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CONODONTS FROM THE KAPP STAROSTIN FORMATION (PERMIAN) OF SPITSBERGEN

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Sixteen morphologic forms of conodonts are described from four sections of Kapp Starostin Formation of Spitsbergen. One new genus and two new species are established (*Sweetocristatus arcticus* gen.n., sp.n., *Neostreptognathodus svalbardensis* sp.n.). The assemblage is considered to be stratigraphically corresponding to that one known from the Upper Leonardian and Lower Roadian of western United States. Affinity of *Neostreptognathodus* to *Adetognathus* and *Idiog-nathodus* is suggested and hypothetical multielement apparatus of the genus is presented. Two distinct conodont biofacies in Kapp Starostin Formation are defined and their depositional environment is discussed.

Key words: conodonts, Permian, Spitsbergen, stratigraphy.

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INTRODUCTION

The Kapp Starostin Formation of Spitsbergen (Burov *et al.* 1965, Cutbill and Challinor 1965) consisting of some hundred meters thick fossiliferous marine deposits has for long been investigated both paleontologically and stratigraphically. The modern authors assigned it most commonly to the Kungurian and Ufimian (cf. Małkowski and Szaniawski 1976). The geographic position of the Kapp Starostin Formation between the Cis-Ural region (that is the type area of the Permian System) and on the other side North America and Greenland makes those strata very important for the Permian correlation all over the northern hemisphere. Therefore, Stepanov (1957, 1973) erected a new stage, the Svalbardian, with its type section comprising the Kapp Starostin Formation, to replace the Kungurian and Ufimian stages the type sections of which comprise

mostly lagoon and continental deposits. Unfortunately, most fossils of the Kapp Starostin Formation represent benthos (brachiopods, bryozoans, sponges, ostracodes, "small" foraminifers) and show merely narrow geographic and facies ranges. Some reference points may be given by the conodonts more and more commonly applied recently to the Permian stratigraphy. However, the Kapp Starostin Formation contains, mostly cherty rocks which makes difficult extraction of those microfossils. Actually, the investigated conodonts derived entirely from some portions of a

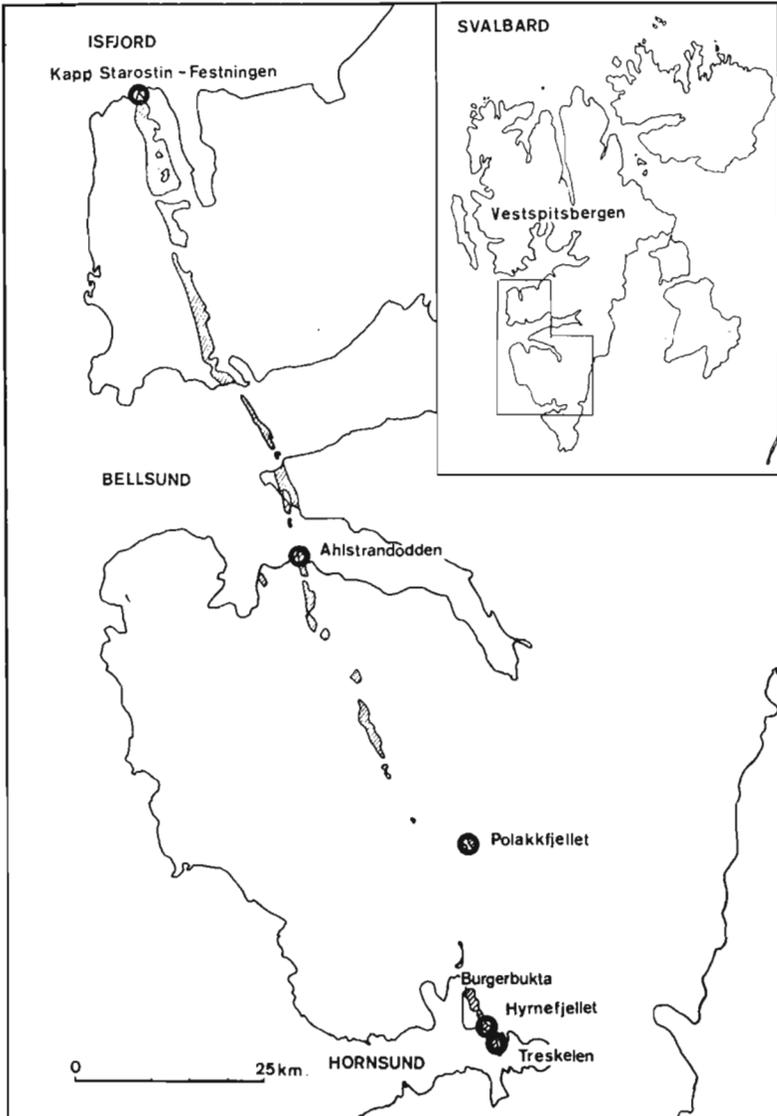


Fig. 1. Outline map of Svalbard showing the location of sections from which the conodonts were collected. The outcrops of the Kapp Starostin Formation is marked.

few geological sections (figs 1, 2). Much further work is needed to recognize well the whole conodont assemblage of the Kapp Starostin Formation.

The field work was performed in 1974—1976 during the scientific expeditions to Spitsbergen organized by the Institute of Paleobiology of the Polish Academy of Sciences. The junior author investigated then several sections of the Kapp Starostin Formation in the southern Vestspitsbergen and took samples for micropaleontological work from five localities (fig. 1). A single conodont specimen has been found in samples from Hyrnefjellet section (Małkowski and Szaniawski 1976), which is out of the present study. Some sixty samples were taken from other geological sections (Treskelen, Polakkfjellet, Ahlstrandodden, Kapp Starostin), of which twenty three yielded conodonts. Location of the conodont-bearing samples is given in fig. 2. In addition, a single sample (B-1) taken from slope debris close to Burgerbukta (fig. 1) also supplied conodonts; it appears equivalent lithologically to the base part of the formation in this area.

Those conodonts from the limestones of Polakkfjellet and Ahlstrandodden sections have been extracted by acetic-acid treatment, while those from the cherty rocks of Treskelen, Burgerbukta and Kapp Starostin sections by hydrofluoric-acid treatment. The data are insufficient to permit any certain reconstruction of multielement conodont apparatuses. Nevertheless, possible assignment of some investigated conodont groups to multielement apparatuses is discussed below.

The systematic part of the paper was prepared by the senior author during his stay in 1978 at the Department of Geology and Mineralogy of the Ohio State University, Columbus, United States. The rest of the paper was prepared by both authors at the Institute of Paleobiology of the Polish Academy of Sciences, Warsaw, Poland.

The investigated collection from Spitsbergen is housed at the Institute of Paleobiology of the Polish Academy of Sciences (abbreviated as ZPAL); the illustrated comparative specimen from North America is in the paleontological repository of the University of Wisconsin, Madison, United States (abbreviated as UW).

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The senior author appreciates greatly the award of the Postdoctoral Fellowship from the Ohio State University, Columbus, and has a pleasure to express his deep gratitude to Professors Stig M. Bergström and Wal-

Table 1

Distribution of conodonts in samples. The position of samples in the section is shown in fig. 2 (except of the sample B-1, see p. 233)

Sample Number	limestone facies										cherty rock facies						Totals				
	<i>Neostreptognathodus svalbardensis</i>	<i>Neostreptognathodus</i> sp. A	<i>Neostreptognathodus</i> sp. B.	<i>Neostreptognathodus</i> sp. C.	<i>Sweetocriscatus arcticus</i>	<i>Sweetognathus</i> sp.	<i>Zillisonia</i> sp. H element	<i>Zillisonia</i> sp. Sa element	<i>Zillisonia</i> sp. Sc element	Unassigned cypridodelliform element	Unassigned hindeodelliform element	Fragments of <i>Neostreptognathodus</i> sp.	Fragments of compound conodonts	<i>Neogondolella idahoensis</i>	<i>Neogondolella</i> cf. <i>gracilis</i>	<i>Neogondolella</i> sp. A		<i>Xanognathus</i> sp.	Unassigned enantiognathiform element	Fragments of <i>Neogondolella</i> sp.	Fragments of compound conodonts
P-1																					
P-2																					
P-3	40				12	2	1		1	1		10	24								91
P-4																					
P-5																					
P-6																					
P-7																					
P-8	4				1								8								13
P-9																					
P-10																					
P-20																					
P-21	13	2	1		5	3		1	1			2	21								49
P-22																					
P-23																					
A-12					3					1	1		2								7
A-10					3			1					5								9
B-1														16				12			28
Tr-B															1			2	1		4
Tr-C														12			1	1	4	2	20
Tr-D														12	1			6			19
Tr-E														14	2			8	1		25
Tr-F														1							1
Tr-G														1				2			3
K-20														21		4	1	23	2		51
Totals	57	2	1	6	18	5	2	1	2	2	1	12	60	77	3	1	5	2	57	6	320

ter C. Sweet for their very helpful assistance during his work at the university. He is particularly indebted to Professor Walter S. Sweet for providing comparative collections and unpublished information as well as for profitable discussions and review of the manuscript. Helpful discussions were also offered by Dr. James W. Collinson, Ohio State Uni-

versity, Columbus; Dr. Bruce R. Wardlaw, United States Geological Survey, Denver; and Dr. Heinz Kozur, Meiningen State Museum, G. D. R. Professor David L. Clark, University of Wisconsin, Madison, kindly loaned to the authors very useful comparative material from North America.

Most SEM micrographs were prepared at the Department of Geology and Mineralogy of the Ohio State University; the others were prepared at the Institute of Experimental Biology of the Polish Academy of Sciences, Warsaw. The text drawings were kindly made by Mrs. D. Sławik and Mr. T. Krasnodębski.

STRATIGRAPHY

The age determination of the Kapp Starostin Formation has so far remained controversial. Basing mostly upon its brachiopod fauna, the formation was assigned to either Artinskian (Tschernyshev 1902, Frebold 1937, Forbes *et al.* 1958), Kungurian and Ufimian or their joint equivalent Svalbardian (Stepanov 1957, 1973; Cutbill and Challinor 1965; Sosipatrova 1967), or the lower Upper Permian — Ufimian or Paykhoyan (Ustritsky 1960, 1967, 1971; Ustritsky and Chernyak 1973; Burov *et al.* 1965). The conodont assemblage of the Kapp Starostin Formation is to be most easily and reliably correlated with the Permian strata of the western United States. In fact, the conodonts of the latter strata appear as the best known conodont fauna of this age in the world.

The most closely related assemblage to the conodont fauna of the Kapp Starostin Formation is that one recorded (Youngquist *et al.* 1951, Clark and Ethington 1962, Clark and Behnken 1971) in the Meade Peak Member of the Phosphoria Formation of Idaho, Wyoming, and Utah (Table 2), presently assigned to the Roadian (Furnish 1973). Actually, only a single species occurs in both assemblages, nevertheless, the evolutionary advancement of other species enumerated in Table 2 permits recognition of a close relationship between the corresponding forms.

