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Correlated Ammonoid Zonation in Ladinian Deposits of the Boreal Realm

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Abstract—Tsvetkovitids and nathorstitids (Ammonoidea) from the entire Boreal realm are revised on the basis of most recent data on their morphology, systematics, and evolution. The elucidated stratigraphic ranges of both taxonomic groups are used to establish the correlated ammonoid zonation in Ladinian deposits of northeastern Asia, Svalbard, Arctic Canada, Franz Josef Land and British Columbia. Ammonoid faunas from British Columbia consist of mixed Boreal and Tethyan taxa useful for correlation of Ladinian biostratigraphy in Boreal regions with the standard Alpine scale.

Key words: *northeastern Asia, Svalbard, Canada, Franz Josef Land, Southern Alps, biostratigraphy, correlation, Ladinian Stage, ammonoids.*

INTRODUCTION

The Ladinian Stage biozonation that would be generally acceptable has not been authorized so far, and positioning of lower and upper boundaries of the stage is still a subject of long-lasting discussion. In 1993, the International Working Group on the Anisian–Ladinian Boundary made an attempt to solve the problem during the field excursion to classical sections of Anisian–Ladinian boundary beds in Southern Alps of Italy and Balaton Highlands of Hungary (*Anisian/Ladinian...*, 1993). Analyzing stratigraphic ranges of ammonoids and discussing correlation between the sections, the group was however unable to choose the final version among three possible positions: at the base of either *Reitziites reitzi* or *Nevadites* and *Eoprotrachyceras curionii* zones. In my work, I accept the last version, because this level marks a considerable change in the ammonoid fauna—the first occurrence of trachyceratids (Genus *Eoprotrachyceras*). In addition, the version is most convenient for the global correlation. I also place the upper boundary of Ladinian Stage at the base of the *Trachyceras aon* Zone, where this index species appears for the first time. The last of chosen boundary positions agrees well with the priority principle, since the *Trachyceras aon* Zone was originally distinguished in the Dolomite Alps as the basal one in the Carnian Stage (Mojsisovics, 1882).

There are many problems concerning correlation of Ladinian deposits in the Boreal and Tethyan paleobiogeographic regions. One is related to the fact that the Ladinian Age was a time of intense biogeographic differentiation of ammonoids, whose evolution decelerated (Dagys *et al.*, 1979; Shevyrev, 1986). It is impossible to distinguish even short-term phases of that period, when taxonomic composition of ammonoid communities in separate biochores was differentiated, and specific taxa dominated in the Boreal basins throughout the Ladinian Age. On the other hand, Ladinian ammonoids are poorly, or inadequately studied in some particular regions. The nomenclature problems and difficulties in correlation procedure reflect a disappointing state of systematics for certain ammonoid groups. It is necessary therefore to reclassify the respective taxa, given that correlation of Ladinian deposits in northeastern Asia and other regions was so far conditional to a considerable extent, even if the deposits yielded some identical boreal forms (Dagys *et al.*, 1979; Tozer, 1981; Dagys and Tozer, 1989; Weitschat and Dagys, 1989).

The recent progress in comprehensive study of ammonoids was used to elaborate the ammonoid zonation of the Ladinian Stage in Svalbard (Weitschat and Lehman, 1983; Dagys *et al.*, 1993; Dagys and Weitschat, 1993), northeastern Asia (Dagys *et al.*, 1991; Dagys and Konstantinov, 1992, 1995, 1997), and Canada (Tozer, 1994). Revising the formerly known sections of the stage and investigating new sequences bearing ammonoids in the type area of Southern Alps, Mietto and Manfrin (1995) finally suggested the detailed standard scale of the Ladinian Stage.

New data also give a chance to refine correlation of Ladinian deposits in the Boreal realm by means of coordinating zonations of boreal ammonoids with the Alpine scale and by discussing some problems pertaining to the issue.

