UPPER CRETACEOUS PLANKTONIC FORAMINIFERA FROM THE ISLE OF WIGHT, ENGLAND

by F. T. BARR

ABSTRACT. Seventeen species and subspecies of planktonic Foraminifera are recorded from approximately 1,000 feet of Senonian Upper Chalk from Culver Cliff, Isle of Wight. Four species, *Planomalina ehrenbergi*, *P. rowei*, *Schackoina cushmani*, and *Globotruncana culverensis*, are described as new. Planktonic-benthonic ratios suggest a neritic or upper bathyal environment for the deposition of most of the Upper Chalk. There is indication of a shallowing of the Upper Cretaceous sea at the beginning of the *Belemnitella mucronata* Zone.

MUCH emphasis has been placed on the study of planktonic Foraminifera during the last 15 to 20 years. The short stratigraphical ranges and wide geographical distribution of many planktonic Foraminifera make them exceptionally useful in correlating strata of diverse facies and over great distances. Planktonic Foraminifera have been studied in great detail from Upper Cretaceous rocks of the Caribbean area (Bolli 1951, 1957, 1959; Brönnimann 1952; Gandolfi 1955), Northern Africa (Dalbiez 1955; Sigal 1949, 1952), and continental Europe (Bolli 1945; Cita 1948; Reichel 1950; Hofker 1956), to mention only a few areas. However, there is little mention in the literature of the planktonic Foraminifera from the extensive Cretaceous rocks of the British Isles.

The purpose of this paper is to describe the planktonic Foraminifera from the Upper Chalk (Senonian) at Culver Cliff, Isle of Wight, and to record their stratigraphical ranges. It is hoped that this and forthcoming studies of the Upper Cretaceous Foraminifera will aid in the more precise dating and correlation of the British Chalk.

Location. Over 1,200 feet (Rowe 1908, p. 285) of steeply dipping Upper Cretaceous chalk are well exposed at Culver Cliff, the sea cliffs just south of Whitecliff Bay, on the east-central coast of the Isle of Wight. The impressive exposures of Culver Cliff are located about 2½ miles north-east of Sandown and approximately 2 miles south-east of Brading. The base of the sea cliffs from the *Belemnitella mucronata* Zone to the Upper *Micraster cor-testudinarium* Zone can best be reached from Whitecliff Bay, whereas the basal beds of the *M. cor-testudinarium* Zone and underlying strata must be approached from Sandown Bay to the south. The base of most of the sea cliffs can only be reached during periods of low tide.

Procedure. Most of the Upper Chalk (Senonian) was measured by means of a tape and Brunton compass traverse. Samples for foraminiferal analysis were collected along the traverse. Traverse data were reduced to stratigraphic thickness through use of Mandelbaum and Sanford's (1952) tables. Chalk, marly chalk, and chalk meal from the insides of cavernous flint nodules were processed for foraminiferal analysis. The chalk meal from the flint nodules contained, by far, the most abundant and best-preserved Foraminifera. Samples were disaggregated by heating in a dilute solution of hydrogen peroxide for several hours. Residues were then washed through a 120-mesh sieve (average opening

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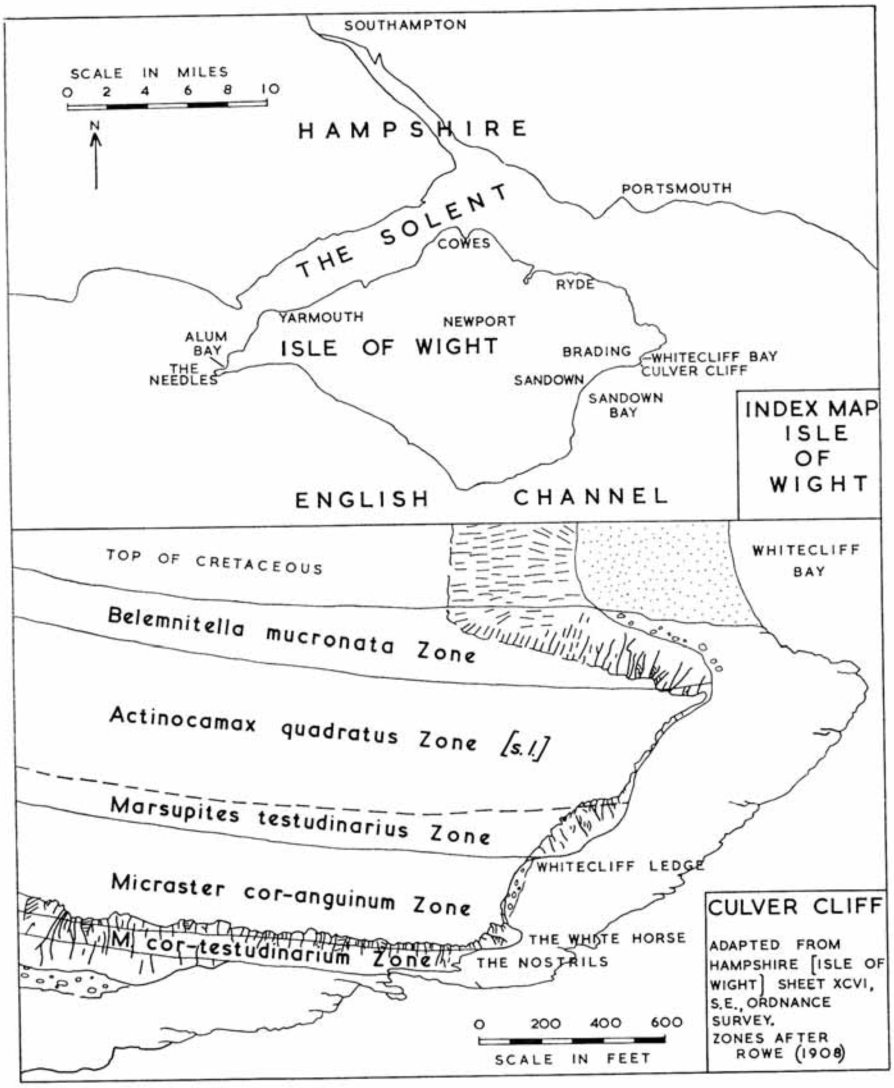

TEXT-FIG. 1. Location map of Culver Cliff, Isle of Wight.

124 microns); also, finer residues were frequently examined. The Foraminifera were concentrated by floating processes using carbon tetrachloride. The remaining residues were also examined for species less susceptible to concentration by floating methods.

Planktonic-benthonic ratio calculations were made from counts of all Foraminifera in representative portions of each sample before concentration by floating. These representative samples were obtained by splitting the washed residues with a micro-sample splitter, described by Kennard and Smith (in press), to a size containing 300 to 500 Foraminifera.

Deposition of types. Holotypes and illustrated specimens are deposited in the British Museum (Natural History), London. Paratypes and additional material are deposited in the collections of University College, University of London.

