FORAMINIFERA FROM THE UPPER CRETACEOUS OF JAMES ROSS ISLAND

By W. A. MACFADYEN*

ABSTRACT. Seventeen species of Foraminifera have been identified, nine of them doubtfully, from a dense glauconite-sandstone. Nine species are of arenaceous forms and all appear to be preserved as pseudomorphs. Three of the species are common and form 70 per cent of the identified material, which is clearly of deep-sea facies, the benthic Foraminifera indicating a minimum depth of 300–400 fathoms (550–730 m.), and possibly much deeper. The fauna is indicative of an Upper Cretaceous age, which, from the evidence of the ammonites in the surrounding area, has been dated as Lower to Middle Campanian.

FORAMINIFERA were found in a sandy glauconite rock at the locality called Tumbledown Cliffs (Fig. 1; station D.2043) at approximately lat. 64°05′S., long. 58°27′W., about the middle

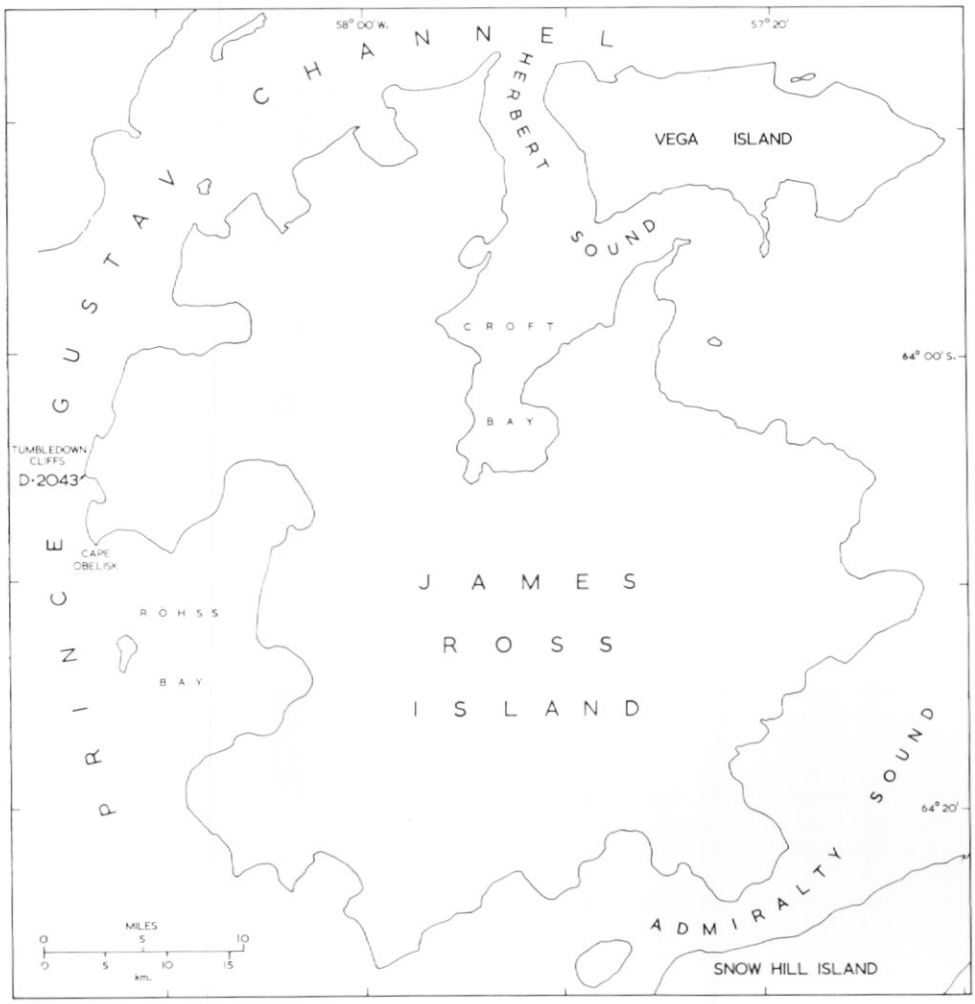

Fig. 1. Sketch map of James Ross Island, showing the location of Tumbledown Cliffs and station D.2043.

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of the west coast of James Ross Island, and some 4 miles (6·4 km.) due north of Cape Obelisk. The island lies off the north-east coast of Graham Land. The foraminiferal fauna was discovered by Mr. Robert Stoneley of the Falkland Islands Dependencies Survey, who investigated the section and collected the material in 1952.

The succession given by him is as follows:

		ft.	m.
Miocene	Jame Ross Island Volcanic Group		
Upper Cretaceous	Sandstones and grits with some conglomerates	190	57·9
	Fine highly glauconitic sandstone with Foraminifera	10	3·0
	Sandstones and grits with some conglomerates	220	67·1
	Alternating sandstones and conglomerates	480	146·3
		900	274·3

No specifically determinable macro-fossils were found in the Tumbledown Cliffs area, but Howarth (1958) concluded from the ammonites that "all the assemblages from the James Ross Island group are of approximately the same age, and this spans, at the most, the Lower and Middle Campanian". The foraminiferal bed is therefore presumed also to be of this age.

The material described in this paper will be deposited in the British Museum (Nat. Hist.).

Previous Records

Holland (1910) had four specimens of Upper Cretaceous Foraminifera collected by the Swedish South Polar Expedition, 1901–03, from a site not exactly recorded, but probably from "locality 4" on Snow Hill Island, though possibly "locality 8" on Seymour Island. These localities, with identical lithology and some 7 miles (11·3 km.) apart, are both about 50 miles (80 km.) east-south-east of Tumbledown Cliffs. The ammonite faunas showed that both belonged to the "Older Seymour Island Beds" [Snow Hill Island Series], assigned to a high Senonian horizon. A revised and slightly more precise age of Lower to Middle Campanian is now indicated. One specimen was described as *Ammodiscus grandis* sp. nov., and the other three as *Trochammina cretacea* sp. nov. From the figures and descriptions this second species would now be classed as *Haplophragmoides* or *Alveolophragmium*. Holland suggested that both species may be compared with deep-water forms. A trace of matrix adhering to the *Ammodiscus* was of exceedingly fine light grey sandy material.

