BUCHIID BIVALVES FROM THE UPPER JURASSIC AND LOWER CRETACEOUS OF EAST GREENLAND

by F. SURLYK *and* V. A. ZAKHAROV

ABSTRACT. Bivalves of the genera *Praebuchia* and *Buchia* described here occur in great abundance in the Oxfordian to Valanginian Stages of East Greenland. Fifteen species have been identified. Their stratigraphic range is roughly the same as in other Arctic areas, and a detailed zonation based on buchiid bivalves seems to be valid from Arctic Canada over East Greenland to Andøy, Svalbard, Petshora River basin, Subarctic Urals, and northern Siberia. The following zones and beds have been recognized in East Greenland: The Upper Oxfordian *Praebuchia kirghisensis* Zone, the Kimmeridgian *Buchia concentrica* and *B. tenuistriata* Zones, the Middle Volgian *B. mosquensis* Zone and *B. russiensis* beds, the Upper Volgian *B. fischeriana* beds, the Upper Volgian-lowermost Ryazanian *B. unschensis*–*B. terebratuloides* beds, the Lower Ryazanian *B. okensis* Zone, the Upper Ryazanian *B. volgensis* Zone, the uppermost Ryazanian–lower Lower Valanginian *B. inflata* Zone, the upper Lower Valanginian *B. keyserlingi* Zone, the Upper Valanginian-(?) Hauterivian *B. sublaevis* and *B. crassicollis* Zones.

THE genus *Buchia* has been recognized at many localities in the Upper Jurassic and Lower Cretaceous of East Greenland (text-fig. 1). Madsen (1904), Ravn (1911), Spath (1936, 1947, 1952), Frebold (1933), Jeletzky (1965), Surlyk and Clemmensen (1975) and Surlyk (1973) all described and figured species of *Buchia*. Most of this material is restricted to scattered finds. A biostratigraphic scheme incorporating figured species of *Buchia* based on a large material collected in measured sections was constructed by Surlyk (1978*a*, *b*), and the present paper is the first monographic account of the Greenland material of this stratigraphically important genus, and its predecessor *Praebuchia*. The material was collected by one of us (F.S.) in south Jameson Land in 1970 and 1971 and in Kuhn Ø and Wollaston Forland in 1974 (text-fig. 1 and fig. 9 in Surlyk 1978*a*). Material collected by F. Fürsich on Milne Land in 1977 has also been incorporated.

Species of *Praebuchia* and *Buchia* occur scattered throughout the Upper Oxfordian–Kimmeridgian dark mudstones of the Hareelv and Bernbjerg Formations (text-figs. 1, 2; Table 1) (Surlyk *et al.* 1973; Surlyk 1977). The shallow marine, coarse sandstones of the Lower Volgian–Lower Valanginian Raukelv Formation and the slightly deeper water silt- and sandstones of the Ryazanian–Lower Valanginian Hesteelv Formation (Surlyk 1973) contain a more diverse *Buchia* fauna. The greatest density and diversity are, however, reached in the relatively deep-water conglomerates, sandstones, and mudstones of the Middle Volgian–Valanginian Wollaston Forland Group (Surlyk 1978*a*).

Some uncertainty still exists concerning the stratigraphic nomenclature across the Jurassic–Cretaceous boundary. The deposits of the Boreal faunal realm cannot yet be precisely dated within the framework of the Tithonian–Berriasian Stages of the Tethyan realm. Russian authors generally use the Volgian as the final Jurassic stage and the Berriasian as the basal Cretaceous stage in the boreal USSR. Casey (1973) suggested that the Volgian and Berriasian Stages overlapped and advocated the use of the Ryazanian Stage for the basal Cretaceous deposits until Tethyan–Boreal correlations were satisfactorily established. This usage has been followed in all subsequent work on the Jurassic–Cretaceous boundary strata in East Greenland (Surlyk *et al.* 1973; Surlyk 1973, 1977; 1978*a*, *b*; Birkelund, Callomon and Fürsich 1978).

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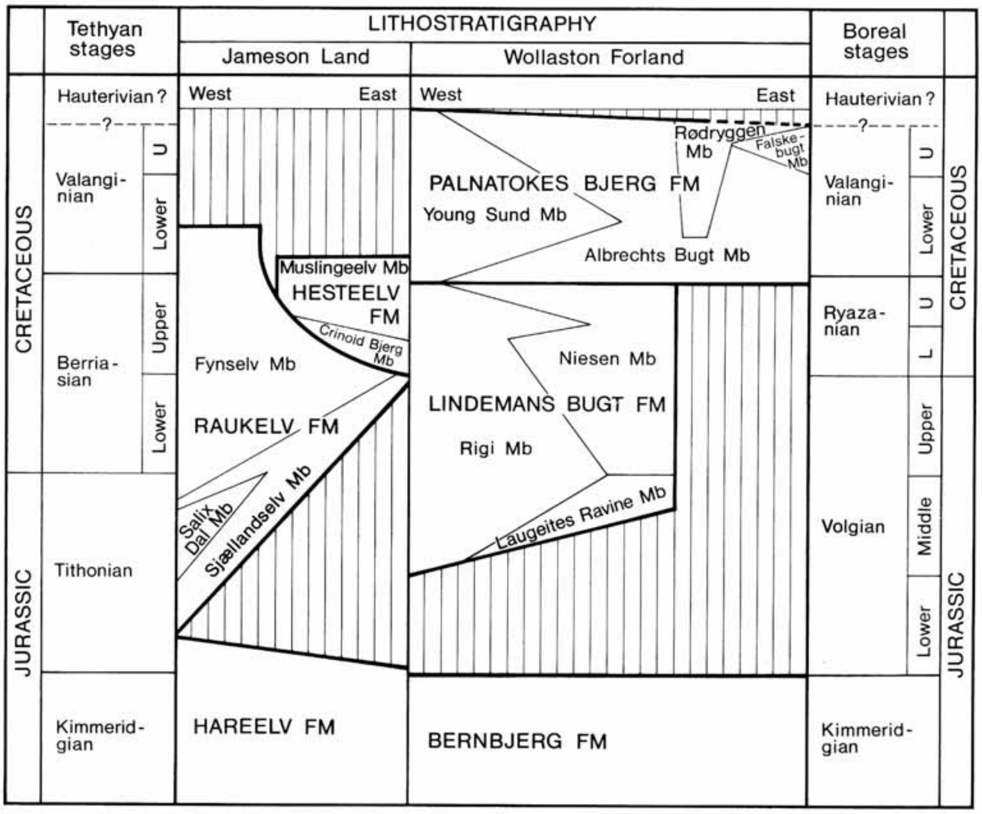
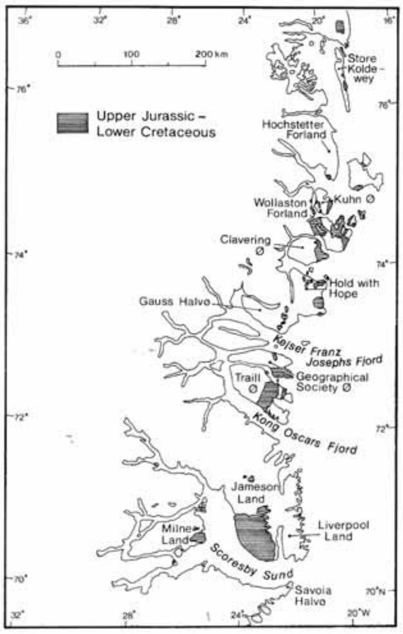
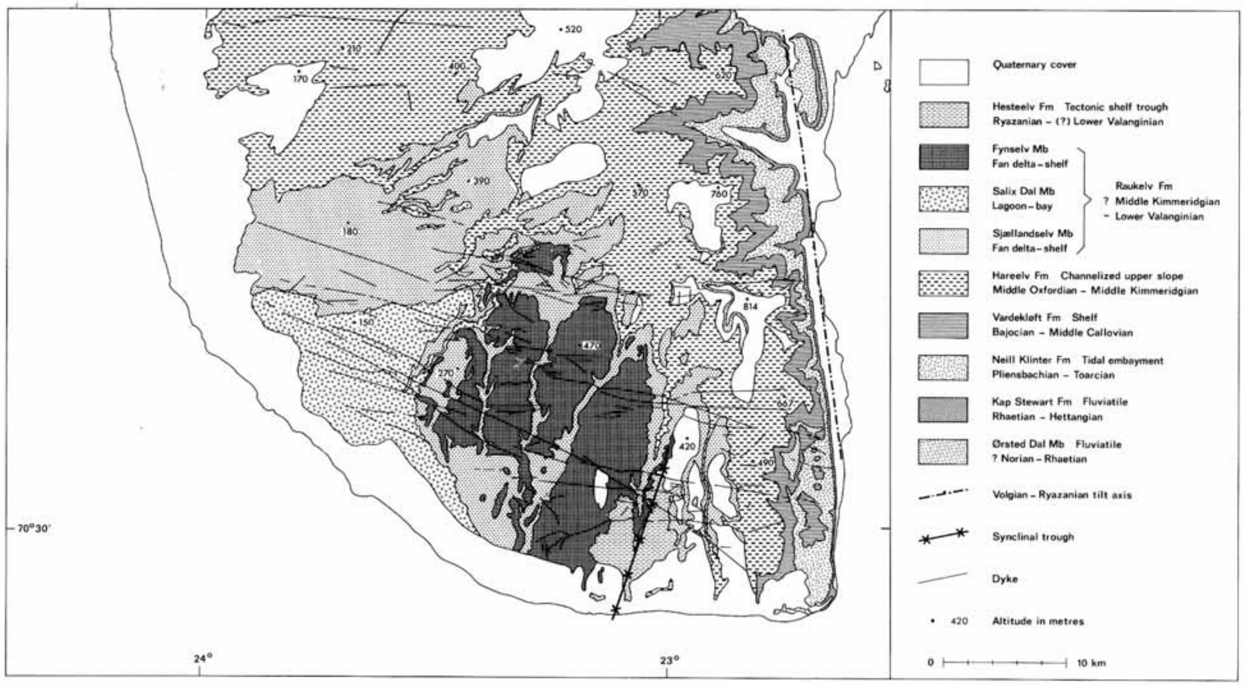


TABLE 1. Lithostratigraphy of the Jurassic–Cretaceous boundary sequences in Jameson Land and Wollaston Forland, East Greenland.



TEXT-FIG. 1. Map showing the localities mentioned in the text and the distribution of the Upper Jurassic–Lower Cretaceous *Buchia*-bearing sediments.



TEXT-FIG. 2. Simplified geologic map of southern Jameson Land showing distribution of the Jurassic–Cretaceous boundary strata and main synsedimentary structural features. Modified from unpublished GGU map compiled by F. Surlyk and T. Birkelund.

It is therefore also used in the present paper, although Zakharov (1981) in his monograph on *Buchia* of the Arctic USSR follows the general Russian practice. It should, however, be noted that Berriasian *sensu Rossico* is identical with the Ryazanian as defined on the Russian Platform (Casey 1973) and more or less identical with Berriasian/Ryazanian as used in Siberia (see Table 1).

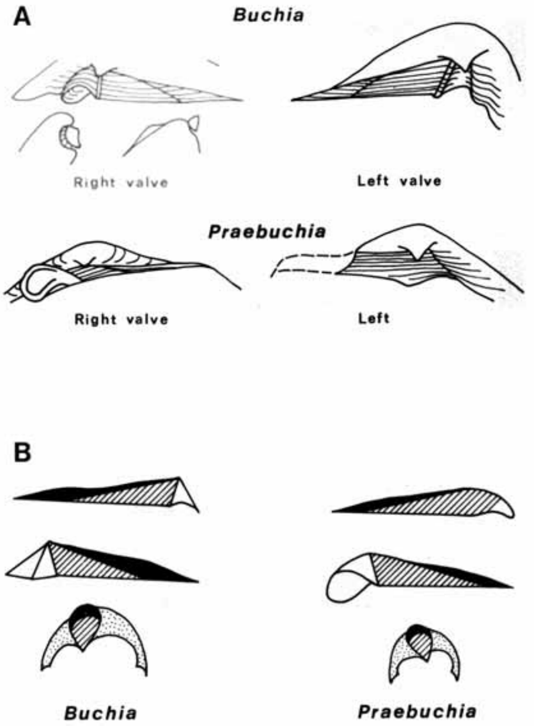
The lithostratigraphic nomenclature follows Surlyk *et al.* (1973) and Surlyk (1973, 1977, 1978*a*) and the majority of the sections where buchiid bivalves have been collected are figured in these papers.

