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CONODONTS OF THE DEVONIAN-CARBONIFEROUS BOUNDARY SECTION, KOZHIM, POLAR URALS, RUSSIA.

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(5 figures, 1 table and 4 plates)

ABSTRACT.- The succession across the Devonian-Carboniferous boundary in the key section at Kozhim, Polar Urals consists of siliceous, carbonate and argillaceous deposits with ammonoid, conodont, ostracod and foraminiferal faunas. Devonian palmatolepid assemblages are replaced by siphonodellids and *Protognathodus*. The basal part of bed 58 is characterized by the appearance of *Siphonodella praesulcata, S. sulcata* and transitional forms. Since the differentiation of *S. praesulcata* and *S. sulcata* was difficult and subjective, we used a biometric approach based on the measurements utilised by Flajs and Feist (1988) for the specimens of *Siphonodella* from the La Serre section. Comparing the curvature of our specimens with those from La Serre, we identified *Siphonodella sulcata* as low as sample H-6a, that is at the base of bed 58. Thus, *S. praesulcata* and *S. sulcata* appear at the same level in the Kozhim section. Ostracod faunas also change at the base of bed 58. Conodonts, ammonoids and ostracods of the underlying deposits (sample H-5) are undoubtedly of late Famennian age. Thus, the Devonian-Carboniferous boundary is identified between the Zigansky and "Humerovsky" horizons, or between samples H-5 and H-6a of the Kozhim section.

The Kozhim section is important because conodont, ostracod, ammonoid and foraminiferal sequences are recorded across the Devonian-Carboniferous boundary. Additional detailed investigations will help to clarify the position of the Devonian-Carboniferous boundary.

INTRODUCTION

For many years the definition of the Devonian-Carboniferous boundary has been one of the most important problems of Carboniferous stratigraphy. In 1935, at the Heerlen Congress, it was agreed that the D/C boundary should be defined within the ammonoid sequence at the base of the *Gattendorfia* ammonoid genozone between the Hangenberg Limestone and Hangenberg Shales in the Hönnetal section at Oberrödinghausen, Germany. More recently, it has become apparent that it is difficult to find a complete cephalopod succession and to differentiate the species and genera of the imitoceratids which occur in an intermediate position between the *Gattendorfia* and *Wocklumeria* genozones.

Foraminifers show essential faunal differences between Western Europe, North America and USSR and therefore cannot be used for definition of the Devonian-Carboniferous boundary.

The Devonian-Carboniferous Boundary Working Group has voted in favour of a conodont-based Devonian-Carboniferous boundary. Conodonts are widespread, easily collected and can serve as good markers for long-distance correlation. The Working Group proposed to take the first appearance of *Siphonodella sulcata* - preferably within a well

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documented *Siphonodella praesulcata-Siphonodella sulcata* succession - as the Devonian-Carboniferous boundary level. This faunal horizon is close to the D/C boundary of 1935 based on the first appearance of the cephalopod *Gattendorfia subinvoluta*.

A number of sections with the *Siphonodella praesulcata-Siphonodella sulcata* sequence as well as the *Protognathodus* fauna were proposed and studied as potential candidates for the stratotype of the D/C boundary in Western Europe, North America, North Africa, China and USSR (Ziegler & Sandberg, 1984; Paproth & Streel, 1984; Yu *et al.*, 1987; Schönlaub *et al.*, 1988; Paproth *et al*, 1989; Golubtsov *et al.*, 1988; etc.).

In 1988 the Working Group on the Devonian-Carboniferous Boundary chose the La Serre section in the Montagne Noir, southern France as the boundary stratotype section (Paproth, 1989). This section fulfils the main requirements of the boundary stratotype as it contains the continuous succession of *Siphonodella praesulcata-Siphonodella sulcata* and can be correlated with other sections with different lithofacies and fossil content.

In the Soviet Union, since 1962, the D/C boundary has been placed at the base of the *Wocklumeria* Genozone or the base of the Zavolzhsky Horizon. For many years this position has been a subject for discussion.

New data on different groups of fossils in the vicinity of the D/C boundary obtained in recent years in the USSR has made it necessary to revise the position of the boundary. 52 reports presented at the Interdepartmental Stratigraphic Committee Meeting in 1986 reflected research on different group of fossils from the D/C boundary deposits of the main regions of the USSR - the Russian Platform, Urals, Caucasus, Transcaucasus, Kazakhstan, Altai, Middle Asia and North Eastern region (Golubtsov *et al.*, 1988).

Several levels were proposed for the D/C boundary: 1) the base of the *Quasiendothyra (Eoendothyra) communis* foraminiferal Zone; 2) the base of the *Wocklumeria* Genozone and the *Q. kobeitusana* foraminiferal Zone; 3) the base of the *Gattendorfia* Genozone - Beds with *Acutimitoceras prorsum*; 4) the earliest occurrence of *Gattendorfia subinvoluta*.

Taking into account the evolution of different faunas and floras, the continuity of sedimentation and the geological development of different regions, it was recommended that the D/C boundary should be drawn at the base of the Beds with *Acutimitoceras prorsum* (*Gattendorfia* Genozone). This level corrresponds approximately to the base of the *Siphonodella sulcata* conodont Zone and the *Richterina latior- Pseudoleperditia tuberculifera* ostracod Zone and the *Vallatisporites pusillites* miospore Zone.

Several sections were proposed as candidates for potential stratotypes (or key sections, as they are now), as follows: the Kiya, Zigan and Sikaza sections (South Urals), Berchogur section (Kazakhstan) and the Omolon Valley (Siberia). The Kiya, Sikaza and Berchogur sections were withdrawn because of their inaccessibility, or because of insufficient data.

At present, the best sections across the Devonian-Carboniferous boundary in the USSR are the Zigan (South Urals) and Kamenka (Omolon Valley) sections. The Kamenka section in the north-east of the USSR contains the *Siphonodella praesulcata-Siphonodella sulcata* and *Protognathodus kockeli-Protognathodus kuehni* successions (Gagiev, 1988).

At the same time an additional section was sampled to assess its potential as a D/C boundary stratotype or key section.

In this paper we report on this Kozhim section, situated in the Polar Urals. It contains *Siphonodella* and *Protognathodus* faunas within the Devonian-Carboniferous boundary deposits, which are also characterized by ammonoids, conodonts, ostracods and foraminifers (Chermnykh *et al.*, 1988). The availability of data on conodonts, ostracods, ammonoids and foraminifers makes this section important in the study of the Devonian-Carboniferous boundary.

STRATIGRAPHY

The Upper Famennian - Lower Tournaisan successions at the north of the Urals fold belt are characterized by approximately north-south facies belts. There is a change from shallow-water deposits fringing a landmass (during the Famennian) in the west (eastern Timan area) to deep-water facies towards the east. Along the eastern slope of the Urals the shallow-water deposits occur again.

The siliceous, carbonate and argillaceous deposits of the Polar Urals are characterized paleontologically most completely.

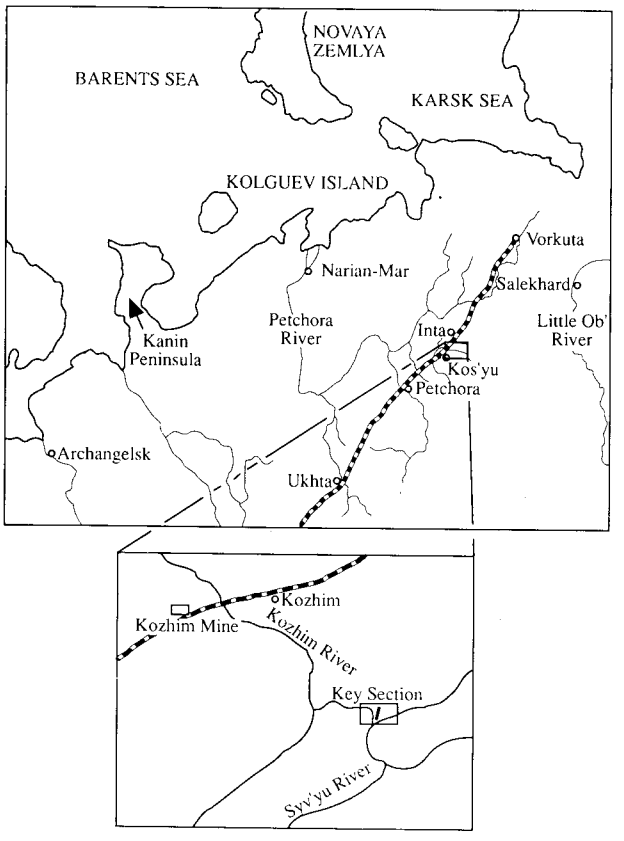

Fig. 1.- Location map for the Devonian-Carboniferous boundary key section in the Kozhim River in the Polar Urals

The Kozhim section is located on the right bank of the lower reaches of the Kozhim River, 11 km up-stream of the railway bridge, Inta district, in the former Komi Autonomic SSR (Fig. 1).