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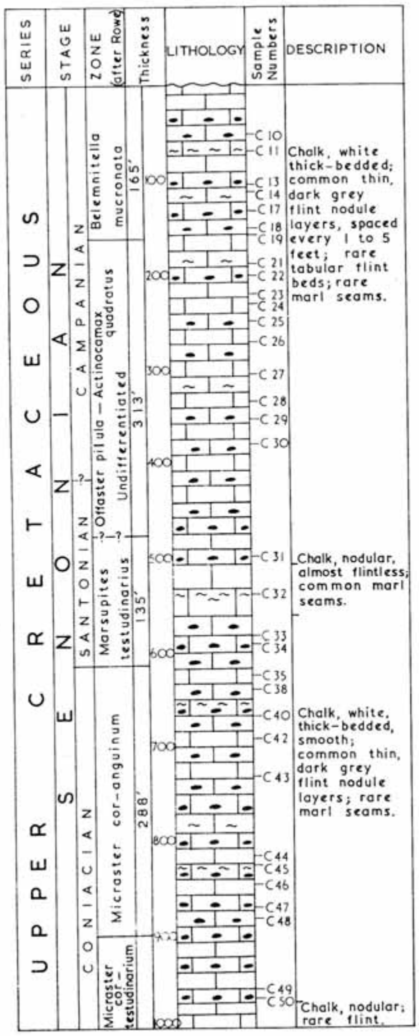
STRATIGRAPHY

In the first half of the nineteenth century geologists began subdividing the Upper Cretaceous chalk of the British Isles into local lithological units or formations. These units were later grouped into the larger units, Upper, Middle, and Lower Chalk, which could generally be recognized over large areas. It soon became apparent that these lithological units had distinctive fossil assemblages. The terms Upper, Middle, and Lower Chalk were then applied to units entirely defined by fossil content, thus having time-stratigraphic significance, but were approximate equivalents to the older lithologic units.

In 1875 the French geologist Barrois made the first serious attempt to zone the Chalk on the Isle of Wight. The next year Barrois (1876) completed a stratigraphic study of the Upper Cretaceous rocks of England and Ireland and showed that it was possible to use the same megafossil zones in the British Isles as were established in the Upper Cretaceous of France, and these zones could be grouped into the stages proposed by d'Orbigny. The zones used by Barrois (1876) are as follows:

STAGES	ZONES
Senonian	Zone of *Belemnitelles*
	Zone of *Marsupites*
	Zone of *Micraster cor-anguinum*
	Zone of *Micraster cor-testudinarium*



TEXT-FIG. 2. Columnar section of Upper Chalk at Culver Cliff showing stratigraphic position of samples.

Turonian	Zone of *Holaster planus* Zone of *Terebratulina gracilis* Zone of *Inoceramus labiatus*
Cenomanian	Zone of *Belemnites plenus* Zone of *Holaster subglobosus* Chloritic Marl Zone of *Pecten asper* Zone of *Ammonites inflatus*

The Zones of *Pecten asper* and *Ammonites inflatus* are now placed in the Albian Stage. The Senonian and Turonian stages of d'Orbigny are approximately equivalent to the Upper and Middle Chalk, respectively. The *Holaster planus* Zone, however, is placed in the Upper Chalk (see Jukes-Browne (1903, pp. 1–10) for a more complete discussion of the early stratigraphic nomenclature of the Upper Cretaceous of Great Britain).

Rowe (1908) published the results of an extensive study of the Chalk of the Isle of Wight, and for the first time clearly defined the zonal divisions of the Upper and Middle Chalk in this area and mapped their boundaries throughout much of the island. He subdivided the Upper Chalk of the Isle of Wight into the following zones:

Zone of *Belemnitella mucronata*
Zone of *Actinocamax quadratus*
Zone of *Marsupites testudinarius*
Zone of *Micraster cor-anguinum*
Zone of *Micraster cor-testudinarium*
Zone of *Holaster planus*

In 1912 Brydone subdivided the Zone of *Actinocamax quadratus* in Hampshire, Sussex, and Wiltshire into two zones, retaining the name *A. quadratus* for the upper zone and proposing the name *Offaster pilula* for the lower zone. In the same year Jukes-Browne (1912) also subdivided the Zone of *A. quadratus* into two zones and proposed the name '*Offaster pilula*' for his lower zone. Later, Brydone (1914, p. 404) extended his study to the Isle of Wight and recognized the Zones of *O. pilula* and the restricted *A. quadratus* at Scratchells Bay on the western shore; however, because of the poor condition of the exposures, he was not able to subdivide the unrestricted Zone of *A. quadratus* at Culver Cliff.

Micraster cor-testudinarium Zone. This zone is exposed at the base of the south-easternmost portion of Culver Cliff which may be approached only during periods of exceptionally low tides. Because of the inaccessibility of the basal beds, only the uppermost 90 feet of this zone were examined. According to Rowe (1908, p. 242), the top of the *M. cor-testudinarium* Zone 'may be placed at the point where the out-jutting cliff called White Horse joins the surface in which the northern Nostril is cut'. The lowermost 15 feet of the examined beds consisted of very hard, often nodular, thick bedded, aphanitic white chalk containing very little flint. The uppermost 75 feet of this unit contain common flint nodule layers, spaced every 1 to 3 feet, which probably represent the highest percentage of flint found in the Upper Chalk at Culver Cliff. The flint is dark brownish-grey to black and the nodules vary greatly in size and shape, usually ranging from 1 to 10 inches in length. Marl seams are rare; and in the upper part of this zone there are several chalk layers containing numerous *Inocerami* fragments.

Micraster cor-anguinum Zone. The *M. cor-anguinum* Zone is exposed at Culver Cliff between the northern Nostril and the southern base of the east–west trending Whitecliff. In the central portion of this unit a large slide of chalk obscures the base of the cliff. This zone has a thickness of 288 feet and consists of a thick bedded, very pure, aphanitic, white chalk which contains very rare glauconite and subangular quartz grains. Most of the chalk has a smooth appearance; however, some nodular chalk bands are present near the base of the zone. There are several beds of chalk containing abundant *Inocerami* fragments in the basal 30 feet. Brownish-grey to black flint nodule layers, similar to those of the *M. cor-testudinarium* Zone, are common throughout the zone, occurring every 1 to 3 feet. These flint nodules are rarely cavernous; however, on the north and south walls of White Horse are several very thin layers containing small, nearly spherical, flint nodules about ½ to 1½ inches in diameter which are often hollow and usually contain very fossiliferous chalk meal.

Marsupites testudinarius Zone. As early as 1865 Whitaker (p. 404) mentioned the presence of a unit of nearly flintless chalk at Culver Cliff and his often-quoted words are as follows: 'Here in the midst of the chalk, with layers of flint at every 3 or 4 feet, is a space some 40 to 50 feet thick with only one seam of tabular flint, but with four lines of green coated nodules like those of the Chalk Rock, but perhaps of a deeper colour.' Rowe (1908, p. 245) described a nearly flintless section of strata about 58 feet thick containing 4 nodule beds and put the contact of the *M. testudinarius–Actinocamax quadratus* Zones between the 2 lowest nodule beds, thus placing about 12 feet of the flintless unit in the *M. testudinarius* Zone and the bulk of the unit in the *A. quadratus* Zone. Rowe (op. cit., pls. 19, 20, F) has very clearly plotted this unit on excellent photographs of Culver Cliff; and on the map accompanying his work, Sherborn has plotted this same zonal boundary. However, the present author has observed the very distinctive, nearly flintless unit about 55 feet in thickness with the greenish chalk nodule layers and 2 tabular flint beds located entirely within the *Marsupites testudinarius* Zone as delimited by Rowe on his plates and on the accompanying geological map by Sherborn. In Rowe's photograph (pl. 19, p. 329) of the cliff section designated as the 'belt of flintless chalk and the nodule beds', the present author has found about 20 flint nodule beds and 3 tabular flint layers. On close inspection of Rowe's plate 19, several flint nodule beds can be seen within the 'flintless chalk' high on the cliff above the algal cover. Rowe has either: (1) misplotted the nearly flintless chalk unit; or (2) misidentified this unit.

If we assume that Rowe misidentified this unit and used the upper boundary of the *M. testudinarius* Zone as shown on his plate 19 and on the accompanying geological map, this zone is composed of three units with a total thickness of 135 feet:

Chalk, common flint nodules	30 ft.
Chalk, nearly flintless with green chalk nodule layers	55 ft.
Chalk, common flint nodules	50 ft.