Macfadyen (1933) described a fossil foraminiferal fauna from three samples dredged during the Discovery Investigations in 1927 and 1931 from Burdwood Bank, which is 600 miles (965 km.) due north of James Ross Island. Some of the specimens lay loose on the sea floor, mixed with Recent Foraminifera. Others were washed in the laboratory from a slightly sandy siliceous shale, light grey and of exceedingly fine texture, which also contained a few Radiolaria. Other material in the same dredging was a very fine green-grey shale, highly glauconitic, which proved to be practically devoid of Foraminifera.

Some 300 specimens of fossil Foraminifera were mounted, and 34 forms recorded. From them the Burdwood Bank beds were held to include both Upper Cretaceous (Senonian) strata and a representative of the Lower Tertiary succession. The fauna as a whole was considered to be of rather deep-water facies, and comparable with those described from the Upper Cretaceous and Lower Tertiary of Trinidad. Many of the specimens were preserved as honey-coloured casts; and some, of other genera, were very much larger than anything now found in the James Ross Island material.

Todd and Kniker (1952) have described from 900 miles (1,450 km.) north of James Ross Island a rich fauna of 114 species. This may be compared, for although of a later date (Eocene) it was claimed to be a deep-water formation deposited under open-sea conditions. It was found in shales with some glauconite, apparently comparable with the Burdwood Bank beds.

The Present Material

The bed from which the present collection of Foraminifera was obtained appears in the hand specimen as a curious hard, dense, blackish green material that may be described as a sandy glauconite rock; fine angular sand and coarser, rounded and vari-coloured grains of different materials are embedded in a matrix of glauconite, which looks far more conspicuous and abundant than the sand.

Tribute must be paid to Mr. Stoneley for his perseverance in extracting any identifiable Foraminifera from this unpromising and intractable material. Pea-sized fragments were broken down by repeated boiling with sodium thiosulphate and allowing to crystallize. The disintegrated material was sieved into fractions and the Foraminifera were picked out and mounted on cardboard slides with gum tragacanth. Mr. Stoneley made some preliminary identifications before the collection was entrusted to the present writer for description.

The Foraminifera are small in size and all are preserved, often perfectly, apparently as pseudomorphs of the original shells, whether of calcareous or arenaceous forms, and uniformly of a white or pale greenish colour. The chemical nature of the pseudomorphs has not been investigated, but the calcareous species no longer react with dilute hydrochloric acid.

The Foraminifera stand out lighter coloured against the blackish green background of the glauconite. Their study has proved tantalizing and exasperating. Of some specimens it has been impossible to be certain of the original nature of the shell wall. Nearly all have varying quantities of the glauconite matrix tightly adhering to the surface, and where this obscures important generic details, such as the aperture and the early development of the test, as it frequently does, identification of the few specimens available of most of the species becomes even more difficult and uncertain; one is forced to attempt direct identification of the species, from a number of possible genera, both calcareous and arenaceous. Were a well-preserved fauna available for comparison, it should be possible to determine certainly forms that at present defy exact identification on their own indifferent merits.

118 specimens have now been assigned to 17 species of Foraminifera, 9 of the identifications being doubtful. There is also a single ostracod valve. Some 35 other specimens appear to be Foraminifera but they are too obscured by glauconite, or otherwise doubtful, to be named even generically.

Foraminifera Identified

	Number of Specimens	*Recorded from Burdwood Bank Beds*	*Recorded from Upper Cretaceous, Trinidad*
Ammodiscus cretaceus (Reuss)	7	+	–
Glomospira charoides var. *corona* Cushman and Jarvis	5	(+)	+
Ammolagena clavata (Jones and Parker)	36	–	+
Haplophragmoides glaber Cushman and Waters	2	?+	–
?*Alveolophragmium ringens* (Brady)	1	–	–
Ammobaculites agglutinans (d'Orbigny)	2	–	+
?*Pseudoclavulina clavata* (Cushman)	6	–	–
?*Dorothia retusa* (Cushman)	3	–	+
Trochammina globigeriniformis (Parker and Jones)	18	+	+
Nonionella aff. *austinana* Cushman	1	–	–
Heterohelix globulosa (Ehrenberg)	1	+	–
?*Siphogenerinoides ewaldi* (Karsten)	4	–	?+
?*Bulimina murchisoniana* d'Orbigny	1	–	+
Pullenia sphaeroides var. *coryelli* White	28	+	+
?*Pullenia cretacea* Cushman	1	–	–
?*Globotruncana contusa* (Cushman)	1	–	+
?*Anomalina tennesseensis* (Berry)	3	–	–
Ostracod valve	1	–	

Direct comparison has been made between the present material and the Burdwood Bank specimens, deposited in the British Museum (Nat. Hist.). When I have considered them identical, the names under which the Burdwood Bank specimens were recorded are given below, in the systematic descriptions.

Of this recognizable fauna, 82 specimens (equal to 70 per cent of the material) consist of three species, *Ammolagena clavata*, *Trochammina globigeriniformis* and *Pullenia sphaeroides* var. *coryelli*. Hence any inquiry into the conditions of deposition and ecology of the foraminiferal fauna must rely largely upon the evidence of these.

Ecology and Age Determination

As shown in detail below, all three of the common species noted above are normally found living in "deep water", which in this context seems to mean any depth greater than about 300 or 400 fathoms (550 or 730 m.), down to nearly 3,000 fathoms (5,485 m.).

Of the less abundant species identified, four forms, or their close relations still found living in the present oceans, are also at home in deep water, i.e. *Ammodiscus cretaceus*, *Glomospira charoides*, *Alveolophragmium ringens* and *Ammobaculites agglutinans*. The remaining species seem to be known only as fossils, so they can give no direct evidence.

I conclude, therefore, that the foraminiferal fauna, which is almost wholly of benthic forms, lived in a sea of probably some 300 or 400 fathoms (550 or 730 m.) or deeper.

Of the four *Discovery Reports* (Heron-Allen and Earland, 1932; Earland, 1933, 1934, 1936) on the present-day Antarctic Foraminifera, the one on the Falkland Islands sector wholly within the Antarctic Convergence (Earland, 1934) yields well over half the total records of the above seven species. While the sea bottoms found in that sector are very variable, the seven species are more frequently found there than in the adjoining areas of the ice-free Falkland Islands area, the South Georgia area or the very deep and cold conditions in the Weddell Sea.