For a long time the Devonian-Carboniferous boundary deposits were erroneously assigned to the upper part of the Tournaisian. Later the presence of beds with *Kalloclymenia* of the Upper Devonian was established (Bogoslovsky & Kuzina, 1980, 1984). Horizons around the Devonian-Carboniferous boundary were identified there initially by conodonts. Their stratigraphical position was subsequently confirmed by data from ostracods and foraminifers (Chermnykh *et al.*, 1988).

According to the local Devonian and Carboniferous stratigraphical schemes, the Upper Famennian of this section is subdivided into the Kushelginsky, Lytvinsky and Zigansky horizons (the *Palmatolepis postera*, *P. expansa* and *Siphonodella praesulcata* standard conodont zones, respectively). Within the Tournaisian, the "Humerovsky", Malevsky, Upinsky, Cherepetsky, Kizelovsky and Kosvinsky horizons are provisionally recognized (the *Siphonodella sulcata*, *S. duplicata*, *S. sandbergi* and *S. quadruplicata* as well as *Polygnathus communis carina* and *Scaliognathus anchoralis* conodont zones, respectively). Because it is not palaeontologically distinctive, the name Humerovsky Horizon was abolished in 1990. The strata referred to the Humerovsky Horizon in this account are not formally named.

In this paper we describe the interval from the upper part of the Zigansky Horizon to the Upinsky Horizon (Figs. 2, 3, 4).

Interbedded platy cherts, siliceous limestones and limestones with chert nodules and dark mudstones containing *Kalloclymenia* (Bed 55) and conodonts *(Palmatolepis)* are overlain by the deposits of the Zigansky Horizon.

The Zigansky Horizon (beds 56-57) is represented by dark grey and black, cherty, muddy limestones, and buff to black mudstones. The thickness is 1.05m. The conodonts *Spathognathodus inornatus* (Branson & Mehl), *S. disparilis* (Branson & Mehl), *Palmatolepis gracilis gracilis* Branson & Mehl, *Pa. gracilis sigmoidalis* Ziegler, *Pa. gracilis expansa* Sandberg & Ziegler and others were found there. The ammonoids *Kalloclymenia kozhimensis* Bogoslovsky, *Imitoceras obsoletum* Kuzina and *I. angustilobatum* Kuzina (Bogolovsky & Kuzina, 1980, 1984) and small moulds of *Synwocklumeria* (Chermnykh *et al.*, 1988) apparently belong to these beds. The limestones yield very small *Parathuramminna, Glomospiranella, Eoendothyra communis minima* Lipina, *Earlandia moderata* Malakhova and *Laxoendothyra* sp. The ostracods *Caratocratia cerata* Blumenstengel, *Orthonaria rectegona* Grundel, *O. subelliptica* Kochetkova, *Bythoceratina brueggei spinosa* Blumenstengel, *Tetrasacculus triloculi* Blumenstengel, *Rectoplacera elongata* Blumenstengel were found there (identifications were made by Dr. N.I. Kochetkova).

The former Humerovsky Horizon (bed 58) is represented by dark grey, massive, bituminous limestone, 0.7m thick. It is characterized by an abundant and diverse conodont fauna as follows: *Palmatolepis gracilis gracilis* Branson & Mehl, *Pa. gr. sigmoidalis* Ziegler, *Pa. gr. expansa* Sandberg, *Siphonodella praesulcata* Sandberg, *S. sulcata* Huddle, *Bispathodus aculeatus aculeatus* (Branson & Mehl), *B. stabilis* (Branson & Mehl), *Polygnathus communis communis* Branson & Mehl, *Po. inornatus* E. Branson, *Po. vogesi* Ziegler, *Pseudopolygnathus dentilineatus* E. Branson, *Ps. primus* Branson & Mehl, *Ps. nodomarginatus* (E. Branson),

Fig. 2.-Critical interval of the Devonian-Carboniferous boundary deposits of the Kozhim key section with the first *Siphonodella sulcata* and *S. praesulcata* (bed 58, sample H-6a)

Ps. marginatus (Branson & Mehl), Po. *purus purus* Voges, *Protognathodus meischneri* Ziegler, *Pr. kockeli* (Bischoff) as well as late Famennian *Ps. trigonicus* Ziegler and *B. costatus* (E. Branson). Foraminifers *Klubovella konesis* Lebedeva, *Quasiendothyra konensis glomiformis* Reitlinger, *Q. kobeitusana* Rauser, *Septaglomospiranella compressa* Lipina, *S.* aff. *primaeva* (Rauser), *B malevkensis* Birina, *Eoendothyra communis radiata* Reitlinger, *Glomospiranella* sp., *Parathurammina cushmani* Lipina, *P. suleimanovi* Lipina and others were discovered (sample H-10). Dr. Kochetkova identified the following ostracods from the lower part of this horizon (sample H-7): *Armilla sibirica* Buschmina, *Glyptopleura plicata* (Jones & Kirkby), *Glyptolichwinella spiralis* (Jones & Kirkby), *Carbonita* aff. *egorovae* (Tchigova), *Knoxiella* aff. *primaris* Kochetkova, *Chamishaella* sp., *Amphissites* cf. *blumenstengeli* Grundel, *Cribroconcha* aff. *primaris* Kochetkova, *Praepilatina triangulata* (Samoilova & Smirnova), *Bairdia zanina* Posner, *Cooperina elongata* Posner and others (Chermnykh *et al.*, 1988).

The Malevsky Horizon (upper part of bed 58 - bed 70) is represented by dark grey, bituminous, detrital limestones with thick platy interbeds and lenses of dark chert and mudstones. The thickness of this unit is 3 m. The conodont assemblage of this horizon is very similar to that of the underlying one. The ostracod association contains early Carboniferous zonal index forms as follows: *Coryellina advena* Schneider & Tkacheva (sample H-11), *C. ziganensis* Kochetkova, *Pseudoleperditia* cf. *tuberculifera* Schneider, *Villozona villosa villosa* (Grundel) (sample H-15) as well as the species recorded from the underlying units. In the upper part of the horizon (sample H-17) the following foraminifers were found

