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Evolution of the boreal marine biota and biostratigraphy at the Middle/Upper Triassic boundary

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With 3 plates and 1 table

Contents

Abstract

New data from different revised sequences in Arctic Siberia (Okhotsk region, Omolon basin, East Taimyr) and from the Svalbard Archipelago has lead to a better understanding of the biostratigraphy of the Ladinian/Carnian transition of the boreal province. For the latest Ladinian a new zone, that of *Nathorstites lindstroemi* is proposed which does not correlate exactly with the *Frankites sutherlandi* zone of NE-British Columbia. It cannot be excluded that the Middle/Upper Triassic transition is not continuous in North Canada as previously supposed. The *Stolleyites tenuis* zone of the lowermost boreal Carnian can be devided into two subzones, at least in sections of the Okhotsk Sea (Yana River) and Eastern Spitsbergen. Precise correlation of the *tenuis* zone with the *Trachyceras desatoyense* zone of British Columbia is still not possible until now.

Zusammenfassung

Profilaufnahmen mit exakt horizontiert entnommenen Ammonoideen-Faunen verschiedener Gebiete der sibirischen Arktis (Okhotsk Region, Omolon Becken, Ost Taimyr) sowie auf dem Svalbard Archipel haben eine Anzahl neuer Daten geliefert, die zum besseren Verständnis der Biostratigraphie im Grenzbereich Ladin/Karn der borealen Provinz beigetragen haben. Für das höchste Ober-Ladin wird eine neue Zone, die des *Nathorstites lindstroemi,* vorgeschlagen. Eine exakte Korrelierung mit der *Frankites sutherlandi* von NE-British Kolumbien ist zur Zeit noch nicht möglich. Es kann nicht ausgeschlossen werden, daß im Grenzbereich Mittel/Ober-Trias in Britisch Kolumbien eine

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Schichtlücke existiert. Die *Stolleyites tenuis* Zone des tiefsten borealen Unter-Karn läßt sich, zumindest in einigen Regionen (Yana Becken, Ost Spitsbergen), in zwei Subzonen untergliedern. Auch in diesem Fall ist eine genaue Korrelierung mit der *Trachyceras desatoyense* Zone der Standardgliederung Britisch Kolumbiens bisher nicht möglich.

I. Introduction

Late Ladinian and early Carnian ammonoid faunas of the boreal province are compared with those from the tethyan and pacific provinces considerably impoverished and furthermore distinctly endemic. The most common ammonoids of this stratigraphical time interval are members of the Fam. Nathorstitidae while the typical trachyceratitids on which the standard scheme of the tethyan province is based are quite rare or totally absent. Usually not only the nectic but also the benthic faunal elements, for example the brachiopod faunas, are dominated by endemic genera or families during this time span.

Of major importance for the correlation of the boreal zonal sequences with the tethyan standard are the British Columbia sections where a mixture between boreal and tethyan faunal elements occurs.

The biostratigraphy of the boreal Late Ladinian and Early Carnian is mainly based on the evolution of the nathorstitids and the definition of the Ladinian/Carnian boundary depends on the interpretation of the latest forms of this ammonoid group. Nearly all nathorstitid species are highly variable, especially in conch thickness and each successive species of this family is representd by inflated and compressed variants (with all transitional forms) (TOZER, 1980; WEITSCHAT & DAGYS, 1989; LINDHORST, pers. comm.). This fact has lead to an unusually great number of misidentifications, followed by wrong correlations, especially for the Siberian faunas. Consequently the current status concerning the biostratigraphy of the boreal Late Ladinian and Early Carnian and its correlation is quite unsatisfactory.

The revision of sections, with bed by bed collected faunas, in different areas of the Siberian Arctic (Yana River Basin, Omolon River, Eastern Taimyr) as well as on the Svalbard Archipelago (East Coast of Spitsbergen, Central Spitsbergen, Bjørnøya) has revealed some new data which lead to a better understanding of the biostratigraphy of this time interval.

II. Previous works

In the earliest publications from British Columbia (WHITEAVES, 1889; SMITH, 1927) as well as from the Svalbard Archipelago (BÖHM, 1903; STOLLEY, 1911; FREBOLD, 1929) all beds with *Nathorstites* were regarded as representing essentially one zone of Carnian age. POPOW (1946) described representatives of the genus *Nathorstites* and two new related genera together with some Daonellas from Triassic beds of Yakutia (Indirka River) and considered them to be mainly of Ladinian age.

MC LEARN (1947) interpreted the strata with *Nathorstites mcconnelli* in British Columbia as Ladinian, on account of the co-occurrence with tethyan ammonoids similar to forms from the *Protrachyceras archelaus* zone of the Alps.

The first zonal scheme of the NE-USSR (POPOW, 1961) included all nathorstitids in one Upper Ladinian generic zone. This scheme dominated for a long time (ARKHIPOV et al. 1971; ARKHIPOV, 1974; DAGYS et al.1979).

On the Svalbard Archipelago KORCHINSKAYA (1972, 1975, 1982) distinguished two different units in the beds with *Nathorstites* - a lower one, of Ladinian age (*N. mcconnelli* zone) which contains besides the index-species, *N.*

strongulatus, N. cf. *gibbosus* and some different species of the bivalve genus *Daonella,* and an upper one (*Halobia zitteli* zone) with *Nathorstites tenuis, N. lenticularis, N. gibbosus,* which due to the presence of *Halobia zitteli* and *Discophyllites taimyrensis* was considerd to be of Early Carnian age.

Apart from some misidentifications of nathorstitid species (WEITSCHAT & DAGYS, 1989) which will be discussed later, KORCHINKAYA's ideas of a Lower Carnian age of beds containing *Nathortites tenuis* was accepted also for the Siberian sequences (BYCHKOV, 1982; DAGYS, 1986).