Table 2

Closely related conodonts of the Kapp Starostin Formation, Spitsbergen, and the Meade Peak Member of the Phosphoria Formation, Idaho, Wyoming, and Utah

Meade Peak Member of the Phosphoria Formation	Kapp Starostin Formation
<i>Neogondolella idahoensis</i> <i>Neogondolella gracilis</i> <i>Xaniognathus abstractus</i> (Clark and Ethington 1962, pl. 1: 16, 20, pl. 2: 2, not pl. 1: 21) <i>Neostreptognathodus sulcopicatus</i> <i>Lambdagnathus</i> sp. (Clark and Ethington, 1962)	<i>Neogondolella idahoensis</i> <i>Negondolella</i> cf. <i>gracilis</i> <i>Xaniognathus</i> sp. <i>Neostreptognathodus svalbardensis</i> ? <i>Ellisonia</i> sp. Sa element

The most important stratigraphically conodonts of the considered strata are *Neogondolella idahoensis* and *Neostreptognathodus sulcopicatus*, both the species reported from several North American localities. However, their stratigraphic ranges are rather poorly correlated with each other. They are apparently facies controlled and rarely occur interbedded in a single geological section (Clark and Behnken 1971, Clark 1974). Both the species have been reported (Behnken 1975a, 1975b; Wardlaw and Collinson 1978) not only from the Roadian but also from the Leonardian strata (*sensu* Furnish 1973). Behnken (1975b) claims that *Neogondolella idahoensis* ranges higher stratigraphically than *Neostreptognathodus sulcopicatus*.

Among the conodonts of the Kapp Starostin Formation not mentioned in Table 2, there occur also in the limestone facies such forms as *Sweetocristatus arcticus*, *Sweetognathus* sp., and *Neostreptognathodus* sp. C. These three species appear to be closely related to the conodonts from the Victorio Peak Formation and Bone Spring Limestone of West Texas, described by Behnken (1975a) as *Xaniognathus abstractus*, *Neostreptognathodus adjunctus*, and *N. prayi*; Behnken (1975a, 1975b) attributed the investigated strata to the Leonardian. However, basing upon the cephalopods, Furnish (1973) attributed the upper Bone Spring Limestone to the Roadian. Wardlaw and Collinson (1978) considered the Victorio Peak Formation and Bone Spring Limestone as equivalent to the Kaibab Limestone of western Nevada and eastern Utah, and attributed them to the Upper Leonardian to Lower Roadian.

One may thus conclude that basing upon the conodonts, the Kapp Starostin Formation is to be correlated with the Upper Leonardian to Lower Roadian of the western United States. The conodont assemblage of the limestone facies of the formation (Polakkfjellet, Ahlstrandodden) comprises more Leonardian forms than does the assemblage typical of the cherty facies (Treskelen, Kapp Starostin). Any more precise correlation is for the moment impossible.

Apart from North America, some conodonts related in age to those of the Kapp Starostin Formation have also been recorded in the Cis-Ural region and Pamirs (Kozur and Mostler 1976, Kozur 1977). Accordingly to Kozur (1977), the conodonts *Neogondolella idahoensis* and *Neostreptognathodus sulcopicatus* are approximately equivalent in age to *Diplognathodus nassichuki* and *Neostreptognathodus leonove* of the Lower Chih-sian of Pamirs. Unfortunately, very poor illustrations of the latter species (Kozur and Mostler 1976) make impossible any precise morphological comparisons. The species *Sweetocristatus arcticus*, *Neostreptognathodus* sp. A, and *Sweetognathus* sp. of the limestone facies of the Kapp Starostin Formation appear related to but nevertheless distinct from *Merrillina oertlii*, *Neostreptognathodus ruzhencevi*, and *Sweetognathus bogoslavskai*.

jae of the Baigendzhinian of the Cis-Ural region (cf. Kozur and Mostler 1976).

From the Lower Svalbardian of Spitsbergen (=lower part of the Kapp Starostin Formation), Kozur (1977) reported the following conodonts: *Gondolella* (= *Neogondolella*) *bisselli*, *Neostreptognathodus pequopensis*, *N. ruzhencevi*, *Sweetognathus* aff. *bogoslavskajae*, *Vjalovites* sp.n., and gen. n. sp.n. However, at the same time, Kozur (*op. cit.*) assessed, that he knew the Svalbardian conodonts only after the collection and preliminary note of the present authors (Małkowski and Szaniawski 1976)¹⁾. All the collected conodonts from the Permian of Spitsbergen (except of some unidentifiable fragments) are described in the following paper. Hence the difference between the conodont lists given herein and by Kozur (*op. cit.*) reflects merely the subjectivity of the taxonomic identifications.

The conodont assemblages recorded by Ching (1960) in China and by Bender and Stoppel (1965) in Greece and Sicily are younger than that of the Kapp Starostin Formation.

Mutual correlation of the investigated sections of the Kapp Starostin Formation can hardly be accomplished with certainty because of the occurrence of two distinct conodont biofacies completely different in their taxonomic composition (Table 1) and their geological record restricted merely to some fragments of the sections. The assemblages with *Neogondolella idahoensis* found in Treskelen and Kapp Starostin sections are closely related and probably age equivalent to each other. The occurrence of *Neogondolella* cf. *gracilis* and *Neogondolella* sp. A in Treskelen section might suggest the higher stratigraphic position of this section but the absence of these conodonts from Kapp Starostin section may result entirely from the conodont scarcity in the latter section (actually, only a single sample from Kapp Starostin section supplied the conodonts). Detail correlation of the limestone-facies sections of Polakkfjellet and Ahlstrandodden is impossible because the collection from Ahlstrandodden is too poor (no specimen from Ahlstrandodden section could be identified at the specific level). A tentative between-facies correlation is possible merely by means of comparisons with the North American fauna. Provided that *Neostreptognathodus svalbardensis* evolved directly from *N. pequopensis* (as *N. sulcopicatus* did) and displayed a similar stratigraphic range to *N. sulcopicatus*, the limestone facies of Polakkfjellet is time equivalent to or slightly older than the cherty facies of Treskelen and Kapp Starostin.

¹⁾ In the preliminary note, the present authors reported *Neostreptognathodus* aff. *pequopensis* and *Neogondolella* cf. *bisselli*; the names were used specially in open nomenclature and the affinities of the investigated forms to *Neostreptognathodus sulcopicatus* and *Neogondolella idahoensis*, respectively, were stressed. The forms described previously as *Neostreptognathodus* aff. *pequopensis* is now attributed to *N. svalbardensis* sp.n. The conodont described previously as *Neogondolella* cf. *bisselli* remains unidentified, as this is the only specimen of this morphological form in the collection and the only specimen found in Hyrnefjellet section (see page 247).

Stepanov (1973) claims that the base of the Svalbardian of Spitsbergen is isochronous to the base of the North American Roadian. However, the present study of the conodont fauna indicates that the Svalbardian comprises also the Upper Leonardian.

ENVIRONMENTAL CONTROL OF CONODONT BIOFACIES

The conodonts of the Kapp Starostin Formation of Spitsbergen form two distinct assemblages without any species in common. The assemblage typical of the limestones is dominated by the genus *Neostreptognathodus*, whereas the genus *Neogondolella* is dominant in the cherty rocks (Table 1). Analogical situation has also been recorded in time equivalent deposits of the United States (Clark 1974). It is noteworthy that similar conodont biofacies dominated by the genera *Gondolella* and *Ca-vusgnathus* (= *Adetognathus*), occur also in the North American Pennsylvanian (Von Bitter 1972, Merrill and Von Bitter 1976).

The conodont biofacies are usually closely related to particular lithofacies; the latter appear, however, insufficiently described in most systematic-paleontologic papers. In the present study, the conodont-bearing deposits of the Kapp Starostin Formation are also described in terms of microfacies analysis. Both biotic and abiotic rock constituents were analysed (Table 3, fig. 3). Only those fossil remains deposited more or less close to the original life environments (as indicated by the lack or insignificance of shell fragmentation or sorting) were taken into account. The numerical relationships among the fossils were treated merely in abundance-presence-absence categories, as the data were hardly compatible for all the groups involved. The fossils were considered in very broad taxonomic terms, since most groups had already been studied by specialists.

The following fossil groups occur in the investigated deposits of the Kapp Starostin Formation:

Brachiopods (Gobbett 1963, Grigorieva *et al.* 1977, Sarytscheva 1977) include mostly abundant productoids and spiriferoids; inarticulates, terebratuloids, and rhynchonelloids occur in minor amounts. The brachiopods occur both in the limestones and in the cherty rocks. However, those specimens derived from the limestones are, larger-sized and thicker-shelled as a rule.

Bryozoans (Małeckı 1977) occur abundantly both in the limestones and in the cherty rocks. More fragile forms (fenestelloids) appear to prevail in the latter lithofacies.

Crinoids occur exclusively in the limestone facies, becoming very common in places. They have so far not been studied in detail.

Table 3

Microfacies analysis of conodont-bearing samples. Occurrence of a facies component indicated by +, when abundant +!

Samples	Biotic factors										Abiotic factors				Conodont fauna
	brachiopods	bryozoans	crinoids	bivalves	gastropods	sponges	foraminifers	ostracods	algae	micrite	amorphous silica	glauconite	pyrite	max. grain size	
P-1	+		+						+	+			0.2	10-15%	
P-2	+	+		+			+		+	+			0.1	2-5%	
P-3	+	+	+	+			+	+	+	+			0.1	5-10%	
P-4	+							+	+	+			0.2	5-10%	
P-5	+	+	+	+					+	+			0.2	15-20%	
P-6		+	+						+	+			0.2	5-10%	
P-7	+			+					+	+			0.2		
P-8	+	+	+						+	+			0.2		
P-9	+								+	+			3.7	15-25%	
P-10	+								+	+			0.2	30%	
P-20							+	+	+	+			0.3	5-10%	
P-21	+							+	+	+			5.0	10-20%	
P-22	+	+	+						+	+			1.0	5-10%	
P-23	+	+	+	+			+		+	+				clay	
A-10	+	+	+		+				+	+			0.1	2-5%	
A-12	+	+	+				+		+	+			0.1	2-5%	
Tr-B		+			+	+	+	+		-	+	+	0.1	10%	
Tr-C	+	+				+	+	+		+	+	+	0.1	10-15%	
Tr-D	+						+	+		-	+	+	0.1	5-10%	
Tr-E	+	+			+	+	+	+		+					
Tr-F	+						+	+		+	+		0.1	2-5%	
Tr-G	+	+			+	+	+	+		+			0.1	5%	
K-20							+			+	+	+	0.1	2%	

Bivalves and gastropods occur sporadically, restricted to some horizons regardless of the lithofacies. They have so far not been studied extensively.

Sponges (Siedlecka 1970) are very abundant, restricted to the cherty lithofacies.

Foraminifers (Sosipatrova 1967) also occur abundantly. Their associations vary in composition, depending probably upon the facies parameters; their environmental controls remain, however, unrecognized. The agglutinate and encrusting forms prevail in the limestone facies.

