

Conodonts from the Permian succession of Bjørnøya (Svalbard)

HANS ARNE NAKREM

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Fourteen conodont species are described from composite Permian (Asselian–?Ufimian) sections of Bjørnøya. Sample richness is generally good with 30–100 specimens per kilo of dissolved carbonate rock in productive samples. The investigated faunas make it possible to propose an Asselian age for the Kapp Dunér Formation, a latest Artinskian age for the upper part of the Hambergfjellet Formation, and a Kungurian–Ufimian age for the Miseryfjellet Formation. These ages are generally in agreement with published datings based on fusulinaceans, brachiopods and bryozoans. Regionally, the conodont faunas are similar to those of other Arctic regions. The generic composition makes it possible to distinguish three conodont biofacies: a shallowest lagoonal *Streptognathodus* biofacies; a slightly more offshore but still high energy biofacies with *Neostreptognathodus* and *Sweetognathus*, but without *Neogondolella*; and a youngest more offshore and probably cooler biofacies with the exclusive presence of *Neogondolella* and *Xaniognathus*. Conodont elements are generally well preserved although discrete denticles are commonly broken off. The elements show little thermal alteration with CAI values between 1.5 and 2.0 indicating a burial temperature of 50–140°C.

H. A. Nakrem, Paleontologisk museum, Sars gt. 1, N-0562 Oslo 5, Norway

Introduction

Bjørnøya, 74.30°N and 19°E, is the southernmost island in the Svalbard Archipelago, and its placement midway on the western margin of the Barents Shelf makes it of considerable geological significance to the understanding of the development of this extensive shelf area.

The material processed for the current investigation was collected during a three-week field expedition to Bjørnøya in 1985, organized by IKU (Continental Shelf and Petroleum Technology Research Institute, Trondheim, Norway). In the course of the work, 28 conodont samples were collected from approximately 170 m of composite sections (see Appendix 1).

Conodont samples were processed as advocated by Jeppsson et al. (1985) and separated using bromoform. All figured specimens are housed in the type and figured collection of the Paleontologisk Museum, Oslo (PMO).

Stratigraphy and paleontology

The Permian succession of Bjørnøya comprises part of the Gipsdalen Group and the entire Tempelfjorden Group. The Permian part of the Gipsdalen Group is represented by the Kapp Dunér and Hambergfjellet Formations, while the Tempelfjorden Group is represented by the Miseryfjellet Formation (see Figs. 1 and 2). Stratigraphical nomenclature is in accordance with Worsley & Edwards (1976), with additional information from Simonsen (1987a, b) for the Kapp Dunér and the Hambergfjellet Formations, and from Hellem (1987) for the Miseryfjellet Formation.

The Kapp Dunér Formation

The lower part of this unit is dominated by dolomitized palaeoaplysinitid buildups (Lønøy 1988) interbedded with limestones rich in fusulinaceans; the upper part is dominated by dolomitized mudstones. The composite maximum thickness is close to 80 m. Fusulinacean-rich beds, large coral colonies, rare bryozoan thickets, *Stromatactis* structures, karst surfaces and intraformational conglomerates suggest that the Kapp Dunér Formation was deposited under shallow marine conditions with fluctuating water salinities. Siedlecka (1972, 1975) suggested the presence of sabkha and schizohaline conditions, as well as lagoonal facies. The lithological succession, in part based on thin section analysis (B. T. Simonsen, pers. comm. 1990) of a collected section in Teltvika, is presented in Fig. 1.

Fauna and age. – Fusulinaceans have previously been used in dating this formation. Simonsen (1987a) reported the presence of species of the *Schwagerina arctica*/*Schwagerina (Daixina) sokensis* Zone in the lowermost fusulinacean bed. The age is latest Gzhelian–earliest Asselian as compared with the standard scheme of the Russian Platform. The middle fusulinacean bed contains fusulinaceans of middle to late Asselian age: *Schwagerina anderssoni* Schellwien and *Schwagerina nathorsti* Staff & Wedekind. The uppermost part of the formation contains fusulinids of the *Sphaeroschwagerina moelleri*/*Schwagerina whartoni* subzone (Simonsen 1987a), indicating a middle Asselian age.

Early Permian (Sakmarian) bryozoans (*Ascopora sterilimakensis* Nikiforova) are reported from the middle

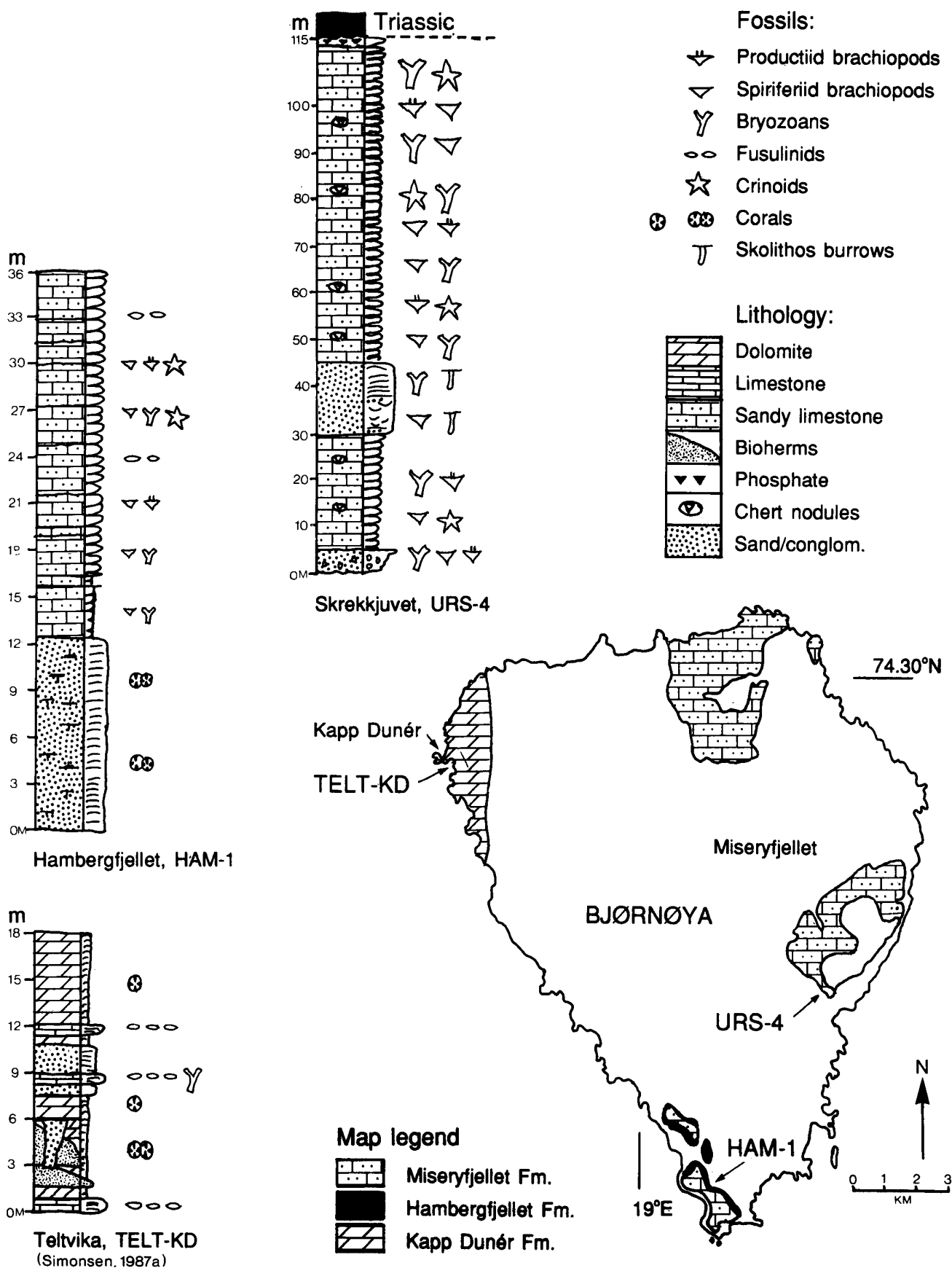


Fig. 1. Lithological sections through investigated Permian sections. Localities marked on map of Bjørnøya. Note: Sections not to scale.