Tozer (1968, 1980) showed that species of *Nathorstites* range throughout most of the Ladinian in British Columbia so that the mere identification of the genus does not contribute to a precies age determination. For the nathorstitids of the Arctic he suggested most of them to be correlative with forms that occur in the *sutherlandi*-zone of British Columbia, mainly because of their alleged association with *Daxatina (Dawsonites) canadensis* on Bjørnøya.

Because in Canada nathorstitids have never been found above the *sutherlandi* zone he doubted whether this genus ranges into the Carnian of Svalbard and Siberia.

Later he agreed with the Carnian age of the *Nathorstites tenuis* zone of Siberia and Svalbard and correlated it with the *Trachyceras desatoyense* zone of Canada (DAGYS & TOZER, 1989).

While the position of the Ladinian/Carnian boundary in the boreal realm is more or less clear, our new investigations of this stratigraphical interval show that the evolution of the faunas, especially that of the ammonoids is more complicated so that the zonal scheme needs some amendments.

III. Material

The new data were received from the revision of sequences from different regions of Siberia and the Svalbard Archipelago.

1. Okhotsk sea region (Yana River basin)
2. Omolonian massive (Omolon River basin)
3. Eastern Taimyr (Cape Tsvetkov)
4. Spitsbergen (east coast)
5. Central Spitsbergen
6. Bjørnøya

The material was collected by the authors, by A. EGOROV (Aerogeological Institut, Moscow) and by A. MORK (IKU, Petroleum Research, Trondheim).

IV. Main sequences

A. Siberia (North-East Asia)

1. Okhotsk Sea Region, (Vtoraya Sentiabrskaya River) Yana River basin.

Total Thickness of the section 550 m.

1st unit 97 m : Siltstone, dark grey, massive, often calcareous, with interbeds of minor clayey siltstone, and rare limestone concretions.

Fauna:

1 m - 56 m *Nathorstites mcconnelli* (WHIT.), *Sphaerocladiscites omolonensis* BYTSCHK.; *Daonella* sp.; *Sinuplicorhynchia kegalensis* DAGYS.

67 m - 68 m *Nathorstites mcconnelli, Sphaerocladiscites omolonensis, Proclydonautilus* cf. *anianiensis* (SHIM.); *Daonella* sp.; *Fletcherithyroides gregarius* DAGYS, *Aulacothyroides bulkutensis* DAGYS, *Pennospiriferina popovi* DAGYS.

88 m: *Nathorstites* sp.

91 m - 93 m: *Nathorstites lindstroemi* BÖHM, *Nathorstites* sp., *Spaerocladiscites omolonensis, Proclydonautilus anianiensis, Cenoceras* sp.; *Sinuplicorhynchia kegalensis, Planirhynchia yakutica* DAGYS, *Fletcherithyroides gregarius. Cenoceras boreale, Pennospiriferina popovi*

2nd unit 62 m Siltstone, dark-grey, massive, with rare layers of limestone concretions.

Fauna:

41 m -52 m: *Stolleyites* (?.) sp., *Cenoceras boreale.*

3rd unit 116 m Mudstone, dark-grey, thin-bedded with interbeds of massive siltstone and rare clayey limestone concretions.

Fauna:

1 m - 10 m: *Stolleyites tenuis* (STOLL.), *Pennospiriferina popovi.*

18 m - 20 m: *Stolleyites tenuis, Stolleyites* cf. *plana, "Discophyllites"* sp..

77 m - 82 m: *Stolleyites tenuis, Cenoceras* cf. *boreale.*

92 m - 105 m: *Stolleyites tenuis, Cenoceras* cf. *boreale; Pennospiriferina popovi, Zeilleria exigua* DAGYS, *Aulacothyroides bulkutensis.*

4th unit 114 m Mudstone, dark-grey, with rare limestone concretions, and interbeds of clayey siltstone.

Fauna:

16 m - 19 m: *Stolleyites* sp.; *Pennospiriferina popovi.*

49 m - 59 m: *Cenoceras boreale; Pennospriferina popovi.*

71 m - 93 m: *Stolleyites tenuis, Stolleyites* sp.; *Cenoceras boreale; Pennospiriferina popovi, Holcorhynchonella anceps* DAGYS.

5th unit 73 m Siltstone, sandy, dark-grey, massive, with rare clayey-calcareous concretions.

Fauna:

6 m - 8 m: *Stolleyites* sp., *"Discophyllites"* sp.; *Cenoceras* cf. *boreale; Holcorhynchonella anceps, Pennospiriferina popovi.*

34 m - 35 m: *"Protrachyceras"* ex gr. *omkutchanicum* BYTSCHK.; *Dentospiriferina pepeliaevi* DAGYS.

The 5th unit is overlain by dark-grey, sandy siltstones which contain *Protrachyceras* cf. *omkutchanicum.*

2. Omolonian Massive

Dzhugudzak River (Omolon River basin).

Total thickness of the section: 49 m.

1st unit 10,5 m Mudstone, black, thin-bedded often calcareous, with abundant sphaerical phosphate nodules.

Fauna:

1 m - 2 m: *Nathorstites mclearni* TOZER (MS), *Aristoptychites kolymensis* KIPAR.; *Daonella* aff. *prima* KIPAR.

2.8 m - 7.1 m: *Nathorstites mcconnelli, Aristoptychites kolymensis, Spaerocladiscites omolonensis, Indigirophyllites oimekonensis* POPOV; *Sinuplicorhynchia kegalensis.*

7.1 m - 9.7 m: *Nathorstites mcconnelli, Sphaerocladiscites omolonensis.*

2nd unit 11.6 m Mudstone, black, soft, with interbeds of hard, calcareous mudstone.