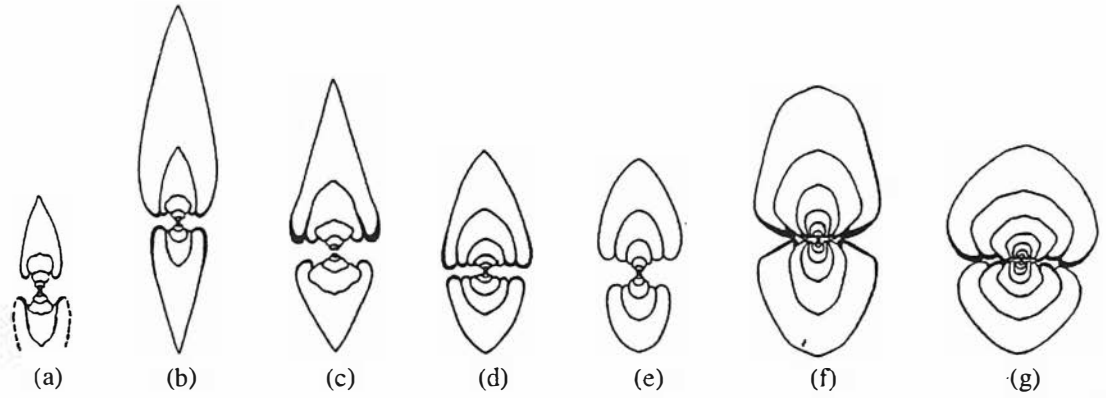

Fig. 1. Transverse sections of tsvetkovitid and nathorstitid shells (×1): (a) *Eonathorstites oleshkoi* (Archipov), specimen no. 286/811*, Laptev Sea, Ulakhan-Crest Cape, *oleshkoi* Zone; (b) *Tsvetkovites constantis* (Archipov), specimen no. 1/994, Kharauiakh Range, Nyakuchan River, *constantis* Zone; (c) *Ts. neraensis* (Popow), specimen no. 39/994, Laptev Sea, Ulakhan-Crest Cape, *neraensis* Zone; (d) *Indigirites krugi* Popow, specimen no. 62/994, Lena River, Taas-Aryy Is., *krugi* Zone; (e) *Nathorstites maclearni* Tozer, specimen no. 71/994, Dzhugadzhak River, *maclearni* Zone; (f) *N. macconnelli* (Whiteaves), specimen no. 79/994, Pravaya Vtoraya Sentyabr'skaya River, *macconnelli* Zone; (g) *N. lindstroemi* Böhm, specimen no. 91/994, Dzhugadzhak River, *lindstroemi* Zone.
*Collections 811 and 994 are stored at the Central Geological Museum of Siberia, Siberian Division, Russian Academy of Sciences, Novosibirsk.

BIOCHRONOLOGICAL BASIS OF CORRELATION

Ladinian deposits in Boreal regions frequently yield ammonoids, but their assemblages, as compared to coeval faunas from low latitudes, are less diverse and usually monotonous in composition. Suffice it to say that number of genera in the Middle Triassic ammonoid assemblages from Boreal regions is three times lesser than in coeval Tethyan faunas (Dagys *et al.*, 1979). Ammonoids representing family Nathorstitidae Spath, 1951, are dominant in Ladinian assemblages from Boreal regions. They are widespread in northeastern Asia (Arkhipov, 1974; Bychkov, 1982; Dagys *et al.*, 1991), Svalbard (Böhm, 1903; Stolley, 1911; Frebold, 1929; Korchinskaya, 1972, 1982), Arctic Canada (Tozer, 1961), and Franz Josef Land (Korchinskaya, 1985). In British Columbia, where Tozer (1967, 1994) elaborated the most detailed ammonoid zonation for the Ladinian Stage, nathorstitids coexist with various Tethyan ammonoids. Accordingly, data on chronological successions of Nathorstitidae genera and species can be used for correlation of Ladinian ammonoid zonations in the Boreal and Tethyan regions, but the stratigraphic potential of this fauna was underused because the group and its systematics have been poorly known before.

Principal trends in morphological evolution of nathorstitids and their phylogeny were elucidated, when the group was recently revised by using the type material from Siberia and comprehensive data on original specimens from Canada and Svalbard (Dagys and Konstantinov, 1997). Several taxa formerly attributed to nathorstitids are now classed with the family Tsvetkovitidae consisting of three successive, exclusively boreal genera, whose early long-evolving oxycone is sculptured, whereas the mature conch usually has thin oxycone and shows lobe line with the pseudoadventive elements. These are genera *Intornites* (Anisian) → *Eonathorstites* (Ladinian, the *oleshkoi* Zone) → *Tsvetkovites* (Ladinian, the *constantis* and *neraensis* zones). The nathorstitids proper are definite descendants of tsvetkovitids. They are represented again by three, chronologically successive boreal genera: *Indigirites* (Ladinian, the *krugi* Zone) → *Nathorstites* (Ladinian, the *maclearni, macconnelli*, and *lindstroemi* zones) → *Stolleyites* (Carnian, the *tenuis* Zone). These taxa had shells of the subspherocone type and simpler lobe lines lacking the pseudoadventive elements.

Eonathorstites is the oldest Ladinian genus of tsvetkovitids. Mature shells of the genus were of a narrow oxycone type and had an acute ventral side (Fig. 1a). Their lobe line consisted of highly dentate lobes and acute phylloid saddles (Fig. 2a). Genus *Tsvetkovites* is descendant of the former and occurs in higher horizons of the sequence. At the mature stage, it retained the whorl morphology characteristic of ancestral conchs, but shells of this genus were of the cadicone type at the intermediate stage of growth (Fig. 1b). During the *krugi* time, last representatives of the genus *Tsvetkovites* (Figs. 1c and 2c) gave rise to first nathorstitids with different morphology of inner whorls as compared to that of the ancestral family (Figs. 1d–1g). When the genus *Indigirites*, subsequently followed by genera *Nathorstites* and *Stolleyites*, appeared in the phyletic line, the morphogenesis of principal shell elements slowed down, and descendants liberated themselves from the final evolutionary stages of ancestral forms. Their lobe line was simplified; it had a lesser number of less dentate lobes combined with less phylloid and more rounded saddles (Fig. 2).

