

# ABSTRACT

A foraminiferal fauna of fifty species was extracted from the Brora Argillaceous and Brora Arenaceous Series of northern Scotland. *Nodosariids*, especially *Lenticulina muensteri* (Roemer), strongly predominate at most horizons, but three samples yielded faunas in which little but arenaceous foraminifera occur. The Brora assemblage is similar to faunas known from the English Oxford Clay and Corallian Beds, and in North America it is most closely comparable to the fauna of the Lower Vanguard Formation of the western interior region.

## Foraminifera from the Callovian (Middle Jurassic) of Brora, Scotland

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### INTRODUCTION

Jurassic rocks occur in a number of small, isolated outcrops in northern Scotland. They are far from the extensive outcrops of Jurassic in England, and the literature on them is small. Cordey (1962) published an account of the Oxford Clay foraminifera from the Isle of Skye, northwest Scotland, and this was the first systematic account of Jurassic foraminifera from Scotland. One or two writers have given short lists of genera in passing, but there has been no other published work on Scottish Jurassic foraminifera. The present work is concerned with foraminifera from beds which are exposed at Brora, Sutherland, on the east coast of north Scotland, and which are equivalent in age to part of the Oxford Clay of England. Twelve samples were collected from these beds in July, 1965, of which nine proved to be fossiliferous. The fossiliferous samples are referable to the *Erymnoceras coronatum* and *Quenstedtoceras* (*Lamberticeras*) *lamberti* Zones of the higher part of the Callovian Stage of the Jurassic.

The Jurassic rocks of the Brora area occur in a narrow coastal strip, 19 miles long and up to about 2½ miles wide. They are down-faulted against Old Red Sandstone and older rocks that make up the mass of northern Scotland. The exposures are not good, some units being exposed only on the foreshore at low tide. At Brora itself, however, it is possible to collect fairly systematically along the banks of the Brora River and in the neighboring brick pit. The succession at Brora which is equivalent to the Oxford Clay begins with a coal that is nowhere exposed. Above the Brora Coal lie in succession the Brora Roof Bed, the Brora Argillaceous Series, and the Brora Arenaceous Series. Higher Jurassic rocks occur to the northeast of the village, and lower Jurassic rocks to the southwest.

The Brora Roof Bed is fossiliferous, but it is a hard, ferruginous, sandy limestone, not suitable for the extraction of foraminifera. Samples were taken from the Brora Argillaceous Series and from the Brora Arenaceous Series. The Brora Argillaceous Series is about 275 feet thick, and the upper half is worked as a brick clay. Nine samples were collected from the brick clays. Arkell (1956, p. 25) noted that these beds are referable to the *Erymnoceras coronatum* Zone. The succeeding Brora Arenaceous Series is divided into several sandstone units and did not seem likely in the field to be ideal for a study of the foraminifera. Only three samples were collected. One was from the Fascally Sandstone, a unit about 20 feet thick assigned to the *Quenstedtoceras* (*Lamberticeras*) *lamberti* Zone (Arkell, 1933, p. 368). Two samples were collected from low in the Brora Sandstone unit, but they proved to be devoid of fossils. Arkell (1933, p. 367) considered that the lower part of the Brora Sandstone probably corresponds with the *Cardioceras* (*Scarburgiceras*) *praecordatum* Zone. This is equivalent to the upper part of the *Quenstedtoceras* (*Pavloviceras*) *mariae* Zone of Arkell, 1956 (p. 10, table 1).

Details of the sample numbers, localities, stratigraphic horizons, and National Grid reference numbers are as follows:

*Brora Arenaceous Series.* Exposed along the north side of the Brora River.  
Sample 220. Low in Brora Sandstone. Friable sandstone. NC 903041.  
Sample 219. Low in Brora Sandstone, 10' below Sample 220. Friable sandstone. NC 903041.  
Sample 218. 5' below top of Fascally Sandstone. Argillaceous sandstone. NC 900040.

*Brora Argillaceous Series*. Exposed in Brora brick pit. NC 898042. All samples are from the upper unit of the series, the Brick Clays. The approximate distance down from the top of the series is given for each sample.

Sample 217. 50' down. Clay.  
 Sample 216. 55' down. Clay.  
 Sample 215. 60' down. Clay.  
 Sample 214. 65' down. Clay.  
 Sample 213. 75' down. Shaly clay.  
 Sample 212. 85' down. Shaly clay.  
 Sample 211. 95' down. Shaly clay.  
 Sample 210. 105' down. Mudstone.  
 Sample 209. 115' down. Mudstone.

Samples 210, 219 and 220 yielded no fossils. In summary the samples correspond with the following standard ammonite zones as given by Arkell (1956, p. 10, table 1): Samples 219–220, *Quenstedtoceras* (*Pavloviceras*) *mariae* Zone; Sample 218, *Quenstedtoceras* (*Lamberticeras*) *lamberti* Zone; Samples 209–217, *Erymnoceras coronatum* Zone.

Table 1 of the present paper shows the distribution of the foraminifera in the Brora section by samples.

TABLE 1  
DISTRIBUTION OF FORAMINIFERA IN THE BRORA SECTION

Species	Sample number									
	209	211	212	213	214	215	216	217	218	
<i>Dentalina</i> sp.	x	.	.	.	.	.	.	.	.	.
<i>Fronclularia</i> sp.	x	.	.	.	.	.	.	.	.	.
<i>Lagenammina diffugiiformis</i> (Brady)	x	x	x	x	x	x	x	x	.	.
<i>Lenticulina quenstedti</i> (Gümbel)	x	.	x	x	x	x	x	.	.	.
<i>Fronclularia moelleri</i> Uhlig	x	.	.	x	x	x	x	.	.	.
<i>Haplophragmoides</i> sp.	x	x	.	x	.	x	x	.	.	.
<i>Reophax horridus</i> (Schwager)	x	x	x	x	x	x	x	.	.	.
<i>Ammobaculites</i> sp. cf. <i>A. suprajurassicus</i> (Schwager)	x	x	x	x	x	x	x	x	.	.
<i>Eoguttulina liassica</i> (Strickland)	x	.	.	x	x	x	x	.	.	.
<i>Textularia jurassica</i> (Gümbel)	x	.	.	.	x	x	x	.	.	.
<i>Pseudonodosaria sowerbyi</i> (Schwager)	x	.	.	x	x	x	x	.	.	.
<i>Vaginulina anomala</i> Blake	x	.	.	.	.	x	x	.	.	.
<i>Citharina flabellata</i> (Gümbel)	x	.	.	.	x	x	x	.	.	.
<i>Fronclularia francoica</i> Gümbel	x	.	.	.	x	x	x	.	.	.
<i>Lenticulina muensteri</i> (Roemer)	x	x	.	x	x	x	x	.	.	.
<i>Planularia anceps</i> (Terquem)	x	.	.	.	.	x	x	.	.	.
<i>Marginulina scapha</i> Lalicker	x	.	.	.	.	x	x	.	.	.
<i>Epistomina parastelligera</i> (Hofker)	x	.	.	.	.	x	x	.	.	.
<i>Dentalina guembeli</i> Schwager	x	.	.	.	.	x	x	.	.	.
<i>Reophax sterkii</i> Haeussler	x	x	.	.	.	.	x	.	.	.
<i>Ammobaculites coprolithiformis</i> (Schwager)	.	x	.	.	x	x	x	x	x	.
<i>Cornuspira</i> sp.	.	.	.	.	.	.	.	.	.	.
<i>Lingulina longiscata</i> (Terquem)	.	.	.	.	.	.	.	.	.	.
<i>Nodosaria</i> sp. cf. <i>N. affinis</i> (Terquem)	.	.	.	.	.	.	.	.	.	.
<i>Lagena globosa</i> (Montagu)	.	.	.	.	.	.	.	.	.	.
<i>Comorboides nudus</i> (Terquem)	.	.	.	.	.	.	.	.	.	.
<i>Eoguttulina pygmaea</i> (Schwager)	.	.	.	.	.	.	.	.	.	.
<i>Reophax multilocularis</i> Haeussler	.	.	.	.	.	.	.	.	.	.
<i>Trochammina squamata</i> Jones and Parker	.	.	.	.	.	.	.	.	.	.
<i>Triplasia bartensteini</i> Loeblich and Tappan	.	.	.	.	.	.	.	.	.	.
<i>Bigenerina</i> sp.	.	.	.	.	.	.	.	.	.	.
<i>Lingulina laevisima</i> (Terquem)	.	.	.	.	.	.	.	.	.	.
<i>Fronclularia hexagona</i> Terquem	.	.	.	.	.	.	.	.	.	.
<i>Nodosaria apheilocula</i> Tappan	.	.	.	.	.	.	.	.	.	.
<i>Ammobaculites canui</i> (Cushman)	.	.	.	.	.	.	.	.	.	.
<i>Pseudonodosaria vulgata</i> (Bornemann)	.	.	.	.	.	.	.	.	.	.
<i>Marginulina epicharis</i> (Loeblich and Tappan)	.	.	.	.	.	.	.	.	.	.
<i>Tristix oolithica</i> (Terquem)	.	.	.	.	.	.	.	.	.	.
<i>Citharina heteropleura</i> (Terquem)	.	.	.	.	.	.	.	.	.	.
<i>Nubeculinella bigoti</i> Cushman	.	.	.	.	.	.	.	.	.	.
<i>Nodosaria mutabilis</i> Terquem	.	.	.	.	.	.	.	.	.	.
<i>Textularia pugiunculus</i> (Schwager)	.	.	.	.	.	.	.	.	.	.
<i>Ammobaculites</i> sp. cf. <i>A. pictonicus</i> (Berthelin)	.	.	.	.	.	.	.	.	.	.
<i>Marginulina</i> sp.	.	.	.	.	.	.	.	.	.	.
<i>Marginulina batrakiensis</i> (Myatliuk)	.	.	.	.	.	.	.	.	.	.
<i>Textularia dumortieri</i> (Schwager)	.	.	.	.	.	.	.	.	.	.
<i>Marginulina irregularis</i> Gümbel	.	.	.	.	.	.	.	.	.	.
<i>Citharina</i> sp.	.	.	.	.	.	.	.	.	.	.
<i>Bolivina</i> sp. cf. <i>B. rhumbleri</i> Franke	.	.	.	.	.	.	.	.	.	.
<i>Saracenaria phaedra</i> Tappan	.	.	.	.	.	.	.	.	.	.

Most species recorded in the present study are fairly well known from previous work on Jurassic foraminifera. Extensive synonymies and descriptions are therefore omitted from the systematic part of the paper, unless there is a particular reason for inserting them. The illustrations of the species (plates 1–4) are pen and ink drawings made by the author with the aid of a camera lucida.