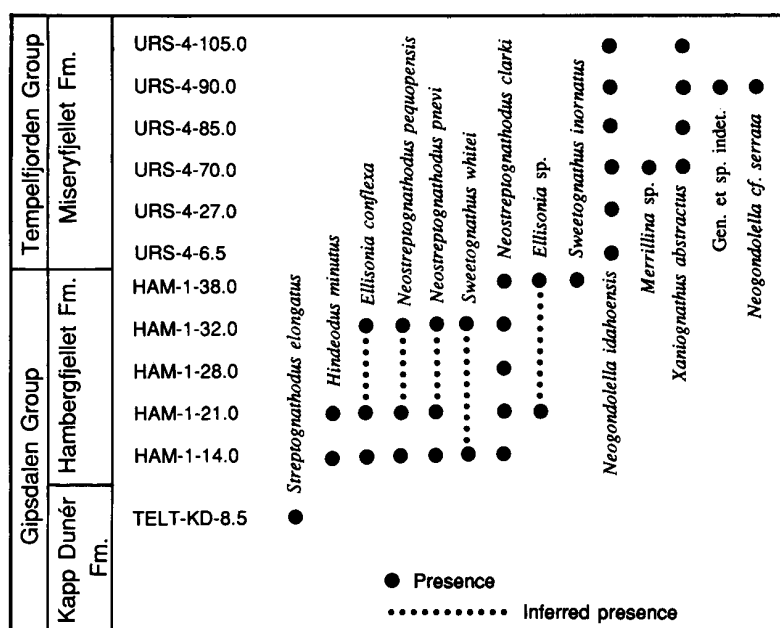


Fig. 2. Ranges of conodonts through the Permian formations of Bjørnøya.

fusulinacean bed (Nakrem, in press), while the corals are of Asselian age (Fedorowski 1986).

A very sparse conodont fauna was extracted from this formation. Only one sample from the middle fusulinacean bed contained a few specimens of *Streptognathodus elongatus*, and a single specimen identified as *Streptognathodus cf. constrictus*. The former species is the index species of the *Streptognathodus elongatus* Zone of the Great Basin (North America) (Clark et al. 1979) and of conodont zone P5 of Beauchamp et al. (1989) in the Sverdrup Basin (Arctic Canada), which are assigned to the Sakmarian. The exact range of this species in these areas is not documented at present, however, *S. elongatus* ranges into the Asselian too (Ritter 1986; Movshovich et al. 1979; Nassichuk & Henderson 1986), whereas *S. constrictus* has a restricted middle Asselian distribution. The age of the conodont sample from Bjørnøya is therefore assigned to the (middle) Asselian.

The Hambergfjellet Formation

This formation consists of a basal greyish calcareous sandstone and an upper reddish medium-bedded limestone with shaly and sandy partings. The maximum thickness is 50 m. Colonial corals are preserved in the lower unit, while the upper part has a more diverse fauna with corals, brachiopods, bryozoans and fusulinaceans. Both lower and upper boundaries are unconformable. The lithology as recorded in the collected section at Hambergfjellet is presented in Fig. 1.

Fauna and age. – The older name for this unit was 'Cora Limestone' because of the occurrence of the brachiopod *Linoproductus dorotheevi* (Fredericks), identified as

Productus cora by Andersson in 1900. Gobbett (1963) assigned the brachiopod faunas to the Sakmarian by comparison with similar faunas from Spitsbergen. Corals from the lower part of this formation were discussed by Fedorowski (1986) and an Asselian age was proposed. Fusulinaceans are currently being studied (Simonsen, pers. comm. 1990), and so far an Artinskian age for the upper part of this unit is proposed based on the presence of fusulinaceans of the *Schwagerina jenkinsi* zone (Simonsen 1987b). Bryozoans of Artinskian age are also known from this unit (Nakrem, in press). Conodonts occur frequently in the upper part of the Hambergfjellet Formation, whereas the lower sandy part was not processed for conodonts. The fauna is characterized by the co-occurrence of neostreptognathodids and sweetognathids, and the absence of neogondolellids. It is not possible to detect any zonation within this unit, as the stratigraphically important species are coeval in most samples. Thus, the fauna comprises *Neostreptognathodus clarki*, *N. pequopensis* and *N. pnevi* together with *Sweetognathus inornatus* and *S. whitei* (see Fig. 2). Additional species include *Hindeodus minutus*, *Ellisonia conflexa* and *Ellisonia sp.*

A similar fauna has previously been described from the Vøringen Member of the Kapp Starostin Formation in Spitsbergen by Szaniawski & Malkowski (1979). Their *Neostreptognathodus svalbardensis* and *Neostreptognathodus sp. A* and *sp. C* have been included in synonymy with *N. pequopensis*, *N. clarki* and *N. ruzhencevi* by Bando et al. (1980) and Orchard & Forster (1988). If these reassignments are followed, as in the present study, the correlation between the upper part of the Hambergfjellet Formation and the Vøringen Member becomes obvious. The Bjørnøya species are previously

reported to be typical of Artinskian age, and furthermore to define sub-zones within the Artinskian. Henderson & McGugan (1986) divided the Ross Creek Formation (southwestern Alberta and southeastern British Columbia) into three zones: Zone 3 (*Neogondolella bisselli-Sweetognathus whitei*); Zone 4 (*Neostreptognathodus pequopensis*-*N. exsculptus*) and Zone 5 (*Neostreptognathodus ruzhencevi*-*N. pnevi*). In the Urals, this fauna is typically late Artinskian (Movshovich et al., 1979), but there is some overlap between the zonal species, and *Neostreptognathodus pequopensis* ranges into the lower Kungurian. The Bjørnøya fauna resembles the late Wolfcampian-early Leonardian fauna described by Behnken (1975), and also embraces the conodont assemblage zones P6b-P8 of the Artinskian 'Unnamed-A' and 'Unnamed-B' Formations as defined in the Sverdrup Basin (Beauchamp et al., 1989).

To conclude, an intra-formational zonation for the Hambergfjellet Formation is not possible using the available conodont material, but the age of the upper part of the formation is clearly late Artinskian (Baigendzhinian).

The Miseryfjellet Formation

This unit unconformably overlies the Hambergfjellet Formation, and is itself overlain disconformably by Triassic shales. The thickness is approximately 115 m, with basal sands and conglomerates grading into yellowish sandy, partially silicified limestones (Fig. 1). The basal pebbly sandstones represent transgressive shoreline deposits, while the overlying sandy grainstones with abundant brachiopods, bryozoans and crinoid debris suggest deposition under moderately shallow high-energy open shelf conditions. The top of this formation is marked by a reddish, partly phosphatic, limestone unit. Samples were collected from several localities, but only those from Skrekkejuvet (SE Miseryfjellet) contained conodonts.