Fauna:

1.3 m - 2.3 m: *Nathorstites lindstroemi, Sphaerocladiscites omolonensis; Daonella* sp.

4.1 m - 6.0 m: *Nathorstites lindstroemi, Sphaerocladiscites omolonensis; Proclydonautilus anianiensis; Fletcherithyroides gregarius.*

3rd unit 9.9 m Siltstone, dark grey, calcareous, bituminous.

Fauna:

0 - 3 m: *Stolleyites* sp., *"Discophyllites"* sp.; *Proclydonautilus anianiensis, Cenoceras boreale; Pennospiriferina popovi.*

4th unit 8,5 m Siltstone, dark-grey, thin-bedded, calcareous, with rare phosphate nodules.

Fauna:

4.5 m - 4.9 m: *"Discophyllites" taimyrensis, Cenoceras boreale, Pennospiriferina costata.*

5th unit 8 m Siltstone, massive, often calcareous.

Fauna:

"Discophyllites" taimyrensis, Pennospiriferina costata.

3. Eastern Taimyr

Cape Tsvetkov

Sandy siltstones with *Indigirites krugi* POPOV are overlain by:

1st unit 9.2 m Siltstone, sandy, dark-grey or greenish-grey, massive.

Fauna:

Nathorstites mclearni TOZER (MS), *Aristoptychites cf. kolymensis.*

(In previous publications (DAGYS, KAZAKOV, 1980; 1984) *N. mclearni erroniously* was determined as *N. tenuis*).

2nd unit 114 m Sandstone, greenish-grey, thin-to coarse-grained, often with cross-beddings, with interbeds of siltstone, conglomerate and coal.

3rd unit 49 m Siltstone, greenish-grey, with interbeds of mudstone and siltstone.

4th unit 25.2 m Mudstone, dark-grey, with abundant limestone concretions.

Fauna: *"Discophyllites" taimyrensis, Proclydonautilus anianiensis, Cenoceras boreale, Planirhynchia yakutica* DAGYS, *Sakawairhynchia olenekensis* DAGYS, *Aulacothyroides bulkutensis, Halobia* ex gr. *zitteli* LINDSTR.

5th unit 34 m: Siltstone, grey to greenish-grey, massive, with interbeds of mudstone; and with frequent limestone concretions.

Fauna:

2 m - 17 m: *"Discophyllites" taimyrensis, Proclydonautilus anianiensis, Cenoceras boreale.*

24 m - 31 m: *"Discophyllites" taimyrenis, Cenoceras boreale, Sakawairhynchia oelenekensis.*

This unit is overlain by sandstones containing *"Discophyllites" taimyrensis and Cenoceras boreale.*

B. Svalbard Archipelago

1. Wichebukta, Teistberget (East Coast of Spitsbergen)

1st unit 17.5 m Shale, dark grey, papery, often calcareous and bituminous, with interbeds of calcareous siltsone, grey, yellow weathering; oval limestone concretions occur at distinct horizons; small phosphate nodules frequent.

Fauna:

1.5 - 2.5 m *Daonella degeeri* BÖHM

14.5 m *Arctoptychites* n. sp., *Protrachyceras* spp., *Daonella* sp., Trauma-

tocrinidae, (?*Vostocovacrinus* sp.),

15.5 m *Protracyceras* sp., *Daonella* sp.

2nd unit 0,5 m Siltstone, dark grey, weathering light, composed of abundant phosphate nodules.

Fauna:

Nathorstites cf. *lindstroemi.*

3rd unit 55 m Shale, grey, weathering light, silty, with frequent small rounded siderite concretions, weathering red and red-brown..

Fauna:

1 m - 2 m: *Stolleyites plana* (FREB.), *Paracladiscites* cf. *diurturnus, "Discophyllites" taimyrensis, "Cenoceras" boreale, Proclydonautilus* sp., *Halobia zitteli, Spiriferina sp.*

5 m - 7 m: *Stolleyites tenuis, Paracladiscites* cf. *diurturnus, ?Arctosirenites* sp., *Proclydonautilus* spp., *Halobia zitteli.*

12 m - 15 m: *Stolleyites tenuis, "Germanonautilus"* sp., *Gastropada.*

2. Roslagenfjellet, Aghardbukta (East Coast of Spitsbergen)

1st unit 26 m Shale, dark-grey, weathering light-grey, often calcareous, bituminous, with large oval limestone concretions at distinct horizons, and frequent small, dark grey phosphate nodules.

Fauna:

1 m: *Aristoptychites trochleaeformis* (LINDSTR.), *Frechites laqueatus* (LINDSTR.), *Parapopanoceras malmgreni* (LINDSTR.), *Daonella lindstroemi* MOJ.

25 m: *Aristoptychites kolymensis, Indigirites tozeri* WEITSCHAT & LEHMANN, *Indigirophyllites spetsbergensis* (ÖBERG), *Daonella degeeri.*

2nd unit 15 m Shale, black, papery, bituminous, with interbeds of yellow weathering, calcareous siltstone; horizons of dark grey phosphate nodules occur.

3rd unit 0.5m Siltstone, composed of small, dark grey, rounded phosphate nodules.

Fauna:

Reptile vertebrae, *Rhizocorallium.*

4th unit 15 m Shale, dark grey, weathering light-grey, with rare phosphate nodules in the lower 3 meters and frequent small, rounded, reddish weathering siderite concretions in the upper part.

Fauna:

1 m - 3 m: *Stolleyites plana, Paracladiscites* cf. *diurturnus.*

8 m - 9 m: *Stolleyites tenuis, Proclydonautilus* spp., *Halobia zitteli,* Gastropoda.