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#### DEPOSITORY

All figured specimens will be deposited in the collections of the British Museum (Natural History), London.

#### CHARACTERISTICS OF THE FAUNA

A total of 3813 specimens distributed among 50 species was extracted from the nine fossiliferous samples. These species are arranged in ten families. The composition of the whole assemblage in terms of numbers of species and specimens in each family is given in Table 2.

TABLE 2

Families	No. of species	No. of specimens
Saccamminidae	1	18
Reophacidae	3	397
Lituolidae	6	366
Textulariidae	4	48
Ophthalmitidae	2	7
Trochamminidae	1	7
Nodosariidae	28	2613
Polymorphinidae	2	207
Buliminidae	1	1
Ceratobuliminidae	2	149
Total	50	3813

The Nodosariidae are by far the most important family in terms of numbers of both species and specimens. More than half of the nodosariids (1605 specimens) belong to the single species *Lenticulina muensteri* (Roemer). Other nodosariids of which more than 100 specimens were found are *Citharina flabellata* (Gümbel), *Dentalina guembeli* Schwager, *Lenticulina quenstedti* (Gümbel), and *Marginulina scapha* Lalicker. Species of other families which are common include *Ammobaculites coprolithiformis* (Schwager), *Eoguttulina liassica* (Strickland), *Epistomina parastelligera* (Hofker), and *Reophax horridus* (Schwager).

Examination of the fauna of each individual rock sample separately reveals much variation from one to another. In Table 3, the percentage of specimens belonging to each family is given for each of the fossiliferous samples. A diversity index is also given, calculated according to the formula advocated by Simpson (1949) and Ager (1963, p. 240).

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TABLE 3  
PERCENTAGE COMPOSITION OF THE FAUNA OF EACH SAMPLE

Families	Sample numbers									
	209	211	212	213	214	215	216	217	218	
Saccamminidae	0.3	7.4	2.8	0.1	0.1	1.2	0.7	—	—	
Reophacidae	5.8	79.7	88.9	8.0	11.6	14.1	7.2	0.5	—	
Lituolidae	4.4	11.2	8.3	17.3	8.1	3.4	5.1	9.5	100.0	
Textulariidae	0.4	—	—	0.6	1.1	5.0	1.0	1.5	—	
Ophthalimididae	—	—	—	0.5	0.1	—	0.3	—	—	
Trochamminidae	—	—	—	0.5	0.2	0.2	—	—	—	
Nodosariidae	87.2	1.9	—	47.1	74.9	64.2	80.0	82.6	—	
Polymorphinidae	1.5	—	—	7.3	4.2	11.1	5.5	5.3	—	
Buliminidae	—	—	—	—	—	—	0.2	—	—	
Ceratobuliminidae	0.3	—	—	18.5	—	0.4	0.2	0.5	—	
Diversity index	3.9	2.9	1.3	6.9	2.9	4.2	4.5	3.1	1.0	
No. of specimens	677	54	36	773	1051	403	584	189	46	

Samples 211, 212 and 218 are notably different from the other samples in having respectively 98.3%, 100% and 100% of arenaceous specimens. The number of specimens obtained from these samples is low compared with the number obtained from the others, and the diversity index of the faunas is low in each case. Of the other six samples, the faunas of 209, 214, 215, 216 and 217 are dominated by nodosariids (from 87.2% of nodosariids in 209 to 64.2% in 215), while the arenaceous foraminifera as a group make up the next strongest element. All other species in these samples comprise from 1.8% to 11.5% of the total. The remaining sample, number 213, is distinguished from the others by its fairly evenly mixed assemblage (47.1% nodosariids, 26.5% arenaceous forms, and 26.3% of all other species), and it also has the highest diversity index. It is thus possible on an empirical basis to distinguish three broadly differing types of assemblage within the Brora material, 1) an exclusively or almost exclusively arenaceous assemblage, 2) an assemblage in which nodosariids dominate strongly and the arenaceous forms comprise a significant second element, and 3) an assemblage that is fairly well balanced between nodosariids, arenaceous forms, and other species. The latter assemblage is represented by one sample only, and it is particularly characterized by the presence of a large proportion of *Epistomina parastelligera* (Hofker). In the field, no lithological variations were noted that would correspond with these three types of assemblage. The significance of the different assemblages in the Brora material is not readily apparent at the present time and must await further work.

## COMPARISON OF THE FAUNA WITH OTHER JURASSIC FAUNAS

### Comparison with other European faunas

The Brora fauna taken as a whole compares closely with the Oxfordian faunas described by Barnard (1952, 1953) from the Oxford Clay and by Gordon (1962, 1965) from the Corallian Beds of England. Twenty-four of the 50 species listed in the present report are considered to be the same as forms recorded from the Oxfordian of England. Most of the common forms at Brora occur also in the English Oxford Clay, the Corallian Beds, or both. A comparison of the Brora fauna with the Bathonian material described by Cifelli (1959) from southern England is not quite so close.

Fourteen or possibly fifteen of the Brora species are considered to be the same as forms recorded from the English Bathonian. The greater similarity between the Brora fauna and that of the English Oxfordian can be attributed to the closer age of the two, and also to the similar dark clay and shale lithofacies at Brora and in much of the English Oxfordian rocks. The Bathonian of southern England is a mixed argillaceous-calcareous phase, with extensive beds of fuller's earth not encountered at Brora. The most notable absences from the Brora assemblage, when it is compared with other British faunas of similar age, are those of *Lenticulina tricarlinella* (Reuss) and of any species of *Ophthalmidium*, both of which can be very numerous at times in Middle and Upper Jurassic rocks.

The foraminiferal fauna that is geographically and stratigraphically closest to the Brora fauna, and on which work has been published, is that described by Cordey (1962) from the Isle of Skye. Cordey's locality is about 100 miles from Brora. Foraminifera were obtained from possible *Quenstedtoceras lamberti* Zone rocks (top Callovian), as well as from *Quenstedtoceras mariae* and possible *Cardioceras cordatum* Zone rocks (lower Oxfordian). The lithology, dark clays and shales, is similar at Brora and in Skye. Cordey listed 46 species from Skye, but only five of these are thought by the writer to be certainly the same as species found at Brora, with two or three others being possibly identical. The principal common element of the two assemblages is the overwhelming numbers of *Lenticulina muensteri* (Roemer) in both. The differences between the two areas are more striking than the similarities.

Parallels are close with many of the published reports on foraminiferal faunas from the higher Dogger and lower Malm of Germany. For example, about 19 or 20 of the Brora species are recorded also by Lutze (1960) from the Callovian and Oxfordian of northwestern Germany. The ranges of variation and the species marked by unusual abundance are also largely the same. Other similar faunas are well known from the U.S.S.R., Poland and France. However, along the Tethyan zone from Switzerland and Austria to Saudi Arabia a new life province has been entered and assemblages of the kind seen at Brora are no longer found. South of the Tethys, faunas comparable with the Brora fauna reappear in Egypt (Said and Barakat, 1958) and Somalia (Macfadyen, 1935).

### Comparisons with North American faunas

Wall (1960) has given an important account of the Jurassic foraminiferal faunas of Saskatchewan. The Brora fauna compares best with the assemblage that Wall recorded from the Lower Vanguard Formation or Rierdon equivalent. In these rocks, the Nodosariidae are the predominant family, and "the arenaceous fauna is definitely overshadowed quantitatively and qualitatively by the calcareous element" (Wall, 1960, p. 39). A number of the species are either the same as species from Brora or comparable to them. The pre-

dominance of *Lenticulina muensteri* (Roemer) at Brora is paralleled by the like abundance of the fairly similar species, *Lenticulina audax* Loeblich and Tappan, in the Lower Vanguard. Present in both assemblages are *Citharina flabellata* (Gümbel), *Fronicularia franconica* Gümbel, *Marginulina scapha* Lalicker, *Pseudonodosaria sowerbyi* (Schwager), *Tristix oolithica* (Terquem), and *Lenticulina quenstedti* (Gümbel). The last-named species is especially numerous both in the Lower Vanguard Formation and at Brora. Other species from Brora, including arenaceous forms, are matched in the Lower Vanguard of Saskatchewan by similar but not identical species. On the other hand, *Ammobaculites coprolithiformis* (Schwager), 269 specimens of which were found at Brora, is not represented in the Lower Vanguard or other Saskatchewan faunas. The rarely occurring specimens of *Ammomarginulina baryntica* Loeblich and Tappan may possibly be a comparable form, for this species is a large litiolite similar in size to *Ammobaculites coprolithiformis*.

The similarities between the Lower Vanguard and the Brora faunas are the result of their approximately coincident age and a fairly similar facies. Other stratigraphic units in the Saskatchewan Jurassic contain faunas that are similar to that from Brora, but the similarities are not so close as with the fauna of the Lower Vanguard Formation.

Comparisons with other North American assemblages are also less clear than comparison with the Lower Vanguard. Loeblich and Tappan (1950a) described a fauna of 56 species of foraminifera from the Redwater Shale, Oxfordian, of South Dakota. Forty of the species are nodosariids, and litiolids and polymorphinids are also important components of the fauna. The number of arenaceous species is low, but the number of arenaceous specimens amounts to "a fairly large percentage" (Loeblich and Tappan, p. 41) of the number of individuals present. The Redwater Shale fauna is therefore similar to the Brora fauna in a general way. Few of the species appear to be the same, however. Species of *Tristix* from the two localities are close, and a large, costate species of *Citharina* occurs both at Brora and in the Redwater Shale. Several of the smooth species of *Lingulina* from the Redwater are reminiscent of *Fronicularia franconica* Gümbel at Brora, but are not quite the same. *Lenticulina muensteri* (Roemer), *Lenticulina quenstedti* (Gümbel) and *Ammobaculites coprolithiformis* (Schwager), so abundant at Brora, are not found in the South Dakota assemblage. *Reophax sundancensis* Loeblich and Tappan from the Redwater is a species similar to *Reophax horridus* (Schwager) from Brora.

Other faunas recorded from the Jurassic of North America by Sandidge (1933), Wickenden (1933), Lalicker (1950), and Loeblich and Tappan (1950b) are marked by the dominance of nodosariids and are broadly the same as the Brora fauna. A constant difference between the North American assemblages and faunas of comparable age from Brora and western Europe is the small role played by species of the *Epistomina*

group in America, so far as present knowledge shows. European workers have found many species of *Epistomina s. l.* in the Middle and Upper Jurassic (often referring them to *Brotzenia*, *Sublamarkella* or *Voorthuysenia*, genera placed in synonymy with *Epistomina* by Loeblich and Tappan, 1964). At times they are sparse, but at occasional levels they occur in great numbers. At Brora, for example, 130 specimens of one species of *Epistomina* were found in Sample 213, representing 16.8% of the total number of specimens found at that level. Species of *Epistomina* differ quite considerably from one level to another in the Jurassic, and they may prove to be of greater stratigraphic value than many of the other foraminifera.

