Jurassic biota and biofacies in erratics from the Sortland area, Vesterålen, northern Norway

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Erratic blocks occurring on the shore at Sortland, northern Norway, consist of fine- to coarse-grained siliciclastics, in places conglomeratic, which exhibit signs of large-scale cross-bedding or, less commonly, are bioturbated. The blocks contain either abundant plant debris (which indicate fluvial environments or at least a strong terrestrial influence) or shells and shell debris of a variety of marine benthic organisms. Most common are bivalves, followed by serpulids, gastropods, brachiopods and echinoid spines. Belemnites constitute the only nektic element. The benthic fauna occurs scattered, as shell pavements, or in small lenses. Altogether 39 taxa were identified, and one of them (*Lopatinia (Paralopatinia) sortlandensis* sp. nov.) is new. The remaining taxa are typical elements of boreal faunas elsewhere (e.g., East Greenland, northern Russia) and suggest a Volgian age of most, if not all, of the boulders with shelly remains at Sortland. This age is supported by $^{87}Sr/^{86}Sr$ isotope ratios of oyster shells. The benthic fauna is grouped into eight assemblages, nearly all of them exhibiting signs of reworking and/or transport. Together with their sediments they form characteristic biofacies. These represent environments ranging from shallow-water, high-energy, nearshore areas above the fair-weather wave-base to offshore, quieter environments. Most likely, deposition took place in a fault-controlled coastal area, on tilted fault blocks, and thus mirrors the situation on the opposite (western) margin of the Arctic Seaway in the Late Jurassic.

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Introduction

In August 2000, Børre Davidsen from the Geological Survey of Norway discovered several Mesozoic erratics in the vicinity of Sortland, Vesterålen, northern Norway. His preliminary investigation (Davidsen et al. 2001) led to a co-operation with Tromsø University Museum in order to recover the erratics for further research. Onshore Mesozoic deposits had, until then, only been recorded in northern Norway from exposures on Andøya and, as an erratic, from Brottøya (Hanø), in Vesterålen (e.g., Lundgren 1894, Sokolov 1912, Birkelund et al. 1978, Ravn & Vogt 1915; see Thomsen 1996 for a review).

The boulders occur along the western shores of the Sortlandsundet from Elvenes in the south to Setnes in the north, and on the eastern shore from the bridge northwards to Kringelneset (Fig. 1; and photos of boulders, Fig. 2). They were all located in the intertidal to supratidal zone.

The aims of this publication are (1) to describe the biota and biofacies in the erratics from the Sortland area based on the macrofossil assemblages and their taphonomic features; (2) to date the erratics using the faunal composition and Sr isotope data; (3) to discuss the likely palaeoenvironments; and (4) to provide a preliminary comparison of the Sortland fauna with other Mesozoic faunas from northern Norway.
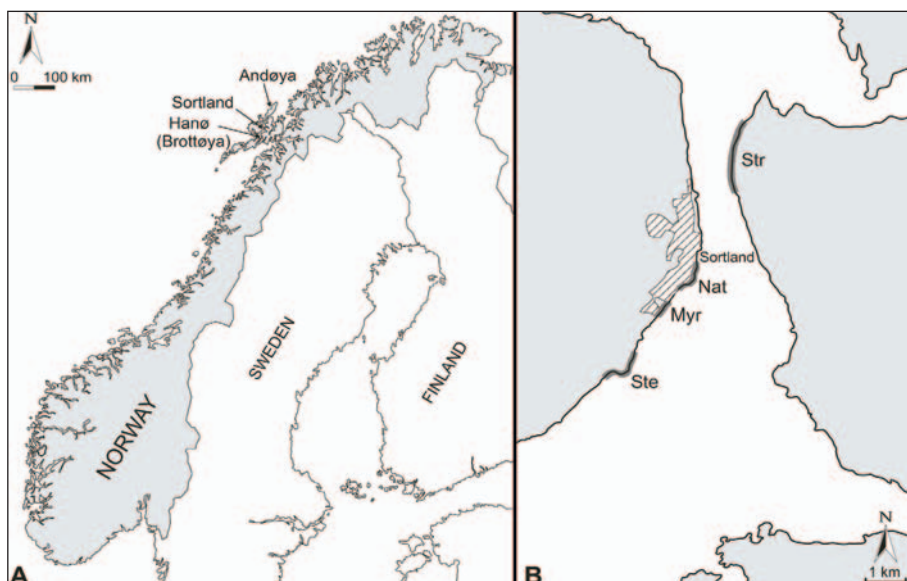

Fig. 1. Maps showing (A) the location of the Sortland area, Andøya and Hanø (Brottøya) and (B) the shorelines with erratic blocks containing Mesozoic fauna and flora in the Sortland district, northern Norway. Myr – Myrland; N – Natland; Ste – Steiro; Str – Strand.

Material and methods

The material was collected during the period 2000-2002. Altogether 250 samples from/of more than 50 fossiliferous erratic boulders of very different size and weight were recovered from four major locations named Ste (Steiro), Myr (Myrland), Nat (Natland) and Str (Strand) (Fig. 1 and Table 1). The samples were taken to the Geological Survey of Norway, Trondheim, and/or Tromsø University Museum (TMU) for further study and repository. Most of the samples are now at TMU and registered in the database of the paleontological collection at the Department of Geology. Some samples underwent mechanical preparation and some were stabilised using Paraloid B 72. A few samples were used for stable isotope analyses which were carried out in Bochum at the isotope laboratory of the University of Ruhr. All macroinvertebrate fossils were recorded (Table 2) with information on their life habits, mode of feeding and abundance. Taxonomic notes on the fossils are presented in the appendix.

The sediments

A detailed petrographic study of the Mesozoic sediments from Sortland is beyond the scope of this paper. The blocks, some of which are shown in Fig. 2, are dominated by immature, carbonate-cemented sandstones. The grain size varies from fine to coarse grained, most of the sandstones being medium-coarse grained. Some blocks are gravelly and/or contain pebbles (up to 10 cm in largest diameter). The clasts consist of different rock types and vein quartz.

Cross-bedding is recognisable in several blocks, indicating that both current ripples and megaripples are present. The fossils commonly occur as pavements with disarticulated bivalves in convex-up position and tubes of annelids exhibiting preferred current orientation.

The macrofauna
Composition

Whereas some of the blocks from Sortland do not contain any shelly macrofauna, but are rich in plant material, others are moderately to highly fossiliferous. The group with the highest diversity are the bivalves (28 taxa), followed by gas-

MACROFOSSILS, LOCALITY AND BLOCK NO.	Ste 1	Ste 2	Ste 3	Ste 4	Ste 5	Ste 10	Ste 17	Ste 28	Ste 29	Ste 31	Ste 32	Ste 33	Ste 34	Ste 35	Ste 36	Ste 37	Ste 38	Myr 1	Myr 2	Nat 1	Nat 7	13A	13B	13C	13D	13E	13F	13G	15B	15C	16A	16B	16C	16D	16E	16F	16G	20	21	23	24	25	27	28	29	30
Serpula (*Cycloserpula*) *intestinalis*																											★				★															
Serpula (*Cycloserpula*) sp. A																														★													★			★
Ditrupa sp.	★	★																				★	★	★		★			★	★			★										★	★		
Spirorbis sp.																																							★							
"Patellid"										★		★																																		
Ataphrus sp.																																	★												
"*Neritaria*" sp.																																	★												
Procerithiid																																	★												
Modiolus sp.													★																													★			
Lopatinia sortlandensis sp. nov.																																★													
Camptonectes (*Camptonectes*) *auritus*										★			★																													★			
Camptonectes (*Mclearnia*) *cinctus*												★																												★					
? *Chlamys* sp.										★																																			
Oxytoma (*Oxytoma*) sp.										★																												★				★			
Meleagrinella sp.																																										★			★
Buchia sp.																																										★			
Entolium (*E.*) *orbiculare*										★		●	★								★			★						★		★									★	★			
Plagiostoma sp.										★																																			★
Pseudolimea sp.										★			★																														★	★		
? *Nanogyra nana*										★																																			
Large ostreid (? *Liostrea* sp.)																																						★	★						
Trigonia (*Trigonia*) sp.																																										★			
Myophorella cf. *Myophorella* (*M.*) *intermedia*												●																				★	★												
Discoloripes fischerianus																														★		★													
Astarte cf. *Astarte* (*A.*) *chetaensis*								★	★				★																	★		★		★						●		★			
Astarte (*Astarte*) *veneriformis*																																★										★			
Nicaniella (*Nicaniella*) sp.													★																			★										★			
Protocardia (*Protocardia*) sp.										★																						★										★			
Tancredia (*Tancredia*) sp. A												●																				●									●				
Tancredia (*Tancredia*) sp. B																																★													
Corbicellopsis sp. A																																●													
Corbicellopsis sp. B												●★																				●													
Hartwellia cf. *Hartwellia* (*H.*) *kharoschovensis*										★																																			
Isocyprina (*Venericyprina*) sp.																																★													
Isocyprina (? *Venericyprina*) *birkelundi*																																						★							
Pleuromya uniformis		?		?																									?			★													
Belemnites (≥ 2 species)										★			★							★			★								★	★								★	★	★			★
Terebratulid										★																																			
Rhynchonellid										★																																★			
Echinoid (spines)										★			★										★															★	★		★				
Miscellaneous		B		B	P	B/P	P			S/O		B			B			B/P		P	P	B					S/O	O	G	O		P	P	P	B		P					Sw G		O	O	O

Table 1. Distribution of macrofossils in the erratic boulders from Sortland. Star = determined to species level: Dot = species not determinable, e.g. fragments of recorded species.; B = Bivalvia indet.; G = Gastropoda indet.; O = Other fragments; S = Shell hash; P = Plantae indet.; W = Wood pieces.