Ostracods are very abundant and diverse in places. There are both

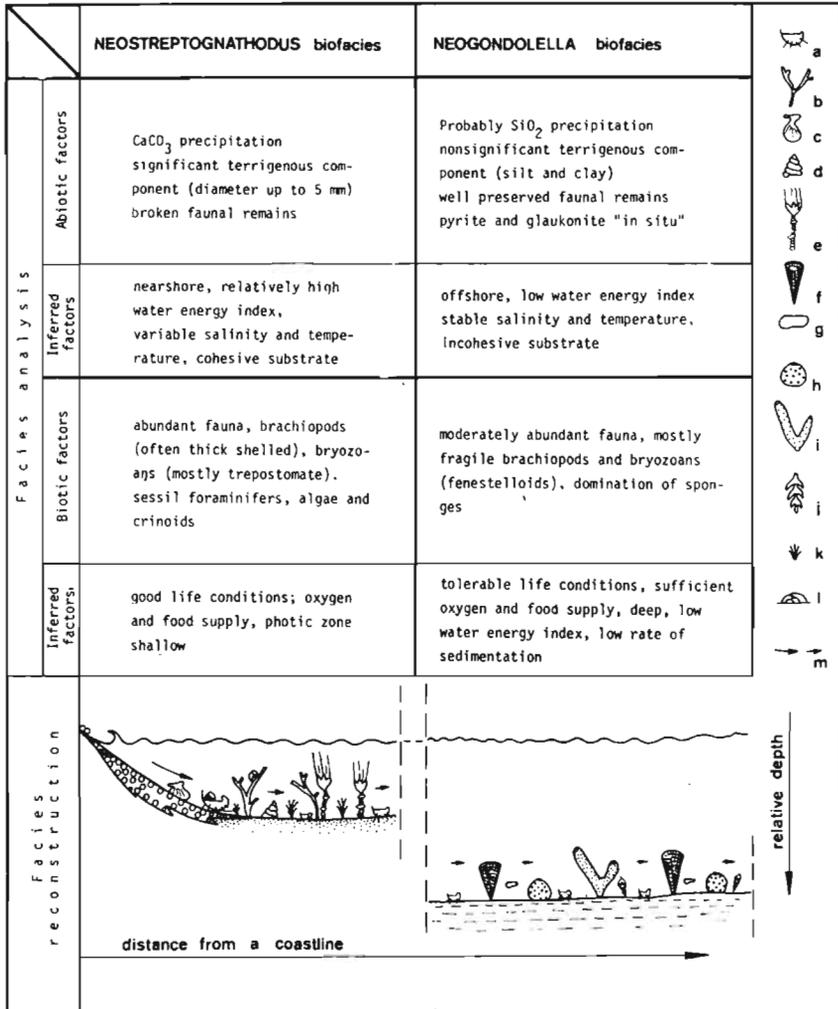


Fig. 3. Analysis and reconstruction of the two conodont biofacies. a brachiopods, b bryozoans (amplexoporoids and timanodictyoids), c bivalves, d gastropods, e crinoids, f bryozoans (fenestelloids), g ostracods, h massive sponges, i branched sponges, j foraminifers (uniserial), k algae, l sessile foraminifers, m water energy index.

smooth and considerably ornamented forms. They have thus far not been studied systematically.

Subtle calcareous structure (multilayered coatings and disorderly reticulate structures) were interpreted by the present authors as being of algal origin. They occur exclusively in the limestones.

The investigated abiotic rock constituents (terrigenous matter and possible autochem) were considered only as means to reconstruction of the life environment of the associated fossils (see also Siedlecka 1970).

Micrite occurs in all the limestone samples. It contributes to the matrix and is sometimes partly sparitized.

Amorphous silica makes up the matrix or fills up post-mortem voids of the skeletons.

Glaucanite and pyrite occur abundantly in the cherty rocks. They do not show any traces of redeposition. Their grain size exceeds considerably the average grain-size of terrigenous matter as a rule.

Terrigenous matter (mostly quartz) occurs in all the investigated samples; it is, however, highly variable in grain size and amounts. The average grain-size is usually larger in the limestones than in the cherty rocks, much larger in some cases (e.g. sample P-9). The contents of terrigenous matter in a sample were estimated after the percent proportion of the thin-section area covered with terrigenous grains.

Life conditions for both the conodont assemblages recognized in the Kapp Starostin Formation are determined (fig. 3) basing upon the microfacies analysis (see also Małkowski and Hoffman 1979). The following simplifying assumptions were accepted during the paleoenvironmental reconstruction: (i) Co-occurrence of non-redeposited biotic and abiotic rock constituents indicates that prior to their simultaneous deposition, they shared also the same life or formation environment. (ii) Characteristics and mode of occurrence of allochthonous rock constituents depend upon the nature of life environment of the associated fauna *in situ*. (iii) Life environment of fauna *in situ* makes also depositional environment of the associated autochems (glaucanite, pyrite, amorphous silica, calcium carbonate), be they formed in the water or in the sediment; actually, the amorphous silica of the Kapp Starostin Formation can be regarded as syndimentary (Siedlecka 1970), as suggested by its supporting nature relative to the bioclasts and terrigenous grains.

The paleoenvironmental reconstruction indicates clearly a difference in life conditions suitable for the conodont assemblages of the Kapp Starostin Formation. The environment inhabited by *Neostreptognathodus* assemblage displayed probably relatively shallow, well lit and oxygenated, fairly turbulent water. The land proximity, small water-depth (and warm climate; cf. Birkenmajer 1964) resulted probably in considerable fluctuations in water salinity and temperature. The water was rich in organic detritus and nutrients. The terrigenous influx was at least periodically high.

The water was deeper and quieter in the life environment of *Neogondolella* assemblage. The bottom was probably outside the euphotic zone and the bottom deposit was fluid and with slightly negative redox potential. Nevertheless, the suspended-food supply was high, as indicated by the abundance of filter feeding benthos.

The limestones underlie cherty rocks in the Kapp Starostin Formation. However, both the similar lithofacies and their associated conodont assemblages interfinger in the United States (Clark 1974) and hence, one may claim that they occur in distinct facies zones of a single basin.

The observed pattern of Permian conodont distribution can be explained by the depth stratification model of Seddon and Sweet (1971). However, the present study shows, that the model can also be enriched with some other factors related to the distance from a coastline rather than to the water depth itself; these factors are: energy conditions, water salinity and temperature, food supply, pH, Eh, etc. In fact, significance of these factors for conodont distribution was already widely discussed by Druce (1973), Merrill and Von Bitter (1976), Klapper and Barrick (1978), and others.

DESCRIPTIONS

Genus *Ellisonia* Müller, 1956

Type species: Ellisonia triassica Müller, 1956

Remarks.—In recent years Permian ramiform conodonts have usually been grouped in multielement taxa. In 1969 Szaniawski suggested that all conodonts known from the Zechstein Series of Europe belonged to one or two natural species. In 1970 Sweet reconstructed 7 Upper Permian and Lower Triassic multielement species and referred them to *Ellisonia* Müller, which was originally erected to include only hibbardelliform elements. Subsequently the same author (Sweet 1973b, Teichert *et al.* 1973) recognised 3 groups of generic rank with *Ellisonia*-type apparatuses: I—typified by *E.triassica* (= *E. s.s.*), II—typified by *E.gradata* Sweet, later on subdivided into two genera (Sweet pers.com.) and III—typified by *E.teichertii* Sweet. Recently it has been recognized that the third of above-cited groups also possesses anchignathodiform elements in their apparatuses and the generic name *Hideodus* Rexroad and Furnish has been adopted for it (Sweet 1976b, 1977).

In 1975 Kozur proposed a new multielement genus—*Stepanovites*. Element composition of the genus is the same as in *Ellisonia* (*sensu stricto*). Moreover all elements of the type species of *Stepanovites* (*S.meyeni* Kozur and Movšovič) except the lonchodiniform element are morphologically very close to those of *E.triassica*. Therefore we consider *Stepanovites* Kozur as a junior synonym of *Ellisonia* Müller.

?*Ellisonia* elements

(pl. 10: 4,5,8,9)

Material.—5 recognized elements and 46 fragments most probably belonging to the genus.

Description.—Only 3 types of elements are known: lonchodiniform—*M*, hibbardelliform—*Sa* and hindeodelliform—*Sc* (symbols after Sweet 1977). All of them are comparatively large, possess stout discrete denticles with subcircular cross section, and have a well-developed aboral side with a large basal opening (*M*) or wide basal groove (*Sa*, *Sc*).

Remarks.—*M* element (pl. 10: 8,9). Only two incomplete elements are in the collection. Similar Permian conodonts were described by Bender and Stoppel (1965) from the Middle Permian of Sicily and by Behnken (1975a) from the Gerster Formation of Nevada as *Lonchodina festiva* Bender and Stoppel and also by Kozur (1975) as the prioniodiniform elements of *Stepanovites meyeri* Kozur and Movšovič and *S.dobruskinae* Kozur and Pjatakova. Our specimens are slightly different from all of them. They seem to be completely devoid of denticles on the anterior process whereas in *Lonchodina festiva* there are rudimentary denticles on it. In *E.meyeri* and *E.dobruskinae* the anterior process of this element is unknown but its basal opening is different. In *E.meyeri* it is narrower and in *E.dobruskinae* it is wider but not so high as in our specimens. Conodonts somewhat similar to our *M* element are also known from the Upper Pennsylvanian (*Lonchodina* sp.B. of Von Bitter, 1972 unassigned B_3 element of Baesemann, 1973) and from the early Wolfcampian (unassigned Type 3 element of Perlmutter, 1975), (fig. 4).

Sa element (pl. 10: 5). Only one specimen of this type is recognized in our material but most probably some fragments also belong to it. This element is conserva-

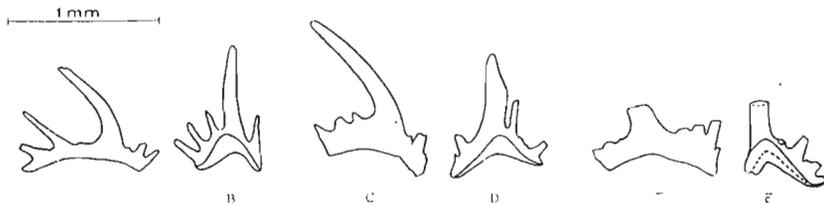


Fig. 4. Three pairs of compound conodonts occurring in association in Pennsylvanian (A, B), Sakmarian (C, D) and "Svalbardian" (E, F). A and B—unassigned B_1 and B_3 elements of Baesemann (1973, pl. 1: 1, 4) from Upper Pennsylvanian of Kansas; C and D—*Ligonodina* sp. and unassigned type 3 element of Perlmutter (1975, pl. 2: 18, 19) from the Lower Sakmarian (Council Grove Group) of Kansas; E and F—*Ellisonia* Sc— and *M* elements from Svalbardian of Spitsbergen, described in the present paper.

tive. Similar forms are known from the Middle and Upper Permian and also from the Lower Triassic (*Lambdagnathus* sp. of Clark and Ethington, 1962, *Hibbardella baltica* Szaniawski, hibbardelliform element of *E.triassica* Müller, *Stepanovites meyeri* Kozur and Movšovič and *S.dobruskinae* Kozur and Pjatakova). Closer comparison can not be made because of the bad preservation of our material and most of that previously described.

