian radiolarians from the Western Tethys (Crete, Greece) and DE WEVER, BOURDILLON-DE GRISSAC & BECHENNEC (1988) figured Permian radiolarians from Oman.

During a one-day excursion (autumn 1986) in the Sosio Valley area under guidance of Dr. P. DI STEFANO, Palermo, KOZUR found in the Torrente San Calogero section near the famous Pietra di Salomone limestone block for the first time pelagic South Tethyan Ladinian rocks with *Daonella*, conodonts and radiolarians, and Lower Permian deep-water radiolarians (see CATALANO, DI STEFANO & KOZUR, 1988 a, b, c).

The discovery of Early Permian radiolarians in Western Sicily drastically changed the former paleogeographic picture of the Permian Tethys as shallow-water gulf in the area of the South European Western Tethys.

The Circum-Pacific radiolarian fauna is dominated by Alibaillellacea. In the Lower Permian Cis-Uralian radiolarian faunas, in contrast, Alibaillellacea are only a subordinate group. Radiolarian faunas of restricted basins or of shallow-water environments both in the Circum-Pacific realm and in the Cis-Urals are characterized by Copicyntrinae KOZUR & MOSTLER.

In the Upper Permian of Japan, the oceanic Circum-Pacific radiolarian faunas can be subdivided in an open oceanic assemblage (mostly cherts) with *Neoalibaillella* TAKEMURA & NAKASEKO and a marginal oceanic assemblage (mostly claystones and siltstones) with the *Follicucullus ? charveti* group and without *Neoalibaillella*. Some Alibaillellacea, like *Ishigaconus scholasticus* (ORMISTON & BABCOCK), occur in both assemblages.

However, it cannot be excluded, that these assemblages have also somewhat different ages. In the Philippines, the *Neoalibaillella ornithoformis* Zone follows above faunas with *F. ? charveti* within a continuous chert sequence.

The Upper Permian radiolarian faunas of Western Sicily belong to the marginal oceanic assemblage of the Circum-Pacific province. However, the Changxingian part of the red claystones has not yielded well preserved radiolarian faunas.

For comparison, the radiolarian fauna of the uppermost Lamar Limestone in the Delaware Basin, West Texas, have been investigated.

From these beds ORMISTON & BABCOCK (1979) have been described the first Permian Alibaillellacea. This radiolarian fauna (*Follicucullus ventricosus*-*Ishigaconus scholasticus* fauna) was assigned to the Capitanian (Middle Permian) by ORMISTON & BABCOCK (1979) and NAZAROV & ORMISTON (1985). This has caused difficulties by the age determination of the Japanese and Sicilian Upper Permian radiolarian faunas.

The discovery of Tethyan Dzhulfian conodonts in the uppermost Lamar Formation and in the post-Lamar/pre-Castile beds near the Guadalupe Mountains as well as in the uppermost Altuda Formation of the Glass Mountains (KOZUR, in press), has solved the contradictions between the ranges of the *F. ventricosus*-*I. scholasticus* fauna in Texas (Capitanian) and in Eurasia (Dzhulfian).

2. Geological Setting

All here described Upper Permian radiolarians have been derived from the Torrente San Calogero section SW of the famous locality Pietra di Salomone in the Sosio Valley area SW of Palazzo Adriano (see Text-Fig. 1).

The Permian and Triassic sequence of the Torrente San Calogero section is part of the Sicilian paleogeographic realm of Western Sicily described by CATALANO, DI STEFANO & KOZUR (1991, 1992). The Permian and Triassic lithologic successions of the Sosio Valley area and the Roccapalumba-Lercara area are shown in Text-Fig. 2.

The exposed sequence in the Torrente San Calogero section (Text-Fig. 3) was described by CATALANO, DI STEFANO & KOZUR (1992). It begins with an Olistostrome Unit of Roadian age (= basal part of Middle Permian Guadalupian Series). These beds have been placed into the Kubergandinian by CATALANO, DI STEFANO & KOZUR (1991, 1992). However, the Kubergandinian cannot be directly recognized in pelagic Tethyan beds without ammonoids.

The Kubergandinian age was therefore concluded by the position above Chihshian and below Wordian pelagic faunas. Because the Kubergandinian is defined by fusulinid faunas that are restricted to central and eastern Tethyan shallow-water deposits and missing in the whole western hemisphere and Boreal realm as well as in pelagic deposits of the Tethyan realm, this Stage is unsuitable as international standard. Moreover, the stratotype lies several 1000 m high in a hardly accessible area in the Central Asian Pamirs and the rocks are thermally altered (CAI = 4-5).

Therefore the Kubergandinian has been replaced by the now well-defined Roadian with an easily accessible stratotype in the Glass Mountains, West Texas. It is well defined around the margins of the Delaware Basin, where also the stratotype is situated. The most complete outcrops are on the opposite slope of the Delaware Basin, at the western slope of the Guadalupe Mountains, where both the underlying Leonardian s.str. and the overlying Wordian are present in several continuous sections with pelagic and shallow-water fossils (ammonoids, conodonts, fusulinids, radiolarians etc.).

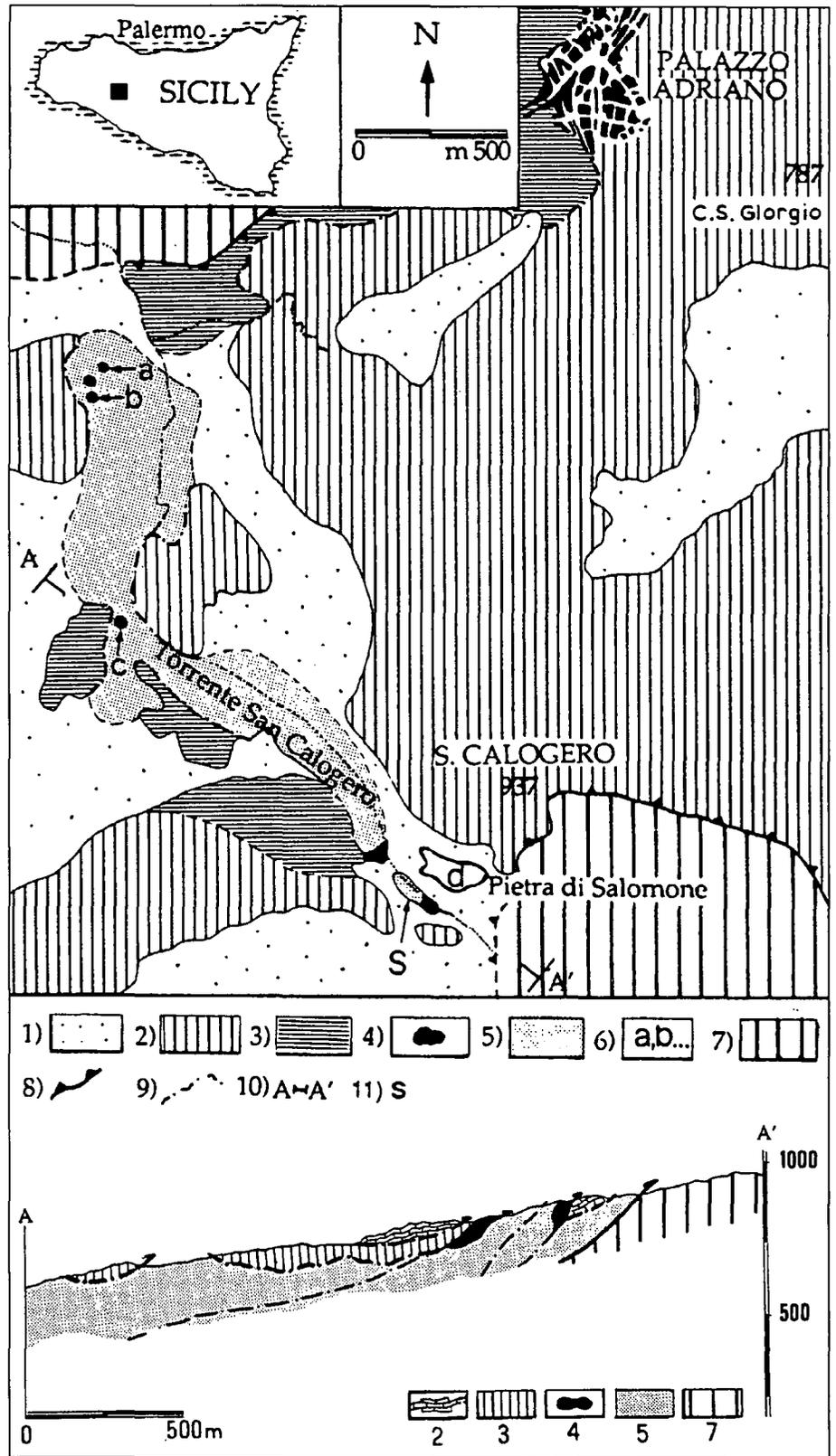
The matrix of the Olistostrome Unit contain few pyritized radiolarians, identical with those described by CORNELL & SIMPSON (1985) and NAZAROV & ORMISTON (1985) from the upper Cutoff Formation that was in the investigated outcrop along the US Highway 62-180 SE of the Guadalupe Mts. erroneously placed into the Bone Spring Formation. NAZAROV & ORMISTON (1985) placed the post-Artinskian Bone Springs Formation with *Mesogondolella idahoensis* (YOUNGQUIST, HAWLEY & MILLER) and the overlying Cutoff Formation with *M. nankingensis* (CHING) (= "*Gondolella*" serrata CLARK & ETHINGTON) into the Artinskian, but this age determination was rejected by KOZUR & MOSTLER (1989). The Artinskian-Kungurian boundary can be well correlated by conodonts with the middle Skinner Ranch Formation, where *Neostreptognathodus pnevi* KOZUR & MOVSHOVICH begins. A little later *Mesogondolella intermedia* (IGO), *Neostreptognathodus foliatus* (IGO), *N. exsculptus* (IGO) and in the uppermost Skinner Ranch Formation *N. prayi* BEHNKEN and *N. idahoensis* YOUNGQUIST, HAWLEY & MILLER appeared. The youngest Artinskian yielded *N. pequopenensis* BEHNKEN and *Mesogondolella bisselli* (CLARK & BEHNKEN). It is at least 4 conodont zones older than the upper Cutoff Formation, from where the "Artinskian" radiolarians of the Bone Spring Formation at the US Highway 62-180 have been derived.

Text-Fig. 1.

Geologic map (a) and cross section (b) of the Torrente San Calogero area, Sosio Valley (Western Sicily, Italy). After CATALANO, DI STEFANO & KOZUR, 1991.

1 = Debris; 2-6 Upper tectonic unit: 2 = Cherty Limestones (upper Carnian-Rhaetian); 3 = Gray platy limestones and marls (Middle-lower part of Upper Carnian); 4 = Gray and greenish, partly red cherts, greenish and pink nodular, often siliceous or cherty limestones, marls, in the lower part tuffitic intercalations (Anisian-Lower Carnian); 5 = Undifferentiated Olistostrome Unit, Claystone Unit and siliciclastic deposits, limestone conglomerates, red micritic limestones (Permian: uppermost Artinskian-Changxingian, and Lower Triassic); 6 = Sosio Limestone blocks (a = Rupe di San Calogero; b = Pietra dei Saracini; c = Rupe del Passo di Burgio; d = Pietra di Salomone). 7 = Lower tectonic unit: Triassic-Miocene deposits. 8 = Main tectonic boundaries. 9 = Minor thrust planes. 10 = Cross section line.

S = Location of the San Calogero section, from where the described radiolarians of Western Sicily have been described.



The conodonts from the matrix of the olistostrome Unit give the same age as the radiolarians. They yielded *Mesogondolella phos-horiensis* (YOUNGQUIST, HAWLEY & MILLER) and *Sweetognathus subsym-metricus* WANG, RITTER & CLARK. This is a typical Roadian conodont fauna. *S. subsymmetricus* is so far only known from the Roadian of South China, but according to a personal communication of Dr. L. LAMBERT, Iowa City, this species is also present in the Roadian of Texas.

Siliceous micritic limestones and dark, hard, limey marls yielded very rich Lower Permian radiolarian faunas of latest Artinskian to Early Leonardian age. Like all deep-water radiolarian faunas, also this fauna consists almost exclusively of Alballiella-cea. This fauna has been described by KOZUR in CATALANO, DI STEFANO & KOZUR (1989). In this paper already some of the Upper Permian radiolarians, described in the present paper, have been figured.