SYSTEMATIC PALAEONTOLOGY

Boreal buchiid bivalves include two genera: *Praebuchia* Zakharov (1981) (Callovian–Oxfordian) and *Buchia* Rouillier (1845) (Oxfordian–Hauterivian) (text-fig. 3). In *Praebuchia* five species are recognized, while *Buchia* is represented by more than thirty species. The main difference between the two genera lies in the morphology of the hinge.

In *Praebuchia* the ligamental area is placed in the commissure plane, while in *Buchia* it forms an angle with this plane. *Praebuchia* is furthermore characterized by continuous grooves on the ligamental area anteriorly to the umbo, while in *Buchia* they are interrupted by a transverse ridge from the umbo (text-fig. 3). The ligament of *Praebuchia* was internal, whereas it was partly external in *Buchia*. *Buchia* possesses a well-developed byssal notch, while the margin of the ligamental area of *Praebuchia* is only slightly curved to allow the passage of an anterior auricle (Zakharov 1981).

Buchiid bivalves are characterized by a rapid rate of evolutionary change, and show a wide geographical distribution within the Late Jurassic–Early Cretaceous of the Boreal Realm, where they occur in a wide variety of facies. Taken together, these features make buchiid bivalves extremely



TEXT-FIG. 3. A, hinge structure in *Buchia* (from Zakharov 1981, fig. 5) and *Praebuchia* (from Zakharov 1981, fig. 26). B, comparison of ligament structure and position in *Buchia* and *Praebuchia*. Upper row, left valves; middle row, right valves; lower row, transverse sections. Lamellar layer is shown in black, and fibrous layer is cross-hatched. The main portion of the shells is indicated with stippled ornamentation.

valuable for stratigraphic purposes and they have accordingly received considerable attention for more than a hundred years.

This has led to a proliferation of names, and at present about 150 specific names have been founded within the genus *Buchia* alone. This extreme splitting is, however, opposed by another group of workers, who have used a very broad species concept. Either approach by itself may be detrimental for sound stratigraphic work, and the taxonomy at species level has to be based on studies of large, well-preserved populations. A discussion of these problems is given by Zakharov (1981). Full synonymy lists are also given for each species by Zakharov (1981) and here we only include earlier references from Greenland.

Family BUCHIIDAE Cox, 1953
Genus PRAEBUCHIA Zakharov, 1981

Type species. Praebuchia orientalis Zakharov, 1981

Range. Upper Callovian–Lower Oxfordian, northern Siberia.

Praebuchia kirghisensis (Sokolow, 1902)

Plate 72, figs. 1–3

1911 *Aucella kirghisensis* Ravn, p. 455, pl. 32, fig. 2.

Material. About ten poorly preserved specimens from Wollaston Forland, sections 38 and 41 in Surlyk (1977), and more than forty well-preserved specimens from Milne Land collected by F. Fürsich in 1977. Includes GGU 139450 (cf.), GGU 139451 (cf.) = MGUH 15341, GGU 139480 (cf.), GGU 235458 = MGUH 15348 (F. Fürsich coll.), GGU 235459 = MGUH 15349 (F. Fürsich coll.).

Remarks. Both casts and preserved valves of this equivalved species are easy to determine because of the lack of concentric ribs, their almost smooth surfaces, and moderately oblique angle (60°) between the hinge and median line. The shell is considerably inflated (Pl. 72, figs. 1, 2). The specimens from Milne Land are almost identical with specimens from Petshora River and Moscow region figured by Zakharov (1981, pl. 2).

Stratigraphical occurrence. The Milne Land material is from the Aldinger Elv Member (Upper Oxfordian Zones of *Amoeboceras glosense* and *A. serratum*). The Wollaston Forland specimens occur in the Upper Oxfordian part of the Bernbjerg Formation (*A. serratum* and *A. regulare* Zones). Ravn's (1911) specimen from Store Koldewey is from the Upper Oxfordian Kløft I Formation (Tables 2, 3).

In the northern part of the northern Eurasian Urals the species occurs throughout the Oxfordian but reaches peak abundances in the Upper Oxfordian (*A. alternans Zone*).

Genus BUCHIA Rouillier, 1845

Type species. Avicula mosquensis von Buch, 1844, p. 537.

Range. Lower–Middle Volgian of the Russian Plain.

Buchia concentrica (J. de C. Sowerby, 1829)

Plate 72, fig. 5

1911 *Aucella bronni* Ravn, p. 455, pl. 32, fig. 5.
1911 *Aucella sinzovi* Ravn, p. 456, pl. 32, fig. 3.
1911 *Aucella* cf. *reticulata* Ravn, p. 458, pl. 32, fig. 4.
1935 *Aucella* aff. *bronni* Spath, p. 53, pl. 3, fig. 2; pl. 8, fig. 3.

Material. About ten specimens from Kuhn Ø and Wollaston Forland (sections 1, 8, 40 in Surlyk 1977). Includes GGU 139305, GGU 139331, GGU 139332 = MGUH 15329, GGU 139471 (cf.).

Remarks. The species is characterized by its distinct radial ribs crossed by concentric ribs resulting in the formation of reticulate ornamentation. The upper part of the right valve is slightly concave in typical specimens. The shell is strongly oblique (Pl. 72, fig. 5). Poorly preserved specimens can be mistaken for *B. tenuistriata.*

Stratigraphical occurrence. Upper Oxfordian of Milne Land and Store Koldewey, and Kimmeridgian of Milne Land, Wollaston Forland, and Kuhn Ø (up to and including the Zone of *Aulacostephanus mutabilis*) (Tables 2, 3).

B. concentrica has the widest geographic distribution within the Boreal Realm of the Oxfordian-Lower Kimmeridgian species of *Buchia.* It is particularly abundant in the Lower Kimmeridgian (Zones of *Pictonia baylei* and *Rasenia cymodoce*). The specimens from the Upper Kimmeridgian of East Greenland (*A. mutabilis* Zone) are poorly preserved and the determination is questionable.

Buchia lindstroemi (Sokolow, 1908)

Plate 72, fig. 4

Material. Well-preserved internal mould of one right and one left valve from Milne Land collected by T. Birkelund and J. H. Callomon. Includes GGU 234071 = MGUH 15347 (F. Fürsich coll.)

Remarks. The species is characterized by its large adult size, strongly oblique shape, and ornamentation comprising strong closely but irregularly spaced folds with superimposed ribs. The less prominent radial ornamentation consists of weak striae.

Stratigraphical occurrence. In East Greenland the species has only been found in the Lower Kimmeridgian. This rare species occurs in the Upper Oxfordian-Lower Kimmeridgian of Eurasia and northern Alaska (Imlay 1959). It is everywhere associated with *B. concentrica,* but in northern Siberia ammonite evidence confirmed occurrences only in the Lower Kimmeridgian.

Buchia tenuistriata (Lahusen, 1888)

Plate 72, figs. 6-11; Plate 73, figs. 1, 2

1911 *Aucella tenuistriata* Ravn, p. 458, pl. 32, fig. 7.

Material. About twenty specimens from Kuhn Ø (section 8, Surlyk 1977), and more than fifty specimens from the collection of Maync (1947). The latter are from a locality on the west coast of Kuhn Ø, but the exact location

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EXPLANATION OF PLATE 72

All specimens except 9 are figured in natural size.

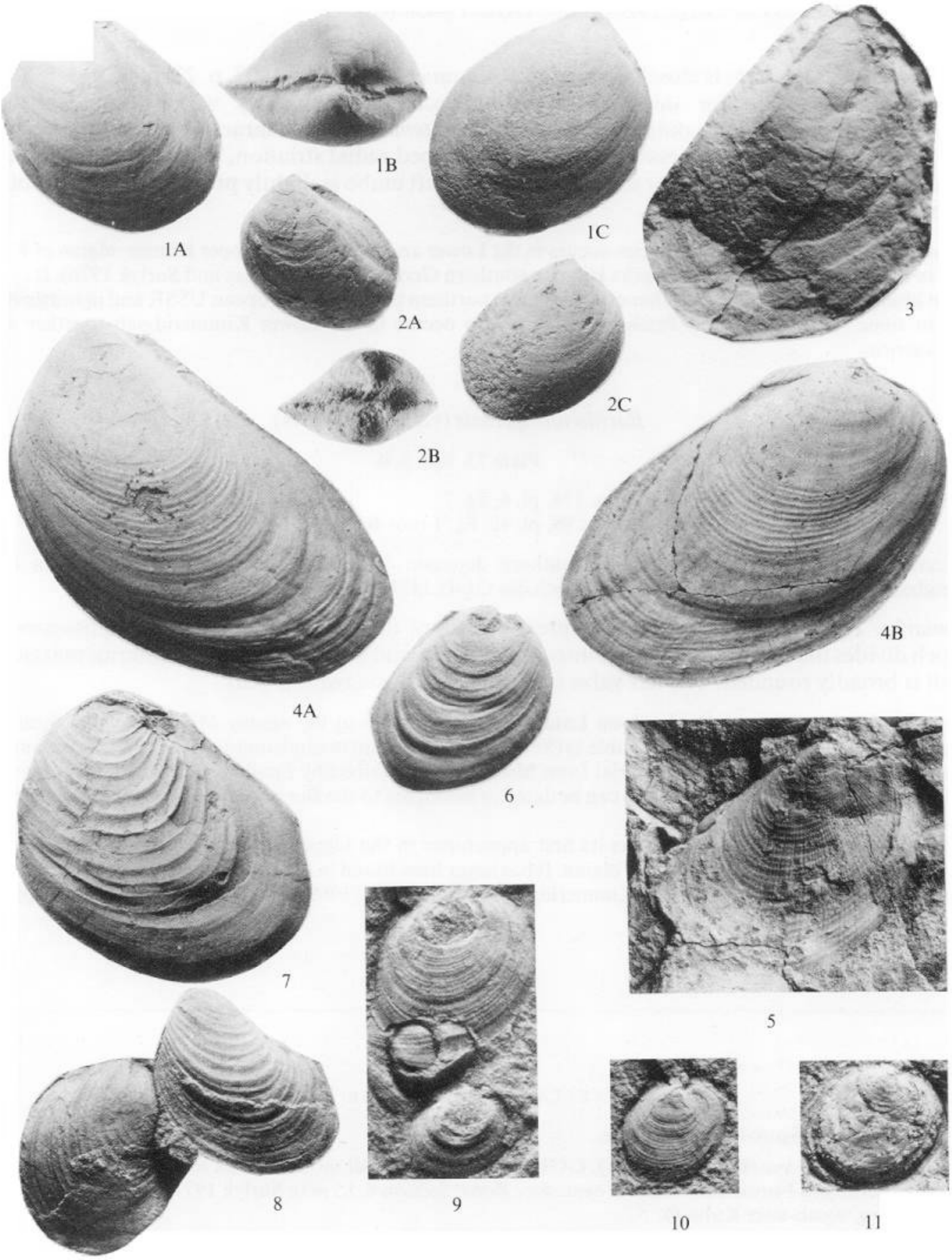
Figs. 1-2. *Praebuchia kirghisensis* (Sokolow). 1, GGU 235458 (F. Fürsich coll. 1977). A, lateral view of left valve, internal mould. B, dorsal view. C, right valve. 2, GGU 235459 (F. Fürsich coll. 1977). A, left valve. B, dorsal view. C, right valve.

Fig. 3. *Praebuchia* cf. *kirghisensis* (Sokolow). GGU 139451. Internal cast of a large, strongly deformed right valve. Bernbjerg Formation, *Amoeboceras (P.) serratum* Zone. Section 38, 228 m in Surlyk 1977, fig. 16. Cardiocerasdal, south-west Wollaston Forland.