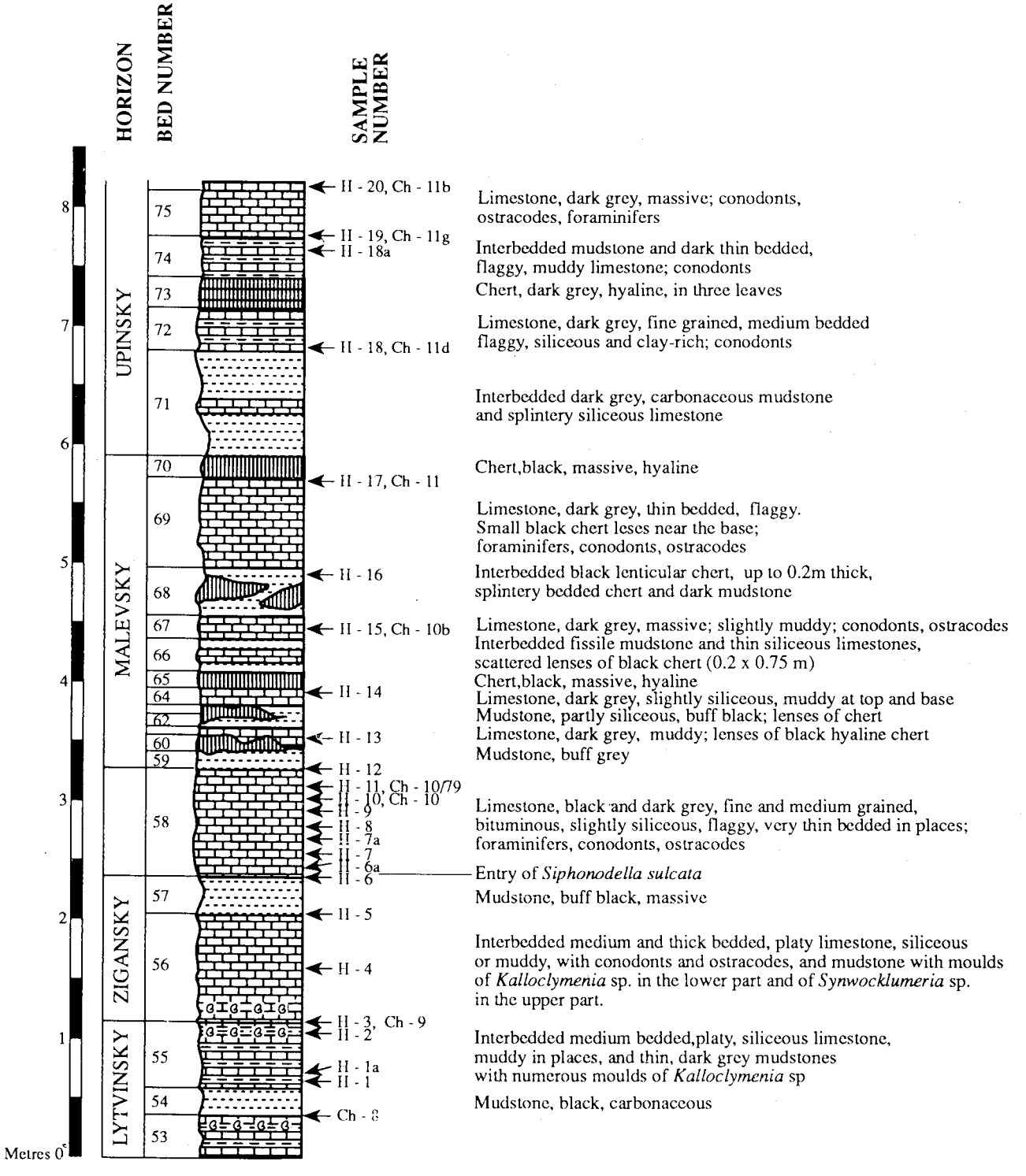

Fig. 3.- The Kozhim section of the Devonian-Carboniferous boundary deposits

Qasiendothyra cf. *kobeitusana* Rauser, *Eoendothyra communis* (Rauser), *E.* cf. *communis radiata* (Reitlinger), *Septaglomospiranella* sp., *Paracalligeloides* aff. *abramjanae* Reitlinger, *Bisphaera irregularis* Bykova, *B. malevkensis* Birina, *B. compressa* Reitlinger, *Parathurammina* cf. *stellata* Lipina, *Neoseptaglomospiranella dainae* Lipina and others. The Upinsky horizon (beds 71 - 78) is tentatively recognized in this section. Interbedded detrital and radiolarian-bearing muddy limestones and dark mudstones (3.7m thick) contain the following conodonts: *Siphonodella duplicata* (Branson & Mehl), *S. sulcata* Huddle, *S. carinthiaca* Schönlaub, *Polygnathus communis communis* Branson & Mehl, *Po. purus purus* Voges, *Po. purus subplanus* Voges, *Pseudopolygnathus fusiformis* Branson & Mehl, *Ps. marginatus* (Branson & Mehl) and others.

CONODONTS

All of the carbonate interbeds of the Kozhim section from the Famennian to the Middle Carboniferous were sampled. As mentioned above, this report is concerned with the part of the section from the uppermost Famennian to the lower Tournaisian. All samples from limestones were productive. The samples from mudstone were mostly barren.

Samples were relatively widely spaced through most of the section (every 0.5-0.8 m), but they were collected more closely across the supposed boundary (at 0.1-0.2 m intervals) within bed 58. The conodonts visible on the bedding planes of mudstones were also studied.

The section was sampled by Nemirovskaya and Pazukhin for the first time in 1978. Those samples were marked by the Russian letter Ч (=Ch) (after the first letter of the Chermnykh's name in Russian), for example Ч-10a. In 1980 the intensity of sampling was doubled by the same workers. In 1983 the section was measured and sampled in more detail, especially the interval from bed 55 to bed 85 by Nemirovskaya. So the section was marked by the first Russian letter of Nemirovskaya's name (N = H; for example H-6a, H-10, etc.). At the same time samples for ostracods were taken for Dr. N. M. Kochetkova (Bashkirian Branch of the Academy of Sciences of the USSR). Conodonts from ostracod samples filled in gaps in the collection of Dr. V.N. Pazukhin. Ostracods of this locality were also studied by Dr. I. D. Tkacheva.

All material illustrated in this paper is housed in the palaeontological collections of the Institute of Geological Sciences of the Ukrainian Academy of Sciences (IGS AS U) and the Institute of Geological Sciences of the Bashkirian Branch of the Academy of Sciences (BashBASUSSR).

The earliest conodont collection of Nemirovskaya was shown to Dr. H. Alberti in 1983 and more complete collections (after additional sampling) to Dr. W.Ziegler in 1984. In 1988, during the Mid-Carboniferous Working Group meeting in Kiev, Dr. H. R.Lane, Dr. G. Webster and Prof. W.L.Manger had a brief opportunity to examine the conodonts from beds 58-66.

Although the authors of this paper discussed the differentiation of *S. praesulcata* and *S. sulcata* for a long time they could not agree about the position of the lower boundary of the *S. sulcata* Zone in this section. This was due to difficulties in understanding the difference between *S. praesulcata* and *S. sulcata.* Within the upper part of the *S. praesulcata* Zone, with advanced *S. praesulcata*, and within the lower part of the *S. sulcata* Zone, with earliest *S. sulcata*, transitional forms are common. It is difficult to recognize undoubted *S. sulcata* and undoubted *S. praesulcata* among them. There are specimens with curved carina and only a slightly curved pseudokeel, and vice versa.

The authors' different views on the assignment of transitional specimens to *S. sulcata* or *S. praesulcata* that led to different views on the position of the Devonian-Carboniferous boundary in this section prevented earlier publication of the available data.

Assignment of the upper part of bed 56 - the top of the marly limestone (sample H-5) with *Palmatolepis gracilis gracilis, Pa. gr. sigmoidalis* and *Pa. gr. expansa* to the Upper Famennian is beyond any doubt. The ammonoids *Kalloclymenia kozhimensis, Imitoceras obsoletum* and *I. angustilobatum* were found in the lower part of bed 5 (near sample H-2 - H-5). Unfortunately a unit of buff black mudstone (bed 57), with a thin interlayer of yellowish-brown clay at the top, was not sampled by the authors. The upper part of these mudstones, which are calcareous in places, is mostly a silty, calcareous, micaceous residue from carbonate concretions. The lower boundary of this unit is sharp (Zhuravlev, 1990). Significant amounts of sand grade material may point to erosion at the base of the unit. These deposits were sampled by Zhuravlev, who found only rounded fragments of conodonts and carbonised fragments, possibly of plant origin (Zhuravlev,