Fauna and age. – Gobbett (1963) identified several Kungurian brachiopods in the lower part of this formation: *Waagenoconcha wimani* (Fredericks), *Horridonia timanica* (Stuckenberga) and *Spirifer striatoparadoxus* Toulou. Brachiopods are common throughout the Miseryfjellet Formation, but the faunas in the upper part are yet to be described. Bryozoans are another significant fossil group through this formation, with approximately 30 species present (Nakrem, in press). The fauna has species in common with Kungurian faunas of the Timan-Pechora region of the USSR (*Polyporella optima* Morozova & Kruchinina, *Rhombotrypella* spp.), the Zechstein (EZ1) faunas of Great Britain (*Rectifenestella retiformis* (Schlotheim)), the Ufimian of Novaya Zemlya and the Russian Platform (*Dyscritella bogatensis* Morozova, *Stenopora grandis* Morozova, *Permoheloclema merum* Ozhigibesov) and the Kapp Starostin Formation of Spitsbergen.

Conodonts have been obtained in large quantities from the upper part of the Miseryfjellet Formation, whereas the lower part yielded very few specimens. The fauna

is of low diversity and is dominated by *Neogondolella idahoensis* in all samples, with *Xaniognathus abstractus* occurring in lesser numbers. This fauna, with the addition of *Neogondolella* cf. *serrata* in a single high sample makes it possible to propose a correlation with conodont zones established outside Bjørnøya. *Neogondolella idahoensis* is commonly regarded as an early Permian species, having a middle Leonardian-Roadian range in North America (Wardlaw & Collinson 1984, 1986). In the Sverdrup Basin, the *N. idahoensis* Assemblage Zone (Zone P11) of Beauchamp et al. (1989) is defined from the Roadian (Kungurian-Ufimian) Assistance Formation. This species is also part of their assemblage zone P10, the *Neostreptognathodus prayi*-*Neogondolella idahoensis* Zone, ranging through the Kungurian Sabine Bay Formation. However, the exact range of *N. idahoensis* in the Permian succession of the Sverdrup Basin is not documented at present. Swift & Aldridge (1985) reported the presence of *N. aff. idahoensis* from the British Zechstein (E.Z.1) below an association with *Merrillina divergens*. In Spitsbergen, *N. idahoensis* is known from a limestone bed in the middle part of the Kapp Starostin Formation at several localities (Szaniawski & Malkowski 1979), and recent investigations (Nakrem, unpublished data) have shown that this species has a restricted vertical distribution in the Spitsbergen succession. Only one horizon (10–25 m thick) contains specimens of *N. idahoensis*, whereas there is a 50 m barren interval above this horizon in the Kapp Starostin Formation at e.g. the Festningen section at western Spitsbergen.

Neogondolella cf. *serrata* is commonly regarded as a descendant of *N. idahoensis* (Clark & Behnken 1979) and has a reported late Roadian-early Wordian range (see Wardlaw & Collinson (1984)).

Conodonts reported from the Upper Permian succession of central East Greenland (Rasmussen et al. 1990) demonstrate the presence of a considerably younger (Wordian-early Capitanian) fauna with *Neogondolella rosenkrantzi*, *Merrillina divergens* and *Xaniognathus abstractus* in the Ravnefjeld Formation. This unit in central East Greenland is thus younger than the youngest Permian of Bjørnøya. To conclude, the conodonts ranging through the Miseryfjellet Formation are correlative with the Roadian (Kungurian-Ufimian) of North America and the Sverdrup Basin, and with the upper Kungurian of the Cis-Urals. Locally, a similar fauna to the one ranging through the Miseryfjellet Formation is present in a single horizon in the middle part of the Kapp Starostin Formation in Spitsbergen.

Biostratigraphic conclusion

The low diversity and fairly low numbers of specimens in most productive samples make it impossible to establish precise local conodont assemblage zones for the Permian succession of Bjørnøya. However, ranges of individual species permit correlation of the investigated horizons

with well-documented conodont zonations of North America, the Sverdrup Basin and the USSR.

The Kapp Dunér Formation has yielded a few specimens of *Streptognathodus elongatus* with an Asselian–Sakmarian range. The upper part of the Hambergfjellet Formation has a mixed fauna with the stratigraphically important species *Sweetognathus whitei*, *S. inornatus*, *Neostreptognathodus clarki*, *N. pequopensis* and *N. pnevi*. These species suggest a late Artinskian age for this interval. The similarity to the conodonts of the Vøringen Member on Spitsbergen implies a late Artinskian age for the Vøringen Member.

Neogondolella idahoensis ranges through most of the Miseryfjellet Formation, and *N. cf. serrata* is present in a single sample high in the succession. The implied age is Roadian–Wordian, or Kungurian–Ufimian, and this also correlates with the middle part of the Kapp Starostin Formation on Spitsbergen.

The stratigraphic information provided in the current conodont work matches well with previously reported ages. Fusulinaceans provide a more precise dating for the Kapp Dunér Formation, whereas conodonts provide equally precise dating for the Hambergfjellet Formation. Fusulinaceans are absent from the Miseryfjellet Forma-

tion, while non-fusulinacean foraminifers are sporadically present but remain undescribed; conodonts are the only important microfossils present. Brachiopods and bryozoans support the age implied by conodonts for this unit. Ranges of all identified conodonts are outlined in Fig. 2, and the element representation is tabulated in Table 1 and in Appendix 1.