Benthic Foraminifera living in deep seas tend to be cosmopolitan and some have very long ranges in geological time. The seven species noted (or closely allied forms) are such; *Ammodiscus cretaceus* (or *A.* "*incertus*"), *Ammolagena clavata* and *Ammobaculites agglutinans* extend back to the Carboniferous; *Glomospira charoides* and *Trochammina globigeriniformis* to the Jurassic; and *Alveolophragmium ringens* (if the present determination is correct) and *Pullenia sphaeroides* to the Cretaceous. They are thus of little value in dating the beds in which they are found, though *P. sphaeroides* var. *coryelli* has the reputation of being a good Upper Cretaceous marker.

While the long ranges of such Foraminifera were accepted as commonplace by Brady and his colleagues, with their liberal views of the variation to be allowed within a species, it is interesting to find that Cushman, an authority with a much narrower concept of a foraminiferal species, arrived at the same conclusion when studying the deep-sea facies Upper Cretaceous Foraminifera of Trinidad. Cushman and Jarvis (1932, p. 1) write: "Many of the genera and also many of the species of the arenaceous group that are still living in the deeper waters off the coast of Trinidad are to be found in this Cretaceous material, often in considerable numbers. Such genera as *Glomospira*, *Ammodiscus*, *Ammodiscoides*, *Ammolagena*, *Hormosina*, *Saccorhiza* and others are common in the Trinidad collections. All these genera are known living off Trinidad and usually in the same species, so that they seem to indicate that conditions of deposition for this material in the Upper Cretaceous are not very different from those that obtain off these coasts at the present day." Trinidad lies across the Equator, 4,500 miles (7,240 km.) north of James Ross Island.

Glauconite

The glauconite which forms a large proportion of the bed yielding the present fossils makes a striking and unusual sedimentary rock. Some explanation of its presence and its bearing on the ecology of the Foraminifera living in Campanian times would be welcome.

Glauconite is a complex mineral, whose mode of formation is not yet completely understood; hypotheses on the subject give rise to controversy and this is not the place to discuss them. It is claimed to be of terrigenous origin, and it is a prominent constituent of the green sands forming in the present oceans at depths around 150 fathoms (275 m.); and of the green muds, between 100 and 700 fathoms (183 and 1,280 m.). Neaverson (1934) has recorded glauconite at a number of *Discovery* stations from 134 to 885 fathoms (244 to 1,618 m.).

In the present bed the Foraminifera and the glauconite are compatible with a deep-sea origin of some 300–900 fathoms (550–1,645 m.); and the glauconite, and the sandstones and conglomerates of the same sedimentary series, with a terrigenous origin. But it seems difficult to reconcile a deep-sea origin with the sandstones and conglomerates.

With the present information I am unable to discern what special conditions were present to give rise to the glauconite deposit, or to appreciate its significance in the ecology of the Foraminifera.

Systematic Descriptions

Ammodiscus cretaceus (Reuss)
Fig. 2a

Operculina cretacea Reuss 1845, pt. i, p. 35, pl. xiii, figs. 64, 65.
Ammodiscus incertus (d'Orbigny); Macfadyen 1933, p. 4.
Ammodiscus cretaceus (Reuss); Cushman 1946, p. 17, pl. i, fig. 35.

Seven specimens, some of them fragmentary; the largest complete specimen is 0·80 mm. in diameter.

These specimens are of a stoutly built form with rather thick walls, the last whorl with broadly rounded periphery; whorls increase regularly in size so that the disc is markedly bi-concave; the microspheric nucleoconch is about 0·05 mm. in diameter, but conspicuous; radial puckering of the wall is slightly marked on the largest specimen.

The late Arthur Earland once sent me some Recent specimens under the name *A. incertus* (d'Orbigny), a specific name long suspect and now relegated to a *nomen dubium* (Macfadyen, 1962, p. 29–31). One specimen from the south-west Pacific in 2,338 fathoms (4,275 m.) shows well the radial puckering characteristic of *A. cretaceus*, and it is otherwise very similar to that species. Other smaller specimens came from *Discovery* station 141, off South Georgia at 155–178 m. From the external appearance I am unable to separate these Recent specimens from the present Cretaceous material.

The four *Discovery Reports* on the Recent Foraminifera record a form under the name *A. incertus* (d'Orbigny) as widespread, in all from some 72 stations, at depths ranging from 45 to 2,739 fathoms (82 to 5,010 m.). The form figured in the first *Discovery Report* (Heron-Allen and Earland, 1932, pl. viii, figs. 18, 19) appears to me inseparable from the present material.

The Burdwood Bank Cretaceous material recorded as *A. incertus* seems to be mainly what I should now call *A. cretaceus*, though there is a fragment of a very large specimen, probably the megalospheric form, which might be called *A. tenuis* Brady.

Three other names must be mentioned, because of their use in comparable records. *A. grandis* Holland was founded on a single specimen, 4 mm. in diameter, from the Senonian of Snow Hill Island or Seymour Island. This was a megalospheric form with few whorls. I find it difficult to appreciate any difference between this and *A. pennyi* Cushman and Jarvis, described from the Upper Cretaceous of Trinidad, or to separate them from the Recent *A. tenuis* Brady. Whether these are really the megalospheric form of *A. cretaceus* is a problem.

Another species from the Upper Cretaceous of Trinidad is *A. glabratus* Cushman and Jarvis. This, however, is a less robust and thinner-walled form than *A. cretaceus*, and it seems distinct. I am much indebted to Dr. John T. Saunders for kindly sending me specimens of this form from the Chaudière Formation (Upper Cretaceous or Eocene) of Trinidad for comparison.

A. cretaceus was described from the Upper Cretaceous Chalk of Bohemia. As understood by Cushman, it is widespread both in Europe and America, from Lower Cretaceous Gault (Albian) to Upper Cretaceous (Senonian), and it has a wide range in the Senonian of Canada, the United States of America and Mexico.

Glomospira charoides var. *corona* Cushman and Jarvis
Figs. 2p and p′

Glomospira charoides var. *corona* Cushman and Jarvis 1928, p. 89, pl. xii, figs. 9–11.
Glomospira charoides var. *corona* Cushman and Jarvis; Cushman 1946, p. 19, pl. ii, figs. 1–3.

Five specimens, 0·25–0·33 mm. in diameter.