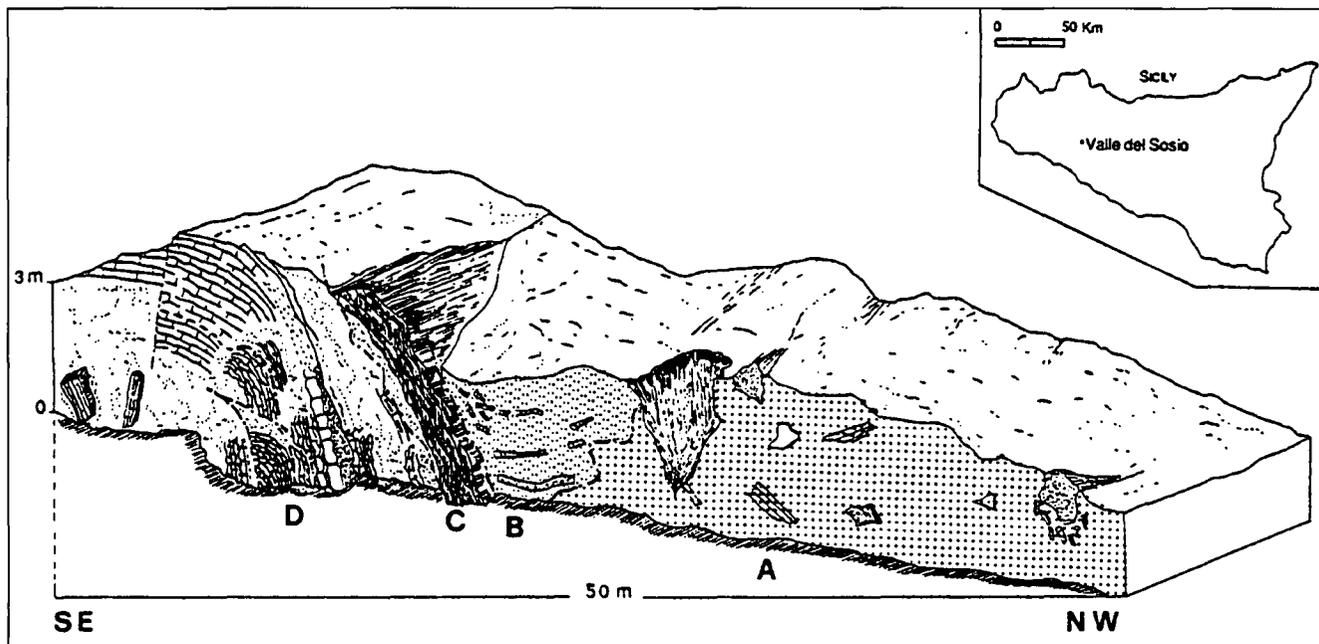
The Olistostrome Unit is overlain by the Claystone Unit that consists of gray, in the upper part predominantly red deep-water soft claystones. The gray, yellowish weathering claystones from the lower part of the Claystone Unit yielded a lot of Wordian conodonts with *Mesogondolella sici-liensis* (KOZUR), but only a few indeterminate radiolarians have been found in these rocks. This part of the Claystone Unit is not exposed in the section SW of the Pietra di Salomone.

In the light-gray limestones immediately below the pre-dominantly red claystones radiolarians are rather fre-quent, but badly preserved. *Follicucullus porrectus* RUDENKO and *Ishigaconus scholasticus* (ORMISTON & BABCOCK) have been determined. A Late Permian age can be assumed for this radiolarian fauna.

The richest radiolarian fauna occurs in the lower part of the red claystones. The bad to well preserved fauna with more than 100 000 radiolarians per kg sample weight is

SYSTEM		STAGE	LITHOLOGY - FOSSILS	
T		Rhaetian	Pelagic gray bedded cherty calcilutites with intercalations of calcarenites. <i>Halobia</i> , <i>Monotis</i> , ammonoids, conodonts, radiolarians.	
		Norian		
R	Upper	Upper	Pelagic gray cherty calcilutites with intercalations of brown calcarenites and, at places calcirudites, gray shales. <i>Halobia</i> , conodonts, radiolarians, ostracods, trace fossils.	
		Carnian Middle		
A		Lower	Pelagic greenish-gray to pink nodular cherty limestones, greenish-gray, rarely violet shales, subordinately thin red radiolarites. <i>Daonella</i> , " <i>Posidonia</i> " <i>wengensis</i> , ammonoids, conodonts (<i>Gladigondolella</i> , <i>Pseudofurnishius</i> etc.) radiolarians, ostracods.	
		S	Upper	Pelagic reddish to greenish-gray nodular cherty or siliceous limestones, greenish tuffites, greenish to gray radiolarites. Conodonts, radiolarians. Or: red siliceous limestones, cherts.
S	Middle		Lower	Pelagic greenish siliceous calcilutites with filaments, some tuffites. Conodonts.
		Anisian (Upp.)		
C	Lower (Scyth.)	Olenekian	Reddish pelagic calcilutites (Hallstatt Limestones), marls, yellowish weathering limestones, marls, limestone conglomerates. Conodonts, foraminifers, ostracods, radiolarians	
		Brahmanian	Pelagic graded yellowish weathering conglomeratic to calcarenitic limestones with shallow-water clasts, grain supported. Conodonts, foraminifers, holothurian sclerites.	
P	Upper	Changxingian	Pelagic red deep-water claystones with few thin calcarenites. Radiolarians, ostracods, foraminifers, conodonts, sponge spicules. Toward the lower part increasingly light-gray intercalations.	Pel. red clays, thick partly sandy calcarenites, calc. sandst., conod., sponge spic.
		Dzhulfian		
E		Capitanian	Gray, yellowish weathering red claystones. Conod., radiol. White reef slope or base-of-slope biogenic limestones. Sponges, bryozoans, conodonts, holothurian sclerites, ammonoids, crinoids.	
		Wordian		
R	Middle	Roadian	Olistostrome Unit: Gray soft claystone with reworked sand grains. Conodonts, ostracods, radiolarians, sporomorphs. Olistoliths from the underlying rocks.	
		M	Leonardian s.str.	Dark gray limestones. Brachiopods ammonoids, echinoderms, conodonts, scolecodonts, radiolarians, sporomorphs. (Olistoliths) Resedimented calcarenites, biogenic ls. Conodonts, sponge spicules. (Olistoliths)
Gray and red flysch: graded sandstones, partly fine-conglomeratic, siltstone, shales. Echinoderms, foraminifers, ostracods, conodonts, trace fossil (Olistoliths and sequences). Gray micritic silic. limest., dark-gray silty marls, marly ls. Radiolarians, conodonts. (Mostly olistoliths).				
A	Lower	Artinskian	Unknown	
		Sakmarian		
		Asselian		
N				

Text-Fig. 2.
Restored stratigraphic scheme of the Permian and Triassic rocks of the Sicilian paleogeographic domain of Western Sicily. Supplemented after CATALANO, DI STEFANO & KOZUR (1991).



Text-Fig. 3.

Torrente San Calogero section. After CATALANO, DI STEFANO & KOZUR (1991, 1992).

A = Olistostrome Unit (Roadian Stage, earliest Middle Permian age); B = Predominantly red claystones with few thin calcarenites, upper part of the Claystone Unit (Upper Permian: Dzhulfian-Changxingian); C = Bedded greenish and gray cherts, tuffites, siliceous and cherty limestones (Lower Ladinian); D = Pink and greenish nodular, cherty limestones, marls, subordinately red cherts (Upper Ladinian-Lower Carnian) described in the present paper. It consists of a typical Upper Permian assemblage of Circum-Pacific character.

described in the present paper. It consists of a typical Upper Permian assemblage of Circum-Pacific character.

The accompanying conodont fauna is very poor and consists of *Clarkina sosioensis* GULLO & KOZUR, *C. changxingensis italicus* KOZUR and *Hindeodus typicalis* (SWEET). *Clarkina sosioensis* is a typical conodont for the Upper Permian deep-sea environment of the Sosio Valley area.

It is also present in the Dzhulfian *Neobaillella ornithoformis* Zone (with *N. ornithoformis* TAKEMURA & NAKASEKO and *N. pseudogrypa* SASHIDA & TONISHI) of the Kanto Mountains, central Japan (SASHIDA & TONISHI, 1985, Pl. 7, Fig. 12, determined as *Neogondolella* sp.) and in Upper Permian cherts with *Ishigaconus scholasticus* of the Chichibu Belt of Japan (SUYARI, KUWANO & ISHIDA, 1983, Pl. 1, Fig. 6, determined as *Gondolella* cf. *orientalis* BARSKOV & KOROLEVA).

A single, about 20 cm thick, broken calcarenite near to the richest radiolarian faunas in the lower part of the red claystones contains a very rich conodont fauna with the above species.

This conodont fauna was placed by GULLO & KOZUR (1992) in the Upper Changxingian because of the presence of *Clarkina changxingensis* WANG & WANG. However, the range of *C. changxingensis* in South China (Upper Changxingian including the transitional beds) is facies-controlled. This species invaded together with radiolarians the shallow-water sea during a slight deepening (or sea level rise) in the Upper Changxingian. In fully pelagic deep-water deposits *C. changxingensis* begins already in the Lower Dzhulfian, but the Dzhulfian representatives belong mostly to *C. changxingensis italica* KOZUR. This subspecies dominates in the lower part of the red claystones, from where the richest and best preserved radiolarians have been derived.

The upper part of the red claystones belong to the Changxingian, indicated by *C. subcarinata* (SWEET) and other Changxingian conodonts from thin, broken calcarenites within the red claystones. This part yielded unfortunately

only badly preserved radiolarians, mainly *Phaenicosphaera* sp. and *Ishigaconus scholasticus* (ORMISTON & BABCOCK).

Except of typical Upper Permian and long-ranging forms as well as new species of characteristic Upper Permian genera, very few forms of Capitanian (Middle Permian) character are present. One specimen of *Parafollicucullus monacanthus* (ISHIGA & IMOTO) was found among several 100.000 specimens of Dzhulfian radiolarians. This species is a Capitanian guideform; reworking is probable.

An other typical Middle Permian species, *Pseudoabaillella eurasiatica* KOZUR, KRAHL & MOSTLER is present with several specimens. This species occurs also in Japan and on the Philippines from the Middle Permian up to the Dzhulfian. It is seemingly an autochthonous component of the Dzhulfian radiolarian faunas of Sicily, at least the forms with short pseudoabdomen. The very rare specimens with longer pseudoabdomen are probably reworked Middle Permian specimens.

The third Middle Permian element is *Parafollicucullus convexus* (RUDENKO & PANASENKO). Only 4 specimens have been found. Reworking cannot be excluded, but also in Oman this species is present in a Dzhulfian radiolarian fauna (see also systematic part).

In West Texas, Upper Permian Albaillellacea are only known from the uppermost Lamar Limestone Member of the Bell Canyon Formation. The Lamar Limestone crops out in a long cuesta running across the western side of the Delaware Basin, SE of the Guadalupe Mountains in Culberson County, West Texas. The locality data have been published in ORMISTON & BABCOCK (1979). The sections H, I, N and O of this paper (for location see ORMISTON & BABCOCK, 1979, Text-Figs. 1-2) have been re-sampled. In the present paper only a few radiolarians will be published from section H along the US Highway 62-180, about 6.5 km SE of the Guadalupe Mountains, the type locality of *Follicucullus ventricosus* ORMISTON & BABCOCK and "*F. scho-*

lasticus ORMISTON & BABCOCK). Detailed papers about the radiolarians and other microfaunas of the Lamar Limestone are in preparation.

The holotypes of both *Follicucullus ventricosus* ORMISTON & BABCOCK and *Ishigaconus scholasticus* (ORMISTON & BABCOCK) have been derived from the top of the Lamar Limestone in locality H. In these beds radiolarians are mostly moderately frequent (about 50–100 specimens per kg sample weight) and well preserved. These data are in agreement with the data by ORMISTON & BABCOCK (1979). However, some samples from the uppermost 80 cm of the outcrop yielded very rich assemblages with several thousands radiolarians per kg sample weight. These samples yielded for the first time *Ishigaconus scholasticus* with fully preserved dorsal columella, very important for comparisons with *Ishigaconus furcus* (CARIDROIT & DE WEVER) and the new *Follicucullus* species *F. bispinosus* n.sp.

The radiolarian fauna with *F. ventricosus* and *I. scholasticus* continues until the top of the Lamar Limestone. Comparisons with the sequence in an outcrop about 1 km SE of section H, where the boundary between the Lamar Limestone and the post-Lamar / pre-Castile beds is exposed, have shown that the stratum typicum for *F. ventricosus* and *I. scholasticus* lies about 1 m below the top of the Lamar Limestone in this area. In this latter outcrop, near to section I of ORMISTON & BABCOCK, a brownish weathered chert is present near the top of the Lamar Limestone. Around this chert, in the limestones both the *F. ventricosus*-*I. scholasticus* radiolarian fauna and conodonts are common. The conodont fauna consists of *Clarkina changxingensis italica* KOZUR, *Clarkina* n.sp. A, *Clarkina* n.sp. B and *Hindeodus typicalis* SWEET. In the post-Lamar/pre-Castile beds additionally *Hindeodus julfensis* (SWEET), a characteristic (Upper) Dzhulfian – Changxingian conodont species, is present. The latter conodont fauna can be also found in the uppermost Alтуда Formation of the Glass Mountains (KOZUR, in press). It is a Tethyan Dzhulfian fauna. The Dzhulfian age of these conodonts is confirmed by the radiolarian fauna (see chapter IV).

ORMISTON & BABCOCK (1979) placed the *F. ventricosus*-*I. scholasticus* fauna in the Capitanian (upper part of Guadalupian Series), in agreement with the prevailing opinion about the age of the Lamar Limestone. Only FURNISH (1973) regarded the Lamar Limestone as post-Capitanian / pre-Dzhulfian.

As shown by KOZUR (in press) only the lower Lamar Limestone with *Yabeina lamarensis* belongs surely to the Capitanian, whereas the uppermost Lamar Limestone with the *F. ventricosus*-*I. scholasticus* fauna belongs surely to the Dzhulfian. The largest part of the Lamar Limestone between these two horizons belongs either to the Capitanian or to the Dzhulfian (Wuchiapingian) depending from the final definition of the base of the Dzhulfian (Wuchiapingian) in the Asian Tethys.

3. Systematic part

If not otherwise indicated, the type locality of the new species is the Torrente San Calogero section (locality S in Text-Fig. 1), SW of the Pietra di Salomone, Sosio Valley area, Western Sicily (Italy).

Stratum typicum is the lower part of the predominantly red upper Claystone Unit, sample 655 (Lower Dzhulfian).

The material with the repository number CK/... is deposited in the Dipartimento di Geologia e Paleontologia, Università di Palermo (Sicilia, Italia). The material with the re-

pository number N... is deposited in the geology collection of Museum of Northern Arizona, Flagstaff (Arizona, U.S.A.).