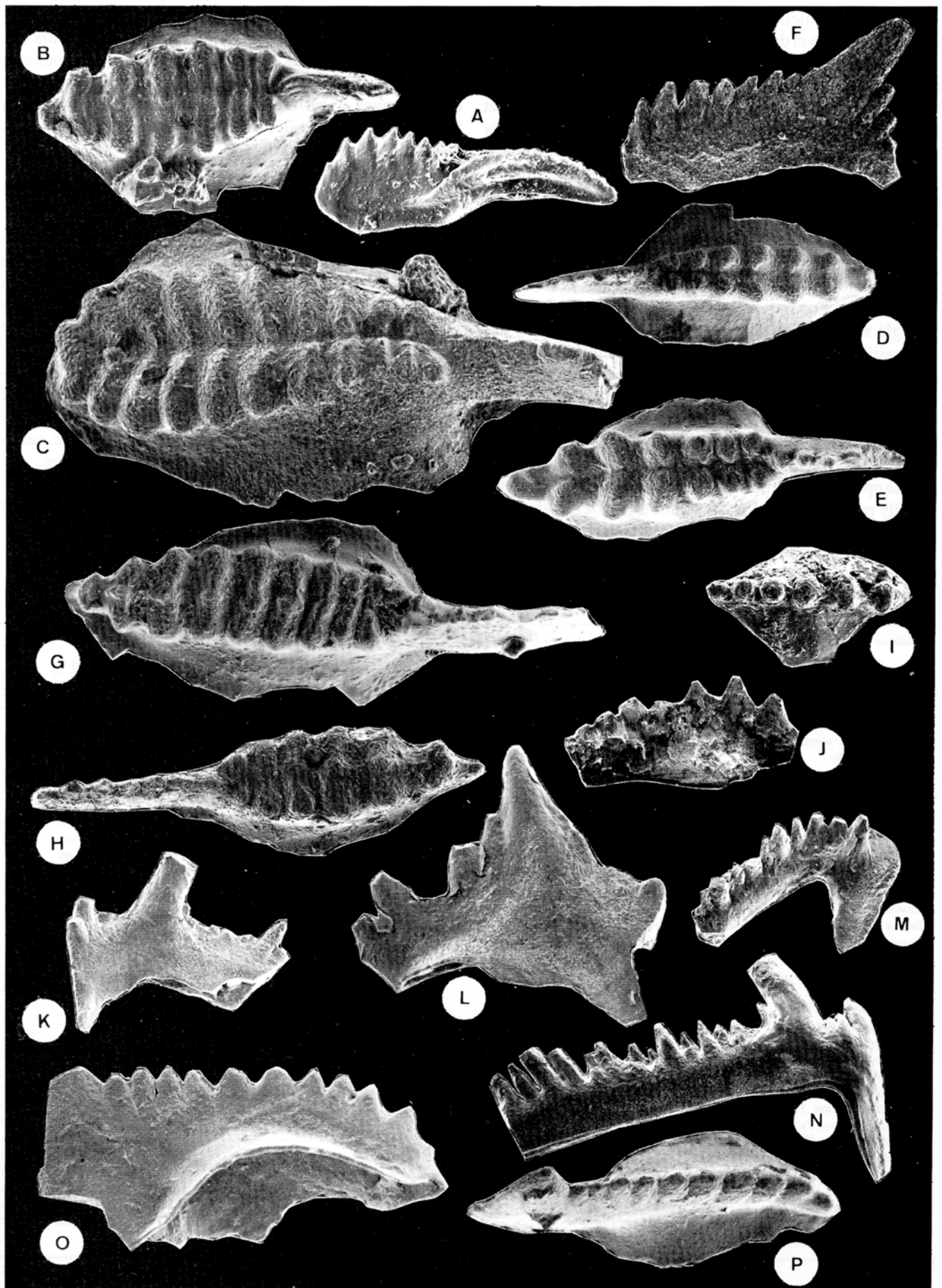
Conodont biofacies

Based on sedimentological and palaeontological interpretations in the literature (see previous sections), the Permian succession at Bjørnøya is believed to reflect a series of slightly deepening episodes separated by episodes of non-deposition. There is a successive development from the shallowest palaeoaplysiniid/fusulinacean bioherm facies of the Kapp Dunér Formation, through the sandy/calcareous brachiopod facies of the Hambergfjellet Formation, into the brachiopod/bryozoan dominated limestone and subordinate sandstone intercalations of the Miseryfjellet Formation.

The distribution of conodonts in the investigated successions has revealed a distinct development of three marine biofacies:

Table 1. Distribution of conodont elements in productive conodont samples.

Productive conodont samples	TELT-KD 8.5	HAM-1- 14.0	HAM-1- 21.0	HAM-1- 28.0	HAM-1- 32.0	HAM-1- 38.0	URS-4 6.5	URS-4 27.0	URS-4 70.0	URS-4 85.0	URS-4 90.0	URS-4 105.0	Total
Taxa													
Gen. et sp. indet.	—	—	—	—	—	—	—	—	—	—	1	—	1
<i>Neogondolella cf. serrata</i> , Pa	—	—	—	—	—	—	—	—	—	—	1	—	1
? <i>Merrillina</i> sp., Sc	—	—	—	—	—	—	—	—	2	—	—	—	2
<i>Xaniognathus abstractus</i> , Pa-Pb	—	—	—	—	—	—	—	—	9	4	—	—	13
<i>Xaniognathus abstractus</i> , Sa-Sb	—	—	—	—	—	—	—	—	10	—	—	3	13
<i>Xaniognathus abstractus</i> , ?Sc	—	—	—	—	—	—	—	—	—	2	1	—	3
<i>Xaniognathus abstractus</i> , M	—	—	—	—	—	—	—	—	4	—	1	—	5
<i>Xaniognathus abstractus</i> , unassign.	—	—	—	—	—	—	—	—	6	3	—	—	9
<i>Neogondolella idahoensis</i> , Pa	—	—	—	—	—	—	?1	3	126	210	98	66	503
<i>Sweetognathus inornatus</i> , Pa	—	—	—	—	—	5	—	—	—	—	—	—	5
<i>Sweetognathus inornatus</i> , ?ramiform	—	—	—	—	—	3	—	—	—	—	—	—	3
<i>Ellisonia</i> sp.	—	—	?1	—	—	22	—	—	—	—	—	—	22
<i>Ellisonia conflexa</i> , Sc	—	10	2	—	—	2	—	—	—	—	—	—	14
<i>Ellisonia conflexa</i> , Sb	—	1	—	—	1	—	—	—	—	—	—	—	2
<i>Ellisonia conflexa</i> , Sa	—	2	1	—	2	—	—	—	—	—	—	—	5
<i>Ellisonia conflexa</i> , S	—	—	6	—	10	—	—	—	—	—	—	—	16
<i>Ellisonia conflexa</i> , M	—	—	—	—	8	1	—	—	—	—	—	—	9
? <i>Ellisonia conflexa</i> , ?Pb	—	11	3	—	—	1	—	—	—	—	—	—	15
<i>Neostreptognathodus clarki</i> , Pa	—	19	8	2	2	1	—	—	—	—	—	—	32
<i>Neostreptognathodus pequopensis</i> , Pa	—	12	12	—	4	—	—	—	—	—	—	—	28
<i>Neostreptognathodus pnevi</i> , Pa	—	14	9	—	1	—	—	—	—	—	—	—	24
<i>Neostreptognathodus</i> sp., Pb	—	3	6	—	3	—	—	—	—	—	—	—	12
<i>Neostreptognathodus</i> spp., Pa	—	17	13	—	5	—	—	—	—	—	—	—	35
<i>Sweetognathus whitei</i> , Pa	—	3	—	—	13	—	—	—	—	—	—	—	16
<i>Hindeodus minutus</i> , Pa	—	3	—	—	—	—	—	—	—	—	—	—	3
<i>Hindeodus minutus</i> , Pb	—	6	2	—	—	—	—	—	—	—	—	—	8
<i>Hindeodus minutus</i> , M	—	2	3	—	—	—	—	—	—	—	—	—	5
? <i>Hindeodus minutus</i> , Sb-Sc	—	8	8	—	—	—	—	—	—	—	—	—	16
? <i>Hindeodus minutus</i> , Sc	—	4	—	—	—	—	—	—	—	—	—	—	4
? <i>Hindeodus minutus</i> , Sb	—	2	1	—	—	—	—	—	—	—	—	—	3
<i>Streptognathodus elongatus</i> , Pa	3	—	—	—	—	—	—	—	—	—	—	—	3
<i>Streptognathodus cf. constrictus</i> , Pa	1	—	—	—	—	—	—	—	—	—	—	—	1
Total	4	117	74	5	49	32	?1	3	157	219	102	69	831



Biofacies 1. Monogeneric occurrence of *Streptognathodus* in the Kapp Dunér Formation above the reef structures.

Biofacies 2. A fauna dominated by *Neostreptognathodus*, with *Sweetognathus*, *Hindeodus* and robust elements of *Ellisonia*, but without *Neogondolella*; in the shelf carbonates of the Hambergfjellet Formation.

Biofacies 3. A *Neogondolella* fauna without *Neostreptognathodus* and *Sweetognathus*, with low numbers of *Xaniognathus*; through the open energy shelf carbonates of the Miseryfjellet Formation.

Except for Biofacies 1, this pattern compares well with the conodont biofacies described from the Phosphoria Formation of Wyoming (Wardlaw & Collinson 1984). However, it should be noted that *Neostreptognathodus* and *Neogondolella* never occur together in the Bjørnøya succession. The interpretation of Wardlaw & Collinson (1984) is followed here in that Biofacies 2 represents nearest-shore conditions and Biofacies 3 the most distal environments. Biofacies 1 conodonts are associated with fusulinacean beds and bioherms representing shallowest lagoonal facies. Most samples collected from within the dolomitic facies and bioherms are devoid of conodonts.