3. Tschermakfjellet, Isfjorden (Central Spitsbergen)

1st unit 24.5 m Shale, black, papery, often calcareous and bituminous, with interbeds of grey calcareous siltstone. Large oval limestone concretions, often with septarian structure are common and occur at distinct horizons.

Fauna:

1 m: *Aristoptychites trochleaeformis, Frechites laqueatus, Parapopanoceras malmgreni, Parafrechites migayi* (KIP.), *Daonella lindstroemi.*

9 m: *Aristoptychites euglyphus* (MOJ.), *Tsvetkovites varius* WEITSCHAT & LEHMANN, *Indigirophyllites* cf. *spetsbergensis, Daonella lindstroemi.*

19 m: *Aristoptychites kolymensis, Indigirites tozeri, Indigirophyllites spets-*

bergensis, Proarcestes sp., *Daonella degeeri.*

21m : *Indigirophyllites spetsbergensis, Daonella* sp.

2nd unit 0.5 m Siltstone composed of small, dark-grey, rounded phosphate nodules.

Fauna:
Reptile vertebrae, *Rhizocorallium.*

3rd unit 41 m Shale, dark-grey, soft, with interbeds of dark-grey calcareous sitlstone, hard and compact, weathering yellow. With frequent small rounded siderite concretions, weathering red and red-brown.

Fauna:
12 m *Stolleyites tenuis, "Discophyllites" taimyrensis, Proclydonautilus* spp., *"Cenoceras" boreale, Halobia zitteli, Planirhynchia yakutica* DAGYS, Lamellibranchia, Gastropoda.

32 m *Stolleyites tenuis*

4. Bjørnøya

Urd mountain

1st unit 115 m Shale, dark grey, shales with red weathering siderite nodules. There are several minor coarsening upwards sequences grading from shales to fine grained sandstones.

Fauna:
63 m *Nathorstites lindstroemi, N.* sp., *Paracladiscites diurturnus*
69 m *Nathorstites lindstroemi, N.* sp.
71 m *Nathorstites lindstroemi*
85 m *Daxatina canadensis*
87 m *Daxatina canadensis*
89 m *"Clionitites" spinosus* BÖHM
90 m *Daxatina canadensis*

2nd unit 20 m Sandstone, fine-grained, thin to thickly bedded (0.1 - 1.0 m), with limestone nodules.

Fauna:
5.5 m? *Stolleyites* sp..

V. Development of marine faunas at the Ladinian/Carnian boundary

The revision of the different sequences of the latest Ladinian and earliest Carnian deposits together with bed by bed collected faunas has shown that the development of the marine communities of this time interval was more complicated than assumed before.

The new data, which concern nectic elements (ammonoids and nautilids) as well as some benthic elements (brachiopods and bivalves) show that the tempo of evolution within the different fossil groups is not constant. Based mainly on ammonoid data it is possible to establish some stages of evolution within this time interval.

The oldest complex under consideration is known only from Siberia (section I and II) and Arctic Canada (TOZER, 1961). Characteristic ammonoid species is *Nathorstites macconnelli* - a species highly variable in thickness, characterized

by distinctly falcoid striae and a flat umbilical depression in middle ontogenetic stages. This complex is also characterized by the first appearance of *Sphaerocladiscites omolonensis* which is quite common. More rare are *Aristoptychites kolymensis* and *Indigirophyllites oimekonensis* represented by transitional forms from the underlying *Nathorstites mclearni* beds. Nautiloids are quite rare within this complex. They are more related to older Ladinian faunas *(Gryponautilus kegalensis, Sybillonautilus arctus)* (SOBOLOV, 1989). Only in a single section (section I) first rare specimens of the genus *Proclydonautilus* appear. Pelagic bivalves are represented only by members of the genus *Daonella*. Exact specific determination for the Siberian daonellas is not possible, because the whole group needs a thorough revision. The brachiopods from the Siberian sections mainly belong to long-living species as *Sinuplicorhynchia kegalensis* but as in the nautiloid faunas some rare specimens appear which are close to those of younger units.

The second complex which can be separated faunistically comes from overlying beds in Siberia (section I, bed 1d; section II, beds 1b, 2a, b) and is also known from the Svalbard Archipelago (Bjørnøya). The characteristic ammonoid species of this assemblage is *Nathorstites lindstroemi* BÖHM. In Siberia it is accompanied only by *Sphaerocladiscites omolonensis* while on Bjørnøya additional ammonoids occur *(Daxatina canadensis* (WHITE.)), *"Clionites"* barentsi BÖHM, *"Cl." spinosus* BÖHM, *Paracladiscites* sp. *Nathorstites lindstroemi* is undoubtly a descendant of *N. mcconnelli* with which it is connected by transitional forms. *N. lindstroemi* mainly differs from *N. mcconnelli* by the course of the growth lines, which are not as falcoid, and by the more pronounced umbilical depression of forms at middle ontogenetic stages.

In Siberia the ammonoid fauna of this level is accompanied by characteristic clydonautilids with highly dissected suture line and a brachiopod fauna with a more "Carnian" feature *(Pennospiriferina popovi, Aulacothyroides bulkutensis)*.

The third complex from the stratigraphical level under discussion is characterized by the appearance of the genus *Stolleyites,* erected by ARCHIPOV (1974) for the latest nathorstitids which show distinct umbilical bullae and a pronounced umbilical depression. In all Siberian and Svalbardian sections a typical phylloceratid also occur in this level. Until now this species was attributed to the genus *Discophyllites* (POPOV and others). In our opinion it represents a new genus which may be essentially distinguished from the younger tethyan true *Discophyllites* by the suture line. The boreal "Discophyllites" is most probably a direct descendants of the genus *Indigirophyllites* POPOV, the characteristic phylloceratid of the boreal Anisian and Ladinian strata, from which it differs by a more complex suture line. The beds with *Stolleyites* in the boreal regions are also characterized by their typical nautiloid fauna, which yields first members of the Fam. Nautilina *(Cenoceras boreale)* besides diverse species of the genus *Proclydonautilus (Proclydonautilus anianiensis)*.