On the other hand, Rowe's (1908, p. 245) description of a nearly flintless chalk unit more closely fits the true flintless chalk unit than the strata present where he has placed this unit on his plates and map. Brydone (1914, pp. 209, 210), however, gives a very detailed description of the nearly flintless chalk, which is in close agreement with the present author's observations. Although Brydone's unit has about the same thickness as that described by Rowe, he remarks that there is a wide discrepancy between their details. If we assume that Rowe misplotted the flintless chalk and that the top of the *M. testudinarius* Zone is between the two lowest green chalk nodule layers, then the zone has a thickness of approximately 65 feet and is composed of two units:

Chalk, flintless with a single green chalk nodule layer	15 ft.
Chalk, common flint nodules	50 ft.

Rowe (p. 246) reports a thickness of 95 feet for the *M. testudinarius* Zone at Culver Cliff which is intermediate between the two preceding thicknesses calculated for the zone. It is therefore still not clear where Rowe wished to place the upper boundary of this zone. In the present report the upper limit of the zone is tentatively placed approximately 30 feet above the flintless chalk unit. The lower boundary of the *M. testudinarius* Zone was located approximately by Rowe at the base of the east–west trending cliff, just above the words 'Whitecliff Ledge' on the location map.

Actinocamax quadratus–Offaster pilula Zones. Brydone (1914) was not able to subdivide the older *Actinocamax* quadratus Zone (s.l.) at Culver Cliff into his *Offaster pilula* Zone and *Actinocamax quadratus* Zone (s.s.), although they are both undoubtedly present as they are in east Sussex and at Scratchell's Bay on the western side of the Isle of Wight. As has been mentioned, there is some question as to whether the base of the *A. quadratus* Zone (s.l.) should be placed within the flintless chalk or about 30 feet above this unit as it tentatively has been done in this report.

The measured thickness of the strata between the base of the *Belemnitella mucronata* Zone and the nearly flintless chalk is 345 feet, the lower 30 feet of which is placed in the *Marsupites testudinarius* Zone. Brydone (op. cit., p. 209) gives a detailed description of the strata, and reports a measurement of 355 feet for the same unit. This unit consists of thick bedded, aphanitic, white chalk with flint nodule layers spaced every 1 to 4 feet. The flint nodules are dark brownish-grey, often with light greyish tan patches in their interiors, and usually with thin white silicious coatings about $\frac{1}{8}$ to $\frac{1}{4}$ inch in thickness. The nodules in the upper part of the zone are often cavernous containing chalk meal, but are rarely cavernous in the lower beds. The greater part of the chalk meal, containing abundant coccoliths, when disaggregated will pass through a 200-mesh sieve. The coarser fraction consists chiefly of amorphous chalk, small hollow spheres about 0·06 mm. in diameter which may be inorganic or of algal origin (see Earland 1939, pp. 30–33), and Foraminifera with lesser amounts of Ostracodes, Inocerami (prisms), sponge spicules, Echinoid spines, and macrofossil fragments. Sponge spicules, although often common in the chalk meal, were not observed in the chalk. The only Radiolaria observed were rare specimens, which had been replaced by flint, from the chalk meal of the upper part of this zone and the *Belemnitella mucronata* Zone. Bryozoa are usually rare; however, about 20 per cent. of the coarse fraction of sample C–23 consists of fragments of Bryozoa. Small subangular grains of quartz, glauconite, and pyrite crystals, although very rare, were found in most of the examined samples. Marl seams are fairly common and there are about 4 tabular flint beds within this unit.

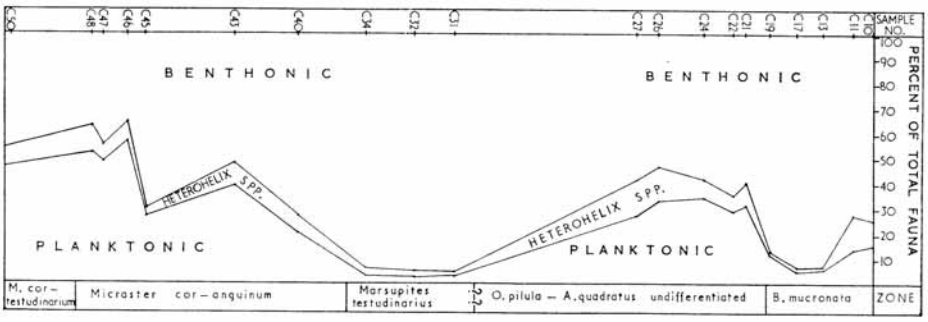
Belemnitella mucronata Zone. The *B. mucronata* Zone represents the youngest Cretaceous strata at Culver. These rocks form the prominent white cliffs of the short southern shore of Whitecliff Bay. The upper portion of this zone is largely covered at the sea cliff by chalk alluvium; however, the entire zone is exposed on the reef at low tide. These strata consist of thick bedded, white, aphanitic, very pure chalk, containing very rare glauconite, subangular quartz grains, and pyrite crystals. Although well indurated, the chalk from this zone is somewhat softer than most of the older chalk. The chalk on the reef exposed to the ocean water is noticeably harder than that high on the cliffs. Thin, dark-grey, flint nodule layers are very common, spaced every 1 to 4 feet. Many nodules are cavernous and contain very fossiliferous chalk meal similar in composition to that of the *A. quadratus* Zone. Thin marl seams, ranging in thickness from 2 to 7 inches, are fairly common especially near the base of the zone. The measured thickness of this zone across the reef is 165 feet which differs from Rowe's (1908, p. 249) reported thickness of 150 feet. The beds of the *B. mucronata* Zone are unconformably overlain by steeply dipping Lower Tertiary shales. The approximate base of this zone as located by Rowe is a ledge which runs due east near the north-easternmost part of the cliff.

ECOLOGY

Thomas Huxley, in 1858 (see Thomson, 1874), referred to the *Globigerina* ooze of the Atlantic as a 'modern Chalk'. For many years afterwards the belief was prevalent among geologists that the Cretaceous chalk deposits of Great Britain were ancient deep-sea *Globigerina* oozes. Murray and Renard (1891, p. xxviii), after their extensive study of the deep-sea deposits collected by the 'Challenger' Expedition, stated: 'The nature of the mineral action, the variability of the residue, the chemical analysis, the character of the organic remains, and the position of the Cretaceous Sea, all point to the white chalk being formed near shore, and not in the abysmal regions of a deep ocean, like a typical *Globigerina* ooze.' Even after this statement by two of the foremost students of deep-sea deposits, the idea that the chalk was a deep-sea ooze continued among some geologists for many years. Earland (1939) discussed the many lines of evidence for the depositional environment of the Chalk and concluded (p. 34): 'The Chalk was formed at the bottom of a comparatively shallow sea, whose depth varied at times between less than 50 and a maximum of about 300 fathoms.'

Jukes-Browne (1904) and others have cited the bathymetric ranges of present-day Foraminifera which they believed were also found in the Chalk as evidence for depth of deposition of the Chalk. These species have been misidentified, and very few if any Foraminifera from the Chalk have survived to the Recent. One approach that may give us information on the depth of deposition of the Chalk, however, is the ratio of planktonic to benthonic Foraminifera found in this deposit. Although Earland (1939, p. 18) states, 'For pelagic Foraminifera are by no means abundant in the chalk. Though their number varies in different zones they are always a negligible constituent and never dominant among other Foraminifera'; it was found that planktonic Foraminifera (*Globigerinaceae*) from the Upper Chalk of the Isle of Wight composed 3 to 57 per cent. of each of the examined foraminiferal assemblages, and species of *Heterohelix*, which may possibly be planktonic, make up another 1 to 13 per cent. of each foraminiferal assemblage.