The Upper Jurassic foraminiferal faunas described from Alaska by Tappan (1955) are the least like the Brora fauna of all known North American faunas. The fossils are from the Kingak Shale, and arenaceous species are frequently predominant. A number of nodosariids were listed by Tappan, especially from the Topagoruk Test Well Number 1, but the similarities are not great. Here again, the *Epistomina* group is absent. The dissimilarity between the Brora and Alaskan faunas is probably largely a matter of facies differences. Much of the Kingak Shale is a dark shale, and Tappan noted when discussing the Canning River material in particular that conditions may have been adverse to foraminifera at the time of deposition. She compared the Canning River black shales to other well-known dark shales that have faunas which may be large in numbers but are lacking in diversity.

#### SYSTEMATIC DESCRIPTIONS

##### Order FORAMINIFERA

##### Family SACCAMMINIDAE

##### Genus LAGENAMMINA Rhumbler, 1911

##### *Lagenammina difflugiformis* (Brady)

Plate 1, figure 13

*Reophax difflugiformis* BRADY, 1879, p. 51, pl. 4, fig. 3a-b.

*Lagenammina difflugiformis* (Brady). — GORDON, 1965, p. 832, text-fig. 3(8-11).

**Material:** Eighteen specimens.

**Dimensions:** Length 0.22-0.77 mm., mean length of all specimens 0.42 mm.

**Remarks:** The variation is similar to that reported by Gordon (1965) from the Corallian Beds of southern England.

##### Family REOPHACIDAE

##### Genus REOPHAX Montfort, 1808

##### *Reophax horridus* (Schwager)

Plate 1, figures 6-8

*Haplostiche horrida* SCHWAGER, 1865, p. 92, pl. 2, fig. 2a-c.

*Nodosaria agglutinans* TERQUEM, 1870, p. 354, pl. 29, fig. 18a-b.

*Reophax horridus* (Schwager) s. l. — LUTZE, 1960, p. 436, pl. 26, figs. 13-14.



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**Material:** Three hundred and five specimens.

**Dimensions:** Length 0.40–0.89 mm.

**Remarks:** Schwager's type locality is in the Oxfordian of Bavaria. Lutze (1960) published a long synonymy for this species. The specimens from Brora are almost all crushed or distorted to some degree, and this, together with the variability of the texture of the test, makes it uncertain whether every specimen here placed in *R. horridus* really belongs to one species only. All specimens are characterized by a very gradual increase in chamber size, and by an ellipsoidal or pyriform apertural chamber. In many specimens, the sutures are strongly constricted.

### *Reophax multilocularis* Haeusler

Plate 1, figure 12

*Reophax multilocularis* HAEUSLER, 1883, p. 26. – HAEUSLER, 1890, p. 28, pl. 3, figs. 9–11. – CIFELLI, 1959, p. 282, pl. 1, figs. 6–7.

**Material:** Ten specimens.

**Dimensions:** Length 0.31–0.39 mm., mean length of all specimens 0.37 mm.

**Remarks:** Haeusler (1883) described this species from the Oxfordian of Switzerland. The Brora material is similar to it in all respects except that none of the specimens have more than seven chambers, whereas Haeusler's specimens have "22–25 small segments". The record by Cifelli (1959) is from the English Bathonian.

### *Reophax sterkii* Haeusler

Plate 1, figures 16–17

*Reophax sterkii* HAEUSLER, 1890, p. 29, pl. 3, fig. 23. – LLOYD, 1959, p. 307, pl. 54, fig. 6a–b.

?*Reophax scorpiurus* Montfort *forma liasica* FRANKE, 1936, p. 19, pl. 1, fig. 18.

*Reophax liasica* Franke. – TAPPAN, 1955, p. 36, pl. 7, figs. 15–19.

**Material:** Eighty-two specimens.

**Dimensions:** Length 0.86–1.96 mm.; most specimens are 0.9–1.2 mm. long.

**Remarks:** This is a large species of *Reophax*, characterized by the rapidly increasing chamber size and by the distinctly pyriform apertural chamber, which may amount to half the length of the test. Most specimens in the Brora material have three or four chambers, but some have as many as six. Tappan's (1955) form is from the Lias of Alaska, and, although a few of my specimens have more chambers than do those of Tappan, my plate 1, figure 17, and Tappan's plate 7, figure 16, illustrate specimens which are strikingly alike. The material of Franke (1936) seems less like the Brora specimens. It is from the Lias of Germany. Lloyd (1959) recorded this species from the Kimmeridgian of England, and the type locality is in the *Gregoryceras transversarium* Zone, Oxfordian, of Switzerland.

## Family LITUOLIDAE

Genus HAPLOPHRAGMOIDES Cushman, 1910

### *Haplophragmoides* sp.

Plate 1, figure 5

**Material:** Sixteen specimens, poorly preserved and often crushed.

**Dimensions:** Greatest diameter of measurable specimens 0.28–0.38 mm., mean of all measurable specimens 0.34 mm.

Genus AMMOBACULITES Cushman, 1910

### *Ammobaculites canui* (Cushman)

Plate 1, figure 1

*Haplophragmoides canui* CUSHMAN, 1930, p. 133, pl. 4, fig. 1a–b. *Cribrostomoides canui* (Cushman). – GORDON, 1965, p. 833, text-fig. 3(1–7).

**Material:** Nine specimens, all but 3 crushed more or less badly.

**Dimensions:** Greatest diameters of the 3 best specimens 0.74, 0.83 and 1.07 mm.

**Remarks:** Although badly damaged, the Brora specimens are recognizably the same as specimens recorded by Gordon (1965) from the Corallian Beds of England. The tendency of some specimens in both the Brora sequence and the Corallian Beds to uncoil in the last one or two chambers and the simple aperture in the center of the apertural face together make it preferable to place this form in *Ammobaculites* rather than in *Cribrostomoides*.

### *Ammobaculites coprolithiformis* (Schwager)

Plate 1, figure 4

*Haplophragmium coprolithiforme* SCHWAGER, 1867, p. 654, pl. 34, fig. 3.

*Ammobaculites coprolithiformis* (Schwager). – GORDON, 1965, p. 832, text-figs. 2, 3(25–28).

**Material:** Two hundred and sixty-nine specimens.

**Dimensions:** Length up to 3.97 mm. Approximately 90% of all specimens are 0.8–2.25 mm. long.

**Remarks:** A synonymy for this species has already been provided (Gordon, 1962) and need not be repeated here. The variation in the Brora material is comparable with that previously reported in individuals from the English Corallian Beds, most specimens being similar to forms *b*, *c*, *g*, and *f*, but none like *a* and *e*, and few like *d* (Gordon, 1965, text-fig. 2).

### *Ammobaculites* sp. cf. *A. pictonicus* (Berthelin)

Plate 1, figure 18

Cf. *Haplophragmium pictonicum* BERTHELIN, 1879, p. 26, pl. 1, figs. 1–2.

**Material:** One specimen.

*Dimensions:* 1.86 mm. long.

*Remarks:* The single specimen from Brora consists of a small coil followed by 7 chambers in an almost straight series, the chambers increasing in size only slightly. The single specimen of what may be a variable species is not adequate to make a firm identification among the many Jurassic species of *Ammobaculites*, but it is very similar to a form described by Berthelin (1879) from the *Amaltheus margaritatus* Zone of the Lias of Vendée, France.

***Ammobaculites* sp. cf. *A. suprajurassicus* (Schwager)**  
Plate 1, figures 2-3

Cf. *Haplophragmium suprajurassicum* SCHWAGER, 1865, p. 92, pl. 2, fig. 1a-b.

*Ammobaculites suprajurassicus* (Schwager). - LUTZE, 1960, p. 442, pl. 26, figs. 10-12; pl. 27, figs. 4-5.

*Material:* Fifty-eight specimens, some of them crushed.

*Dimensions:* Length 0.32-0.75 mm.

*Remarks:* These specimens are compared with material described by Schwager (1865) from the Oxfordian of Bavaria. They seem to be close morphologically, but the illustration provided by Schwager is not very clear. Specimens referred to this species by Lutze (1960) from the Bathonian to middle Oxfordian of northwest Germany are identical with the Brora specimens.

Genus *TRIPLASIA* REUSS, 1854

***Triplasia bartensteini* Loeblich and Tappan**  
Plate 1, figures 19-20

*Triplasia variabilis* (Brady). - BARTENSTEIN and BRAND, 1937, p. 185, pl. 14A, fig. 6.

*Triplasia bartensteini* LOEBLICH and TAPPAN, 1952, p. 8, pl. 1, fig. 9. - CIFElli, 1959, p. 285, pl. 1, fig. 11.

*Triplasia* cf. *emslandensis* Bartenstein and Brand. - LUTZE, 1960, p. 441, pl. 27, fig. 13.

*Material:* Thirteen specimens.

*Dimensions:* Length 0.79-2.07 mm., mean length of all specimens 1.68 mm.

*Remarks:* The type description of this species (Bartenstein and Brand, 1937, cited from Loeblich and Tappan, 1952) states that the aperture is a slit. All of the Brora specimens have a roughly circular aperture, but there is otherwise no disagreement. The type material is from the upper Dogger of Westphalia. My specimens are rather larger than those recorded by Cifelli (1959) from the English Bathonian, and, although they are similar in other respects, none of them grade from the typical triradiate form into a quadrate form as occurs in Cifelli's material. The Brora specimens agree with those of Cifelli in having a coil conspicuously developed in 10 out of the 13 specimens which were found. The other three specimens from Brora show little or no trace of the coil on the outside of the roughly constructed test.

Family TEXTULARIIDAE  
Genus TEXTULARIA Defrance, 1824

***Textularia dumortieri* (Schwager)**  
Plate 1, figure 9

*Textularia dumortieri* SCHWAGER, 1866, p. 309, text-fig. 14.

*Material:* Two specimens.

*Dimensions:* Length 0.33 and 0.36 mm. respectively.

***Textularia jurassica* (Gümbel)**  
Plate 1, figure 11

*Textularia jurassica* GÜMBEL, 1862, p. 228, pl. 4, fig. 17a-b.

*Material:* Thirty-five specimens.