The established morphogenetic succession of tsvetkovitid and nathorstitid taxa was used as the phylogenetic basis for the Ladinian ammonoid zonation in northeastern Asia (Dagys and Konstantinov, 1992, 1995). It is clear now that the successive taxa are tightly interrelated, as they show gradual changes in the shell shape, ornamentation, and lobe line configuration. In addition, progeny retains some archaic features of ancestral taxa, and all this suggests, if we take into account the endemism of ammonoids under consideration, that the elaborated zonation lacks any significant hiatus and adequately reflects all evolutionary stages of the considered fauna.

A similar chronological succession of tsvetkovitid and nathorstitid genera and species is established as well in sedimentary sequences of Svalbard, Arctic Canada, and British Columbia. Some nathorstitid taxa are perfectly studied in the Franz Josef Land. The ammonoids under consideration represent either the index species or zonal guide fossils offering a good chance to correlate in detail the Ladinian deposits in Boreal regions (Table 1). In addition, the ecotone sections of British Columbia, where the ammonoid fauna is of the mixed Boreal–Tethyan type, can be used for coordination of Boreal and Alpine ammonoid zonations (Table 2).

CORRELATIVE LADINIAN SECTIONS IN BOREAL REGIONS

Svalbard Archipelago. In the so-called upper *Daonella* Shales of the Botneheia Formation, Weitschat and Lehmann (1983) recognized three levels of bituminous carbonate nodules. In the lower one situated 10–15 m above the base of the *Daonella* Shales, they detected the late Anisian faunas of ammonoids and bivalves characterizing the *Frechites laqueatus* (Lindström), *Aristoptychites* (=Ptychites) *trochlaeformis* (Mojsisovics), *Ussurites spetsbergensis* (Oberg), and *Daonella lindstroemi* Mojsisovics zones.

The middle level with nodules, ten meters above the first one, yielded ammonoids *Tsvetkovites varius* Weitschat et Lehmann, *Aristoptychites* (=Aristoptychites) *euglyphus* Mojsisovics, and *Ussurites spetsbergensis* (Oberg). The level was termed as the *Tsvetkovites varius* Zone of the lower Ladinian (Weitschat and Lehmann, 1983).

A few meters below the top of the *Daonella* Shales, there is the third level of nodules bearing ammonoids *Aristoptychites kolymensis* (Kipárisova), *Indigirites tozeri* Weitschat et Lehmann, *Ussurites spetsbergensis* (Oberg), and *Proarcestes* forms in association with bivalves *Daonella degeeri* Böhm. These fossils are characteristic of the *Indigirites tozeri* Zone that has been originally attributed to the lower Ladinian (Weitschat and Lehmann, 1983) and displaced later into the basal upper Ladinian (Weitschat and Dagys, 1989).