Fig. 2. Fossiliferous blocks from the Strand shoreline, near Sortland (see Fig. 1 for location). (A) Block Str 13A. (B) Close-up of block Str 13A. Note the belemnite, c. 4 cm in length, upper left. (C) Block Str 16A. (D) Close-up of block Str 16A; abundant shells of astartid bivalves in fine- to medium-grained sandstone. (E) Block Str 16D. Photos A-D, Børre Davidsen, NGU; photo E, Elsebeth Thomsen, TMU.

tropods and annelids (4 taxa each), brachiopods and cephalopods (2 taxa each), and echinoderms (1 taxon) (Table 2). Bivalves also dominate in numerical abundance, but in some blocks, tubes of the annelid *Ditrupa* are, in fact, the most common faunal element.

Palaeoecology

In contrast to the boulders with abundant plant remains, which indicate fluvial environments or at least a strong terrestrial influence (no marine dinocysts were found in them in contrast to the remaining blocks; M. Smelror, pers. comm. 2003), those containing shelly faunas (Fig. 2A-E) point to a fully marine environment. Although bivalves and gastropods are groups known to contain many euryhaline taxa, there is not a single taxon that points to lowered salinity values. Rather, the taxa are the same as those occurring in fully marine settings elsewhere in the Boreal Sea (e.g., northern England, East Greenland, northern Siberia; Zakharov 1970, Fürsich 1982, Kelly 1984). The lack of ammonites and the scarcity of belemnites, both common elements of open shelf environments of the Boreal Sea, suggest a fairly nearshore setting, which is supported by the sedimentary features and the common wood fragments and plant debris.

In terms of feeding mode, suspension-feeders dominate by far (Table 2), herbivores being represented by the comparatively rare gastropods and the echinoid, carnivores by the belemnites (Fig. 2B), whilst a chemosymbiotic mode of feeding is represented by the equally rare bivalve *Discoloripes*. Deposit-feeders such as nuculid bivalves are absent. In terms of life habits, two-thirds of the taxa lived epifaunally, most of them attached with a byssus, but some of them, in particular the annelid *Ditrupa*, rested freely on the sea floor. Cemented taxa (oysters, serpulids) are comparatively rare, as are mobile forms (gastropods). The infauna consists almost exclusively of shallow burrowing taxa, especially astartid bivalves (Fig. 2D), whereas deep burrowing forms are represented only by the bivalves *Pleuromya* and *Discoloripes* (the latter only found as juvenile specimens). Some of these shallow burrowers, in particular the bivalves *Corbicellopsis* and *Tancredia*, are thought to have been able to burrow fairly rapidly and thus were adapted to life in unstable, shifting substrates. The more strongly inflated, deep infaunal *Pleuromya*, in contrast, was probably a slow burrower. Once excavated by currents or waves, *Pleuromya* most likely was unable to re-burrow and died on the sea floor, being an easy prey to predators, similar to the Recent *Mya arenarea* (e.g., Schäfer 1962).

The autecology of some taxa and the guild composition of the benthic macrofauna, except that of

Table 2. List of macroinvertebrates recovered from the erratic blocks at Sortland and information on their life habits (LH), mode of feeding (FM), and abundance (A). Life habits: EB= epibyssate bivalves or pedicle-attached brachiopods; EC= epifaunal, cemented; EF= epifaunal, free-living; EM= epifaunal, mobile; IB= endobyssate; IS= shallow infaunal; ID= deep infaunal; P= pelagic. Mode of feeding: C= carnivorous; CH= chemosymbiotic; D= deposit-feeding; H= herbivorous; S= suspension-feeding; r= rare; o= occurring; c= common: a= abundant.

Taxa	LH	FM	A
ANNELIDA			
Serpula (Cycloserpula) intestinalis	EF	S	r
Serpula (Cycloserpula) sp. A	EC	S	r
Ditrupa sp.	EF	S	a
Spirorbis sp.	EC	S	r
GASTROPODA			
«patellid»	EM	H	o
Ataphrus sp.	EM	?H	r
«*Neritaria*» sp.	EM	H	r
procerithiid	EM	?H	r
BIVALVIA			
Modiolus sp.	IB	S	o
Lopatinia (Paralopatinia) sortlandensis sp. nov.	EB	S	o
Camptonectes (Camptonectes) auritus (Schlotheim)	EB	S	c
Camptonectes (Mclearnia) cinctus (J. Sowerby)	EF	S	o
?*Chlamys* sp.	EB	S	r
Oxytoma (Oxytoma) sp.	EB	S	o
Meleagrinella sp.	EB	S	c
Buchia sp.	EB	S	o
Entolium (Entolium) orbiculare (J. Sowerby)	EF	S	c
Plagiostoma sp.	EB	S	r
Pseudolimea sp.	EB	S	c
?*Nanogyra nana*	EC	S	o
large ostreid (?*Liostrea* sp.)	EC	S	o
Trigonia (Trigonia) sp.	IS	S	r
Myophorella cf. *Myophorella (M.) intermedia* (Fahrenkohl)	IS	S	o
Discoloripes fischerianus (d´Orbigny)	ID	CH	r
Astarte cf. *Astarte (A.) chetaensis* Zakharov	IS	S	a
Astarte (Astarte) veneriformis Zakharov	IS	S	r
Nicaniella (Nicaniella) sp.	IS	S	c
Protocardia (Protocardia) sp.	IS	S	o
Tancredia (Tancredia) sp. A	IS	S	r
Tancredia (Tancredia) sp. B	IS	S	o
Corbicellopsis sp. A	IS	S	o
Corbicellopsis sp. B	IS	S	r
Hartwellia cf. *Hartwellia (H.) kharoschovensis* (Rouillier & Vossinsky)	IS	S	r
Isocyprina (Venericyprina) sp.	IS	S	r
Isocyprina (?Venericyprina) birkelundi	IS	S	o
Pleuromya uniformis (J. Sowerby)	ID	S	o
CEPHALOPODA			
belemnites (≥2 species)	P	C	o
BRACHIOPODA			
terebratulid	EB	S	r
rhynchonellid	EB	S	o
ECHINODERMATA			
echinoid (spines)	EM	H	o

one block (Str 16D, Fig. 2E), thus indicate unstable substrates and high-energy conditions with food particles kept in suspension rather than accumulating on the sea floor. The macrofauna of block Str 16D records a more stable substrate less often affected by reworking processes. These conclusions agree with those reached by the taphonomic analysis (see below).

The benthic fauna has been clearly reworked. As a result, it does not represent the autochthonous relics of former communities but rather the mixed and sorted relics of several communities that lived in nearshore, shallow waters. A synecological analysis is therefore pointless. However, mixing has not been complete and there exist sufficient differences between the faunal compositions of the various blocks to recognize the following eight assemblages, which, together with the sediment in which they occur, constitute characteristic biofacies:

(a) The Ditrupa assemblage
(blocks Str 13B/13C/13F/16A/27/28)
This assemblage is characterised by a low-diversity fauna consisting overwhelmingly of whole and fragmented tubes of the annelid *Ditrupa* occurring either scattered or as loosely packed pavements. Additional faunal elements are the bivalves *Entolium (Entolium) orbiculare* and *Astarte* cf. *Astarte (A.) chetaensis* and the serpulid *Serpula (Cycloserpula) intestinalis.* The sediment is a pebbly, medium-coarse-grained to gravelly sandstone. Cross-bedding indicates the presence of current ripples. In places, the tubes of *Ditrupa* exhibit preferred plan view orientation.

(b) The Camptonectes (Mclearnia) assemblage
(blocks Ste 33/Str 24)
Disarticulated valves of the bivalve *Camptonectes (Mclearnia) cinctus* occur together with belemnites and a large, unidentifiable, fragmented gastropod. The sediment is a pebbly, coarse-grained sandstone.

(c) The Entolium - Pseudolimea - Oxytoma assemblage
*(blocks S*te 31/Str 25)
This assemblage is characterised by byssally attached or free-living epifaunal bivalves. Associated members of the assemblage are the bivalves *Nicaniella, Buchia, Modiolus, Protocardia*, rhynchonellid brachiopods, serpulids, and echinoids in the form of spines. The diversity is moderate. The sediment is a medium- to coarse-grained sandstone rich in shell debris; large wood fragments are common.

