

A *Dactylioceras* – *Meleagrinnella* (*Clathrolima*) assemblage from the Agardhbukta (eastern coast of Spitsbergen): a first in situ Toarcian molluscan occurrence from Svalbard providing interregional correlation

Mikhail A. Rogov¹, Oleg A. Lutikov¹

¹Geological institute of RAS, Pyzhevski lane 7/1, 119017 Moscow, Russia

E-mail corresponding author (Mikhail A. Rogov): russianjurassic@gmail.com

Keywords:

- Lower Jurassic
- Palaeogeography
- Biostratigraphy
- Ammonites
- Bivalves
- Svalbard

Received:
27. June 2021

Accepted:
7. February 2022

Published online:
6. April 2022

Diverse microfossil assemblages characterise the Lower Jurassic deposits on Svalbard, but until recently nearly all Lower Jurassic macrofossils from this region were known only from re-deposited phosphorite pebbles in the Brentskardhaugen Bed. Here, we briefly describe a unique in situ molluscan assemblage from the lower Toarcian part of the Agardhbukta section. This assemblage is dominated by ammonites (*Dactylioceras* only), while belemnites and bivalves are less common.

Ammonites are typical for the Commune zone of the Arctic and belong to the new species *Dactylioceras* (*D.*) *kopiki* Rogov, sp. nov. and *D.* (*Microdactylites*) sp., and their findings are characteristic for a new *kopiki* biohorizon located in the top of this zone. Bivalves are dominated by *Meleagrinnella* (*Clathrolima*) *substriata* providing additional evidence for the age of this assemblage. The pattern of ammonite and bivalve stratigraphical and geographical distributions in the Arctic suggest bilateral molluscan immigrations via the Greenland–Norwegian seaway during the latest early Toarcian: dactylioceratid ammonites migrated northwards, while oxytomid bivalves migrated southwards.

Introduction

Early to earliest Middle Jurassic macrofossils from Svalbard are well known and have been described in many papers (Frebald, 1929a, b, 1930; Kopik, 1968; Birkenmajer & Pugaszewska, 1975; Wierzbowski et al. 1981; Ershova & Repin, 1983; Bäckström & Nagy, 1985), but all previously reported material came from the phosphorite conglomerate located in the top of the Wilhelmøya Subgroup, the 0.2–1.2 m-thick Brentskardhaugen Bed, containing numerous phosphorite pebbles (Krajewski, 1992). These pebbles yield common

Rogov, Mikhail A. & Lutikov, Oleg A. 2022: A *Dactylioceras* – *Meleagrinnella* (*Clathrolima*) assemblage from the Agardhbukta (eastern coast of Spitsbergen): a first in situ Toarcian molluscan occurrence from Svalbard providing interregional correlation. *Norwegian Journal of Geology* 102, 202202. <https://dx.doi.org/10.1785/njg102-1-2>

© Copyright the authors.

This work is licensed under a Creative Commons Attribution 4.0 International License.

macrofossils, mainly ammonites, and bivalves of Toarcian and Aalenian age, with a possible admixture of the Bajocian species, which permit recognising here a succession of provisional zones (Ershova & Repin, 1983). However, very few in situ findings of Early Jurassic macrofossils were reported from Svalbard until recently.

Generally, the thickness and completeness of the Lower Jurassic succession in Svalbard increase eastwards. At the western coast of Spitsbergen, the Lower Jurassic is represented by the Brentskardhaugen Bed which is underlain by a poorly fossiliferous Teistberget Member (usually 5–26 m). Successions of the Agardhbukta, Kapp Mühry and Wilhelmøya show much more complete sections with a total thickness up to ~60–65 m (Pchelina, 1980), and farther eastwards attaining ~200 m at Svenskøya (Olaussen et al., 2018). Sections exposed at Kapp Mühry and on Wilhelmøya are crucial for our understanding of the Lower Jurassic history of Svalbard due to the significant thickness of the Lower Jurassic here. Klubov (1965) presented the first relatively detailed description of the Lower Jurassic succession on Wilhelmøya. There, he distinguished Pliensbachian–Toarcian deposits, which in the lower part (member 28 in Klubov, 1965, represented by light-yellow weathered mudstones) yields a foraminiferal assemblage dated by Basov as Pliensbachian (see also Basov et al., 2009). Worsley (1973) erected here the Wilhelmøya Formation which was elevated to subgroup rank by Mørk et al. (1999). The Tumlingodden Member, upper unit of this subgroup, belongs to the Lower Jurassic based on foraminifer dating (Klubov, 1965). Additional evidence for an Early Jurassic age of the upper part of the Wilhelmøya Formation came from an analysis of dinoflagellate cyst assemblages derived from the study of the succession in Marhøgda, Sassenfjorden (Bjærke & Dypvik, 1977). A Pliensbachian to Aalenian age of this part of the succession has recently been supported by the analysis of dinocysts from DH2 and DH4 wells (western central Spitsbergen) performed by Rismyhr et al. (2018). Pchelina (1980) summarised all available data about the uppermost Triassic and Lower Jurassic of Spitsbergen, including results of geological mapping by Soviet geologists. She provided a description of key sections and erected a set of new formations and members. Among the new paleontological findings, important for establishing the age of the Lower Jurassic part of the succession, she mentioned the occurrence of *Modiolus tiungensis* Petrova. 14 m above the base of the Tumlingodden Member at Kapp Mühry, i.e., from the level a little below Pliensbachian foraminifers of the same member. This bivalve species ranges from upper Pliensbachian to lower Toarcian in Northern Siberia (Kirina, 1976a, b). Thus, the age of its occurrence at Kapp Mühry is late Pliensbachian. Until now, no other in situ macrofossil records were known from the Lower Jurassic of Spitsbergen.

Material

During fieldwork in the Agardhbukta area in 2018, interesting Toarcian macrofossils were collected from a coastal section located south of Myklegardfjellet mountain (Fig. 1; coordinates 78.03945°N, 18.70837°E). A rich fossil assemblage was recorded from the topmost part of the Svenskøya Formation. In this section, a light-yellow sandstone (bed 1), containing numerous pebbles and fossil wood, is overlain by a ~2 m-thick siltstone (bed 2, Figs. 2 & 3) with numerous hard phosphorite concretions, especially common between 0.5 and 1.5 m above the base of this unit.