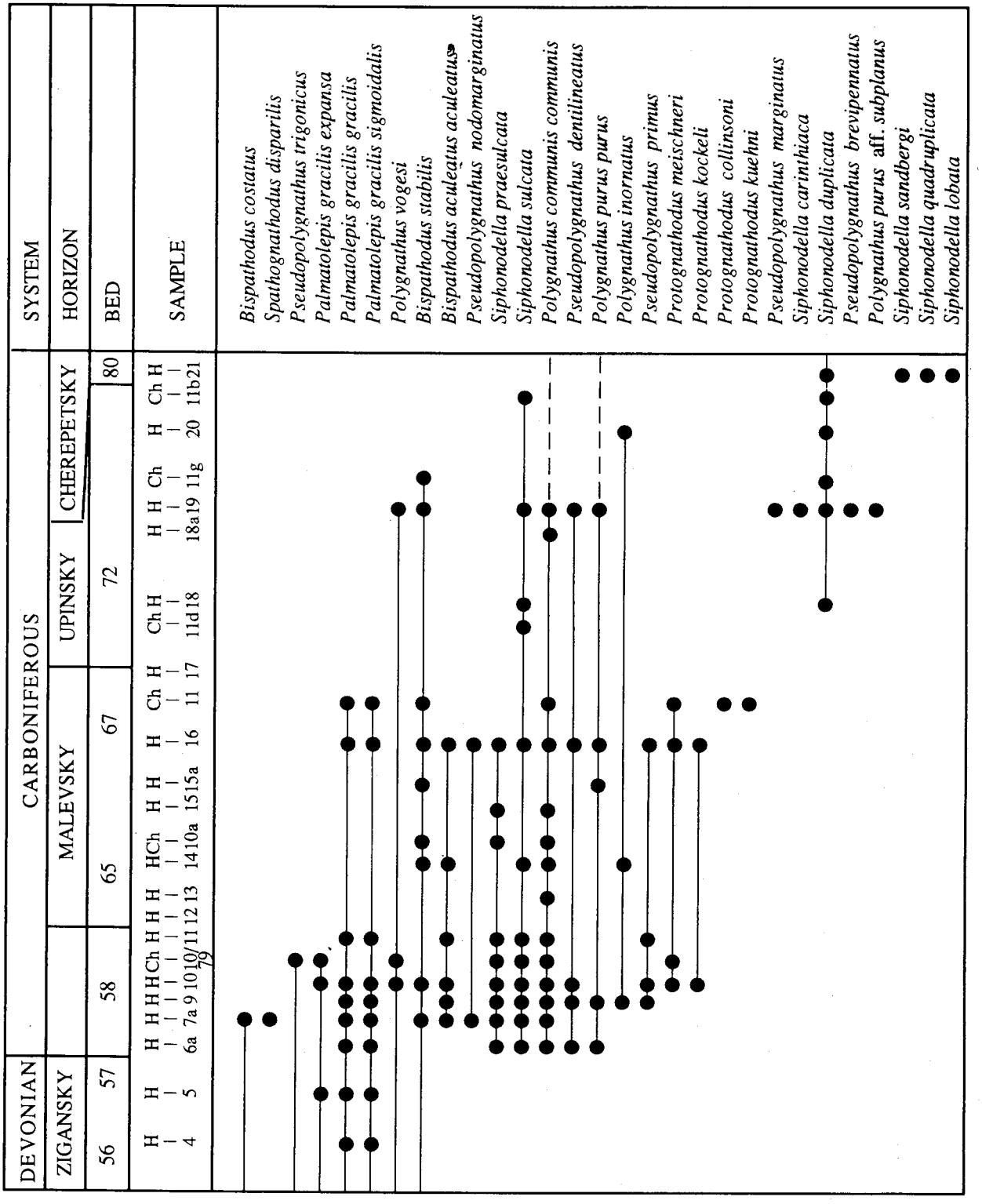

Fig. 4.- Distribution of the main conodont species through the Devonian-Carboniferous boundary deposits of the Kozhim section

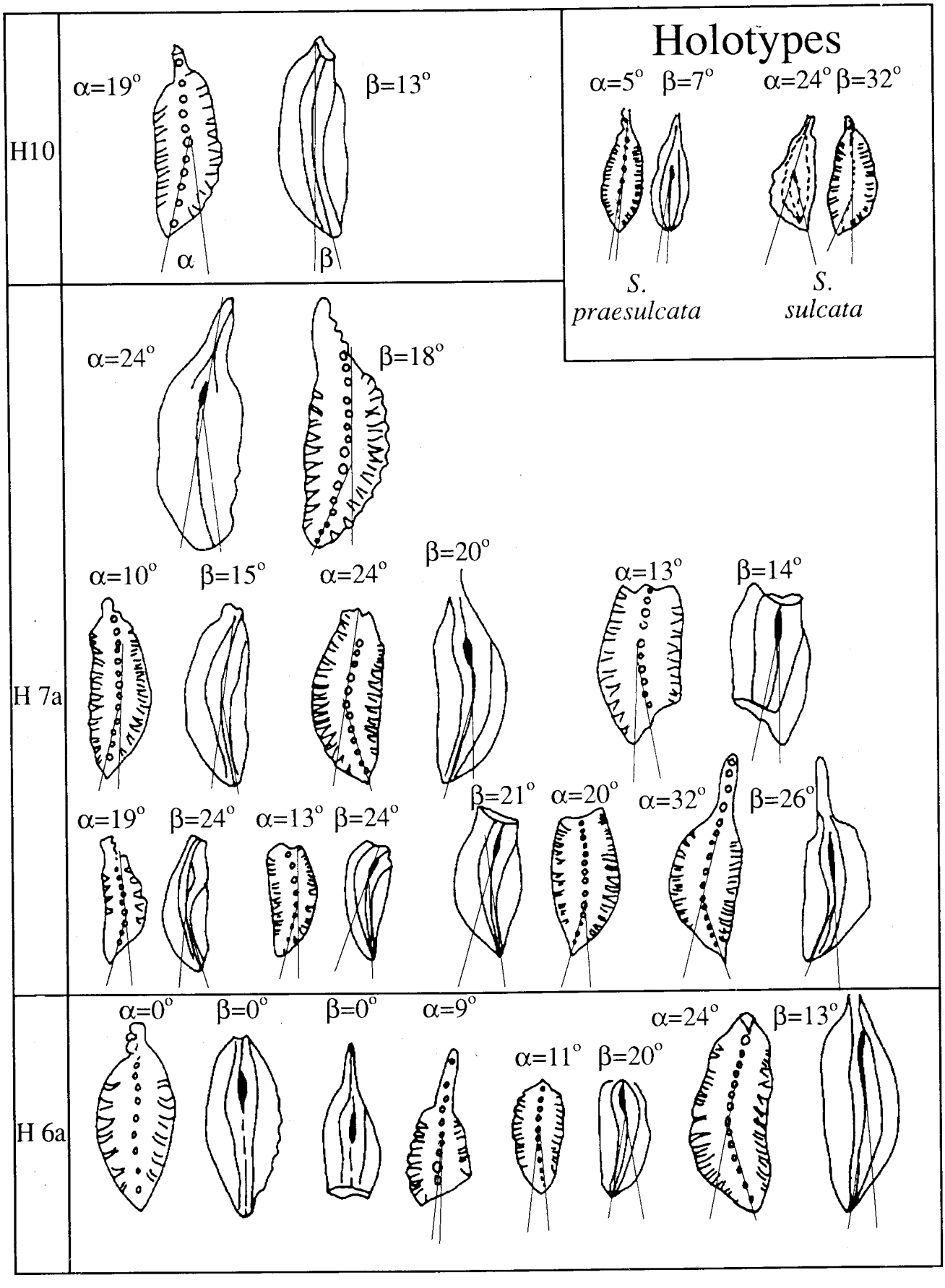

Fig. 5.-Some representatives of *Siphonodella praesulcata* and *S. sulcata* of the Kozhim section. Biometrical measurements : α-curvature of carina, β-curvature of pseudokeel, H-6a - number of samples, 1,2,3... - number of the illustration on Plate 1

Table 1.- The results of biometrical measurements of *Siphonodella praesulcata* and *S. sulcata* from the samples H-6a, H-7a and H-10.