*Dimensions:* Length up to 0.43 mm., usually 0.3-0.4 mm.

***Textularia pugiunculus* (Schwager)**  
Plate 1, figure 10

*Textularia pugiunculus* SCHWAGER, 1865, p. 140, pl. 7, fig. 16.

*Material:* Three specimens, of which one is incomplete.

*Dimensions:* Lengths of the complete specimens are 0.51 and 0.53 mm.

*Remarks:* The aperture of the complete specimens is circular and is situated in a small pit near the inner margin of the final chamber.

Genus BIGENERINA d'Orbigny, 1826

***Bigenerina* sp.**  
Plate 1, figure 14

*Material:* Eight specimens, mostly damaged or crushed.

*Dimensions:* Length 0.43-0.57 mm., mean length of 5 measurable specimens 0.49 mm.

Family OPTHALMIDIIDAE  
Genus CORNUSPIRA Schultze, 1854

***Cornuspira* sp.**  
Plate 4, figure 28

*Material:* Four specimens.

*Dimensions:* Greatest diameters of the specimens 0.2, 0.23, 0.24 and 0.29 mm.

*Remarks:* The specimens are all preserved in pyrite. They are only tentatively placed among the ophthalmidiids, since the nature of the original material of the test is unknown.

Genus NUBECULINELLA Cushman, 1930

***Nubeculinella bigoti* Cushman**  
Plate 4, figure 29

*Nubeculinella bigoti* CUSHMAN, 1930, p. 134, pl. 4, figs. 3-4. - GORDON, 1965, p. 838, text-fig. 11(16-19).

## CALLOVIAN FORAMINIFERA

**Material:** Three fragments.

**Dimensions:** Length of a single chamber is 0.38–0.53 mm.

### Family TROCHAMMINIDAE

Genus TROCHAMMINA Parker and Jones, 1859

#### Trochammina squamata Jones and Parker Plate 1, figure 15

*Trochammina squamata* JONES and PARKER, 1860, p. 304.

**Material:** Seven specimens.

**Dimensions:** Greatest diameters of the best specimens are 0.33, 0.36, 0.44, 0.44 and 0.55 mm.

### Family NODOSARIIDAE

Genus LENTICULINA Lamarck, 1804

#### Lenticulina muensteri (Roemer) Plate 4, figures 4, 12–14

*Robulina münsteri* ROEMER, 1839, p. 48, pl. 20, fig. 29a–b.

*Lenticulina muensteri* (Roemer). – GORDON, 1965, p. 840, text-figs. 5, 6 (9–10).

**Material:** One thousand six hundred and five specimens.

**Dimensions:** Greatest dimension of the test up to 1.52 mm., usually between 0.5 and 1.2 mm.

**Remarks:** A synonymy and discussion of this species have been presented previously (Gordon, 1962, p. 526). The range of variation in the Brora material is less than that recorded by Gordon (1965, text-figure 5) in the material from the English Corallian Beds, most of the Brora specimens being close to forms *a* and *b* of the Corallian. On the whole, the Brora specimens are slightly more compressed than the Corallian ones. As at other levels in the Jurassic, occasional specimens deviate from the normal planispiral mode of coiling in the last whorl. An extreme example of this is shown in plate 4, figure 12. The other three figures on plate 4 show the common variants in the Brora material.

Although possibly not the same species, an abundant form from the Vanguard Formation of Saskatchewan, referred by Wall (1960, p. 67) to *Lenticulina audax* Loeblich and Tappan, should be noted here. It is fairly similar to *L. muensteri* in morphology. It seems to occupy the same position of numerical dominance in the Vanguard fauna that *L. muensteri* does in the British Callovian and Oxfordian assemblages. The type material of *L. audax* from the Redwater Shale of South Dakota (Loeblich and Tappan, 1950a) is less like *L. muensteri*.

#### Lenticulina quenstedti (Gümbel) Plate 2, figures 6–10

*Cristellaria quenstedti* GÜMBEL, 1862, p. 226, pl. 4, fig. 2a–b. – KLAHN, 1921, p. 49, pl. 2, figs. 16, 18–25.

?*Cristellaria sarthacensis* SCHWAGER, 1866, p. 306, text-fig. 10.

*Cristellaria helios* TERQUEM, 1870, p. 445, pl. 16, figs. 19–21.

*Cristellaria polonica* WISNIEWSKI, 1890, p. 222, pl. 10, fig. 3a–c.

*Cristellaria quenstedti* Gümbel var. *rotaliniformis* PAALZOW, 1917, p. 244, pl. 47, figs. 4–5.

*Cristellaria quenstedti* Gümbel var. *evoluta* PAALZOW, 1917, p. 244, pl. 47, fig. 7.

*Lenticulina helios* (Terquem). – SANDIDGE, 1933, p. 178, pl. 1, figs. 1–2.

*Lenticulina sarthacensis* (Schwager). – WICKENDEN, 1933, p. 160, pl. 1, figs. 9–11.

?*Cristellaria* (*Lenticulina*) *quenstedti* Gümbel. – BARTENSTEIN and BRAND, 1937, p. 177, many figures on pls. 11a, 11b, 12a, 12b, 13, 14, 15a, 15c.

*Lenticulina dilecta* LOEBLICH and TAPPAN, 1950, p. 7, pl. 1, figs. 5–8. – WALL, 1960, p. 68, pl. 9, fig. 5; pl. 16, figs. 13–16.

*Lenticulina quenstedti* (Gümbel). – BARNARD, 1952, p. 339, text-fig. A,6. – CIFELLI, 1959, p. 292, pl. 2, figs. 6–7.

**Material:** Two hundred and seventy-six specimens, 239 of which are from Sample 209.

**Dimensions:** Length up to 1.25 mm. (a partly uncoiled specimen). Usually the greatest diameter of the test is 0.4–0.7 mm.

**Remarks:** This well-known species has been widely reported from the Bathonian, Callovian and Oxfordian rocks of Europe. The type material of Gümbel was from the Oxfordian of Bavaria. Synonymies have been provided by Barnard (1952) and Cifelli (1959). The forms recorded by several workers under names such as *Lenticulina dilecta*, *L. helios*, and *L. sarthacensis* from rocks of comparable age in North America do not appear to differ in any essential way from Gümbel's species. In the Brora material, there is considerable variation in morphology, but not more than 5% of the specimens show an appreciable degree of uncoiling, such as is displayed on plate 2, figures 8–10. Most of the specimens correspond with those illustrated on plate 2, figures 6 and 7. Among the uncoiling specimens, the cross section of the uncoiled part is usually elliptical, with one end of the ellipse flattened to form the non-apertural margin. A few specimens (plate 2, figure 9) are *Saracenaria*-like with a nearly triangular cross section. Most specimens have an acutely angled or carinate periphery. A few have an angular shoulder on each side of the test, running parallel with the periphery, thus approaching a tricarinate margin in form. This is the closest that the Brora specimens come to *Lenticulina tricarinella* (Reuss), although several authors have made the likely suggestion that the latter species is an evolutionary offshoot of the *L. quenstedti* stock.

Paalzow (1917) described two varieties of *L. quenstedti* that fall within the range of variation of the Brora specimens. The North American specimens show a range of variation which is similar to that of the European material. The variation recorded by Wickenden (1933) from Alberta and Saskatchewan, where this form is very common at one level, is closely comparable with that known from Europe. The specimen illustrated by Sandidge (1933, plate 1, figures 1–2) is notably similar to the Brora specimen here illustrated in plate 2, figure 7.

## Genus MARGINULINA d'Orbigny, 1826

*Marginulina batrakiensis* Myatliuk

Plate 4, figures 24–25

*Cristellaria batrakiensis* MYATLIUK, 1939, pp. 61, 74, pl. 4, figs. 52–53.*Marginulina caelata* LOEBLICH and TAPPAN, 1950, p. 46, pl. 12, fig. 10a–b.*Marginulina batrakiensis* (Myatliuk). – CORDEY, 1962, p. 383, pl. 46, fig. 7a–c.*Material*: Four specimens.*Dimensions*: Lengths 0.29, 0.31, 0.43 and 0.44 mm.*Remarks*: The type level of this species is in the middle Callovian, Kuibyshev District, U.S.S.R. The species is characterized by inflated chambers ornamented with longitudinal costae that are not continuous from one chamber to the next. The coil in the Brora specimens is slightly more robust than that of the specimen figured by Cordey (1962) from the Oxford Clay of Skye. The aperture in the Brora specimens is apparently simple (although this is not distinct in any specimen) and is situated at the end of a neck extending from the last chamber.*Marginulina epicharis* (Loeblich and Tappan)

Plate 2, figures 14–15

Cf. *Cristellaria prava* TERQUEM, 1870, p. 434, pl. 10, figs. 25–29, especially fig. 26a–b.*Vaginulinopsis epicharis* LOEBLICH and TAPPAN, 1950, p. 47, pl. 12, figs. 21–23b.*Material*: Fifteen specimens.*Dimensions*: Length 0.23–0.91 mm., but usually less than 0.65 mm.*Remarks*: Loeblich and Tappan's (1950a) material is from the Redwater Shale, Oxfordian, near Spearfish, South Dakota. This species may be the same as *Cristellaria prava* Terquem (1870a) from the Bathonian of Fontoy, Moselle, France, but a varied series of specimens was figured by Terquem, and only his plate 10, figure 26a–b corresponds well with the Brora material.*Marginulina irregularis* Gumbel

Plate 2, figure 11

*Marginulina irregularis* GÜMBEL, 1862, p. 220, pl. 3, figs. 15–19.*Material*: One specimen.*Dimensions*: Length 0.64 mm.*Marginulina scapha* Lalicker

Plate 2, figures 1–5

*Marginulina scapha* LALICKER, 1950, p. 12, pl. 1, fig. 7.*Marginulina* cf. *scapha* Lalicker. – WALL, 1960, p. 72, pl. 5, figs. 8–10.*Material*: One hundred and twenty-two specimens.*Dimensions*: Length 0.4–0.95 mm., most specimens not over 0.75 mm.*Remarks*: Lalicker described this species from the Ellis Group, Bathonian of southwestern Montana. *Marginulina ambigua* Schwager, 1866, may be the same species, but Lalicker distinguished his species from that of Schwager on the basis of the wider uniserial portion and the curving (rather than straight) sutures in *M. scapha*. He does not mention the nature of the aperture, but in the Brora specimens it is radiate.*Marginulina* sp.

Plate 2, figures 12–13

*Material*: Two specimens.*Dimensions*: Length 0.57 and 0.93 mm. respectively.*Remarks*: One of the specimens has an irregular triradiate apertural chamber that may have formed as a result of injury to the organism during life. Except for this end chamber, the other specimen is identical with the first. The chambers are moderately inflated in the curvilinear part of both specimens, and the aperture is radiate.