Sc element (pl. 10: 4). There are many fragments in our material that most probably represent this element but only 2 of them can be recognized with certainty. This element is very conservative and most common among ramiform conodonts of the Permian. Similar forms were described from the Permian by Bender and Stoppel (1965) as *Hindeodella triassica* Müller; by Szaniawski (1969) as *Hindeodella* sp.; by Clark and Behnken (1971) as *Hindeodella nevadensis* Müller; by Kozur (1975) as hindeodelliform element of *Stepanovites meyeri* Kozur and Movšovič and *S.dobruskinae* Kozur and Pjatakova; and by Perlmutter (1975) as *Ligonodina* sp. Similar elements are known also from the Lower Triassic as *Hindeodella nevadensis* Müller which according to Sweet (1970) is a component of *Ellisonia triassica* Müller. The bad state of preservation of our and most of other Permian specimens makes closer comparison impossible.

From the material at hand it is not possible to state with certainty that all above described elements represent one species. We assign them tentatively to *Ellisonia* because the hindeodelliform and hibbardelliform elements are morpholo-

gically very close to corresponding elements of the type species of the genus and the lonchodiniiform element is most probably also homologous with the corresponding element of the species. The *P* element (=LF in Sweet 1970) is not recognized in our collection but it may occur among the fragments.

Conodonts similar to our lonchodiniiform and hindeodelliform elements are known to occur in association also in the Upper Pennsylvanian and early Sakmarian (fig. 4), thus before the Permian crisis *sensu* Clark (1972). This suggest that similar species of *Ellisonia* probably existed in the Carboniferous and survived the crisis.

Described elements of ?*Ellisonia* are close to corresponding elements of apparatuses of this genus reconstructed by Kozur (1975): *E.meyeni* (Kozur and Movšovič), *E.dobruskinae* (Kozur and Pjatakova), *E.festiva* (Bender and Stoppel) and *E.inflata* (Bender and Stoppel). Unfortunately Kozur did not explain the basis for his reconstructions. The only statistical data cited by him is that *E.dobruskinae* has been reconstructed from 9 partly fragmented specimens. Such reconstructions are not reliable and we can not be sure if all the above-cited species are really recognizable in multielement sense.

Sweet (1973b) suggested that skeletal apparatuses of *Ellisonia* probably also included an ozarkodiniiform element. In our material elements of ?*Ellisonia* sp. occur in association with *Sweetocristatus arcticus* sp.n. and it can not be ruled out that the latter was a component of the same apparatus (see also remarks with *Sweetocristatus* n.gen. and *Neostreptognathodus* Clark).

Occurrence.—Polakkfjellet and Ahlstrandodden.

Sa and *Sc* elements were illustrated in our preliminary note (Małkowski and Szaniawski 1976) as *Hibbardella* sp. and *Hindeodella* sp.

Genus *Neogondolella* Bender and Stoppel, 1965

Type species: Gondolella mombergensis Tatge, 1956

Remarks.—The current concept of the genus *Neogondolella* is not clear. Sweet (1973a) suggests that the species assigned to it may be polyphyletic. The genus was erected with the intention of grouping in it those species that evolved from *Neospathodus* (Bender 1967?; date of the publication is not known, see Sweet 1970) but origin of the type species, *Neogondolella mombergensis*, is controversial. According to Mosher (1968) this species is not related to *Neospathodus*. The consequence of

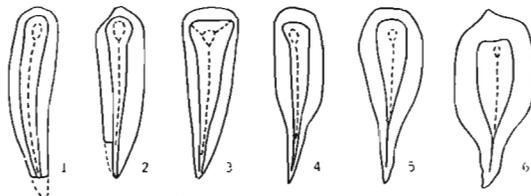


Fig. 5. Outline of under views of Permian neogondolellid sequence showing their evolution. In stratigraphically younger forms posterior part of the platform and keel become wider and their anterior part—narrower (basal grooves and pits drawn schematically). 1 *N.bisselli* (Clark and Behnken), Sakmarian (after Clark and Behnken 1971, pl. 1: 12); 2 *N.idahoensis* (Youngquist, Hawley and Miller), Leonardian—Roadian (after Youngquist, Hawley and Miller, 1951, pl. 54: 1); 3 *N.rosenkrantzi* (Bender and Stoppel), Wordian? (after Bender and Stoppel, 1965, pl. 14: 7b); 4 *N.bitteri* (Kozur), Wordian—?Capitanian (after Clark and Behnken, 1971, pl. 2: 12); 5 *N.orientalis* (Barskov and Koroleva), Dzhulfian (after Teichert, Kummel and Sweet, 1973, pl. 13: 11); 6 *N.carinata subcarinata* Sweet, Dzhulfian (after Teichert, Kummel and Sweet, 1973, fig. 16H). Not to scale.

evolutionary development of the Permian neogondolellids (fig. 5) shows clearly that all of them represent one phylogenetic branch. Ontogenetic development recognized in some of the species (*N. bitteri*, *N. idahoensis*) shows that this stock has no relation to *Neospathodus*. If *N. mombergensis* really evolved from *Neospathodus* as Bender (1967?) presumes then all species of that stock should have another generic name.

It is also not clear if the Permian gondolelliform elements belonged to single or multielement apparatuses. They are often associated with xaniognathiform and enantiognathiform elements and it is possible that all of them were components of one apparatus (this does not imply that all Triassic species now assigned to *Neogondolella* also possessed similar apparatuses). However, hitherto investigated Permian collections are insufficient as the basis for any reconstructions. Above mentioned associations can be also caused by similar ecological requirement of different species. The reconstructions of *Neogondolella leveni* (Kozur, Mostler and Pjatakova) and *N. orientalis* (Barskov and Koroleva) presented by Kozur (1975) are not documented.

Neogondolella cf. *gracilis* Clark and Ethington, 1962
(pl. 5: 3, 4)

Remarks. — Three specimens in the collection have a very long, narrow platform, similar to that of *N. gracilis*. In the all other morphological details, these specimens do not differ significantly from *N. idahoensis* Youngquist, Hawley and Miller. Thus it is possible that these specimens represent extremely elongated forms of *N. idahoensis*, but on the basis of our collection this can not be stated with certainty.

Occurrence. — Treskelen.

Neogondolella idahoensis Youngquist, Hawley and Miller, 1951
(pl. 4; pl. 5: 5)

1951. *Gondolella idahoensis* Youngquist, Hawley and Miller: 361, pl. 54: 1—3, 14, 15.
1962. *Gondolella idahoensis* Y., H. and M.; Clark and Ethington: 108, pl. 2: 15, 16.
1966. *Gondolella idahoensis* Y., H. and M.; Clark and Mosher: 588, pl. 47: 9—12.
1971. *Gondolella idahoensis* Y., H. and M.; Clark and Behnken: 431, pl. 1: 9.
1975a. *Neogondolella idahoensis* (Y., H. and M.) Behnken: 306, pl. 1: 28—30.

Material. — 77 specimens and 57 unidentified fragments probably belonging to this species.

Description. — *Juvenile.* Small, subsymmetrical slightly arched units with thin but well-developed platform and distinct carina. The platform is widest in the posterior portion, tapers in the anterior half, and is rounded on the posterior margin. Lateral zones of the platform are upturned. Carina consists of 8—10 triangular, laterally compressed, reclined denticles that decrease in size posteriorly. The cusp is higher than all other denticles, rounded in cross section, situated behind the platform, inclined posteriorly and extended downward forming one unit with the loop surrounding the pit. Basal surface bears narrow but very high keel with strongly elevated flange on the posterior end. Basal groove very narrow extends the entire length of the keel and terminates posteriorly in narrow, elongated pit.

Mature. With maturity the platform becomes thicker and wider but the length to the width ratio of mature specimens varies greatly. Posteriorly the platform extends beyond the cusp as a narrow but distinct brim. Posterior margin is nearly

straight, and is rounded only on the corners. Anterior portion of the platform tapers, and is triangular in shape. Carina bears 10—13 denticles and nodes. Anterior 3—4 denticles are high, laterally compressed. Posterior denticles are very low, node-like. Cusp subterminal, comparatively low, not fused with basal keel. Longitudinal grooves adjacent to carina deepen anteriorly. Upper surface of the platform covered with fine polygonal pits. Keel on the basal side wider but lower than in juvenile forms. Basal groove widening posteriorly, terminated with wide pit. Loop only slightly elevated, rounded or even transversely elongated, separated from the posterior margin by a brim of platform.

Remarks. — Juvenile forms of *Neogondolella idahoensis* have not previously been illustrated. They are very similar to those of *N. bitteri* (Kozur) described by Clark and Behnken (1971: 429, 434—435, pl. 2: 10, 11, 14, 15) and this shows a close relationship between these two species. Mature forms described here do not differ significantly from all hitherto known specimens. We can state only that there is a great variation in shape and in length to width ratio. There are some mature specimens with nearly rectangular posterior portion of the platform as in *N. rosenkrantzi* (Bender and Stoppel) (pl. 4: 8). Mature forms of *N. rosenkrantzi* differ from those specimens by more triangular shape of the entire unit, larger number of denticles and usually wider keel. However in the population of *N. rosenkrantzi* from the Permian of Greenland (collection of Prof. W. Sweet, Ohio State University; for locality see Sweet 1976a) there are large (mature?) specimens with a rounded posterior margin and shape very similar to that of *N. idahoensis*. For distinguishing these two species it is necessary then to have many specimens which represent well their variability. Most probably *N. rosenkrantzi* and *N. bitteri* evolved directly from *N. idahoensis*. This fits well with the suggestion of Sweet (1976a) that *N. rosenkrantzi* is stratigraphically older than was previously supposed (Bender and Stoppel 1965).

Clark and Mosher (1966) and Behnken (1975a) regarded *N. phosphoriensis* Youngquist, Hawley and Miller as a later growth stage of *N. idahoensis*. In our collection there are no forms having the ridge-like posterior portion of the carina that is a characteristic feature of *N. phosphoriensis* and this is why we have not put this species into the synonymy. Our collection is not sufficient however for us to state definitively whether or not *N. phosphoriensis* represents a separate species.

The specimen illustrated by us (Maikowski and Szaniawski 1976) as *N. cf. bisselli* (Clark and Behnken) seems to represent a form intermediate between *N. bisselli* and *N. idahoensis*. Its platform shape is similar to that of *N. bisselli* but the mode of denticulation is typical of *N. idahoensis*. Unfortunately this is the only specimen obtained from the Hyrnejellet section.

Occurrence. — Kapp Starostin Formation at Treskelen and Kapp Starostin, Spitsbergen; Leonardian and Roadian of western United States.

Neogondolella sp.A (pl. 5: 7)

Material. — 1 specimen

Description. — Platform large, thick and wide, tapering in the most anterior part. Posterior margin rounded. Carina composed of 8? low nodes in the posterior part and blade-like ridge in the anterior part. Cusp unknown. Keel on the lower side low and broad. Basal groove wide, V-shaped, ending in a small pit, which is surrounded by a wide loop.

Remarks. — The most characteristic feature of *N. sp.A* is the blade-like ridge formed by the anterior part of the carina, which most probably originated by fusion of some high anterior denticles. A somewhat similar feature is known in *N. rosen-*

krantzi, which, according to Bender and Stoppel (1965), possesses anterior denticles fused up to 2/3 of their height. This species however has a differently shaped platform. *N. bitteri* (Clark and Behnken) has a platform that is similar in shape to that of *N. sp.A*, but it has a different carina and much more strongly developed lateral troughs.