Sample	Figures on Plate I	α	β	Species
H-6a	1	24°	13°	*Siphonodella sulcata*
	2	09°	00°	*S. praesulcata*
	3	00°	00°	*S. praesulcata*
	4	11°	20°	*S. praesulcata - S. sulcata* transitional form
H-7a	5	17°	24°	*S. sulcata*
	6	19°	24°	*S. sulcata*
	7	21°	20°	*S. sulcata*
	8	32°	26°	*S. sulcata*
	9	10°	15°	*S. praesulcata*
	10	18°	24°	*S. sulcata*
	11	24°	20°	*S. sulcata*
	12	13°	14°	*S. praesulcata*
H-10	13	19°	13°	*S. praesulcata - S. sulcata* transitional form

1990). Palynological analysis did not yield any results.

Sample H-6, taken at the contact between the clay-rich bed 57 and overlying limestone (bed 57), was barren. A. Zhuravlev (personal communication, 1991) has found the conodont assemblage with *S. sulcata* approximately at this level.

The next sample H-6a, 5cm above H-6, contains 7 specimens of *Siphonodella* (4 well preserved specimens were examined biometrically, see Fig.5 and Table 1) that were a subject of discussion. Dr. Kononova assigned all of them to *S. sulcata* while the other specialists including Dr. W. Ziegler, some American conodontologists as well as Dr. Nemirovskaya - to *S. praesulcata.*

The next sample H-7 could not be broken down completely due to strong silicification of the limestone. Conodonts were not extracted.

Sample H-7a contains an assemblage of conodonts similar to sample H-6a, with *Palmatolepis, Bispathodus* and *Siphonodella praesulcata* and *S. sulcata* as well as *Polygnathus communis communis* and others (Fig. 4). The last named species dominates in the assemblage of sample H-9 where Bispathodus, *Palmatolepis, Siphonodella praesulcata* and *S. sulcata* are common.

Sample H-10 yielded a diverse conodont fauna with *Siphonodella praesulcata, S. sulcata,* abundant *Polygnathus communis communis,* rare *Palmatolepis gracilis gracilis* and *Pa. gr. sigmoidalis* and others. The last occurrence of *Palmatolepis gracilis expansa* and *Pseudopolygnathus trigonicus,* as well as the first appearance of the *Protognathodus* fauna (*Pr. meischneri* and *Pr. kockeli*) are characteristic of the assemblage from this level. The possibility that *Pa. gr. expansa* and *Ps. trigonicus* are reworked has not been ruled out.

Sample H-11 is characterized by the occurrence of *Siphonodella praesulcata, S. sulcata* with rare palmatolepids and the last *Bispathodus costatus.*

Sample H-12 was taken at the top of limestone bed 58 and was barren of platform elements.

Sample H-13, taken above the shales and siliceous lenses within dark grey, bituminous limestones yielded only *Polygnathus communis communis.*

A small conodont fauna, consisting of *Siphonodella sulcata, Polygnathus communis communis* and *Po. inornatus,* was obtained from sample H-14, a dark grey limestone between cherts just below a thin clay.

Sample Ch-10a contains *Siphonodella praesulcata* and *Polygnathus communis communis.*

Sample H-15a, taken in dark mudstone with chert lenses, yielded *Bispathodus stabilis, Pseudopolygnathus multistriatus* and *Polygnathus purus purus.* Sample H-16 (bed 69) collected from the basal part of a muddy limestone contains an abundant and diverse conodont fauna, including typical *S. sulcata, S. praesulcata, Pr. meischneri* and *Pr. kockeli.*

Sample Ch-11 does not contain *Siphonodella.* However, *Pr. meischneri, Pr. collinsoni* Ziegler and *Pr. kuehni* Ziegler & Leuteritz, as well as polygnathids and pseudopolygnathids common in the underlying deposits were found. The last occurrence of palmatolepids is at this level (Fig. 4).

The first *Siphonodella duplicata* was found in the marly portion of limestone bed 70 (sample H-18).

A more diverse and abundant conodont assemblage was recorded in sample H-19, taken at the base of a massive siliceous limestone (bed 75). It

includes: *Siphonodella duplicata, S. sulcata, S.praesulcata,* which still occurs at this level, *Polygnathus communis communis, Po. vogesi* and others. The first *Siphonodella carinthiaca* and *Pseudopolygnathus fusiformis* were extracted from this level.

Higher in the section (samples H-21, Ch-11B and above) a diverse *Siphonodella* assemblage occurs. It includes: *Siphonodella cooperi* Hass, *S. quadruplicata* (Branson & Mehl), *S. sandbergi* Klapper, *S. lobata* (Branson & Mehl), *S. duplicata* and *S. sulcata.*

Higher, the same species of *Siphonodella* range up to the mudstone strata (about 30m thick) that is not characterized by conodonts. Above the mudstones, *Scaliognathus anchoralis* Branson & Mehl and *Hindeodella segaformis* Bischoff were recovered from limestone lenses within the shales.

DISCUSSION

As mentioned above, the authors, as well as the other specialists who had seen the collection, had different points of view on the differentiation of *S. sulcata* and *S. praesulcata* and therefore on the position of the Devonian-Carboniferous boundary in this section.

To resolve this problem Dr. Kononova made use of biometrical measurements similar to those that G. Flajs and R. Feist had made with their specimens of *Siphonodella praesulcata*, *S. sulcata* and transitional forms from the La Serre section (Flajs & Feist, 1988).

To differentiate these species Flajs and Feist measured the asymmetry and curvature of the platform and pseudokeel and the position of the basal pit. The curvature yielded the best results. We have made measurements of the curvature of the carina as well as that of the pseudokeel, and have compared our values to those of the La Serre material.

Specimens of *Siphonodella praesulcata* from the La Serre section show curvatures between 0° and 15°, with an average value of about 7°. Transitional forms have shown a position near the upper limit of variability of *S. praesulcata.* The first *S. sulcata* in bed 89 of the La Serre section shows an average curvature of 12° In general the curvature of about 15° is significantly higher than in all the *S. praesulcata* and transitional forms of this section. The younger specimens of *S. sulcata* have shown much higher curvature.

By comparison of the curvature of the carina and pseudokeel of our specimens in samples H-6a, H-7a and H-10 with values of those from the La Serre section, we obtained the results shown in Figure 5 an Table 1.

Figure 5 shows that the single specimen that is assigned to *S. sulcata* by its curvature occurs as low as the base of bed 58, sample H-6a. *S. praesulcata* dominates here. Hence the interval between H-6a and H-17 (beds 58-71) appears to correspond to the *S. sulcata* Zone. If this is the case the shales below bed 58 might be the equivalent of the Hangenberg Shales. The first *Protognathodus* fauna occurs considerably higher (sample H-10). The late Famennian conodonts range into the *S. sulcata* Zone. For example, *Palmatolepis gracilis gracilis* and *Pa. gr. sigmoidalis* were found as high as sample H-16. Moreover, *Pseudopolygnathus trigonicus* was recorded in sample H-10. The ranges of foraminifers show the same picture. *Quasiendothyra* cf. *kobeitusana* was found in sample H-17; *Q. konensis glomiformis* in sample H-10. These forms are not known to range into the Malevsky Horizon in the nearest Timan-Pechora area (Durkina & Avchimovich, 1988) and other regions of the USSR either. Meanwhile rare *Quasiendothyra* (Reitlinger & Durkina, 1988) occur with the first *Siphonodella* in the South Urals.

Several conodont zones can be recognized in this section: *Siphonodella sulcata* Zone (beds 58-71, samples H-6a - Ch-11d), *Siphonodella duplicata* Zone (beds 72 - 92, samples H-18 - H-20) and *S. sandbergi - S. quadruplicata* Zone (bed 80 and higher, sample H-21 and higher). As to the underlying deposits, bed 57 seems to be an equivalent of the *S. praesulcata* Zone and strata below bed 57 probably correspond to the *Pa. gr. expansa* Zone.

CONCLUSION

Although the Kozhim section is not well documented, it is clearly one of the more important and interesting sections through the boundary deposits. It contains diverse fossil assemblages. Famennian conodonts are replaced by early Carboniferous forms at the base of bed 58 (sample H-6a). Conodonts are represented by *Siphonodella* and *Protognathodus* successions that allow correlation of the Kozhim section with others of different facies.