(d) Astarte - Entolium assemblage (blocks Ste 28/29/37/Str 16A)
The bivalve *Astarte* cf. *Astarte (A.) chetaensis* predominates in this assemblage, generally forming small nests of disarticulated shells and, in places, lenses and stringers. The number of associated taxa (e.g., the bivalves *Entolium, Pseudolimea, Modiolus* and *Tancredia*) varies, but the diversity is generally low. The sediment is a fine- to medium-grained sandstone.

(e) The Entolium assemblage (blocks Str 16F, Myr 2)
Monospecific pavements and lenticles of disarticulated shells of *Entolium (Entolium) orbiculare* occur in micaceous, microconglomeratic, coarse-grained sandstone.

(f) The Myophorella - Nicaniella assemblage (block Str 16D)
This is the assemblage with the highest diversity. Although the bivalve *Myophorella* cf. *Myophorella (M.) intermedia* is not abundant, it is a characteristic element of the assemblage. Far more numerous are small shells of the bivalve *Nicaniella*. In addition, the bivalves *Tancredia, Corbicellopsis, Astarte, Pleuromya* and *Discoloripes*, several gastropods, and serpulids are present. All bivalves are infaunal taxa; pectinids, so abundant in most of the other assemblages, are totally absent. This is the only assemblage in which articulated specimens occur, albeit rarely. The sediment is a highly bioturbated, micaceous, fine- to medium-grained sandstone with plant debris.

(g) The Lopatinia assemblage (block Str 16E)
The bivalve *Lopatinia sortlandensis* forms a near-monospecific assemblage of convex-up oriented, disarticulated shells in a gravelly, medium- to coarse-grained, quartzose sandstone with scattered, well rounded quartz pebbles. Rare, additional elements are *Myophorella (Myophorella)* and a large unidentifiable heterodont bivalve. *Lopatinia* occurs in small lenticles or as pavement.

(h) The Isocyprina (?Venericyprina) assemblage (block Str 16G)
The small heterodont bivalve *I. (?Venericyprina) birkelundi* occurs as scattered, mainly disarticulated, convex-up oriented shells in loosely packed pavements on the foresets of large cross-beds. In places, shells occur in butterfly position. The associated sediment is a highly micaceous fine-grained sandstone with scattered subangular quartz pebbles. Apart from plant fragments and rare *Astarte* cf. *Astarte (A.) chetaensis*, no other fossils were found associated with *Isocyprina*. Apparently, the bivalves suffered comparatively little transport, judging from their relatively high preservation quality and the occurrence of gaping articulated shells.

These eight assemblages, forming characteristic biofacies, may record remnants of former communities that either became mixed and therefore increased in diversity or strongly sorted and thus decreased in diversity (e.g., the *Ditrupa, Isocyprin*a and *Lopatinia* assemblages). Apparently, the lowest degree of reworking took place in the *Myophorella - Nicaniella* assemblage, judging from the scarcity of abrasion on shells and the presence of some articulated shells. It clearly reflects a lower energy environment than the other assemblages.

Taphonomic remarks
Biostratinomic observations
None of the faunal elements of the erratic boulders occurs in life position. Moreover, except in the *Myophorella - Nicaniella*

biofacies, shells are invariably disarticulated, even deep bur-rowing forms such as *Pleuromya*. Shell hash and larger frag-ments are common. They occur either scattered or concen-trated in small nests, as lenses, thin shell beds or as loosely packed pavements on the foresets of large-scale cross-beds. In the last case, the shells are predominantly found in a con-vex-up position. Encrusted specimens are relatively rare, the encrusting taxa being serpulids. Some large oysters are riddled with bivalve borings (*Gastrochaenolites* isp.). The preservation of some fossils is excellent; in many cases; how-ever, there are distinct signs of abrasion such as loss of orna-mentation. Evidence of size sorting is the near-monospecific occurrence of shells of *Astarte* cf. *Astarte (A.) chetaensis* in lenses and stringers.

All these features indicate that the shelly macrofauna was subject to frequent reworking, usually above the fair-weather wave base. Specimens with only a short residence time within the zone of constant reworking are well pre-served, whereas those suffering such processes for a long time are badly worn. Thus, all faunal elements can be regarded as allochthonous. The only exception to these con-clusions is the *Myophorella-Nicaniella* biofacies which is highly bioturbated and in which burrowing forms such as *Myophorella*, *Protocardia*, *Pleuromya* and *Discoloripes* rarely are preserved articulated. Here, storm processes rather than fair-weather waves were the decisive taphonomic agents.

Fossil diagenesis

Many elements of the shelly macrobenthos are preserved as internal or composite moulds. In others, the shell has been degraded into a chalky substance that makes preparation of such specimens virtually impossible. Other shells, however, are preserved in their original shell chemistry, be it calcite or aragonite. Aragonite preservation is found, for example, in large shells of *Myophorella* and in tiny gastropods.

Dissolution of shell material and chalky texture are clearly a result of present-day weathering. Exposure of the blocks, which at present are found in the intertidal to supratidal zone, to both rain water and marine waters, quickly led to deterioration of the original shell material, especially of specimens occurring on or close to the outside of the blocks.

A puzzling feature is the preservation of aragonitic shell material in such porous, coarse-grained sediments. In most cases, such sediments are devoid of any skeletal hard parts due to early diagenetic dissolution. Aragonite preservation in Jurassic rocks is usually tied to fine-grained sediments, often clays, where porosity is low and the flow of pore water is retarded. An explanation for the preservation of aragonite may be the high rate of sedimentation that can be assumed, judging from the ubiquitous large-scale primary sedimen-tary structures and the general scarcity of bioturbation. Rapid deposition of thick sediment packages, common in very shallow-water coastal environments, may have placed some of the shell material immediately below the tapho-nomic active zone and hence beyond the influence of disso-lution processes. Alternatively, the coarse sediment pack-

ages were sealed by clay layers that impeded migration of pore fluids and thus prevented dissolution of the unstable aragonite. Unfortunately, this hypothesis cannot be tested with the present material.

Discussion
Chronostratigraphy

The following discussion concentrates on the boulders that contain shelly macrofauna. No statement is given here with respect to the age of those boulders that contain only abun-dant plant material, except that they are possibly Middle Jurassic (M. Smelror, pers. comm. 2000) judging from similar floral remains discovered in glacial erratics along the shores of Trondheimsfjorden (Vigran 1970) and on Andøya, for which a Middle Jurassic age has been ascertained based on palynomorphs (Vigran & Thusu 1975).

Although no classical index fossils such as ammonites were found in the blocks, and as the belemnites are too poorly preserved to be identified, the age of the erratic boul-ders can be determined, within limits, using the bivalve fauna. The most conspicuous taxon is *Camptonectes (Mclearnia) cinctus*, which ranges from the Middle Volgian to the Aptian (see Appendix: Taxonomic notes). The wide-spread *Entolium (E.) orbiculare* is known from the Kimmeridgian to the Albian (Kelly 1984). *Hartwellia (H.) kharoschovensis* is known from the Middle Volgian of East Greenland, the genus occurring from the Kimmeridgian to the Barremian (Casey 1952, S.R.A. Kelly, pers. comm. 2003). Although the first members of the genus *Lopatinia* occur in the Boreal Sea as early as Callovian (*L. (Paralopatinia) pectun-culoides* (Trautschold, 1861) from northern Siberia; Sanin et al. 1984) and Oxfordian (*L. callomoni* Fürsich, 1982 from the Oxfordian Aldinger Elv Member of Milne Land, East Greenland; Fürsich 1982), the genus characteristically occurs in northern Siberia from the Volgian to the Hauterivian. The new species from the Sortland Basin does not provide infor-mation on the age of the boulder in which it occurs. However, in shape and size *L. sortlandensis* is more closely related to the Callovian *L. pectunculoides* than to the large Cretaceous members of the genus and therefore might be a Late Jurassic representative of the genus. *Astarte (A.) chetaensis* has been recorded from the Volgian of northern Siberia (Zakharov 1970) whereas *A. (A.) veneriformis* was described from the Valanginian of Siberia (Zakharov 1970). The genus *Meleagrinella* ranges from the Late Triassic to the end of the Jurassic. *Discoloripes fischerianus* is known from the Volgian and Ryazanian (Kelly 1992). *Myophorella (M.) intermedia* has been described from the Middle and Late Volgian (Kelly 1984), and *Isocyprina (?Venericyprina) birkelundi* from the Middle Volgian (Fürsich 1982). The speci-mens of *Buchia* found in the boulders are unfortunately too poorly preserved to be identified at the species level. Still, they appear to belong to a group of *Buchia* characteristic of the Late Jurassic rather than the Early Cretaceous. In conclu-sion, the available evidence points to an end-Jurassic, possi-bly Middle to Late Volgian age of the erratics, if all boulders

represent a single time span. [No agreement has yet been reached on the placement of the Jurassic-Cretaceous boundary. It is here taken to coincide with the Volgian-Ryazanian boundary as proposed by Gradstein & Ogg (1996) and not between the Middle and Upper Volgian (= Tithonian-Berriasian boundary) as envisaged by other authors such as Zakharov et al. (1996) and Zeiss (2003)].