Characteristic bivalve for this complex is *Halobia zitteli*. In Siberia it also contains abundant alate spiriferinids *(Pennospiriferina popovi)*.

The third complex may be divided into two successive ammonoid assemblages: A lower one which contains quite rare *Stolleyites tenuis* and abundant thicker forms which formerly were described as *Nathorstites gibbosus* (FREBOLD, 1929; BYCHKOV, 1982). *Nathorstites gibbosus* was first erected by STOLLEY (1911) for forms from one distinct horizon at Tschermakfjellet (Spitsbergen), where it occurs together with *Nathorstites tenuis* from which it can be distingushed by the presence of umbilical bullae and a slightly thicker conch. In our opinion

both species are variants of one species (LINDHORST, pers. comm.). *Nathorstites concentricus* described by OEBERG (1877) from the same stratigraphical level is most probbably also conspecific with *Nathorstites tenuis*. The holotype of this species (only one specimen in OEBERG`s collection) is so badly preserved that even the generic determination would have been questionable if it would not show the typical red weathering sideritic nodule unique for this stratigraphical level on Central Spitsbergen. Therefore we consider that *N. concentricus* must be interpreted as a nomen dubium.

For the above mentioned thick forms of the lower ammonoid assemblage KORCHINSKAYA (1972) has proposed the new specific name *N. strongulatus*. The priority, however, have the varieties described and figured by FREBOLD (1929) from the East Coast of Spitsbergen and from Edgeøya as *N. gibbosus* var. plana, intermedia and globosa. According to the rules of zoological nomenclature the correct species name must be *Stolleyites planus* (FREBOLD, 1929), because var. *plana* was mentioned first by FREBOLD (p. 305, pl. 2, fig. 1-3).

Stolleyites planus is characterized by a very distinct umbilical depression in early and middle ontogenetic stages and by the presence of strongly pronounced umbilical bullae in middle and late ontogenetic stages. It is similar to its probable ancestor *Nathorstites lindstroemi,* from which it mainly differs by the presence of the distinct bullae up to the latest ontogenetic stages.

The upper ammonoid assemblage of the beds with *Stolleyites* is characterized by only one nathorstitid species - *Stolleyites tenuis* (including *N. gibbosus*). It can easely be distinguished from *S. planus* by its thinner conch, the indistinct umbilical depression and the sculpture. In Siberia the uppermost part of the section contains some rare specimen without any bullae, which may represent a new species. The evolutionary trend within the genus *Stolleyites* seems to be thinning of the conch, decreasing of the umbilical depression and weekening of the sculpture. On Spitsbergen (East Coast, Wichebukta) in the upper assemblage some rare badly preserved Sirenitidae occur besides the nathorstitids.

The strata which overlie the beds with *Stolleyites* in Siberia (sect. I, sect. II., sect. III) yield a quite distinct fauna with its own character. Nathorstititids disappeared fully and the typical ammonoids are *"Protrachyceras" omkutchanicum* (which most probably represents a new trachyceratid genus) and *"Discophyllites" taimyrensis*. The nautiloid fauna of this complex contains some "older" elements *(Cenoceras boreale)* besides a new form - *Cosmonautilus polaris* SOB.-, which is most probably the direct descendant of *Proclydonautilus anianiensis*.

The brachiopod assemblage is characterized by some new spiriferoid genera *Spondylospiriferina* and *Deutospiriferina,* while the genus *Pennospiriferina* is quite rare in this complex.

According to POLUBOTKO (1984) the fauna of pelagic bivalves also changes essentially at this level. *Halobia zitteli* becomes extinct and is replaced by new species - *Halobia korkodonica* POLUB. and *Halobia zhilnenis* POLUB.

VI. Biostratigraphical conclusions

The analysis of the development of the boreal marine faunas at the Middle/ Upper Triassic boundary shows, that the boreal zonal standard needs certain amendments for this stratigraphical interval. It seems clear that the *Nathorstites mcconnelli* zone is not the last biostratigraphical unit in the boreal Upper Ladinian and we therefore propose as a new zone that of *Nathorstites lindstroemi*. Although *N. lindstroemi* is quite close to *N. mcconnelli* this seems justified

because within the *lindstroemi* zone some typical Middle Triassic elements disappeard (e. g. Ptychitidae) while especially within the brachiopod and nautiloid fauna some typical Carnian elements appear.

TOZER (1980) considered the beds with *Nathorstites lindstroemi* of Bjørnøya as to be correlative with the upper part of the *sutherlandi* zone of British Columbia because of the co-occurrence of *Daxatina canadensis*. In Canada only a single nathorstitid *N. mcconnelli* occurs in this zone, which according to our new data from the Siberian sections is older than *N. lindstroemi*.

Thus, the newly established *lindstroemi* zone of the boreal standard cannot be correlated exactly with British Columbia and it seems possible that the transition between the Middle/Upper Triassic is not continuous in Northern Canada as previously supposed by SILBERLING & TOZER (1968).

For the Lower Carnian the new data show that within the *tenuis* zone two biostratigraphical units may be distinguished in Siberia and on Svalbard. They are interpreted as subzones (*planus* and *tenuis* subzone) and it seems possible to separate an additional unit (in Siberia) for the highest beds which contain a *Stolleyites* fauna with characteristic smooth conchs on adult stages.