Fig. 4. *Buchia lindstroemi* (Sokolow). GGU 234071 (Fürsich coll. 1977). A, lateral view of left valve. B, lateral view of right valve, probably the same individual as in A.

Fig. 5. *Buchia concentrica* (J. de C. Sowerby). GGU 139332. Internal cast of right valve with flattened lower part. Bernbjerg Formation, *Aulacostephanus mutabilis* Zone. Section 8, 168 m in Surlyk 1977, fig. 24. Eastern slope of Bernbjerg, south-west Kuhn Ø.

Figs. 6-11. *Buchia tenuistriata* (Lahusen). 6, Internal cast of right valve, and 7, of compressed left valve, GGU 139472. Bernbjerg Formation, *Rasenia cymodoce-Aulacostephanus mutabilis* Zones. Section 40, 172 m in Surlyk 1977, fig. 31. Cardiocerasdal, south-west Wollaston Forland. 8, 10, GGU 139336. Internal moulds of two left valves (8), and a right valve (10). Bernbjerg Formation. *A. mutabilis-A. eudoxus* Zones. Section 8, 273 m in Surlyk 1977, fig. 24. Eastern slope of Bernbjerg, south-west Kuhn Ø. 9, 11 (Nos. 1240, 87, Maync coll.). Internal moulds of three right valves. Bernbjerg Formation, western Kuhn Ø. Exact locality unknown.



SURLYK and ZAKHAROV, *Buchia*, *Praebuchia*

is unknown. Includes GGU 139330 = MGUH 15328, GGU 139331 (cf.), GGU 139332 (cf.), GGU 139336 = MGUH 15330, GGU 139337 (cf.), GGU 139458 (cf.), GGU 139472 = MGUH 15342, (1240-87, Maync coll.).

Remarks. B. tenuistriata is closely related to *B. mosquensis* (Pavlow 1907, p. 22, pl. 2, figs. 5-8) and is quite often mistaken for this species. Both species are extremely variable and satisfactory identifications can be made only on large samples. *B. tenuistriata* is characterized by its narrower and less oblique shell and in possessing more well-developed radial striation. The radial keel of the right valve is only feebly developed or totally absent. The left umbo is slightly prosogyrate and is obliquely truncated anteriorly.

Stratigraphical occurrence. The species occurs in the Lower and in particular Upper Kimmeridgian of Kuhn Ø, and in the Kimmeridgian at Danmarks Havn in southern Germania Land (Sykes and Surlyk 1976). It occurs in great abundances in the Upper Kimmeridgian in the northern part of the European USSR and in northern Asia, but in some localities such at Petshora River it also occurs in the Lower Kimmeridgian together with *B. concentrica.*

Buchia mosquensis (von Buch, 1844)

Plate 73, figs. 3, 4

1904 *Aucella pallasii* Madsen, p. 178, pl. 6, fig. 7.
1936 *Buchia mosquensis* Spath, p. 98, pl. 42, fig. 1 (not 1*e*).

Material. About ten specimens from southern Jameson Land. Very common in the Perna Ryggen Member of Milne Land (F. Fürsich coll.). Includes GGU 143120 = MGUH 15346.

Remarks. The specimens are typical representatives of the species. The right valve possesses a keel which divides the surface of the valve into flat posterior and anterior parts. The anterior margin of the shell is broadly rounded. The left valve is inflated and has a twisted beak.

Stratigraphical occurrence. On Jameson Land the species occurs in the mainly Middle Volgian Sjællandselv Member of the Fynselv Formation (Table 1) (Surlyk *et al.* 1973) and in sandstones presumably of the same age at Aucellaelv (Madsen 1904). The material from Milne Land described by Spath (1936) is also from the Middle Volgian, and collections by F. Fürsich can be dated as belonging to the *Dorsoplanites ilovaiskii, D. maximus,* and *Crendonites* sp. Zones (Table 2).

In northern Eurasia the species has its first appearance in the Upper Kimmeridgian but reaches its main abundance in the Lower and Middle Volgian. It has never been found in the Upper Volgian. The species has been reported from the Lower and Upper Kimmeridgian by Paraketsov (1968), but his material can in our opinion be referred to *B. tenuistriata.*

EXPLANATION OF PLATE 73

All specimens are figured in natural size.

Figs. 1-2. *Buchia tenuistriata* (Lahusen). GGU 139330. 1, internal moulds of six left valves and, 2, of a right valve. Bernbjerg Formation, *Rasenia cymodoce* Zone. Section 8, 85 m in Surlyk 1977, fig. 24. Eastern slope of Bernbjerg, south-west Kuhn Ø.

Figs. 3-4. *Buchia mosquensis* (von Buch). GGU 143120. All specimens are internal moulds. 3*a*, lateral view of left valve. 3*b*, dorsal view of umbonal part of same valve as in 3*a*. 4, lateral view of right valve. Raukelv Formation, Sjællandselv Member, Middle Volgian, 305 m above sea level. Southern Jameson Land.

Figs. 5-12. *Buchia russiensis* (Pavlow). GGU 139393. All specimens are internal moulds. 5-8, lateral view of right valves. 9-12, lateral view of left valves. Lindemans Bugt Formation, Laugeites Ravine Member, *Epilaugeites vogulicus* Zone. Section 20, 88 m in Surlyk 1978*a*, appendix. Niesen, northern Wollaston Forland.

SURLYK and ZAKHAROV, *Buchia*

Buchia russiensis (Pavlow, 1907)

Plate 73, figs. 5–12; Plate 74, figs. 1–4

1978*a* *Buchia* ex gr. *volgensis* Surlyk, p. 30, pl. 1, fig. 2; pl. 2, fig. 3.

Material. About sixty casts and moulds of left and right valves from western Kuhn Ø, section 5 in Surlyk (1978*a*) and locs. 7, 9, 10, 11 of Donovan (1964), and several casts and moulds from northern Wollaston Forland, section 20 of Surlyk (1978*a*). Includes GGU 139317 = MGUH 15327, GGU 139318, GGU 139319 (cf.), GGU 139321 (cf.), GGU 139323 (cf.), GGU 139393 = MGUH 15333, GGU 139432 = MGUH 15338, GGU 139433 (cf.).

Remarks. *B. russiensis* is geographically widespread and shows great variation both within and between populations. The present material is most closely related to populations from the Petshora and Volonga Rivers (*D. maximus–Laugeites groenlandicus* Zones) (Zakharov 1981, pl. 15). The main characteristic of this type is the large size, and the left valves show great resemblances to *B. volgensis* in being inflated and in possessing a large incurved beak. Some of the left valves and most of the right valves correspond to the form called *B. russiensis* var. *mniovnikensis* by Jeletzky (1965, pl. 1, figs. 4, 5, 9). Several right valves are close to *B. fischeriana* from northern Siberia (Zakharov 1981, pl. 21, fig. 22) and from Arctic Canada (Jeletzky 1966, pl. 8, figs. 2–6, 9), but differ in not having regular concentric ribs.

Stratigraphical occurrence. All the material comes from the Middle Volgian Zones of *L. groenlandicus* and *Epilaugeites vogulicus*. Outside East Greenland *B. russiensis* occurs in the Middle Volgian and the lowermost Upper Volgian (Zone of *Kachpurites fulgens*) of the Petshora River basin. Populations composed of large-sized specimens are characteristic of the uppermost Middle Volgian.

Buchia fischeriana (d'Orbigny, 1845)

Plate 74, figs. 5, 6

1978*a* *Buchia* aff. *fischeriana* Surlyk, pl. 4, fig. 12 (some of the specimens on the slab of sandstone may belong to *B. unschensis*).

EXPLANATION OF PLATE 74

All specimens are figured in natural size.

Figs. 1–4. *Buchia russiensis* (Pavlow). 1–3, GGU 139317. All specimens are internal moulds. 1–2, lateral view of left valves. 3, lateral view of right valve. Lindemans Bugt Formation, Laugeites Ravine Member, *Laugeites groenlandicus* Zone. Section 5, 10 m in Surlyk 1978*a*, appendix. Laugeites Ravine, western Kuhn Ø. 4, GGU 139432. A, lateral view of left valve and B, dorsal view of umbonal part. Lindemans Bugt Formation, Laugeites Ravine Member, probably *Laugeites groenlandicus* Zone. West of Sillerendal, northern Wollaston Forland.

Figs. 5–6. *Buchia fischeriana* (d'Orbigny). GGU 139417. 5, lateral view of left valve and 6, of right valve. Lindemans Bugt Formation, Niesen Member, '*Virgatosphinctes*' *tenuicostatus* beds. Section 20, 175–180 m in Surlyk 1978*a*, appendix.

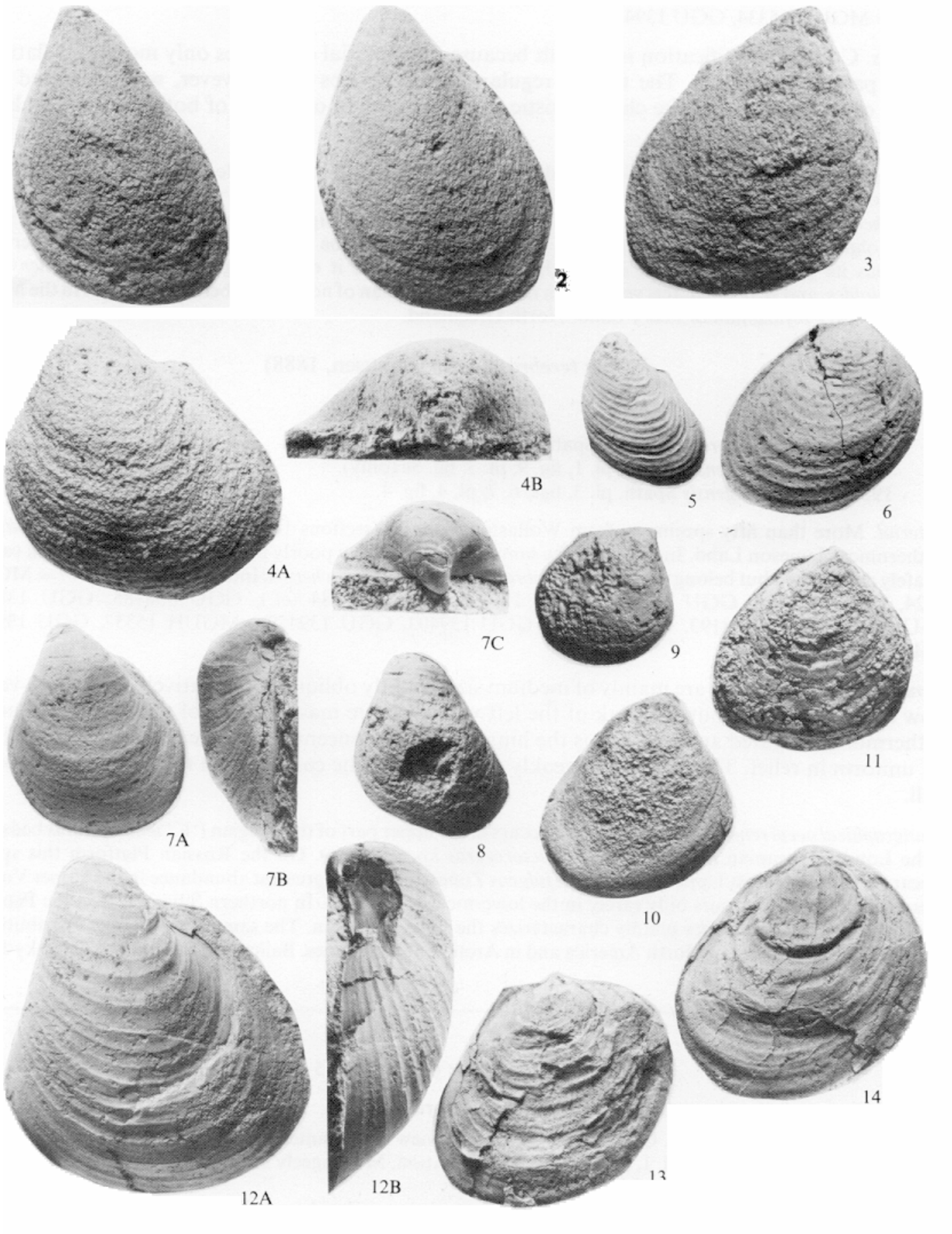
Figs. 7–9. *Buchia terebratuloides* (Lahusen). GGU 139429. 7*a*, *b*, *c*, lateral, posterior, and dorsal view of left valve. 8, lateral view of left valve. 9, lateral of right valve. Lindemans Bugt Formation, Rigi Member, Upper Volgian, Section 14, 120 m in Surlyk 1978*a*, appendix.