Subclass: Radiolaria MÜLLER, 1858
Order: Polycystina EHRENBERG, 1838
Suborder: Albaillellaria DEFLANDRE, 1953 emend. HOLDSWORTH, 1969
Superfamily: Albaillellacea DEFLANDRE, 1952
Family: Follicucullidae ORMISTON & BABCOCK, 1979 emend. KOZUR, 1981
Subfamily: Follicucullinae ORMISTON & BABCOCK, 1979
Genus: *Follicucullus* ORMISTON & BABCOCK emend. KOZUR & MOSTLER, 1989

Type species: *Follicucullus ventricosus* ORMISTON & BABCOCK, 1979.

Remarks: KOZUR & MOSTLER (1989) emended *Follicucullus* and excluded forms, in which on the outer side the segmentation is not more visible, but they left "*Follicucullus*" *monacanthus* ISHIGA & IMOTO, 1982 in this genus. This species is a transitional form between the genera *Parafollicucullus* HOLDSWORTH & JONES, 1980 and *Follicucullus* ORMISTON & BABCOCK, 1979. Its forerunner is *Parafollicucullus convexus* (RUDENKO & PANASENKO, 1990).

The so far known difference between *Follicucullus* and *Parafollicucullus* is the presence of two lateral wings at the pseudothorax in all *Parafollicucullus* species and the absence of these lateral wings in *Follicucullus*. "*F.*" *monacanthus* with only one wing at the pseudothorax is regarding to this feature equidistant to *Parafollicucullus* and *Follicucullus*. If we continue to place this species in *Follicucullus* then the original diagnosis of this genus has to be extended to include not only forms without lateral wings on the pseudothorax, but also forms with one lateral wing.

The new investigations of the transition from *Parafollicucullus* in *Follicucullus* have shown that not only the lateral wings of *Parafollicucullus*, but also the pseudothorax of this genus is totally reduced and included in the large apical cone of *Follicucullus*. The former pseudoabdomen of *Parafollicucullus* is by this transformed into the pseudothorax of *Follicucullus* (see under remarks to *Parafollicucullus convexus*). In "*Follicucullus*" *monacanthus* the pseudothorax of *Parafollicucullus* is still present, but it may be already totally reduced on the wingless side. Because the pseudothorax of "*F.*" *monacanthus* is homologous with the pseudothorax of *Parafollicucullus*, but not homologous with the pseudothorax of *Follicucullus* (homologous to the abdomen of *Parafollicucullus*, see above), "*F.*" *monacanthus* is by far closer related to *Parafollicucullus* than to *Follicucullus*. For this reason, this species is here placed into *Parafollicucullus*.

Because the *Follicucullus* ? *charveti*-*F. porrectus* of the *Lepidolina kumaensis* fusulinid Zone (?) of Japan belongs probably to the Dzhulfian (Araxoceratidae are present in this level), the genus *Follicucullus* begins near the base of the Dzhulfian (or Wuchiapingian).

***Follicucullus ventricosus* ORMISTON & BABCOCK, 1979**

(Pl. 3, Fig. 13)

1979 *Follicucullus ventricosus* n.sp. – ORMISTON & BABCOCK, p. 332–333, Pl. 1, Figs. 6–14.

Distribution: Upper Permian of Circum-Pacific realm and West Texas. So far unknown from the Upper Permian of Western Sicily.

Remarks: *Follicucullus ventricosus* ORMISTON & BABCOCK have been so far only reported from the Upper Permian of West Texas and Japan. The species was always correctly determined; therefore no synonymy list is given. Both in West Texas and in Japan *F. ventricosus* is a common form. In Japan it occurs in the entire Upper Permian. Therefore its absence in the Eurasian Tethys and on the Philippines is difficult to explain.

***Follicucullus bispinosus* n.sp.**

(Pl. 3, Figs. 10, 11)

Derivatio nominis: According to the dorsal columella that is bifurcated into two spines.

Holotype: The specimen on Pl. 3, Fig. 10; rep.-no. N 4062.

Locus typicus: Outcrop at the SE side of the US Highway 62-180, 16 km WSW of its intersection with Texas Ranch Road, 1108, Culberson County, West Texas. Western part of the Delaware Basin, about 7 km east of the reef, exposed in the Guadalupe Mts. Section H of ORMISTON & BABCOCK (1979).

Stratum typicum: Light-gray weathered black limestone of the Lamar Limestone Member, Bell Canyon Formation. Thin bed about 10 cm below the top of the outcrop. Lower Dzhulfian.

Material: 23 specimens.

Diagnosis: Apical cone very large, straight, unsegmented, but at its base sometimes with an indistinct, narrow ring. Pseudothorax large, elongated, inflated to a variable degree, along the dorsal side with a shallow sinus. Pseudoabdomen short, broad, somewhat ventralwards inclined. Aperture margin lobate in lateral view. Aperture elliptical in outline. Both free columellae are obliquely ventralwards directed. The ventral free columella is short, undivided. The dorsal free columella is very long, in full preservation up to 5 times longer than the ventral columella. It bears one long outer spine. The upper half of the dorsal columella is laterally broadened, the lower half is spine-like after the branching point of the outer spine. Within the test the columellae are totally fused with the shell margin. They range upward until the lower half of the apical cone, but are often not visible in transmitted light, except in the pseudoabdomen, where they are mostly visible.

Measurements:

Length of apical cone = 159-172 μm

Length of pseudothorax = 98-120 μm

Maximum width of pseudothorax = 91-105 μm

Length of pseudoabdomen = 52-70 μm

Maximum width of pseudoabdomen = 111-120 μm

Distribution: So far only known from the uppermost Lamar Limestone Formation (Early Dzhulfian age) of the type locality.

Remarks: *Follicucullus ventricosus* ORMISTON & BABCOCK, 1979 has no outer spine on the outer free columella.

***Follicucullus dilatatus* RUDENKO, 1984**

(Pl. 1, Figs. 4-6)

1983 *Follicucullus ventricosus* ORMISTON & BABCOCK - SUYARI, KUWANO & ISHIDA, Pl. 4, Figs. 6, (?)7, non ! Fig. 10.

1984 *Follicucullus dilatatus* RUDENKO, sp.nov. - BELJANSKIJ, NIKITINA & RUDENKO, p. 54-55, Pl. 8, Figs. 6, 7.

1984 *Follicucullus lagenarius* RUDENKO, sp.nov. - BELJANSKIJ, NIKITINA & RUDENKO, p. 55, Pl. 8, Fig. 11.

Material: Several 1000 specimens.

Diagnosis: Apical cone unsegmented, slightly curved or straight. Pseudothorax distinctly inflated, longer than broad, subcylindrical. Pseudoabdomen indistinct or missing. Distal free columella ventralwards curved, only rarely preserved.

Measurements:

Length of apical cone = 130-159 μm

Length of pseudothorax = 112-141 μm

Maximum width of pseudothorax = 94-106 μm

Distribution: Uppermost "Midian" Stage (uppermost Capitanian or lowermost Dzhulfian s.l.) of Primorje area (SE Siberia). Dzhulfian of Sosio Valley. Upper Dzhulfian *Neoaibaillella ornithoformis* Zone of Japan in the open oceanic fauna.

Remarks: In *Follicucullus lagenarius* RUDENKO, 1984 the pseudothorax is more abruptly separated from the apical cone than in *F. dilatatus* RUDENKO, 1984. However, all transitional forms are present between these two species in Sicily. Both in Sicily and in the Sichote Alin both species occur together in the same samples. *F. lagenarius* is therefore regarded as synonym of *F. dilatatus* (both species are figured in the same paper, *F. dilatatus* has page priority and the type material is better preserved than in *F. lagenarius*). Internal molds of *F. dilatatus* have always the character of *F. lagenarius*.

Follicucullus ventricosus ORMISTON & BABCOCK, 1979 has a short, but distinct pseudoabdomen, the apical cone is always straight, and it displays a low, ring-like segment at its base.

Follicucullus porrectus RUDENKO, 1984 with short, but distinct pseudoabdomen is similar, but the pseudothorax is not so wide.

***Follicucullus porrectus* RUDENKO, 1984**

(Pl. 1, Figs. 7-11)

1980 *Follicucullus scholasticus* ORMISTON & BABCOCK, pars. - ISHIGA & IMOTO, p. 340, Pl. 4, only Figs. 5-7.

1982 *Follicucullus scholasticus* ORMISTON & BABCOCK - ISHIGA, KITO & IMOTO, Pl. 2, Figs. 8-10.

1983 *Follicucullus scholasticus* ORMISTON & BABCOCK, pars. - SUYARI, KUWANO & ISHIDA, Pl. 3, Figs. 1, (?)2, 3-5, 7, (?)8, non ! Figs. 6, 9.

?1983 *Follicucullus ventricosus* ORMISTON & BABCOCK, pars. - SUYARI, KUWANO & ISHIDA, Pl. 4, Fig. 10, non ! Figs. 6, 7.

1984 *Follicucullus porrectus* RUDENKO, sp.nov. - BELJANSKIJ, NIKITINA & RUDENKO, p. 55-56, Pl. 8, Figs. 3, 10.

1984 *Follicucullus scholasticus* ORMISTON et BABCOCK, 1979. - BELJANSKIJ, NIKITINA & RUDENKO, p. 54, Pl. 8, Figs. 4, 5.

1984 *Follicucullus scholasticus* ORMISTON & BABCOCK, morphotype II, pars. - ISHIGA, Pl. 1, only Figs. 2-4, (?)5, (?)6.

1985 *Follicucullus scholasticus* ORMISTON & BABCOCK, morphotype II, pars. - ISHIGA, p. 180, Pl. 1, Figs. 22-28, Pl. 2, Figs. 2, 3, non (?) Figs. 1, 4 (perhaps strongly deformed *Follicucullus porrectus* n.sp.).

1985 *Follicucullus scholasticus* ORMISTON & BABCOCK, pars. - NAKA & ISHIGA, Pl. 1, Figs. 1, (?)2, 5, 7, non ! Figs. 3, (?)4, (?)6.

1985 *Follicucullus scholasticus* ORMISTON & BABCOCK, pars. - ISHIDA, Pl. 1, Fig. 6, non (!) Fig. 5.

1985 *Follicucullus* sp. cf. *scholasticus* ORMISTON & BABCOCK, pars. - WAKITA, Figs. 3/1, (?)3/2, non ! Figs. 3/4, 3/5.

1985 *Follicucullus ventricosus* ORMISTON & BABCOCK - WAKITA, Fig. 3/4.

1985 *Follicucullus scholasticus* ORMISTON & BABCOCK - SASHIDA & TONISHI, Pl. 7, Figs. 1, 3.

- ? 1986 *Follicucullus scholasticus* ORMISTON & BABCOCK, 1979. – ISHIGA & MIYAMOTO, p. 330–331, Pl. 64, Figs. 9–11.
- 1986 *Follicucullus scholasticus* ORMISTON & BABCOCK, morphotype II (in the plate explanations erroneously designated as morphotype I). – ISHIGA, WATASE & NAKA, p. 129, Pl. 2, Figs. 12–16, (?)17–19.
- 1987 *Follicucullus scholasticus* ORMISTON & BABCOCK, morphotype II ISHIGA – NISHIMURA & ISHIGA, Pl. 1, Figs. 4–6.
- ? 1987 *Follicucullus scholasticus* ORMISTON & BABCOCK, morphotype II ISHIGA (1984), pars. – PILLAI & ISHIGA, Pl. 1, only Fig. 10.
- 1988 *Follicucullus scholasticus* ORMISTON & BABCOCK (morphotype 1 sensu ISHIGA et al., 1986). – DE WEVER, BOURDILLON-DE GRISSAC & BECHENEC, Fig. 2A.
- 1989 *Follicucullus* n.sp. (*Follicucullus scholasticus*, morphotype II sensu ISHIGA). – CATALANO, DI STEFANO & KOZUR, Fig. 6 D.
- 1991 *Follicucullus japonicus* ISHIGA n.sp. – ISHIGA, p. 108–111, Pl. 1, Figs. 1–15; Pl. 2, Fig. 1.
- 1992 *Ishigaconus* n.sp. (= *Follicucullus scholasticus*, morphotype II sensu ISHIGA, 1985). – CATALANO, DI STEFANO & KOZUR, Fig. 6 L.

Material: Several 10.000 specimens.

Diagnosis: Test slender conical, also on the outer test surface clearly subdivided in apical cone, pseudothorax and pseudoabdomen. Apical cone long, unsegmented, straight or slightly curved, sometimes oblique. Pseudothorax, narrow, but distinctly broader than remaining test. Pseudoabdomen short to moderately long, situated mostly somewhat obliquely to the pseudothorax.

Measurements:

- Length of the apical cone = 110–200 μm
- Length of pseudothorax = 80–141 μm
- Maximum width of pseudothorax = 83–94 μm
- Length of pseudoabdomen = 59–100 μm

Distribution: (?) *Lepidolina kumaensis* fusulinid Zone (Upper Capitanian or Lower Dzhulfian / Lower Wuchiapingian) of Japan and time-equivalent beds of Sichote Alin (SE-Siberia), Dzhulfian s.str., (?) Changxingian of Japan, Upper Permian of Oman and Sicily.

Remarks: Despite of the huge amounts of specimens in the Sicilian material, no forms with preserved free columellae are present. Also in most of the Japanese material, the free columellae are broken away. Only ISHIGA (1991) published well preserved material, in which both free columella are mostly preserved. If they are present, both the dorsal and ventral free columella are obliquely ventralwards directed.

Follicucullus porrectus RUDENKO, 1984 corresponds to *F. scholasticus*, morphotype II sensu ISHIGA, 1984. However, this species is closer related to *F. ventricosus* ORMISTON & BABCOCK, 1979 than to *Ishigaconus scholasticus* ORMISTON & BABCOCK, 1979. It was described by ISHIGA (1991) as *Follicucullus japonicus* n.sp. that is a junior synonym of *F. porrectus* RUDENKO, 1984. The holotype of *F. porrectus* is a slender form with rather long pseudoabdomen. But it fits into the intraspecific variability, shown in the well preserved material by ISHIGA (1991). The paratype is a typical specimen. The rather big intraspecific variability can be also confirmed in the Sicilian material. However, *F. japonicus* ISHIGA, var. A and var. B do not belong to *F. porrectus* RUDENKO.