Siphonodella sulcata, *S. praesulcata*, *Protognathodus meischneri*, *Pr. kockeli*, *Pr. collinsoni* and *Pr. kuehni* as well as *Palmatolepis*, *Polygnathus*, *Pseudopolygnathus* and *Bispathodus* species are characteristic of the Devonian-Carboniferous boundary deposits of this section. Ostracods are common and change in the lower part of bed 58. This could be explained by facies control (the Upper Famennian deposits reflect deeper water than the Lower Tournaisian) but a similar change of late Famennian assemblages into early Carboniferous assemblages is observed in the South Urals within a single facies type (Kochetkova *et al.*, 1988; personal communication, 6.04.1989).

The extinction and disappearance of *Quasiendothyra* is characteristic of this boundary interval. Such extinction is typical for a passage from the late Famennian to early Tournaisian.

In general, the small thickness and favourable facies for fossils, the relatively uninterupted succession with the presence of ammonoids, ostracods, conodonts and foraminifers, as well as the possibility of obtaining information on miospores and radiolarians, make the Kozhim section one of the most important key section for the Devonian-Carboniferous boundary of the Russia. Therefore it needs comprehensive and detailed investigations.

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PLATE 1

All specimens except Figures 15 and 16 held with the IGSAS UkrSSR (Institute of Geological Sciences of the Academy of the Sciences of the Ukrainian SSR), Kiev, Ukraine. The others - with the IGS Bash Br. AS USSR (Institute of Geological Sciences of the Bashkirian, Ufa, USSR. All figures are x 50 except where otherwide noted; stratigraphical location is shown in Figure 2.

1, 5-8, 10, 11, 13-15, 17. *Siphonodella sulcata* Huddle
1a,b. specimen IGSU-I, sample H-6a.
5a,b, 6a,b, 7a,b, 8a,b, 10a,b, 11a,b.
specimens IGSU-2, IHSU-3, IGSU-4, IGSU-5, IGSU-6 and IGSU-7 respectively; all from sample H-7a.
13,a,b. specimen IGSU-8, sample H-10.
14a,b. specimen IGSU-9, sample H-9, x 40.
15a,b. specimen BBAS-I, sample 4-10/79, x 40.
17a,b. IGSU-10, sample H-14, x 40.

4, 9, 12. *Siphonodella praesulcata* - *Siphonodella sulcata* transition forms.
4a,b. specimen IGSU-11, sample H-6a.
9a,b, 12a,b. specimens IGSU-12 and IGSU-13 respectively; both from sample H-7a.

2, 3, 16a,b. *Siphonodella praesulcata* Sandberg.
2a,b, 3a,b.specimens IGSU-14 and IGSU-15 respectively;both from sample H-6a.
16a,b. specimen BBAS-2, sample -10/79, x 40.

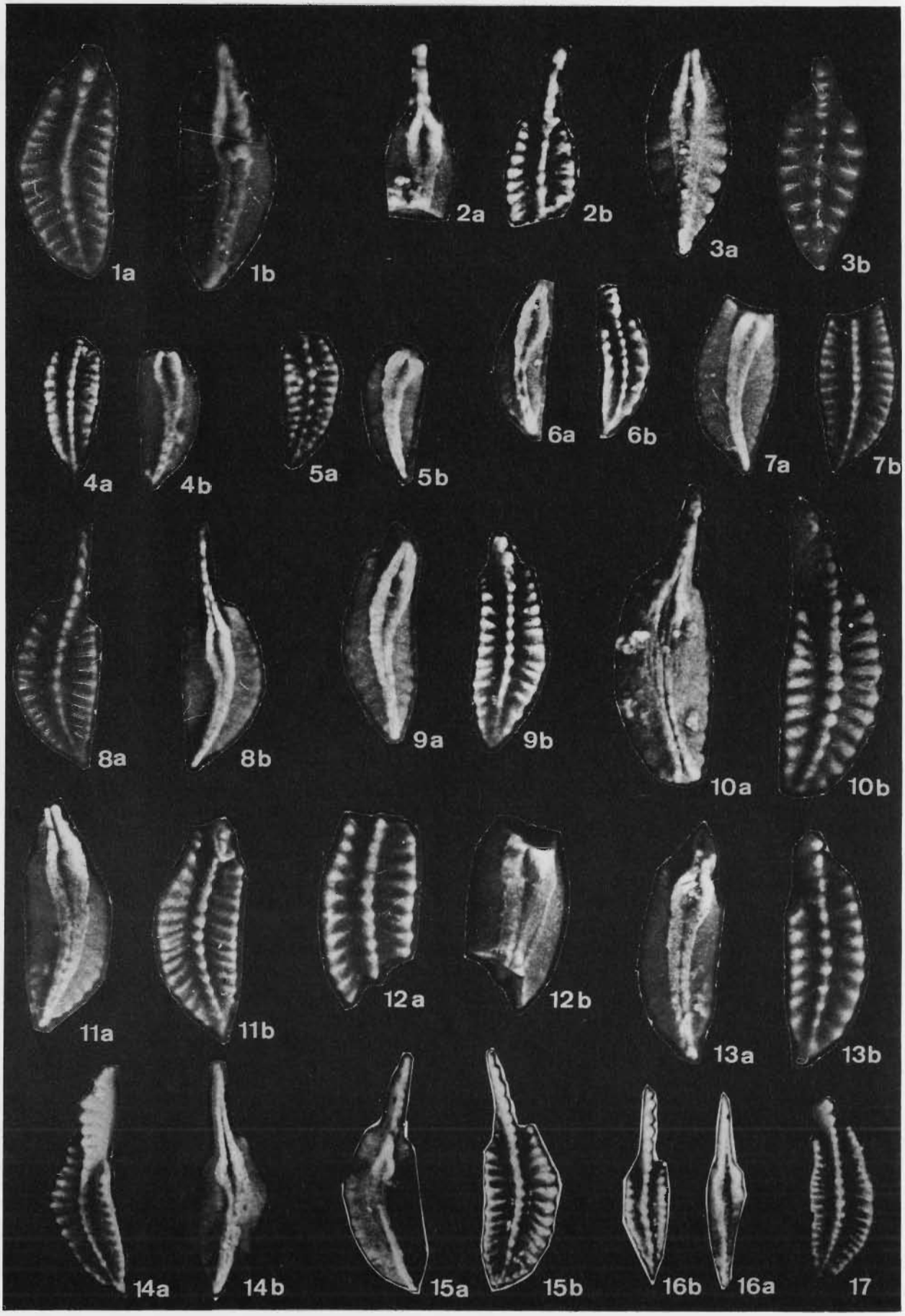
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PLATE 2

All specimens except Figures 1a,b, 15 and 16 held with IGS AS UkrSSR, Kiev, Ukraine. others - with IGSBB AS USSR, Bashkiria, Ufa, USSR. All figures are x 40, stratigraphical location of samples is shown in Figure 2.

1a,b, 3-6. *Siphonodella sulcata* Huddle.
- 1a,b. specimen BBAS-3, sample H-16.
- 3. specimen IGSU-16, sample H-9.
- 4. specimen IGSU-17, sample H-10.
- 5,6. specimens IGSU-18 and IGSU-19 respectively; both from sample H-16.

2. *Siphonodella praesulcata - S. sulcata* transitional form.
specimen IGSU-20, sample H-9.

7, 8, 9, 11. *Siphonodella duplicata* (Branson & Mehl).
- 7. specimen IGSU-22, sample H-18.
- 8,9,11. specimens IGSU-21, ISU-23 and IGSU-24 respectively; all from sample H-19.

10. *Siphonodella carinthiaca* Schönlaub.
specimen IGSU-26, sample H-19.

12a,b. *Siphonodella duplicata - S. carinthiaca* transitional form.
specimen IGSU-25, sample H-19.

13, 14. *Protognathodus meischneri* Ziegler.
specimens IGSU-63 and IGSU-64 respectively; both from sample H-16.

15, 16, 21. *Protognathodus kockeli* (Bischoff).
- 15. specimen IGSU-65, sample H-16.
- 16. specimen IGSU-66, sample 4-10/H-10/.
- 21. specimen BBAS-14, sample 4-10/79.