Since the early studies of Recent Foraminifera it has been realized that in deep-sea deposits such as *Globigerina* ooze planktonic Foraminifera compose a much higher percentage of the foraminiferal assemblages than do the benthonic Foraminifera and that the converse is true in near shore environments. Grimsdale and Morkhoven (1955) have studied the planktonic-benthonic ratios of numerous Recent foraminiferal assemblages from the Gulf of Mexico and have shown that there is a general progressive increase in the percentage of planktonic Foraminifera with depth. This increase with depth is due largely to: (1) an increased water column which will contain a greater number of planktonic Foraminifera per square unit of ocean bottom; and (2) a general



TEXT-FIG. 3. Chart showing percentage of planktonic–benthonic Foraminifera per sample.

decrease in the number of benthonic Foraminifera with increased depth, at least, from lower neritic to abyssal depths. Phleger (1945, 1951) has shown that living planktonic Foraminifera are present in the water column down to depths of over 1,000 metres. Proximity of oceanic currents, bottom conditions, turbidity in surface waters, and numerous other ecologic factors may also locally affect the planktonic–benthonic ratios. It is obvious, therefore, that any interpretation of paleobathymetry from planktonic–benthonic ratios in Tertiary or Upper Cretaceous rocks can only be attempted in a general sense and by analysis of many samples.

The percentages of planktonic and benthonic forms from twenty foraminiferal assemblages from the Upper Chalk have been calculated. Complete counts were made of all Foraminifera present in representative portions of each sample. All assemblages but three contained 300 to 500 Foraminifera. The complete faunas were counted of samples C31, C32, and C34, each containing less than 60 Foraminifera. These three faunas which contain anomalously low percentages of planktonic Foraminifera are poorly preserved and appear to have undergone a selective destruction of certain faunal elements. It is believed that most of the fragile forms, which most often contain a high percentage of planktonics, have been destroyed by post-depositional processes; and, therefore, the ratios for these three samples may be quite unreliable. The faunas of the other seventeen samples are well preserved and there is no evidence of any selective destruction. The planktonic percentages of samples C50 to C46 from the upper *Micraster cor-testudinarium* Zone and lower *Micraster cor-anguinum* Zone range from 40 to 57 per cent. Grimsdale and Morkhoven's (1955, text-fig. 1) depth distribution chart suggests 90 to 800 metres as the depth of deposition for these samples. Samples C45 to C40, from the middle and upper *M. cor-anguinum* Zone, have planktonic percentages ranging from 22 to 40 per cent. which suggest a depth of deposition of 65 to 500 metres. The percentages of planktonic Foraminifera from samples C27 to C21 from the *Actinocamax quadratus* Zone range from 28 to 35 per cent., suggesting a depth of deposition of 75 to 500 metres. Faunas from samples C19 to C10 from the *Belemnitella mucronata* Zone contain from 5 to 16 per cent. planktonics, suggesting a depth of deposition of 30 to 50 metres.

The above bathymetric ranges of deposition are very broad but agree well with Earland's estimates (1939, p. 34). The evidence from this study is not conclusive that there was any fluctuation in depositional depth from the upper *Micraster cor-testudinarium* Zone to the top of the *Actinocamax quadratus* Zone. The planktonic–benthonic ratios, however, do suggest that there was a shallowing of the Cretaceous sea in the Isle of Wight area at the beginning of deposition of the *Belemnitella mucronata* Zone. A shallowing of the Cretaceous sea at this time is in close agreement with the opinion of Jukes-Browne (1904, pp. 374–7) who came to the same conclusion from evidence along other geologic lines. The results of this study are very general indeed, and it must be kept in mind that the size of the study adds further limitations. It is hoped, however, that this may be the first step in a more encompassing study, both geographically and stratigraphically, of the percentages of planktonic Foraminifera in the Chalk of Great Britain.

SYSTEMATIC DESCRIPTIONS

Family HANTKENINIDAE Cushman 1927
Subfamily PLANOMALININAE Bolli, Loeblich, and Tappan 1957
Genus PLANOMALINA Loeblich and Tappan 1957

Planomalina aspera (Ehrenberg)

Plate 69, figs. 4*a*, *b*

Rotalia aspera Ehrenberg, 1854, p. 24, pl. 27, figs. 57–58; pl. 28, fig. 42; pl. 31, fig. 44.
Phanerostomum asperum Ehrenberg 1854, p. 23, pl. 30, figs. 26*a*–*b*.
Rotalia aspera Ehrenberg, Beissel, p. 73, pl. 14, figs. 1–6.
Globigerina aequilateralis (not Brady), Chapman 1892, p. 517, pl. 15, fig. 14.
Globigerina aequilateralis (not Brady), Heron-Allen and Earland 1910, p. 424, pl. 8, figs. 11–12.
Globigerinella aspera (Ehrenberg), Brotzen 1936, p. 170, pl. 13, fig. 2.
Globigerinella aspera (Ehrenberg), Schijfsma 1946, pp. 94–96, pl. 6, fig. 8.
Globigerinella aspera (Ehrenberg), Bandy 1951, p. 508, pl. 75, fig. 3.
Globigerinella aspera (Ehrenberg), Belford 1960, p. 91, pl. 25, figs. 4–6.

Description. Test free, planispiral with slightly trochoid initial whorl, biumbilicate, semi-evolute, loosely coiled containing 2 to 3 whorls, periphery circular, lobulate; chambers globular; 5 to 6 chambers in final whorl rapidly and uniformly increasing in size; sutures distinct, radial, depressed, slightly curved; wall thin, calcareous, composed of laminae of radial calcite, finely perforate; surface hispid; primary aperture interiomarginal, equatorial, broad low arch extending back along both umbilical margins to the septum; distinct porticus borders entire aperture, often obscuring parts of earlier

ZONE	Sample \ Species	Globotruncana concavata	G. linneiana coronata	G. culverensis	Planomalina ehrenbergi	Globotruncana marginata	G. linneiana linneiana	G. cretacea	Planomalina rowei	P. aspera	G. linneiana tricarinata	G. fornicata	G. cf. ventricosa	Planomalina multispina	Schackoina cushmani	Globotruncana rosetta	G. rugosa	G. arca
Belemnitella mucronata	C10						R	A		A	C			F	C		A	C
	C11						R	F		R	R				R		R	
	C13						R	R		C	C			R			R	
	C14							R		C	R	R						
	C17						R	F		F	F	F			R		R	
	C18						R	C		F	C	R			R		R	
	C19					R	R	A		F	F	C						
O. pilula – A. quadratus undifferentiated	C21					R		F		C	C	C						
	C22					C	F	F		F	C	A	R			R		
	C23					A	R	A		C	C	A		R				
	C24					R	C	F		A	C	A		F		R		
	C25					F		R		F		R						
	C26					R		R		F								
	C27					C	F	A		C	C	A	R	R	?			
	C28					R	R	R		R	R	F						
	C29					F	R	A		C	R	F						
–?—?– Marsupites testudinarius	C31					R		R		R								
	C32							R		R								
	C33							R	R	R								
	C34					R	R	R		R								
Micraster cor-anguinum	C35						R	R		F								
	C38									R								
	C40			R	F	C	R	C	R	C								
	C42	R	F		C	F	F	R	C	A	R							
	C43		F	F		C	F	F	R	C	R							
	C44		C	F		C	R	F	R	R	R							
Micraster cor-testudinarium	C45	R	C	R		C	F	F	R	R								
	C46	R	A	C		A	F	C		R								
	C47		C	F	R	F	F	C	R									
	C48	F	C	F	R	C	F	C										
	C49		F	R	R	F		C										
	C50	R	C		R	C	R	A										

A = abundant C = common F = few R = rare

TEXT-FIG. 4. Distribution of Foraminifera.

whorls; umbilical portions of apertures of successive chambers remain open as relict apertures; average maximum diameter 0·38 mm.