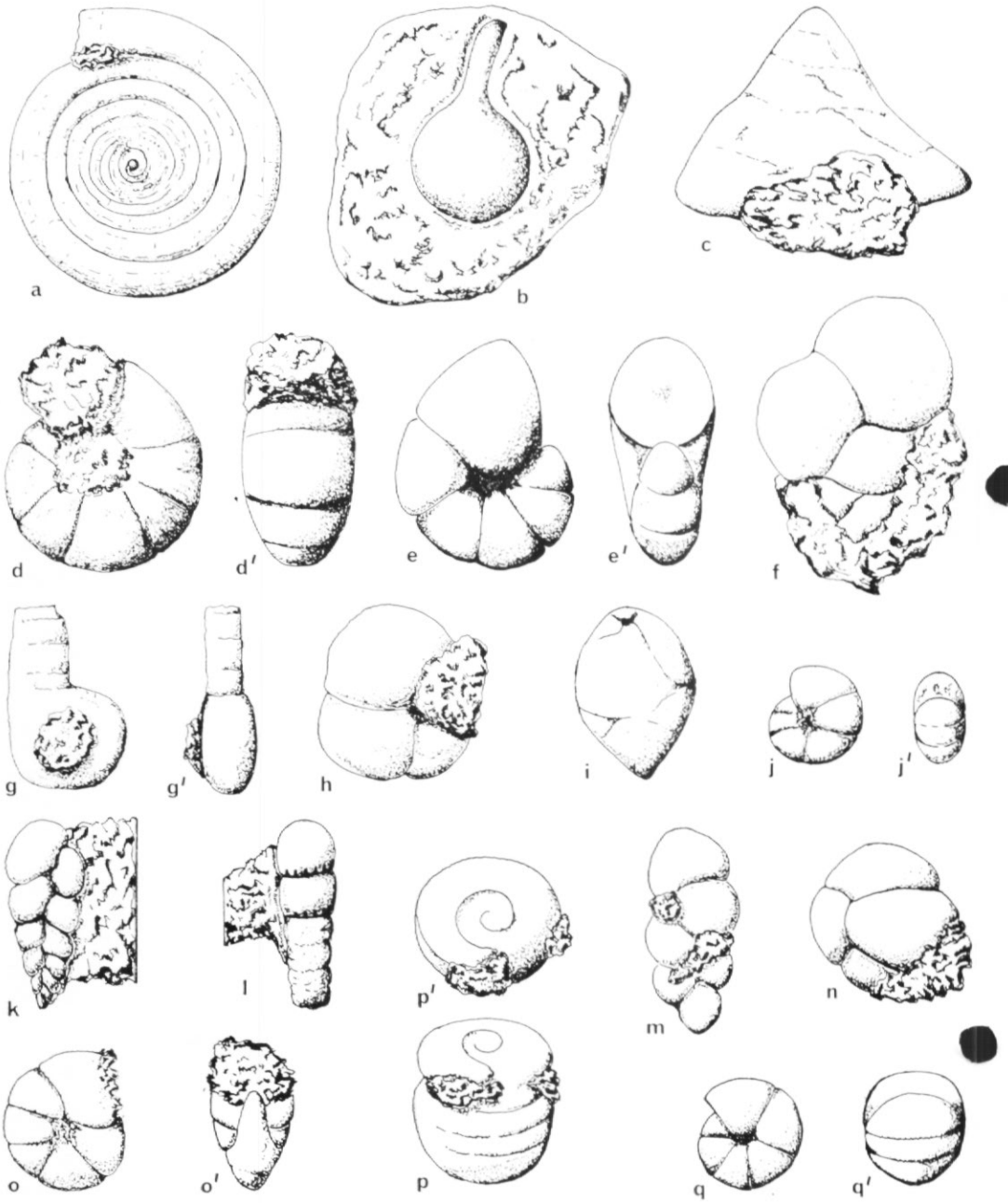

Fig. 2. Foraminifera from the Upper Cretaceous of James Ross Island. All drawings are ×60 approximately. a. *Ammodiscus cretaceus* (Reuss); b. *Ammolagena clavata* (Jones and Parker); c. ?*Globotruncana contusa* (Cushman) (side view); d and d′. *Haplophragmoides glaber* Cushman and Waters; e and e′. *Nonionella* aff. *austinana* Cushman; f. ?*Dorothia retusa* (Cushman); g and g′. *Ammobaculites agglutinans* (d'Orbigny); h. ?*Alveolophragmium ringens* (Brady); i. ?*Bulimina murchisoniana* d'Orbigny; j and j′. ?*Pullenia cretacea* Cushman; k. *Heterohelix globulosa* (Ehrenberg); l. ?*Siphogenerinoides ewaldi* (Karsten); m. ?*Pseudoclavulina clavata* (Cushman); n. *Trochammina globigeriniformis* (Parker and Jones); o and o′. ?*Anomalina tennesseensis* Berry; p and p′. *Glomospira charoides* var. *corona* Cushman and Jarvis; q and q′. *Pullenia sphaeroides* var. *coryelli* White.

Owing to various difficulties, it has not been possible to represent all the specimens exactly in these figures.

This differs little from the species but the present specimens are clearly of this variety, which is recorded for what it may be worth. It was described from the Upper Cretaceous of Trinidad, and has also been recorded from the Velasco Shale of Mexico. Cushman and Jarvis stated that they have seen Recent specimens of this same variety. The Burdwood Bank specimens are of the species, but not of the present variety.

Its distribution may be compared with that of *G. charoides*. The *Discovery Reports* record this species from 44 stations, 25 of them in the Falkland Islands sector (Earland, 1934). It is found most commonly between 1,090 and 2,225 fathoms (1,995 and 4,070 m.), reaching 2,764 fathoms (5,055 m.).

It is noteworthy that the commoner and more widespread present-day Antarctic form, except in the Weddell Sea sector, is *G. gordialis* (Jones and Parker), which is found at all depths down to 2,650 fathoms (4,845 m.).

Ammolagena clavata (Jones and Parker)
Fig. 2b

Trochammina irregularis var. *clavata* Jones and Parker 1860, p. 304.
Ammolagena clavata (Jones and Parker); Cushman 1946, p. 19, pl. ii, fig. 6.

Some 36 specimens, ranging from about 0·40 to 0·85 mm. in length. Both microspheric and megalospheric forms appear to be present.

A. clavata has a world-wide distribution at the present day and it is generally found in rather deep water. The *Discovery Reports* record it from 22 stations in all, 15 of them in the Falkland Islands sector (Earland, 1934), where all records but one were from depths ranging from 1,410 to 2,375 fathoms (2,580 to 4,345 m.).

Geologically, its range is given from Carboniferous to Recent. Of it Cushman and Jarvis (1932, p. 11) write: "This is another of the species that has kept its identity and its characters at least since Cretaceous times."