17. *Siphonodella lobata* (Branson & Mehl).
specimen BBAS-4, sample 4-11a/78.

18. *Siphonodella sandbergi* Klapper.
specimen BBAS-5, sample 4-11a/78.

19. *Protognathodus kuehni* Ziegler & Leuteritz.
specimen IGSU-67, sample 4-11.

20. *Protognathodus collinsoni* Ziegler.
specimen IGSU-68, sample 4-11.

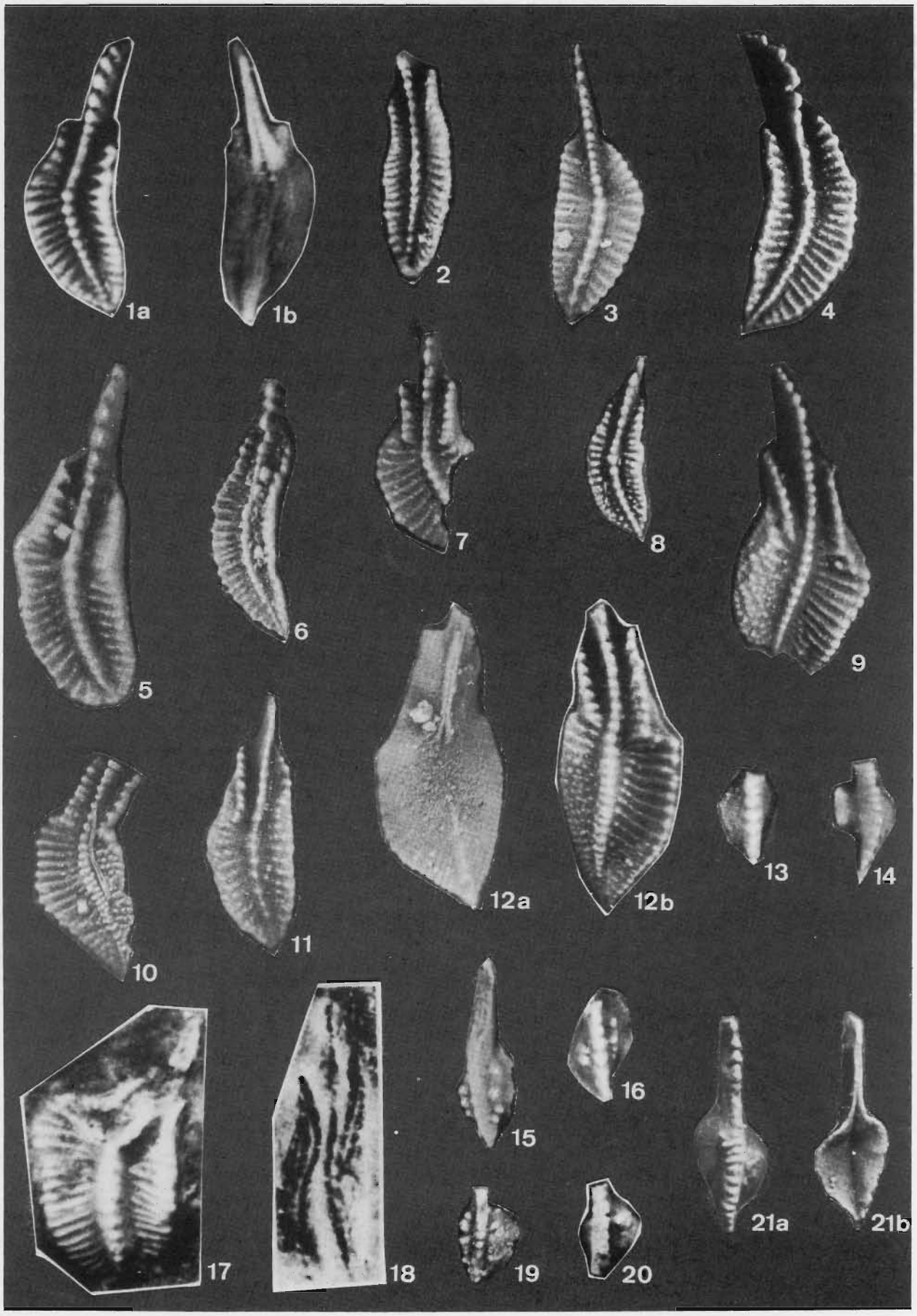
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PLATE 3

All specimens except figs 2,7,23 are located in the Institute of Geological Sciences of the Academy of Sciences of the Ukrainian SSR (IGSU), Kiev, the others - in the Institute of Geological Sciences of the Bashkirian Branch of the Academy of Sciences of the USSR., Ufa. All magnification, x40.

1. *Pseudopolygnathus* aff. *primus* Branson & Mehl.
   1a,b. specimen IGSU-43, sample H-6a.

2-4. *Pseudopolygnathus primus* Branson & Mehl
   2a,b. specimen BBAS-11, sample H-16;
   3. specimen IGSU-44, sample H-9;
   4a,b. specimen IGSU-45, sample H-10.

5,7. *Pseudopolygnathus marburgensis trigonicus* Ziegler
   5. specimen IGSU-46, sample H-10;
   7a,b. specimen BBAS-12, sample H-10.

6. *Pseudopolygnathus marginatus* (Branson & Mehl)
   specimen IGSU-48, sample H-7a.

8,13,16. *Polygnathus communis carina* Hass
   8,13. specimen IGSU-49 and IGSU-50, sample Ch-13;
   16. specimen IGSU-57, sample Ch-13.

9. *Pseudopolygnathus marginatus* (Branson & Mehl)
   specimen IGSU-32, sample H-19.

10,14. *Pseudopolygnathus fusiformis* (Branson & Mehl)
   10. specimen IGSU-51;
   11. specimen IGSU-52;
   14a,b. specimen IGSU-53, sample H-19.

12,15,19-21. *Polygnathus communis communis* Branson & Mehl
   12a,b. specimen IGSU-54, sample H-7a;
   15,19. specimen IGSU-56 and IGSU-57, sample H-16;
   20. specimen IGSU-58, sample H-16;
   21. specimen IGSU-55, sample H-9.

17. *Polygnathus purus* cf. *subplanus* Voges
   17a,b. specimen IGSU-62, sample H-19.

18. *Polygnathus purus purus* Voges; specimen IGSU-60, sample H-16.

22,23. *Polygnathus vogesi* Ziegler
   22. specimen IGSU-59, sample H-19;
   23. specimen BBAS-13, sample Ch-8a.