The development of conodont biofacies correlates with energy in that there is a gradual deepening through the investigated sections, and *Neostreptognathodus* in Biofacies 2 is commonly regarded as thriving under fairly shallow, high energy conditions. During Permian time Svalbard moved northwards, from 30°N to 40°N resulting in establishment of cooler temperate regimes (Steel & Worsley 1984). The latter implication is supported by the absence of fusulinaceans, and the high abundance of siliceous sponges in Biofacies 3. Consequently, *Neogondolella* is believed to reflect deeper waters and cooler conditions. The lowermost metres of the Miseryfjellet Formation with conglomerates, coarse siliciclastics and cherts are devoid of conodonts, but rich in other marine fauna. The enrichment of phosphate in the highest part of the formation is believed to reflect an episode of slow or non-deposition. Conodonts are absent from this horizon.

Conodont colour alteration (CAI)

The few conodont specimens from the Kapp Dunér Formation show very little colour alteration. CAI (Colour Alteration Index) values are 1.5, indicating a burial temperature around 50–90°C (Epstein et al. 1977). The Ham-

bergfjellet Formation contains conodonts with CAI values around 2.0, indicating a temperature around 60–140°C. The specimens from the Miseryfjellet Formation show CAI values around 1.5–2.0, reflecting a temperature of about 50–140°C. Although a limited number of observations have been made, the figures indicate a trend of increasing thermal maturation going eastwards. The overall values indicate temperatures around 50–140°C, which are within the range of petroleum generation and retention. TAI (Thermal Alteration Index) indexes from the Permian rocks of Bjørnøya are 3 to 3-, which in turn can be calibrated to R_o values between 1.0 and 1.3 (Bjørøy et al. 1980). These figures narrow the thermal ranges provided by the current conodont CAI values, and the investigated rocks have maturities between the oil and the condensate/wet gas zone (Bjørøy et al. 1980).

Taxonomic remarks

Ellisonia conflexa (Ellison, 1941)

Fig. 4A–D

Type species. – *Prioniodus? conflexus* Ellison, 1941: 114, pl. 20, fig. 25.

Remarks. – Despite the absence of Pa elements, the extracted fauna compares well with the description of von Bitter & Merrill (1983). All elements are robust, but most of the long discrete denticles are broken off.

Biostratigraphical significance. – Originally described from the middle Desmoinesian to late Virgilian (see von Bitter & Merrill 1983), this species is also known to range into the early Permian (late Sakmarian–Kungurian) of British Columbia (Orchard & Forster 1988)

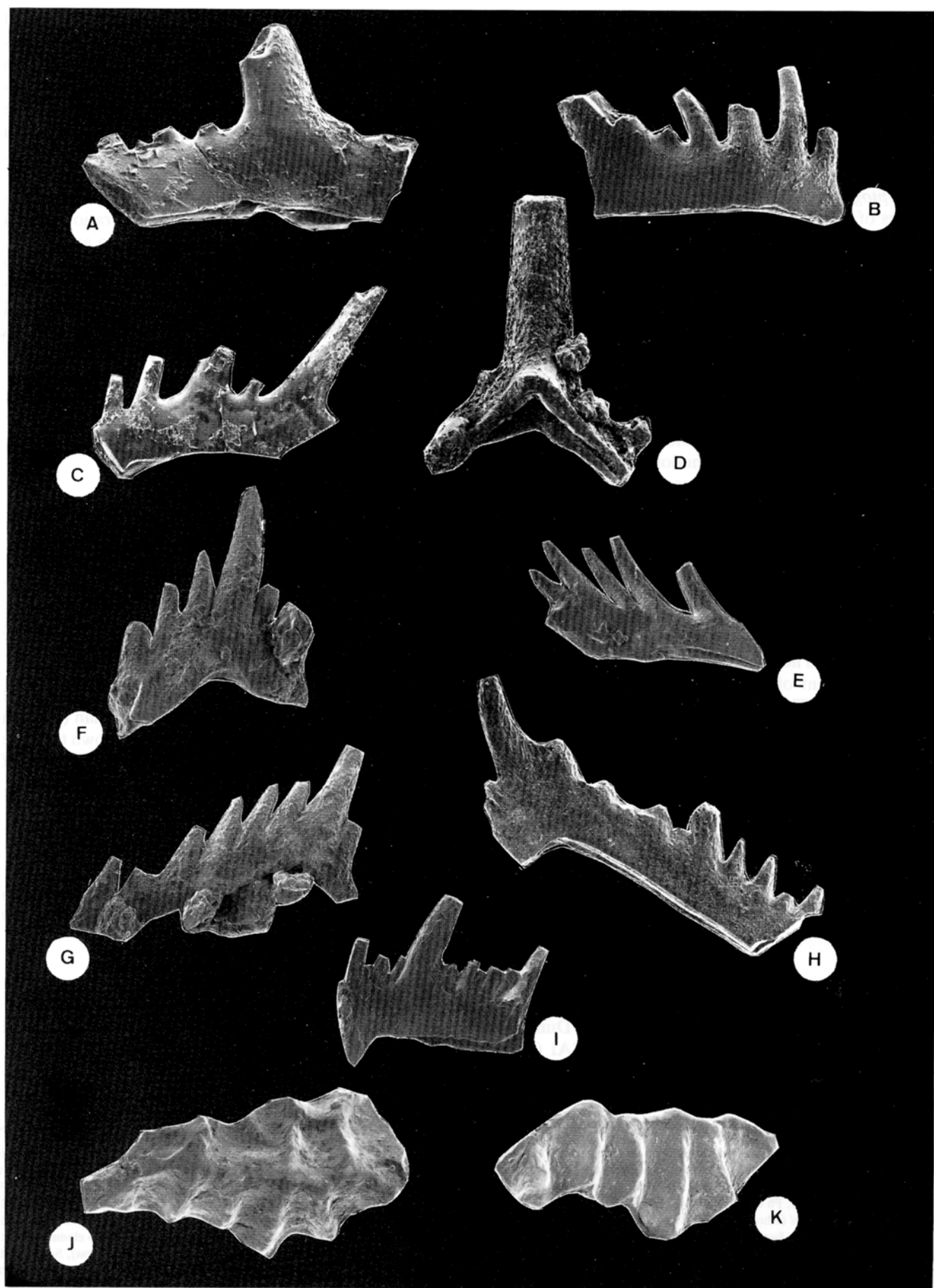
Occurrence on Bjørnøya. – HAM-1-14.0m, HAM-1-21.0m, HAM-1-32.0m, HAM-1-38.0m.

Material. – 15 ?Pb elements, 5 Sa elements, 2 Sb elements, 14 Sc elements, 16 unassigned S elements, 9 M elements (see Table 1).

Ellisonia sp.

Remarks. – These elements of *Ellisonia* are separated from *E. conflexa* because of their smaller sizes, and the lack of preserved diagnostic features because of breakage prevent closer identification.

Fig. 3. A. *Streptognathodus elongatus* Gunnell, Pa element, 10×, TELT-KD-8.5, PMO 120.952/3. B. *Neostreptognathodus clarki* Kozur, Pa element, 100×, HAM-1-32.0, PMO 120.955/4. C. *Neostreptognathodus clarki* Kozur, Pa element, 100×, HAM-1-14.0, PMO 120.953/1. D. *Neostreptognathodus pequopensis* Behnken, Pa element, 100×, HAM-1-14.0, PMO 120.953/2. E. *Neostreptognathodus pnevi* Kozur & Movshovich, Pa element, 100×, HAM-1-14.0, PMO 120.953/4. F. *Neostreptognathodus* sp., Pb element, 100×, HAM-1-21.0, PMO 120.954/7. G. *Sweetognathus whitei* (Rhodes), Pa element, 100×, HAM-1-32.0, PMO 120.955/1. H. *Sweetognathus whitei* (Rhodes), Pa element, 100×, HAM-1-32.0, PMO 120.955/2. I. *Sweetognathus inornatus* Ritter, Pa element, upper view, 100×, HAM-1-38.0, PMO 120.956/4. J. *Sweetognathus inornatus* Ritter, lateral view, 100×, HAM-1-38.0, PMO 120.956/4. K. *Hindeodus minutus* (Ellison), Sa-Sb element, 100×, HAM-1-14.0, PMO 120.953/10. L. *Hindeodus minutus* (Ellison), Pb element, 100×, HAM-1-14.0, PMO 120.953/12. M. *Hindeodus minutus* (Ellison), Sc element, 100×, HAM-1-14.0, PMO 120.953/9. N. *Hindeodus minutus* (Ellison), Sc element, 100×, HAM-1-14.0, PMO 120.953/8. O. *Hindeodus minutus* (Ellison), Pa element, 100×, HAM-1-14.0, PMO 120.953/5. P. *Hindeodus minutus* (Ellison), Pa element, 100×, HAM-1-14.0, PMO 120.953/6.