## Genus PLANULARIA Defrance, 1824

*Planularia anceps* (Terquem)

Plate 4, figures 15–20

*Cristellaria anceps* TERQUEM, 1870, p. 428, pl. 9, figs. 11–21.*Planularia anceps* (Terquem). – CIFELLI, 1959, p. 298, pl. 3, figs. 14–15.*Material*: Forty-five specimens.*Dimensions*: Length 0.39–0.67 mm., mean length of all specimens 0.53 mm.*Remarks*: About five specimens have barely perceptible striations on the test, but they are otherwise similar to the other specimens. The species is quite variable in the breadth of the test and in the degree to which the later chambers reach towards the non-apertural margin.

## Genus SARACENARIA Defrance, 1824

*Saracenaria phaedra* Tappan

Plate 2, figures 17–18

*Saracenaria phaedra* TAPPAN, 1955, p. 64, pl. 26, fig. 22.*Material*: Sixteen specimens.*Dimensions*: Length 0.33–0.97 mm., mean length of all specimens 0.62 mm.*Remarks*: Tappan's specimen is from the Oxfordian or lower Kimmeridgian of northern Alaska, and the aperture is described as being "tiny and rounded" (Tappan, 1955, p. 64). The better-preserved of the Brora specimens have a radiate aperture, but other characteristics are the same. The test is composed of a curving series of chambers, and it lacks a true coil.



## CALLOVIAN FORAMINIFERA

Genus DENTALINA d'Orbigny, 1826

### *Dentalina guembeli* Schwager Plate 4, figures 1-2

*Dentalina guembeli* SCHWAGER, 1865, p. 101, pl. 2, fig. 20. — BARNARD, 1953, p. 188, text-fig. B, 6. — GORDON, 1965, p. 843, text-fig. 6(13-18).

**Material:** One hundred and sixty-three specimens, some broken and incomplete.

**Dimensions:** Length of the largest specimen 1.19 mm. Usually the length is between 0.5 and 0.9 mm.

**Remarks:** The specimens are highly variable, but they lack ornament or other characters that might be taxonomically significant. Smooth species of *Dentalina* are widespread in the Jurassic, but lines of morphological separation between them are not yet clear.

### *Dentalina* sp. Plate 2, figure 16

**Material:** Fragments of 5 specimens, none complete.

**Dimensions:** Length of the longest and most complete fragment (plate 2, figure 16), consisting of the last 4 chambers, 1.48 mm. Two other fragments are of seemingly bigger specimens.

**Remarks:** This form is distinguished principally by its unusually large size. The specimens are devoid of ornament and cannot be referred satisfactorily to any particular species. They probably correspond with one or more of the many species of *Dentalina* erected by Schwager (1865) or Terquem (1870b).

Genus NODOSARIA Lamarck, 1812

### *Nodosaria apheilolocula* Tappan Plate 4, figure 31

*Nodosaria incerta* TERQUEM and BERTHELIN, 1875, p. 18, pl. 1, fig. 15 (not Neugeboren, 1856; not Silvestri, 1872).  
*Nodosaria apheilolocula* TAPPAN, 1955, p. 68, pl. 24, figs. 6-7.

**Material:** Ten fragments, each consisting of one chamber and a length of neck at each end.

**Dimensions:** Mean length of the chambers, exclusive of necks, 0.33 mm. There is little variation in length of the chambers.

**Remarks:** Terquem and Berthelin (1875) proposed their new species on the basis of material from the *Amaltheus margaritatus* Zone, Lias, near Nancy, France. The original name was preoccupied, however, and Tappan therefore introduced a new name. Tappan's material is from the Upper Lias of Alaska. The Brora specimens agree well in size and in other respects with those from the Lias. There is no aperture preserved in any of the specimens from Brora.

### *Nodosaria* sp. cf. *N. affinis* (Terquem) Plate 4, figure 6

Cf. *Dentalina affinis* TERQUEM, 1870, p. 363, pl. 27, figs. 17-22 (not *Nodosaria* (*Dentalina*) *affinis* Reuss, 1845; not *Nodosaria affinis* d'Orbigny, 1846).

**Material:** Twelve specimens, mostly incomplete, some crushed.

**Dimensions:** Length of the longest fragment, consisting of 4 chambers, 0.59 mm. Lengths of complete specimens, consisting of 3 chambers each, 0.47, 0.48 and 0.51 mm.

**Remarks:** The aperture is obscure in all specimens but appears to be radiate. The test is slightly compressed. The species with which comparison is made was described by Terquem (1870b) from the *Parkinsonia parkinsoni* Zone of Fontoy, Moselle, France. The Brora specimens most closely resemble the specimen figured by Terquem in his plate 27, figure 17a-b. It is not clear from Terquem's description whether, or to what extent, his other specimens are compressed.

### *Nodosaria mutabilis* Terquem Plate 4, figure 5

*Nodosaria mutabilis* TERQUEM, 1870, p. 353, pl. 26, figs. 6-12 (not Costa, 1855).

**Material:** Eight specimens, all incomplete.

**Dimensions:** One fragment, consisting of 3 chambers, 0.37 mm. long; a second fragment, consisting of 4 chambers, 0.5 mm. long.

**Remarks:** The shape of the chambers varies from bead-like to barrel-shaped. Sometimes a smaller chamber is inserted into an otherwise uniform or slowly enlarging series of chambers. The Brora specimens correspond best with the one depicted in Terquem's plate 26, figure 6. The type material is from the *Parkinsonia parkinsoni* Zone of Fontoy, Moselle.

Genus PSEUDONODOSARIA Boomgaart, 1949

### *Pseudonodosaria sowerbyi* (Schwager) Plate 4, figures 9-11

*Nodosaria sowerbyi* SCHWAGER, 1867, p. 656, pl. 34, fig. 8. — GORDON, 1965, p. 849, text-fig. 7(8-11).

**Material:** Twenty-four specimens, about half of which are well preserved.

**Dimensions:** Length of complete specimens 0.22-0.66 mm.

**Description:** The test is straight, consisting of up to 8 embracing chambers, and it is circular in cross section. The proloculum is spherical, often with a low apex at the base. The height of the following chambers varies from about two-thirds to one-half of the width in most specimens. The end chamber is pyriform, with a terminal radiate aperture. Four or five specimens (for

example, plate 4, figure 9) have smaller initial chambers than the majority and seem to be microspheric forms of the same species. There is no ornamentation.

**Remarks:** The Brora specimens differ slightly from those recorded by Gordon (1965) from the Corallian Beds in having more chambers, and in having chambers that embrace rather more strongly. The type material of the species is from the Bajocian of Switzerland.

**Pseudonodosaria vulgata (Bornemann)**

Plate 4, figures 7–8

*Glandulina vulgata* BORNEMANN, 1854, p. 31, pl. 2, figs. 1a–b, 2.  
*Pseudonodosaria vulgata* (Bornemann). – CIFELLI, 1959, p. 318, pl. 5, fig. 3.

*Rectoglandulina vulgata* (Bornemann). – LUTZE, 1960, p. 480, pl. 29, figs. 4–7; text-figs. 16–17.

**Material:** Twenty-four specimens, some crushed.

**Dimensions:** Length 0.38–0.73 mm., but usually less than 0.65 mm.

**Remarks:** Barnard (1950) has described the variation of this highly variable species in the Lias, and Lutze (1960) has described the variation in the higher Jurassic. Three of the Brora specimens differ from the remainder in being slightly arcuate at the initial end, but otherwise there seems to be no difference. *Pseudonodosaria* is generally differentiated from *Pandaglandulina* Loeblich and Tappan, 1955, by its characteristically rectilinear form, and, if found alone, the curvilinear forms would be referred to *Pandaglandulina*, which is slightly arcuate.

**Genus TRISTIX Macfadyen, 1941**

**Tristix oolithica (Terquem)**

Plate 3, figure 14

*Tritaxia oolithica* TERQUEM, 1886, p. 60, pl. 7, fig. 5a–b.

*Tristix oolithica* (Terquem). – GORDON, 1965, p. 849, text-figs. 8, 10(3, 4).

**Material:** Twelve specimens.

**Dimensions:** Length 0.39–0.9 mm., mean length of all specimens 0.57 mm.

**Remarks:** Most of the Brora specimens correspond with form *b* from the English Corallian Beds, but others have rounded rather than angular peripheries and are similar to form *d* (Gordon, 1965, text-figure 8). The aperture is radiate in all specimens.

**Genus VAGINULINA d'Orbigny, 1826**

**Vaginulina anomala Blake**

Plate 4, figures 21–23

*Vaginulina anomala* BLAKE, 1876, p. 464, pl. 17, fig. 23 (?23a). – GORDON, 1965, p. 852, text-fig. 7 (30, 31).

**Material:** Twenty-four specimens, usually not well preserved.

**Dimensions:** Length 0.28–0.77 mm., usually 0.28–0.55 mm.

**Remarks:** The Brora specimens are smaller and usually less inflated than those recorded by the present writer from the Corallian Beds (Gordon, 1965).

**Genus CITHARINA d'Orbigny, 1839**

**Citharina flabellata (Gümbel)**

Plate 2, figures 19–22

*Marginulina flabellata* GÜMBEL, 1862, p. 223, pl. 3, fig. 24.

*Citharina flabellata* (Gümbel). – CORDEY, 1962, p. 384, pl. 47, fig. 16; text-figs. 26–30.

**Material:** One hundred and twenty-six specimens.

**Dimensions:** Length up to 2.27 mm., usually 0.6–1.5 mm.

**Remarks:** These triangular, costate citharines are common in Callovian and Oxfordian rocks in both Europe and North America. Cordey (1962) has discussed this species and provided a long synonymy.

**Citharina heteropleura (Terquem)**

Plate 3, figure 11

*Marginulina heteropleura* TERQUEM, 1868, p. 116, pl. 7, fig. 19a–b.

*Citharina heteropleura* (Terquem). – CIFELLI, 1959, p. 324, pl. 6, figs. 4–5. – LUTZE, 1960, p. 459, pl. 30, fig. 1.

**Material:** One specimen, broken at the aperture.

**Dimensions:** Estimated length when complete 0.47 mm.

**Citharina sp.**

Plate 3, figure 1

**Material:** One specimen.

**Dimensions:** Length 0.96 mm.

**Genus FRONDICULARIA Defrance, 1824**

**Frondicularia franconica Gümbel**

Plate 3, figures 2–8

*Frondicularia franconica* GÜMBEL, 1862, p. 219, pl. 3, fig. 13a–c. – BARNARD, 1952, p. 340, text-fig. A, 1. – BARNARD, 1953, p. 186, text-fig. B, 2a–b, 3a–b. – CORDEY, 1962, p. 387, pl. 47, figs. 20–21; text-figs. 31–36.