Slender representatives of *F. ventricosus* are very similar, but their pseudothorax is broader than in *F. porrectus* and the likewise broader pseudoabdomen is more obliquely arranged. Sometimes slender specimens of *F. ventricosus* have been included in *Follicucullus scholasticus*, morphotype II.

Ishigaconus scholasticus ORMISTON & BABCOCK displays a slender conical test that is on its outer surface undivided.

Whereas all previous authors placed *F. porrectus* into *F. scholasticus*, morphotype II, DE WEVER et al. (1988) placed this species into *F. scholasticus*, morphotype I. However, ISHIGA (1984) and all other previous authors designated all forms that correspond to the holotype of *F. scholasticus* ORMISTON & BABCOCK as morphotype I. Only in ISHIGA, WATASE & NAKA (1986) *F. scholasticus*, morphotype II was in the plate explanation erroneously designated by a printing mistake as morphotype I, but in the text of this paper both morphotypes have been correctly designated.

Genus: *Parafollicucullus*
HOLDSWORTH & JONES, 1980

Type species: *Parafollicucullus fusiformis* HOLDSWORTH & JONES, 1980

Parafollicucullus monacanthus
(ISHIGA & IMOTO, 1982)

(Pl. 1, Fig. 23)

- 1980 *Follicucullus* sp. A – ISHIGA & IMOTO, p. 340, Pl. 4, Figs. 11–15.
- 1982 b *Follicucullus monacanthus* ISHIGA & IMOTO n.sp. – ISHIGA, KITO & IMOTO, p. 276–277, Pl. 4, Figs. 15–19.
- 1990 *Follicucullus monacanthus* ISHIGA & IMOTO – GRAPES, LAMB et al., Fig. 69.

Material: One reworked specimen in sample 655 among huge amounts of Upper Permian radiolarians.

Distribution: Guideform for the Capitanian of Japan. The single specimen in the Dzhulfian of Western Sicily is surely reworked. This species indicates the presence of pelagic Capitanian in Western Sicily that has been so far not found in outcrops. Most probably, it consists of gray pelagic claystones, like the underlying Wordian and the overlying lowermost Dzhulfian.

Remarks: The new assignment of *P. monacanthus* (ISHIGA & IMOTO) to the genus *Parafollicucullus* is discussed under the remarks to the genus *Follicucullus*. The relation to *Parafollicucullus postfusiformis* n.sp. is discussed under this species.

Parafollicucullus convexus
(RUDENKO & PANASENKO, 1990)

(Pl. 1, Fig. 20)

- 1987 *Pseudoalbaillella* sp. cf. *P. fusiformis* (HOLDSWORTH & JONES), pars. – NISHIMURA & ISHIGA, p. 176–177, Pl. 1, only Fig. 14.
- 1988 *Follicucullus monacanthus* ISHIGA & IMOTO, 1980. – DE WEVER, BOURDILLON-DE GRISSAC & BECHENEC, Fig. 2 D.
- 1989 *Parafollicucullus* n.sp. – KOZUR in CATALANO et al., Fig. 6 H.
- 1990 *Pseudoalbaillella convexa* RUDENKO et PANASENKO, sp.nov. – RUDENKO & PANASENKO, p. 184, Pl. 18, Figs. 6, 7.

Material: 4 specimens.

Diagnosis: Apical cone long, mostly a little curved. Pseudothorax small, globular, with two short wings. The pseudoabdomen consists of a long, narrow neck without a ring-like, short segment, followed by a bottle-like to ellipsoidal part that is considerably broader than the neck. The last segment is short, a little ventralwards inclined. Dorsal and ventral free columellae short, obliquely ventralwards directed. Aperture at the lower end oval.

Measurements:

- Length of apical cone = 100–170 μm
- Length of pseudothorax = 41–63 μm
- Maximum width of pseudothorax = 58–70 μm
- Length of pseudoabdomen = 176–280 μm
- Width of neck (minimum width of pseudoabdomen) = 47–64 μm
- Maximum width of pseudoabdomen = 106–120 μm

Distribution: Capitanian, (?) Wordian. In Western Sicily and Oman very rare reworked (?) forms occur in Lower Dzhulfian deposits. In sequences of Japan this species occurs above the Wordian *Parafollicucullus fusiformis* HOLDSWORTH & JONES and below the Capitanian *Parafollicucullus monacanthus* (ISHIGA & IMOTO). In Primorje (SE-Siberia) *P. convexus* occurs in the lowermost part of the Capitanian *P. monacanthus* fauna.

Remarks: The few (?) reworked specimens of the Sicilian material are badly preserved. The upper part of the apical cone and the distal part of the test are always broken away. However, the diagnostic most important part, the small globular pseudothorax with its two wings, the following long, narrow neck without a ring-like segment and the following bottle-like part of the pseudoabdomen are always preserved.

Parafollicucullus fusiformis HOLDSWORTH & JONES, 1980 is distinguished by a distinct, narrow, ring-like segment on the shorter and not so narrow neck. Most similar to *P. convexus* are specimens of *P. fusiformis* with long, narrow neck, figured by TAZAWA et al. (1984). However, also these forms have a distinct, ring-like narrow segment in the middle part of the neck.

It is not sure, whether *P. convexus* has evolved directly from *P. fusiformis*. Together with *P. fusiformis*, but also before the first occurrence of this species, there occur forms, that NISHIMURA & ISHIGA (1987) placed together with *P. convexus* in *Pseudoalbaillella* sp. cf. *P. fusiformis* (NISHIMURA & ISHIGA, 1987, Pl. 1, Figs. 16–18). These forms have a broader, shorter neck than *P. convexus*, but also without narrow segment in the middle part of the neck. They are very similar to *Parafollicucullus nanjingensis* SHENG & WANG, 1985, which is only distinguished by the wider and shorter segment after the neck. May be, that *P. nanjingensis* is the forerunner of *P. convexus* (through transitional forms, like *P. sp. cf. P. fusiformis* sensu NISHIMURA & ISHIGA, 1987, Pl. 1, Figs. 16–18).

Parafollicucullus monacanthus (ISHIGA & IMOTO, 1982) evolved from *P. convexus* by disappearance of one wing on the pseudothorax. Simultaneously, the pseudothorax is strongly reduced and only at the wing side still hemiglobular. The other side of the pseudothorax is often already inseparable from the apical cone. Simultaneously with total disappearance of the wings also the pseudothorax disappears and the former neck (upper part of the pseudoabdomen), the former pseudothorax and the apical cone of *Parafollicucullus* are transformed into a single apical cone of *Follicucullus*. Therefore the lower big part of the pseudoabdomen in *Parafollicucullus convexus* and *P. monacanthus* is transformed into the pseudothorax of typical *Follicucullus*.

In well preserved material of *Follicucullus ventricosus* (type species), the former pseudothorax of *Parafollicucullus* is visible in transmitted light within the lower part of the apical cone. Even the narrow ring of the neck between the pseudothorax and pseudoabdomen of *Parafollicucullus fusiformis* is still present in *Follicucullus ventricosus* and situated there at the base of the apical cone, a further

evidence that the pseudothorax and the following neck of *Parafollicucullus* were transformed into the apical cone of *Follicucullus*.

The pseudothorax of *Follicucullus* is therefore not homologous to the pseudothorax in *Parafollicucullus*. For this reason "*Follicucullus*" *monacanthus* with *Parafollicucullus*-pseudothorax is here placed in *Parafollicucullus* (see also remarks to the genus *Follicucullus*). It is a transitional form to *Follicucullus* (beginning reduction of the wings and of the *Parafollicucullus*-pseudothorax), but all the main characters of the genus *Parafollicucullus* are still present and no feature of the real *Follicucullus* (absence of *Parafollicucullus*-pseudothorax, absence of lateral wings, transformation of the lower part of the *Parafollicucullus*-pseudoabdomen into the *Follicucullus*-pseudothorax) is already present.

In continuation of this development, in the most advanced *Follicucullidae* the whole outer segmentation disappeared or is only very indistinct.

DE WEVER, BOURDILLON-DE GRISSAC & BECHENNEC (1988) placed *Parafollicucullus convexus* into "*Follicucullus*" *monacanthus* ISHIGA & IMOTO, 1980. This species, however, has been only established in 1982. Moreover, the specimen, figured as "*F. monacanthus*" by DE WEVER et al. (1988) displays a well developed globular pseudothorax (unreduced on both sides) with the proximal part of two broken away lateral wings. This form has nothing to do with *P. monacanthus*.

The presence of *Parafollicucullus convexus* in Oman within a typical Upper Permian association with *Follicucullus porrectus* n.sp. and *Ishigaconus scholasticus* (ORMISTON & BABCOCK) is insofar important, as this species may really range into the Upper Permian. However, DE WEVER et al. (1988) have not given any sample data and any data about the distribution of the Permian radiolarians of Oman. Therefore it is not clear, whether the figured radiolarians have been derived from the same bed. Because only one sample (FB 703) is mentioned, all 3 figured forms by DE WEVER et al. (1988) may have been derived from a single sample. In this case, the Capitanian *P. convexus* may range upward (with few specimens) into the Dzhulfian or also in Oman reworking of Middle Permian radiolarians into Upper Permian radiolarian faunas occurs.

Genus: *Pseudoalbaillella* HOLDSWORTH & JONES, 1980

Type species: *Pseudoalbaillella scalprata* HOLDSWORTH & JONES

Pseudoalbaillella eurasiatica KOZUR, KRAHL & MOSTLER, 1989 (Pl. 1, Figs. 21, 22)

- 1982a *Pseudoalbaillella* sp. aff. *Ps. longicornis* ISHIGA & IMOTO – ISHIGA, KITO & IMOTO, Pl. 3, Fig. 11.
- 1982b *Pseudoalbaillella* sp. aff. *Ps. longicornis* ISHIGA & IMOTO – ISHIGA, KITO & IMOTO, p. 75, Pl. 2, Figs. 1–4, 6, non ! Figs. 5, 7.
- 1987 *Pseudoalbaillella* cf. *eurasiatica* KOZUR, KRAHL & MOSTLER in KOZUR & MOSTLER (im Druck). – KOZUR & KRAHL, p. 363, Figs. 4–6.
- 1989 *Pseudoalbaillella* (*Pseudoalbaillella*) *eurasiatica* KOZUR, KRAHL & MOSTLER n.sp. – KOZUR & MOSTLER, p. 177–178.
- 1989 *Pseudoalbaillella eurasiatica* KOZUR, KRAHL & MOSTLER – KOZUR in CATALANO et al., Fig. 6 F.
- 1990 *Pseudoalbaillella* aff. *P. longicornis* ISHIGA and IMOTO – TUMAN-DA, SATO & SASHIDA, Pl. 1, Fig. 4.

- 1991 *Pseudoalbaillella eurasiatica* KOZUR, KRAHL & MOSTLER – CATALANO, DI STEFANO & KOZUR, Pl. 6, Fig. 5.
 1992 *Pseudoalbaillella eurasiatica* KOZUR, KRAHL & MOSTLER – CATALANO, DI STEFANO & KOZUR, Fig. 6 I.

Material: 18 specimens.

Distribution: Wordian (Middle Permian) to Dzhulfian (Upper Permian) of Japan, Philippines, Crete (Greece) and Sicily.

Remarks: Representatives of *P. eurasiatica* KOZUR, KRAHL & MOSTLER with short pseudoabdomen have been reported from undoubtedly Dzhulfian radiolarian associations of Japan. Therefore such forms may belong to the autochthonous components of the Dzhulfian radiolarian faunas of Sicily.

Representatives with long pseudoabdomen (Pl. 1, Fig. 21) are surely reworked, because such forms are characteristic for the Wordian and lower Capitanian of the Eurasian Tethys.

Genus: *Ishigaconus* KOZUR & MOSTLER, 1989

Type species: *Follicucullus scholasticus* ORMISTON & BABCOCK, 1979

Ishigaconus scholasticus (ORMISTON & BABCOCK, 1979)

(Pl. 1, Figs. 1–3; Pl. 3, Figs. 9, 12)

- 1979 *Follicucullus scholasticus* n.sp. – ORMISTON & BABCOCK, p. 333–334, Pl. 1, Figs. 1–5.
 1989 *Ishigaconus scholasticus* ORMISTON & BABCOCK – KOZUR & MOSTLER, p. 181–182.

Material: Several 1000 specimens.

Distribution: Topmost Lamar Limestone of the Guadalupe Mountains (according to KOZUR, in press, of Dzhulfian age), Upper Permian of Japan, Philippines, Oman and Western Sicily.

Remarks: *Ishigaconus scholasticus* (ORMISTON & BABCOCK) have been reported in numerous papers from the whole Circum-Pacific realm, but also from Western Sicily and (type material) from West Texas. This easily determinable species was always correctly determined. Therefore only the original description and the change of the genus assignment is quoted in the reference list.

Often *Follicucullus porrectus* RUDENKO, 1984 was placed into "*Follicucullus*" *scholasticus* as well, but since ISHIGA (1984) mostly separated as morphotype II (see synonymy list of *Follicucullus porrectus*).

Ishigaconus bipartitus (CARIDROIT & DE WEVER, 1984) is easily to distinguish by its strongly curved apical cone. According to ISHIGA & MIYAMOTO (1986) "*Follicucullus*" *hamatus* CARIDROIT & DE WEVER, 1984 is a synonym of "*F.*" *bipartitus* CARIDROIT & DE WEVER, 1984, representing the isolated upper half of this species. This view is accepted in the present paper.