These concretions occurred in laterally traced levels located at 0.5–1, 1.1, 1.2 and 1.5 m above the base of bed 2. Phosphorite concretions frequently contain ammonite moulds and belemnite phragmocones, while partially dissolved belemnite guards and bivalves are less common. Small pebbles are numerous in the lower part of the bed (0.5–1 m above the base) but disappear above. The ammonite assemblage consists of micro- and macroconchs of late *Dactylioceras* and shows no features of re-deposition or condensation. The ammonites are generally well-preserved moulds of complete

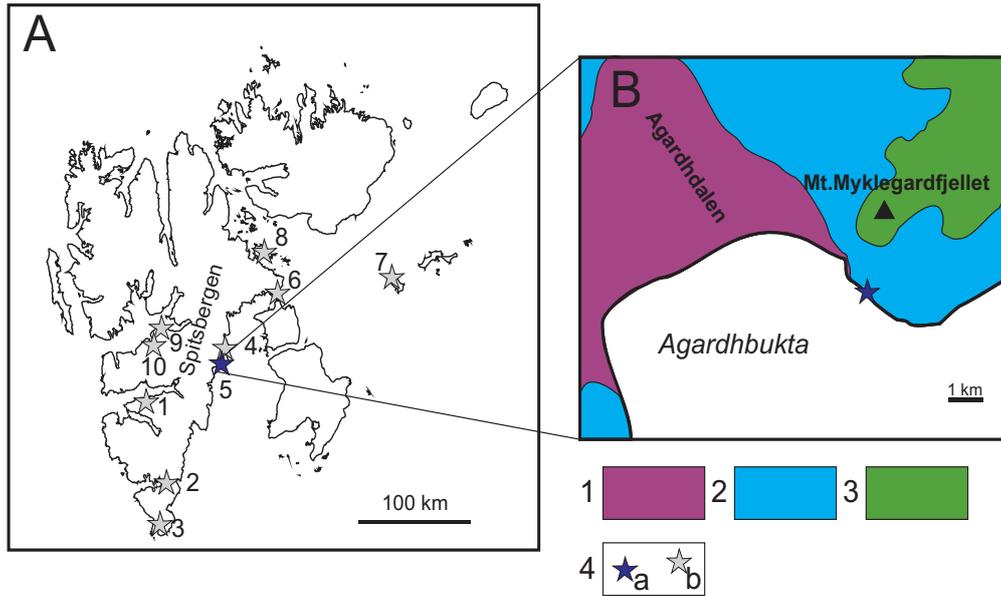


Figure 1. Outcrops with Toarcian fossils on Svalbard mentioned in this paper. (A) General overview map of Svalbard, 1. Van Mijenfjorden; 2. Hyrnefjellet; 3. Sørkapland; 4. Dunerbukta; 5. Agardhbukta; 6. Kapp Mühry; 7. Svenskøya; 8. Wilhelmøya; 9. Marhøgda; 10. DH2, DH4 wells; (B) Map of Agardhbukta. Figure legend: 1 – Triassic, 2 – Jurassic, 3 – Cretaceous, 4 – localities on Spitsbergen (a – studied section, b – other sites).

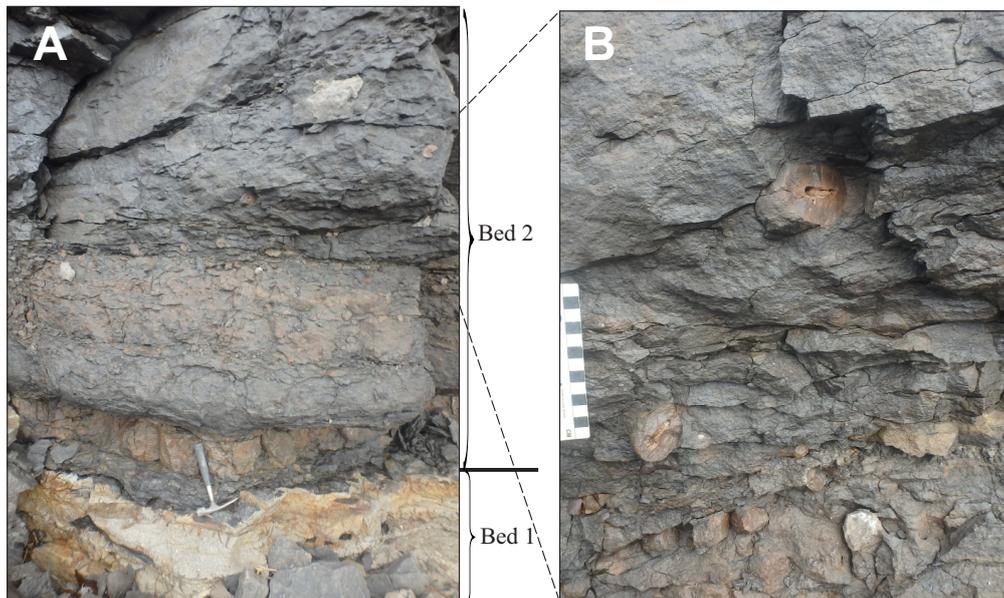


Figure 2. Close view of the studied section (A) and details of ammonite-bearing interval (B) with clearly visible ammonite moulds embedded in phosphorite concretions.

adult specimens and their fragments, and usually rest horizontally to subhorizontally (Fig. 2B). Ammonite moulds are uncrushed (except for their body chambers in some cases) suggesting quick cementation of phosphorite concretions during the early diagenesis. Bivalves mainly belong to *Meleagrinea* (*Clathrolima*), as well as a single specimen of *Entolium*.