*Lingulina hathra* Loeblich and Tappan. – WALL, 1960, p. 91, pl. 13, figs. 1–5.

*Frondicularia franconica franconica* Gümbel. – LUTZE, 1960, p. 470, pl. 32, figs. 4, 6, 14.

*Frondicularia franconica impressa* LUTZE, 1960, p. 472, pl. 32, figs. 3, 5.

**Material:** Sixty-nine specimens.

**Dimensions:** Length 0.36–1.05 mm.

**Remarks:** This is a highly variable species. An abnormal form, presumably injured during shell growth, is illustrated by plate 3, figure 8. In all specimens, the

test is at least slightly bilobed, having a median depression running longitudinally on each side. Cordey (1962) has given a long synonymy for this species, and he has also discussed its variation. When compared with the material of Lutze (1960), the Brora specimens are mostly closer to subspecies *impressa* than to subspecies *franconica*, but the range of variation is broad enough to encompass both.

***Fronicularia hexagona* Terquem**  
Plate 3, figure 9

*Fronicularia hexagona* TERQUEM, 1858, p. 594, pl. 1, fig. 13a-c.

**Material:** Five specimens.

**Dimensions:** Lengths 0.46, 0.46, 0.51, 0.61 and 0.69 mm.

**Remarks:** The Brora specimens agree well with the type description given by Terquem of his specimens from the Lias of the Metz region. They are also very similar to a form from the Lias beta of East Germany referred by Pietrzenuk (1961, pl. 8, fig. 2) to *Lingulina tenera tenera* Bornemann. The specimen figured by Pietrzenuk as plate 8, figure 1, is less like the Brora material, but both this and other specimens referred by Pietrzenuk to different subspecies of *Lingulina tenera* are broadly similar. The Brora specimens seem to be late members of the *L. tenera* complex, which has been described in detail by Barnard (1956) from the Lias of England and by Nørvang (1957) from the Lias of Denmark. The Brora specimens differ from the closest Lias forms of Barnard in having no true ribs, but instead a hexagonal cross section with angles in the test wall which are aligned longitudinally.

This species is placed in *Fronicularia* rather than in *Lingulina* because the present specimens have a circular aperture rather than an elongate one. The distinction between these two genera is very unsatisfactory in the Jurassic. If the Brora specimens could with certainty be ascribed to a late stage of the *Lingulina tenera* complex, then presumably they would have to be placed in *Lingulina*.

***Fronicularia moelleri* Uhlig**  
Plate 3, figures 15-18

*Fronicularia mölleri* UHLIG, 1883, p. 758, pl. 9, figs. 12-15.

*Fronicularia moelleri* Uhlig. - LUTZE, 1960, p. 465, pl. 31, fig. 7; pl. 32, figs. 1-2. - CORDEY, 1962, p. 388, pl. 47, fig. 23; text-figs. 37-38.

*Flabellinella mölleri* (Uhlig). - BIELECKA and POŻARYSKI, 1954, p. 48, pl. 7, fig. 31.

**Material:** Thirty-three specimens, about half of them incomplete.

**Dimensions:** Length 0.39-2.48 mm.

**Remarks:** In the Brora material, the number of chambers varies from 3 to 11. Out of 28 specimens in which the observation could be made, 3 had no wedge-shaped chambers intervening between the proloculum and the

first chevron-shaped chamber, 21 had one such chamber, and 4 had 2 such chambers. There is considerable variation in the angle of divergence of the margins at the initial end, but all specimens seem to belong to a continuously grading series. The type level of this species is the upper Callovian of localities in European Russia.

***Fronicularia* sp.**  
Plate 3, figure 13

**Material:** One specimen.

**Dimensions:** Length 0.71 mm., width 0.42 mm.

**Remarks:** This specimen may be slightly crushed, but the aperture seems to be simple and circular, so that the distortion of the test has probably not been great. The test is composed of 6 chambers, with a keel at the margins and a central rib on each side of the test running from the proloculum to the aperture. The specimen is just possibly a crushed *Tristix*, but this is not considered to be likely, because no other specimens of *Tristix* were found at the same level (Sample 209), and because the median rib on each side of the test would mean that the specimen was originally one of the rare quadrate individuals instead of one of the common triangular specimens of *Tristix*. In addition, the Brora specimen is similar to forms described from the Middle Lias of Germany by Burbach (1886, pp. 47-48, pls. 1-2) as *Fronicularia carinata*, *F. elliptica* and *F. lata*, especially the latter. Terquem and Berthelin (1875, p. 38, pl. 3, fig. 8a, a<sup>1</sup> only) described a similar species from the Middle Lias of eastern France under the name of *Fronicularia texta*. The Brora specimen has a more prominent keel, usually a lesser number of chambers, and a greater width than the Lias forms. It is therefore a different and probably a new species, but it is merely wished to place it on record at the present time.

**Genus LINGULINA d'Orbigny, 1826**

***Lingulina laevisissima* (Terquem)**  
Plate 3, figure 12

*Fronicularia laevisissima* TERQUEM, 1866, p. 481, pl. 19, fig. 19.

*Lingulina laevisissima* (Terquem). - CIFELLI, 1959, p. 326, pl. 6, figs. 6-8.

?*Lingulina* cf. *laevisissima* (Terquem). - BARNARD, 1952, p. 347, text-fig. A, 3.

**Material:** Three specimens, one incomplete.

**Dimensions:** Lengths of complete specimens 0.36 and 0.43 mm.

**Remarks:** The largest of the Brora specimens differs from the type in having angular margins on the last chamber. The earlier chambers are rounded on this specimen, and the other two specimens have rounded margins throughout. Terquem described this species from the Lias of the Metz region, and his specimens have rounded margins.

*Lingulina longiscata* (Terquem)

Plate 3, figure 10

*Frondicularia longiscata* TERQUEM, 1870, p. 318, pl. 22, figs. 23–24.*Frondicularia nodosaria* TERQUEM, 1870, p. 319, pl. 22, figs. 25–30. – BARTENSTEIN and BRAND, 1937, p. 155, pl. 12A, fig. 6; pl. 13, fig. 14; pl. 15A, fig. 21. – CIFELLI, 1959, p. 330, pl. 7, figs. 4–6. – LUTZE, 1960, p. 468, pl. 32, fig. 13.*Frondicularia inaequalis* DEECKE, 1884, p. 27, pl. 1, figs. 24, 24a.*Frondicularia deeckeana* PAALZOW, 1922, p. 18, pl. 2, fig. 10.*Lingulina nodosaria* (Terquem). – BARNARD, 1950, p. 29, text-fig. 16.*Material*: One specimen.*Dimensions*: Length 0.95 mm.*Remarks*: This species is placed in *Lingulina* because of its slitlike aperture, although it is in other respects frondicularine in appearance. The type specimens were described from the *Parkinsonia parkinsoni* Zone, Bajocian, of Fontoy, Moselle, France, but the species ranges from the Lias to the Upper Jurassic. The formgiven the name of *Frondicularia inaequalis* by Deecke (1884) appears to be a megalospheric specimen of this species.

Genus LAGENA Walker and Jacob, 1798

*Lagena globosa* (Montagu)

Plate 3, figure 19

*Vermiculum globosum* MONTAGU, 1803, p. 523.*Material*: Three specimens.*Dimensions*: Lengths of the specimens 0.23, 0.23 and 0.25 mm.

Family POLYMORPHINIDAE

Genus EOGUTTULINA Cushman and Ozawa, 1930

*Eoguttulina liassica* (Strickland)

Plate 4, figure 26

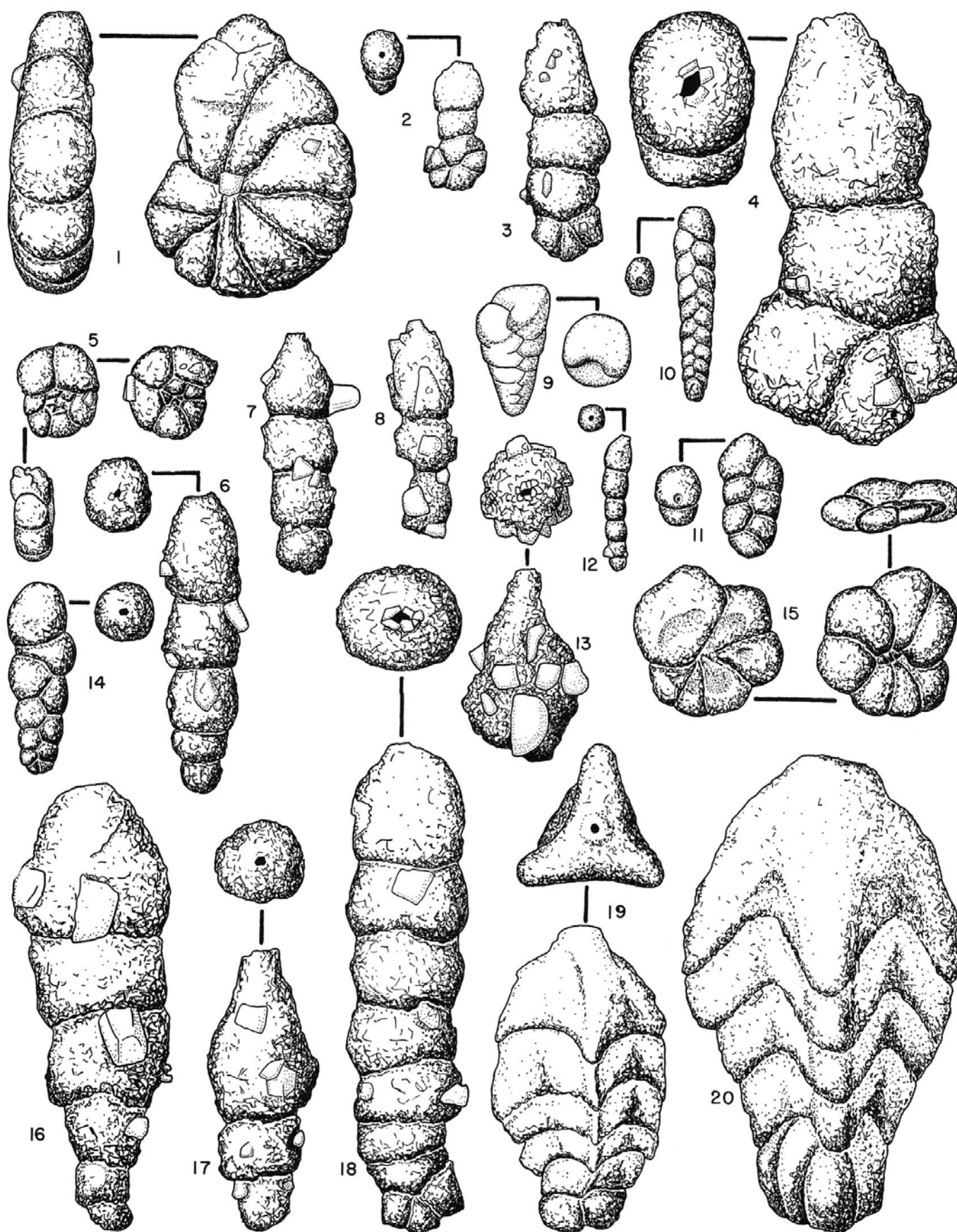
*Polymorphina liassica* STRICKLAND, 1846, p. 31, fig. b.*Material*: One hundred and seventy-two specimens, most not well preserved.*Dimensions*: Length 0.21–0.49 mm.