Ishigaconus furcus (CARIDROIT & DE WEVER, 1986) n. corr. is distinguished by the second spine on the dorsal free columella. Because the free columella are rarely fully preserved, the separation of these two species is difficult. The subdivision of the shell into two halves regarded by CARIDROIT & DE WEVER (1986) as characteristic feature of "*F.*" *furcus*, is also present in *I. scholasticus* (see ORMISTON & BABCOCK, 1979, Pl. 1, Figs. 3–5 and present

paper, Pl. 1, Fig. 2). This feature is especially well visible in slightly corroded specimens.

As pointed out by ORMISTON & BABCOCK (1979, p. 333), the dorsal free columella is not fully preserved in any specimen of the type series of *Ishigaconus scholasticus*. Therefore it was uncertain, whether the dorsal free columella of *I. scholasticus* has a second outer spine, as in *I. furcus*, or not. Re-investigations of excellently preserved material from the type locality have shown, that the second spine on the dorsal columella is also absent in specimens with fully preserved dorsal columella. Therefore *Ishigaconus furcus* (CARIDROIT & DE WEVER) is an independent species.

Genus: *Cariver* n.gen.

Derivatio nominis: Combined from CARIDROIT and DE WEVER, in honour of the authors of the type species

Type species: *Follicucullus orthogonus* CARIDROIT & DE WEVER, 1984

Diagnosis: Apical horn long, unsegmented. Pseudothorax large, inflated. Pseudoabdomen, partly also posterior part of pseudothorax ventralwards curved. Aperture oval, situated on the ventral side, perpendicularly or nearly perpendicularly to the test axis. A ventral sinus on the pseudothorax is always present, a dorsal sinus may be additionally present.

Assigned species:

Follicucullus orthogonus CARIDROIT & DE WEVER, 1984 *Cariver dorsoconvexus* n.sp.

Cariver n.sp. A (= *Follicucullus* sp. aff. *charveti* sensu CARIDROIT & DE WEVER, 1986).

Cariver n.sp. B (= *Follicucullus* sp. aff. *orthogonus* sensu CARIDROIT & DE WEVER, 1986).

Distribution: Circum-Pacific realm and Western Sicily. Restricted to the Upper Permian (Dzhulfian).

Remarks: In *Follicucullus* ORMISTON & BABCOCK, 1979 the aperture is always situated at the lower end of the test. Typical representatives of *Follicucullus* display a dorsal, but no ventral sinus in the pseudothorax.

Follicucullus ? *charveti* CARIDROIT & DE WEVER, 1984 is the forerunner of *Cariver* n.gen. and a transitional form between *Follicucullus* and *Cariver*. The pseudoabdomen of *F.?* *charveti* is mostly clearly inclined towards the ventral side and the aperture is mostly situated obliquely to the test axis towards the ventral side. A distinct ventral sulcus is present in the pseudothorax, like in all *Cariver* species. Unfortunately, the taxonomic importance of the presence of a ventral sulcus is unknown. If the presence of a ventral sulcus in the pseudoabdomen would be a taxonomically important feature, then *F.?* *charveti* CARIDROIT & DE WEVER, 1984 and *F.?* *falx* CARIDROIT & DE WEVER, 1984 should be placed into the genus *Cariver* n.gen.

By development of a strongly curved pseudoabdomen with ventrally situated aperture (perpendicularly to the test axis), *Cariver* n.sp. A developed from *F.?* *charveti*.

ISHIGA & MIYAMOTO (1986) regarded *Cariver orthogonus* (CARIDROIT & DE WEVER, 1984) as morphotype of *Follicucullus* ? *charveti* CARIDROIT & DE WEVER, 1984. However, the two forms that were figured as *F.?* *charveti*, morphotype *orthogonus* are transitional forms from *F.?* *charveti* to *Cariver* n.sp. A (ISHIGA & MIYAMOTO, 1986, Pl. 64, Fig. 5) or into *Cariver* n.sp. B (Pl. 64, Fig. 4). In these specimens the pseudoabdomen is clearly curved toward the ventral

side and the aperture lies obliquely to the test axis. This is also the case in all other forms, figured by ISHIGA & MIYAMOTO (1986) under *Follicucullus charveti*, only the degree of the bent of the pseudoabdomen is variable, like in the type series of *F. ? charveti*.

The drawing of *F. ? charveti* by CARIDROIT & DE WEVER (1984) with an aperture at the lower end of the test (in continuation of the test axis) is rather misleading compared with the photographs of the type material. The material published by ISHIGA & MIYAMOTO (1986) is by far better preserved than the type material of *F. ? charveti*, published by CARIDROIT & DE WEVER (1984). It shows clearly the transition character of *F. ? charveti* between *Follicucullus* and *Cariver*.

F. ? charveti begins in the latest Capitanian or earliest Dzhulfian (?) *Lepidolina kumaensis* Zone of Japan, whereas the typical *Cariver* species, including *Cariver orthogonus* (CARIDROIT & DE WEVER, 1984), began later, in undoubtedly Upper Permian deposits.

***Cariver dorsoconvexus* n.sp.**

(Pl. 1, Figs. 15–17, 19)

1989 *Follicucullus ?* n.sp. aff. *charveti* CARIDROIT & DE WEVER – KOZUR in CATALANO et al., Fig. 6 K.

1992 Highly evolved representative of the Follicucullidae (n.gen., n.sp.). – CATALANO, DI STEFANO & KOZUR, Fig. 6 K.

Derivatio nominis: According to the strongly convex dorsal margin of the pseudothorax and pseudoabdomen.

Holotype: The specimen on Pl. 1, Fig. 16; rep.-no CK/III-64

Material: Several 100 specimens.

Diagnosis: Apical horn long, straight or insignificantly curved. Pseudothorax large, inflated, inclined towards the dorsal side. Its dorsal margin is strongly convex and displays in well preserved specimens a shallow sulcus (Pl. 1, Fig. 15). The ventral margin is also convex and displays a broad, deep sulcus. The pseudoabdomen is long, strongly ventralwards curved. The oval aperture is situated in fully preserved specimens on the ventral side, perpendicularly (or nearly so) to the test axis. The dorsal margin of the pseudoabdomen is strongly convex, the ventral margin straight to slightly concave.

Measurements:

Length of apical horn = 106–129 μm .

Length of pseudothorax = 88–127 μm .

Maximum width of pseudothorax = 82–94 μm .

Length of pseudoabdomen = 59–71 μm .

Distribution: Dzhulfian of Sosio Valley area, Western Sicily.

Remarks: *Cariver dorsoconvexus* n.sp. is characterized by its strongly convex dorsal margin of pseudothorax and pseudoabdomen. This is mainly caused by a dorsalward bent of the pseudothorax before the ventralwards bent of the pseudoabdomen. No other *Cariver* species shows a dorsalward bent of the pseudothorax. In contrast, at least the distal part of the pseudothorax is in different degree ventralwards curved or inclined in the other *Cariver* species.

Genus: *Lacisus* n.sp.

Derivatio nominis: Arbitrary composition of letters.

Type species: *Lacisus siphunculus* n.gen. n.sp.

Diagnosis: Test slender, smoking-pipe-shaped. Apical cone very long, unsegmented. Pseudothorax elongated ellipsoidal, rather narrow, but distinctly broader than apical cone and pseudoabdomen. The long pseudoabdomen is in its apical part straight, in the following part curved perpendicularly or nearly perpendicularly to the test axis. Distal part of pseudoabdomen widened. Aperture round, situated on the ventral side, perpendicularly (or nearly so) to the test axis.

The inner structure of the pseudothorax and pseudoabdomen consists of densely spaced narrow rings (trabecles ?) that connect the two columellae. In slightly corroded specimens, this structure is seen also externally.

Distribution: Until now only known from the Dzhulfian of the Sosio Valley area, Western Sicily.

Assigned species:

Lacisus siphunculus n.gen. n.sp.

Lacisus n.sp.

Remarks: *Ishigaconus* KOZUR & MOSTLER, 1989 displays no long pseudoabdomen curved perpendicularly ventralwards against the test axis.

Cariver n.gen. displays a considerably broader pseudothorax and a laterally compressed pseudoabdomen with oval aperture. *Cariver* has only very few trabecles on the ventral side that do not reach the dorsal side.

***Lacisus siphunculus* n.gen. n.sp.**

(Pl. 1, Figs. 12–14)

Derivatio nominis: According to the shape of the test.

Holotype: The specimen on Pl. 1, Fig. 12; rep.-no. CK/1188 VI-33.

Material: Several 100 specimens.

Diagnosis: Apical cone very long, straight, unsegmented. Pseudothorax elongated-ellipsoidal, long, with gradual transition to both apical cone and pseudoabdomen. The narrow, densely spaced rings between the dorsal and ventral columellae are especially well developed in the distal half of the pseudothorax. Pseudoabdomen long, strongly curved, distal part situated perpendicularly (or nearly so) to the test axis. The distal part of the pseudoabdomen is strongly widened and often somewhat wider than the pseudothorax. Aperture round, situated on the ventral side of the test, perpendicularly (or nearly so) to the test axis.

Measurements:

Length of apical cone = 108–147 μm .

Length of pseudothorax = 118–147 μm .

Maximum width of pseudothorax = 71–82 μm .

Length of pseudoabdomen = 129–165 μm .

Distal diameter of pseudoabdomen = 71–85 μm .

Distribution: Only known from the Dzhulfian of the Sosio Valley area.

Remarks: *Lacisus* n.sp. (Pl. 1, Fig. 18) displays a sigmoidally bent test. The pseudothorax of this species is only a little wider than adjacent parts of the test.

Suborder: Entactinaria
KOZUR & MOSTLER, 1982
Superfamily: Palaeoscenidiacea
RIEDEL, 1967
Family: Hindeosphaeridae
KOZUR & MOSTLER, 1981
Genus: *Hindeosphaera*
KOZUR & MOSTLER, 1979

Type species: *Hindeosphaera foremanae* KOZUR & MOSTLER, 1979

***Hindeosphaera* ? n.sp.**

(Pl. 2, Fig. 3)

Remarks: By the presence of a single main spine and numerous by-spines this very rare form is similar to the Triassic Entactinaria genus *Hindeosphaera* KOZUR & MOSTLER, 1979. However, it is considerably smaller and the inner structures are unknown. There are also some morphological similarities to Jurassic and Cretaceous Nassellaria.

Family: Hexaporobrachiidae
KOZUR & MOSTLER, 1979

***Mostlerispongus* n.gen.**

Type species: *Mostlerispongus sosioensis* n.gen. n.sp.

Derivatio nominis: In honour of Prof. Dr. H. MOSTLER, Innsbruck.

Diagnosis: Spongy shell globular to slightly ellipsoidal, with 6 spongy, short round arms with the same diameter throughout their length. These arms are arranged in 3 axes, perpendicularly to each other. All arms end in a terminal, basally carinate spine of round cross section.

Assigned species:

Mostlerispongus sosioensis n.gen. n.sp.

Distribution: Dzhulfian of Western Sicily. Upper Permian of Philippines.

Remarks: *Hexaporobrachia* KOZUR & MOSTLER, 1979 is double-walled and has coarse outer pore frames.

***Mostlerispongus sosioensis* n.sp.**

(Pl. 2, Fig. 5)

Derivatio nominis: According to the occurrence in the Sosio Valley area.

Holotype: The specimen on Pl. 2, Fig. 5; rep.-no CK/III-65.

Material: 7 specimens.

Diagnosis and distribution: As for the genus.

Measurements:

Diameter of shell = 150–277 μm .

Length of arms = 118–161 μm .

Diameter of arms = 71–123 μm .

Remarks: The figured specimen from the Busuanga Island, Philippines (TUMANDA, TADASHI & SASHIDA, 1990) is larger than the material of Western Sicily, but otherwise identical. The measurements of this specimen were taken into consideration in the above measurements.

Suborder: Nassellaria EHRENBERG, 1875
Superfamily: Eucyrtideacea
EHRENBERG, 1847
Family: Syringocapsidae
FOREMAN, 1973
Genus: *Urocyrtis*
PANTANELLI, 1880 emend.

Type species: *Urocyrtis amaliae* PANTANELLI, 1880

Synonyma: *Syringocapsa* NEVIANI, 1900; *Gigi* DE WEVER, 1982

Emended diagnosis: Slender elongated proximal part with 1–3 small segments, on the outer surface not clearly separated from each other. Apical horn often present. The distal segment is very large, globular or a little ellipsoidal. It bears a moderately to very long hollow tubus with mostly large pores. Test wall with pores.

Remarks: All *Urocyrtis* species (including the later designated type species *U. amaliae* PANTANELLI, 1880), established by PANTANELLI (1880), display a slender elongated apical part, built up of one-two segments (outside mostly not separated by constrictions) and a big globular to slightly ellipsoidal distal segment that ends in a very long, narrow, hollow distal tubus. No spines are present at the large segment.

The same structure displays *Theosyringium robustum* VINCIGUERRA, 1900, the type species of *Syringocapsa* NEVIANI, 1900. Only the distal tubus is considerably shorter in this species. But the length of the distal tubus is highly variable in this group. Moreover, if the distal tubus is very long, it is often not preserved in its full length.

The genus *Gigi* DE WEVER, 1982 has a very long distal tubus, like the type species of *Urocyrtis*. No differences are recognizable between *Gigi* DE WEVER, 1982 and *Urocyrtis* PANTANELLI, 1880. Therefore also *Gigi* DE WEVER, 1982 is a junior synonym of *Urocyrtis* PANTANELLI, 1880.

***Urocyrtis* ? sp.**

(Pl. 2, Fig. 2)

Remarks: This species is very similar to *Urocyrtis* PANTANELLI that is, however, only known since the Norian. In contrast to *Urocyrtis*, the distal tube ends in a (? solid) part without pores. However, in some Upper Triassic *Urocyrtis* the tubus may be terminally closed and its distal part has so small pores that it looks poreless in recrystallized specimens.

Unfortunately, the inner features of the Upper Permian forms are unknown. Their generic assignment is therefore unsure, but it is very probable that these forms belong to the Nassellaria.