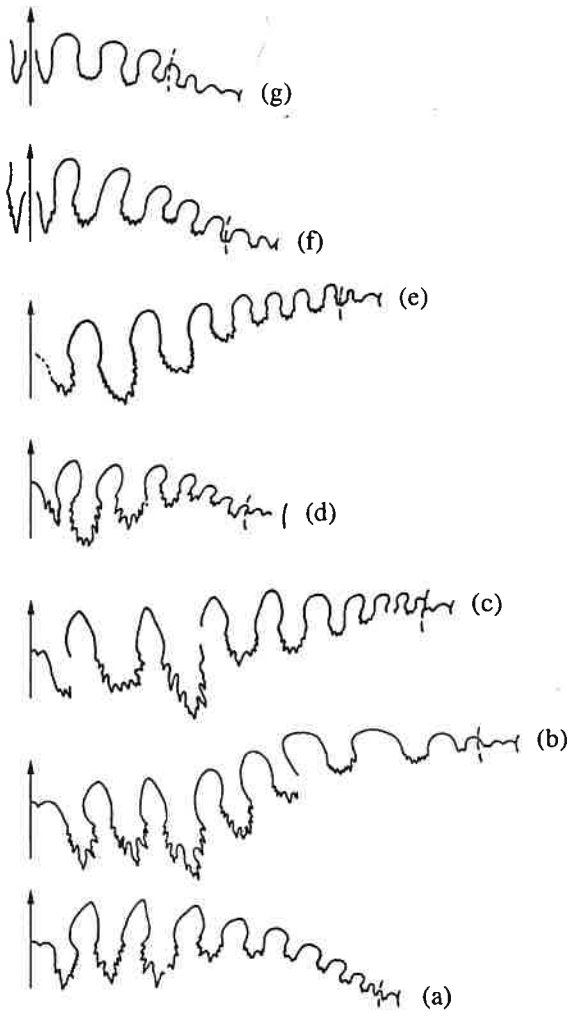

Fig. 2. Lobe lines of tsvetkovitids and nathorstitids: (a) *Eonathorstites oleshkoi* (Archipov), specimen no. 312/811, width (W) = 12 mm, height (H) = 25 mm, Laptev Sea, Ulakhan Crest Cape, *oleshkoi* Zone; (b) *Tsvetkovites constantis* (Archipov), specimen no. 10/994, W = 24 mm, H = 50 mm, Kharaulakh Range, Nyakuchan River, *constantis* Zone; (c) *Ts. neraensis* (Popow), specimen no. 36/994, H = 15 mm, Laptev Sea, Tumul Cape, *neraensis* Zone; (d) *Indigirites krugi* Popow, specimen no. 52/994, W = 17.5 mm, H = 15 mm, Indigirka River, Turakh-Yuryakh Creek, *krugi* Zone; (e) *Nathorstites maclearni* Tozer, specimen no. 77/994, W = 15.8 mm, H = 21.6 mm, Dzhugadzhak River, *maclearni* Zone; (f) *N. macconnelli* (Whiteaves), specimen no. 86/994, W = 16.6 mm, H = 15.5 mm, Dzhugadzhak River, *macconnelli* Zone; (g) *N. lindstroemi* Böhm, specimen no. 97/994, W = 16.7 mm, H = 10.5 mm, Dzhugadzhak River, *lindstroemi* Zone.

The *varius* and *tozeri* zones of Svalbard can be easily correlated with coeval Ladinian zones in northeastern Asia, where shells of *Tsvetkovites varius* are concentrated in the lower part of the *Tsvetkovites constantis* Zone (Dagys and Konstantinov, 1995). The *varius* Zone of Svalbard thus corresponds to a lower part of the *constantis* Zone. The *Indigirites tozeri* and *Indigirites krugi* zones appear to be stratigraphic equivalents,

Table 1. Correlation scheme for Ladinian deposits in the Boreal regions

Substage	Northeastern Asia (Dagys and Konstantinov, 1995)	Arctic Canada (Tozer, 1994)	Svalbard Archipelago		Franz Josef Land (Korchinskaya, 1985)
			Spitsbergen (Weitschat and Lehmann, 1983; Weitschat and Dagys, 1989; with modifications)	Bear Island (Dagys *et al.*, 1993)	
Upper	*Nathorstites lindstroemi*	*Nathorstites* Beds	*Nathorstites* Beds	*Nathorstites lindstroemi*	*Daonella subarctica*
	Nathorstites macconnelli				*Daonella frami*
	Nathorstites maclearni		*Protrachyceras* and *Daonella* ex gr. *subarctica* beds		*Daonella parva* *Daonella* aff. *prima*
	Indigirites krugi	*Daonella frami* Beds	*Indigirites tozeri*		*Indigirites krugi*
	Tsvetkovites neraensis				*Daonella* cf. *arctica*
	Tsvetkovites constantis		*Tsvetkovites varius*		*Meleagrinella* cf. *omolonensis*
Lower	*Eonathorstites oleshkoi*				*Dacryomya scorochodi*

because the common genus and species *Indigirites tozeri* and *Aristoptychites kolymensis* are present in both units.

Taxa characterizing the *Eonathorstites oleshkoi* and *Tsvetkovites neraensis* zone of Siberia are unknown in Svalbard, and presence of respective zonal units in this archipelago seems to be problematic.

It is difficult to establish in Svalbard the stratigraphic equivalents of *Nathorstites maclearni, N. macconnelli*, and *N. lindstroemi* zones of northeastern Asia. The *macconnelli* Zone is distinguished by Korchinskaya (1982) in her stratigraphic scheme of Ladinian deposits as a consequence of incorrect determinations of nathorstitids (Weitschat and Dagys, 1989). In my opinion, it is possible to class with *Nathorstites macconnelli* (Whiteaves) only those ammonoids, which have constrictions in the early whorls like in the Canadian type species (Tozer, 1994, Plate 86, fig. 3b, Plate 87, fig. 4) and are described as *Nathorstites strongulatus* Korchinskaja (Korchinskaya, 1972, p. 69, Plate 2, figs. 10–12). These ammonoids are recovered from the upper Ladinian phosphorite nodules of the Agarddalen section (Ruslagenfjellet) in the eastern coast of Spitsbergen, where they occur below the level of *Zittelihalobia zitteli* (Lindström) and *Stolleyites* cf. *tenius* (Stolley). At the same time, ammonoids from upper Ladinian deposits in the southeastern coast of this island were also classed with *Nathorstites macconnelli* (Korchinskaya, 1972, p. 68, Plate 2, figs. 8 and 9), although their swollen cadicone shells have the almost straight growth lines and the well-developed umbilical depression bounded by umbilical shoulder. As shown by Dagys and Konstantinov (1997), all these features better correspond to *Nathorstites lindstroemi* (Böhm) that has been also found in the 0.5-m-thick bed of dark gray siltstone bearing abundant phosphorite nodules (Dagys *et al.*, 1993). In the overlying gray siltstone, frequent siderite nodules taking rusty dye by weathering yield ammonoids of genera *Stolleyites, Paracladiscites*, and "*Discophyllites*" (=*Arctophyllites*) in association with nautiloids and bivalves *Zittelihalobia zitteli* Lindstr. Unfortunately, *Nathorstites macconnelli* (Whit.) and *N. lindstroemi* Böhm do not occur in Spitsbergen within a single sequence. It is clear however that they are characteristic of the uppermost beds of the Botneheia Formation, where phosphorite nodules are abundant. I consider this interval as the *Nathorstites* Beds corresponding to the *macconnelli* and *lindstroemi* zones of northeastern Asia.