However, there exists also the possibility that the boulders come from different levels of the stratigraphic column, possibly separated by large stratigraphic gaps. If true, a Late Jurassic to Early Cretaceous age appears likely. At present, this point cannot be decided based on the available faunal data.

These conclusions are in sharp contrast to results obtained by analysis of the dinocyst assemblages found in boulders that also contained the shelly macrobenthos. According to M. Smelror (pers. comm. 2000) *Cyclopsiella*, occurring abundantly in these blocks, indicates a Middle Jurassic age. None of the macrobenthic taxa, however, supports such an age. The apparent discrepancy in age based on the two lines of evidence can be explained by reworking of the plant microfossils. This, in turn, would imply extensive non-sedimentation or erosion of Middle to Late Jurassic sediments in some parts of the basin. Assuming a fault-controlled basin margin subject to antithetic block faulting (see below; Davidsen et al. 2001), such a situation might have existed at the top of a tilted fault block. In this way, sediment and microflora eroded from the top could have been redeposited in younger sediments of the adjacent graben.

In order to obtain additional, independent evidence on the chronostratigraphic position of the rocks, the $^{87}Sr/^{86}Sr$ stable isotope ratio of two oyster shells has been determined in the isotope laboratory of the Ruhr University in Bochum. The sample TSGF 11693 (Ste 31) comes from the *Entolium - Pseudolimea - Oxytoma* biofacies, and the sample TSGF 11627 (Str 30) from a block with rare, non-diagnostic fragmented fossils (oysters, belemnites, *Meleagrinella*, rhynchonellid, *Serpula, ?Plagiostoma*). Both samples yielded more or less identical values ($\delta^{87}Sr = 0.707088$ +/- 0.000006 and 0.707085 +/- 0.000007). According to T. Steuber (pers. comm. 2003), the values of the Bochum laboratory have to be corrected by + 0.000029 in order to use the look-up table of McArthur et al. (2001). [For a discussion of the method of strontium isotope stratigraphy, see McArthur (1998)]. Using the time scale of Gradstein et al. (1994), the corrected mean value (0.707116) corresponds to an age of 147.4 Ma, i.e. the late Early Volgian. Thus, the Sr isotope values clearly support the Late Jurassic age of the two investigated boulders, arrived at by the analysis of the benthic macrofauna.

Palaeoenvironments

Sedimentological and taphonomic data of most erratics indicate a nearshore, high-energy environment. The highly immature sediment suggests a high relief hinterland, from which the weathered rock material was transported into the sea, most likely via short-headed streams. Nearshore conditions are also indicated by boulders in which plant material is common. Boulders devoid of fossils apart from plant fossils may represent fluvial to estuarine environments, as these beds also lack marine dinocysts. As discussed before, they probably are Middle Jurassic in age and thus distinctly older than the boulders containing the benthic macrofauna.

Bedding planes and foresets of crossbeds rich in plant debris and plant fragments or wood pieces associated with marine bivalves (and thus Late Jurassic in age) also point to nearshore environments. However, judging from the autecology of the shelly macrobenthos and its distribution elsewhere in the Jurassic, only a few of the faunal elements are characteristic of shallow-water, high-energy environments. Thus, *Ditrupa* has been encountered as a very common fossil in the Oxfordian Aldinger Elv Member of Milne Land, East Greenland, which has been interpreted as a high-energy submarine shoal (Fürsich & Heinberg 1983). The fast burrowing bivalves *Tancredia* and *Corbicellopsis* were able to cope with shifting substrates and thus were also adapted to life in shallow, high-energy environments. The bulk of the benthic macrofauna, in contrast, is more characteristic of open marine shelf environments below the fair-weather wave base. Many of the taxa recorded here also occur in the Volgian Pernaryggen Member of East Greenland, interpreted to record offshore conditions (Fürsich 1984). A major difference lies in the relative abundance of the taxa. Thus, brachiopods and *Buchia* are rare elements in the erratics, whilst they are abundant in East Greenland where they dominate several benthic associations.

The faunal composition of the erratics and the different biofacies thus record several environments in the Sortland Basin during the Late Jurassic, ranging from high-energy, nearshore, above the fair-weather wave base, to somewhat quieter, more offshore environments (*Myophorella - Nicaniella* biofacies). A littoral (beach) facies is not directly recorded but the vein quartz pebbles occurring in some of the blocks might have had their origin in pebbly beaches where they became well rounded in the swash zone. The bulk of the sediment is structurally and compositionally immature. The discrepancy between the immature sediment and signs of high-energy conditions can be solved by assuming a steep topography, as a result of which sediment was quickly removed from areas of constant wave action and became deposited in deeper parts of the basin. A prerequisite for this scenario is rapid differential subsidence, by which accommodation space and the steep morphological gradient is upheld. This corroborates the model of a fault-controlled shoreline with tilted fault blocks, which is also supported by seismic data. Such a scenario mirrors the western margin of the Arctic Sea in East and Northeast Greenland, which has been demonstrated to have consisted of antitethically faulted blocks (e.g., Surlyk 1978). Surlyk also showed that block faulting was active in the Late Jurassic-Early Cretaceous, i.e., at the presumed time that the sediments of the Sortland erratics were deposited.

Table 3. List of benthic macroinvertebrates recovered from Upper Jurassic-Lower Cretaceous strata of Andøya (compiled and modified from Birkelund et al. 1978, Zakharov et al. 1981, Thomsen 1996, Norborg et al. 1997).

Buchia ex gr. *Buchia russiensis* (Pavlow)
Buchia mosquensis (v. Buch)
Buchia cf. *Buchia terebratuloides* (Lahusen)
Buchia volgensis (Lahusen)
Buchia inflata (Lahusen)
Buchia keyserlingi (Trautschold)
Buchia sublaevis (Keyserling)
Buchia crassicollis (Keyserling)
Entolium (Entolium) orbiculare (J. Sowerby)
Camptonectes (Camptonectes) sp.
Camptonectes aff. *Camptonectes (Mclearnia) cinctus* (J. Sowerby)
Chlamys sp.
« *Inoceramus* » sp.
Gryphaea cf. *Gryphaea (Bilobissa) dilatata* J. Sowerby
Lima sp.
«*Ostrea*» sp.
Astarte sp.
Corbicellopsis sp.
Pleuromya aff. *Pleuromya uniformis* (J. Sowerby)
Pholadomya (Pholadomya) sp.

Comparison with of other Mesozoic faunas from northern Norway

An erratic boulder containing Mesozoic faunas has been discovered in northern Norway at Brottøya, Hanø, Vesterålen (Ravn & Vogt 1915) and dated as Neocomian based on bivalves. However, the fauna figured and described by Ravn & Vogt (*Barbatia, Oxytoma, Lima, Acesta, Camptonectes (Camptonectes)*, and *Isognomon*) is not diagnostic enough to warrant a designation as precise as Neocomian. It may equally well belong to the Upper Jurassic.

Outcrops of Mesozoic sediments and faunas occur on Andøya, where plant microfossils (pollen, spores, dinocysts and acritarchs), plant macrofossils, the benthic macrofauna (in particular *Buchia*) and ammonites record a Middle Jurassic (Bajocian-Bathonian) to Early Cretaceous (Valanginian) age (Lundgren 1894, Sokolov 1912, Ørvig 1960, Dalland 1975, 1979, 1980, Birkelund et al. 1978, Zakharov et al. 1981, Manum et al. 1991. For a review see Thomsen 1996). Despite the relatively large total area and wider stratigraphic range, the diversity of the benthic macrofauna is distinctly lower than that recovered from the Sortland erratics (Table 3): It consists of 20 taxa, all of them bivalves, in 13 genera/subgenera compared to 38 taxa in 34 genera/subgenera from Sortland. This difference in faunal diversity may partially be an artefact, as the benthic macrofauna from the Andøy Basin has never been comprehensively described. The difference is even more striking considering that eight of the 20 taxa belong to the genus *Buchia*. The dominance of *Buchia* and the occurrence of ammonites in the Volgian-Neocomian succession of the Andøya Basin (Birkelund et al. 1978) suggest a deeper, more offshore setting than that recorded by the Sortland erratics.

Conclusions

The erratic blocks occurring on the shore at Sortland are rich either in plant debris or in skeletal elements. Except for belemnites, the latter belong to benthic taxa, mainly bivalves, but also brachiopods, serpulids, echinoderms and gastropods have been recorded. The benthic fauna is represented by 39 taxa and can be grouped into eight assemblages that, in most cases, represent reworked, sorted and/or transported relics of former communities. These assemblages occur in poorly sorted, fine- to coarse-grained siliciclastic sediments that either exhibit large-scale cross-bedding or are thoroughly bioturbated. They form characteristic biofacies that record a range of environments, from shallow-water, high-energy settings to offshore quieter environments below fair-weather wave base. It is proposed that the depositional setting was a fault-controlled coastal environment with tilted fault blocks, similar to the situation at the western margin of the Arctic Sea at that time. The benthic macrofauna suggests a Volgian age for most of the Sortland erratics. This assumption is corroborated by the $^{87}Sr/^{86}Sr$ stable isotope ratio of two oyster shells that yielded a late Early Volgian (= Early Tithonian) age.