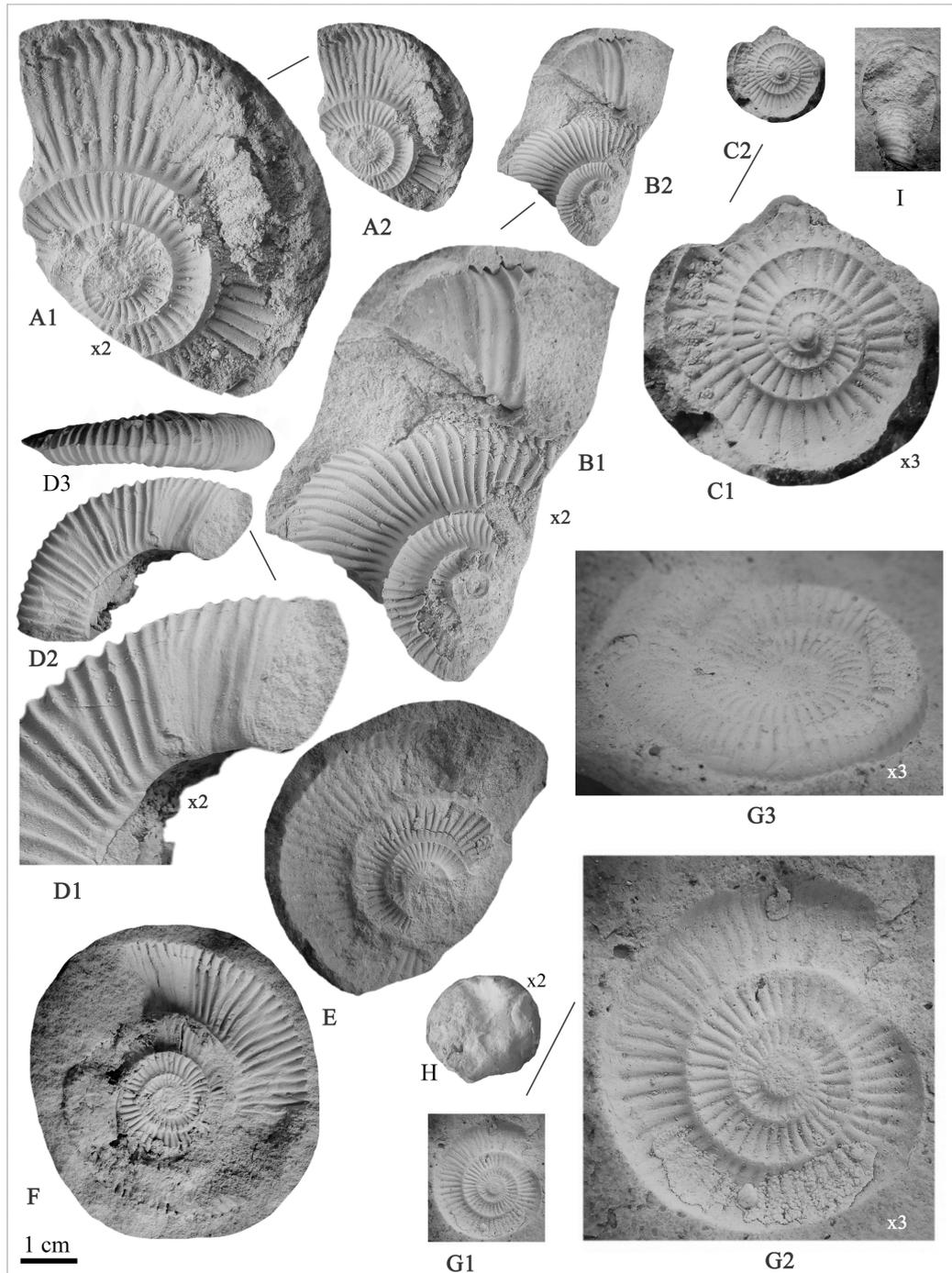


Figure 3. *Dactyloceratid* ammonites from bed 2 (Lower Toarcian, *Commune* zone, *kopiki* horizon) of the Agardhbukta section. Scale bar – 1 cm (for specimens figured in natural size only; otherwise, magnification is marked as either x2 or x3). (A–B), (D–F), (H–I) – *Dactyloceras* (*D.*) *kopiki* Rogov, sp. nov. (A) – specimen ESM 146/25, 1 m above the base of bed 2; (B) – specimen ESM 146/18, 1.2 m above the base of bed 2; (D), (F) – holotype ESM 146/16, 1.2 m above the base of bed 2; (H) – specimen ESM 146/10, 1.2 m above the base of bed 2; (I) – specimen ESM 146/8, 1.2 m above the base of bed 2; (C), (G) – *Dactyloceras* (*Microdactylites*) sp., (C) – specimen ESM 146/11, 1 m above the base of bed 2; (G) – specimen ESM 146/15, loose from bed 2.

It should be noted that Lower Jurassic fossils from this area are well known, and have been described or mentioned in a few publications (Friebold, 1929a; Pchelina, 1980; Ershova & Repin, 1983), but in contrast to the studied collection all these occurrences came from the Brentskardhaugen Bed, and include only younger ammonite taxa, such as diverse *Pseudolioceras*, *Porpoceras* and *Coeloceras* species.

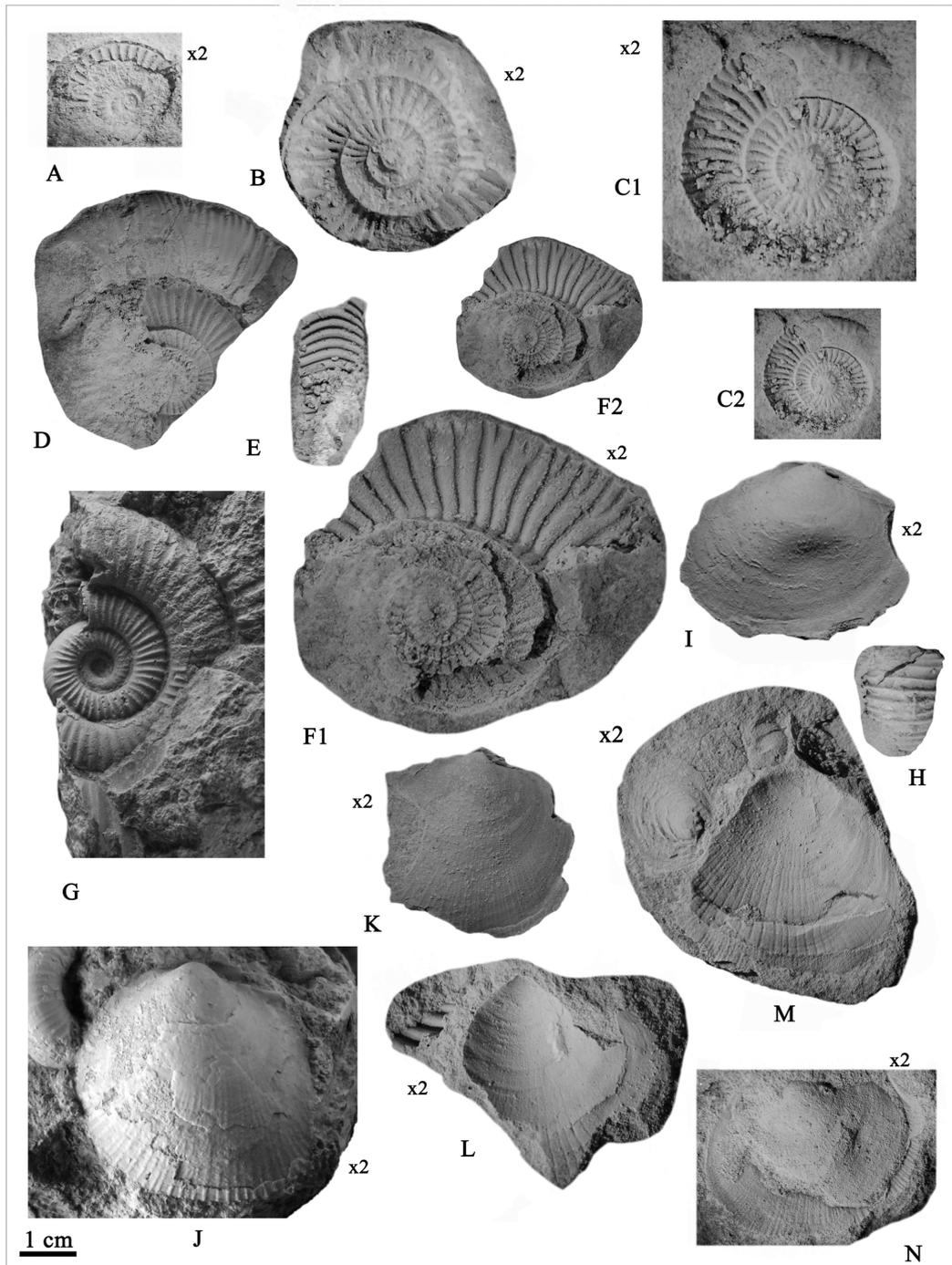


Figure 4. Lower Toarcian (*Commune* zone, *kopiki* horizon) *dactylioceratid* ammonites and *oxytomid* bivalves. Scale bar – 1 cm (for specimens figured in natural size only; otherwise, magnification is marked as either x2 or x3). All specimens except Figs. 7 & 10 came from the Agardhbukta section. (A–C) – *Dactylioceras* (*Microdactylites*) sp., (A) – specimen ESM 146/6, 1.15–1.2 m above the base of bed 2; (B) – specimen ESM 146/21, 0.7–1 m above the base of bed 2; (C) – specimen ESM 146/17, 1.2 m above the base of bed 2; (D–F), (H) – *Dactylioceras* (*D.*) *kopiki* Rogov, sp. nov., (D) – specimen ESM 146/14, 1.3 m above the base of bed 2; (E) – specimen ESM 146/36, 1.2 m above the base of bed 2; (F) – specimen ESM 146/4, 1.15–1.2 m above the base of bed 2; (H) – specimen ESM 146/38, 1.2 m above the base of bed 2; (G) – *Dactylioceras* (*D.*) cf. *kopiki* Rogov, sp. nov., *Astronomicheskaya* river, section 2, bed 17 (Knyazev et al., 2003, Fig. 27), specimen ESM 146/34; (I–N). *Meleagrinea* (*Clathrolima*) *substriata* (Muenster, 1831), all figured with x2 magnification. (I), (K–M) – 1.5 m above the base of bed 2; (I) – specimen ESM 146/30; (K) – specimen ESM 146/29; (L) – specimen ESM 146/31; (M) – specimen ESM 146/32; (J) – the same specimen as Fig. 7; (N) – specimen ESM 146/28, 1.2 m above the base of bed 2.