Suborder: Spumellaria EHRENBERG, 1875
Superfamily: Actinommmacea HAECKEL, 1862
emend. KOZUR & MOSTLER, 1979
Family: Praeconocaryommidae
PESSAGNO, 1976
Genus: *Phaenicosphaera*
HAECKEL, 1887

Type species: *Carposphaera nodosa* HAECKEL

Remarks: The genus *Phaenicosphaera* HAECKEL is a very conservative taxon, present at least since the Lower Permian. Several genera have been established for this taxon. At least the Upper Paleozoic and Mesozoic genera are inseparable from each other, but also the Recent *Phaenicosphaera* cannot be separated at the present stage of our knowledge from these Upper Paleozoic – Mesozoic forms.

NAZAROV & ORMISTON (1985) introduced the new genus *Hegleria* without any discussion of similar Mesozoic and Cenozoic genera that have been established for these forms since the last century.

I agree with SHENG & WANG (1985) that all these simple forms with mammae and 2–3 medullary shells, connected to each other by numerous spines, should be placed in *Phaenicosphaera* HAECKEL. At least *Hegleria* NAZAROV & ORMISTON (1985) is inseparable from the Triassic–Upper Cretaceous *Praeconocaryomma* PESSAGNO, 1976 that was seemingly unknown to NAZAROV & ORMISTON (1985).

***Phaenicosphaera mammifera*
(NAZAROV & ORMISTON, 1985)**

(Pl. 2, Fig. 1)

1985 *Hegleria mammifera* NAZAROV & ORMISTON, n.sp. – NAZAROV & ORMISTON, p. 22–23, Pl. 6, Figs. 3–5.

1989 *Phaenicosphaera mammifera* (NAZAROV & ORMISTON). – KOZUR in CATALANO et al., Fig. 6 I.

1991 *Phaenicosphaera mammifera* (NAZAROV & ORMISTON). – CATALANO, DI STEFANO & KOZUR, Pl. 6, Fig. 6.

1992 *Phaenicosphaera mammifera* (NAZAROV & ORMISTON). – CATALANO, DI STEFANO & KOZUR, Fig. 6 J.

Material: Several 1000 specimens.

Distribution: Middle and Upper Permian. World-wide.

Remarks: The Roadian *Phaenicosphaera mamilla* SHENG & WANG, 1985 has larger mammae.

**Superfamily: Ruzhencevispongacea
KOZUR, 1980**

Synonym: *Latentifistulacea* NAZAROV & ORMISTON, 1983

**Family: Latentifistulidae
NAZAROV & ORMISTON, 1983**

**Genus: *Latentifistula*
NAZAROV & ORMISTON, 1983**

Type species: *Latentifistula crux* NAZAROV & ORMISTON, 1983

***Latentifistula* n.sp.**

(Pl. 2, Fig. 6)

Material: 3 specimens.

Description: 3 arms diverging at 120°. The arms become distalwards slightly wider. They are in the central part very high, terminally low. Pores small, irregularly arranged. Inner features unknown.

Measurements:

Length of arms = 235–241 μm .

Width of arms (central) = 64–71 μm .

Width of arms (subterminal, widest part) = 93–96 μm .

Distribution: Dzhulfian of the Torrente San Calogero section.

Remarks: This species is clearly distinguished from all other *Latentifistula* species by the cross section of the arms (very high in the central part, low in the distal part).

Unfortunately, the preservation is too bad for establishing a new species.

Suborder, superfamily and family inc.

Genus: *Gustefana* n.gen.

Derivatio nominis: Arbitrary combination.

Type species: *Gustefana obliqueannulata* n.gen.

Diagnosis: Test large, slender conical to cylindrical. Pore frames consisting of oblique rings and often indistinct vertical ridges.

Assigned species:

Gustefana obliqueannulata n.gen. n.sp.

Gustefana sp.

Distribution: Abundant in the Upper Permian of Western Sicily.

Remarks: This genus is perhaps an aberrant representative of the Ruzhencevispongacea KOZUR, 1980 with only one arm. The internal structure is, however, unknown. Therefore the systematic position of the new genus is uncertain.

***Gustefana obliqueannulata* n.gen. n.sp.**

(Pl. 2, Figs. 8–10; Pl. 3, Figs. 1, 2, 4, (?)6, 7, 8)

Derivatio nominis: According to the oblique pore rings.

Holotype: The specimen on Pl. 3, Fig. 1, rep.-no. CK 1188/VI-38 Material: Several 1000 specimens.

Diagnosis: Large, slender, slightly conical test. Pore frames consisting of oblique rings and often indistinct vertical ridges.

Measurements:

Length of test = 618–1065 μm .

Maximum width of test = 176–225 μm .

Minimum width of test = 75–106 μm .

Distribution: Abundant in the Dzhulfian of Western Sicily.

Remarks: *Gustefana* n.sp. has a cylindrical test.

None of the numerous specimens is fully preserved. The apical tip is always broken away. Despite of this fact, the form is described here, because it is one of the most characteristic and abundant radiolarians of the Dzhulfian in Western Sicily, and well distinguished from all hitherto known radiolarians.

Gen. et spec. indet.

(Pl. 2, Fig. 4)

Material: 1 specimen.

Remarks: This form with a globular shell and two round polar spines is probably a representative of the Entactinaria. The preservation is very bad and the inner structure is unknown. Therefore the systematic position of this form is doubtful.

4. Paleoecologic Evaluation of the Radiolarian Faunas

According to KOZUR (1991 a, b) the paleopsychrospheric ostracod fauna from the radiolarian-bearing sample 655 indicates psychrospheric conditions on the margin of the oceanic Permian Tethys. These conditions require an unrestricted deep-water connection to the world ocean to include these areas in the oceanic deep-water circulation. In subtropical to tropical areas to which belong the westernmost Tethys during the Permian, psychrospheric conditions indicate a water depth below 500 m.

This paleoecologic evaluation of the ostracod faunas is supported by other faunal elements. The conodonts consist of pelagic deep-water species of Circum-Pacific character. Rich trace fossil associations in the Lower Permian part of the sequence belong to the deep-bathyal to abyssal *Nereites* ichnofacies with abundant *Palaeodictyon*.

Also the radiolarian faunas with dominating Albaillellacea indicate unrestricted deep-water connections. This could be confirmed by investigations of the Permian radiolarian faunas of the Delaware Basin. The Permian reef slope of the Guadalupe Mountains at the margin of the Delaware Basin corresponds to the present day SE slope of the Guadalupe Mountains. The water depth during the deposition of the Permian sequence in the Delaware Basin is therefore well known.

The shallow-water radiolarian association down to 50 m water depth consists almost exclusively of Copicyntrinae KOZUR & MOSTLER, 1989. The interval of 50–500 m water depth is dominated by Entactinaria, accompanied in the shallower water depths by Copicyntrinae, below 200 m by the first rare Albaillellacea.

In water depth below 500 m, Albaillellacea are dominating, accompanied by variable amounts of Entactinaria, Ruzhencevispongaacea and *Phaenicosphaera*. With growing distance from the margin of the basin, the percentage of Entactinaria drops, whereas the percentage of Albaillellacea and partly also of *Phaenicosphaera* increases.

Both the Lower Permian and the Dzhulfian radiolarian faunas of Western Sicily are dominated by Albaillellacea and *Phaenicosphaera*. Ruzhencevispongaacea are rare. Entactinaria are nearly missing. Copicyntrinae are missing. These radiolarian faunas indicate off-shore deep-water assemblages. Similar assemblages are known from Permian cherts of Oman, China, Philippines and Japan.

5. Biostratigraphic Evaluation of the Radiolarian Faunas

Conodonts and radiolarians are the stratigraphically most important fossils in pelagic Permian deposits. Ammonoids are important as well, but in off-shore deep-water deposits, like in the Sicilian Paleogeographic Domain of Western Sicily, nearly absent. Only in the reef-slope or base-of-slope deposits of the Sosio Limestone blocks and in olistoliths of facially similar rocks ammonoids have been found.

In cherts and deep-water claystones and siltstones even pelagic conodonts are very rare or absent and mostly represented by smooth gondolellids that are of lesser stratigraphic value than the often sculptured conodonts of

Table 1.
Radiolarian zonation of the Tethyan and Circum-Pacific Permian.

Stage	Substage	Radiolarian Zone
Changxingian		Neoalbaillella grypa Zone
Dzhulfian		Neoalbaillella ornithoformis Zone
		Follicucullus ventricosus - Ishigaconus scholasticus A.Z.
Capitanian		Follicucullus charveti - F. porrectus A.Z.
		Follicucullus monacanthus Zone
		Parafollicucullus fusiformis - Parafollicucullus globosus A.Z.
Wordian		Parafollicucullus longtanensis Zone
Roadian		Spinodeflandrella foremanae - Parafollicucullus cornelli A.Z.
Leonardian		Pseudoalbaillella rhombothoracata Zone
		Parafollicucullus ornatus Zone
Artinskian	Baigendzhinian	Parafollicucullus lomentarius A.Z.
	Aktastinian	
Sakmarian	Sterlitamakian	
	Tastubian	Pseudoalbaillella (Kitoconus) elegans Zone
Asselian		Curvalbaillella uforma A.Z.
Upper Gzhelian (Carboniferous)		Curvalbaillella bulbosa Zone

near-shore or shallow pelagic environments. In these offshore deep-water deposits the radiolarians are the stratigraphically most important fossils. The correlations of these radiolarian faunas with other faunas are, however, often difficult. Fusulinids and most of the conodont faunas, reported from such deposits, have been derived from olistoliths or tectonic blocks inside these deep-water sequences. These rocks have often a different age as the radiolarian-bearing matrix that is in general free of macrofauna and barren or very poor in conodonts.

For the above reasons, the radiolarian successions are often well known (Tab. 1), but their correlation with the marine Permian standard is still disputed. Radiolarian faunas of well dated Permian sequences, as in the Delaware Basin of West Texas and in the Sicilian Palaeogeographic Domain of Western Sicily, are therefore very important for the correlation of the radiolarian zonation with the international standard.

Unfortunately, these radiolarian faunas have been erroneously dated for long time. The red Dzhulfian claystones of the Sosio Valley have been placed for long time into the Tertiary and only CATALANO, DI STEFANO & KOZUR (1988 a, b, 1991, 1992) have proven an Upper Permian age for these deposits. Surprisingly, also the radiolarian faunas from the Delaware Basin have been erroneously dated (ORMISTON & BABCOCK, 1979; NAZAROV & ORMISTON, 1985; CORNELL & SIMPSON, 1985). Especially the dating of the *Follicucullus ventricosus-Ishigaconus scholasticus* fauna of the uppermost Lamar Limestone as Capitanian (Middle Permian) by ORMISTON & BABCOCK (1979) and NAZAROV & ORMISTON (1985) has hindered very much the correct application of the radiolarian zonation in the Upper Permian of the Tethys.

The *F. ventricosus-I. scholasticus* radiolarian fauna was originally described by ORMISTON & BABCOCK (1979) from the uppermost Lamar Limestone of a road cut on US Highway 62-180. They placed this fauna in the Capitanian, like most of the American authors before. Only FURNISH (1983) recognized that at least the larger part of the Lamar Limestone is post-Capitanian and he placed this member in his post-Capitanian / pre-Dzhulfian Amarassian Stage.

Re-investigations of the type locality of *F. ventricosus* and *I. scholasticus* (road cut on the US Highway 62-180) and of other localities of the uppermost Lamar Limestone Member have shown that the *F. ventricosus-I. scholasticus* fauna is accompanied by Dzhulfian conodonts. In the underlying beds *Mesogondolella "babcockae"* (CLARK & BEHNKEN) is present. The holotype of this species is inseparable from *M. postserrata* BEHNKEN and therefore *M. babcockae* is a junior synonym of *M. postserrata*. However, most of the specimens placed by CLARK & BEHNKEN (1979) into "*Neogondolella "babcockae"* are separable from *M. postserrata* as an independent species.

In the lower Lamar Limestone typical *M. postserrata*, the Capitanian guideform, is present and *M. "babcockae"* (*Mesogondolella* n.sp. A) is still absent. In these beds *Yabeina lamarensis*, an advanced Middle Permian (Capitanian) fusulinid is present. This genus is characteristic for the Abadehian Stage (junior synonym: Midian Stage) of the Eurasian Tethys. Therefore the lower Lamar Limestone belongs undoubtedly to the Middle Permian Guadalupian Series (Capitanian Stage).

An Early Dzhulfian age of the uppermost Lamar Limestone is not only indicated by conodonts (*Clarkina changxingensis italica* n. subsp., *Clarkina* n.sp., *Mesogondolella* n.sp. A), but also by the *F. ventricosus-I. scholasticus* radiolarian fauna.

This fauna occurs in Japan in undoubtedly Dzhulfian deposits. Because of the assumed Capitanian age of the type material of these species in West Texas, the Japanese radiolarian workers placed the *F. ventricosus-I. scholasticus* Zone in the upper Capitanian-Lower Dzhulfian. However, no Capitanian faunal elements occur together with these radiolarians in Japan.

The oldest radiolarian fauna of Late Permian character in Japan is characterized by *Follicucullus porrectus* RUDENKO (= *Follicucullus scholasticus*, morphotype II sensu ISHIGA, 1984), *F.? charveti* CARIDROIT & DE WEVER, *Ishigaconus bipartitus* (CARIDROIT & DE WEVER), *Pseudoalbaillella eurasiatica* KOZUR, KRAHL & MOSTLER and *Nazarovella gracilis* DE WEVER & CARIDROIT. Both *F. ventricosus* and *I. scholasticus* are not yet present in this fauna. However, *F. porrectus*, common in this fauna, is the direct forerunner of *I. scholasticus*. Undoubtedly, this *F.? charveti-F. porrectus* fauna is older than the *F. ventricosus-I. scholasticus* fauna of the uppermost Lamar Limestone that follows in Japan immediately above the *F.? charveti-F. porrectus* fauna (ISHIGA, 1984).