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Appendix
Taxonomic notes on the macrofossils

The following account is by no means a monographic treatment of the nearly 40 taxa that have been identified from the erratics of Sortland. In many cases, poor preservation prevented a precise identification of the taxa and does not merit their description. Moreover, most of them are common Jurassic taxa that have been described repeatedly in the past and the present material offers little new information. The account therefore deals largely with taxa that either offer information on the age of the boulders or else are very characteristic elements of the biofacies.

Phylum Annelida Lamarck, 1802
Class Polychaeta Grube, 1850

Genus *Ditrupa* Berkeley, 1835

Ditrupa sp.

Remarks. In some of the blocks, the small, slightly curved conical tubes with a circular cross-section, are the most characteristic faunal element. Although in many cases, the tubes are broken, there are also layers in which they are mainly

complete. Similar concentrations of *Ditrupa* are known from the Oxfordian Aldinger Elv Member of Milne Land, East Greenland (Fürsich 1984).

Phylum Mollusca Cuvier, 1797
Class Bivalvia Linné, 1758

Genus *Lopatinia* Schmidt, 1872
Subgenus *Paralopatinia* Sanin, 1984

Type species. *Arca pectunculoides* Trautschold, 1861.

Lopatinia (Paralopatinia) sortlandensis sp. nov.
Fig. 3 A-F, H

Derivation of name. After Sortland, the locality of the boulder, in which the specimens were found.

Material. Holotype: Right valve TSGF11843a on erratic boulder from Sortland (?Upper Jurassic). Numerous paratypes, partly preserved as internal moulds, partly with remains of shell on the same boulder.

Diagnosis. Relatively small, moderately inflated, subtriangular *Lopatinia* with faint, broadly rounded posterior umbonal ridge and obliquely subtruncated posterior margin. Surface ornamentation of numerous fine, rounded radial riblets, many of which are paired.

Dimensions (in mm).	L	H
	165	130
	195	160

Description. The moderately inflated shells are subtriangular in outline and longer than high. The umbo is mesial, broadly rounded, and slightly anteriorly directed. There is a faint, broad, posterior umbonal ridge. The ventral margin is straight to slightly convex, the anterior margin well rounded and the posterior margin is nearly straight and oblique. Anterior and posterior margins form a rounded, blunt angle with the straight dorsal margin. There is a distinct cardinal area below the beak, ornamented with inverted V-shaped striae. The shell is ornamented with numerous fine, rounded, radial riblets many of which are paired. The radial riblets are crossed by still finer growth lines. Where growth lines are more pronounced, a reticulate pattern may be seen. Growth halts are commonly developed.

The hinge consists anteriorly and posteriorly of four subhorizontal teeth, slightly downwards directed with respect to the shell margin. In the centre of the hinge plate there are a number of small, vertical to subvertical teeth. Ventrally, these teeth are increasingly shorter due to the curvature of the hinge plate.

Remarks. The present specimens fit none of the known species of *Lopatinia* figured, for example, by Sanin et al. (1984). The Volgian to Lower Cretaceous species from northern Siberia discussed by these authors [*L. woodsi* Sanin,

1984, *L. taimyrensis* Sanin, 1984, *L. uralica* Sanin, 1984, *L. gigantae* Sanin, 1984, and *L. arctica* (Bodylevsky, 1968)] are generally much larger and, except for the latter one, more elongated. The Oxfordian *L. callomoni* Fürsich, 1982 from Milne Land, East Greenland, is less inflated and also distinctly more elongated. *L. (Paralopatinia) pectunculoides* (Trautschold, 1861) from the Callovian to Kimmeridgian of northern Siberia is more strongly ribbed, but appears to be quite variable. Finally, in *L. petchorae* (Keyserling, 1846) from glacial erratics of northern Siberia, the lateral teeth are far more steeply inclined than in the present specimens.

Sanin (in Sanin et al. 1984) erected the new subgenus *Paralopatinia*, based on the type species *Lopatinia (Paralopatinia) pectunculoides* (Trautschold, 1861). Sanin´s diagnosis reads as follows [translated from Russian]: "Shell small, covered with paired radial ribs. Pseudocardinals poorly developed. Ventral margin straight". In contrast, the subgenus *Lopatinia* is characterised, according to Sanin et al. (1984), by a medium to large shell, covered with very characteristic, flat, narrow, radial ribs. The cardinal area is well developed. Pseudocardinals are of two types.

The morphological features of *L. sortlandensis* are somewhat intermediate between the features of the two subgenera. The ribbing is identical to that found on some *Lopatinia* s.s. (e.g. *Lopatinia (L.) arctica* as figured by Sanin et al. 1984 on pl. 6, fig.3). The well developed cardinal area also speaks for *Lopatinia* s.s.. In contrast, the small size of the species is more characteristic of *Paralopatinia*. The ribbing of the type species of this subgenus is, however, quite different from that of *L. sortlandensis*. Considering the features of the present species, it is highly doubtful whether a distinction between the various species of *Lopatinia* at the subgeneric level is practical.

Genus *Modiolus* Lamarck, 1799

Modiolus sp.
Fig. 3G

Remarks. The small, highly inflated composite mould of a right valve shown in Fig. 3G is damaged in the umbonal area.

Next page:
Fig. 3: A-F, H. *Lopatinia (Paralopatinia) sortlandensis* sp. nov.. A. Hinge of right valve, latex cast of internal mould, x 3; Str 16E; TSGF 11841. B. Hinge of left valve, latex cast of internal mould, x 3; Str 16E; TSGF 11842. C. Right valve (holotype), x 1.5; Str 16E; TSGF 11843a. D. Internal mould of right valve, x 1.5; Str 16E; TSGF 11843b. E, F. Characteristic surface ornamentation, E, x 6, F, x 8; Str 16E; TSGF 11843a. H. Monospecific concentration of disarticulated shells, x 0.75; Str 16E; TSGF 11843a.
G. *Modiolus* sp., right valve, x 2; Ste 37; TSGF 11753.
I. *Camptonectes (Camptonectes) auritus* (Schlotheim, 1813), right valve, x 2 ; Ste 37; TSGF 11765.
J. *Buchia* sp., right valve, x 1.5; Str 25; TSGF 11719.
K, L. *Discoloripes fischerianus* (d´Orbigny, 1845), articulated specimen; K, left valve view, L, dorsal view, x 3; Str 16D; TSGF 11844.
M. *Isocyprina (Venericyprina)* sp., internal mould of left valve with shell preserved in the hinge region, x 1.5; Str 16D; TSGF 11795.
Scale grid: 1 mm spacing.
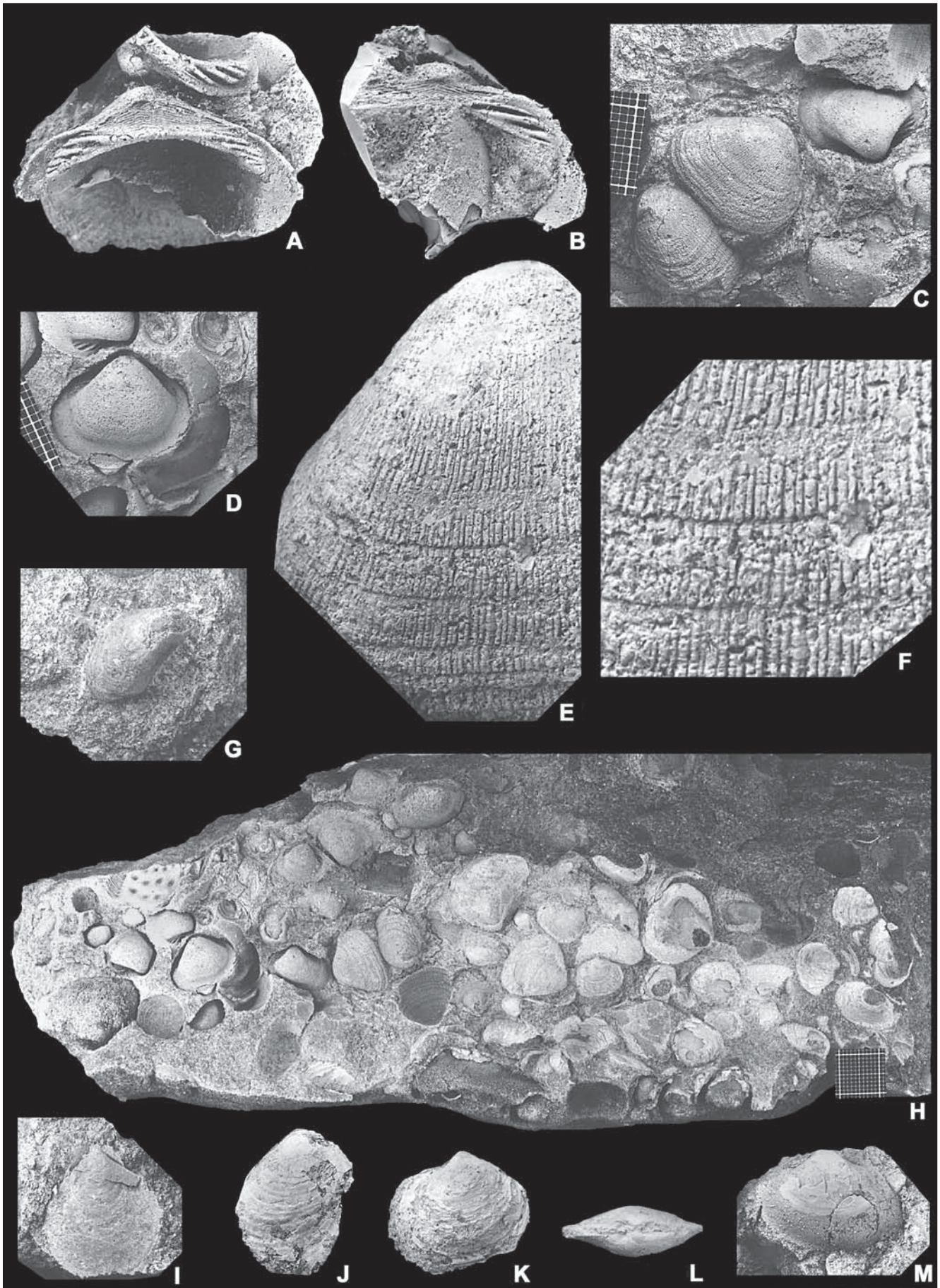
It is either a juvenile of the well known Upper Jurassic *Modiolus bipartitus* J. Sowerby, 1818, or else a closely related, but small-sized species.