Fig. 10. *Buchia terebratuloides* (Lahusen). GGU 138177. Lateral view of right valve. Hesteelv Formation, Muslingeelv Member, *Hectoroceras kochi* Zone. Muslingeelv, southern Jameson Land.

Figs. 11–12. *Buchia unschensis* (Pavlow). GGU 138182. 11, lateral view of right valve. 12A, lateral and B, anterior view of left valve. Hesteelv Formation, Muslingeelv Member, *Hectoroceras kochi* Zone. Muslingeelv, southern Jameson Land.

Figs. 13–14. *Buchia unschensis* (Pavlow). GGU 139437. Lateral view of right valves. Lindemans Bugt Formation, Upper Volgian, '*Virgatosphinctes*' *tenuicostatus* beds. West of Sillerendal, 235 m above sea level, northern Wollaston Forland.

PLATE 74



SURLYK and ZAKHAROV, ***Buchia***

Material. About thirty specimens from Wollaston Forland, section 20 of Surlyk (1978*a*), including GGU 139417 = MGUH 15334, GGU 139428.

Remarks. Correct identification is difficult because the material comprises only moulds of flattened densely packed specimens. The typical regular concentric ribs are, however, well preserved on a number of specimens, and the characteristic slight increase in obliquity of both valves can also be observed.

Stratigraphical occurrence. In East Greenland the species occurs in the top Middle Volgian (*E. vogulicus* Zone) and Upper Volgian ('Virgatosphinctes' tenuicostatus beds).

B. fischeriana has often been observed in the uppermost Middle Volgian (*Epivirgatites nikitini* Zone), in the Upper Volgian, and in the basal Ryazanian of the central part of the Russian Plain. In northern Siberia the species has its greatest abundance in the Upper Volgian, where it occurs together with *B. unschensis*, *B. terebratuloides*, and *B. obliqua*. It is very rare in the basal Ryazanian of northern Siberia, but occurs in the Middle Volgian–Lower Ryazanian of Peary Land, North Greenland.

Buchia terebratuloides (Lahusen, 1888)

Plate 74, figs. 7–10

1947 *Buchia* cf. *terebratuloides* Spath, pl. 2, figs. 7, 8.
1947 *Buchia volgensis* Spath, pl. 1, fig. 9; pl. 3, fig. 5*c* (only).
1952 *Buchia volgensis* Spath, pl. 3, figs. 6, 7; pl. 4, fig. 4.

Material. More than fifty specimens from Wollaston Forland (sections 14, 20, and 45 of Surlyk 1978*a*) and southernmost Jameson Land. In addition, the samples contain many poorly preserved specimens which cannot be safely determined but belong either to *B. terebratuloides* or to *B. unschensis*. Includes GGU 138177 = MGUH 15324, GGU 138181, GGU 138182, GGU 138183, GGU 138184 (cf.), GGU 138185, GGU 138187, GGU 138191, GGU 138193, GGU 139402, GGU 139403, GGU 139429 = MGUH 15337, GGU 139491, GGU 139502 (cf.).

Remarks. The specimens are mainly of medium size, slightly oblique, and relatively high. Both valves show equal convexity, but the beak of the left valve is more massive than of the right valve and is furthermore elongated and overhangs the hinge line. The concentric ribs are irregularly spaced and not uniform in relief. They are more weakly developed on the cast than on the outer surface of the shell.

Stratigraphical occurrence. B. terebratuloides occurs in the upper part of the Volgian ('*V.*' *tenuicostatus* beds) and in the Lower Ryazanian (*P. maynci* and *Hectoroceras kochi* Zones). On the Russian Platform this species appears in the lowermost Upper Volgian (*K. fulgens* Zone), reaches its greatest abundance in the Upper Volgian *Craspedites* beds, and occurs only rarely in the lowermost Ryazanian. In northern Siberia and in the Petshora River basin *B. terebratuloides* mainly characterizes the Upper Volgian. The same stratigraphic distribution is found at the Pacific coast of North America and in Arctic Canada (Jones, Bailey and Imlay 1969; Jeletzky 1973).

EXPLANATION OF PLATE 75

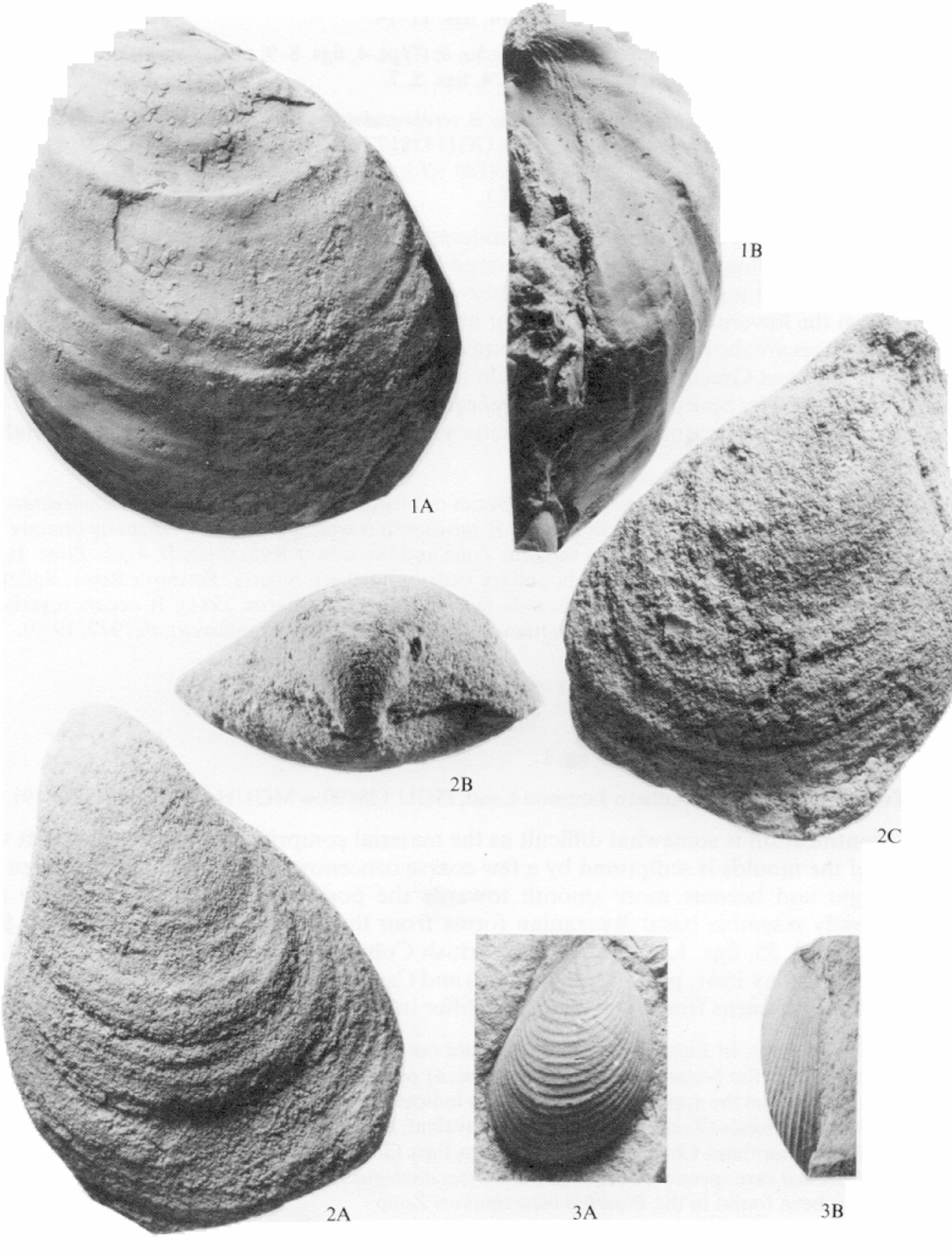
All specimens are internal moulds and are figured in natural size.

Fig. 1. *Buchia okensis* (Pavlow). GGU 138190. A, lateral view and B, anterior view, of left valve. The specimen was figured by Surlyk 1973, pl. 1, fig. 1. Hesteelv Formation, Muslingeelv Member, *Hectoroceras kochi* Zone, Muslingeelv, southern Jameson Land.

Fig. 2. *Buchia volgensis* (Lahusen). GGU 143101. A, lateral view and B, dorsal view of left valve. C, lateral view of right valve. Raukelv Formation, Fynselv Member, top beds, Upper Ryazanian, 420 m above sea level. West of Fynselv, upper reach, southern Jameson Land.

Fig. 3. *Buchia inflata* (Lahusen). GGU 139439. A, lateral and B, anterior view of right valve. Palnatokes Bjerg Formation, Albrechts Bugt Member, Lower Valanginian, Section 35, 430 m, south side of Niesen, Wollaston Forland.

PLATE 75



SURLYK and ZAKHAROV, ***Buchia***

Buchia unschensis (Pavlow, 1907)

Plate 74, figs. 11–14

1947 *Buchia volgensis* Spath, p. 34, pl. 3, fig. 5*a*, *b*; (?) pl. 4, figs. 8–9; pl. 5, figs. 1–2.
1952 *Buchia volgensis* Spath, pl. 1, fig. 1; pl. 4, figs. 5, 7.

Material. More than twenty specimens (see also under *B. terebratuloides*) from Wollaston Forland (section 20 of Surlyk, 1978*a*) and southern Jameson Land. Includes GGU 138177 (cf.), GGU 138181, GGU 138182 = MGUH 15325, GGU 138185 (cf.), GGU 138187, GGU 138189 (cf.), GGU 139402, GGU 139403, GGU 139437 = MGUH 15339, GGU 139502 (cf.), GGU 143065 (cf.).

Remarks. The specimens are of medium to moderately large size for the species. The shell has a rounded non-oblique shape. The surface is covered by regularly spaced ribs of equal strength. The posterior part is broad and wing-like. The better-preserved specimens are strongly reminiscent of specimens from the lowermost *H. kochi* Zone of northern Siberia (Zakharov 1981, pl. 29, figs. 1–3). The only differences are the less convex valves, more narrow elongated beaks on the left valve, and less regular ribs of the East Greenland specimens. On the basis of these features Jeletzky (1973) referred the specimens figured by Spath (1947) to *B. terebratuloides* and *B.* sp. nov. aff. *okensis*.

Here we interpret the features as intraspecific variation within the Greenland material of *B. unschensis*.

Stratigraphical occurrence. In East Greenland the species occurs in the Upper Volgian ('*V.*' *tenuicostatus* beds) and Lower Ryazanian (*P. maynci–H. kochi* Zones). *B. unschensis* is widespread in the northerly (mainly Arctic) depositis of the Upper Volgian *Craspedites subditus* Zone and the Lower Ryazanian *H. kochi* Zone. It is even more abundant in the Jurassic–Cretaceous boundary beds in northern Siberia, Petshora River, Spitzbergen, North Greenland, and probably in Arctic Canada (Jeletzky 1966, Zakharov 1981). It occurs together with *Hectoroceras* sp. in the lower part of the Ryazanian at the Oka River (Mesezhnikov *et al.* 1977, 1979).

Buchia okensis (Pavlow, 1907)

Plate 75, fig. 1

1973 *Buchia okensis* Surlyk, pl. 1, fig. 1.

Material. Two specimens from southern Jameson Land, GGU 138190 = MGUH 15326, GGU 138191.