The age of the *F.? charveti-F. porrectus* fauna of Japan has been well dated by ISHIGA & MIYAMOTO (1986). They could prove that the *F.? charveti-F. porrectus* fauna corresponds to the *Lepidolina kumaensis* Zone of the fusulinid zonation. However, the shallow-water fusulinids may be reworked and older than the Dzhulfian pelagic faunas (radiolarians, ammonoids).

The age of the *Lepidolina kumaensis* Zone has been disputed. Most of the Japanese Permian stratigraphers placed this zone into the Dzhulfian. KOTLIAR et al. (1989) have shown that this zone is older than the type Dzhulfian of Transcaucasia and they placed therefore the *L. kumaensis* Zone into the "Midian Stage" (junior synonym of the Abadehian that is, in turn, a junior synonym of the Capitanian). However, the "Midian" / Dzhulfian boundary of Transcaucasia is characterized by a facies-controlled immigration of Dzhulfian fossils (fusulinids, brachiopods, conodonts, ammonoids, often in this order) on a sinking carbonate platform. The uppermost "Midian" rocks are extremely shallow-water algal-foraminifer limestones, in which even fusulinids are missing. The overlying lowermost Dzhulfian rocks are shallow pelagic, followed by pelagic ammonoid- and conodont-rich limestones. The immigration of the Dzhulfian ammonoid- and conodont faunas is not contemporaneous with the first appearance of these faunas. The typical Dzhulfian araxoceratids among the ammonoids are already present in the *L. kumaensis* Zone. This Zone has therefore already a Dzhulfian fauna, but it is older than the type Dzhulfian of Transcaucasia.

The base of the Dzhulfian has to be redefined outside the Dzhulfian type area. Best suitable are sections in South China, where in some places the Wuchiapingian follows without break above the Middle Permian Maokouan within pelagic or shallow-water rocks. In this case, however, the term Dzhulfian should be replaced by the term Wuchiapingian.

If the *Lepidolina kumaensis* Zone were finally placed into the Dzhulfian (or Wuchiapingian), the largest part of the Lamar Limestone of West Texas (all beds above the horizon with *Yabeina lamarensis* in the lower Lamar Limestone) would be placed into the Dzhulfian (or Wuchiapingian).

All faunas above the *Lepidolina kumaensis* Zone in Japan are undisputed Upper Permian (Dzhulfian and Changxingian). Thus, the Dzhulfian age of the *F. ventricosus-I. scholasticus* fauna (that follows immediately above the *F.? charveti-F. porrectus* fauna of the *Lepidolina kumaensis* Zone), is un-

far assumed, but Early Dzhulfian in age. The *F. ventricosus*-*I. scholasticus* Zone of Japan is therefore not of Late Capitanian age (assumed because of the Capitanian assignment of this fauna in West Texas) and Early Dzhulfian age (dated by accompanying faunas in Japan), but exclusively of Early Dzhulfian age.

This new age determination of the *F. ventricosus*-*I. scholasticus* Zone in its type locality is very important for the age determination of the Upper Permian radiolarian fauna of Western Sicily. *Ishigaconus scholasticus* (ORMISTON & BABCOCK) and the genus *Cariver* n. gen. are common in this fauna. Both are restricted in Japan to the Upper Permian and Dzhulfian respectively. *Mostlerispongus sosioensis* n.sp. is also known from the Upper Permian of the Philippines, figured as *Octatormentum* sp. Upper Dzhulfian and Changxingian radiolarians, like *Imotoella excelsa* (ISHIGA, KITO & IMOTO), *I. levis* (ISHIGA, KITO & IMOTO), *Neobaillella ornithoformis* TAKEMURA & NAKASEKO, *N. optima* ISHIGA, KITO & IMOTO, and *N. grypa* ISHIGA, KITO & IMOTO are missing in these beds. Therefore the radiolarian faunas of the lower part of the red claystones and of the uppermost light-gray claystones in the Torrente San Calogero section indicate Early Dzhulfian age.

This Dzhulfian age for the lower part of the red claystones of the Torrente San Calogero section is confirmed by the conodont fauna with *Clarkina changxingensis italica* KOZUR, *C. sosioensis* GULLO & KOZUR and *Hindeodus typicalis* (SWEET). Changxingian conodonts are missing in these beds. They are present in the upper part of the red claystones, where *C. subcarinata* (SWEET), *C. changxingensis changxingensis* (WANG & WANG), *C. deflecta* (WANG & WANG) are common. No determinable radiolarians have been found in these Changxingian beds.

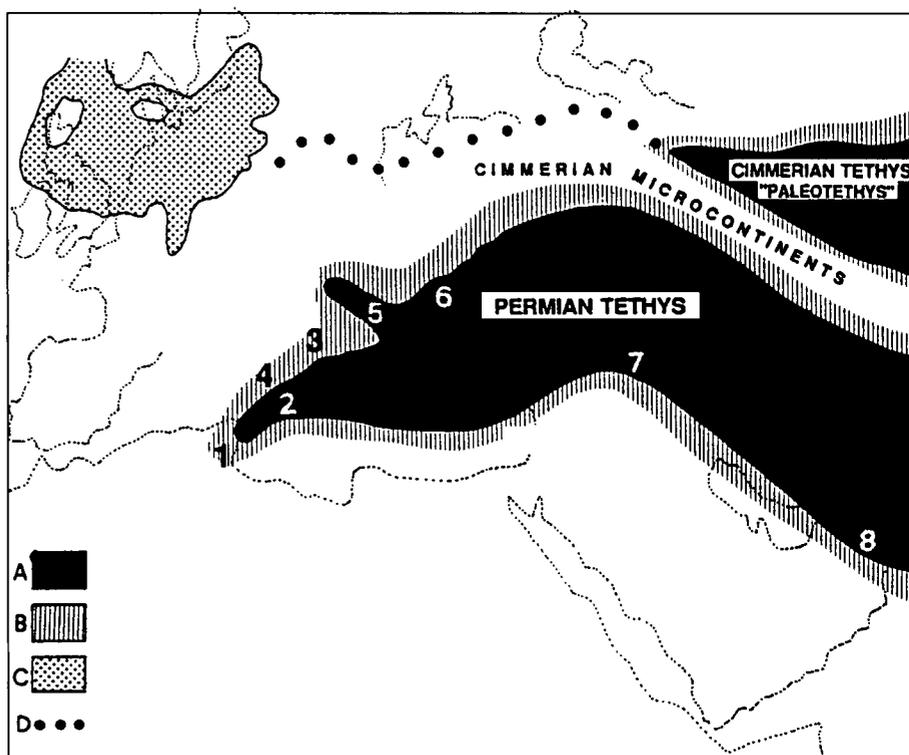
Whereas the Lower Permian is rich in Albaillellacea-dominated radiolarian faunas of latest Artinskian and Lower Leonardian age, described by KOZUR in CATALANO et al. (1989), the Middle Permian of the Sosio Valley area yielded so far only few and badly preserved radiolarians. Only *Parafollicucullus cornelli* KOZUR & MOSTLER, 1989 and *Pseudoalbaillella cf. scalprata* HOLDSWORTH & JONES, 1980 could be determined. *P. cornelli* is an index form of the *Spinodefflandrella foremanae-Parafollicucullus cornelli* A.Z. The age of this fauna has been disputed.

CORNELL & SIMPSON (1985) and NAZAROV & ORMISTON (1985) originally described this fauna from the "Bone Spring Limestone" of the Delaware Basin. NAZAROV & ORMISTON (1985) correlated the Bone Spring Formation and overlying Cutoff Formation with the Artinskian of the Cis-Urals and pointed out that the radiolarian fauna from the upper Bone Spring

Formation of the Delaware Basin has even pre-Artinskian character.

The reason for this opinion is not clear. The *S. foremanae-P. cornelli* fauna is a transitional fauna between Lower and Middle Permian radiolarian complexes. In other faunas (e.g. ammonoids, conodonts) such faunas with Middle and Lower Permian elements are characteristic for the Roadian, the lower Stage of the Middle Permian Guadalupian Series. For this reason, KOZUR & MOSTLER (1989) rejected the correlation of the Bone Spring- and Cutoff Formation with the Artinskian and they pointed out that the radiolarian fauna of the upper "Bone Spring Formation" of the Delaware Basin is considerably younger than the type Artinskian and can not be older than Upper Chihisian (= uppermost Leonardian). This lowermost assignment was not based on radiolarians, but on conodonts, because the uppermost Bone Spring Formation contains *Mesogondolella idahoensis* (YOUNGQUIST, HAWLEY & MILLER), an index species for the Chihisian (= middle and upper Leonardian).

In two excursions in spring 1991 under guidance of Prof. D. LEMONE, El Paso, and Prof. B.F. GLENISTER, Iowa City, numerous samples have been taken from the classical "Bone Spring Limestone" outcrop from a road cut on the northwestern side of the U.S. Highway 62-180, 3 km NE of



Text-Fig. 4.

Simplified paleogeographic reconstruction of the Permian Tethys during the Middle Permian time. Based on new data about the Permian of Sicily, Crete, Oman and Fariman (eastern Iran) by KOZUR & KRAHL (1987), CATALANO, DI STEFANO & KOZUR (1988 a, b, 1989, 1991, 1992), KOZUR (1989, 1991 a, b), DE WEVER, BOURDILLON-DE GRISSAC & BECHENNEC (1988), KOZUR & MOSTLER (1989, 1991).

A = deep-water areas, partly oceanic. B = shallow-water areas, partly hypersaline; in Transcaucasia, central Iran and western Turkey during the Upper Permian also pelagic. The shallow-water areas are not shown in their full extent. Only the assumed boundary between deep-water and shallow-water is indicated. C = Place of the Dzhulfian-Lower Changxingian predominantly hypersaline Zechstein Basin. D = Place of the later opening of the northern branch of the early Tethys: toward the west until the Pontides during the Dzhulfian, until the Transylvanides (Eastern Carpathians) during the Upper Scythian and in the Meliata-Hallstatt sphenochasma during the upper Lower Anisian and Pelsonian.

1 = Middle Permian shallow-water deposits, partly with pelagic influx in Tunisia. 2 = Permian deep-water deposits and subordinate reef-slope deposits in western Sicily (Sicilian domain). 3 = shallow-water Middle and Upper Permian deposits of the Lagonegro domain in southern Apennines and its possible prolongation (4) in the Imerese domain of Sicily. 5 = "Clastic Trogkofel Beds" with partly pelagic Lower and basal Middle Permian, overlain by shallow-water Middle and Upper Permian limestones. 6 = Phyllite Unit of Crete with pelagic Bashkirian to Lower Triassic deposits. 7 = Middle Permian pelagic limestones in Kurdistan, northeastern Iraq. 8 = Middle to Upper Permian radiolarites in Oman.

its junction with Texas Highway 54, S of the Guadalupe Mountains (for locality data see CORNELL & SIMPSON, 1985, Text-Fig. 1). This is the type locality for all guideforms of the *S. foremanae*-*P. cornelli* A.Z.

According to a pers. comm. of Dr. L.L. LAMBERT, Iowa City, these beds do not belong to the Bone Spring Formation, but to the upper Cutoff Formation. This is confirmed by a conodont fauna with *Mesogondolella nankingensis* CHING [(junior synonym: *M. serrata* (CLARK & ETHINGTON))] and *Neostreptognathodus clinei* BEHNKEN. This conodont fauna indicates Roadian age, like the ammonoids (SPINOSA, FURNISH & GLENISTER, 1975). By this the view of KOZUR & MOSTLER (1989) is confirmed that the *S. foremanae*-*P. cornelli* Zone is considerably younger than the Artinskian.

According to the above data, the *S. foremanae*-*P. cornelli* Zone belongs to the Roadian Stage. The radiolarians of the matrix of the Olistostrome Unit indicate therefore the same age as the conodonts with *Mesogondolella phosphoriensis* (YOUNGQUIST, HAWLEY & MILLER) and *Sweetognathus subsymmetricus* WANG, RITTER & CLARK. The latter species is one of the Roadian index species.

6. Paleogeographic Implications

The presence of a Circum-Pacific, Albaillellacea-dominated off-shore deep-water radiolarian fauna throughout the Permian (at least since the uppermost Artinskian) indicates a broad, open deep-water connection of the Sicilian Paleogeographic domain of Sicily with the Permian Pacific. This is also indicated by the presence of paleo-psychrospheric ostracods (KOZUR, 1991 a, b), pelagic

conodonts and trace fossils of the deep-bathyal to abyssal *Nereites* ichnofacies with *Palaeodictyon*.

This stable connection throughout the Permian indicates that the Permian oceanic Tethys reached by far further towards the W as so far assumed. This Permian Western Tethys was situated in the S, immediately north of Gondwana (Text-Fig. 4). The Cimmerian Tethys in the N, often designated as "Paleotethys", extended in the Lower and Middle Permian not further toward the W than eastern Iran (westernmost proven occurrence: Fariman, eastern Iran, KOZUR & MOSTLER and RUTTNER [in RUTTNER, 1991]). During the Upper Permian, the rifting in the Cimmerian (northern) Tethys continued until western Turkey, during the uppermost Scythian until the Transylvanids (Eastern Carpathians) and in the Middle Triassic until the Eastern Alps (Meliata-Hallstatt sphenochasma of the Cimmerian ocean; KOZUR, 1991a,b).

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I thank all the above organisations and colleagues for their very important help.

Plate 1

If not otherwise indicated, all figured specimens have been derived from sample 655 of the Dzhulfian (Upper Permian) lower part of predominantly red claystones of the upper Claystone Unit of the Torrente San Calogero section, SW of the Pietra di Salomone, Sosio Valley area, Western Sicily (Italy).