Genus *Camptonectes* Agassiz in Meek, 1864
Subgenus *Camptonectes* Agassiz in Meek, 1864

Camptonectes (Camptonectes) auritus (Schlotheim, 1813)
Fig. 3I

1813 *Chamites auritus* sp. nov. - Schlotheim: 103.

Remarks. *Camptonectes (C.) auritus* occurs as relatively small specimens (height up to 16 mm), whereby often only the shell interior is seen. In some cases, part of the shell has flaked off and the characteristic ornament of divaricate punctae can be observed.

The cosmopolitan species is very long-ranging, occurring from the Hettangian to the Ryazanian (Johnson 1984).

Subgenus *Mclearnia* Crickmay, 1930

Camptonectes (Mclearnia) cinctus (J. Sowerby, 1822)
Fig. 4A

1822 *Pecten cinctus* sp. nov. - J. Sowerby: 96, pl. 371.
1936 *Camptonectes praecinctus* sp. nov. - Spath: 104, pl. 40, fig. 6, pl. 41, fig. 1.
1982 *Camptonectes (Boreionectes) praecinctus* Spath - Fürsich: 42, figs. 17A-B, 18, 19A-B.

Remarks. The large, disarticulated, weakly inflated, suborbicular shells reach up to 15 cm in height. There are only two species in which they can be accommodated; *C. (Mclearnia) cinctus* (J. Sowerby, 1822) or *C. (Mclearnia) praecinctus* Spath, 1936. According to Kelly (1984), the two species differ in *cinctus* being larger and having proportionally larger auricles. Accordingly, our specimens should be placed in *C. (M.) cinctus*. However, the size mentioned by Kelly (1984: 74) as characteristic for *C. (M.) praecinctus* is one-third the size of specimens of that species recorded from the Volgian of East Greenland (Fürsich 1982). Moreover, the proportionally smaller auricles of *C. (M.) praecinctus* may reflect allometric growth. It is therefore highly likely that *praecinctus* and *cinctus* are synonyms, the latter having priority.

According to Kelly (1984), *C. (M.) praecinctus* occurs from the Middle Volgian to the Ryazanian, whereas *C. (M.) cinctus* occurs from the Ryazanian to the Aptian. There are several large species of *Camptonectes* known also from the Oxfordian and Kimmeridgian of the Boreal Realm such as *C. (Mclearnia) broenlundi* (Ravn, 1911) and *C. (M.) validus* (Lindström, 1865), but they do not reach the size either of the Volgian and Lower Cretaceous species or of the specimens from Sortland.

Genus *Meleagrinella* Whitfield, 1885

Meleagrinella sp.

Remarks. The small internal mould of the left valve exhibits remains of shell material in the umbonal area. The high inflation of the umbonal area, indication of a posterior wing, and remains of radial ornamentation identify the specimen as *Meleagrinella*. The distinct posterior wing distinguishes the specimen from otherwise superficially similar internal moulds of *Pseudolimea*. In *Oxytoma*, the umbo of the left valve is less inflated.

Meleagrinella is locally abundant in fine-grained sediments of the subboreal and boreal Upper Jurassic, but the total range of the cosmopolitan taxon is from the uppermost Triassic to the end of the Jurassic.

Genus *Buchia* Rouillier, 1845

Buchia sp.
Fig. 3J

Remarks. The poorly preserved right valve shown in Fig. 3J is weakly convex and exhibits an outline and a posterior slope similar to that seen in *Buchia mosquensis* (v. Buch, 1844) and *Buchia rugosa* (Fischer de Waldheim, 1837). Remains of a fairly coarse ornamentation suggest that the specimen might belong to the latter species, but the preservation is too poor to decide this point. In any case, it appears to belong to the group of Late Jurassic buchiids rather than to Cretaceous forms.

Genus *Entolium* Meek, 1865
Subgenus *Entolium* Meek, 1865

Entolium (Entolium) orbiculare (J. Sowerby, 1817)
Fig. 5C-D

1817 *Pecten orbicularis* sp. nov. - J. Sowerby: 193, pl. 86.

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Fig. 4: A. *Camptonectes (Mclearnia) cinctus* (J. Sowerby, 1822), internal mould, x 0.75; TSGF 11667.
B. *Corbicellopsis* sp. A, internal mould of right valve with remains of shell in the hinge region, x 1; Str 16D, TSGF 11826.
C, G. *Corbicellopsis* sp. B. C, resin cast of external mould of a left valve, x 1; Ste 38; TSGF 11676. G, left valve, x 1; Ste 37; TSGF 11729.
D-F. *Astarte* cf. *Astarte (Astarte) chetaensis* Zakharov, 1970. D, left valve, x 1.5; Str 16A; TSGF 11845. E, right valve, x 1.5; Str 16A; TSGF 11681a. F, right valve, x 1.5; Str 16A; TSGF 11681b.
H. *Astarte (Astarte) veneriformis* Zakharov, 1970, right valve, x 3; Str 25; TSFG 11728.
I. *Tancredia* sp. A, composite mould of right valve, x 1; Ste 37; TSGF 11732.
J. *Hartwellia* cf. *Hartwellia (Hartwellia) kharoschovensis* (Rouillier & Vossinsky, 1848), resin cast of external mould of a left valve, x 1; Ste 31; TSGF 11676.
K. *Tancredia* sp. B, internal mould of left valve, x 2; Str 16D; TSGF 11814.
L-M. patellid gastropod, internal mould, L, apex view, x 2, M, side view, x 2; Ste 31; TSGF 11639.
N. *Isocyprina (?Venericyprina) birkelundi* Fürsich, 1982, articulated specimen in butterfly position, x 3, Str 16G, TSGF 11846.
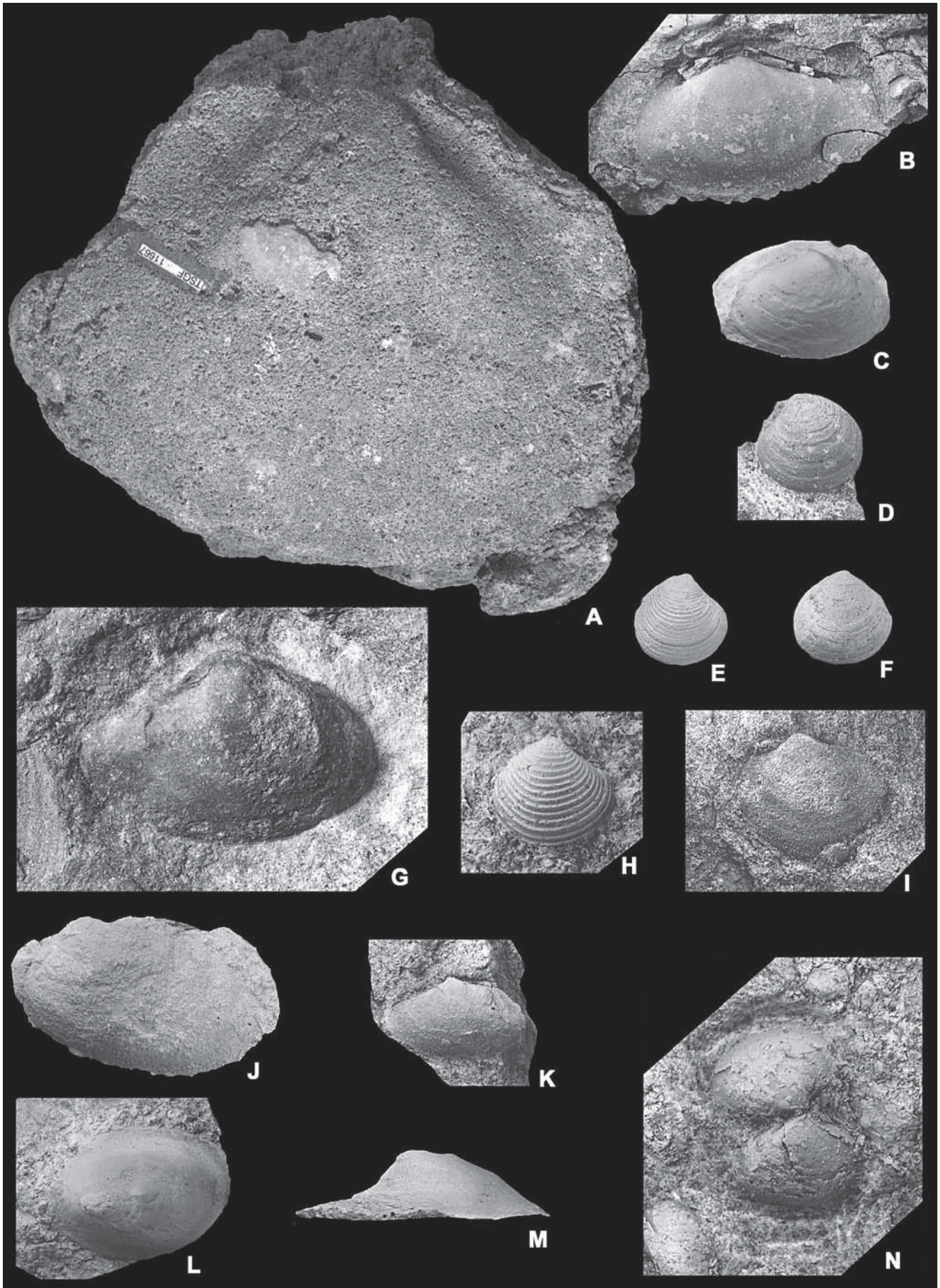
Remarks. This well known species is a common element of Upper Jurassic and Lower Cretaceous boreal faunas, occurring from the Kimmeridgian to the Cenomanian (Kelly 1984). It is one of the most abundant benthic taxa occurring in Volgian strata of East Greenland (e.g., Fürsich 1984). It is also a common component of several of the biofacies encountered in the erratic boulders from Sortland. The species is characterised by spaced, regular, commarginal grooves on the right valve. The left valve is smooth except for faint growth lines and thus indistinguishable from *Entolium (E.) corneolum*. The specimens are preserved with shell or occur as external moulds.