Haplophragmoides glaber Cushman and Waters
Figs. 2d and d′

Haplophragmoides glabra Cushman and Waters 1927, p. 83, pl. x, figs. 6a, b.
Haplophragmoides glabra Cushman and Waters; Cushman 1946, p. 20, pl. ii, figs. 17a, b (only).

Two specimens, the larger 0·61 mm. in diameter and 0·31 mm. thick, with seven or eight chambers in the outer whorl.

Described from the Navarro of Texas, it has been claimed by Cushman (1946) to be characteristic of the upper part of the Navarro group, equivalent to the Maestrichtian. It has also been recorded from strata of similar age in Arkansas (United States of America), Saskatchewan (Canada) and the Lizard Springs Marl of Trinidad.

?*Alveolophragmium ringens* (Brady)
Fig. 2h

Trochammina ringens Brady 1879, p. 57, pl. v, figs. 12a, b.
Trochammina ringens Brady 1884, p. 543, pl. xl, figs. 17, 18.
Haplophragmoides ringens (Brady); Cushman 1920, p. 49, pl. ix, fig. 2.

One specimen, 0·47 mm. in greatest diameter; it is very well preserved but unfortunately the aperture is obscured by a patch of glauconite.

This is a Recent species but one that dwells in deep water; in 1884 Brady remarked that it had by then been found on no bottoms of less than 1,600 fathoms (2,925 m.). It is widely distributed about the present oceans and Cushman (1920) recorded it mostly from depths between about 1,000 and 2,369 fathoms (1,830 and 4,330 m.), with a few records under 1,000 fathoms (1,830 m.). In the four *Discovery Reports* on the Foraminifera, only a single specimen is recorded (Earland, 1933) under the name *Ammochilostoma ringens* (Brady) from 640 fathoms (1,170 m.), and Earland states that its aperture is not typical.

I am not aware that it has been recorded as a fossil. The identification of the present specimen cannot be certainly given, for in addition to the obscured aperture the original nature of the shell wall is now not ascertainable.

Ammobaculites agglutinans (d'Orbigny)
Figs. 2g and g′

Spirolina agglutinans d'Orbigny 1846, p. 137, pl. vii, figs. 10–12.
Ammobaculites coprolithiformis (Schwager); Cushman 1946, p. 22, pl. iii, figs, 7–9.

Two specimens, 0·47 and 0·40 mm. in length respectively.

In the present Antarctic seas, it is recorded in the four *Discovery Reports* from 31 stations, in depths from 85 to 2,745 fathoms (155 to 5,020 m.), generally distributed but rather rare. Of it Brady (1884) stated that it is comparatively rare in shallow water.

This species was described from the Miocene of Vienna but it, or forms so close that for the present purpose they may be considered together under this name, appears to range from the Carboniferous, through the Lias, other Jurassic stages, Cretaceous, Tertiary and Recent, being well represented in the Upper Cretaceous.

The present specimens agree well with Cushman and Jarvis's (1932) good figures named *A. coprolithiformе*, but two errors are unfortunately involved. In 1927 Cushman identified two species from the Cretaceous of western Canada; one he called *A. coprolithiformе* (Schwager), which from the figure and description I identify as *A. agglutinans*. For the other he erected a new species *A. fragmentaria*, which I identify as *A. coprolithiformе* (Schwager). In 1932 Cushman and Jarvis again misidentified *A. agglutinans* as *A. coprolithiformis*, adding that the latter was described by Schwager from the Cretaceous of Europe. In fact, Schwager described his species from the Dogger (Bajocian, Jurassic) of Gingen in Württemberg, south Germany. These errors are perpetuated in Cushman's later papers up to 1949.

A. coprolithiformе Cushman 1927 (*non* Schwager) was re-named *A. tyrrelli* Nauss (1947, p. 333), but in my view this new name falls into the synonymy of *A. agglutinans*.

?*Pseudoclavulina clavata* (Cushman)
Fig. 2m

Clavulina clavata Cushman 1926*b*, p. 589, pl. xvii, fig. 4.
Pseudoclavulina clavata (Cushman); Cushman 1946, p. 36, pl. viii, figs, 23–31; pl. ix, figs. 1, 2.

Six specimens, the largest 0·64 mm. in length.

All are unfortunately so cluttered and obscured by tightly adhering glauconite that essential details of the test cannot be clearly seen, and the present identification must be provisional.

This fossil species, described from the Velasco Shale (Danian) of Mexico, has been widely recorded in the United States of America from strata ranging from Austin age to the Velasco Shale, approximately the whole of the Senonian and Danian, and also from Peru.

?*Dorothia retusa* (Cushman)
Fig. 2f

Gaudryina retusa Cushman 1926*b*, p. 588, pl. xvi, figs. 10a, b.
Dorothia retusa (Cushman); Cushman 1946, p. 46, pl. xiii, figs. 1–4.

Three specimens, the best preserved 0·72 mm. in length. All are so obscured by adhering glauconite that the identification can only be provisional.

This fossil species was described from the Velasco Shale (Danian) of Mexico, and it has also been recorded elsewhere in Mexico from both the Velasco Shale and the Mendez Shale (top of the Santonian, Campanian and Maestrichtian), and from the Upper Cretaceous of Trinidad.

Trochammina globigeriniformis (Parker and Jones)
Fig. 2n

Lituola nautiloidea var. *globigeriniformis* Parker and Jones 1865, p. 407, pl. xv, figs. 46, 47; pl. xvii, figs. 96, 97.
Trochammina globigeriniformis (Parker and Jones); Macfadyen 1933, p. 4.
Trochammina globigeriniformis (Parker and Jones); Cushman 1946, p. 51, pl. xv, figs. 8, 10, 11.

About 18 specimens are assigned to this species with some degree of confidence in the identification, though all are badly obscured by adhering glauconite, so that only parts of any one specimen can be seen. They range up to about 0·80 mm. in diameter.

The species was described from the Arctic and North Atlantic Oceans. Its geographical distribution in the present oceans is world-wide. It is essentially a deep-water species, at home in depths of not less than about 400 fathoms (730 m.) (Brady, 1884), and recorded down to 3,950 fathoms (7,225 m.).

The *Discovery Reports* record it from 59 stations, of which 48 are in the report by Earland (1934), wherein it is stated to be generally distributed in all areas and at all depths down to 2,745 fathoms (5,020 m.).