Remarks. Specimens of *P. aspera* from the Isle of Wight have been compared to topotypic specimens of *Globigerinella messinae messinae* Brönnimann at the University of Basel, and the two species were found to be very similar. *P. aspera*, however, is less compressed than *P. messinae messinae* (Brönnimann) and usually has 6 chambers in the final whorl while *P. messinae messinae* most commonly contains 5 chambers in its last whorl. The equatorial aperture of *P. messinae messinae* is usually much higher than that of *P. aspera*. Rare variants of *P. aspera* possess low double extraumbilical apertures caused by the convergence of the final chamber with the earliest chamber of the last whorl. None of the examined specimens, however, contain extraumbilical apertures which are as high as those of *Globigerinella biforaminata* Hofker.

Occurrence. P. aspera occurs in abundance in the Culver Cliff section and ranges from sample C46 in the lower *Micraster cor-anguinum* Zone to sample C10, the uppermost sample in the *Belemnitella mucronata* Zone. There are numerous recorded occurrences of this species in Senonian rocks from many areas of the world.

Planomalina ehrenbergi sp. nov.

Plate 69, figs. 1*a*, *b*

Description. Test free, planispiral with slightly trochoid initial whorl, biumbilicate, semi-evolute, periphery nearly circular, weakly lobulate, loosely coiled containing approximately 2½ whorls; chambers globular to subglobular; final whorl contains 7 or 8 chambers; sutures radial, distinct, depressed, slightly curved; wall calcareous, thin, finely perforate; surface finely hispid; aperture interiomarginal, equatorial, a low arch extending back along both umbilical margins to the septum; thin porticus borders entire aperture and partially covers shallow umbilici; umbilical portion of apertures of successive chambers remain open as relict apertures.

Dimensions of holotype. Maximum diameter of holotype 0·27 mm.; maximum thickness 0·10 mm.

Remarks. Planomalina ehrenbergi has more chambers, is more compressed, not as lobulate, and not as coarsely hispid as the much more common *P. aspera*. *P. ehrenbergi* is more compressed and more nearly evolute than *P. aissana* (Sigal). The sutures of *P. ehrenbergi* are radial while those of *P. aissana* appear to be oblique.

Occurrence. P. ehrenbergi is fairly rare and is restricted to the *Micraster cor-testudinarium* and *Micraster cor-anguinum* Zones on the Isle of Wight.

Planomalina multispina (Lalicker)

Plate 69, figs. 5*a*, *b*

Biglobigerinella multispina Lalicker 1948, p. 624, pl. 92, figs. 1–3.
Biglobigerinella multispina Lalicker; Bolli, Loeblich, and Tappan 1957, p. 25, pl. 1, figs. 11–12.

Description. Test free, planispiral with slightly trochoid initial whorl, biumbilicate, semi-evolute, loosely coiled containing approximately 3 whorls, periphery circular, lobulate; early chambers inflated, globular, final 1 to 3 chambers become broadly flattened and finally replaced by two paired globular chambers, one on each side of plane of coiling, 7 to 10 chambers in final whorl; sutures distinct, radial, slightly curved, depressed; wall calcareous perforate; surface hispid; primary apertures in final stage paired extraumbilical at base of each paired chamber, apertures extend back along both umbilical margins to septum, umbilical portions of apertures of successive chambers appear to remain open as relict apertures; portici poorly preserved; average maximum diameter 0·42 mm.

Remarks. Banner and Blow (1959, p. 9), in their classification of the superfamily *Globigerinaceae* (Carpenter), regard the genus *Biglobigerinella* Lalicker as a junior synonym of the genus *Globigerinelloides* Cushman and ten Dam, and have lowered the rank of *Globigerinelloides* to a subgeneric level. They place the subgenus *Globigerinelloides* within the genus *Planomalina* Loeblich and Tappan. In the present study, however, the taxon subgenus has not been used.

Planomalina multispina (Lalicker), the type species of *Biglobigerinella*, grades imperceptibly into *Planomalina aspera* (Ehrenberg) and may represent a late ontogenetic stage of *P. aspera*. These two forms are regarded as separate species in this study, however, as they appear to have different stratigraphic ranges on the Isle of Wight.

Occurrence. P. multispina is restricted to samples from the *Belemnitella mucronata* Zone and the *Actinocamax quadratus* Zone (s.l.) at Culver Cliff. The holotype of *P. multispina* is from the Campanian of Arkansas.

Planomalina rowei sp. nov.

Plate 69, figs. 2*a*, *b*

Description. Test free, planispiral with slightly trochoid initial whorl, biumbilicate, semi-evolute, loosely coiled containing approximately 2 whorls; periphery somewhat rect-

EXPLANATION OF PLATE 69

Photographs retouched by author.

Fig. 1. *Planomalina ehrenbergi* sp. nov., holotype, ×125. 1*a*, side view; 1*b*, edge view. *M. cor-anguinum* Zone, sample C42, P44608.

Fig. 2. *P. rowei* sp. nov., holotype, ×125. 2*a*, side view; 2*b*, edge view. *M. cor-anguinum* Zone, sample C42, P44609.

Fig. 3. *Schackoina cushmani* sp. nov., paratype, ×125. Side view; *B. mucronata* Zone, sample C10, P44625.

Fig. 4. *Planomalina aspera* (Ehrenberg), ×125. 4*a*, side view; 4*b*, edge view. *M. cor-anguinum* Zone, sample C42, P44612.

Fig. 5. *P. multispina* (Lalicker), ×88. 5*a*, side view; 5*b*, edge view. *A. quadratus* Zone (s.l.), sample C24, P44626.

Fig. 6. *Globotruncana fornicata* Plummer, ×72. 6*a*, dorsal view; 6*b*, side view; 6*c*, ventral view. *A. quadratus* Zone (s.l.), sample C24, P44623.

Fig. 7. *G. linneiana linneiana* (d'Orbigny), ×72. 7*a*, dorsal view; 7*b*, side view; 7*c*, ventral view. *A. quadratus* Zone (s.l.), sample C27.

Fig. 8. *G. arca* (Cushman), ×72. 8*a*, dorsal view; 8*b*, side view; 8*c*, ventral view. *B. mucronata* Zone, sample C10, P44621.

Fig. 9. *G. cretacea* (d'Orbigny), ×72. 9*a*, dorsal view; 9*b*, side view; 9*c*, ventral view. *B. mucronata* Zone, sample C10, P44619.

angular, lobulate; chambers subglobular to globular, final chamber radially elongate; final whorl contains 4½ to 5 chambers; sutures distinct, radial, depressed, very slightly curved; wall calcareous, thin, finely perforate; surface finely hispid; umbilici shallow; aperture interiomarginal, equatorial, broad low arch extending back along both umbilical margins to the septum; porticus distinct, thin, borders entire aperture; umbilical portions of apertures of successive chambers remain open as relict apertures.

Dimensions of holotype. Maximum diameter of holotype 0·25 mm.; maximum thickness 0·11 mm.

Remarks. *Planomalina rowei* is distinguished from *P. aspera* (Ehrenberg) by its smaller size, fewer chambers, and its peripheral outline, which, due to the elongate final chamber, is somewhat rectangular, whereas in *P. aspera* it is circular or subcircular. *P. rowei* is smaller and less compressed than *P. messinae subcarinata* (Brönnimann), although they appear to have similar peripheral outlines.

Occurrence. *P. rowei* occurs commonly in the *Micraster cor-anguinum* Zone and is very rare in the *Marsupites testudinarius* Zone on the Isle of Wight.

Genus SCHACKOINA Thalmann 1932
Schackoina cushmani sp. nov.

Plate 69, fig. 3; text-figs. 5*a–h*

Description. Test free, nearly planispiral, loosely coiled, semi-evolute, biumbilicate; early chambers globular, radially elongate; final 1 or 2 chambers bulbous, almost polyhedral, 3 chambers in final whorl; 5 to 6 tubulospines from final whorl; earliest chamber of final whorl has 1 tubulospine, located in the median plane; second chamber has either 1 tubulospine located in the median plane or 2 tubulospines arranged on both sides of median plane; final chamber usually has 3 tubulospines, 1 located posteriorly in the median plane and the other 2 further forward on both sides of the median plane; sutures depressed, oblique, slightly curved; wall calcareous, thin, finely perforate; surface smooth; primary aperture interiomarginal, equatorial, a broad low arch; lip distinct, thin, borders entire aperture covering much of umbilici; umbilical portions of apertures of successive chambers appear to remain open as relict apertures; umbilici small, shallow.