The precise correlation of the *tenuis* zone of the boreal standard with the Lower Carnian of British Columbia can not be solved until now. But from first discoveries of nathorstitids (most probably belonging to the genus *Stolleyites*) in beds analogue to the desatoyense zone in British Columbia as well as from the

STAGE	British Columbia	Siberia			Arctic Canada	Svalbard Archipelago		
		Okhotsk Sea Yana River	Omolon Massiv	Eastern Taimyr		East Spitsbergen	Central Spitsbergen	Bjørnøya
EARLY CARNIAN	Austrotrachyceras obesum	„Protrachyceras" omkutchanicum		Beds with Pennospiriferina costata				
	Trachyceras desatoyense	Stolleyites tenuis	Stolleyites tenuis	Beds with Cosmonautilus polaris		Stolleyites tenuis	Stolleyites tenuis	Beds with "Discophyllites"
		Stolleyites planus		Beds with Proclydonautilus anianiensis		Stolleyites planus		
LATE LADINIAN	----------	Nathorstites lindstroemi	Nathorstites lindstroemi					Nathorstites lindstroemi
	Frankites sutherlandi	Nathorstites mcconnelli	Nathorstites mcconnelli		Nathorstites mcconnelli			
	Maclearnoceras maclearni	Nathorstites maclearni	Nathorstites maclearni	Nathorstites maclearni				

Tab. 1: Correlation of the latest Ladinian and early Carnian of the Boreal Triassic Realm

stratigraphical position of the *tenuis* zone (above beds with *Daxatina* on Svalbard) it can be correlated at least with some parts of the *desatoyense* zone.

The complex overlying the *tenuis* zone which is known only from Siberia contains a very endemic ammonoid fauna and gives no additional data for clarifying the correlation of the *tenuis* zone with British Columbia.

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Plate I

Fig. 1a, b: *Nathorstites mcconnelli* (WHITEAVES); River Pravaya Vtoraya , Sentiabrskaya, (Okhotsk Sea basin); Upper Ladinian, *Mcconnelli* Zone. x 1.

Fig. 2a, b: *Nathorstites mcconnelli* (WHITEAVES); River Pravaya Vtoraya; Sentiabrskaya, (Okhotsk Sea basin); Upper Ladinian, *Mcconnelli* Zone. x 2

Fig. 3a, b, 4a, b: *Nathorstites lindstroemi* BÖHM; River Dzhugudzak (Omolon R. basin); Upper Ladinian, *Lindstroemi* Zone. x 1.

Fig. 5: *Stolleyites tenuis* (STOLLEY); River Pravaya Vtoraya, Sentiabrskaya, (Okhotsk Sea basin); Lower Carnian, *Tenuis* Zone. x 1.

Fig. 6: *Stolleyites planus* (FREBOLD); River Pravaya Vtoraya, Sentiabrskaya, (Okhotsk Sea basin); Lower Carnian, *Tenuis* Zone (*Planus* Subzone). x 1.

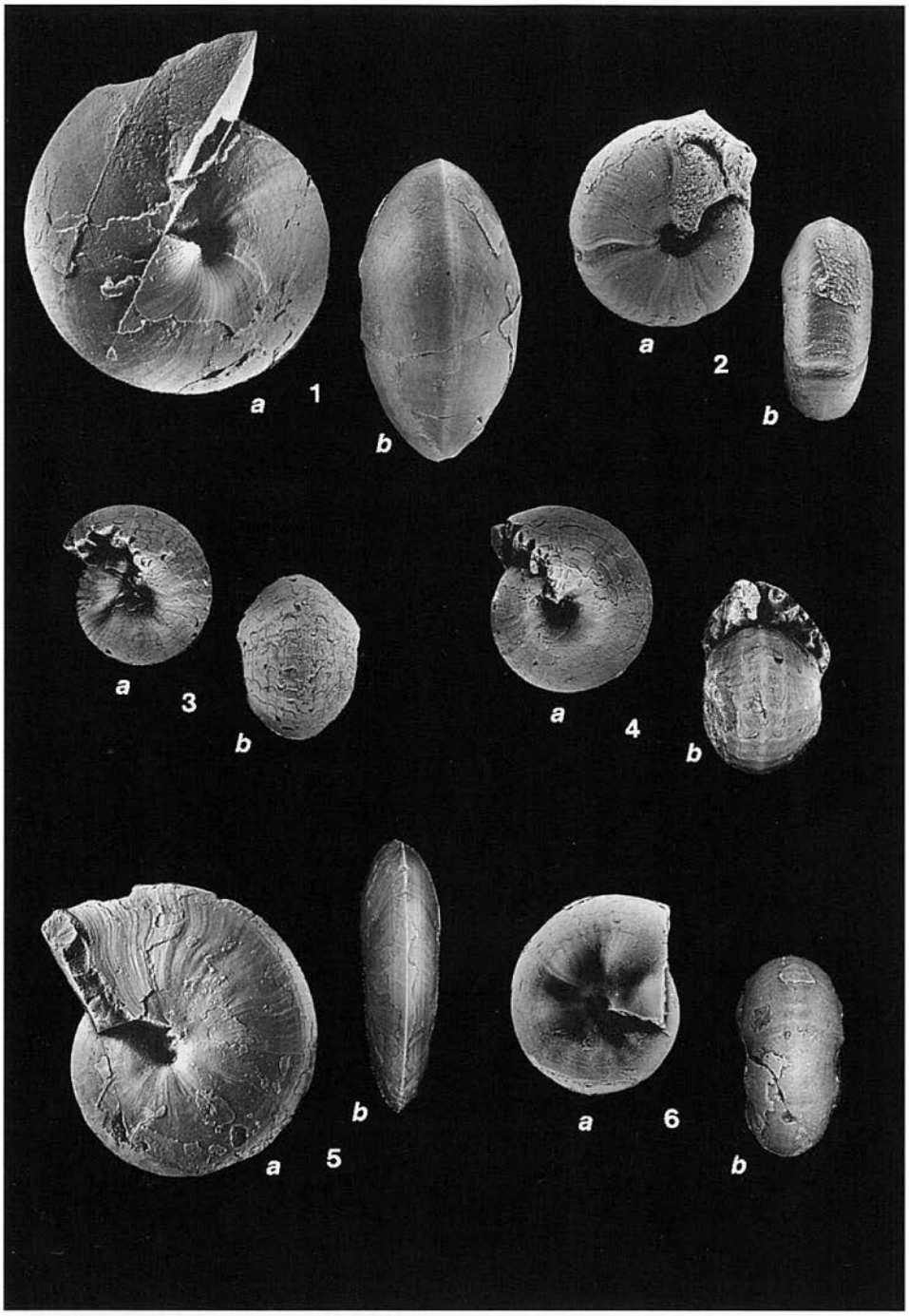
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Plate II