Deposits occurring in the top portion of the Botneheia Formation of Spitsbergen between the nodular interbed (the *Indigirites tozeri* Zone) and below the upper phosphorite conglomerate (the *Nathorstites* Beds) are as thick as 16 m in the eastern areas of the island. They exhibit two levels yielding ammonoids *Protrachyceras* sp., bivalves *Daonella* ex gr. *subarctica* Popow, and crinoids *Traumatocrinus*. The lower one also yields ptychitid remains of unclear generic affinity. I consider this interval of the sequence as beds with *Protrachyceras* and *Daonella* ex gr. *subarctica* and correlate them conditionally with the *maclearni* Zone of northeastern Asia. This seems to be reasonable, because the last ptychitids detectable in the *maclearni* Zone are missing from overlying beds in Asian sections (Dagys and Konstantinov, 1995).

Table 2. Correlated biostratigraphic zonation of the Ladinian Stage in northeastern Asia, British Columbia, and Southern Alps

<table>
<tr><th rowspan="2">Stage</th><th rowspan="2">Substage</th><th colspan="4">Ammonoid zones and subzones</th></tr>
<tr><th>Northeastern Asia (Dagys and Konstantinov, 1995)</th><th colspan="2">British Columbia (Tozer, 1994)</th><th colspan="2">Southern Alps (Mietto and Manfrin, 1995)</th></tr>
<tr><td rowspan="11">Ladinian</td><td rowspan="9">upper</td><td>Nathorstites lindstroemi</td><td rowspan="2">Frankites sutherlandi</td><td>Asklepioceras laurenci</td><td rowspan="5">Protrachyceras</td><td rowspan="2">Frankites regoledanus</td></tr>
<tr><td rowspan="2">Nathorstites macconnelli</td><td>Frankites glaber</td></tr>
<tr><td rowspan="3">Nathorstites maclearni</td><td rowspan="3">Maclearnoceras maclearni</td><td>Maclearnoceras ensio</td><td rowspan="2">"Protrachyceras" neumayri</td></tr>
<tr><td>Anolcites angustus</td></tr>
<tr><td>Anolcites impolitus</td><td rowspan="3">Protrachyceras longobardicum</td></tr>
<tr><td rowspan="2">Indigirites krugi</td><td rowspan="3">Meginoceras meginae</td><td>Meginoceras aylardi</td></tr>
<tr><td>Silenticeras hatae</td><td rowspan="2">Protrachyceras gredleri</td></tr>
<tr><td>Tsvetkovites neraensis</td><td>Meginoceras triviale</td></tr>
<tr><td>Tsvetkovites constantis</td><td colspan="2">Tuchodiceras poseidon</td><td>Protrachyceras margaritosum</td></tr>
<tr><td>lower</td><td>Eonathorstites oleshkoi</td><td colspan="2">Eoprotrachyceras matutinum</td><td>Eoprotrachyceras</td><td>Eoprotrachyceras recubariense</td></tr>
<tr><td colspan="5"></td><td>Eoptotrachyceras curionii</td></tr>
</table>

The *lindstroemi* Zone was recently distinguished in the Bear Island (Dagys *et al.*, 1993), where it yields *Nathorstites lindstroemi* Böhm, *Daxatina canadensis* (Whiteaves), "*Clionites*" *barentsi* Böhm, "Cl." *spinosus* Böhm, and *Paracladiscites* sp. Owing to the present index species, the unit is an equivalent of the synonymous zone in northeastern Asia.

Arctic Canada. In the Sverdrup basin, deposits of the Ladinian Stage are known as constituents of the Blaa-Mountain and Shei-Point formations (Tozer, 1961). Very rare Ladinian ammonoids are confined here to particular, very thin horizons.