## PLATE 1

Figures  $\times 66$  unless otherwise stated

- |  |   |
|--|---|
| 1 <i>Ammobaculites canui</i> (Cushman)<br>Sample 217; $\times 50$ .                  | 12 <i>Reophax multilocularis</i> Haeusler<br>Sample 213.                                      |
| 2–3 <i>Ammobaculites</i> sp. cf. <i>A. suprajurassicus</i> (Schwager)<br>Sample 213. | 13 <i>Lagenammina difflugiiformis</i> (Brady)<br>Sample 216.                                  |
| 4 <i>Ammobaculites coprolithiformis</i> (Schwager)<br>Sample 213; $\times 50$ .      | 14 <i>Bigennerina</i> sp.<br>Sample 213.  |
| 5 <i>Haplophragmoides</i> sp.<br>Sample 213.   | 15 <i>Trochammina squamata</i> Jones and Parker<br>Sample 213.                                |
| 6–8 <i>Reophax horridus</i> (Schwager)<br>Sample 213.                                | 16–17 <i>Reophax sterkii</i> Haeusler<br>Sample 213; $\times 50$ .                            |
| 9 <i>Textularia dumortieri</i> (Schwager)<br>Sample 216.                             | 18 <i>Ammobaculites</i> sp. cf. <i>A. pictonicus</i> (Berthelin)<br>Sample 215; $\times 50$ . |
| 10 <i>Textularia pugiunculus</i> (Schwager)<br>Sample 214.                           | 19–20 <i>Triplasia bartensteini</i> Loeblich and Tappan<br>Sample 216; $\times 50$ .          |
| 11 <i>Textularia jurassica</i> (Gümbel)<br>Sample 214.                               |   |





*Eoguttulina pygmaea* (Schwager)  
Plate 4, figure 27

*Polimorphina pygmaea* SCHWAGER, 1865, p. 138, pl. 7, fig. 8a-b  
(*Polymorphina pygmaea* in plate explanation, p. 150).  
*Guttulina pygmaea* (Schwager). – LUTZE, 1960, p. 482, pl. 28,  
figs. 14–15.

*Material*: Thirty-five specimens.

*Dimensions*: Length 0.19–0.26 mm.

Family BULIMINIDAE  
Genus BOLIVINA d'Orbigny, 1839

*Bolivina* sp. cf. *B. rhumbleri* Franke  
Plate 4, figure 3

Cf. *Bolivina rhumbleri* FRANKE, 1936, p. 125, pl. 12, fig. 21.

*Material*: One specimen.

*Dimensions*: Length 0.21 mm.

*Remarks*: The single specimen from Brora is damaged on one side and at the aperture. It is compared to a form described by Franke (1936) as very rare from the Middle Lias of Brunswick, Germany. The Brora specimen is about half the size of the Brunswick form, and it has curving instead of almost straight sutures.

Family CERATOBULIMINIDAE  
Genus CONORBOIDES Hofker, 1952

*Conorboides nudus* (Terquem)  
Plate 4, figure 30

*Epistomina nuda* TERQUEM, 1883, p. 376, pl. 43, fig. 2 (not fig. 1).

*Conorboides nuda* (Terquem). – LUTZE, 1960, p. 492, pl. 33, fig. 8.

*Material*: Fourteen specimens.

*Dimensions*: Greatest diameter of the test 0.37–0.82 mm., mean of all specimens 0.54 mm.

*Remarks*: Of the 13 specimens in Sample 213, 10 are coiled dextrally and 3 sinistrally.

Genus EPISTOMINA Terquem, 1883

*Epistomina parastelligera* (Hofker)  
Plate 4, figure 32

*Epistomina stelligera* (Reuss). – UHLIG, 1883, p. 770, pl. 7, fig. 10a–c; pl. 8, figs. 1–3.

*Brotzenia parastelligera* HOFKER, 1954, p. 180, text-figs. 4–6. – ?LLOYD, 1962, p. 377, pl. 2, fig. 8a–c; text-fig. 7B. – CORDEY, 1963, pp. 654–656, pl. 93, figs. 5–6; text-fig. 2a–b.

*Epistomina parastelligera* (Hofker). – LUTZE, 1960, p. 491, pl. 33, figs. 3, 6.

*Material*: One hundred and thirty-five specimens, all but 5 of them in Sample 213.

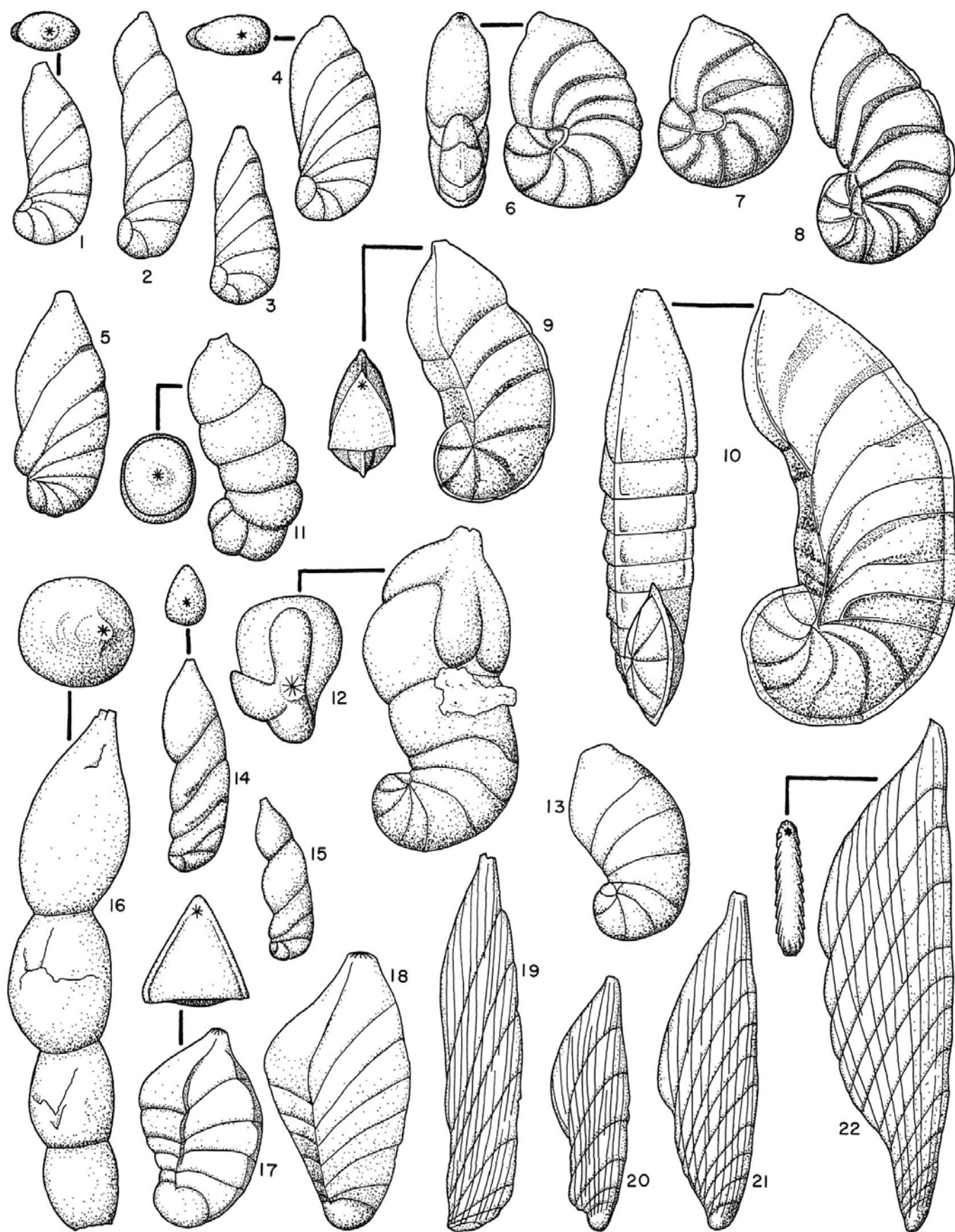
*Dimensions*: Greatest diameter of the test 0.35–1.02 mm.

*Remarks*: Of the 130 specimens in Sample 213, 95 are coiled sinistrally and 35 dextrally. Uhlig (1883) recorded this species from the Ornatenton, Callovian. Other records are from the Callovian and Oxfordian of Britain and Germany. The form described by Lloyd (1962) differs from the Brora specimens in having more strongly developed sutural ribs on the ventral side.