Remarks. Identification is somewhat difficult as the material comprises only incomplete left valves. The surface of the moulds is sculptured by a few coarse concentric folds, which are strongest at the anterior margin and become more smooth towards the posterior margin. The coarsely ribbed specimens closely resemble basal Ryazanian forms from the Pakhsa Peninsula, northern Siberia (Zakharov 1981, pl. 35, figs. 1, 2), Vancouver, British Columbia (Jeletzky 1965, pl. 6, figs. 1, 3–5), northern Alaska (Imlay 1961, pl. 7, figs. 12, 17–20) and Canadian Arctic Archipelago (Jeletzky 1964, pl. 1, fig. 1). The specimens from Jameson Land differ in having more irregularly spaced folds.

Stratigraphical occurrence. In East Greenland the species occurs in the Lower Ryazanian (*H. kochi* Zone). *B. okensis* is widespread in the boreal Berriasian (Ryazanian) of both northern Eurasia and northern America. According to most authors the appearance of *B. okensis* indicates the start of the Cretaceous. It is, however, not found in the *Chetaites sibiricus* Zone, nor in its time equivalent, the *Praetollia maynci* Zone (see Surlyk 1978*a*) in northern USSR (Petshora and Chatanga Rivers) and in East Greenland. It first appears at the base of the *H. kochi* Zone and the last rare specimens occur in the *Surites analogus* Zone (Zakharov 1981). No representatives of *B. okensis* have been found in the *Bojarkia mesezhnikovi* Zone.

Buchia volgensis (Lahusen, 1888)

Plate 75, fig. 2

1978*a* *Buchia volgensis* Surlyk, p. 32, pl. 6, figs. 1–5 (only).

Material. About seventy specimens from southern Jameson Land and Wollaston Forland, including GGU 139493, GGU 139503 (cf.), GGU 143028 (cf.), GGU 143094 (cf.), GGU 143101 = MGUH 15345, GGU 143143, GGU 137999 (cf.), GGU 138191 (cf.), GGU 139375, GGU 139376 (cf.), GGU 139400 (cf.), GGU 139407, GGU 139418 (cf.), GGU 139420 (cf.).

Remarks. The Greenland material is typical of this well-known species (see e.g. Zakharov 1981).

Stratigraphical occurrence. In East Greenland *B. volgensis* occurs throughout the Ryazanian except for the basal *Praetollia maynci* Zone. *B. volgensis* is extremely widespread in the Boreal and Subboreal Ryazanian. In northern USSR the species appears above the Jurassic–Cretaceous boundary at the base of the *H. kochi* Zone (Zakharov 1977, 1979), and most of the earlier identifications from the Upper Volgian in the Middle Siberia (Saks 1972) are erroneous. The alleged specimens of *B. volgensis* from the Upper Volgian can probably all be explained as misidentified specimens of *B. unschensis* (Zakharov 1981, pl. 3, fig. 4).

The species has the same stratigraphic range in northern North America (Jeletzky 1965). All the specimens from the *P. maynci* Zone of East Greenland described by Spath (1947, 1952) as *B. volgensis* belong to *B. unschensis* or *B. terebratuloides*, while some cannot be identified (Jeletzky 1973, p. 52). The specimens described as *B.* ex gr. *volgensis* from the upper part of the Middle Volgian and as *B. volgensis* from the Upper Volgian by Surlyk (1978*a*) are here referred to *B. russiensis* (Pavlow).

Buchia inflata (Lahusen, 1888)

Plate 75, fig. 3; Plate 76, fig. 1

1965 (?) *Buchia inflata* Jeletzky, pl. 1, figs. 7–8.
1978*a* *Buchia keyserlingi* Surlyk, p. 33, pl. 7, figs. 4–5, (?) 6.

Material. Twenty-two specimens from Wollaston Forland and Kuhn Ø, partly from sections 10, 15, and 53 in Surlyk (1978*a*). Including GGU 139348, GGU 139351, GGU 139356, GGU 139378 (cf.), GGU 139383 (cf.), GGU 139413, GGU 139439 = MGUH 15340, GGU 139352 = MGUH 15332.

Remarks. B. inflata is represented by medium- and moderately large-sized, subtriangular, high and almost equilateral specimens. The surface is covered by regularly spaced concentric ribs. Several of the specimens compare well with material from northern Siberia, Subarctic Urals, and Petshora River (Zakharov 1981, pls. 43–47) and from Andøy (Sokolow, 1912). The mode of growth of the right valve of several specimens (Surlyk 1978*a*, pl. 7, figs. 4, 5) much resembles *B. pacifica* from Vancouver, British Columbia (Jeletzky 1965, pl. 16, fig. 7), but strongly convex forms which are characteristic of samples from northern Siberia and British Columbia are absent from the Greenland material.

Stratigraphical occurrence. In East Greenland *B. inflata* occurs in the Lower Valanginian of Wollaston Forland and Kuhn Ø. The first appearance of *B. inflata* in northern Eurasia (Petshora and Cheta Rivers) is in the uppermost part of the *Bojarkia mesezhnikovi* Zone (uppermost Ryazanian). In northern Siberia the species reaches its greatest abundance in the Lower Valanginian (*Neotollia klimovskiensis Zone*) while it is very rare in uppermost Lower Valanginian.

Buchia keyserlingi (Trautschold, 1868)

Plate 76, figs. 2, 3; Plate 77, fig. 1

1874 *Aucella concentrica* var. *rugosa* Toula, p. 503, pl. 2, figs. 2–4.
1911 (?) *Aucella* sp. Ravn, p. 459, pl. 33, fig. 1.
1911 (?) *Aucella concentrica* Ravn, p. 461, pl. 32, figs. 9–10.
1911 (?) *Aucella piriformis* Ravn, p. 460, pl. 32, figs. 11, 12.
1965 *Buchia keyserlingi* Jeletzky, pl. 19, figs. 1, 2, 5, 7.
1975 (?) *Buchia keyserlingi* Surlyk and Clemmensen, pp. 67, 69, fig. 9.
1978*a* *Buchia keyserlingi* Surlyk, p. 33, pl. 8, fig. 4 (*non* pl. 7, figs. 4–6).
1978*b* *Buchia keyserlingi* Surlyk, p. 80, fig. 7E, F.

Material. More than 200 specimens from Kuhn Ø and Wollaston Forland (much of the material is from sections 10, 15, 18, 20, and 53 in Surlyk 1978*a*, and section 40 in Surlyk 1977). Including GGU 139349 (cf.), GGU 139350, GGU 139351 (cf.), GGU 139342 (cf.), GGU 139356, GGU 139357, GGU 139379 (cf.), GGU 139381, GGU 139382, GGU 139383 (cf.), GGU 139386 (cf.), GGU 139394, GGU 139395, GGU 139397 (cf.), GGU 139411, GGU 139412 (cf.), GGU 139413, GGU 139414, GGU 139421 (cf.), GGU 139440 (cf.), GGU 139441, GGU 139462 (cf.), GGU 139475, GGU 139476, GGU 139477, GGU 139478 (cf.), GGU 139499 (cf.), GGU 139504 (cf.), GGU 139511, GGU 139519, GGU 139522 (sp. juv.), GGU 139524, GGU 139525, GGU 139526, GGU 139528, GGU 139532 (cf.), GGU 139534 = MGUH 15344, GGU 139535 (cf.), GGU 143161 (cf.).

Remarks. B. keyserlingi is by far the most abundant species of *Buchia* from East Greenland and practically all the varieties described in the literature are represented.

The majority have a rounded outline and regularly spaced ribs (Pl. 76, fig. 2; Pl. 77, fig. 1; see also Surlyk and Clemmensen 1975, fig. 9; Surlyk 1978*b*, figs. 7E, F), near to the lectotype (Keyserling 1846, pl. 16, fig. 16; see also Zakharov 1981, pl. 50, fig. 4). These forms have in the earlier literature been called *B. keyserlingi* var. *sibirica* (Sokolow). Another form represented is close to the original specimen of Lahusen (1888, pl. 4, figs. 18–23; see also Zakharov 1981, pl. 54, fig. 3). Its main characteristic is the closely spaced ribs. The form is well known from Middle (?) Valanginian of the Arctic Canadian Archipelago (Jeletzky 1964, pl. 5, fig. 2) and from the *Temnoptychites syzranicus* Zone of the Petshora River basin (Zakharov 1981, pl. 55, fig. 4). *B. keyserlingi* var. *gigas* (Crickmay) is probably a gerontic form of this closely ribbed variety. Such large specimens have also been found in East Greenland (Jeletzky 1965, pl. 9, fig. 1; Surlyk 1978*a*, pl. 8, fig. 4) and have also been recorded from northern Siberia (Zakharov 1981, pl. 54, fig. 2) and Kong Karls Land (so-called variety *brasiliensis*, Blüthgen, 1936). A fairly rare variety with a smooth internal mould (Pl. 77, fig. 1) usually occurs together with ribbed varieties in the Lower Valanginian of the Anabar River, northern Siberia (Zakharov 1981, pl. 53). In large samples from eastern Wollaston Forland all transitions occur between the above-mentioned varieties.

B. piriformis and *B.* sp. of Ravn (1911) are represented by internal moulds of the left valves only and determination is thus not definitive. It should be noted, however, that these specimens have a high shell, smooth surface of the moulds, and that the middle part of the valves display a strong convexity. These features are highly reminiscent of *B. sublaevis* from the Upper Valanginian of the Petshora River basin (Zakharov 1981, pl. 58).

Stratigraphical occurrence. In East Greenland *B. keyserlingi* occurs in the Lower Valanginian of Kuhn Ø, Wollaston Forland, Hochstetter Forland, and probably Store Koldewey. *B. keyserlingi* is typical of the Boreal Lower Valanginian, where it occurs in great abundance. The species does not occur in the Ryazanian, but in large samples of Ryazanian *B. unschensis* or *B. volgensis* there will normally occur several specimens which strongly resemble *B. keyserlingi. B. keyserlingi* reaches its maximum abundance in the middle part of the Valanginian (*T. syzranicus* and *Polyptychites keyserlingi* Zones). The species is rare in the Upper Valanginian, where other species such as *B. sublaevis* have taken over. The youngest occurrence is in northern Germany (Westphalia and Lower Rhine), where rare *B.* ex gr. *keyserlingi* occur together with *Endemoceras* of Early Hauterivian Age (Kemper 1975).

Buchia sublaevis (Keyserling, 1846)

Plate 77, figs. 2–7

1978*a* (?) *Buchia sublaevis* Surlyk, pl. 8, fig. 3.