Genus *Pseudolimea* Arkell in Douglas & Arkell, 1932

Pseudolimea sp.
Fig. 5F

Remarks. *Pseudolimea* is a common element of many of the erratics from Sortland. The specimens usually ocur as internal moulds so that a specific identification is not possible.

Genus *Liostrea* Douvillé, 1904

? *Liostrea* sp.

Remarks. Fragments of large oysters are relatively common, but usually not well enough preserved to be identified. Most likely, the specimens belong to the genus *Liostrea*, one of the most common genera of Jurassic oysters.

Genus *Myophorella* Bayle, 1878
Subgenus *Myophorella* Bayle, 1878

Myophorella cf. *Myophorella (Myophorella) intermedia* (Fahrenkohl, 1844)
Fig. 5A-B, E

cf. 1844   *Lyriodon intermedium* sp. nov. - Fahrenkohl: 796, pl. 19, fig. 2.

Remarks. *Myophorella* cf. *M. (M.) intermedia* is a common element of some of the erratic boulders. The few well preserved specimens exhibit the typical features of the genus and subgenus, i.e. an area subdivided roughly mid-way by a distinct groove and ornamented with transverse ridges, and a flank ornament of oblique rows of tubercles. The stenomorphic specimens are very close to *Myophorella (M.) intermedia* as discussed in detail by Kelly (1984) from the Spilsby Sandstone of eastern England. They differ, however, in some details and as it is not clear at present whether these differences still fall within the range of variation of the species, the specimens are referred to Fahrenkohl's species only with doubt. For example, the outline of the specimens is distinctly subrectangular and not subtrigonal to subquadrate as described by Kelly (1984). The median groove of the area appears to be more pronounced than in the specimens from

the Spilsby Sandstone, and the transverse ornamentation of the area is stronger, consisting of distinct ridges.

Irregular tubercles, elongated in the direction of the transverse ridges border the area and are found ventrally of the median groove. The ornamentation of the flank consists of coarse tubercles, which extend in faint and irregular arcs from the area towards the ventral and anterior margins.

The irregular and very coarse flank ornament is very similar to that of *Myophorella (M.) exaltata* (Lycett, 1877) which differs, however, in tapering towards the posterior and in being much larger. Kelly (1984) suggested the possibility that *M. (M.) exaltata* is a gerontic form of *M. (M.) intermedia*, a view not supported by the present averaged-sized specimens. Still, the likelyhood cannot be ruled out that *exaltata* is merely an extreme variant of *intermedia*.

The species has been recorded from the Middle and Late Volgian (e.g. eastern England, Russian Platform, East Greenland, Poland; Kelly 1984).

Genus *Discoloripes* Wellnhofer, 1964

Discoloripes fischerianus (d´Orbigny, 1845)
Fig. 3K, L

1845   *Lucina Fischeriana* sp. nov. - d´Orbigny: 458, pl. 38, figs. 31-32.

Remarks. The small specimen (length: 8.9 mm; height: 7.5 mm) exhibits a suborbicular outline and a compressed shape. The anterodorsal margin is distinctly concave and the posterior margin somewhat truncated. These features correspond well with *Discoloripes fischerianus* (d´Orbigny, 1845), a common species in the Volgian and Ryazanian of the Boreal Realm (e.g., Fürsich 1982, Gerasimov 1955, 1969, Kelly 1992) occurring from England to East Greenland and in northern Russia. The small size of the specimen identifies it as a juvenile.

Genus *Astarte* J. Sowerby, 1816

Astarte cf. *Astarte (Astarte) chetaensis* Zakharov, 1970
Fig. 4D-F

cf. 1970   *Astarte (Astarte) chetaensis* sp. nov. - Zakharov: 52, pl. 3, figs. 1-3.

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Fig. 5: A-B, E. *Myophorella* cf. *Myophorella (Myophorella) intermedia* (Fahrenkohl, 1844), articulated specimen. A, left valve view, B, dorsal view, x 1; Str 16D; TSGF 11788. E, latex cast of external mould, x 1; Str 16D; TSGF 11788.
C, D. *Entolium (Entolium) orbiculare* (J. Sowerby, 1817). C, ?left valve, x 1; Str 25; TSGF 11686. D, right valve, x 1; Ste 37; TSGF 11674a.
F. *Pseudolimea* sp., internal mould of right valve, x 2; Ste 37, TSGF 11750.
G. *Pleuromya uniformis* (J. Sowerby, 1813), composite mould of left valve, x 1; Ste 37; TSGF 11674b.
H. Bedding plane view of block Ste 37 TSGF 11674 with pavement of bivalve shells.
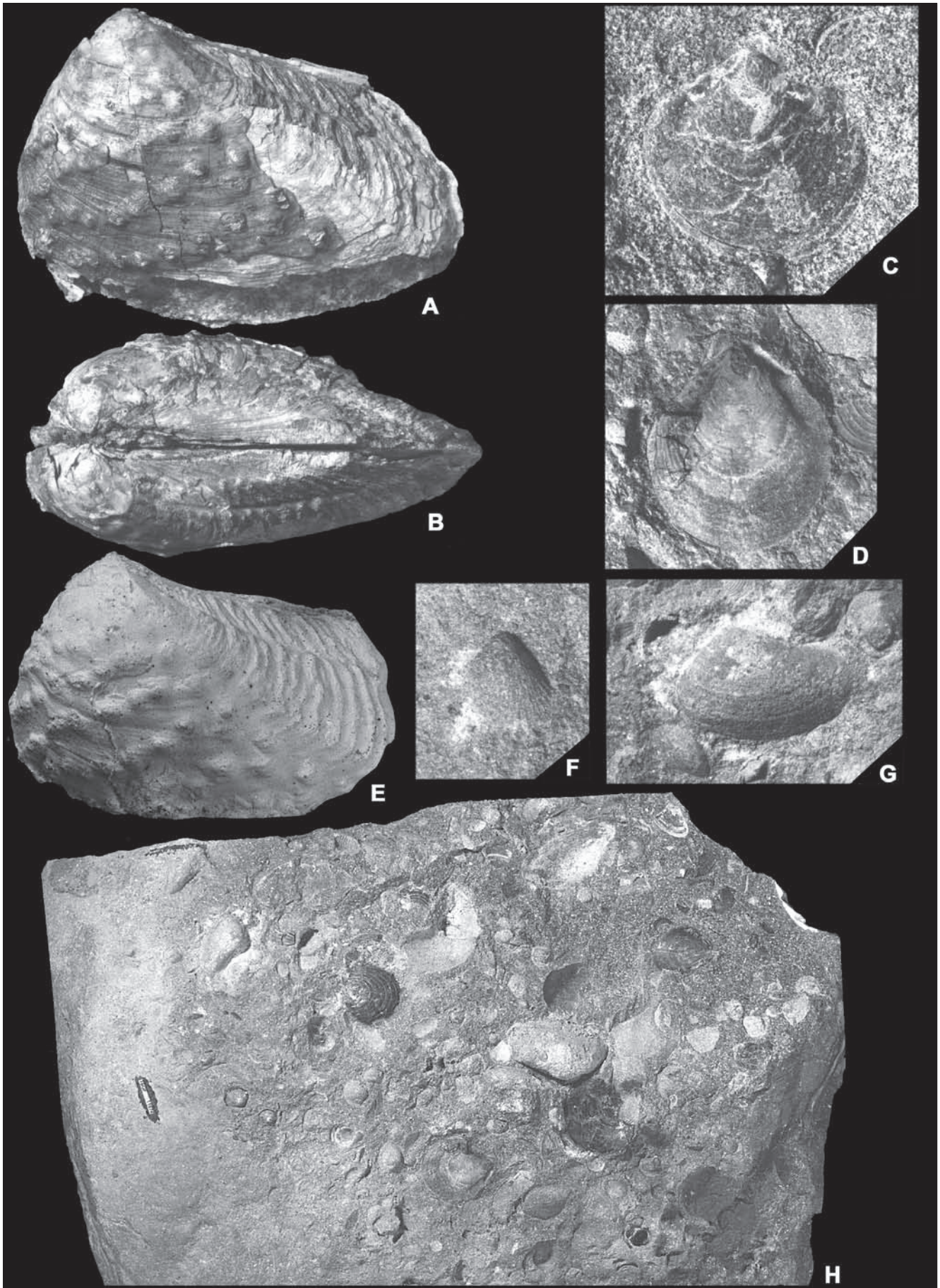
Remarks. Apart from its small size, the specimen TSGF 11681 (Fig. 4E-F) corresponds closely to Zakharov´s *A. chetaensis* from the Lower Volgian of northern Siberia. The moderately inflated specimens exhibit a distinctly concave anterodorsal margin and an ornamentation of numerous regular commarginal ribs, which appear to fade towards the ventral margin. The interior of the ventral margin is crenulated. In most specimens the ornamentations have been partially or completely worn off.