Occurrence. — Treskelen.

Genus *Neostreptognathodus* Clark, 1972

Type species: *Streptognathodus sulcopicatus* Youngquist, Hawley and Miller, 1951.

Remarks. — *Neostreptognathodus* is considered a single-element genus by Behnken (1975a) and by Sweet (1977). However Sweet does not rule out the possibility that other elements of the apparatus existed but have not been recognized. Kozur

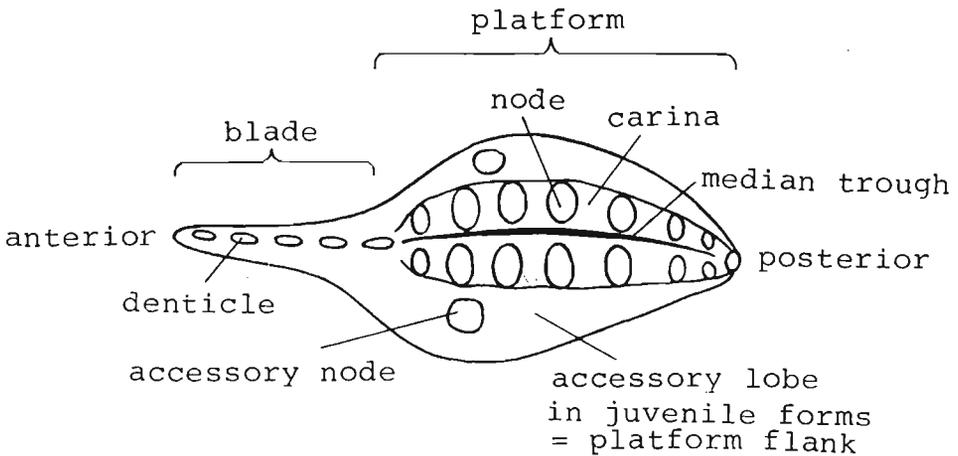


Fig. 6. Terminology of *Neostreptognathodus* Clark used in the descriptions.

and Mostler (1976) postulated that the genus was multielemental but did not make any reconstruction of its apparatus.

According to Clark (1972) *Neostreptognathodus* evolved from *Anchignathodus* Sweet (= *Hindeodus* Rexroad and Furnish) through *Sweetognathus* Clark. This would mean that it is not related to similar, but older, platform conodonts assigned to the genera *Idiognathodus* Gunnel (according to Baesemann 1973, and Perlmutter 1975, *Streptognathodus* Stauffer and Plummer is a synonym of *Idiognathodus*) or *Adeognathus* Lane. Since the time of Clark's publication our knowledge of Upper Carboniferous and Permian conodonts has significantly increased. Upper Pennsylvanian and early Sakmarin platform elements of the above-mentioned genera are now usually regarded (Von Bitter 1972; Baesemann 1973; Perlmutter 1975) as components of multielement apparatuses which also include ozarkodiniiform (O_1), synprioniodiniiform or neoprioniodiniiform (N) elements and a symmetry transition series consisting of hindeodelliform (A_1) angulodiform (A_2) and diplododelliform (A_3) elements (symbols after Klapper and Philip (1971). The basic plan of these apparatuses conforms to the model established by study of "natural assemblages" and named *Lewistownella* Scott and *Scottognathus* Rhodes. *Neostreptognathodus* in our collection occur in association with a few specimens corresponding to O_1 , N and A_1 elements of *Idiogna-*

thodus and *Adetognathus* (fig. 7). They are described in the present paper as *Sweetocristatus arcticus* sp.n. (O_1) and unassigned cypridodelliform (N) and hindeodelliform (A_1) elements. It is possible that they belonged to one apparatus. Rarity of ramiform elements could be explained by their small size and delicate structure. They are much smaller than corresponding Pennsylvanian elements. However hitherto published data on Permian conodonts and our material are not enough to make it possible to state with the certainty if this reconstruction is correct. Therefore we describe these elements separately. If the reconstruction is correct then similarity between the apparatuses of *Neostreptognathodus*, *Idiognathodus* and *Adetognathus* suggests a relationship. Lack of intermediate form of platform elements can be explained by the stratigraphic gap in their known occurrence, rapid evolu-

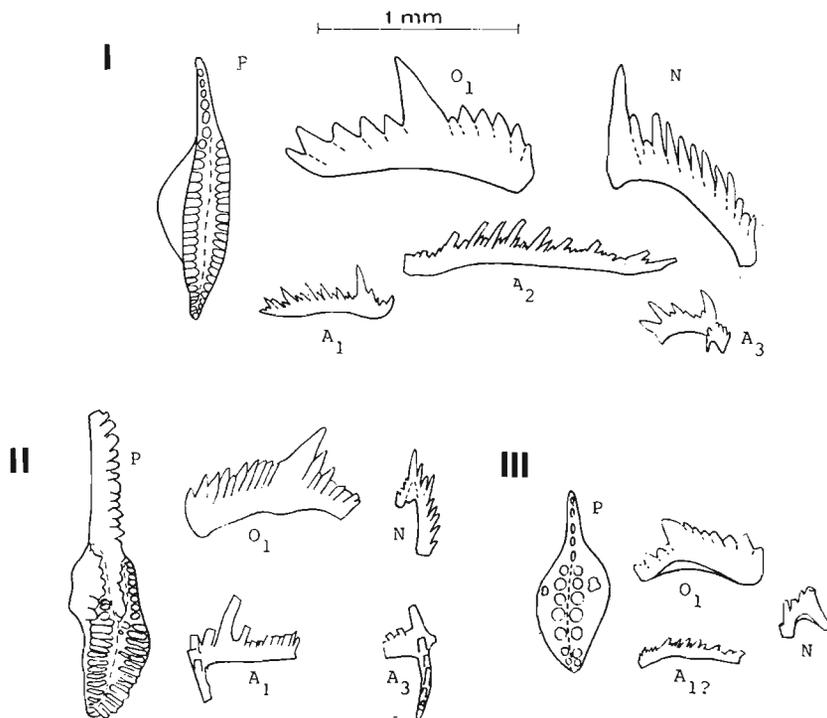


Fig. 7. *Adetognathus* (I) and *Idiognathodus* (II) apparatuses and hypothetical apparatus of *Neostreptognathodus* (III).

I *Adetognathus gigantus* (Gunnel), Upper Pennsylvanian of Kansas (after Baesemann 1973, pl. 2: 27, 28, 32, 37, 40); II *Idiognathodus elegantulus* (element P) and *Idiognathodus* compound elements, Lower Sakmarian of Kansas (after Perlmutter 1975, pl. 1: 9, pl. 2: 2, 8, 11, 12); III *Neostreptognathodus svalbardensis* (P), *Sweetocristatus arcticus* (O_1), unassigned cypridodelliform element (N) and unassigned hindeodelliform element ($A_{1?}$), Svalbardian of Spitsbergen, described in the present paper.

tion and geographic migration due to the changing of environmental conditions caused by tectonic movements. Behnken (1975a) supported the hypothesis of Clark (1972) about the derivation of *Neostreptognathodus* from *Anchignathodus* because, according to him "Earliest stages of *N. pequopensis* sp.n. resemble species of *Anchignathodus* Sweet in the possession of single row of denticles over a basal cavity and a short free blade" (p. 310). However he did not illustrate juvenile forms of

N. pequopensis and mistakes in his identification of juvenile forms are possible¹⁾. *N. svalbardensis* sp.n. possesses carinae separated by a median trough in even the earliest growth stages. Our material is not adequate to solve the problem of the origin of *Neostreptognathodus*, but in our opinion a close relationship with *Idiog-nathodus* or *Adetognathus* is not excluded (see also remarks to *Neostreptognathodus* sp.A).

Neostreptognathodus svalbardensis Szaniawski sp.n.
(pls 6, 7)

1976. *Neostreptognathodus* aff. *pequopensis* Behnken; Małkowski and Szaniawski: 82—83, pl. 1: 6—8, 10; not pl. 1: 9

Holotype: Specimen illustrated on pl. 7: 5, ZPAL C. VII/115.

Type horizon and locality: Limestone of the lower Kapp Starostin Formation at Polakkfjellet.

Derivation of the name: Found on the Svalbard archipelago.

Diagnosis. — Slightly arched, individually asymmetric units. Free blade high, with 4—6 denticles, constitutes about 0.4 the length of the element. Platform inclined posteriorly. Carinae almost straight, separated by median trough in all growth stages, convergent at the posterior end. Each carina bears up to 10 discrete nodes ornamented with small postules on the upper surface. Accessory lobes in mature forms wide, asymmetric, ornamented on each side with 1—2 large, irregular nodes.

Material. — 57 specimens.

Description. — Free blade highest in the anterior part; declines in height posteriorly. Its two anterior denticles are comparatively high; the remaining ones decrease strongly posteriorly. On the anterior side of the first denticle there are the tips of one or two small additional, fused denticles. Posterior denticle is very small and transitional in form with the nodes of the carinae. The carinae begin just posterior to the termination of the blade. They are separated by a median trough, which is widest in the middle part. Nodes of the carinae are small in the anterior part, increase in size posteriorly; and then decrease in size in the most posterior part. On the posterior end the carinae converge usually forming a single node. Upper surface of platform inclined posteriorly, pointed at the posterior end. Basal cavity large and deep; occupies the entire underside of the platform and continues under the free blade as a deep, gradually narrowing groove.

Juvenile forms are very small, narrow and almost symmetrical. Their free blade is comparatively high with narrow, discrete, sharp-tipped denticles. Carinae have few nodes, which are high, comparatively slender, outwardly directed, and separated by wide free spaces. Median trough is deep and wide; accessory lobes are not developed. Flanks of the platform are narrow, steep and without any ornamentation.

With maturity, denticles of the free blade become wider and less discrete. Nodes of the carinae are more numerous, wider and flattened. In some specimens they

¹⁾ After writing this chapter we had the opportunity to study some specimens of *Neostreptognathodus pequopensis*, *Sweetognathus whitei* and *anchignathodiform* elements from the Riepetown Formation of Nevada and the basal Skinner Ranch Formation of west Texas. Among them there is one specimen of *N. pequopensis* that represents an early growth stage (pl. 8: 4). It is similar in shape to juvenile forms of *Sweetognathus whitei*, but it differs from them by possessing two carinae separated by a median trough. The carinae and trough are very narrow and because of that, in smaller magnification similar to the singular but wider carinae of *Sweetognathus*. The nodes of carinae of juvenile *N. pequopensis* are laterally compressed and longitudinally elongated.

develop into short, wide ridges, which are transverse or slightly oblique to the long axis. Grooves between nodes are narrow. The entire upper side of the nodes is covered with numerous round pustules. In some specimens the pustules form rows on the inner slopes of the nodes which extend down to the median trough. Platform flanks develop into accessory lobes, which are wide, asymmetric and not so steep as the flanks of juvenile forms. In completely mature forms there are one or two accessory nodes on the middle zones of the lobes. They are large, flat irregular in shape and position and may develop into a form of wide transverse ridges. Well-developed additional nodes are also covered with pustules. In somewhat younger forms accessory nodes are very small, and hardly discernible.