Material. More than twenty specimens from Wollaston Forland, including GGU 139351 = MGUH 15331,

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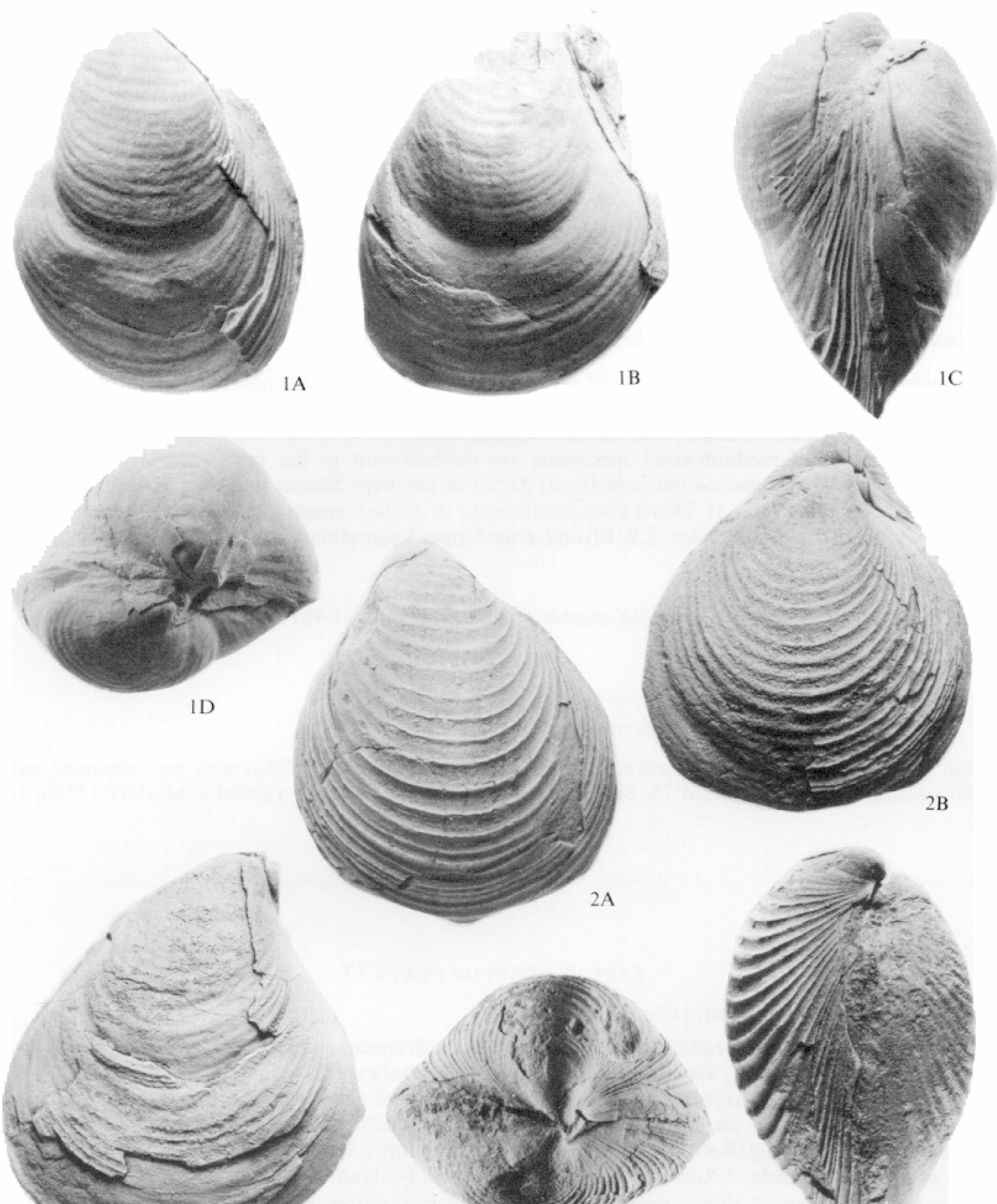
EXPLANATION OF PLATE 76

All specimens are figured in natural size.

Fig. 1. *Buchia inflata* (Lahusen). GGU 139352. A, whole specimen viewed from the left and B, right side. C, posterior view. D, dorsal view. Palnatokes Bjerg Formation, Albrechts Bugt/Rødryggen Member transition, Lower Valanginian, Section 10, Surlyk 1978*a*, appendix. Perisphinctes Ravine, eastern Kuhn Ø.

Figs. 2–3. *Buchia keyserlingi* (Trautschold). GGU 139534. 2A, whole specimen viewed from left side and B, right side; C, dorsal view and D, posterior view. 3, lateral view of right valve. Palnatokes Bjerg Formation, Albrechts Bugt Member. Lower Valanginian, Sumpdalen, north-east Wollaston Forland.



SURLYK and ZAKHAROV, *Buchia*

GGU 139384 (cf.), GGU 139385 (cf.), GGU 139386 (cf.), 139387 (cf.), GGU 139387 (cf.), GGU 139423 = MGUH 15335, GGU 139442 (cf.), GGU 139504, GGU 139523 = MGUH 15343, GGU 139535 (cf.), GGU 139536 (cf.).

Remarks. The material is dominated by small- and medium-sized specimens, while large specimens are absent. Accordingly, precise identification is not always possible. The moulds are smooth and straight and the left valves are slightly more convex than the right valves. Medium-sized specimens have a slightly prosogyrate beak. There is a considerable morphological overlap between *B. keyserlingi*, *B. sublaevis*, and *B. crassicollis* and one often needs populations to make correct identification. Single specimens can only be identified with some doubt. This is the case with a specimen from the Albrechts Bugt Member of Wollaston Forland (Surlyk 1978*a*, pl. 8, fig. 3, and this paper Pl. 77, figs. 2–7). On the one hand the specimen recalls rare high forms of *B. sublaevis* from the Upper Valanginian (*Dichotomites* beds) at the Izhma River, Petshora basin (Zakharov 1981, pl. 58, fig. 3), while on the other hand it is reminiscent of younger *B. crassicollis* from the *Homolsomites bojarkensis* Zone (Zakharov 1981, pl. 60, figs. 5–7).

Stratigraphical occurrence. In East Greenland *B. sublaevis* occurs in the lower part of the Upper Valanginian in Wollaston Forland. In northern Siberia and Petshora River Basin the species has its first appearance at the Lower–Upper Valanginian boundary and reaches its greatest abundance in the Upper Valanginian (*Dichotomites* spp. Zone). Small- and medium-sized specimens are predominant in the uppermost Upper Valanginian (*Dichotomites* beds and *Homolsomites bojarkensis* Zone) of northern Siberia and East Greenland (Zakharov 1981, pl. 56, figs. 2–5, pl. 57, fig. 1). This is also characteristic in Arctic Canada (*Dichotomites quatsinoensis* Zone) (Jeletzky 1964, pl. 11, fig. 3, pl. 13, figs. 7, 9, 10) and in the Upper Valanginian of northern Alaska (Imlay 1961, pl. 8, figs. 1–15).

Buchia crassicollis (Keyserling, 1846)

Plate 77, fig. 8

1911 (?) *Aucella crassicollis* Ravn, p. 459, pl. 32, fig. 8.
1978*a* *Buchia crassicollis* Surlyk, pl. 8. fig. 5.

Material. One specimen from Wollaston Forland (section 20, Surlyk 1978*a*) and one specimen which is transitional to *B. sublaevis* (section 15, Surlyk 1978*a*); GGU 139387 (cf.), 139424 = MGUH 15336, 139535.

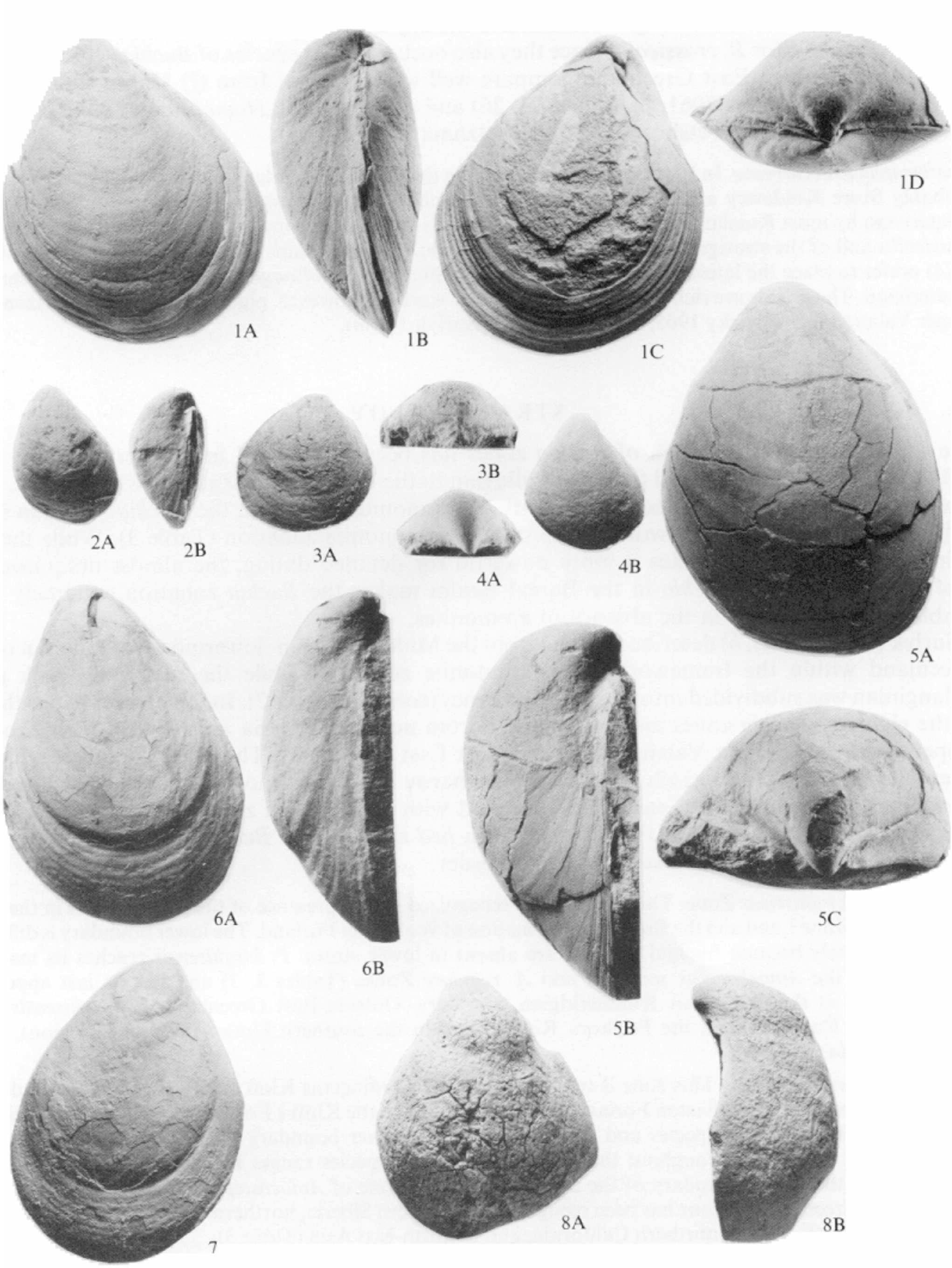
EXPLANATION OF PLATE 77

All specimens are figured in natural size.

Fig. 1. *Buchia keyserlingi* (Trautschold). GGU 139534. Smooth specimen. A, whole specimen viewed from the left side. B, posterior view. C, view from the right side. D, dorsal view. Locality as pl. 76, figs. 2–3.

Figs. 2–7. *Buchia sublaevis* (Keyserling). GGU 139523. 2A, lateral view of left valve. 2B, posterior view. 3A, lateral view of right valve. 3B, dorsal view. 4A, dorsal view of left valve. 4B, lateral view. Palnatokes Bjerg Formation Albrechts Bugt/Rødryggen Member transition. Upper Valanginian, Section 53, 135 m in Surlyk 1978*a*, appendix. East side of Rødryggen, eastern Wollaston Forland. 5, GGU 139351. A, lateral view of left valve. B, posterior view. C, dorsal view. Palnatokes Bjerg Formation, Albrechts Bugt, Rødryggen Member transition, upper Lower Valanginian, Section 10, Surlyk 1978*a*, appendix. Perisphinctes Ravine, eastern Kuhn Ø. 6, 7, GGU 139423. 6A, exterior view of left valve. 6B, posterior view. 7, exterior view of right valve (also figured by Surlyk 1978*a*, pl. 8, fig. 3). Palnatokes Bjerg Formation, Albrechts Bugt/Young Sund Member transition, Section 20, Upper Valanginian, 635 m in Surlyk 1978*a*, appendix. Niesen, northern Wollaston Forland.

Fig. 8. *Buchia crassicollis* (Keyserling). GGU 139424. A, exterior view of left valve. B, anterior view (also figured by Surlyk 1978*a*, pl. 8, fig. 5). Palnatokes Bjerg Formation, Albrechts Bugt Member, uppermost Valanginian or lowermost Hauterivian, Section 20, 688 m, top of Niesen. Northern Wollaston Forland.



SURLYK and ZAKHAROV, *Buchia*

Remarks. Only two rather poorly preserved external moulds of left valves are found. They are high and almost smooth with a strong constriction in the upper part. Such constrictions are characteristic but not diagnostic for *B. crassicollis* since they also occur in other species of *Buchia* (Zakharov 1981). The specimens from East Greenland compare well with material from (?) Upper Valanginian of northern Alaska (Imlay 1961, pl. 8, figs. 23-26) and also from the *Homolsomites bojarkensis* Zone of northern Siberia and Petshora River basin (Izhma River).