Dimensions of holotype. Maximum diameter (excluding tubulospines) of holotype 0·22 mm.; thickness of umbilicus 0·05 mm.; thickness of final chamber 0·13 mm.

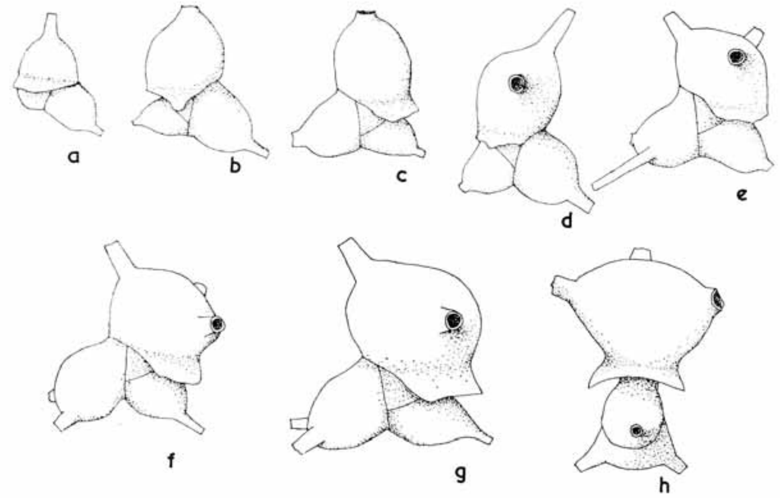
Remarks. *Schackoina cushmani* is morphologically similar to *S. multispinata* (Cushman and Wickenden) and may be closely related. *S. cushmani* differs from *S. multispinata*, however, in the following characters:

1. *S. cushmani* has a maximum development of 6 tubulospines from the final whorl compared to 7 tubulospines from the final whorl of the holotype of *S. multispinata*, and, furthermore, some specimens of *S. multispinata* have as many as 5 tubulospines from one chamber. Over 50 specimens of *S. cushmani* have been examined and only 1 specimen had over 6 tubulospines. This specimen had an extra tubulospine of

considerably smaller diameter which had penetrated the final chamber from an earlier whorl.

2. *S. cushmani* has a much larger and more prominent lip.
3. *S. multispinata* appears to be more involute (see Cushman and Wickenden 1930, pl. 6) than *S. cushmani*.

Young forms of *S. cushmani* somewhat resemble mature specimens of *S. trituberculata* (Morrow). Adult specimens of *S. cushmani*, however, have larger, more polyhedral,



TEXT-FIG. 5. *Schackoina cushmani* sp. nov. 5*a–f*, ontogenetic series of paratypes, P44624; 5*g*, side view of holotype, P44618; 5*h*, edge view of holotype. All illustrations are camera lucida drawings, ×160. All specimens from sample C10 from the *Belemnitella mucronata* Zone.

final chambers. The holotype of *S. trituberculata* has 4 chambers in the final whorl while the final whorl of all examined specimens of *S. cushmani* contained only 3 chambers. *S. tappanae* Montanaro Gallitelli is similar to young specimens of *S. cushmani* and may represent an ancestral species. Adult specimens of *S. cushmani* are distinct, however, in having much more bulbous, nearly polyhedral, final chambers and by having 3 tubulospines on the final chamber.

Occurrence. *Schackoina cushmani* appears to be restricted to the *Belemnitella mucronata* Zone; however, two immature specimens of *Schackoina* were found in sample C27 from the *Actinocamax quadratus* Zone (s.l.) which may represent young forms of *S. cushmani* or a closely related species. This is the first recorded occurrence of the genus *Schackoina* from the British Isles.

Family GLOBOTRUNCANIDAE Brotzen 1942
Genus GLOBOTRUNCANA Cushman 1927
Globotruncana arca (Cushman)

Plate 69, figs. 8*a–c*

Pulvinulina arca Cushman 1926, p. 23, pl. 3, figs. 1*a–c*.
Globotruncana arca (Cushman), Cushman 1927, p. 91, pl. 19, fig. 11.
Globotruncana arca (Cushman), Cushman 1927*a*, p. 169, pl. 28, figs. 28*a–c*.
Globotruncana arca (Cushman), Cushman and Todd 1943, p. 71, pl. 12, fig. 11.
Globotruncana arca (Cushman), Cushman 1946 (part), p. 150, pl. 62, figs. 4*a–c*.
Globotruncana arca (Cushman), Dalbiez 1955, text-figs. 5*a–c*.
Globotruncana arca (Cushman), Brönnimann and Brown 1956, pp. 539–40, pl. 23, figs. 10–12.
Globotruncana arca (Cushman), Edgell 1957, p. 110, pl. 1, figs. 10–12; pl. 3, figs. 4–6.
Globotruncana arca (Cushman), Bolli, Loeblich, and Tappan 1957, p. 44, pl. 11, figs. 6–11.

Description. Test free, low trochospiral, biconvex, evolute, umbilicate, $2\frac{1}{2}$ to 3 whorls, equatorial periphery nearly circular, lobulate with 2 well-developed, subparallel, beaded keels; dorsal keel diverges on to spiral side of test as dorsal sutural ridge; ventral keel diverges to umbilical side of terminal chamber face usually not coinciding precisely with ventral suture and then extends back along the umbilical margin as slightly raised ridge; chambers angular truncate, inflated ventrally, 6 to 8 chambers in final whorl uniformly increasing in size; dorsal sutures distinct, oblique, strongly curved, raised; ventral sutures distinct, nearly radial, slightly curved, depressed in late chambers, flush or raised in early portion of test; umbilicus moderately broad, deep, in well-preserved specimens covered by a complex tegillum with marginal accessory apertures; primary aperture interiomarginal, umbilical; wall calcareous, composed of radial calcite, perforate except for imperforate keels, peripheral area between keels, and tegilla; chamber surfaces weakly hispid; all 20 examined specimens coiled dextrally; average maximum diameter 0·52 mm.

Remarks. Specimens from the Isle of Wight are slightly less convex ventrally than the holotype of *G. arca*, and the keels may be more closely spaced. Nevertheless, these specimens appear to be within the range of variation of *G. arca*.

Occurrence. G. arca is rare in the samples studied from Culver Cliff, occurring only in the uppermost sample, C10, from the *Belemnitella mucronata* Zone. Two specimens similar to *G. arca* were found about 82 feet lower in the same zone in sample C17. These forms were less convex dorsally and their chambers were more elongate in the direction of coiling than *G. arca* (s.s.). The holotype of *G. arca* is from the upper portion of the Papagallos shale (Maestrichtian), San Luis Potosi, Mexico. Bolli (1957, p. 53) records *G. arca* in Trinidad from the Campanian and Lower Maestrichtian. Brönnimann and Brown (1956, p. 540) believe *G. arca* (s.s.) to be restricted to Maestrichtian strata. There are, however, numerous reported occurrences of this species from Campanian strata from many parts of the world.

Globotruncana cretacea (d'Orbigny)

Plate 69, figs. 9*a–c*; Plate 72, fig. 6

Globigerina cretacea d'Orbigny 1840, p. 34, pl. 3, figs. 12–14.
Globigerina cretacea d'Orbigny var. *saratogaensis* Applin, in Applin, Ellisor, and Kniker 1925, p. 98, pl. 3, figs. 8*a–c*.