The *Daonella frami* Beds in the lower part of the stage are widespread and traceable in marginal and axial zones of the Sverdrup basin. Usually, they yield only the index species *Daonella frami* Kittl. that coexists with ammonoids *Longobardites* sp. indet., *Protrachyceras* sp. indet., and *Ptychites* (= *Aristoptychites*) *nanuk* Tozer. This level can be correlated in a tentative manner only. The specimen of *Longobardites* sp. indet from the *Daonella frami* Beds (Tozer, 1994, Plate 68, fig. 1) is poorly preserved. Nevertheless, its lobe line that shows the acute phylloid saddles and individualized central denticles in the distinctly dentate lobes suggests a certain similarity with the species *Tsvetkovites constantis* (Archipov). In opinion of Weitschat and Lehmann (1983), ptychitids from the beds belong to the genus *Aristoptychites* being similar to the Siberian species *Aristoptychites kolymensis* (Kiparisova). In northeastern Asia, representatives of this genus appear for the first time in the *neraensis* Zone, and *A. kolymensis* is characteristic of the *krugi* and *maclearni* zones.

The *Nathorstites* Beds are known in the upper part of the Ladinian Stage of Canadian Arctic areas (Tozer, 1961, 1967; Silberling and Tozer, 1968). The recent revision of nathorstitids (Tozer, 1994; Dagys and Konstantinov, 1997) showed that only one of pictured specimens of *Nathorstites macconnelli* from the beds (Tozer, 1961, Plate 22, fig.7) represents this taxon. Two other specimens (Tozer, 1961, Plate 22, figs. 5 and 6) coexisting with *Procladiscites* (= *Sphaerocladiscites*) cf. *martini* (Smith) in the lower Shale Member of the Blaa-Mountain Formation of the Ellesmere Island have swollen cadicone shells with the well-developed umbilical shoulder. In their lobe line, saddles are oval, and lobe denticles are underdeveloped. All these features are typical of *Nathorstites lindstroemi*, and both specimens are classed with this taxon (Dagys and Konstan-

tinov, 1997). Thus, we can distinguish in Arctic Canada two Ladinian levels distinctly corresponding to the *macconnelli* and *lindstroemi* zones of northeastern Asia. In addition, the beds under consideration may also span the *maclearni* Zone.

Franz Josef Land. In this archipelago, the Ladinian Stage is represented by alternating members of shale, siltstone, and sandstone, the total thickness of which (if we ignore the intercalated intrusive bodies) varies from 870 to 1085 m according to data of deep parametrical boreholes (Preobrazhenskaya *et al.*, 1985). Bivalves are principal forms of macrofauna detected in core sections. In the borehole section Severnaya, where basal beds of the upper Ladinian Substage are composed of dark gray to black shales with pyrite, phosphate–siderite, and carbonate nodules, the *Daonella* shells coexist at the depth level of 2331.8 m with ammonoids defined as *Nathorstites* cf. *lenticularis* (Whiteaves). The pictured specimen from this level (Korchinskaya, 1985, Plate 5, fig. 6) shows the well-preserved sculptural elements on lateral sides, namely the radial folds and threads sharply bent backward approximately in the middle of the whorl height. Growth lines like these are untypical of *Nathorstites* forms, *Nathorstites lenticularis* (= *Nathorstites macconnelli*) included, as the latter lack folds on lateral sides and show threads curving forward by approaching the ventral side. The above sculptural elements are characteristic of the genus *Indigirites*, and the specimen under consideration can be definitely classed with *Indigirites* cf. *krugi* Popow. Consequently, the Borehole Severnaya penetrated in the eastern part of the archipelago a stratigraphic equivalent of the *Indigirites krugi* Zone of northeastern Asia.

CORRELATION OF LADINIAN DEPOSITS IN NORTHEASTER ASIA, BRITISH COLUMBIA, AND SOUTHERN ALPS

As is shown above, it is impossible, owing to the distinct provincialism, to correlate in a simple manner the Ladinian ammonoid zonations established in the Boreal and Tethyan regions. The key area for such a correlation is the northeastern part of British Columbia, where Ladinian ammonoids apparently evolved within the past ecotone between the Boreal and Tethyan paleobiogeographic regions and represented the mixed fauna.

British Columbia. On the basis of very complete ammonoid successions studied in the region, Tozer (1967) and Silberling and Tozer (1968) suggested the detailed ammonoid zonation for the Ladinian Stage divided into five zones. The lower Ladinian Substage was initially considered as corresponding to the *Protrachyceras subasperum* and *Progonoceratites poseidon* zones. Later, the *poseidon* Zone was attributed to the upper Ladinian Substage (Tozer, 1981), because there were found *Protrachyceras* forms similar to *P. longobardicum* Mojsisovics from the *Protrachyceras archelaus* Zone of the Alpine region. In his recent fundamental book on ammonoid faunas, Tozer (1994) considerably refined the Ladinian ammonoid zonation in British Columbia, though without its subdivision into substages. He revised the generic affinity of some ammonoids and changed the nomenclature of particular zones considering *Eoprotrachyceras matutinum* Tozer as the index species of the lowermost zone and attributing the index species of the overlying *poseidon* Zone to the new genus *Tuchodiceras*. In addition, the *Meginoceras meginae, Maclearnoceras maclearni*, and *Frankites sutherlandi* zones were divided into subzones. In total, the Ladinian ammonoid zonation in British Columbia includes now 13 biostratigraphic units ranked as zones and subzones.