Fig. 1a, b: *Proclydonautilus anianiensis* (SHIMANSKY); Cape Tsvetkov, Eastern Taimyr; Lower Carnian, *Tenuis* Zone. x 0.8.

Fig. 2a, b: *Cosmonautilus polaris* SOBOLEV; Kharaulakh Range, River Darky (Lena River basin) Lower Carnian, *Omkutchanicum* Zone. x 0.7.

Fig. 3a, b: *Cenoceras boreale* DAGYS & SOBOLEV; Cape Tsvetkov, Eastern Taimyr; Lower Carnian, *Tenuis* Zone. x 1

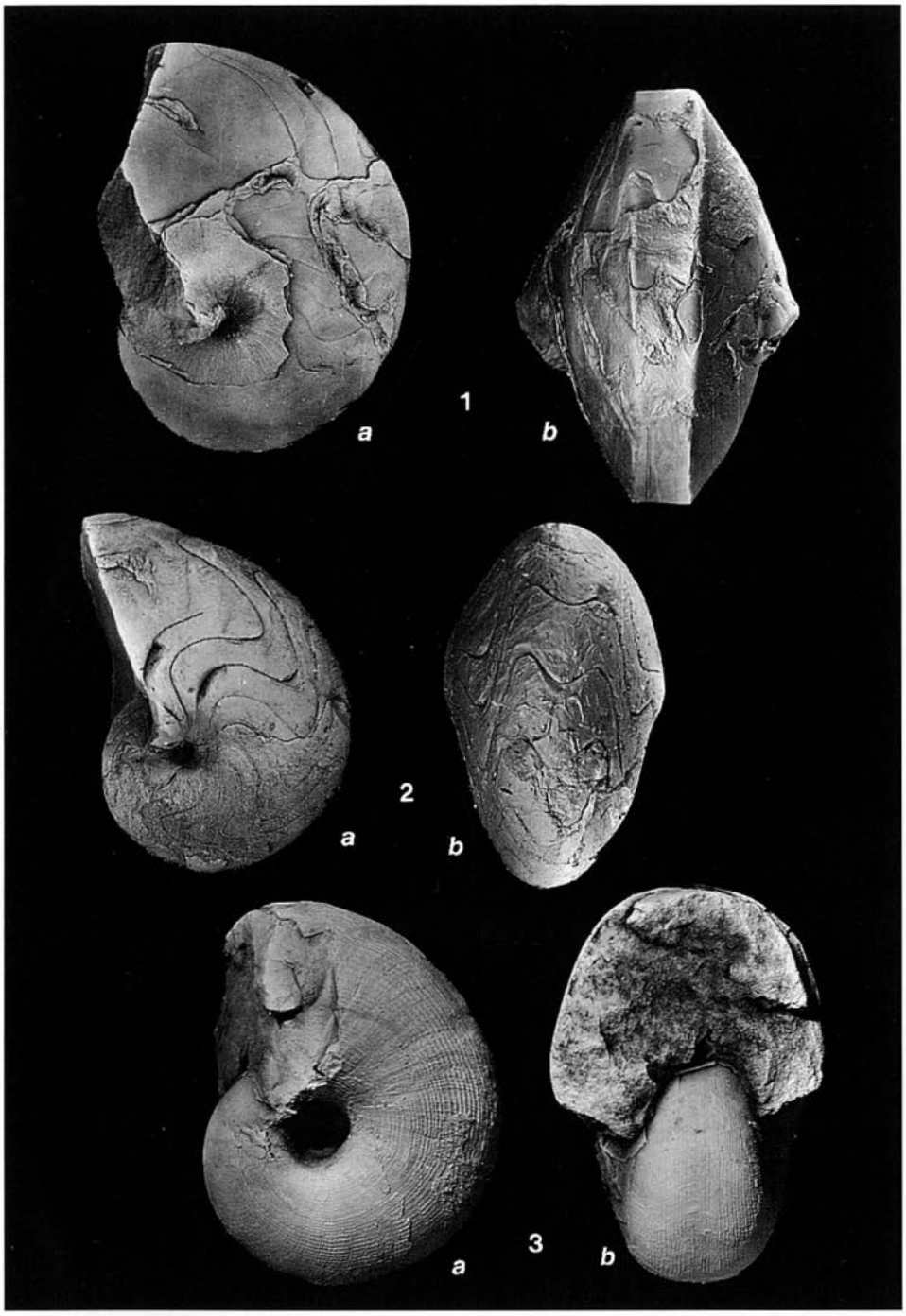
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Plate III

Fig. 1a, b: *Daxatina canadensis* (WHITEAVES); Svalbard Archipelago, Bjørnøya, Urdmountain, Upper Ladinian, *Lindstroemi* Zone. x 1.
P.M.O.No.