As a fossil it has been widely recorded from the Jurassic: Lower and Middle Lias of Germany, Bathonian of England, Corallian of Switzerland and Malm of Germany; from the Cretaceous: Gault of England, Upper Cretaceous of Trinidad, Peru and the Burdwood Bank; and from the Quaternary of Italy.

Nonionella aff. *austinana* Cushman
Figs. 2e and e′

References to the species are:

Nonionella austinana Cushman 1933*a*, p. 57, pl. vii, figs. 2a–c.
Nonionella austinana Cushman 1946, p. 100, pl. xliii, figs, 18–20.

One specimen, 0·61 mm. in greatest diameter.

This appears to be of a form characteristic of *N. austinana*, with six chambers in the outer whorl. But it is roughly two and a half times the size of the type specimen which is only 0·25 mm. in length.

The true species has been described from the Austin Chalk (Coniacian) of Texas, and it ranges from the top of the Eagle Ford Shale (Turonian) to the top of the Taylor Marl (Campanian); so in Texas it is typically Senonian. It has also been recorded from the Taylor Marl of Arkansas.

One other specimen is still larger, 0·72 mm. in greatest diameter, and more nearly circular in outline, possibly distorted during fossilization. It is doubtfully included here.

Heterohelix globulosa (Ehrenberg)
Fig. 2k

Textularia globulosa Ehrenberg 1839, p. 135, pl. iv, fig. *β*.
Pseudotextularia globulosa (Ehrenberg); Macfadyen 1933, p. 4, figs. k, l.
Gümbelina globulosa (Ehrenberg); Cushman 1946, p. 105, pl. xlv, figs. 9–15.

One specimen, 0·46 mm. in length, partly obscured by glauconite.

This species is a very common Upper Cretaceous fossil. According to Cushman (1946), it occurs in Europe mainly in the Senonian and Maestrichtian, and in America mainly in the Taylor and Navarro Formations (Campanian and Maestrichtian). It is widely recorded in the Gulf coastal region of the United States of America but curiously not from Mexico or Trinidad.

The single specimen from Burdwood Bank is smaller but broader than the present specimen.

?*Siphogenerinoides ewaldi* (Karsten)
Fig. 2l

Orthocerina ewaldi Karsten 1858, p. 114, pl. vi, figs. 3a–c.
Siphogenerinoides ewaldi (Karsten); Cushman 1946, p. 118, pl. l, figs. 9–11.

Four specimens, about 0·64 mm. in length.

A fossil species, described from the Upper Cretaceous of Colombia. From the various figures and descriptions I find it difficult to distinguish this species from *S. cretacea* Cushman and *S. parva* Cushman. All three occur in the Colon Shale of Venezuela, and one or more names have been recorded from the Upper Cretaceous of Colombia, Venezuela, Peru and Trinidad. The costae are shown as varying considerably from sharp until they are practically obsolete as in the present specimens, so far as can be seen, for they are badly obscured by adhering glauconite. But the frilled bases of the later chambers seem characteristic and they are most clearly seen in nearly smooth specimens and in internal casts. Differences in size seem inadequate for specific differentiation.

The age of the three species is that of the Colon Shale (Coniacian to Campanian inclusive) and higher beds, the equivalent of Maestrichtian to Danian.

?*Bulimina murchisoniana* d'Orbigny
Fig. 2i

Bulimina murchisoniana d'Orbigny 1840, p. 41, pl. iv, figs. 15, 15′.
Bulimina reussi Morrow; Cushman 1946, p. 120, pl. li, figs. 1–5.

One specimen, 0·37 mm. in length.

A fossil species described from the White Chalk of Saint-Germain near Paris, and also from England; the former is claimed to be of Lower Campanian age.

If the above synonymy (and including *B. reussi* var. *navarroensis* Cushman and Parker, which seems to consist merely of the smaller specimens) is accepted, the species occurs widely in the United States Gulf coast region, in strata of Austin, Taylor and Navarro age, equivalent to the whole of the Senonian; and also in the Upper Cretaceous of Colombia, Peru and Trinidad.

Pullenia sphaeroides var. *coryelli* White
Figs. 2q and q′

Pullenia coryelli White 1929, p. 56, pl. v, fig. 2.
Pullenia sphaeroides (d'Orbigny); Macfadyen 1933, p. 4.
Pullenia coryelli White; Cushman 1946, p. 147, pl. lx, figs. 10, 11.

28 specimens, maximum diameter about 0·4 mm.

These shells are of globular form reminiscent of tiny footballs, with some 5 or 6, or even 7, chambers visible in the last whorl. The sutures are generally clearly defined but flush with the surface. Many of the present specimens are badly obscured by tightly adhering glauconite.

The distribution of the comparable *P. sphaeroides* (d'Orbigny) in the present-day Antarctic seas has been recorded at 63 *Discovery* stations, of which 45 are in the Falkland Islands sector. Found between 45 and 2,610 fathoms (82 and 4,775 m.), it lives most commonly between about 1,700–2,550 fathoms (3,110–4,665 m.).

P. coryelli was described from the Velasco Shale of Mexico, and it has also been recorded from strata of similar Upper Cretaceous age in Trinidad and various localities in the United States Gulf coast region. Its range is recorded as the upper part of the Santonian, and the Campanian, Maestrichtian and Danian.

A number of globular forms of *Pullenia* have been recognized, for example, under the names *P. bulloides* (d'Orbigny), *P. coryelli* White, *P. duplicata* Stainforth, *P. miocenica* Kleinpell, *P. reussi* Cushman and Todd, *P. sphaeroides* (d'Orbigny), amongst others, ranging from Upper Cretaceous to Recent. I have found no really adequate differentiation of these, one from another, and the two ratios described by Cushman and Todd (1943, p. 1), when plotted

comparatively, have not helped me much. Comparison of the figures and descriptions shows only a very limited amount of variation that could well be included within a single species. In some figures slight differences may be attributed to deficiencies in perfect representation by the artist.

The genus is at home in deep water, which provides a uniform habitat that favours long-ranging species of the Foraminifera. There is, therefore, a reasonable case for uniting many of such so-called species under the oldest available name, *P. sphaeroides*. The most obvious distinction of *P. coryelli* lies in the larger number of chambers visible, 6 or 7 instead of 5 or 4; but this by itself does not call for more than varietal distinction even if it is a constant feature.