Occurrence on Bjørnøya. – ?HAM-1-28.0m, HAM-1-38.0m. *Material.* – 22 unassigned elements (see Table 1).

Hindeodus minutus (Ellison, 1941)

Fig. 3 K–P.

Type species. – *Spathodus minutus* Ellison, 1941: 120, pl. 20, figs. 50–52.

Remarks. – The denticles including the large cusp possess a relatively straight profile in lateral view (Fig. 2H) and are slightly sinuously bent in oral view (Fig. 2I) in the Pa elements. The Pb elements possess a large cusp which is variably inclined posteriorly (Fig. 2F, G). S elements are commonly broken, but they are separated from homologous elements of other genera (e.g. *Ellisonia*) based on the presence of diagnostic Pa and M elements. The multi-element composition compares well with the reconstructions discussed by von Bitter & Merrill (1985: fig. 1C, D).

Biostratigraphical significance. – Late Carboniferous of North America (von Bitter 1972), Sakmarian of British Columbia (Henderson & McGugan 1986), Early Permian of Japan (Igo 1981), Early Triassic of Japan (Matsuda 1985).

Occurrence on Bjørnøya. – HAM-1-14.0m, HAM-1-21.0m.

Material. – 3 Pa elements, 8 Pb elements, 4 ?Sb elements, 16 ?Sb/Sc elements, 5 M elements (see Table 1).

?*Merrillina* sp.

Fig. 4E.

Remarks. – Only one element that can be referred to *Merrillina* was found, and closer taxonomic assignment is impossible.

Occurrence on Bjørnøya. – URS-4-70.0m.

Materials. – 2 Sc elements (see Table 1).

Neogondolella idahoensis (Youngquist, Hawley & Miller 1951)

Fig. 5C–H

Type species. – *Gondolella idahoensis* n.sp. – Youngquist, Hawley & Miller 1951:361; pl. 54, figs. 1–3, 14, 15.

Remarks. – This species is characterized by a denticulated platform that has parallel margins for 2/3 of its length

and then narrows abruptly. The denticles are discrete, usually numbering 10–12 and highest near the anterior end. A pointed main cusp is situated on the posterior margin in juvenile specimens; during growth it migrates slightly inwards from the margin. The posterior end of the platform is curved in juvenile elements, lobate in intermediate stages and slightly quadrate in mature elements. The oral side of the platform bears a strong reticulated ornamentation (Fig. 5H). The basal cavity is asymmetrically elongate in juvenile elements and more quadrate to triangular in mature specimens.

Biostratigraphical significance. – Leonardian–early Roadian of North America (Wardlaw & Collinson 1984, 1986), late Kungurian of the Cis-Urals (Movshovich et al. 1979), middle part of the Kapp Starostin Formation (Ufimian) of Spitsbergen (Szaniawski & Malkowski 1979). *N. aff. idahoensis* has been reported from Zechstein E.Z.1 of Great Britain (Swift & Aldridge 1985).

Occurrence on Bjørnøya. – URS-4-6.5m, URS-4-27.0m, URS-4-70.0m, URS-4-85.0m, URS-4-90.0m, URS-4-105.0m.

Material. – 503 Pa elements (see Table 1).

Neogondolella cf. *serrata* (Clark & Ethington 1962)

Fig. 5A, B.

Type species. – *Gondolella serrata* Clark & Ethington, 1962.

Remarks. – A single element of *Neogondolella* with faint serration throughout oral side of platform (Fig. 5B) was found. Serration is also present on aboral side and inside basal cavity. The platform has parallel margins with reticulated micro-ornamentation on the oral surface. Denticles, including the cusp, are small, number >14. Adcarinal grooves are developed on anterior half on the upper side of the platform.

Biostratigraphical significance. – Late Roadian–early Wordian of North America (Wardlaw & Collinson 1984, 1986).

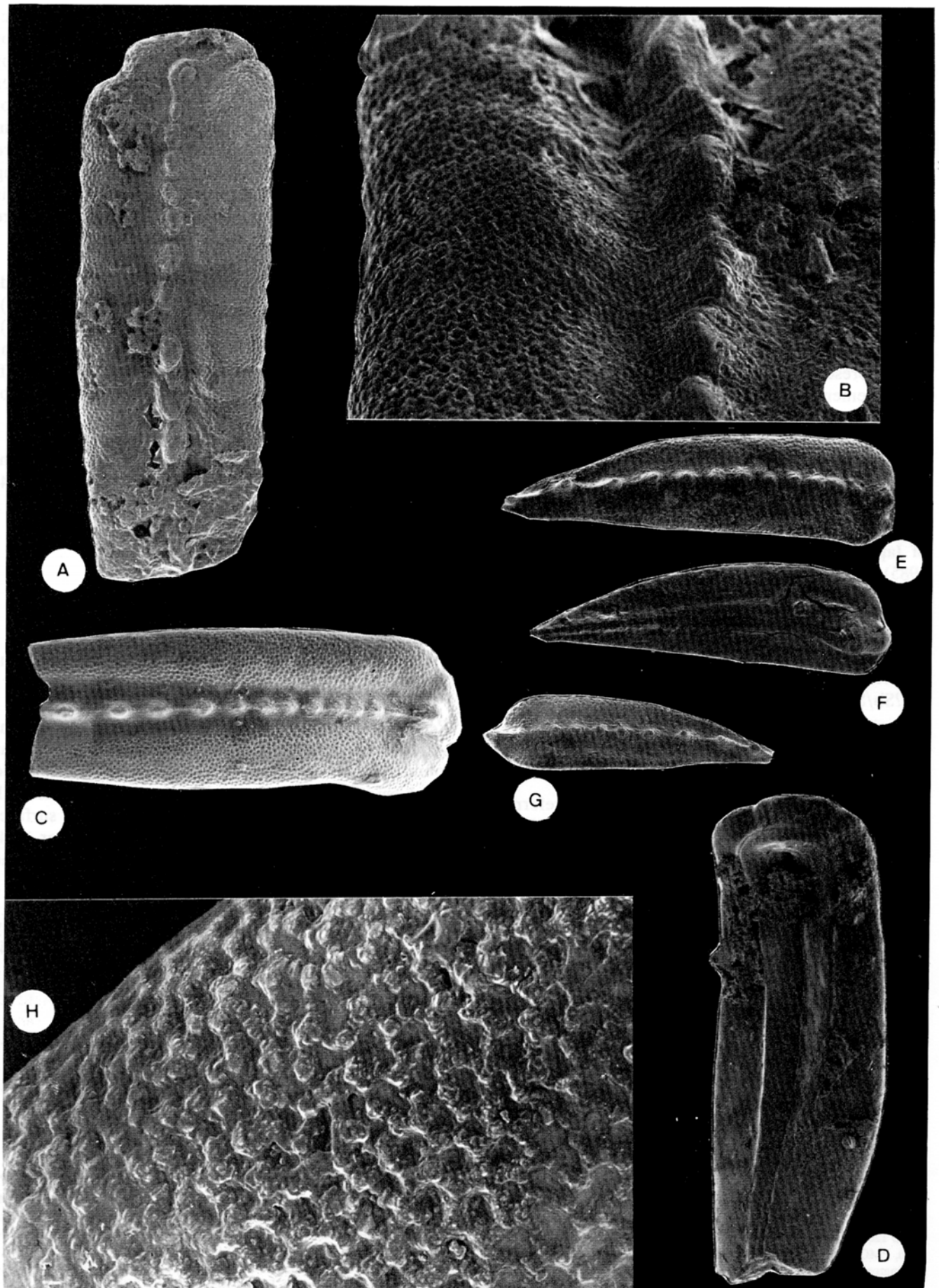
Occurrence on Bjørnøya. – URS-4-90.0m.