Globotruncana globigerinoides Brotzen 1936, p. 177, pl. 12, figs. 3*a–c*; pl. 13, fig. 3.
Rosalinella globigerinoides (Brotzen), Schijfsma 1946, p. 96, pl. 7, figs. 9*a–c*.
Globotruncana saratogaensis (Applin), Brönnimann and Brown 1956, pp. 544–5, pl. 21, figs. 1–3.
Globigerina cretacea d'Orbigny; Banner and Blow 1960, pp. 8–10, pl. 7, figs. 1*a–c*.

Description. Test free, low trochospiral, slightly biconvex, evolute, umbilicate, 2½ to 3 whorls, equatorial periphery nearly circular, lobulate with 2 weakly developed keels, often indistinct on late chambers; chambers inflated, globular, slightly elongate in direction of growth, 5 to 6 chambers in final whorl uniformly increasing in size; sutures distinct, depressed, nearly radial, slightly oblique in late chambers; umbilicus broad, deep, in well-preserved specimens covered by a complex tegillum with accessory apertures; primary aperture interiomarginal, umbilical; surface of first two whorls coarsely hispid, surface of final 2 or 3 chambers finely hispid; coiling predominantly dextral; 91 of 100 specimens selected randomly coiled dextrally; average maximum diameter 0·46 mm.

Remarks. The test wall of *G. cretacea* is thinner than that of any other species of *Globotruncana* in this study and consists of numerous laminae of calcite. This species appears to be especially susceptible to recrystallization. Although the test wall of a few of the examined specimens shows a poorly preserved radial arrangement of calcite crystals, most specimens exhibit a finely granular wall structure which is undoubtedly the result of diagenetic change. The peripheral portion of the test wall between the keels appears to be imperforate or, at least, less perforate than the remainder of the test wall. The keels are usually not discernible in thin section. It is suggested that *G. cretacea* may be a transition species between the genera *Globotruncana* and *Rugoglobigerina*.

In the original description of *Globigerina cretacea*, d'Orbigny (1840) does not mention the presence of keels or tegilla. Banner and Blow (1960, p. 8) re-examined d'Orbigny's material from the Lower Campanian White Chalk of St. Germain, near Paris, and designated a lectotype of *G. cretacea* from a syntypic series. The lectotype possesses two broadly spaced but weakly developed keels, and it is suggested, considering the optical instruments available in 1840, that d'Orbigny overlooked this faintly defined feature. Other specimens from d'Orbigny's collections which were 'clearly conspecific with the lectotype' possessed well-preserved tegilla. The presence of keels and tegilla indicates that this species should be placed in the genus *Globotruncana* Cushman.

Brotzen (1936, p. 177) regarded *Globotruncana globigerinoides* morphologically similar to *Globigerina cretacea*, but because *G. globigerinoides* possessed a weakly developed double keel these two species were considered distinct. Banner and Blow's observation of a weak double keel on d'Orbigny's specimens of *Globigerina cretacea* indicates that these two species are probably conspecific.

Specimens from this current study have been compared to specimens of *Globigerina cretacea* in the collections of Alcide d'Orbigny in the Muséum National de l'Histoire Naturelle, Paris, France, and were found to be conspecific.

Occurrence. Banner and Blow (op. cit., p. 10) state: 'With the evidence available to us we consider that *Globotruncana cretacea* (d'Orbigny) is limited in range from the Coniacian to Campanian, with the possibility of its occurrence in the highest Turonian. It is also possible that typical forms with the weak carinae do not occur above the

Lower Campanian.' This species occurs commonly throughout the studied Culver Cliff section, the uppermost part of which is Upper Campanian in age.

Globotruncana concavata (Brotzen)

Plate 71, figs. 4*a–c*

Rotalia concavata Brotzen 1934, p. 66, pl. 3, fig. *b*.
Globorotalia asymetrica Sigal 1952, p. 35, fig. 35.
Globotruncana (*Globotruncana*) *ventricosa ventricosa* (not White), Dalbiez 1955, p. 168, text-figs. 7*a–d*.
Globotruncana concavata (Brotzen), Bolli 1957, p. 57, pl. 13, figs. 3*a–c*.

Description. Test free, very low trochospiral, dorsal side flat to slightly concave, ventral side strongly convex, evolute, umbilicate, $2\frac{1}{2}$ to 3 whorls, equatorial periphery nearly circular, weakly lobulate, with 2 well-developed, very closely spaced, finely beaded keels; dorsal keel diverges on to spiral side of test as slightly raised sutural ridge; ventral keel diverges to umbilical side of terminal chamber face usually not coinciding precisely with ventral suture and usually not completely visible on ventral side of test because of slightly embracing nature of chambers, ventral keel then extends back along umbilical margin as an indistinct weakly raised ridge; chambers hemispherical, 5 to 6 chambers in final whorl uniformly increasing in size; dorsal sutures distinct, oblique, strongly curved, slightly raised, finely beaded; ventral sutures distinct, radial, depressed; umbilicus moderately broad, deep, in well-preserved specimens covered by a complex tegillum with marginal accessory apertures; primary aperture interiomarginal, umbilical; wall calcareous, composed of radial calcite, perforate except for imperforate keels, peripheral area between keels, and tegilla; dorsal surface weakly hispid to smooth; ventral surface coarsely hispid becoming less hispid with growth; all of limited number of specimens coiled dextrally; approximate diameter 0·58 mm.

Remarks. *G. concavata* is quite similar to *Globotruncana ventricosa* White in general appearance. Bolli (1957, p. 57, pl. 13, figs. 3 *a–c*, 4*a–c*) has examined topotype specimens of both species and offers a pertinent discussion and excellent illustrations of *G. concavata* and *G. ventricosa*. *G. concavata* is usually flat to concave dorsally while the dorsal side of *G. ventricosa* is flat to slightly convex. The dorsal sutures of *G. ventricosa* are much more strongly raised and thicker than those of *G. concavata*.

Occurrence. *G. concavata* is rare and is restricted in the samples studied to the *Micraster cor-anguinum* and *Micraster cor-testudinarium* Zones. This occurrence agrees well with that reported by Bolli (loc. cit.) who states, '*Globotruncana concavata* appears to be restricted to the upper part of the Coniacian and Lower Santonian, . . .'.

Globotruncana culverensis sp. nov.

Plate 71, figs. 1*a–c*

Description. Test free, low trochospiral, slightly biconvex, evolute, umbilicate, 3 to $3\frac{1}{2}$ whorls, equatorial periphery nearly circular, lobulate with 2 fairly well-developed, closely spaced, finely beaded keels which often merge into single keel on final 1 to 4 chambers; dorsal keel extends on to spiral side of test as slightly raised sutural ridge;

ventral keel diverges on to umbilical side of test and is often obscured by embracing nature of chambers, then extends back along umbilical margin as a slightly raised ridge; chambers inflated, slightly truncate, slightly elongate in direction of coiling, overlapping, 7 to 8 chambers in final whorl uniformly increasing in size, often added in slightly oblique position; sutures distinct, depressed, nearly radial; umbilicus broad, deep, in well-preserved specimens covered by a complex tegillum with marginal accessory apertures; primary aperture interiomarginal, umbilical; wall calcareous, composed of radial calcite, uniformly perforate except for imperforate keels, peripheral area between keels, and tegilla; surface hispid becoming less hispid with growth; coiling predominantly dextral; 29 of 30 specimens selected at random coiled dextrally.

Dimensions of holotype. Maximum diameter of holotype 0·74 mm.; maximum thickness 0·27 mm.