Stratigraphical occurrence. In East Greenland it occurs in the uppermost Valanginian of Wollaston Forland and probably Store Koldewey and Kuhn Ø. This stratigraphic level is considered to belong to the lowermost Hauterivian by most Russian authors (see below). There is no clear agreement on the stratigraphic range of *B. crassicollis* and of the stratigraphic position of the strata in which it occurs. Some workers (Saks and Shulgina 1974) prefer to place the latest marine beds of northern Siberia (*Homolsomites bojarkensis* Zone) in the Lower Hauterivian. These beds are rich in *B. crassicollis*. Other workers, however, place the equivalent horizons in the Upper Valanginian (Jeletzky 1965; Jones *et al.* 1969; Surlyk 1978*a*).

STRATIGRAPHY

The most complete succession of *Buchia* zones has been established in northern Siberia, where eighteen zones were recognized from the Callovian to the Hauterivian (Zakharov 1977, 1979, 1981). The same interval is subdivided into forty-three ammonite zones and the *Buchia* zonation is thus well defined within the framework of the standard ammonite zonation (Table 3). While the great refinement of the latter makes it more powerful for detailed dating, the almost ubiquitous and profuse occurrence of *Buchia* in the Boreal Realm makes the *Buchia* zonation extremely useful (Tables 2, 3), especially in the absence of ammonites.

Surlyk (1973, 1978*a*, *b*) described *Buchia* from the Middle Volgian-lowermost Valanginian of East Greenland within the framework of an ammonite zonation, while the remaining bulk of the Valanginian was subdivided into three *Buchia* zones (compare Table 2). In the present paper thirteen of the eighteen *Buchia* zones and beds known from northern Siberia are now recorded from the Upper Oxfordian-Upper Valanginian interval of East Greenland. The Siberian zones, which are assemblage zones, are precisely defined by Zakharov (1981). In most cases the East Greenland *Buchia*-bearing horizons can easily be correlated with the Siberian zones. In other cases a zonal assignment is less certain and the informal term *bed* is used. The *Buchia* zones and beds of East Greenland will now be described in ascending order.

1. *Praebuchia kirghisensis* Zone. This zone can be recognized by the presence of the index species in the Upper Oxfordian of Milne Land and the Bernbjerg Formation of Wollaston Forland. The lower boundary is difficult to establish precisely because buchiid bivalves are absent in lower strata. *P. kirghisensis* reaches its maximum abundance in the *Amoeboceras serratum* and *A. regulare* Zones (Tables 2, 3) and has its last appearance approximately at the Oxfordian-Kimmeridgian boundary. Outside East Greenland. *P. kirghisensis* occurs widely on the Russian Plain, the Petshora River basin, in the southern Urals (Orenbourg region), and in northern Siberia (Table 3).

2. *Buchia concentrica* Zone. This zone is represented in the Cardioceras Kløft Member of Milne Land, in the Bernbjerg Formation of Wollaston Forland and Kuhn Ø, and in the Kløft I Formation of Store Koldewey. It is characterized by the index species and *B. lindstroemi.* The lower boundary coincides with the Oxfordian-Kimmeridgian boundary throughout the Boreal Realm. The species ranges higher in East Greenland than elsewhere and the upper boundary of the zone is within the zone of *Aulacostephanus mutabilis* (Tables 2, 3). Outside East Greenland the zone has been recognized in northern Siberia, northern Urals, Petshora River basin, Spitzbergen, North Alaska, northern California, and in north-east Asia (Table 3).

3. *Buchia tenuistriata* Zone. This zone has a restricted occurrence in East Greenland, where it has been demonstrated only in the Bernbjerg Formation of Kuhn Ø and at Danmarkshavn. The index species occurs together with *Amoeboceras* (*Euprionoceras*) ex gr. *sokolowi* and various aulacostephanid species. Numerous specimens have been found in the *Aulacostephanus mutabilis* Zone together with rare *B. concentrica.* The upper boundary of the zone cannot be safely ascertained because the adequate parts of the section have not yielded sufficient material. The upper part of the zone is supposed roughly to correlate with the ammonite zones of

Stages		1 Ammonite zonation	2 *Buchia* zonation
Valanginian	Upper		*Buchia crassicollis*
			Buchia sublaevis
	Low.		*Buchia keyserlingi*
		Tollia tolli	*Buchia inflata*
Ryazanian	Upper	*Bojarkia mesezhnikovi*	*Buchia volgensis*
		Surites tzikwinianus	
		Surites (Caseyiceras) analogus	?
	Low.	*Hectoroceras kochi*	*Buchia okensis*
		Praetollia maynci	*Buchia unschensis* –
Volgian	Upper	"*Virgatosphinctes*" *tenuicostatus*	*Buchia terebratuloides*
			Buchia fischeriana
	Middle	*Epilaugeites vogulicus*	*Buchia russiensis*
		Laugeites groenlandicus	
		Crendonites sp.	
		Dorsoplanites maximus	*Buchia mosquensis*
		Dorsoplanites ilovaiskii	
		Pavlovia iatriensis	
	Lower	*Pectinatites pectinatus*	?
		Pectinatites huddlestoni	
		Pectinatites wheatleyensis	
		Pectinatites scitulus	
		Pectinatites elegans	
Kimmeridgian		*Aulacostephanus autissiodorensis*	*Buchia tenuistriata*
		Aulacostephanus eudoxus	
		Aulacostephanus mutabilis	*Buchia concentrica*
		Rasenia cymodoce	
		Pictonia baylei	
Oxfordian	Upper	*Amoeboceras rosenkrantzi*	*Praebuchia kirghisensis*
		Amoeboceras regulare	
		Amoeboceras serratum	
		Amoeboceras glosense	
		Cardioceras tenuiserratum	

TABLE 2. Correlation of *Buchia* and ammonite zones and beds in East Greenland. *Sources*: 1, Surlyk (1977, 1978*a*); Surlyk *et al.* (1973); Sykes and Surlyk (1976); Birkelund *et al.* (1978). 2, Surlyk (1978*a*) and the present paper.

Aulacostephanus eudoxus and *A. autissiodorensis* (Tables 2, 3). In the Volga and Petshora River basins and southern Urals the boundary relations are likewise unclear as *Buchia*-bearing continuous sections have not been found covering the Upper Kimmeridgian–Lower Volgian interval.

4. *Buchia mosquensis* Zone. Beds with *B. mosquensis* are well represented in the Middle Volgian of Milne Land. In Jameson Land it has been found in one locality in the Sjællandselv Member (Table 1), and it is also known from Store Koldewey. The zone of *B. mosquensis* has a wide distribution in the Boreal Realm and it contains beds with *B. mosquensis* s.s., *B. rugosa*, *B. russiensis*, and *B. taimyrensis* (Table 3).

5. *Buchia russiensis* beds. These beds have been found in the late Middle Volgian Laugeites Ravine and Rigi Members of Wollaston Forland and Kuhn Ø (Table 1). This horizon seems to correspond to the beds with *B. taimyrensis* in northern Siberia and in the Petshora River basin (Table 3).

6. *Buchia fischeriana* beds. In East Greenland *B. fischeriana* has a fairly long range, although it mainly occurs above *B. russiensis* in the top Laugeites Ravine and Niesen Members of Wollaston Forland, where it occurs with Upper Volgian '*Virgatosphinctes*' (Tables 1–3).

System	Stage	Substage	1 Northern Siberia: Ammonites	1 Northern Siberia: *Buchia*	2 East Greenland	3 Spitzbergen Franz Joseph Land Novaya Semlya	4 Petshora River Basin	5 Canadian Boreal Region	6 Northern Alaska	7 Western British Columbia	8 Northern California	9 North-Eastern Asia
LOWER CRETACEOUS	Hauterivian	U	*Simbirskites decheni*	non marine beds	hiatus	*Buchia* absent	aff. *crassicollis*	?	?	?	?	*Buchia* absent
		L	*Speetoniceras versicolor*									
			Homolsomites bojarkensis	*crassicollis*	*crassicollis*		*crassicollis*		*crassicollis*	*crassicollis*	*crassicollis*	*crassicollis* *sublaevis*
	Valanginian	U	*Dichotomites* spp.	*sublaevis*	*sublaevis*		*sublaevis*	*sublaevis*	*sublaevis*	aff. *inflata*	?	
		L	*Polyptychites michalskii*	*keyserlingi*	*keyserlingi*	*keyserlingi*	*keyserlingi*	*keyserlingi*		?	*keyserlingi*	*crassa*
			Temnoptychites syzranicus									
			Neotollia klimovskiensis	*inflata*	*inflata*	?	*inflata*	?	hiatus	*pacifica*	*pacifica*	*inflata*
	Ryazanian	U	*Bojarkia mesezhnikowi*	[*volgensis*] *tolmatschowi*	*volgensis*	?	[*volgensis*] *uncitoides*	[*volgensis*] *uncitoides*		*tolmatschowi*	*uncitoides*	*sibirica*
			Surites analogus	*jasikovi*	?					*uncitoides*		*volgensis*
		L	*Hectoroceras kochi*	*okensis*	*okensis*	*okensis*	?	*okensis*	*okensis*	*okensis*	?	*okensis*
			Chetaites sibiricus			[*fischeriana*]		*terebratuloides*	*subokensis*	*terebratuloides*		*unschensis*
UPPER JURASSIC	Volgian	U		*unschensis*	*unschensis* – *terebratuloides*	*unschensis*	*unschensis*	*unschensis*	hiatus	aff. *okensis*	aff. *okensis*	*terebratuloides*
					fischeriana	*obliqua*	*obliqua*	*fischeriana*		?	[*piochii*] *fischeriana*	*tenuicollis* *fischeriana*
			Taimyrosphinctes excentricus		*russiensis*		*taimyrensis*			cf. *blanfordiana*		
		M	*Dorsoplanites maximus*					*piochii*	*piochii*	*russiensis*	*elderensis*	*piochii*
			Dorsoplanites ilovaiskii	[*mosquensis*] *russiensis*	*mosquensis*	*russiensis*	*russiensis*					
			Pavlovia iatriensis									
		L	*Pectinatites pectinatus*	*rugosa*					*rugosa*			
			Subdichotomoceras subcrassum		?		*mosquensis*	*mosquensis*		*mosquensis*		*mosquensis* *mosquensis* ssp. *piochii*
			Eosphinctoceras magnum	*mosquensis*					*mosquensis*		hiatus	
	Kimmeridgian	U	*Streblites taimyrensis*									*rugosa*
			Aulacostephanus eudoxus	*tenuistriata*	*tenuistriata*	*tenuistriata*	*tenuistriata*	?	?	?		*mosquensis* *paradoxa* ssp.
			Aulacostephanus mutabilis									
		L	*Rasenia borealis*	*concentrica*	*concentrica*	*concentrica*	*concentrica*	*concentrica*	*concentrica*		*concentrica*	*mosquensis* *tenuistriata* ssp. *concentrica*
			Pictonia involuta									
	Oxfordian	U	*Amoeboceras ravni*									*concentrica*
			Amoeboceras alternans	*Praebuchia kirghisensis*	*kirghisensis*	*kirghisensis*	*kirghisensis*	?	?		?	*Praebuchia kirghisensis*
			Amoeboceras alternoides									
		L	*Cardioceras cordatum*									*Praebuchia impressa*
			Cardioceras percaelatum									
			Cardioceras gloriosum	*Praebuchia orientalis*		?						
			Cardioceras obliteratum									
	Callovian	U	*Eboraciceras subordinarium*		*Buchia* absent		*Buchia* absent					
			Longaeviceras keyserlingi									?
		M	*Rondiceras milaschevichi* and *Erymnoceras* beds	?		*Buchia* absent						
		L	*Cadoceras emelianzevi*	*Praebuchia anabarensis*								*Praebuchia anyuensis*
			Cadoceras elatmae									

TABLE 3. *Buchia* zonation of the Boreal Callovian to Hauterivian Stages. *Sources*: 1, 4, Zakharov (1977, 1979, 1981). 2, the present paper. 3, Sokolov and Bodylevsky (1931); Frebold and Stoll (1937); Pĉelina (1965). 5, Jeletzky (1965, 1973). 6, Imlay (1959, 1961). 7, Jeletzky (1965, 1973). 8, Jones Bailey and Imlay (1969); Imlay and Jones (1970). 9, Paraketsov (1980).