The described material is stored in the collections of the Earth Science Museum, Moscow State University, Moscow, Russia (abbreviated as ESM). Ammonites were studied by M.A. Rogov, and bivalves by O.A. Lutikov.

Description of recorded species

AMMONITES (by M.A. Rogov)
Family DACTYLIOCERATIDAE Hyatt
Subfamily DACTYLIOCERATINAE Hyatt

Genus *Dactylioceras* Hyatt

Remarks. – Dimorphism in dactylioceratids has been distinguished since the late 60s, when Lehmann (1968) and Guex (1971, 1973) recognised micro- and macroconchs in this ammonite group. In spite of the lack of clear mature aperture modifications in dactylioceratid ammonites, dimorphs are more or less clearly recognised. Two different approaches were in use for the description of dimorphs in this group: corresponding micro- and macroconchs were either referred to different (sub)genera (e.g., Guex, 1971; Kovacz, 2014) or described under the same species name accompanied by [m] or [M] symbols (e.g., Bardin et al., 2015). Here, corresponding micro- and macroconchs are ascribed to different subgenera.

Subgenus *Dactylioceras* (*Dactylioceras*) Hyatt [M]

Dactylioceras (*D.*) *kopiki* Rogov sp. nov. [M]
Figs. 3A–B, 3D–F, 3H–I; 4D–F, and 4H

- 1955 *Dactylioceras* cf. *D. commune* (Sowerby): Imlay, pl. 10, fig. 10.
1955 *Dactylioceras* cf. *D. directum* (Buckman): Imlay, pl. 11, figs. 7–11, 14.
1957 *Dactylioceras commune* (Sowerby) var. a: Frebold, pl. 1, fig. 4.
1968 *Dactylioceras* sp.nov.: Kopik, p. 40, pl. I, fig. 3 & 4, text-fig. 3 a–b.
1985 *Dactylioceras toxophorum* (Buckman): Bäckström & Nagy, p. 36, pl. 6, fig. 4 & 5, text-fig. 24a–b.

Holotype. – ESM 146/16 (Museum of Natural History, Moscow State University, Moscow, Russia), figs. 3.4 & 3.6.

Derivation of name. – in the memoir of Dr. Janusz Kopik (1930–2021).

Nomenclatural acts. – This published work and the nomenclatural acts it contains, have been registered in ZooBank: urn:lsid:zoobank.org:act:FA0D504E-5D44-463D-A811-E2C2B2C06E88

Type locality and horizon. – Commune Zone, *kopiki* biohorizon, Agardhbukta, Spitsbergen.

Material. – 21 specimens (ESM 146/1–5, 7–10, 13–14, 16, 18–20, 22–25, 36), preserved as imprints and internal moulds, from 0.7 to 1.3 m above the base of bed 2, Agardhbukta, Spitsbergen.

Diagnosis. – Semievolute coiling, subcircular whorl section, ribbing with alternating prorsiradiate simple and biplicate ribs. Terminal aperture accompanied by shallow constriction.

Table 1. Measurements of *D. (D.) kopiki* Rogov, sp. nov. *D* – diameter, *Wh* – whorl height, *Wb* – whorl breadth, *U* – umbilical diameter, *R/2* – number of primary ribs per half of whorl

Specimen no.	D	Wh	Wh/D	Wb	Wb/D	U	U/D (%)	R/2
ESM 146/9	48.1	14.2	29.5%			26.54	55%	30
ESM 146/16 holotype	50.2	12.6	25%			26.52	53%	32
ESM 146/25	37.3	11.1	29.7%			16.6	44.5%	26
ESM 146/18								38
ESM 146/4								22
ESM 146/19								20

Description. – Semievolute coiling, with rib furcation point covered by overlying whorl. Umbilicus wide and shallow, suboval whorl-section with little flattened flanks and venter (Table 1). The peristome is simple, and in some cases accompanied by a shallow constriction and a significant decrease of rib ratio towards the aperture. Sharp and rectiradiate ribs develop a little above umbilical seam; they curved forwards in the upper third of flanks, where they split into two ribs, with secondaries which sometimes are not connected with primaries, or usually remain undivided. Ribs cross the venter either with a forward bend or remain straight. The secondary/primary rib ratio in the outer whorl is between 1.25 and 1.7. Near the terminal aperture, ribbing becomes irregular. The suture-line is unknown due to poor preservation of inner whorls.

Remarks. – The type of ribbing and shell outline of this species strongly resembles those of *Zugodactylites*, except for lacking tubercles in the rib furcation point throughout the ontogenesis. One doubtful specimen, though, does actually have possible tubercles (fig. 4.F). Only in some specimens, ribs in the terminal body chamber may show weak thickenings in the rib furcation point. Corresponding microconchs (see below) show a clear tuberculate stage up to a diameter of c. 1 cm. Such a mix of *Dactylioceras*–*Zugodactylites* ribbing suggests the stratigraphic position of the discussed species near to a transition between these genera, i.e., in the top of the *Communis* zone.

The described species strongly resembles *Dactylioceras (D.) toxophorum* (Buckman) (the type specimen figured in Buckman, 1928, pl. DCCCLXXVI), but differ by a little more involute coiling, lower position of rib furcation point, and more prominent ribs. *D. (D.) athleticum* (Simpson) also shows a close resemblance to the new species, but is characterised by more evolute coiling and a higher rib furcation point. Variability of *D. (D.) kopiki* sp. nov. is mainly expressed in a variation of primary rib frequency, ranging in inner whorls from ~40 to 76 per whorl, and a rib ratio ranging from 1.25 to 1.7. The position of the rib furcation point is also variable, but it usually covered by outer whorls. In some specimens (fig. 4.D) ribbing became smoother on the terminal body chamber. A closely related specimen from the Astronomicheskaya river (NE Russia) (fig. 4.G) can be referred to this species as cf.-form. A single specimen intermediate in size between *D. (D.) kopiki* sp. nov. and *D. (Microdactylites) sp.*, has a rib pattern intermediate between these two taxa, with small prominent nodes in inner whorls and alternating biplicate and single ribs in the outer whorls (fig. 4.F). This ammonite specimen can be tentatively referred to as *D. (D.) kopiki*. Ammonites from Prince Patrick Island (Arctic Canada) referred to by Imlay (1955) as *Dactylioceras* cf. *D. directum* (Buckman) show the same rib pattern and variability as *D. (D.) kopiki* and could be ascribed to this species. The same is true for specimens from South Barrow test well 3 (northern Alaska) figured by Imlay (1955, pl. 10, fig. 10). These ammonites are associated with possible microconchs showing the presence of small nodes in the rib furcation points (Imlay, 1955,

pl. 10, fig. 15), as well as *D. kopiki* Rogov, sp. nov. Additional *Dactylioceras* from Prince Patrick Island figured by Frebold (1957, pl. 1) also resembles *D. (D.) kopiki*, and the figured assemblage may represent a mix of *D. commune* with *D. kopiki*.