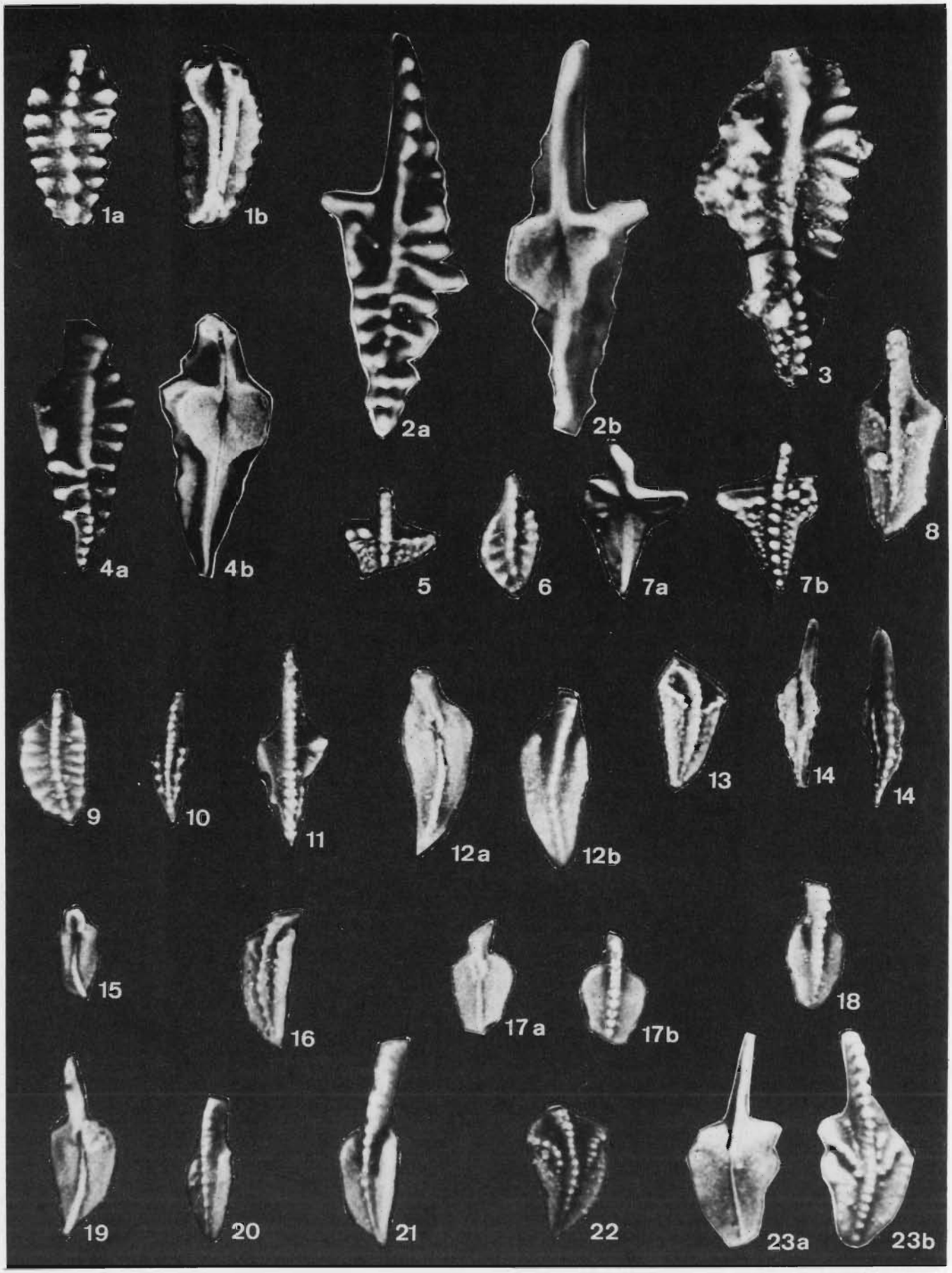
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PLATE 4

All specimens except figs 3,13,15,16 and 20 are located in the Institute of Geological Sciences of the Academy of Sciences of the Ukrainian SSR (IGSU), Kiev, the others - in the Institute of Geological Sciences of the Bashkirian branch (BBAS) of the Academy of Sciences of the Ukraine, Ufa. All magnification, x40.

1. *Palmatolepis gracilis sigmoidalis* Ziegler
specimen IGSU-27, sample H-6.

2,7,8. *Palmatolepis gracilis gracilis* Branson & Mehl
2. specimen IGSU-28, sample H-10;
7. specimen IGSU-30, sample ?-11;
8. specimen IGSU-29, sample H-9.

3. *Palmatolepis gracilis expansa* Sandberg & Ziegler
3. specimen BBAS-6, sample ?-10/79.

4-6,9,12. *Bispathodus aculeatus aculeatus* (Branson & Mehl)
4. specimen IGSU-31, sample H-7a;
5. specimen IGSU-32, sample H-9;
6,9,12. specimen BBAS-7, IGSU-33 and IGSU-34, sample H-16.

10,11. *Bispathodus stabilis* (Branson & Mehl)
10. specimen IGSU-36, sample H-7a;
11. specimen IGSU-35, sample Ch-11.

13. *Polygnathus parapetus* Druce
specimen BBAS-9, sample H-16.

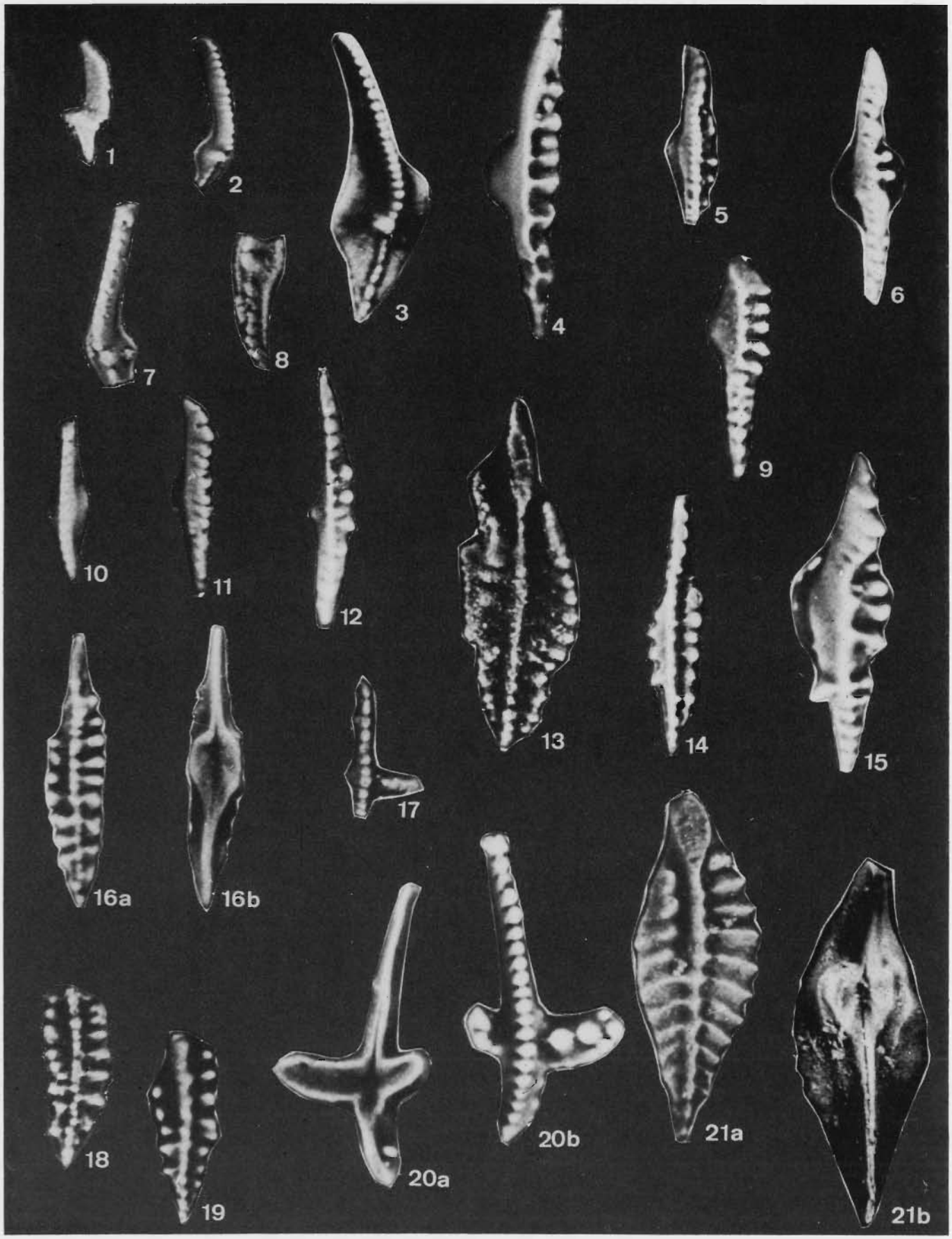
14,18,19. *Pseudopolygnathus dentilineatus* E.Branson
14. specimen IGSU-38, sample H-16;
18,19. specimen IGSU-39 and IGSU-40, sample H-10.

15. *Pseudopolygnathus* sp.
specimen BBAS-9, sample H-16.

16. *Pseudopolygnathus multistriatus* Mehl & Thomas
16a,b. specimen BBAS-9, sample 13.

17,20. *Spathognathodus disparilis* (Branson & Mehl)
17. specimen IGSU-41, sample H-7a;
20. specimen BBAS-10, sample 7/83.

21. *Pseudopolygnathus altaicus* Kononova
21a,b. specimen IGSU-42, sample 13.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