Ladinian ammonoids from the region under consideration are very diverse and belong to 35 genera (Tozer, 1994). Only eight of these genera, namely *Eonathorstites, Tsvetkovites* (*"Indigirites" freboldi* Tozer), *Indigirites, Nathorstites, Arctoptychites, Longobardites, Proarcestes*, and *Lobites*, are known from Ladinian deposits of northeastern Asia. Three last genera of a wide stratigraphic range are cosmopolitan and useless for the detailed correlation analysis. Suggesting here the correlation scheme for the Ladinian ammonoid zonations in British Columbia and northeastern Asia, I used available data on stratigraphic ranges of tsvetkovitids (genera *Eonathorstites* and *Tsvetkovites*), nathorstitids (genera *Indigirites* and *Nathorstites*), and ptychitids (genus *Arctoptychites*).

The *maclearni* Zone of British Columbia appears to be well correlative with the synonymous zone of northeastern Asia, because they both yield the common species *Nathorstites maclearni* Tozer. Species *Indigirites boehmi* Tozer, the younger synonym of *Indigirites krugi* Popow (Dagys and Konstantinov, 1997), is abundant in two upper subzones of the *meginae* Zone. Consequently, the *Silenticeras hatae* and *Meginoceras aylardi* subzones of the *meginae* Zone in British Columbia can be correlated with the *Indigirites krugi* Zone in northeastern Asia. The greater upper part of the *Tuchodiceras poseidon* Zone seems to be an equivalent of the *Tsvetkovites constantis* Zone, since the genus *Arctoptychites* is typical of these stratigraphic intervals enclosing as well the *Tsvetkovites* species similar in morphology of their relatively narrow shells: *Ts. freboldi* (Tozer) from the *poseidon* Zone and *Ts. constantis* (Archipov) from the *constantis* Zone. The lower part of the *poseidon* Zone is correlative, as we will see below, with the *Eonathorstites oleshkoi* Zone. The *Meginoceras triviale* Subzone of the *meginae* Zone is situated above the *poseidon* Zone, but below the *hatae* and *aylardi* subzones. According to this stratigraphic position, it may correspond to the *Tsvetkovites neraensis* Zone. I consider the *Frankites sutherlandi* Zone of British Columbia as spanning the range of the *Nathorstites macconnelli* and *N. lindstroemi* zones of northeastern Asia. This conclusion is substantiated by occurrence of *N. macconnelli* (Whiteaves) in the upper *Asklepioceras laurenci* Subzone of the *sutherlandi*

Zone. Analyzing data on composition and relative position of ammonoid assemblages presented by Tozer (1994), I assume that *N. macconnelli* does not occur as high in the sequence as the upper beds of the *sutherlandi* Zone, where characteristic forms are trachyceratids *Daxatina laubei* Tozer and *D. canadensis* (Whiteaves). In the Bear Island of the Svalbard Archipelago, the last species coexists with *Nathorstites lindstroemi* Böhm (Böhm, 1903; Dagys *et al.*, 1993). Accordingly, an upper part of the *laurenci* Subzone of the *sutherlandi* Zone is correlative with the *lindstroemi* Zone, and the lower part of this subzone corresponds to the *macconnelli* Zone. I also think with a reservation that the latter, according to its position above the *Nathorstites maclearni* Beds in northeastern Asia, may also include an equivalent of the *Frankites glaber* Subzone of the *sutherlandi* Zone.

Correlation between the lowermost Ladinian beds in British Columbia and northeastern Asia is very complicated. In the last region, the index species of the lowermost Ladinian zone was originally described as *Longobardites oleshkoi* Archipov (Archipov, 1974). Revising the described species, Dagys and Konstantinov (1997) emphasized that it had the ventral keel at the early stages of growth. Owing to this feature and numerous, highly dentate lobes, the form in question cannot be attributed to *Longobardites* or *Intornites* genera and must be classified as a species of the genus *Eonathorstites*. In British Columbia (Tozer, 1994), representatives of this genus have been discovered in association with *Ptychites hamatus* Tozer, *Protrachyceras sikanianum* McLearn, and *Metatirolites withrowi* Tozer within a single section below the occurrence level of *Tsvetkovites freboldi* (Tozer). Tozer conditionally included the respective strata into the *poseidon* Zone and mentioned that they may correspond to an individual subzone. The noteworthy fact is that the beds bearing *Eonathorstites* forms in British Columbia are unknown as members of sections exhibiting the lower *Eoprotrachyceras matutinum* Zone of the Ladinian Stage. As we do not know relations between the *Eonathorstites* level and *matutinum* Zone, I consider the *oleshkoi* Zone, which is situated below the first occurrence level of *Tsvetkovites* forms in both regions, as corresponding to the lower *poseidon* interval coupled with the whole range of the *matutinum* Zone. Considering the lower *poseidon* strata as correlative with the *oleshkoi* Zone, I used as an evidence the occurrence of *Eonathorstites* forms in both subdivisions. The traditional scheme, where the *oleshkoi* Zone is correlated with the lower ammonoid zone of the Ladinian Stage in British Columbia (Dagys *et al.*, 1979, 1991; Konstantinov, 1991), is more hypothetical, because it is based on stratigraphic position of the unit between the occurrence levels of last *Frechites* and first *Tsvetkovites* forms.