The genus *Pullenia* was erected by Parker and Jones (1862, p. 184) for "a minute form which has been represented by M. d'Orbigny (*Modèles*. No. 43) under the name of *Nonionina sphaeroides*, and has been subsequently described by him under the name of *N. bulloides*".

P. sphaeroides (d'Orbigny) was generally accepted as the genotype until Cushman and Todd (1943, p. 15) proposed to allow that specific name to lapse, on the grounds that d'Orbigny's *Modèle* of it showed "a very peculiarly shaped specimen, broader than long, with only three chambers in the final whorl". A second objection was the lack of a definite age and locality for *P. sphaeroides*, whose provenance was described merely as ballast sand.

As for the first objection, the *Modèle* may very likely be not a perfect representation, though the example of it preserved in the British Museum (Nat. Hist.) looks to me to be quite a reasonable likeness, for a model made so early as 1826; it is considerably better than Cushman and Todd's (1943, pl. ii, figs. 19a, b) figure suggests, and far better than the caricature given by Parker, Jones and Brady (1865, pl. ii, fig. 57). That only three chambers are shown may be reasonably regarded as an error. The "broader than long" effect is approached in Cushman and Todd's (1943, pl. i, figs. 11b, 12b) own figures named *P. reussi*, and still more in their reproduction of Egger's figure re-named by them as *P. eggeri* (Cushman and Todd, 1943, pl. i, fig. 5b), which indeed also seems to show only three chambers in the final whorl!

I cannot agree entirely with Cushman and Todd's second objection that "there are almost no references by later authors to the other seven [*sic*] species described from this ballast material by d'Orbigny". One of them (*Rotalia punctata*) came from a differently named, *marine*, ballast sand, and in the second edition of d'Orbigny's (1843) list of his *Modèles* (see Cushman, 1933*b*) it was stated to be living in the Adriatic. Of the remaining seven species [my counting] four had no *Modèle* and seem to have been stillborn, though perhaps figured in d'Orbigny's *Planches Inèdites*. But the remaining three had *Modèles*: *Rotalia bisaculeata* referred to *Calcarina* in 1843), *Cassidulina laevigata* (the genotype, figured in 1826 as well as modelled), and *Nonionina sphaeroides* (first species mentioned by Parker and Jones (1862) for their new genus *Pullenia*). All three were stated in d'Orbigny's (1843) list to be living in the Mediterranean, which must be adequate to indicate the provenance of the ballast sand. This is repeated on the printed label of the tablet on which the British Museum (Nat. Hist.) specimen of d'Orbigny's *Modèle* is mounted, which reads "*Nonionina sphaeroides* d'Orb. Recent. Mediterranean. No. 43".

A final point to be noted is that d'Orbigny's type specimens of *Nonionina sphaeroides* were reported by Heron-Allen and Earland (1932, p. 403) to be preserved in Paris, and one of these presumably only required a description and new figure to establish its true form. I regret that I have not been able to go to see them.

Cushman and Todd (1943) did not propose an alternative type species, and the evidence available and prospective seems adequate to retain *N. sphaeroides* as the genotype of *Pullenia*.

?*Pullenia cretacea* Cushman
Figs. 2j and j'

Pullenia cretacea Cushman 1936, p. 75, pl. xiii, figs, 8a, b.
Pullenia cretacea Cushman 1946, p. 146, pl. lx, figs. 9a, b.

One specimen, 0·30 mm. in greatest diameter, 0·20 mm. in thickness.

There are apparently six chambers in the last whorl, but neither the earliest chamber in the whorl nor the apertural face are satisfactorily seen. Between the later chambers the septa are broad but flush with the surface.

This species was described from the Selma Chalk of Navarro age (Maestrichtian) of Tennessee. It has been recorded from strata of Navarro and of Taylor age (mainly Campanian) in the Gulf region of the United States, and also from the Colon Shale (Senonian) of Colombia.

The species is comparable with the European *P. quaternaria* (Reuss) but it has more chambers, "about five", in the last whorl. It is a rather thicker form than *P. quinqueloba* (Reuss), which also differs in its somewhat lobulate periphery, a feature shared with Cushman's three closely similar Upper Cretaceous forms named *P. americana*, *P. minuta* and *P. jarvisi*, which seem to differ amongst themselves only in size.

?*Globotruncana contusa* (Cushman)
Fig. 2c

Pulvinulina arca var. *contusa* Cushman 1926*a*, p. 23.
Globotruncana arca var. *contusa* (Cushman); Cushman 1946, p. 150, pl. lxii, fig. 6.
Globotruncana contusa (Cushman); Bolli 1957, p. 53, 54.

One specimen, diameter 0·83 mm., spire height 0·63 mm. The umbilical side is obscured by glauconite.

An Upper Cretaceous species described from the Mendez Shale of Mexico, which is dated to the uppermost Santonian, Campanian and Maestrichtian, and recorded by Bolli (1957) from the Maestrichtian of Trinidad.

?*Anomalina tennesseensis* Berry
Figs. 2o and o′

Anomalina tennesseensis Berry 1929, p. 13, pl. ii, figs. 13–15.
Anomalina tennesseensis Berry; Cushman 1946, p. 155, pl. lxiv, figs. 3a–c.

Three specimens, the largest 0·39 mm. in diameter.

A fossil species described from the Upper Cretaceous Ripley Formation of Navarro age (Maestrichtian) in Tennessee, and recorded from the Taylor Marl (Upper Santonian to Campanian) of Arkansas, United States.

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REFERENCES

BERRY, W. 1929. (*In* BERRY, W. *and* L. KELLEY. The Foraminifera of the Ripley Formation on Coon Creek, Tennessee. *Proc. U.S. natn. Mus.*, **76**, Art. 19, 1–20.)

BOLLI, H. M. 1957. The Genera *Praeglobotruncana*, *Rotalipora*, *Globotruncana*, and *Abathomphalus* in the Upper Cretaceous of Trinidad, B.W.I. *Bull. U.S. natn. Mus.*, No. 215, 51–60.

BRADY, H. B. 1879. Notes on Some of the Reticularian Rhizopoda of the *Challenger* Expedition. Part I. On New or Little-known Arenaceous Types. *Q. Jl microsc. Sci.*, New Ser., **19**, 20-63.

———. 1884. Report on the Foraminifera Dredged by H.M.S. Challenger, during the Years 1873–1876. *Report on the Scientific Results of the Voyage of H.M.S. Challenger during the Years 1873–1876. Zoology*, **9**, 1–814.