- Figs. 1– 3: ***Ishigaconus scholasticus* (ORMISTON & BABCOCK); × 170.**
Fig. 1: rep.-no. CK/III-68.
Fig. 2: rep.-no. CK/III-70.
Fig. 3: rep.-no. CK/III-70A.
- Figs. 4– 6: ***Follicucullus dilatatus* RUDENKO; × 170.**
Fig. 4: rep.-no. CK/III-74.
Fig. 5: rep.-no. CK/III-72.
Fig. 6: rep.-no. CK/III-83.
- Figs. 7–11: ***Follicucullus porrectus* RUDENKO; × 170.**
Fig. 7: rep.-no. CK/III-81.
Fig. 8: rep.-no. CK/III-71.
Fig. 9: rep.-no. CK/III-80.
Fig. 10: rep.-no. CK/III-82.
Fig. 11: rep.-no. CK/III-73.
- Figs. 12–14: ***Lacisus siphunculus* n.gen. n.sp.; × 170.**
Fig. 12: holotype, rep.-no. CK 1188/VI-33.
Fig. 13: rep.-no. CK/III-35.
Fig. 14: rep.-no. CK/III-52.
- Figs. 15–17,19: ***Cariver dorsoconvexus* n.sp.**
Fig. 15: × 170, rep.-no. CK/III-39.
Fig. 16: holotype; × 170, rep.-no. CK/III-64.
Fig. 17: × 170, rep.-no. CK/III-66.
Fig. 19: × 320, rep.-no. CK/III-45.
- Fig. 18: ***Lacisus* n.sp.; × 170.**
Rep.-no. CK/III-12.
- Fig. 20: ***Parafollicucullus convexus* (RUDENKO & PANASENKO); × 170.**
Upper part of apical horn and distal part of test broken away.
Rep.-no. CK/III-26.
- Figs. 21, 22: ***Pseudoalbaillella eurasiatica* KOZUR; KRAHL & MOSTLER; × 170.**
Fig. 21: rep.-no. CK/III-15.
Fig. 22: rep.-no. CK/III-50.
- Fig. 23: ***Parafollicucullus monacanthus* (ISHIGA & IMOTO); × 170.**
Rep.-no. CK 1188/VI-24.

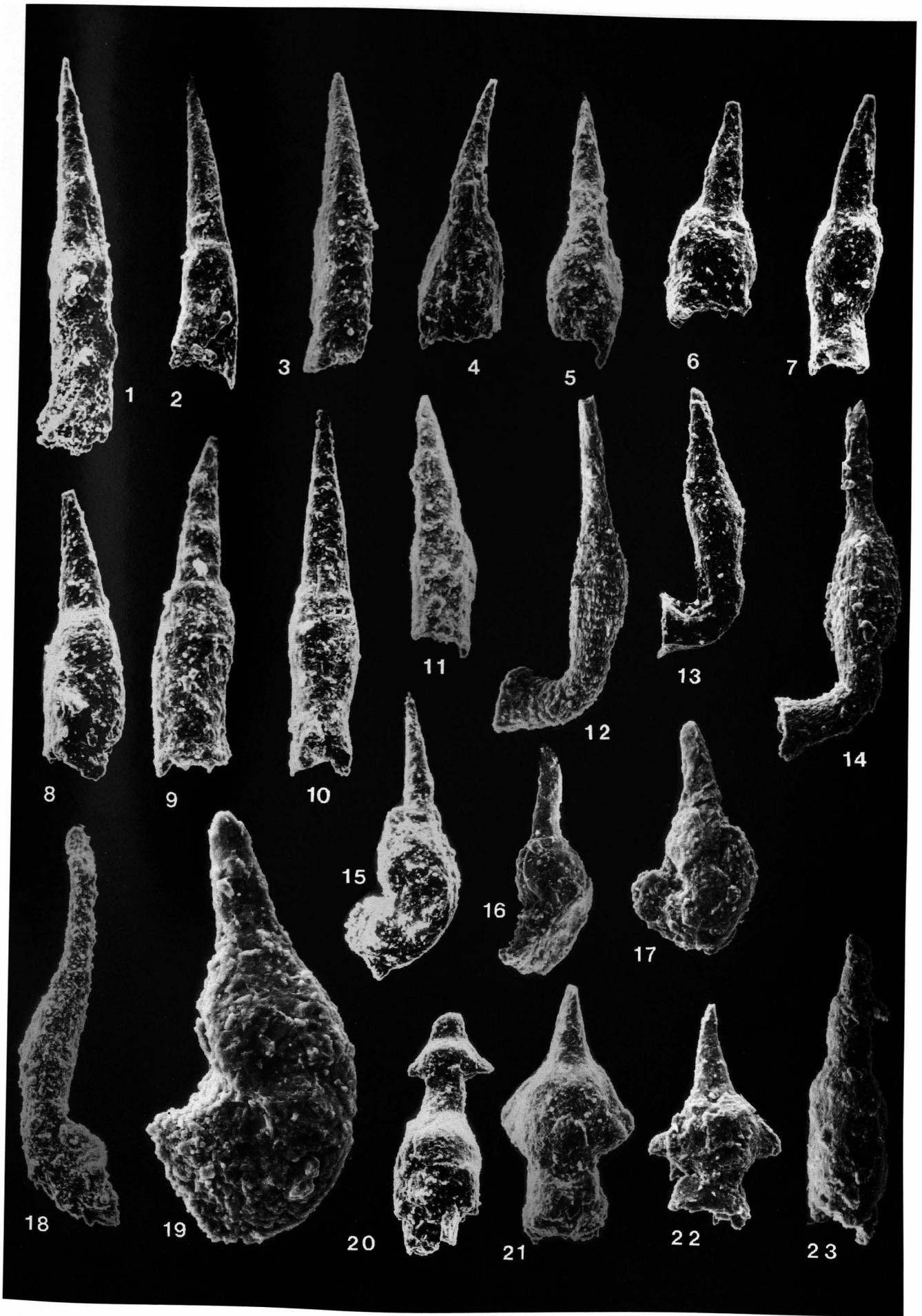


Plate 2

If not otherwise indicated, all figured specimens have been derived from sample 655 of the Dzhulfian (Upper Permian) lower part of predominantly red claystones of the upper Claystone Unit of the Torrente San Calogero section, SW of the Pietra di Salomone, Sosio Valley area, Western Sicily (Italy).

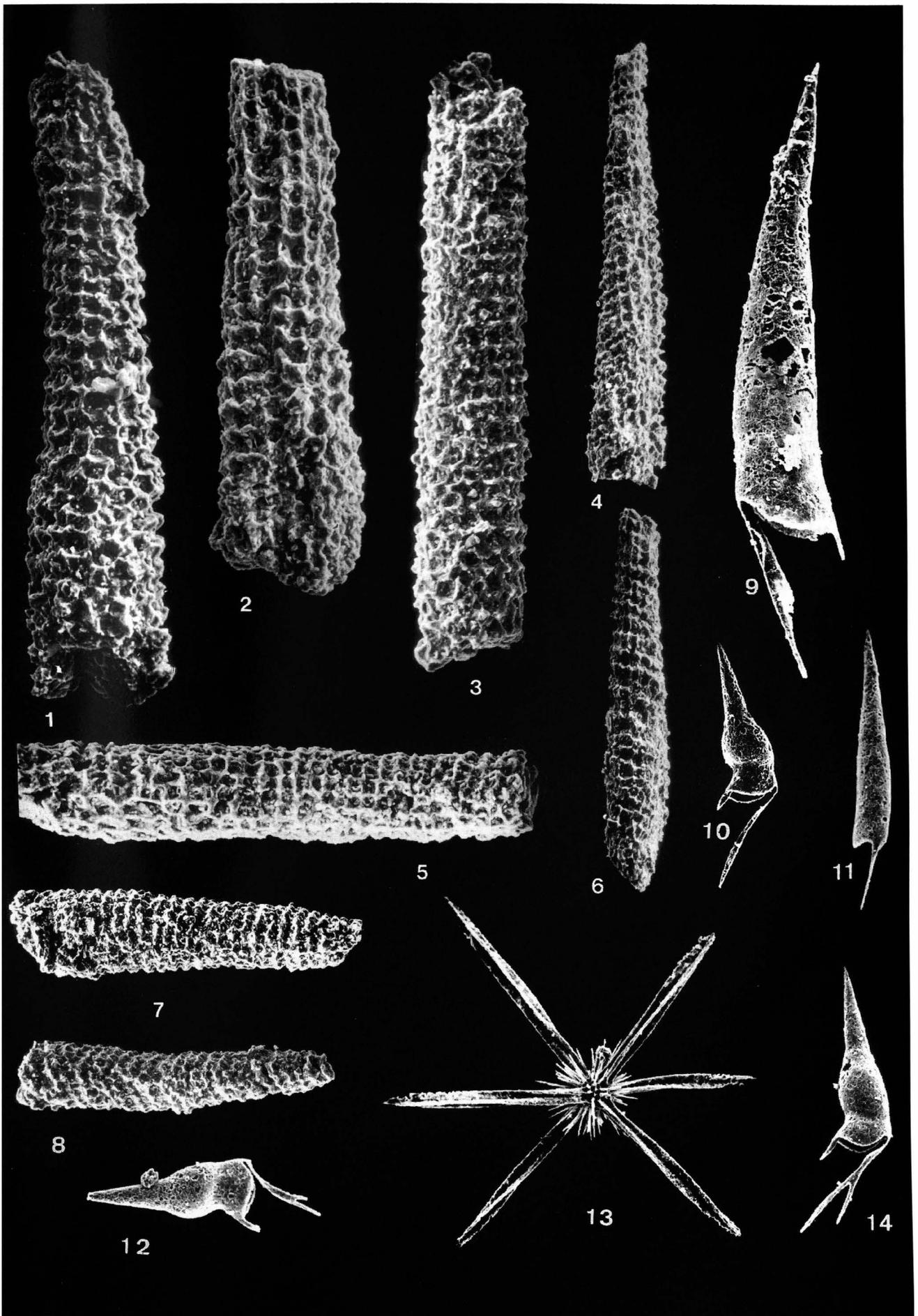
- Fig. 1: ***Phaenicosphaera mamifera* (NAZAROV & ORMISTON).**
× 170, rep.-no. CK/III-59.
- Fig. 2: ***Urocyrtis ? sp.***
× 320, rep.-no. CK/III-44.
- Fig. 3: ***Hindeosphaera ? n.sp.***
× 320, rep.-no. CK/III-24.
- Fig. 4: **gen. et spec. indet.**
× 170, rep.-no. CK/III-62.
- Fig. 5: ***Mostlerispongus sosioensis* n.gen. n.sp.**
Holotype, × 170, rep.-no. CK/III-65.
- Fig. 6: ***Latentifistula* n.sp.**
× 170, rep.-no. CK/III-32.
- Figs. 7,11,12: **Bryozoa.**
- Fig. 7: Two zooids still connected, × 80, sample S 6 (out of sequence), olistolith or block of light-gray biogenic limestone, uppermost Leonardian, Pietra dei Saracini, Sosio Valley area, Western Sicily, rep.-no. CK/VI-16.
- Figs. 11,12: Single zooids, morphologically similar to advanced Follicucullidae, but unrelated to them, × 170.
Fig. 11: Rep.-no. CK/III-31.
- Fig. 12: Sample S 12 D, Wordian reef-slope limestone, Rupe del Passo di Burgio, Sosio Valley area, Western Sicily; rep.-no. CK/IV-50.
- Figs. 8–10: ***Gustefana obliqueannulata* n.gen.sp.**
- Fig. 8: × 170, rep.-no. CK 1188/VI-39.
Fig. 9: × 170, rep.-no. CK 1188/VI-40.
Fig. 10: × 80, rep.-no. CK/III-60.



Plate 3

If not otherwise indicated, all figured specimens have been derived from sample 655 of the Dzhulfian (Upper Permian) lower part of predominantly red claystones of the upper Claystone Unit of the Torrente San Calogero section, SW of the Pietra di Salomone, Sosio Valley area, Western Sicily (Italy).

- Figs. 1,2,4,(?)6,7,8: ***Gustefana obliqueannulata* n.gen. n.sp.**
Fig. 1: Holotype, ×160, rep.-no. CK 1188/VI-38.
Fig. 2: ×160, rep.-no. CK 1188/VI-29.
Fig. 4: ×80, rep.-no. CK 1188/VI-40 A.
Fig. 6: ×80, rep.-no. CK 1188/VI-37.
Fig. 7: ×80, rep.-no. CK/III-61.
Fig. 8: ×80, rep.-no. CK 1188/VI-27.
- Figs. 3,5: ***Gustefana* n.sp..**
Fig. 3: ×160, rep.-no. CK 1188/VI-3.
Fig. 5: ×80, specimen lost.
- Figs. 9,11: ***Ishigaconus scholasticus* (ORMISTON & BABCOCK).**
Specimens with fully preserved dorsal free columella sample 216, Delaware Basin (West Texas), road cut on US Highway 62-180 (section H by ORMISTON & BABCOCK, type locality of *F. bispinosus*, *F. ventricosus* and *I. scholasticus*), uppermost Lamar Limestone, 10 cm below the top of the section (about 0.5-1 m below the top of the Lamar Limestone in this area), Lower Dzhulfian.
Fig. 9: lateral view, ×200, rep.-no. N 4060.
Fig. 11: oblique dorsal view, ×100, rep.-no. N 4063.
- Fig. 10: ***Follicucullus ventricosus* ORMISTON & BABCOCK**, lateral view.
×100, sample 216 (see Figs. 9, 11), rep.-no. N 4069.
- Figs. 12,14: ***Follicucullus bispinosus* n.sp..**
Lateral views, ×100, sample 216 (see Figs. 9, 11).
Fig. 12: rep.-no. N 4061.
Fig. 14: holotype, rep.-no. 4062.
- Fig. 13: ***Stigmatosphaerostylus itsukaichiensis* (ISHIGA & TONISHI).**
×100, sample 216 (see Figs. 9, 11).



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