PLATE 2

Figures  $\times 66$  unless otherwise stated

- |       |   |       |  |
|-------|---|-------|--|
| 1–5   | <i>Marginulina scapha</i> Lalicker<br>Sample 213; $\times 50$ . | 14–15 | <i>Marginulina epicharis</i> (Loeblich and Tappan)<br>Sample 213.                        |
| 6–10  | <i>Lenticulina quenstedti</i> (Gümbel)<br>Sample 209.           | 16    | <i>Dentalina</i> sp.<br>Sample 209.  |
| 11    | <i>Marginulina irregularis</i> Gümbel<br>Sample 216.            | 17–18 | <i>Saracenaria phaedra</i> Tappan<br>Sample 216.   |
| 12–13 | <i>Marginulina</i> sp.<br>Sample 215.                           | 19–22 | <i>Citharina flabellata</i> (Gümbel)<br>19–21, Sample 216; 22, Sample 209; $\times 50$ . |



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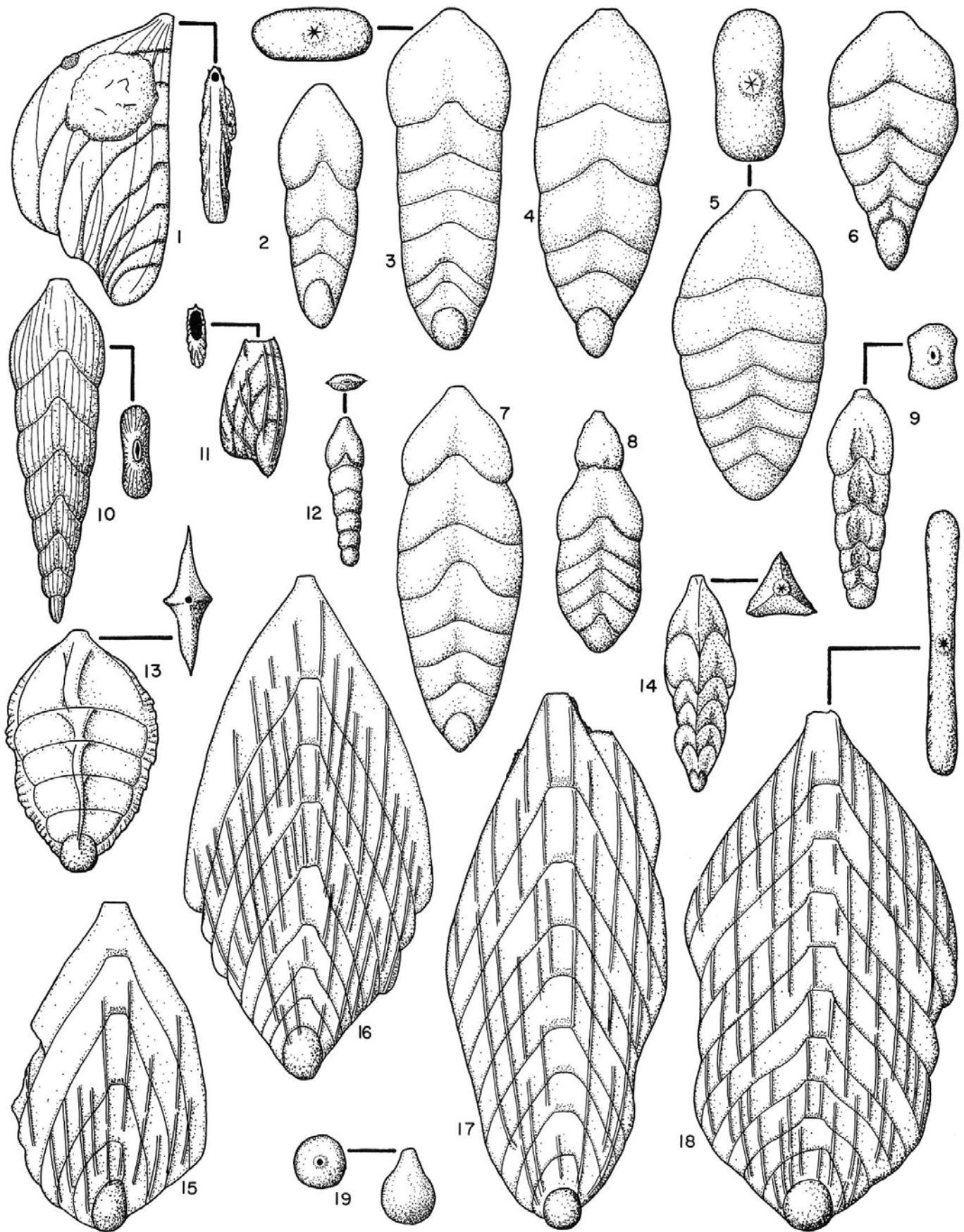
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## PLATE 3

Figures  $\times 66$  unless otherwise stated

- |  |   |
|--|---|
| 1 <i>Citharina</i> sp.<br>Sample 216.  | 12 <i>Lingulina laevis</i> (Terquem)<br>Sample 213.                   |
| 2-8 <i>Fronicularia franconica</i> Gümbel<br>2-7, Sample 214; 8, Sample 213. | 13 <i>Fronicularia</i> sp.<br>Sample 209.                             |
| 9 <i>Fronicularia hexagona</i> Terquem<br>Sample 213.                        | 14 <i>Tristix oolithica</i> (Terquem)<br>Sample 213.                  |
| 10 <i>Lingulina longiscata</i> (Terquem)<br>Sample 213.                      | 15-18 <i>Fronicularia moelleri</i> Uhlig<br>Sample 215; $\times 50$ . |
| 11 <i>Citharina heteropleura</i> (Terquem)<br>Sample 214.                    | 19 <i>Lagena globosa</i> (Montagu)<br>Sample 214.                     |



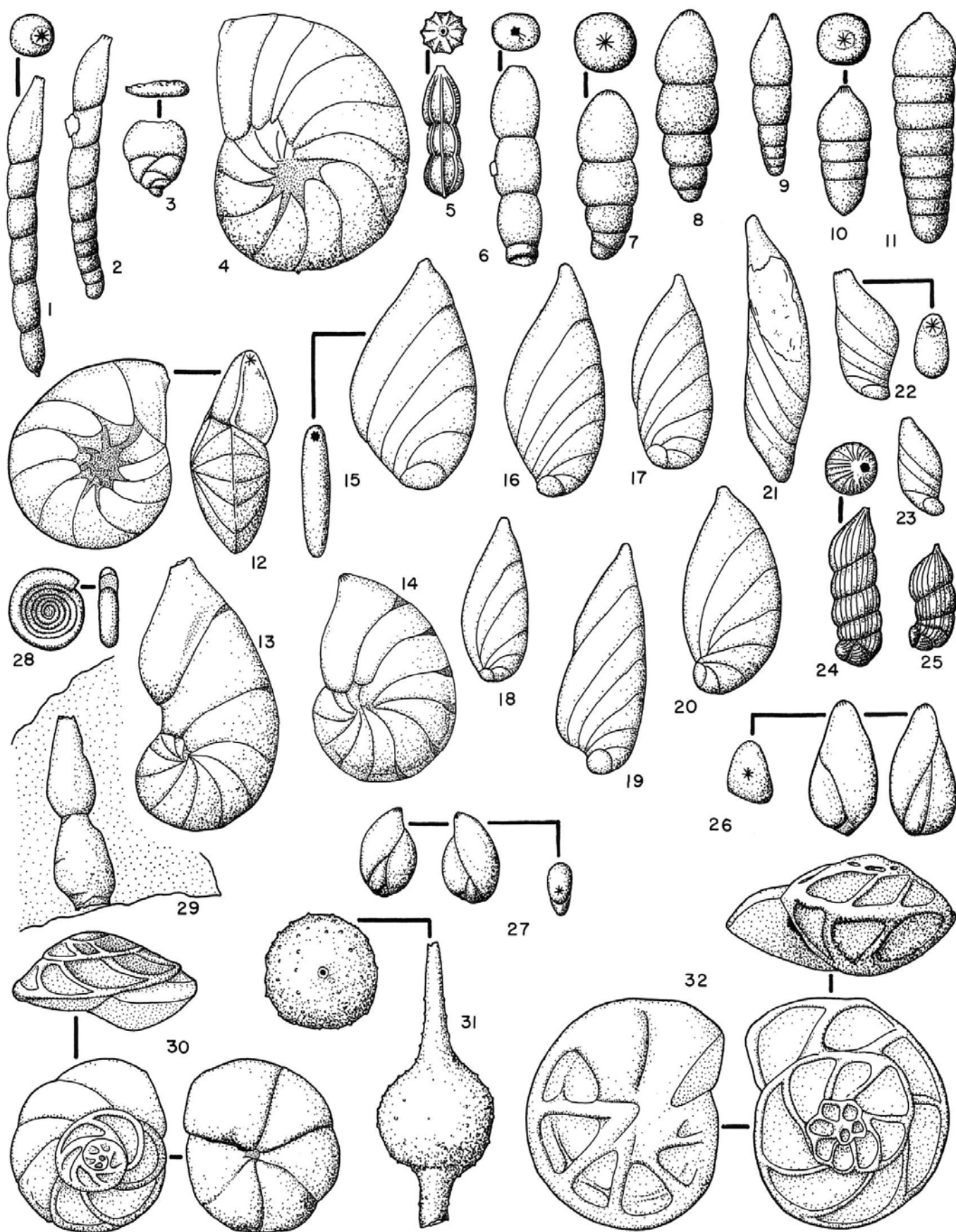


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## PLATE 4

Figures  $\times 66$  unless otherwise stated

- |   |   |
|---|---|
| 1-2 <i>Dentalina guembeli</i> Schwager<br>Sample 214.   | 21-23 <i>Vaginulina anomala</i> Blake<br>Sample 216.            |
| 3 <i>Bolivina</i> sp. cf. <i>B. rhumbleri</i> Franke<br>Sample 216.                             | 24-25 <i>Marginulina batrakiensis</i> (Myatliuk)<br>Sample 215. |
| 4 <i>Lenticulina muensteri</i> (Roemer)<br>Sample 214; $\times 50$ .                            | 26 <i>Eoguttulina liassica</i> (Strickland)<br>Sample 214.      |
| 5 <i>Nodosaria mutabilis</i> Terquem<br>Sample 214.   | 27 <i>Eoguttulina pygmaea</i> (Schwager)<br>Sample 216.         |
| 6 <i>Nodosaria</i> sp. cf. <i>N. affinis</i> (Terquem)<br>Sample 213.                           | 28 <i>Cornuspira</i> sp.<br>Sample 213.                         |
| 7-8 <i>Pseudonodosaria vulgata</i> (Bornemann)<br>Sample 213.                                   | 29 <i>Nubeculinella bigoti</i> Cushman<br>Sample 214.           |
| 9-11 <i>Pseudonodosaria sowerbyi</i> (Schwager)<br>Sample 213.                                  | 30 <i>Conorboides nudus</i> (Terquem)<br>Sample 213.            |
| 12-14 <i>Lenticulina muensteri</i> (Roemer)<br>12, Sample 209; 13-14, Sample 214; $\times 50$ . | 31 <i>Nodosaria apheilolocula</i> Tappan<br>Sample 214.         |
| 15-20 <i>Planularia anceps</i> (Terquem)<br>Sample 213.   | 32 <i>Epistomina parastelligera</i> (Hofker)<br>Sample 213.     |



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