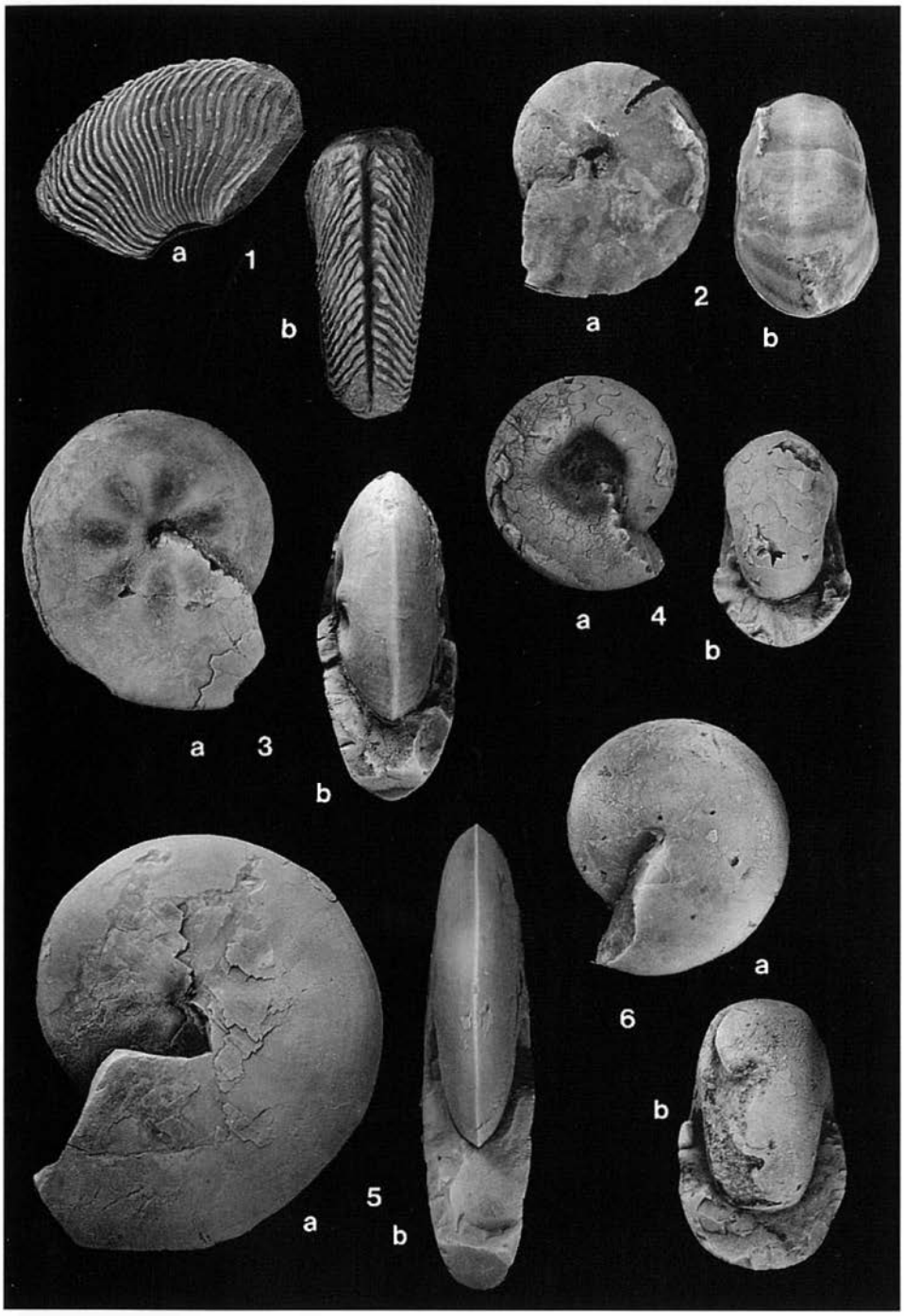
Fig. 2a, b: *Nathorstites lindstroemi* BÖHM; Svalbard Archipelago, Bjørnøya, Urdmountain, Upper Ladinian, *Lindstroemi* Zone. x 1.5.
P.M.O. No.

Fig. 3a, b: *Stolleyites planus* (FREBOLD); Svalbard Archipelago, East Spitsbergen, Hahnfjella, Tschermakfjellet Formation, Lower Carnian, *Tenuis* Zone, (*Planus* Subzone). x 1.
SGPIMH Typ. Kat. Nr.3016.

Fig. 4a, b: *Stolleyites planus* (FREBOLD); Svalbard Archipelago, East Spitsbergen, Hahnfjella, Tschermakfjellet Formation, Lower Carnian, *Tenuis* Zone (*Planus*-Subzone), subadult specimen with typical umbilical depression. x 1,5.
SGPIMH Typ. Kat. Nr.3017.

Fig. 5a, b: *Stolleyites tenuis* (STOLLEY); Svalbard Archipelago, East Spitsbergen, Hahnfjella, Tschermakfjellet Formation, Lower Carnian, Tenuis Zone (Tenuis Subzone). x 1.
SGPIMH Typ. Kat.Nr.3018.

Fig. 6a, b: *Paracladiscites* cf. *diurturnus* (MOJ.); Svalbard Archipelago, East Spitsbergen, Hahnfjella, Tschermakfjellet Formation; Lower Carnian, *Tenuis* Zone (*Tenuis* Subzone) x 1.
SGPIMH Typ.Kat.Nr.3019.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