Distribution. – In addition to studied specimens, this species is also known from the Brentskardhaugen Bed of Sørkappland and Hyrnefjellet, Spitsbergen (see synonymy), Prince Patrick Island (Canada), northern Alaska, and possibly from NE Russia (Astronomicheskaya river). Lower Toarcian, Commune Zone, *kopiki* biohorizon.

Subgenus *Dactylioceras* (*Microdactylites*) Buckman [m]

Dactylioceras (*Microdactylites*) sp. [m]

Figs. 3C, G; 4A–C

1929a *Dactylioceras* (*Peronoceras?*) *annuliferum* Simpson: Frebold, p. 259, pl. 2, figs. 14 & 15.
1955 *Dactylioceras* cf. *D. delicatum* (Buckman): Imlay, 1955, pl. 10, fig. 15.

Material. – 7 specimens (ESM 146/6, 11, 12, 15, 17, 21, 26) from 0.7 to 1.2 m above the base of bed 2, Agardhbukta section; one specimen from the Brentskardhaugen Bed of (ESM 146/35, collected by E.S. Ershova in 1977), Spitsbergen.

Description. – Evolute to semievolute coiling, umbilicus wide and shallow, suboval whorl-section (Table 2). Rib pattern is highly variable. Inner whorls (in some cases up to 1 cm diameter) are covered by straight primaries, which terminate with small but prominent nodes near to ventrolateral shoulder. Later, 1 or 2 thin secondaries appear here, and nodes fade gradually.

Remarks. – The present material strongly resembles *Dactylioceras* sp. 2 (Guex, 1973, pl. VIII, fig. 5), which also shows the occurrence of ventrolateral nodes in its inner whorls, but studied ammonites are characterised by much more distant ribs. Attribution of the described specimens to subgenus *Microdactylites* remains questionable, as the presence of ventrolateral nodes in inner whorls was previously unknown for this taxon (Guex, 1971). Microconchs with such a rib pattern were supposed

Table 2. Measurements of *Dactylioceras* (*Microdactylites*) sp.. *D* – diameter, *Wh* – whorl height, *Wb* – whorl breadth, *U* – umbilical diameter, *R/2* – number of primary ribs per half of whorl

Specimen no.	D	Wh	Wh/D	Wb	Wb/D	U	U/D (%)	R/2
ESM 146/35	19.2					8.3	43%	20
ESM 146/17	21.7	5.6	26%			10.5	48%	21
ESM 146/15	22.2	5.7	26%			12.2	55%	23
ESM 146/12	15.2	4.1	27%			8.3	55%	19
ESM 146/11	15.4	4.3	27.9%			7.7	50%	16

to be counterparts of macroconchiate *Rakusites* (Guex, 1971, p. 235), but in the Agardhbukta section they co-occur with typical *Dactylioceras* (*Dactylioceras*). Intraspecific variation is expressed by different longevity of the tuberculate stage.

Distribution. – Spitsbergen and northern Alaska. Lower Toarcian, Commune Zone, *kopiki* biohorizon.

BIVALVES (by O.A. Lutikov)
Family OXYTOMIDAE Ichikawa

Genus *Meleagrinnella* Whitfield
Subgenus *Meleagrinnella* (*Clathrolima*) Cossman

Meleagrinnella (*Clathrolima*) *substriata* (Münster)
figs. 4.9–14

- 1831 *Monotis substriata*: Münster, p. 406.
1836 *Monotis substriata*: Goldfuss, p. 138, pl. CXX, fig. 7a, b.
2020b *Arctotis* (*Praearctotis*) *substriata*: Lutikov & Arp, pl. I, figs. 9–13.

Lectotype. – (chosen by Lutikov & Arp, 2020b): specimen IGPB-Goldfuss-729 a/1 from the collection by Goldfuss; Posidonienschiefer Formation, lower Toarcian, Bifrons Zone, Commune Subzone, Banz, Germany (re-figured in Lutikov & Arp, 2020b, pl.1, fig. 9).

Material. – 6 specimens from the Agardhbukta section (moulds and imprints, ESM 146/28–33), Spitsbergen; 1 specimen with shell preserved (ESM 146/34) from the Start Formation of the Astronomicheskaya river, and more than 20 specimens from the Suntar formation from the Tyung, Markha and Vilyui rivers.

Revised diagnosis. – Posterior auricle of the left valve is obtuse. The outer margin of the posterior margin of the left valve forms a S-like curve. Its curvature is either narrow or wide. The left valve is strongly convex. The posterior ligamental field of the left valve is very short.

Discussion. – Until recently this species has been referred to as subgenus *Arctotis* (*Praearctotis*) (Lutikov & Arp, 2020a, b). However, as follows from the re-examination of ligamental area of the type series of this species by Lutikov (details will be published elsewhere), it should be re-assigned to the subgenus *Meleagrinnella* (*Clathrolima*). Lectotype for *M. (C.) substriata* (Muenster) has been chosen by Lutikov & Arp (2020b) among specimens from *Dactylioceras*–*Monotis*-Bed (Posidonienschiefer Formation, *Hildoceras bifrons* Zone, *Dactylioceras commune* Subzone).

Bivalves collected from other German sections (Lutikov & Arp, 2020b, pl. I, fig. 11 & 12), the Agardhbukta section, as well as from the sections in Siberia (Lutikov & Arp, 2020b, pl. I, fig. 14) and NE Asia (Lutikov & Arp, 2020b, pl. I, fig. 13) showing the same S-like curvature of the posterior wing and can be referred to the same species.

Distribution. – Range zone of *C. substriata* (Muenster) is corresponding to the lower Toarcian Bifrons ammonite zone (Lutikov & Arp, 2020a), but this species is especially common in the Commune ammonite subzone. This species is known from Spitsbergen (Agardhbukta), Northern Siberia and NE Russia (Tyung, Markha, Vilyui, Levy Kedon rivers: Lutikov & Arp, 2020b), Germany (Harries & Little, 1999; Arp & Gropengießer, 2016), the Yorkshire coast, England: (Harries & Little, 1999), Arctic Canada (Ya Ha Tinda lagerstätte: Martindale & Aberhan, 2017), Iran (Semnan area: Repin, 2000), and Japan (Okayama Prefecture: Hayami, 1961).

Discussion

Occurrences of Lower Toarcian macrofossils in Svalbard are relatively scarce, and all previous records came from the Brentskardhaugen Bed. These include uncommon *Dactylioceras*, *Harpoceras* and *Ovaticeras*, and more numerous younger taxa, such as *Zugodactylites*, *Porpoceras*, *Collina*, *Mucrodactylites* and *Pseudolioceras* (Wierzbowski et al., 1981; Ershova & Repin, 1983; Bäckström & Nagy, 1985). Based on this evidence, Ershova & Repin (1983) proposed a tentative zonal succession for the Toarcian of Spitsbergen. Recently, this “virtual” zonal succession has been corrected by Shurygin et al. (2011). Currently, it includes the following zones (from below to above): *Harpoceras* spp.; *Dactylioceras* commune; *Zugodactylites* ex gr. *braunianus*; *Pseudolioceras* *rosenkrantzi*. The present work records the first in situ findings of *Dactylioceras* – *Clathrolima* association, indicating the presence of molluscan-bearing Lower Toarcian in non-reworked preservation. Its age is indicated from the integrated analysis of ammonites and bivalves. Ammonites recovered from the studied section show some features transitional from *Dactylioceras* to *Zugodactylites*. This stratigraphic interval is distinguished here as the *kopiki* biohorizon (with the studied section as the type section, with the type interval 1–1.5 m above the base of bed 2), which is correlated with topmost levels of the Commune Zone, and tentatively can be considered as the equivalent of the *athleticum* horizon, the highest horizon of this subzone in the succession of NW Europe (Page, 2004).