Southern Alps. This Alpine region represents the stratotype area of the Ladinian Stage, where stratigraphic investigations ceased long ago, when the stage was divided into the lower (Fassan) and upper (Longobardian) substages corresponding to the *Eoprotrachyceras curioni* and *P. archelaus* zones, respectively (*Obshchaya shkala...*, 1984). However, Italian researchers recently discovered new localities of ammonoid faunas and investigated anew the Ladinian type sections. As a result, they elucidated the stratigraphic succession of ammonoid assemblages and suggested the detailed ammonoid zonation for the stage (Mietto and Manfrin, 1995). Being based on the hierarchical principle, the suggested scheme includes two substages, three genus-zones, and ten subzones of distinguished index species. Lower boundaries of all subdivisions are universally defined as the first occurrence levels of indicative genera or index species. Accepting the scheme in general, I feel it necessary to place the lower boundary of the stage at the base of the *Eoprotrachyceras curioni* Zone and correlative units.

Principal for correlation of Ladinian deposits in British Columbia and Southern Alps are data on stratigraphic distribution of trachyceratids, particularly of genera *Eoprotrachyceras, Protrachyceras, Liardites, Maclearnoceras*, and *Frankites*.

The *Eoprotrachyceras* Genus-zone of Southern Alps corresponding in its range to the lower Ladinian (Fassan) Substage correlates with the *matutinum* Zone of British Columbia, because *Eoprotrachyceras* is the common genus of both. Lower boundaries of the *Protrachyceras* Genus-zone in Alps and *poseidon* Zone in Canada are definitely synchronous and mark in two regions the first occurrence level of true *Protrachyceras* forms, which have partite saddles in the lobe line. The ammonoid assemblage from the *"Protrachyceras" neumayri* Subzone includes genera *Maclearnoceras* and *Liardites*. In British Columbia, these genera are characteristic of the *Anolcites angustus* and *Maclearnoceras ensio* subzones of the *maclearni* Zone, and these two units are correlative with the *neumayri* Subzone. Three lower subzones of the *Protrachyceras* Genus-zone (those of *P. margaritosum, P. gredleri*, and *P. longobardicum*) correspond in their stratigraphic interval to the summary range of the *poseidon* and *meginae* zones coupled with the *Anolcites impolitus* Subzone of the *maclearni* Zone of British Columbia. The more precise correlation of these biozonal subdivisions is now impossible on the stipulation that *Protrachyceras sikanianum* McLearn, the only form of the genus occurring in the *poseidon, meginae*, and *maclearni* zones of British Columbia, is highly variable in morphology, being represented in the whole distribution interval by both the involute shells resembling those of *P. longobardicum* Mojsisovics and the evolute specimens similar to *P. archelaus* Mojs. (Tozer, 1994). The upper *Frankites regoledanus* Subzone of the *Protrachyceras* Genus-zone in Southern Alps bears *Lobites ellipticus* Hauer and genera *Frankites, Asklepioceras*, and *Muensterites*, which are also characteristic of the correlative *sutherlandi* Zone in Canada. This is also evident from the fact that the first Carnian forms of

the genus *Trachyceras* appear in strata overlying the last correlation level in Alps (Urlichs, 1994; Mietto and Manfrin, 1995) and Canada (Tozer, 1994).

Finally, the *macconnelli* and *lindstroemi* zones of northeastern Asia are correlative with the *sutherlandi* Zone of British Columbia and also with the *regoledanus* Subzone of the *Protrachyceras* Genus-zone of Southern Alps. Then, the *Nathorstites maclearni* and *Maclearnoceras maclearni* zones correlative one to another correspond to the *"Protrachyceras" neumayri* Subzone combined with the upper part of the *Protrachyceras longobardicum* Subzone. Lastly, the *oleshkoi, constantis, neraensis*, and *krugi* zones of northeastern Asia can be correlated, via sections of British Columbia, with the summary stratigraphic range spanning the *Eoprotrachyceras* Genus-zone coupled with *margaritosum, gredleri*, and *longobardicum* subzones of the *Protrachyceras* Genus-zone in Southern Alps.

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