7. *Buchia terebratuloides–Buchia unschensis* beds. The Jurassic–Cretaceous boundary occurs in a sequence poor in *Buchia* and thus cannot be precisely placed within the *Buchia* zonation. The *terebratuloides–unschensis* assemblage occurs together with '*Virgatosphinctes*', *Praetollia*, and *Hectoroceras* in the Rigi and Niesen Members of Wollaston Forland and in the Muslingeelv Member of Jameson Land (Table 1). The assemblage thus spans the Jurassic–Cretaceous boundary and characterizes the uppermost Volgian and the Lower Ryazanian.

8. *Buchia okensis* Zone. This zone has been recognized in the Muslingeelv Member of Jameson Land (Surlyk 1973). It occurs below *B. volgensis* together with abundant *B. unschensis*, *B. terebratuloides*, and *B. fischeriana*. The zone is one of the best biostratigraphic markers in the Boreal Realm (Table 3; see also Jeletzky 1973).

9. *Buchia volgensis* Zone. The zone has been identified in the topmost part of the Fynselv Member and in the Muslingeelv Member of southern Jameson Land and in the Rigi Member of Wollaston Forland (Table 1). The upper boundary cannot be precisely identified as the zone forms the top stratum in Jameson Land and the correlative part of the Wollaston Forland section is poorly fossiliferous. *B. volgensis* occurs together with species of *Hectoroceras*, *Surites*, and (?) *Bojarkia*. The zone is mainly of Late Ryazanian Age, but the species also occurs in the top of the Lower Ryazanian Zone of *Hectoroceras kochi*. The reports of this zone by Spath (1947, 1952) are, however, erroneous as his specimens belong to the *B. unschensis–B. terebratuloides* group.

10. *Buchia inflata* Zone. This zone is well represented in the Palnatokes Bjerg Formation of Wollaston Forland and Kuhn Ø (Surlyk 1978*a*) (Table 1). It is characterized by several *Buchia* assemblages. In the basal part the index species occurs together with *B. volgensis*, while *B. keyserlingi* is abundant in the upper part of the zone.

11. *Buchia keyserlingi* Zone. The presence of this zone in East Greenland was established by Surlyk (1978*a*). It is represented in the Palnatokes Bjerg Formation of Wollaston Forland and Kuhn Ø and it has a wide distribution in the Boreal Realm (Tables 1, 3). It extends even to the Sub-Boreal/Sub-Tethyan provinces (northern California, Mangyshlak, Copet-Dag, Sikhote-Alyn) (Table 3; Zakharov 1977, 1979). In the North Atlantic region the species is known furthermore from north-west Europe, Andøy and Spitzbergen. The *B. keyserlingi* Zone is easy to recognize and constitutes an excellent biostratigraphic marker in the Boreal Valanginian (Table 3).

12. *Buchia sublaevis* Zone. The zone was established in East Greenland by Surlyk (1978*a*). It is represented in the younger parts of the Palnatokes Bjerg Formation (Table 1). The age of the zone is Late Valanginian. This is supported by the co-occurrence of ammonites belonging to *Dichotomites* spp. which may be conspecific with forms found in the Siberian *Homolsomites bojarkensis* Zone. If this zone belongs to the Lower Hauterivian, the top part of the zone may, however, span the Valanginian–Hauterivian boundary (Table 3).

13. *Buchia crassicollis* beds. The beds with *B. crassicollis* are the youngest *Buchia*-bearing strata in East Greenland (Surlyk 1978*a*). The age of this part of the sequence, which belongs to the Albrechts Bugt and Rødryggen Members (Table 1), cannot be precisely determined because ammonites found together with *B. crassicollis* are indeterminable. In accordance with Jeletzky (1973) a latest Valanginian age was proposed for the *B. crassicollis* beds (Surlyk 1978*a*), while Russian geologists assign an Early Hauterivian Age for this level (see discussion in Jeletzky (1973)). The presence of *B. crassicollis* in the top of the marine *Buchia*-bearing sequence is established almost everywhere in the Boreal Realm (Table 3).

GEOLOGICAL IMPLICATIONS

The present study of the *Praebuchia–Buchia* fauna of East Greenland has in most cases substantiated the previous age-assignments of the lithostratigraphic units (Surlyk 1973, 1977, 1978*a*; Surlyk *et al.* 1973; Sykes and Surlyk 1976). Furthermore, some previously undated localities can now be firmly placed within the *Buchia* zonation, and the new datings have in a few cases led to considerable revisions of earlier ideas with significant geological implications (text-fig. 2). In particular, in southern Jameson Land the shallow marine coarse clastic Raukelv and Hesteelv Formations of Kimmeridgian to Valanginian Age can now be further interpreted in terms of the controlling synsedimentary tectonics.

Southern Jameson Land

The strong tectonic phase extending across the Jurassic–Cretaceous boundary throughout most of the North Sea–northern North Atlantic region was in southern Jameson Land heralded by an abrupt transition from upper slope black shales with channel sands to coarse, shallow marine sandstones. The sandstones are placed in the Raukelv Formation and the lowest faunas indicate an Early Volgian Age, while the higher beds contain successive faunas of Middle and Late Volgian and Ryazanian Age (Table 1) (Surlyk 1973; Surlyk *et al.* 1973). The Raukelv Formation represents several coarse sandy fan delta lobes separated by prodelta, lagoonal, and bay mudstones (Surlyk 1975). Approximately at the Volgian–Ryazanian boundary the southernmost Jameson Land was gently folded into three or more low anticlines and synclines with southward-plunging axes. The folding, which dies out towards the north, has been interpreted as caused by transpression in connection with lateral movements along a NW–SE cross-fault thought to be present in Scoresby Sund (text-fig. 1).

The deepest of the synclines formed a 10-km-wide submarine trough narrowing towards the north and with a southward-tilted axis (Surlyk 1973). It was filled with a 150-m-thick coarsening upwards black mudstone–siltstone–sandstone sequence deposited from the prograding fan deltas (Hesteelv Formation on Table 1). This unconformable trough-fill constitutes the Hesteelv Formation of Ryazanian–Early Valanginian Age. Sandy fan delta deposition continued in the surrounding shallow-water areas, and the higher parts of the Raukelv Formation are thus roughly contemporaneous with the Hesteelv Formation. This interpretation was suggested by Surlyk (1973, p. 91), but the hypothesis was based on rather meagre faunal data. The present study confirms the earlier notions concerning the contemporaneity of the Hesteelv and upper Raukelv Formation and *B. volgensis* of mid-Ryazanian Age has now been identified from the top of the Fynselv Member, which is the highest unit in the Raukelv Formation (Table 1).

The boundaries of the Raukelv Formation can be shown to be highly diachronic (Table 1). Along the easternmost outcrops the basal Raukelv Formation containing *B. volgensis* and *Hectoroceras kochi* of Lower Ryazanian Age overlies the lowermost Volgian top part of the Hareelv Formation, indicating the presence of a hiatus corresponding to almost all of the Volgian. To the west the presence of both the Lower, Middle, and Upper Volgian has been demonstrated on the basis of Ammonites (Surlyk *et al.* 1973; Surlyk 1973) and *B. mosquensis*. The boundary between the Raukelv and the underlying Hareelv Formation thus conceals a very small hiatus at maximum corresponding to a few Lower Volgian ammonite zones. The top of the Raukelv Formation is of Valanginian Age as indicated by the presence of cf. *Polyptychites mokschensis* in an outlier on the summit of J. P. Kochs Fjeld immediately west of the *B. volgensis–H. kochi* assemblage (Surlyk *et al.* 1973, pl. 4, fig. 5). The outlier was in earlier papers described under the Hesteelv Formation. The Raukelv Formation shows marked thickness variation in both N.–S. and E.–W. directions. It has wedged out completely in south-east Jameson Land, where the Hesteelv Formation rests directly on the Hareelv Formation. Along its eastern outcrop margin it is consistently about 100 m thick, and according to the new stratigraphic data it here corresponds mainly to the uppermost portion of the Raukelv Formation further westwards.

The thickness and stratigraphical completeness increase gradually in a westward direction. The maximum onshore thickness is not precisely known as the base of the formation is not exposed in this area, but it can be roughly estimated to be 400–500 m. Stratigraphically the Raukelv Formation in the western part of the area displays a probably unbroken Lower Volgian–Lower Valanginian sequence.

The strong E.–W. asymmetry of the Raukelv Formation suggests a position on a westward-tilted fault-block. The position of the western border fault is not known, but it is most likely a southwards continuation into Scoresby Sund of the main N.–S.-trending border fault, as also envisaged for the Upper Jurassic Hareelv Formation (Surlyk, Clemmensen, and Larsen 1981, fig. 11). This is supported by the nature of the contemporaneous deposits in Milne Land situated to the west of this fault. Here a condensed sequence of glauconitic fine-grained shelf sediments corresponds to the first phases of coarse-clastic syntectonic fan delta sedimentation of the Raukelv Formation.

In Milne Land fan delta sedimentation of the Hartz Fjeld Formation first started in the latest Middle Volgian. The lowest 45 m of this formation is of Middle Volgian Age. This is followed without any marked facies change by Valanginian, and all of the Upper Volgian–Ryazanian is absent (Birkelund *et al.* 1978).

Wollaston Forland–Kuhn Ø

The *Buchia* fauna of this region is well known from the work of Surlyk (1978*a*, table 1, fig. 1*b*), and the present study mainly supports the stratigraphic conclusions (see Table 1). The Niesen section of northern Wollaston Forland has, however, been used as a key section for the Volgian, Ryazanian, and Valanginian Stages in East Greenland. The exposed sequence is about 700 m thick. It is situated in a relatively deep part of the trough formed by antithetic block-faulting in Volgian–Valanginian times. The dominant facies are silty and sandy mudstones, sandstone turbidites, and resedimented conglomerates described in detail by Surlyk (1978*a*).

The Middle Volgian rests with erosional and angular unconformity on dark mudstones of the Upper Oxfordian–Kimmeridgian Bernbjerg Formation with *Praebuchia*. It is followed by a seemingly uninterrupted sequence of Middle Volgian to Valanginian deposits which contain ammonites and *Buchia* throughout. The lithostratigraphic scheme of Surlyk (1978*a*) (see Table 1) can now be firmly placed within the *Buchia* zonation. The Lindemans Bugt Formation includes the *B. russiensis*, *fischeriana*, *unschensis*/*terebratuloides*, *okensis*, and *volgensis* Zones and beds. The formation is subdivided into three members with diachronous boundaries (Table 1). The lower Laugeites Ravine Member comprises mudstones with subordinate turbidites and resedimented conglomerates representing the first phase of antithetic block faulting and the formation of coarse-grained submarine fans along the partly submerged western fault scarp. It is included in the *russiensis* and *fischeriana* beds. Towards the fault scarp and upwards it passes into the extremely coarse-grained, conglomeratic Rigi Member, which in its proximal parts includes the *russiensis*, *fischeriana*, *unschensis*/*terebratuloides*, *okensis*, and *volgensis* Zones and beds. In the more distal parts it interfingers with and is followed by the Niesen Member, which includes the *unschensis*/*terebratuloides*, *volgensis*, and possibly lower part of the *inflata* Zones and beds.

Submarine fan deposition continued into the Valanginian, but a regional transgression resulted in a change to more muddy sediment containing lesser amounts of conglomerates.

The proximal coarse-grained deposits characteristic of the inner and midfan environments are grouped into the Young Sund Member, which includes the *inflata*, *keyserlingi*, *sublaevis*, and probably also *crassicollis* Zones. The outer fan and basin environments were characterized by the mudstones with thin turbidites of the Albrechts Bugt Member including the same four zones. The easternmost block crest was exposed to erosion during part of the Valanginian and a fringe of sandstones constituting the Falskebugt Member was deposited on the proximal dip slope (Table 1). This member has only yielded fossils of the *sublaevis* Zone. Finally, the red mudstones of the Rødryggen Member characterizing isolated submerged crestal highs include the *inflata*, *keyserlingi*, *sublaevis*, and *crassicollis* Zones, although the lower zone may be absent.

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