Remarks.— This is the only known species of *Neostreptognathodus* that bears ornamentation on the accessory lobes. Somewhat similar ornamentation is known in *Idiognathodus* and *Adetognathus*. Intermediate growth stages of the new species are similar to those of *N.sulcopicatus* Youngquist, Hawley and Miller. They can be distinguished from them by the different course of the carinae in their anterior portion, where they are somewhat convergent, whereas they flare outward in *N.sulcopicatus*. Moreover nodes of the carina in the new species are usually rounded or only slightly elongated transversely while in *N.sulcopicatus* they are mostly in form of transversely elongated ridges. Also some forms of *N.pequopensis* (Behnken 1975, pl. 1: 21) can be easily confused with intermediate growth stages of the new species. They differ mainly by having a narrower platform and longitudinally rather than transversely elongated nodes on the carinae. From the holotype of *N.pequopensis* the new species differs also by having a much shorter free blade.

The relationship of the new species to *N.sulcopicatus* and *N.pequopensis* is difficult to establish due to some confusion concerning the concept of the last two species: 1. Conodonts on which Behnken (1975a) based his revised diagnosis of *N.sulcopicatus* differ considerably from the holotype of the species and were derived from another locality and probably another stratigraphic level (Sweet 1977) than the type material. 2. *N.sulcopicatus* and *N.pequopensis* according to Behnken (1975a) differ greatly by their ontogenetic development, but he did not illustrate juvenile forms of *N.pequopensis* and the "juvenile" form of *N.sulcopicatus* he illustrated (pl. 4: 1) most probably represent another hitherto unnamed species. In our opinion the above cited specimen can not represent a juvenile form of any species. Rather, it is a mature form because it possesses wide accessory lobes, which in neostreptognathodids develop at maturity. 3. The "primitive" form of *N.pequopensis* illustrated by Behnken (1975a, pl. 1: 21), which is a paratype of the species, is very similar to the holotype of *N.sulcopicatus* and differs from the holotype of *N.pequopensis* having a much shorter free blade. 4. The "advanced" forms of *N.pequopensis* illustrated by Behnken (1975a, pl. 1: 19, 20) differ from the holotype by much narrower platform and it is doubtful if they really belong to that species.

Ontogenetic development of *N.svalbardensis* is completely different than that described by Behnken (1975a) for *N.pequopensis* (see also remarks to the genus). Even the earliest growth stages of the new species possess two carinae separated by a deep median trough. Although in most specimens there is a single node at the posterior end, and in some specimens an adjacent pair of nodes are not completely separated, however this happens in different growth stages and is a result of the normal mode of growth. New nodes are accreted from the posterior and are always singular initially.

N.svalbardensis most probably evolved from the same ancestor as *N.sulcopicatus* but *N.sulcopicatus* developed better transverse ridges on the carinae while *N.svalbardensis* developed ornamentation on the accessory lobes.

Occurrence.— Polakkfjellet.

Neostreptognathodus sp.A
(pl. 8: 2, 6)

Material. — 2 specimens.

Description. — Strongly elongated and arched units. Free blade high, almost as long as the platform, bears 8—9 sharply pointed denticles. The most anterior denticle, much smaller than all the rest. The posterior denticles pass gradually into nodes of one of the carinae. Platform narrow, inclined posteriorly. Carinae slightly bowed, converge at both ends. Median trough deep; wide in central part; tapers in both directions. Nodes of the carinae high and widely spaced except for the 2—3 most anterior ones which are smaller and more closely approximated. Flanks of the platform narrow and steep; continue anteriorly to mid-length of the free blade; in most posterior part of the unit they are hidden under the platform. Basal opening deep and long; extends anteriorly under the free blade passing gradually into a narrow groove. Available specimens have 7—8 nodes on each carinae and most probably represent intermediate growth stages. One specimen has a free blade that is slightly bowed.

Remarks. — *Neostreptognathodus* sp.A represents an undescribed species. We do not propose a specific name for it because there are only two specimens of it in the collection at hand and most probably neither is mature. *N. sp.A* differs from *N. pequopensis* Behnken and *N. svalbardensis* sp.n. by having a longer free blade with a larger number of denticles. Strong convergence of the carinae at the anterior end of *N. sp.A* makes it somewhat similar to *N. rushencevi* Kozur, but that species has large well-developed accessory lobes and a shorter free blade. Passage of the free blade into one of the carinae (pl. 8: 2c) is similar to a feature of the platform elements of *Adetognathus* Lane. A similar feature also exists in juvenile forms of *N. pequopensis* (pl. 8: 4b) and *N. prayi* (Behnken 1975a, pl. 2: 12).

Occurrence. — Polakkfjellet, sample P-20-23.

Neostreptognathodus sp.B
(pl. 8: 1)

Material. — 1 incomplete specimen.

Description. — Platform long, slightly inclined posteriorly. Carinae separated by deep median trough; converge at both ends. Anterior third of each carinae smooth; posterior part bears rounded flattened nodes. Toward the posterior, nodes become more widely spaced. Flanks steep incompletely preserved. Free blade unknown.

Remarks. — There is only one specimen of this form available but it is distinguished from all other neostreptognathodids in the collection by the smooth anterior parts of the carinae. Behnken (1975a) noted a similar feature among mature forms of *N. sulcopicatus* but in that species the anterior portions of the carinae diverge whereas in our specimen they converge anteriorly. It is possible that *N. sp.B* represents a mature form of *N. sp.A* in which the anterior portion of the carinae become smooth by fusion of the nodes.

Occurrence. — Polakkfjellet, sample P-20-23.

Neostreptognathodus sp.C
(pl. 8: 3, 5)

Material. — 6 incomplete specimens.

Description. — Free blade high with 5—6 discrete, sharply pointed denticles, the third of which from the anterior one is the largest in most specimens. Platform

very narrow, inclined posteriorly. Carinae almost parallel to each other, slightly converging on both ends. Median trough narrow and deep. Carinae ornamented with very widely spaced nodes bearing narrow ridges on their inner slopes. The ridges are perpendicular or slightly oblique to the longitudinal axis. In well-preserved specimens upper surfaces of nodes and ridges are covered with tiny pustules. In some specimens not all of the nodes are situated opposite themselves. Slopes of the platform are not completely preserved in all available specimens. Their preserved upper parts are narrow and steep. In dorsal view they are clearly visible as far as the posterior end of the unit. Basal opening extends under the posterior part of free blade.

Remarks.—*Neostreptognathodus* sp.C is similar to juvenile forms of *N.pequensis* Behnken and *N.svalbardensis* sp.n. but differs from them by better developed ridges on the nodes. The same feature makes *N. sp.C* somewhat similar to *N.prayi*. From *N. sp.A* it differs mainly by having a shorter free blade with a smaller number of denticles and by the more parallel course of the carinae.

Occurrence.—Ahlstrandodden.

Genus *Sweetocristatus* Szaniawski gen.n.

Type species: *Sweetocristatus arcticus* Szaniawski sp.n.

Derivation of the name: Sweet—in honour of professor Walter C. Sweet (The Ohio State University); lat. *cristatus* = crested, due to the shape of the blade.

Diagnosis.—Paired asymmetrical blade-like units with reclined cusp, well-developed, high anterior process and shorter posterior process which is bent downwardly in most known specimens. Both processes denticulated. Basal cavity in advanced forms prominent, flaring beneath the cusp, narrowing more strongly anteriorly than posteriorly; in primitive forms, small, elongated.

Species assigned: ?*Neospathodus arcucristatus* Clark and Behnken, 1971; *Merrillina oertlii* Kozur and Mostler, 1976; *Sweetocristatus arcticus* Szaniawski sp.n.

Remarks.—Sweet (1973a) has noted that *Neospathodus arcucristatus* Clark and Behnken differs significantly from the type species of *Neospathodus* and that "This species may represent an undescribed genus" (p. 161). In 1975 Kozur established a new genus, *Merrillina*, and included *N.arcucristatus* in it. As type species of *Merrillina*, Kozur chose *Spathognathodus* (= *Neospathodus*) *divergens* Bender and Stoppel. Species assigned to *Sweetocristatus* differ significantly from that species in possessing a well-developed, denticulated posterior process and by having a basal cavity that narrows into the basal groove at least under the anterior process, whereas in *M.divergens* wide basal cavity occupies the entire under side of the unit. Moreover species of *Sweetocristatus* are much longer in proportion to the height and their denticles are laterally compressed. In *M.divergens* denticles are round in cross section. There are some Triassic species (*Neospathodus peculiaris* Sweet, *N.hungaricus* (Kozur and Mostler) that are close to *M.divergens*. It is possible that they evolved from species assigned by us to *Sweetocristatus* but they are quite distinct from them. If those species should really be distinguished from *Neospathodus* then the name *Merrillina* ought to be preserved for them.

Conodonts of *Sweetocristatus* are close to the Upper Pennsylvanian and Lower Sakmarian ozarkodiniform elements considered in recent years (Von Bitter 1972, Baesemann 1973, Perlmutter 1975) to be components of the apparatuses *Idiognathodus* Gunnell or *Adetognathus* Lane. It is possible that they evolved from those elements and belonged to similar apparatuses (see remarks to *Neostreptognathodus*). It is also possible, however, that they formed an apparatus with elements assigned

in this paper to *Ellisonia* Müller (see remarks to *Ellisonia*). In this situation we prefer as yet to treat *Sweetocristatus* as a single-element taxon.

Conodonts of *Sweetocristatus* are superficially similar to some ozarkodiniform elements of *Xaniognathus* but they differ from them by lacking a mid-lateral rib and by having a larger basal cavity. They occur in different ecological conditions than *Xaniognathus* and there is no close relationship between them. *Sweetocristatus* underwent rapid evolution and can be very useful in stratigraphy.

Occurrence.—Known from the Upper Artinskian (Baigendzhinian) to Lower Guadalupian from Western United States, the Urals and Spitsbergen. Exact range not yet established.

Sweetocristatus arcticus Szaniawski sp.n.

(pl. 9)

?1975. *Xaniognathus abstractus* (Clark and Ethington); Behnken: 313, 1: 15.

1976. *Xaniognathus* sp.; Małkowski and Szaniawski: 83, p. 1: 2.

Holotype: Specimen illustrated on pl. 9: 3, ZPAL C. VII/201.

Type horizon and locality: Limestones, of the lower Kapp Starostin Fm at Polakkfjellet.

Diagnosis.—Straight, arched, high units with large, strongly reclined cusp, 5—7 triangular, nearly erect denticles on the anterior process and 3—4 steeply reclined denticles on the posterior process. Basal cavity large, strongly flaring under the cusp, passing anteriorly into a deep groove.

Material.—18 specimens.

Description.—Anterior process much longer than posterior process; high for its entire length. Denticles triangular, discrete only in upper half of their height. The distal denticle is small and slender in most specimens; the second or the third is the largest and the remaining decrease in size posteriorly. Some anterior denticles are nearly erect; but posteriorly they become reclined. The cusp is much larger than the other denticles; is triangular in lateral view; and is steeply reclined. The posterior process is bent downwardly, and tapers posteriorly; it bears 3—4 posteriorly inclined denticles. The denticle situated at the posterior end forms an extension of the process. Basal cavity large and deep, subcircular beneath the cusp; passes anteriorly into a deep groove; posteriorly it tapers, but extends to the extremity of the unit.