Material. – One Pa element (see Table 1).

Neostreptognathodus clarki Kozur in Kozur & Mostler 1976

Fig. 3B,C.

Fig. 4. A. *Ellisonia conflexa* (Ellison), 100×, Sc element, HAM-1-21.0, PMO 120.954/19. B. ?*Ellisonia conflexa* (Ellison), 100×, ?Pb element, HAM-1-21.0, PMO 120.954/20. C. ?*Ellisonia conflexa* (Ellison), 100×, ?Pb element, HAM-21.0, PMO 120.954/18. D. *Ellisonia conflexa* (Ellison), 100×, M element, HAM-1-38.0, PMO 120.956/9. E. ?*Merrillina* sp., 100×, Sc element, URS-4-70.0, PMO 120.957/4. F. *Xaniognathus abstractus* (Clark & Ethington), 100×, Pa element, URS-4-85.0, PMO 120.958/11. G. *Xaniognathus abstractus* (Clark & Ethington), 100×, Pb element, URS-4-85.0, PMO 120.958/8. H. *Xaniognathus abstractus* (Clark & Ethington), 100×, Pb element, URS-4-85.0, PMO 120.958/7. I. *Xaniognathus abstractus* (Clark & Ethington), 100×, Sc element, URS-4-70.0, PMO 120.957/5. J. Gen. et sp. indet., 100×, upper view, URS-4-90.0, PMO 120.959/10. K. Gen. et sp. indet., 100×, lateral view, URS-4-90.0, PMO 120.959/10.



Type species. – *Neostreptognathodus clarki* Kozur, 1976: 12–13, pl. 2, fig. 8.

Remarks. – Pa elements of this species bear two rows of transversely elongated carinal nodes. These nodes merge posteriorly to form transverse ridges, and thus display a feature typical of *Sweetognathus*. The upper surface of the nodes commonly possesses micro-ornamentation as small pustules. The medial carinal furrow is developed only on the anterior part of the platform. The basal cavity is commonly very wide. Large specimens are usually broken along the medial furrow.

Biostratigraphical significance. – Artinskian of the Urals (Kozur & Mostler 1976), Artinskian of the Sverdrup Basin (Beauchamp et al. 1989), Vøringen Member of the Kapp Starostin Formation in Spitsbergen (Szaniawski & Malkowski 1979: pl. 7, figs. 4, 5 as *N. svalbardensis* Szaniawski).

Occurrence on Bjørnøya. – HAM-1-14.0m, HAM-1-21.0m, HAM-1-28.0m, HAM-1-32.0m, HAM-1-38.0m.

Material. – 32 Pa elements (see Table 1).

Neostreptognathodus pequopensis Behnken, 1975
Fig. 3D.

Type species. – *Neostreptognathodus pequopensis* Behnken, 1975: 310, pl. 1, figs. 19–22, 25.

Remarks. – The platform has two rows of equidimensional circular nodes separated by a well-defined but shallow medial groove. The free blade contains 5–6 compressed denticles. The centrally located basal cavity is wide and flaring. The circular and upright carinal nodes are used as distinguishing characters of this species as compared with *N. pnevi*.

Biostratigraphical significance. – Late Wolfcampian–early Leonardian of North America (Behnken 1975), Artinskian–Kungurian of the Urals (Movshovich et al. 1979), Artinskian of China (Wang & Wang 1981), late Sakmarian–early Artinskian of Japan (Igo 1981), Vøringen Member of the Kapp Starostin Formation in Spitsbergen (Szaniawski & Malkowski 1979: pl. 6, fig. 1 as *N. svalbardensis* Szaniawski).

Occurrence on Bjørnøya. – HAM-1-14.0m, HAM-1-21.0m, HAM-1-32.0m.

Material. – 28 Pa elements (see Table 1).

Neostreptognathodus pnevi Kozur & Movshovich, 1979
Fig. 3E.

Type species. – *Neostreptognathodus pnevi* Kozur & Movshovich in Movshovich et al., 1979: 115–116, pl. 3, figs. 1–10.

Remarks. – This species is characterized by two carinae separated by a well-developed median furrow. The nodes are fairly circular close to the free blade; larger and more subcircular in posterior portion of platform. Subcircular nodes are bent outwards, and the platform terminates in a single weakly developed node. Micro-ornamentation (pustules) is rarely present on upper surface of nodes. The free blade is not a continuation of either of the carinae, but terminates medially on the platform. The increasing size of carinal nodes in posterior position is a diagnostic feature in distinguishing his species from *N. pequopensis*.

Biostratigraphical significance. – Late Artinskian and early Kungurian of the Urals (Movshovich et al. 1979), middle Artinskian of Alberta and British Columbia (Henderson & McGugan 1986), Leonardian and Roadian of Idaho (Behnken et al. 1986; Mytton et al. 1983).

Occurrence on Bjørnøya. – HAM-1-14.0m, HAM-1-21.0m, HAM-1-32.0m.

Material. – 24 Pa elements (see Table 1).

Neostreptognathodus sp., Pb elements
Fig. 3F.

Remarks. – Pb elements of *Neostreptognathodus* occur with Pa elements in most samples. The element displays a row of 5–7 denticles anterior to the large posteriorly inclined cusp, and only 1–2 denticles on the posterior margin. As different species of *Neostreptognathodus* occur coevally in the Bjørnøya samples, the correct taxonomic placement of these Pb elements cannot be demonstrated in the investigated material. Pb elements of *Neostreptognathodus* from Spitsbergen were also figured by Szaniawski & Malkowski (1979: pl. 9) as *Sweetocristatus arcticus* Szaniawski. The Spitsbergen specimens were considered as synonyms in the *Xaniognathus abstractus* multielement configuration (Pb elements) by Wardlaw & Collinson (1984, p. 271). However, they do not occur together with *Xaniognathus* in the Bjørnøya

Fig. 5. A. *Neogondolella* cf. *serrata* (Clark & Ethington), Pa element, 100×, URS-4-90.0, PMO 120.959/9. B. *Neogondolella* cf. *serrata* (Clark & Ethington), Pa element, 400×, URS-4-90.0, PMO 120.959/9. C. *Neogondolella idahoensis* (Youngquist, Hawley & Miller), gerontic Pa element, 100×, URS-4-105.0, PMO 120.960/2. D. *Neogondolella idahoensis* (Youngquist, Hawley & Miller), basal view of gerontic Pa element, 100×, URS-4-105.0, PMO 120.960/4. E. *Neogondolella idahoensis* (Youngquist, Hawley & Miller), intermediate Pa element, 100×, URS-4-85.0, PMO 120.958/3. F. *Neogondolella idahoensis* (Youngquist, Hawley & Miller), basal view of intermediate Pa element, 100×, URS-4-85.0, PMO 120.958/12. G. *Neogondolella idahoensis* (Youngquist, Hawley & Miller), juvenile Pa element, 100×, URS-4-85.0, PMO 120.958/8. H. *Neogondolella idahoensis* (Youngquist, Hawley & Miller), Pa element, micro-ornamentation on upper surface, 1000×, URS-4-105.0, PMO 120.960/2.

collections, and they are assigned to *Neostreptognathodus* herein.