CUSHMAN, J. A. 1920. The Foraminifera of the Atlantic Ocean. Part 2. *Bull. U.S. natn. Mus.*, No. 104, 1–111.

———. 1926*a*. Some Foraminifera from the Mendez Shale of Eastern Mexico. *Contr. Cushman Lab. foramin. Res.*, **2**, 16–26.

———. 1926*b*. The Foraminifera of the Velasco Shale of the Tampico Embayment. *Bull. Am. Ass. Petrol. Geol.*, **10**, 581–612.

———. 1927. Some Foraminifera from the Cretaceous of Canada. *Trans. R. Soc. Can.*, Sect. 4, **21**, 127–32.

———. 1933*a*. New American Cretaceous Foraminifera. *Contr. Cushman Lab. foramin. Res.*, **9**, 49–64.

———. 1933*b*. Some Notes on d'Orbigny's Models. *Contr. Cushman Lab. foramin. Res.*, **9**, 70–73.

———. 1936. Cretaceous Foraminifera of the Family Chilostomellidae. *Contr. Cushman Lab. foramin. Res.*, **12**, 71–78.

———. 1946. Upper Cretaceous Foraminifera of the Gulf Coastal Region of the United States and Adjacent Areas. *Prof. Pap. U.S. geol. Surv.*, No. 206, 1–241.
———. *and* P. W. JARVIS. 1928. Cretaceous Foraminifera from Trinidad. *Contr. Cushman Lab. foramin. Res.*, **4**, 85–103.
———. *and* ———. 1932. Upper Cretaceous Foraminifera from Trinidad. *Proc. U.S. natn. Mus.*, **80**, Art. 14, 1–60.
———. *and* R. TODD. 1943. The Genus *Pullenia* and Its Species. *Contr. Cushman Lab. foramin. Res.*, **19**, 1–23.
———. *and* J. A. WATERS. 1927. Some Arenaceous Foraminifera from the Upper Cretaceous of Texas. *Contr. Cushman Lab. foramin. Res.*, **2**, 81-85.
EARLAND, A. 1933. Foraminifera. Part II. South Georgia. '*Discovery*' *Rep.*, **7**, 27–138.
———. 1934. Foraminifera. Part III. The Falklands Sector of the Antarctic (excluding South Georgia). '*Discovery*' *Rep.*, **10**, 1–208.
———. 1936. Foraminifera. Part IV. Additional Records from the Weddell Sea Sector from Material Obtained by the S.Y. 'Scotia'. '*Discovery*' *Rep.*, **13**, 1–76.
EHRENBERG, C. G. 1839. Uber die Bildung der Kreidefelsen und des Kreidemergels durch unsichtbare Organismen. *Abh. preuss. Akad. Wiss.*, (für 1838), 59–147.
HERON-ALLEN, E. *and* A. EARLAND. 1932. Foraminifera. Part I. The Ice-free Area of the Falkland Islands and Adjacent Seas. '*Discovery*' *Rep.*, **4**, 291–460.
HOLLAND, R. 1910. The Fossil Foraminifera. *Wiss. Ergebn. schwed. Südpolarexped.*, Bd. 3, Lief. 9, 1–11.
HOWARTH, M. K. 1958. Upper Jurassic and Cretaceous Ammonite Faunas of Alexander Land and Graham Land. *Falkland Islands Dependencies Survey Scientific Reports*, No. 21, 16 pp.
JONES, T. R. *and* W. K. PARKER. 1860. On the Rhizopodal Fauna of the Mediterranean, Compared with That of the Italian and Some Other Tertiary Deposits. *Q. Jl geol. Soc. Lond.*, **16**, Pt. 1, 292–307.
KARSTEN, H. 1858. Ueber die geognostischen Verhältnisse des westlichen Columbien, der heutigen Republiken Neu-Granada und Equador. *Amtl. Ber. Vers. dt. Naturf. Ärzte Wien*, **32** (für 1856), 80–117.
MACFADYEN, W. A. 1933. Fossil Foraminifera from the Burdwood Bank and their Geological Significance. '*Discovery*' *Rep.*, **7**, 1–16.
———. 1962. *Ammodiscus* Reuss, 1862 (Foraminifera): Proposed Designation of a Type Species under the Plenary Powers. Z.N.(S) 1087. *Bull. zool. Nom.*, **19**, Pt. 1, 27–34.
NAUSS, A. W. 1947. Cretaceous Microfossils of the Vermilion Area, Alberta. *J. Paleont.*, **21**, No. 4, 329–43.
NEAVERSON, E. 1934. The Sea-floor Deposits. I. General Characters and Distribution. '*Discovery*' *Rep.*, **9**, 295–350.
D'ORBIGNY, A. D. 1840. Mémoire sur les Foraminifères de la Craie Blanche du Bassin de Paris. *Mém. Soc. géol. Fr.*, **4**, Pt. 1, 1–51.
———. 1843. *Modèles de Foraminifères, Vivans et Fossiles, par Alcide d'Orbigny*. 2nd edition. Paris. (See Cushman, 1933*b*.)
———. 1846. *Foraminifères Fossiles du Basin Tertiaire de Vienne* (*Autriche*). Paris, Gide et Comp.
PARKER, W. K. *and* T. R. JONES. 1862. (*In* CARPENTER, W. B., PARKER, W. K. *and* T. R. JONES. *Introduction to the Study of the Foraminifera*. London, Ray Society.)
———. *and* ———. 1865. On Some Foraminifera from the North Atlantic and Arctic Oceans, including Davis Straits and Baffin's Bay. *Phil. Trans. R. Soc.*, **155**, 325–441.
———., ———. *and* H. B. BRADY. 1865. On the Nomenclature of the Foraminifera. XII. The Species Enumerated by d'Orbigny in the *Annales des Sciences Naturelles*, Vol. vii, 1826; (3) The Species Illustrated by Models. *Ann. Mag. nat. Hist.*, Ser. 3, **16**, 15–41.
REUSS, A. E. 1845. *Die Versteinerungen der böhmischen Kreideformation*. Stuttgart.
TODD, R. *and* H. T. KNIKER. 1952. An Eocene Foraminiferal Fauna from the Agua Fresca Shale of Magallanes Province, Southernmost Chile. *Spec. Publs Cushman Fdn*, No. 1, 1–28.
WHITE, M. P. 1929. Some Index Foraminifera of the Tampico Embayment Area of Mexico. *J. Paleont.*, **3**, No. 1, 30–57.