The bivalve family Oxytomidae is widely distributed in the Pliensbachian and Toarcian of the Northern Hemisphere. Elucidation of the geographical distribution patterns of the family is currently difficult for two reasons. First, there is insufficient information on this group from Southeast Asia, Africa, Australia and New Zealand, South America and southern North America. Secondly, the reason that complicates biogeographic studies is still our insufficient knowledge of the taxonomy of the family. The revision of the genera *Meleagrinnella*, *Clathrolima* and the species “*Monotis*” *substriata* (Münster) is far from complete (Lutikov & Shurygin, 2010; Lutikov & Arp, 2020b), and the generic identity of many taxa is questionable.

The species *Meleagrinnella* (*Clathrolima*) *substriata* was previously reported from all ammonite zones of the lower Toarcian of Germany (Urlichs, 1971) and Northeastern Russia (Knyazev et al., 2003). Recently, this taxon was tentatively assigned to *Arctotis* (*Praearctotis*) (Lutikov & Shurygin, 2010), and it was found that its stratigraphic range covers the Commune Zone and possibly Monestieri Zone (Lutikov & Arp, 2020a, b). However, after viewing photographs of the ligament site of type series of this species (Goldfuss, 1836, pl. CXX, fig. 7 C–D) stored in the Munich Museum, it was established that this taxon belongs to the subgenus *Meleagrinnella* (*Clathrolima*). In Europe, bivalves similar to *M. (C.) substriata* are typical for the Commune subzone of Germany (Riegraf et al., 1984; Arp & Gropengießer, 2016) and England (Harries & Little, 1999), and findings of closely related bivalve specimens are also known in Iran and Japan (Fig. 5).

Early Toarcian palaeobiogeography of the Arctic remains uncertain due to the rarity of macrofossils between East Greenland and Eastern Siberia. The abundance and high diversity of Pliensbachian–Toarcian species of *Meleagrinnella* (*Clathrolima*) and *M. (Praemeleagrinnella)* in Northeast Russia suggest that this taxon originated in this area, and then spread widely around the world,

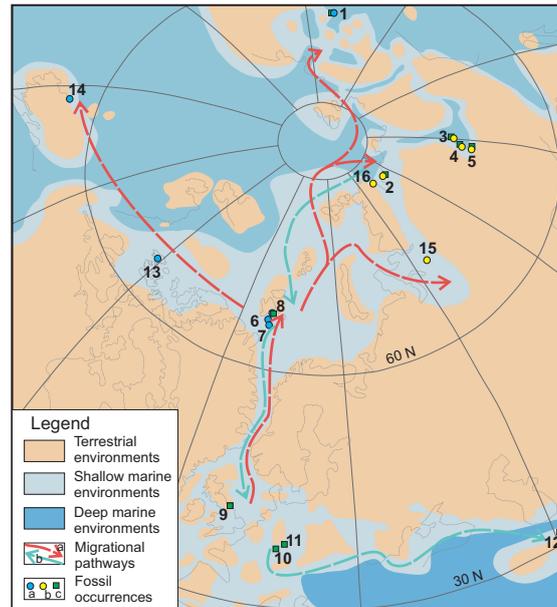


Figure 5. Simplified palaeogeography of the early Toarcian (modified from van der Schootbrugge et al., 2020, with minor corrections) and possible immigrational routes for *Meleagrinea* (*Clathrolima*) (blue; occurrences of *M. (C.) substriata* marked by green squares) and *Dactylioceras* (red; occurrences of *D. (D.) kopiki* – *D. (Microdactylites) sp.* marked by blue circles, while findings of other *Dactylioceras ex gr. commune* – by yellow circles). Key localities and their clusters are indicated by numerals: 1 – Astronomicheskaya river, NE Russia (this paper); 2 – Anabar Bay, Northern Siberia (Lutikov & Arp, 2020b); 3 – Tyung river, Yakutia (Lutikov & Arp, 2020b); 4 – Markha river, Yakutia (Lutikov & Arp, 2020b); 5 – Viluyi river, Yakutia (Lutikov & Arp, 2020b); 6 – Hyrnefjellet, Van Mijenfjorden (Kopik, 1968; this paper); 7 – Sørkappland (this paper); 8 – Agardhbukta, Dunérbukta (Frebold, 1929b; this paper); 9 – Yorkshire localities, England (Harries & Little, 1999); 10, 11 – German localities (Banz, Ludwigskanal, Bisinger Berg, Quarry Kromer, Dörlbach – Riegraf et al., 1984; Harries & Little, 1999; Arp & Gropengießer, 2016); 12 – Semnan province, Iran (Repin, 2000); 13 – Prince Patrick Island, Canada (Imlay, 1955); 14 – South Barrow test well 3, Alaska (Imlay, 1955); 15 – borehole Medvezh'ya-316, Western Siberia (Devyatov et al., 2006); 16 – Tsvetkov Cape, Northern Siberia (Knyazev et al., 2003).

in the direction of Eastern and Western Siberia, farther westwards through the Barents Sea and a Greenland–Norwegian seaway ('Viking corridor') to Europe, and possibly through the Arctic Ocean in the direction of North America. A similar migrational pathway has recently been proposed for dinoflagellates, as some taxa first appear in Siberia and later in Europe (van de Schootbrugge et al., 2020). Importantly, mass immigration of Arctic dinoflagellates to Europe began during the Bifrons Chron, i.e., synchronous with the appearance of *Meleagrinea* (*Clathrolima*) *substriata* in the same area. However, the migration pattern of dactylioceratid ammonites appears to be different. In Europe they have a continuous record, whereas in Siberia and NE Russia there is a significant hiatus in dactylioceratid lineage (Kutygin & Knyazev, 2000; Knyazev et al., 2003; Fig. 6). This suggests repetitive invasions of this ammonite group to the Boreal seas. On the other hand, dactylioceratid successions of Arctic Canada are still insufficiently known (Imlay, 1955; Frebald, 1975) and the presence of the '*Dactylioceras* gap' is possible here. In the southern part of Canada, such as in Alberta, the dactylioceratid succession is complete (see Them et al., 2017).

In our opinion, the discovery of the *Dactylioceras* – *Meleagrinea* (*Clathrolima*) assemblage in Spitsbergen indicates an important Arctic cross-road influenced by both westward and eastward faunal migration during the early Toarcian Bifrons Chron.