This species is very abundant in some of the blocks from Sortland, in places occurring as near-monospecific concentrations.

Astarte (Astarte) veneriformis Zakharov, 1970
Fig. 4H

1970   *Astarte (Astarte) veneriformis* sp. nov. - Zakharov: 64, pl.
         5, figs. 9-14.

Remarks. The small specimen figured in Fig. 4H (TSGF 11728) closely resembles Zakharov´s species from the Valanginian of northern Siberia, in particular the specimen figured on his pl. 5, fig. 14. The present right valve is well preserved, suborbicular in outline, and covered with about 19 very regular commarginal ribs.

Genus *Nicaniella* Chavan, 1945
Subgenus *Nicaniella* Chavan, 1945

Nicaniella sp.

Remarks. The small size and the poorly inflated umbo identify the poorly preserved specimens (many of them are external moulds) as *Nicaniella (Nicaniella)*. A specific determination is not possible. The taxon occurs in moderate numbers in some of the blocks from Sortland.

Genus *Tancredia* Lycett, 1850

Tancredia sp. A
Fig. 4I

Remarks. Two composite moulds are moderately inflated, inequilateral and exhibit remains of fine commarginal ribs or coarse growth lines. The anterior end appears to be slightly tapering. There are signs of a weakly developed posterior umbonal ridge.

These features are not sufficient to identify the material with confidence. The specimens resemble short, relatively inflated species of *Tancredia* such as *Tancredia (T.) gibbosa* Lycett (1863: 68, pl. 35, fig. 7, pl. 36, fig. 11) from the Middle Jurassic of England, but the ventral margin of that species is less strongly curved. However, as no information on the hinge structure is available, the identification remains tentative.

Tancredia sp. B
Fig. 4K

Remarks. The figured internal mould of a left valve (TSGF 11814) exhibits the characteristic features of *Tancredia* s.s., such as the tapering anterior end, the obliquely truncated posterior margin that forms a distinct angle with the posterodorsal margin, and a pallial line that bends abruptly upward posteriorly.

Genus *Corbicellopsis* Cox, 1929

Corbicellopsis sp. A
Fig. 4B

Remarks. In two of the specimens, remains of shell show that they were fairly thick-shelled. The specimens are comparatively large for the genus and distinctly elongated. The anterior end is tapering, but rounded; the posterodorsal margin is obliquely truncated and grades into the convex posteroventral margin. The anterodorsal margin is concave. The umbones are prosogyrate. In the internal moulds, the pallial line bends abruptly upward towards the posterior to meet the posterior adductor scar.

The observable features fit the genera *Tancredia* and *Corbicellopsis*. Species of *Corbicellopsis* are generally larger than those of *Tancredia* and for this reason the specimens are placed in *Corbicellopsis*. Although no species was found in the literature that could accommodate the specimens, we refrain from erecting a new species because the preservation is too poor. *Corbicellopsis laevis* (J. de C. Sowerby, 1827) from the Oxfordian of England (e.g., Arkell 1934) and also recorded from the Volgian of East Greenland (Fürsich 1982) is somewhat similar, but lacks the distinct posterodorsal angulation and has a more strongly convex ventral margin.

Corbicellopsis sp. B
Figs. 4C, G

Remarks. The external mould of a left valve is slightly damaged anteriorly. The shell is fairly compressed. The somewhat tapering anterior end of the shell is longer than the posterior one, the small, depressed umbo being in a submesial position. There is a faint posterior umbonal ridge; the slightly damaged shell surface is smooth.

Although the hinge is not known, the general shape of the bivalve closely resembles that of a typical *Corbicellopsis* so that the specimen has been referred to this genus. There is a certain similarity to *Corbicellopsis laevis* (J. de C. Sowerby, 1827) as figured, for example, by Arkell (1933: pl. 34, figs. 1-5).

Genus *Hartwellia* Kitchin, 1926

Hartwellia cf. *Hartwellia (Hartwellia) kharoschovensis*
(Rouillier & Vossinsky, 1848)
Fig. 4J

cf. 1848 *Cyprina kharoschovensis* Rouillier & Vossinsky -
       Rouillier & Vossinsky: 285, pl. 4, figs. 32 A, B, 33A-C.

Remarks. Although the anteroventral part of the external mould is missing, growth lines allow to trace the outline of the shell. It corresponds closely to that of *H. (Hartwellia) kharoschovensis* (Rouillier & Vossinsky, 1848), especially to the specimens from the Middle Volgian of East Greenland figured by Fürsich (1982: figs. 34 A-D, F).

According to Casey (1952), the genus *Hartwellia* occurs from the Kimmeridgian to the Berriasian (S.R.A. Kelly, pers. comm. 2003).

Genus *Isocyprina* Roeder, 1882
Subgenus *Venericyprina* Casey, 1952

Isocyprina (Venericyprina) sp.
Fig. 3M

Remarks. The elongated-ovate to sub-rectangular internal mould of a left valve exhibits the typical hinge of *Venericyprina*. Its outline is similar to *Isocyprina (Venericyprina) argillacea* Casey (1952: 137, pl. 8 figs. 8-9, pl. 9, figs. 5-6, text-figs. 14, 27-28, 63-64), but the preservation of the specimen is too poor to justify an identification at the species level.

According to Keen & Casey (1969), *Venericyprina* occurs from the Kimmeridgian to the Aptian.

Isocyprina (?Venericyprina) birkelundi Fürsich, 1982
Fig. 4N

1982 *Isocyprina (?Venericyprina) birkelundi* sp. nov. – Fürsich: 92, fig. 32 F-L.

Remarks. The small bivalves (maximum length 10.5 mm) resemble in outline *Isocyprina (?Venericyprina) birkelundi* recorded from the Middle Volgian of Milne Land, East Greenland (Fürsich 1982). The subtrigonal shell is slightly longer than high, moderately inflated and exhibits a faint, broadly rounded umbonal ridge. The shell is smooth except for faint commarginal growth lines. The hinge is not seen. The species is one of the commonest faunal elements in the Pernaryggen Member of Milne Land, usually occurring in great numbers. In the erratics from Sortland it was found only in one boulder, but there in great abundance. The bivalve is either preserved with its thin shell or as internal mould.

Genus *Pleuromya* Agassiz, 1843

Pleuromya uniformis (J. Sowerby, 1813)
Fig. 5G

1813 *Unio uniformis* sp. nov. - J. Sowerby: 83, pl. 33, fig. 4.

Remarks. *Pleuromya uniformis* is a long-ranging, widespread species in the Jurassic. Some of the specimens from Sortland, invariably preserved as composite moulds, exhibit a distinctly convex ventral margin (e.g., the specimen TSGF 11674 of Fig. 5G) and relatively fine commarginal growth rugae and are intermediate in shape and ornamentation between typical *P. uniformis*, *P. triangularis* Fürsich, 1982, and *P. alduini* (Brongniart, 1821). Thus, they are a characteristic example of the morphological plasticity of this species in the Jurassic.