Variability of the species is great, mainly with respect to size of the basal cavity, of the blade, and curvature of its lower margin, which can be nearly straight or strongly arched. At stratigraphically younger horizon (samples P-20-23) there are more specimens with a larger basal cavity and higher blade than at older levels (samples P 1—5). In juvenile forms both processes are comparatively shorter than in more mature forms, and the blade is higher; their lower margin is almost straight.

Remarks.—*S.arcticus* is closest to *Sweetocristatus oertlii* (Kozur) from which it differs by having smaller cusp, a comparatively longer posterior process and fewer but larger and more discrete denticles on the anterior process. Conodonts illustrated by Behnken (1975a, pl. 1: 15) as *Xaniognathus abstractus* (Clark and Ethington) most probably belong to *S.arcticus*, but we can not state this with certainty because of a lack of information about the development of its basal cavity.

Occurrence.—Polakkfjellet.

Genus *Sweetognathus* Clark, 1972

Type species: Spathognathodus whitei Rhodes, 1963

Sweetognathus sp.
(pl. 5: 1, 2)

Material. — 5 incomplete specimens

Description. — Carina composed of six or more transversely elongated nodes. The nodes are very high, widely spaced, and covered with tiny pustules. Spaces between the nodes become wider toward the posterior. A very narrow, faintly marked median ridge extends along the carina. The flanks of the platform are high and steep. Their basal part in most of the specimens is incompletely preserved. Free blade unknown. In the younger growth stages the nodes are shorter and more widely spaced.

Remarks. — Incomplete preservation of all available specimens prohibits their specific determination. The nodes of our specimens are very similar to those of *Sweetognathus whitei* (Rhodes) but that species is known thus far only from the Sakmarian. Stratigraphically closest is *S.adjunctus* (Behnken), which, however does not possess a median ridge, and has posterior portion of platform bowed laterally. *Sweetognathus* sp. was previously considered by us (Małkowski and Szaniawski 1976: 82—83, pl. 1: 9) as a juvenile form? of *Neostreptognathodus* aff. *pequopensis* Behnken (= *N.svalbardensis* sp.n.) because of Behnken's (1975a) remark that juvenile forms of *N.pequopensis* are almost identical to those of *S.whitei* (Rhodes). Now, studying a larger collection, we are able to state that juvenile forms of *N.svalbardensis* are completely different (pl. 6: 2,5).

Occurrence. — Polakkfjellet.

Genus *Xaniognathus* Sweet, 1970

Type species: Xaniognathus curvatus Sweet, 1970.

Remarks. — *Xaniognathus* was originally erected by Sweet (1970) to include skeletal elements of a single morphological type. Subsequent investigations led this author to the conclusion that they were components of multielement apparatuses to which also belonged five or six morphologically intergradational ramiform elements previously grouped in the genus *Ellisonia* Müller as species of the *E.gradata* type (Sweet 1973b, see also remarks with *Ellisonia*). Similar opinion expressed Babcock (1976). Kozur (1975) is of the opinion that some of the xaniognathiform elements belonged to apparatuses that also possessed gondolelliform and 3 ramiform elements.

We have found five xaniognathiform elements at two localities. In samples from both localities there were also numerous neogondolellids, singular enantiognathiform elements and a few fragments of ?other ramiform conodonts. Rarity and bad preservation of conodonts from these two sections is partly caused by the necessity of processing the samples in hydrofluoric acid. The material in our possession is insufficient for any reconstructions of multielement apparatuses and since the reconstructions of Sweet are not published as yet and the reconstructions of Kozur (1975) are not complete and not documented we apply here the generic name *Xaniognathus* only to xaniognathiform elements (see also remarks with *Neogondolella*).

Xaniognathus sp.
(pl. 5: 6)

Material. — 5 incomplete specimens.

Remarks. — *Xaniognathus* sp. is closest to *X.abstractus* (Clark and Ethington, 1962., 112, pl. 1: 16, 20, pl. 2: 2; not pl. 1: 21) from which it differs by having a slightly

longer and more tapering posterior process; wider and shorter but more discrete denticles; a larger cusp and probably a wider basal groove. *Xaniognathus* sp. is also close to conodonts described by Bender and Stoppel (1965) as *Ozarkodina tortilis* Tatge, and by Behnken (1975a) as *Xaniognathus tortilis* (Tatge). However those Middle Permian conodonts differ significantly from the Middle Triassic type material of *Ozarkodina tortilis* and are also close to *X.abstractus*.

Occurrence. — Treskelen and Kapp Starostin.

Unassigned elements

Cypridodelliform element

(pl. 10: 7, 10)

Remarks. — Only two specimens are in the collection. The most similar Permian conodonts were described by Behnken (1975a) from the late Leonardian and ?early Guadalupian of United States as the LA (=M)-element of *Ellisonia excavata* Behnken. Later on that species, with the addition of an anchignathodiform element (*Anchignathodus minutus* (Ellison) was assigned by Sweet (1977) to ?*Hindeodus* Rexroad and Furnish. Our specimens differ from those described by Behnken by having a less expanded basal cavity and denticles that are not so strongly diversified. The hindeodelliform element described below could be a counterpart of the Sc element of ?*Hindeodus excavatus* (Behnken), but neither anchignathodiform nor Sa and Sc elements of that apparatus were found in the investigated section.

Somewhat similar Permian conodonts were also described by Perlmutter (1975) from the early Sakmarian of Kansas as N (=M) elements of *Ozarkodina expansa* Perlmutter (= *Diplognathodus expansus*) and *Idiognathodus* (see remarks to *Neostreptognathodus*). We have illustrated this element in the preliminary note (Małkowski and Szaniawski 1976, pl. 1: 4) as *Cypridodella* sp.

Occurrence. — Polakkfjellet and Ahlstrandodden.

Hindeodelliform element

(pl. 10: 3)

Remarks. — Only one specimen of this element was found in the limestone at Ahlstrandodden. It is characterized by a small cusp, diversified height of denticles and very delicate construction. Similar late Leonardian and ?early Guadalupian conodonts were described by Behnken (1975a) as LB (=Sc) elements of *Ellisonia excavata* Behnken (see discussion above). Our specimens differ from them by having a smaller cusp and a longer anterior process. Perlmutter (1975) described similar Sakmarian conodonts as unassigned A₁ elements (103, pl. 2: 25) and also as A₁ (=Sc) elements of *Ozarkodina expansa* Perlmutter (= *Diplognathodus expansus*) and *Idiognathodus* (see also remarks with *Neostreptognathodus*).

Enantiognathiform element

(pl. 5: 8)

Remarks. — Two specimens of this element were found in association with *Neogondolella* and *Xaniognathus* (the better-preserved specimen was partly damaged during the study). Permian enantiognathiform elements have previously been reported by Clark and Ethington (1962) as *Apatognathus tribulosus* Clark and Ethington, by Sweet (1970) as a component of *Ellisonia gradata* Sweet, by Behnken (1975a)

as a component of *Ellisonia tribulosa* (Clark and Ethington) and by Kozur (1975) as components of *Gondolella leveni* Kozur, Mostler and Pjatakowa and *Gondolella orientalis* Barskov and Koroleva. The bad state of preservation of our specimens does not permit comparisons (see also remarks with *Neogondolella*).

Occurrence.—Treskelen and Kapp Starostin.

Fragments (pl. 10: 1, 2, 6)

There is 66 unidentified fragments of compound conodonts in the collection. Fragment 1 illustrated on pl. 10: 2 is very characteristic because of very long, slender and widely spaced denticles distributed over a very thin bar. Similar Permian conodonts are not known. Fragment 2 (pl. 10: 1) most probably belonged to the element described in the present paper as unassigned cypridodelliform element. Fragment 3 (pl. 10: 6) probably represents element of ?*Ellisonia* sp.

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HUBERT SZANIAWSKI i KRZYSZTOF MAŁKOWSKI

KONODONTY Z FORMACJI KAPP STAROSTIN (PERM) NA SPITSBERGENIE

Streszczenie

Formacja Kapp Starostin na Spitsbergenie wykształcona jest w formie kilkusetmetrowej serii osadów morskich z bogatą fauną i była już przedmiotem licznych opracowań geologicznych i paleontologicznych. Jej wiek jest jednak stale kontrowersyjny. Zamieszczano ją w różnych miejscach tabeli stratygraficznej pomiędzy sakmarem i kazaniem. Stiepanow (1957, 1973) proponował w oparciu o tę formację ustanowienie nowego piętra „Svalbardian” w zastępstwie kunguru i ufimu.

Fauna formacji Kapp Starostin badana była ostatnio w czasie wypraw Zakładu Paleobiologii Polskiej Akademii Nauk na Spitsbergen (1974, 1975, 1976). Poza znanymi już w tych utworach grupami skamieniałości o charakterze bentonicznym (ramienionogi, mszywioly, gąbki, małżoraczki, „małe” otwornice) znaleziono w nich również konodonty (Małkowski i Szaniawski 1976). Niniejsza praca zawiera opisy systematyczne konodontów z formacji Kapp Starostin, charakterystykę środowiska ich sedimentacji i próbę ich zastosowania do korelacji tych utworów z permem Stanów Zjednoczonych, gdzie fauna konodontowa tego wieku poznana została stosunkowo najlepiej. Z pięciu przekrojów formacji Kapp Starostin na południowym Vestspitsbergenie (fig. 1, 2) zbadano około 60 prób, z których 23 zawierały konodonty. Wypreparowano z nich 320 okazów należących do 16 różnych form morfologicznych (tabela 3). Opisano jeden nowy rodzaj (*Sweetocristatus*) i 2 nowe gatunki (*Sweetocristatus arcticus* i *Neostreptognathodus svalbardensis*). Wysunięto przypuszczenie, że rodzaj *Neostreptognathodus* nie rozwinął się jak przyjmowano (Clark 1972, Behnken 1975a) z rodzaju *Sweetognathus* lecz jest blisko spokrewniony z rodzajami *Idiognathodus* i *Adetognathus* oraz przedstawiono hipotetyczny, wieloelementowy aparat tego rodzaju (fig. 7). Większość konodontów z formacji Kapp Starostin jest blisko spokrewniona z konodontami znanymi z górnego leonardianu i dolnego roadianu Ameryki Północnej. Najbardziej zbliżony zespół znany jest z członu Meade Peak

formacji Phosphoria występującej w stanach Idaho Wyoming i Utah Stanów Zjednoczonych (tabela 1). Poza gatunkiem wspólnym dla obu tych regionów (*Neogondolella idahoensis* (Youngquist, Hawley and Miller) najważniejszy pod względem stratygraficznym jest *Neostreptognathodus svalbardensis* sp.n. Posiada on najprawdopodobniej zbliżony zasięg stratygraficzny do powszechnego w utworach górnego leonardianu i dolnego roadianu Ameryki Północnej *Neostreptognathodus sulcopicatus* (Y., H. and M.). Niektóre konodonty z formacji Kapp Starostin są nieco zbliżone także do konodontów znanych z utworów baigendżinu (górný artinsk) rejonu Przy-Uralu.