Sub-stage	Subboreal Province			Spitsbergen		N Siberia and NE Asia			
	Zone	Subzone	Biohorizon	Zone	Biohorizon	Zone	Subzone		
Lower Toarcian	Bifrons	Crassum	<i>semipolitum</i>	Braunianus		Braunianus			
			Fibulatum					<i>vortex</i>	
		<i>braunianus</i>							
		<i>turriculatum</i>							
		<i>athleticum</i>							
		Commune	<i>commune</i>					Commune	Commune
	<i>ovatum</i>								
	Serpentinum	Falciferum	<i>falciferum</i>	Falciferum	Falciferum				
			<i>pseudoserpentinum</i>						
		Exaratum	<i>elegans</i>			Exaratum			
			<i>exaratum</i>						
	<i>elegantulum</i>	Elegantulum							
	<i>antiquum</i>								
	Tenuicostatium	Semicelatum		Antiquum	gap				
Tenuicostatium		<i>tenuicostatium</i>							
Clevelandicum		<i>clevelandicum</i>							
Paltum		<i>crosbeyi</i>							
		<i>paltum</i>							

Figure 6. Stratigraphic position of the studied assemblage and its correlation with NW European ammonite zonal scale. Succession of Subboreal Province after Page (2004); succession of Spitsbergen after Shurygin et al. (2011) with corrections; succession of Northern Siberia and Northeast Asia after Shurygin et al. (2011).

Acknowledgements. We kindly acknowledge our Norwegian colleagues, Snorre Olausen, Erik Holmlund and Jørn H. Hurum, who introduced the studied section to the first author and assisted him with collecting fossils in the field. We also thank P. Alsen and H.A. Nakrem for their valuable comments and corrections. We are grateful to Dr. Winfried Werner (Bayerische Staatssammlung für Paläontologie und Geologie, München) for providing photographs of the ligamental area of *Meleagrinea* (*Clathrolima*) substriata. This study is supported by RSF grant no. 21-17-00245..

References

- Arp, G. & Gropengießer, S. 2016: The Monotis–*Dactyloceras* Bed in the Posidonienschiefer Formation (Toarcian, southern Germany): condensed section, tempestite, or tsunami-generated deposit? *Paläontologische Zeitschrift* 90, 271–286. <https://doi.org/10.1007/s12542-015-0271-7>
- Bäckström, S. A. & Nagy, J. 1985: Depositional history and fauna of a Jurassic phosphorite conglomerate (the Brentskardhaugen Bed) in Spitsbergen. *Norsk Polarinstitutt Skrifter* 183, 1–61.
- Bardin, J., Rouget, I., Benzaggagh, M., Fürsich, F. T. & Cecca, F. 2015: Lower Toarcian (Jurassic) ammonites of the South Riffian ridges (Morocco): systematics and biostratigraphy. *Journal of Systematic Palaeontology* 13, 471–501. <https://doi.org/10.1080/14772019.2014.937204>
- Basov, V. A., Nikitenko, B. L. & Kupriyanova, N. V. 2009: Lower–Middle Jurassic foraminiferal and ostracode biostratigraphy of the Barents Sea shelf. *Russian Geology and Geophysics* 50, 396–416. <https://doi.org/10.1016/j.rgg.2008.08.006>
- Birkenmajer, K. & Pugaszewska, H. 1975: Jurassic and Lower Cretaceous marine fauna of SW Torell Land, Spitsbergen. *Studia Geologica Polonica* 44, 45–89.

Bjærke, T. & Dypvik, H. 1977: Sedimentological and palynological studies of Upper Triassic–Lower Jurassic sediments in Sassenfjorden. Spitsbergen. *Norsk Polarinstitutt Årbok 1976*, 131–150.

Devyatov, V. P., Knyazev, V. G., Kutygin, R. V., Meledina, S. V., Shurygin, B. N. & Khmelevskii, V. B. 2006: First find of Lower Jurassic ammonites (*Dactylioceras*) in West Siberia. *Doklady Earth Sciences* 406, 15–18. <https://doi.org/10.1134/S1028334X06010053>

Ershova, E. S. & Repin, Yu. S. 1983: Toarcian and Aalenian ammonites of the Spitsbergen archipelago. In Krasil'shnikov A. A. (ed.): *Geology of Spitsbergen, collection of scientific papers*. PGO “Sevmorgeologija”, Leningrad, pp. 150–170. [in Russian]

Frebold, H. 1929a: Die Schichtenfolge des Jura und der Unterkreide an der Ostküste Südwest-Spitzbergens. *Abhandlungen aus dem Gebiete der Naturwissenschaften Herausgegeben vom Naturwissenschaftlichen Verein in Hamburg XXII*, 253–292.

Frebold, H. 1929b: Oberer Lias und unterer Callovien in Spitsbergen. *Skrifter om Svalbard og Ishavet* 20, 1–24.

Frebold, H. 1930: Verbreitung und Ausbildung des Mesozoikums in Spitsbergen. *Skrifter om Svalbard og Ishavet* 31, 1–127.

Frebold, H. 1957: Fauna, age and correlation of the Jurassic rocks of Prince Patrick Island. *Geological Survey of Canada Bulletin* 41, 1–69. <https://doi.org/10.4095/101539>

Frebold, H. 1975: The Jurassic faunas of the Canadian Arctic, Lower Jurassic Ammonites, biostratigraphy and correlations. *Geological Survey of Canada Bulletin* 243, 1–24. <https://doi.org/10.4095/103979>

Goldfuss, G.A. 1836: *Petrefacta Germaniæ tam ea: quae in Museo Universitatis Regiae Borussicae Fridericiae Wilhelmae Rhenanae servantur quam alia quaecunque in Museis Hoeninghusiano Muensteriano aliisque extant, iconibus et descriptionibus illustrata. Teil 2*. Leipzig, 312 S.

Guex, J. 1971: Sur la classification des Dactylioceratidae (Ammonoidea) du Toarcien. *Eclogae Geologicae Helvetiae* 64, 225–243. <https://doi.org/10.5169/seals-163980>

Guex, J. 1973: Dimorphisme des Dactylioceratidae du Toarcien. *Eclogae geologicae Helvetiae* 66, 545–583. <https://doi.org/10.5169/seals-164207>

Harries, P. J. & Little, C. T. S. 1999: The early Toarcian (Early Jurassic) and the Cenomanian–Turonian (Late Cretaceous) mass extinctions: similarities and contrasts. *Palaeogeography, Palaeoclimatology, Palaeoecology* 154, 39–66. [https://doi.org/10.1016/S0031-0182\(99\)00086-3](https://doi.org/10.1016/S0031-0182(99)00086-3)

Hayami, I. 1961: Pelecypods from the Liassic Yamaoku Formation in West Japan (Studies on the Liassic Pelecypods in Japan, 11). *Transactions and proceedings of the Paleontological Society of Japan. New series* 43, 113–116. https://doi.org/10.14825/prpsj1951.1961.43_113

Imlay, R.W. 1955: Characteristic Jurassic mollusks from northern Alaska. *US Geological Survey Professional Paper* 274-D, 69–96. <https://doi.org/10.3133/pp274D>

Kirina, T.I. 1976a: The left bank of the lower course of the Lena River. In Sachs V. N. (ed.): *Stratigraphy of the Jurassic System of the north of the USSR*, Moscow, Nauka, pp. 98–107. [in Russian]

Kirina, T.I. 1976b: Vilyuy River. In Sachs V. N. (ed.): *Stratigraphy of the Jurassic System of the north of the USSR*, Moscow, Nauka, pp. 108–118. [in Russian]

Klubov, B.A. 1965: Triassic and Jurassic deposits of the Wilhelmsøya. In Sokolov V. N. (Ed.) *Materials on geology of Spitsbergen*, NIIGA, Leningrad, pp. 174–184. [in Russian].