Occurrence on Bjørnøya. – HAM-1-14.0m, HAM-1-21.0m and HAM-1-32.0m.

Material. – 12 elements (see Table 1).

Streptognathodus elongatus Gunnell, 1933
Fig. 3A.

Type species. – *Streptognathodus elongatus* Gunnell, 1933: 283–284, pl. 33, fig. 30.

Remarks. – The platform bears two rows of elongated ridge-like nodes which appear as transverse ridges in posteriormost part of the elements. The medial furrow is weakly developed, U-shaped in juvenile specimens, deeper and more V-shaped in larger mature specimens. In oral view, the platform is slightly curved. The long free blade contains eight compressed denticles. The basal cavity is narrow and elongated. The identification is based on one complete and two broken specimens. A single specimen of *Streptognathodus* cf. *constrictus* Chernikh & Reshetkova was found associated with *S. elongatus* Gunnell. *S. simplex* Gunnell, considered as a junior synonym to *S. elongatus* Gunnell, is incorporated into the biostratigraphical significance below.

Biostratigraphical significance. – Late Pennsylvanian of North America (Gunnell 1933), Gzhelian–Artinskian of the Urals (Movshovich et al. 1979), late Asselian (Nassichuk & Henderson 1986) and Sterlitamakian (Beauchamp et al. 1989) of the Sverdrup Basin. *Streptognathodus constrictus* Chernikh & Reshetkova has a more restricted middle Asselian distribution in the Urals as well as in the Sverdrup Basin.

Occurrence on Bjørnøya. – TELT-KD-8.5m.

Material. – 3 Pa elements (see Table 1).

Sweetognathus inornatus Ritter, 1986
Fig. 3I–J.

Type species. – *Sweetognathus inornatus* Ritter, 1986: 150, pl. 3, figs. 1, 6, 12–15, pl. 4, figs. 2, 9, 13, 14.

Remarks. – The element has a long blade and suberect, almost circular or weakly transversely elongated nodes connected with a faintly developed longitudinal ridge. Pustulose micro-ornamentation is present on the node surface. The basal cavity is situated centrally or slightly anterior under the element.

Biostratigraphical significance. – Late Sakmarian–early Artinskian of North America (Ritter 1986), early Artinskian of the Sverdrup Basin (Beauchamp et al. 1989).

Occurrence on Bjørnøya. – HAM-1-38.0m.

Material. – 5 Pa elements, 3 ramiform elements that are tentatively assigned to *S. inornatus* (see Table 1).

Sweetognathus whitei (Rhodes, 1963)
Fig. 3G, H.

Type species. – *Spathognathodus whitei* Rhodes, 1963: 404–405, pl. 47, figs. 4, 9, 10, 25, 26.

Remarks. – Platform elements have nodes developed as transverse ridges separated by transverse troughs. The transverse ridges are connected along the carinal midline by elevated secondary pustules. The free blade contains 6–7 compressed denticles. The basal cavity is located under platform portion of the element. The transversely elongated nodes and ridges distinguish this species from *S. inornatus* Ritter.

Biostratigraphical significance. – Late Wolfcampian of North America (Behnken 1975), late Sakmarian–early Artinskian of the Urals (Movshovich et al. 1979), Sakmarian of Japan (Igo 1981), late Sakmarian–early Artinskian of China (Wang & Wang 1981).

Occurrence on Bjørnøya. – HAM-1-14.0m, HAM-1-32.0m.

Material. – 16 Pa elements (see Table 1).

Xaniognathus abstractus (Clark & Ethington, 1962)
Fig. 4F–I.

Type species (Pa element). – *Subbryantodus abstractus* Clark & Ethington, 1962: 112, pl. 1, figs. 16, 20, pl. 2, fig. 2.

Remarks. – Diagnostic Pa element bears a long denticulated posterior process and a small denticulated anterior process. The element possesses a large erect cusp and two and six discrete denticles on the posterior and anterior processes, respectively. Pa element differs from Pb element mainly in having a weakly convex anterior process, while the Pb element possesses a straight anterior process with six discrete denticles. Multielement reconstruction by Wardlaw & Collinson (1984) and Rasmussen et al. (1990) is supported by the faunal composition in the Bjørnøya samples.

Biostratigraphical significance. – Roadian–Wordian of North America (Wardlaw & Collinson 1984), Wordian–early Capitanian of central East Greenland (Rasmussen et al. 1990).

Occurrence on Bjørnøya. – URS-4-70.0m, URS-4-85.0m, URS-4-90.0m, URS-4-105.0m.

Material. – 13 Pa/Pb elements, 13 Sa/Sb elements, 3 ?Sc elements, 5 M elements and 9 unassigned elements (see Table 1).

Gen. et sp. indet
Fig. 4J, K.

Remarks. – A single element was found to resemble *Sweetognathus* in possessing a medial ridge connecting transverse ridges. Carinal nodes are not developed and the ridges run down along the margins of the platform. The present element slightly resembles an indeterminate P element figured in Swift & Aldridge (1982: pl. 90, fig. 16) as well as the posteriormost part of an immature specimen of *Sweetognathus behnkeni* Kozur figured in Ritter (1986: pl. 2, fig. 15). Bearing the late Permian age of the sample in mind, a connection with *Sweetognathus* is unlikely, however.

Occurrence on Bjørnøya. – URS-4-90.0m.

Material. – 1 element (see Table 1).

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Appendix 1. Sample weights of productive and barren conodont samples before and after (dried residue) processing. Number of conodonts refer to identifiable + fragments. Asterisks indicate repeatedly processed samples. Codes are explained in Figure 1.

Sample identification	Initial weight	Undissolved weight	Conodonts
URS-4-112.5	2.25	1.50	Barren
URS-4-112.0	2.70	1.65	Barren
URS-4-105.0	2.49	0.14*	45 + 20
URS-4-90.0	2.37	0.14*	48 + 50
URS-4-85.0	2.60	0.22*	149 + 60
URS-4-70.0	2.42	0.12*	97 + 55
URS-4-60.0	2.80	1.00	Barren
URS-4-50.0	2.50	1.10	Barren
URS-4-43.0	2.65	0.99	Barren
URS-4-27.0	2.36	1.30*	3
URS-4-24.0	2.24	1.80	Barren
URS-4-18.0	1.98	1.60	Barren
URS-4-12.0	2.70	1.85	Barren
URS-4-6.5	2.21	1.25	1
URS-4-2.0	2.13	1.40	Barren
URS-4-0.1	2.59	1.55	Barren
HAM-1-38.0	2.90	0.32*	28 + 35
HAM-1-32.0	2.60	0.32*	43 + 3
HAM-1-28.0	2.42	1.77	2
HAM-1-21.0	2.36	0.36*	70 + 25
HAM-1-14.0	2.16	0.10*	95 + 38
TELT-KD-16.0	2.80	2.25	Barren
TELT-KD-13.0	2.15	1.55	Barren
TELT-KD-8.5	4.90	1.00*	5
TELT-KD-8.0	1.70	1.15	Barren
TELT-KD-6.0	2.10	1.05	Barren
TELT-KD-1.0	2.70	2.12	Barren
TELT-KD-0.0	2.10	1.00	Barren