Konodonty z formacji Kapp Starostin występują w dwóch różnych asocjacjach (tab. 3), związanych z różnymi facjami osadów (tab. 2). W jednej z asocjacji związanej z facją wapieni dominuje *Neostreptognathodus*, w drugiej związanej ze skałami krzemionkowymi — *Neogondolella*. Na podstawie analizy bio- i litofacjalnej (tab. 2), przeprowadzono porównanie i rekonstrukcję środowisk odpowiadających strefom życia obu zespołów konodontowych (fig. 3). Strefy te różniły się takimi cechami jak: odległość od brzegu i głębokość morza, ruchliwość, temperatura, chemizm i eutroficzność wody oraz skład towarzyszącego konodontom zespołu organizmów.

ХУБЕРТ ШАНЯВСКИ, КРИШТОФ МАЛКОВСКИ

КОНОДОНТЫ СТАРОСТИНСКОЙ СВИТЫ (ПЕРМЬ) ШПИЦБЕРГЕНА

Резюме

Старостинская свита Шпицбергена представляет собой серию в несколько сот метров морских осадков с богатой фауной и была уже предметом многочисленных геологических и палеонтологических исследований. Однако возраст её является всё ещё нерешенной проблемой. Её размещали в различных местах стратиграфической шкалы между сакмарским и казанским ярусами. Степанов (1957, 1973) предложил на основе этой свиты новый ярус „свальбардский”, вместо кунгурского и уфимского ярусов.

Фауна старостинской свиты недавно была исследована во время экспедиции Института палеобиологии Польской Академии Наук на Шпицбергене (1974, 1975, 1976). Кроме уже известных в этих образованиях групп окаменелостей бентонного характера (плеченогие, мшанки, губки, остракоды, „мелкие” фораминиферы) также были найдены конodontы (Małkowski и Szaniawski 1976). В данной статье представлены систематические описания конodontов старостинской свиты, характеристика их среды седиментации и попытка применения их для корреляции этих отложений с пермом США, где конodontовая фауна этого же возраста была

относительно хорошо исследована. Из пяти профилей свиты в южной части Вестшпицбергена (фиг. 1, 2) было изучено около 60 проб, 23 из которых содержали конодонты. Из этих проб были выделены 320 образцов фауны, принадлежащих к 16 различным морфологическим типам (таблица 3). Описан один новый род (*Sweetocristatus*) и 2 новых вида (*Sweetocristatus arcticus* и *Neostreptognathodus svalbardensis*). Было высказано предположение, что род *Neostreptognathodus*, не развился, как было принято (Clark 1972; Behnken 1975a) из рода *Sweetognathus*, а является близким по родству с родами *Idiognathodus* и *Adetognathus*; представлен гипотетический многоэлементный аппарат этого рода (фиг. 7). Большая часть конодонтов старостинской свиты родственна конодонтам, известным в верхнем леонардяне и нижнем роадяне Северной Америки. Наиболее близкий комплекс известен в части Meade Peak свиты Phosphoria, выступающей в Штатах Америки: Айдахо, Вайоминг и Юта (таблица 1). Кроме общего для этих регионов вида (*Neogondolella idahoensis* (Youngquist, Hawley and Miller) самым важным со стратиграфической точки зрения является *Neostreptognathodus svalbardensis* sp.n. Он, как кажется, имеет близкий стратиграфический возраст к распространённому в верхнем леонардяне и нижнем роадяне Северной Америки *Neostreptognathodus sulcopicatus* (Y. H. and M.). Некоторые конодонты старостинской свиты также близки к конодонтам, известным из отложений байгенджинского яруса (верхний артинск) района Приуралья.

Конодонты старостинской свиты выступают в двух разных ассоциациях, (таблица 3), связанных с различными фациями осадков (таблица 2). В одной из этих ассоциаций, связанной с фацией известняков преобладает *Neostreptognathodus*, в другой, связанной с кремнистыми породами — *Neogondolella*. На основе био- и литофациального анализа были проведены сравнение и реконструкция среды, отвечающей жизненным зонам обоих комплексов конодонтов (фиг. 3). Эти зоны отличаются такими чертами, как: отдаленность от берега и глубокость моря, подвижность, температура, химизм и эвтрофность воды, а также состав сопутствующего конодонтам комплекса организмов.

EXPLANATION OF THE PLATES 4—10

Plate 4

Neogondolella idahoensis (Youngquist, Hawley and Miller)

- 1—4. Juvenile forms. 1 under view, ZPAL C.VII/6, sample Tr-C, $\times 130$; 2 lateral view of incomplete specimen, ZPAL C.VII/7, sample K-20, $\times 130$; 3a, b lateral and upper views, ZPAL C.VII/8, sample K-20, $\times 130$; 4a, b lateral and upper views, ZPAL C.VII/9, sample Tr-E, $\times 130$.

- 5—6. Intermediate growth stages. 5a oblique upper view, ZPAL C.VII/10, sample B-1, $\times 100$, 5b fragment showing position of cusp $\times 265$; 6 upper-lateral view, ZPAL C.VII/11, sample Tr-E, $\times 100$.
- 7—8. Mature forms. 7 upper view of incomplete specimen, ZPAL C.VII/12, sample B-1, $\times 150$; 8a upper view of the posterior part, ZPAL C.VII/13, sample B-1, $\times 130$, 8b fragment of the same showing position of the cusp, $\times 300$.

Plate 5

- 1—2. *Sweetognathus* sp.: 1a, b lateral and upper views of incomplete specimen, ZPAL C.VII/202, sample P-20-23, $\times 130$; 2 upper view of incomplete specimen, ZPAL C.VII/105, sample P-20-23, $\times 125$.
- 3—4. *Neogondolella* cf. *gracilis*: 3 juvenile form, ZPAL C.VII/3, sample Tr-B, $\times 100$; 4 intermediate growth stage? with the cusp broken off, ZPAL C.VII/4, sample Tr-E, $\times 130$.
5. *Neogondolella idahoensis* Youngquist, Hawley and Miller: a under view $\times 85$, b fragment of the same specimen showing edges of laminae in the basal groove, $\times 660$, ZPAL C.VII/14, sample Tr-E.
6. *Xaniognathus* sp.: ZPAL C.VII/83, sample K-20, $\times 130$.
- 7a, b. *Neogondolella* sp.A in the upper and under views, ZPAL C.VII/2, sample Tr-D, $\times 70$.
8. Unassigned enantiognathiform element; ZPAL C.VII/87, sample K-20, $\times 130$.

Plate 6

Neostreptognathodus svalbardensis Szaniawski sp.n., immature forms

- 2, 5. Juvenile forms: 2a, b lateral and upper views of incomplete specimen of very young growth stage, ZPAL C.VII/106, sample P-1-5, $\times 185$, 5a, b, c lateral, upper and under views, ZPAL C.VII/107, sample P-20-23, $\times 85$, 5d fragment of the biggest denticle of free blade showing its microsculpture $\times 600$.
- 1, 3, 4, 6. Intermediate growth stages, 1a upper view of incomplete specimen with unusually narrow and flat median trough, ZPAL C.VII/108, sample P-6-10, $\times 100$, 1b fragment showing pustules on the nodes, $\times 570$; 3 oblique view of incomplete specimen, ZPAL C.VII/108, sample P-20-23, $\times 105$; 4 upper view, ZPAL C.VII/109, sample P-20-23, $\times 85$; 6a, b lateral and under views of incomplete specimen, ZPAL C.VII/110, sample P-20-23, $\times 115$.

Plate 7

Neostreptognathodus svalbardensis Szaniawski sp.n., mature forms

- 1a, b. Upper and lateral views of incomplete specimen, ZPAL C.VII/111, sample P-1-5, $\times 100$.
- 2a, b. Upper and lateral views of incomplete specimen, ZPAL C.VII/112, sample P-1-5, $\times 100$.
3. Incomplete specimen in lateral view, ZPAL C.VII/113, sample P-1-5, $\times 115$.
4. Incomplete specimen ZPAL C.VII/114, sample P-1-5, a upper view $\times 100$, b fragment showing pustules on the accessory nodes $\times 330$.
5. Holotype, ZPAL C.VII/115, sample P-1-5, a upper view of the platform, $\times 100$, b lateral view of free blade of the same specimen, $\times 100$, c fragment of the same specimen showing pustules of the incompletely developed additional node, $\times 330$.

Plate 8

- 1a, b *Neostreptognathodus* sp.B.: incomplete specimen in lateral and upper views, ZPAL C.VII/170, sample P-20-23, $\times 100$.
- 2, 6. *Neostreptognathodus* sp.A.: 2a, b lateral and upper views, ZPAL C.VII/168, sample P-20-23, $\times 100$, 2c fragment of the same specimen showing merger of the free blade with the platform, $\times 330$; 6a, b lateral and upper views, ZPAL C.VII/169, sample P-20-23, $\times 85$.
- 3, 5. *Neostreptognathodus* sp.C.: 3 upper view of incomplete specimen, ZPAL C.VII/171, sample A-10, $\times 130$; 5a, b upper and lateral views of incomplete specimen, ZPAL C.VII/172, sample A-12, $\times 120$.
4. *Neostreptognathodus pecuopensis* Behnken: a upper view $\times 100$, b fragment of the same specimen showing merger of the free blade with the platform, Riepetown Formation, Nevada, UW 1695.

Plate 9

Sweetocristatus arcticus Szaniawski sp.n.

- 1—2. Juvenile forms. 1 lateral view ZPAL C.VII/83, sample P-1-5, $\times 130$; 2a lateral view, ZPAL C.VII/184, sample P-20-23, $\times 130$, 2b fragment of the same showing microsculpture on the denticles $\times 660$.
- 3, 4, 7. Intermediate growth stages. 3 holotype lateral view, ZPAL C.VII/201, sample P-20-23, $\times 100$; 4a, b lateral and under views of the same specimen, ZPAL C.VII/185, sample P-1-5, $\times 100$; 7a, b lateral and under views of the same specimen, ZPAL C.VII/188, sample P-20-23, $\times 90$.
- 5, 6. Mature forms. 5a, b lateral and under views of the same specimen, ZPAL C.VII/186, sample P-1-5, $\times 140$; 6a, b lateral and under views, of the same specimen ZPAL C.VII/187, sample P-1-5, $\times 105$.

Plate 10

1. Fragment 2: ZPAL C.VII/174, sample P-1-5, $\times 130$.
2. Fragment 1: ZPAL C.VII/216, sample A-12, $\times 100$.
3. Unassigned hindeodelliform element: ZPAL C.VII/180, sample A-12, $\times 130$.
- 4, 5, 8, 9. ?*Ellisonia* sp. elements: 4 element Sc, ZPAL C.VII/211, sample P-1-5, $\times 65$, 5 element Sa, ZPAL C.VII/213, sample P-20-23, $\times 100$, 8, 9 elements M, ZPAL C.VII/208, 209, samples A-10 and P-1-5, $\times 100$.
6. Fragment 3: ZPAL C.VII/215, sample P-1-5, $\times 130$.
- 7, 10. Unassigned cypridodelliform elements: ZPAL C.VII/212, 216, samples P-1-5 and P-20-23, $\times 200$.