Knyazev, V.G., Devyatov, V.P., Kutugin, R.V., Nikitenko, B.L. & Shurygin, B.N. 2003: Zonal Standart of the Toarcian Stage of the North–East Part of Asia. *Yakutsk, YB of the SD RAS Publishing House*, 105 pp. [in Russian]

Kopik, J. 1968: Remarks on some Toarcian ammonites from the Hornsund area, Vestspitsbergen. *Studia Geologica Polonica* 21, 33–51.

Kovács, Z. 2014: Toarcian *Dactyloceratidae* (*Ammonitina*) from the Gerecse Mts (Hungary). *Hantkeniana* 9, 45–77.

Krajewski, K. P. 1992: Phosphorite-bearing sequence of the Wilhelmsøya Formation at Hornsund and along western coast of Sørkapp Land, Spitsbergen. *Studia Geologica Polonica* XCVIII, 201–233.

Kutugin, R. V. & Knyazev, V. G. 2000: The genus *Dactyloceras* (*Ammonoidea*) from Northeastern Russia. *Paleontological Journal* 54, 14–22.

Lehmann, U. 1968: Stratigraphie und Ammonitenführung der Ahrensburger Glazial-Geschiebe aus dem Lias epsilon (Unt. Toarcium). *Mitteilungen aus dem Geologischen Staatsinstitut in Hamburg* 37, 41–68.

Lutikov, O.A. & Arp, G. 2020a: Biochronological scale of the Lower Toarcian for bivalve mollusks of the family *Oxytomidae* Ichikawa, 1958. In Zakharov V.A. (ed.): *Proceedings of the VIIIth All-Russian Meeting with international participation. Online, September 7–10, 2020*. Syktyvkar: IG Komi SC UB RAS, pp. 132–141.

Lutikov, O.A. & Arp, G. 2020b: Revision of *Monotis substriata* (Münster, 1831) and new species of bivalve in the Lower Toarcian in northern Russia and southern Germany (family *Oxytomidae* Ichikawa, 1958). In Zakharov V.A. (ed.): *Proceedings of the VIIIth All-Russian Meeting with international participation. Online, September 7–10, 2020*. Syktyvkar: IG Komi SC UB RAS, pp. 125–131.

Lutikov, O.A. & Shurygin, B.N. 2010: New data on systematics of Jurassic and Cretaceous bivalves of Family *Oxytomidae* Ichikawa, 1958. *News of paleontology and stratigraphy* 14, 111–140. [in Russian]

Martindale, R. C. & Aberhan, M. 2017: Response of macrobenthic communities to the Toarcian Oceanic Anoxic Event in northeastern Panthalassa (Ya Ha Tinda, Alberta, Canada). *Palaeogeography, Palaeoclimatology, Palaeoecology* 478, 103–120. <https://doi.org/10.1016/j.palaeo.2017.01.009>

Mørk, A., Dallmann, W.K., Dypvik, H., Johannesen, E.P., Larssen, G.B., Nagy, J. & Worsley, D. 1999: Mesozoic lithostratigraphy. In Dallmann, W.K. (Ed.) *Lithostratigraphic lexicon of Svalbard: Review and recommendations for nomenclature use: Upper Palaeozoic to Quaternary Bedrock*. Norsk Polarinstitut, Tromsø, pp. 127–214.

Münster, G. 1831: Über das geognostische Vorkommen einiger zu *Monotis* gehörenden Versteinerungen. *Jahrbuch für Mineralogie, Geognosie, Geologie und Petrefaktenkunde*, 403–408.

Olaussen, S., Larssen, G.B., Helland-Hansen, W., Johannessen, E.P., Nøttvedt, A., Riis, F., Rismyhr, B., Smelror, M. & Worsley, D. 2018: Mesozoic strata of Kong Karls Land, Svalbard, Norway; a link to the northern Barents Sea basins and platforms. *Norwegian Journal of Geology* 98, 1–69.

<https://doi.org/10.17850/njg98-4-06>

Page, K. N. 2004: A sequence of biohorizons for the Subboreal Province Lower Toarcian in northern Britain and their correlation with a Submediterranean Standard. *Rivista Italiana di Paleontologia e Stratigrafia* 110, 109–114.

Pchelina, T.M. 1980: New data on Triassic and Jurassic boundary beds of the Svalbard archipelago. In Semenevsky V. D. (ed.) *Geology of the sedimentary cover of the Svalbard archipelago*, NIIGA, Leningrad, pp. 44–60 [in Russian].

Repin, Yu. S. 2000: Toarcian ammonites of genus *Dactylioceras* from northern Iran. *Bulletin of Moscow Society of Naturalists, Geological section* 75, 37–45 [in Russian].

Riegraf, W., Werner, G. & Lorcher, F. 1984: *Der Posidonienschiefer: Biostratigraphie, Fauna und Fazies des südwestdeutschen Untertoarciums (Lias ε)*. Stuttgart, Enke, 195 pp.

Rismyhr, B., Bjærke, T., Olaussen, S., Mulrooney, M. J. & Senger, K. 2018: Facies, palynostratigraphy and sequence stratigraphy of the Wilhelmøya Subgroup (Upper Triassic– Middle Jurassic) in western central Spitsbergen, Svalbard. *Norwegian journal of geology* 99, 35–64. <https://doi.org/10.17850/njg001>

Shurygin, B. N., Nikitenko, B. L., Meledina, S. V., Dzyuba, O. S. & Knyazev, V. G. 2011: Comprehensive zonal subdivisions of Siberian Jurassic and their significance for Circum- Arctic correlations. *Russian Geology and Geophysics* 52, 825–844. <https://doi.org/10.1016/j.rgg.2011.07.007>

Them II, T.R., Gill, B.C., Caruthers, A.H., Gröcke, D.R., Tulskey, E.T., Martindale, R.C., Poulton, T.P. & Smith, P.L. 2017: High-resolution carbon isotope records of the Toarcian Oceanic Anoxic Event (Early Jurassic) from North America and implications for the global drivers of the Toarcian carbon cycle. *Earth and Planetary Science Letters* 459, 118–126. <https://doi.org/10.1016/j.epsl.2016.11.021>

Urlichs, M. 1971: Alter und Genese des Belemniten-schlachtfeldes im Toarcium von Franken. *Geologische Blätter für Nordost-Bayern* 21, 65–83.

van de Schootbrugge, B., Houben, A.J.P., Ercan, F.E.Z., Verreussel, R., Kerstholt, S., Janssen, N.M.M., Nikitenko, B. & Suan, G. 2020: Enhanced Arctic-Tethys connectivity ended the Toarcian oceanic anoxic event in NW Europe. *Geological Magazine* 157, 1593–1611.

<https://doi.org/10.1017/S0016756819001262>

Wierzbowski, A., Kulicki, C. & Pugaczewska, H. 1981: Fauna and stratigraphy of the Uppermost Triassic and the Toarcian and Aalenian deposits in Sassenfjorden, Spitsbergen. *Acta Palaeontologica Polonica* 26, 195–241.

Worsley, D. 1973: The Wilhelmøya Formation - a new lithostratigraphical unit from the Mesozoic of eastern Svalbard. *Norsk Polarinstitutt Årbok* 1971, 7–15.