Remarks. Immature specimens of *G. culverensis* are almost identical to more mature specimens of *G. marginata* (Reuss) and there is a gradation of forms between these two species. Mature specimens of *G. culverensis* are quite distinct, however, having 7 or 8 chambers and being much larger than *G. marginata* which usually has 5 or 6 chambers. *G. marginata* has a double keel on the periphery of all of its chambers while the double keel of *G. culverensis* usually merges into a single dichotomous keel on the periphery of the final 1 to 4 chambers. These two species have different stratigraphic ranges, and although the true lower limits of the stratigraphic ranges of both species are not known from this study, it is suggested that *G. culverensis* was derived from *G. marginata*.

Occurrence. In the studied samples *G. culverensis* is restricted to the *Micraster cor-anguinum* and *Micraster cor-testudinarium* Zones while *G. marginata* ranges into the *Belemnitella mucronata* Zone.

Globotruncana fornicata Plummer

Plate 69, figs. 6*a–c*; Plate 72, figs. 1, 2

Globotruncana fornicata Plummer 1931, p. 198, pl. 13, figs. 4*a–c*, 5, 6.
Globotruncana fornicata Plummer, Sandidge 1932, p. 285, pl. 44, figs. 12–13.
Globotruncana fornicata Plummer, Cushman and Hedberg 1941, p. 99, pl. 23, figs. 18*a–c*.
Globotruncana fornicata Plummer, Cushman and Deaderick 1944, p. 340, pl. 53, figs. 28*a–b*.
Globotruncana fornicata Plummer, Cushman 1946, p. 149, pl. 61, figs. 19*a–c*.
Globotruncana fornicata Plummer, Cita 1948, p. 153, pl. 3, figs. 8*a–c*.
Globotruncana fornicata Plummer, Hagn 1953, p. 98, pl. 8, figs. 8*a–c*; text-figs. 22, 23.
Globotruncana fornicata Plummer, Frizzell 1954, p. 129, pl. 20, figs. 26*a–c*.
Globotruncana fornicata Plummer, Brönnimann and Brown 1956, pp. 542–4, pl. 21, figs. 7, 14, 15.
Globotruncana fornicata Plummer, Edgell 1957, p. 112, pl. 3, figs. 10–12.

Description. Test free, low to moderately high trochospiral, dorsal side convex, ventral side flat to slightly convex, evolute, umbilicate, $2\frac{1}{2}$ to 3 whorls; equatorial periphery circular, slightly lobulate with 2 well-developed, finely beaded keels, closely spaced and slightly diverging anteriorly, keels on early portion of chamber more closely spaced than on late portion of preceding chamber producing a 'cone in cone' arrangement, but, in general, becoming progressively more closely spaced with growth; dorsal keel extends on to spiral side of test as sutural ridge; ventral keel diverges to umbilical side of terminal chamber face forming sutural ridge and then extends back along umbilical margin as a slightly raised ridge; chambers angular truncate, strongly curved, elongate in direction of growth, 4½ to 6 chambers in final whorl, somewhat irregularly increasing in size; sutures distinct, oblique, strongly curved, raised, beaded; umbilicus broad, deep, in well-preserved specimens covered by a complex tegillum with marginal accessory apertures; primary aperture interiomarginal, umbilical; wall calcareous, composed of radial calcite, uniformly perforate except for imperforate keels, peripheral area between keels, and tegilla; surface weakly hispid; coiling predominantly dextral; 220 of 226 specimens selected at random coiled dextrally; average maximum diameter 0·54 mm.

Remarks. Globotruncana fornicata exhibits considerable variation. Many specimens are higher spired dorsally than Plummer's figured holotype, but none is as high spired as the possibly related *Globotruncana contusa* Cushman. The 'cone in cone' arrangement of the keels and the broadly curved chambers of *G. fornicata* clearly distinguish this species from most other double keeled *Globotruncana*.

Occurrence. This species, although in abundance, appears to be restricted on the Isle of Wight to the *Actinocamax quadratus* Zone (s.l.) and the lower part of the *Belemnitella mucronata* Zone. The holotype of *G. fornicata* is from the Upper Taylor formation (L. Campanian ?) of south-eastern Texas. Bolli (1957, p. 53) lists the range of *G. fornicata* in Trinidad as Santonian to possibly Lower Maestrichtian. Cita (1948, p. 153) records the range of this species in Italy as Santonian to Maestrichtian.

Globotruncana linneiana linneiana (d'Orbigny)

Plate 69, figs. 7*a–c*; Plate 72, fig. 5

Rosalina linneiana d'Orbigny 1839, p. 101, pl. 5, figs. 10–12.
Rosalina linnei d'Orbigny, type 1, de Lapparent 1918, p. 4, figs. *a*, *c*.
Globotruncana lapparenti Brotzen 1936, p. 175.
Globotruncana linnei (d'Orbigny), Renz 1936, pl. 6, figs. 32–34.
Globotruncana linnei (d'Orbigny), Gandolfi 1942, pp. 125–30, pl. 3, fig. 3; pl. 4, figs. 18, 32, 33.
Globotruncana linnei typica Vogler 1941, p. 286, pl. 23, figs. 12–21.
Globotruncana lapparenti lapparenti Brotzen, Bolli 1945, p. 230, pl. 9, fig. 11; text-fig. 1, nos. 15–16.
Globotruncana canaliculata (Reuss), Cushman 1946 (part), p. 149, pl. 61, figs. 17*a–c*.
Globotruncana lapparenti lapparenti Brotzen, Cita 1948, pp. 155–6, pl. 4, figs. 2*a–c*.
Globotruncana lapparenti Brotzen, Reichel 1950, p. 613, pl. 16, fig. 9; pl. 17, fig. 9.
Globotruncana lapparenti lapparenti Brotzen, Hagn 1953, p. 96, pl. 8, fig. 12; text-figs. 16–17.
Globotruncana lapparenti lapparenti Brotzen, Hagn and Zeil 1954, pp. 39–42, pl. 3, fig. 3; pl. 6, figs. 5, 8.
Globotruncana linneiana (d'Orbigny), Brönnimann and Brown 1956, pp. 540–2, pl. 20, figs. 13–17; pl. 21, figs. 16–18.
Globotruncana lapparenti lapparenti Brotzen, Edgell 1957, p. 113, pl. 1, figs. 7–9.

Description. Test free, very low trochospiral, both sides flat to slightly convex, evolute, umbilicate, 3 to 3½ whorls; equatorial periphery circular, slightly lobulate with 2 well-developed, broadly spaced, subparallel, beaded keels; dorsal keel diverges slightly to dorsal side extending on to spiral surface of test as dorsal sutural ridge; ventral keel diverges to umbilical side of terminal chamber face forming ventral sutural ridge and then extends back along umbilical margin as a slightly raised ridge; chambers slightly angular truncate, 6 to 6½ chambers in final whorl uniformly increasing in size; dorsal sutures distinct, oblique, strongly curved, raised, beaded; ventral sutures distinct, slightly oblique, curved, slightly raised, beaded; umbilicus broad, deep, in well-preserved specimens covered by a complex tegillum with marginal accessory apertures; primary aperture interiomarginal, umbilical; wall calcareous, composed of radial calcite, uniformly perforate except for imperforate keels, peripheral area between keels, and tegilla; chamber surfaces weakly hispid; coiling predominantly dextral; 59 of 60 specimens selected at random coiled dextrally; average maximum diameter 0·50 mm.

Remarks. Bolli (1951, p. 191) discussed the taxonomic problems of this group of *Globotruncanae*. He suggested, although it is possible that the poorly known species *Rosalina canaliculata* Reuss 1854 and *R. marginata* Reuss 1845 may be synonymous with *R. linneiana* d'Orbigny 1839, that for the purpose of convenience and simplification until the taxonomic problems regarding these species are clarified all double-keeled specimens which fulfil the general requirements of this group be regarded as subspecies of *Globotruncana lapparenti* Brotzen.

Brönnimann and Brown (1956, pp. 540–2) have proposed a neotype for *Rosalina linneiana* d'Orbigny from topotypic material. They tentatively regard *R. linneiana* as conspecific with *R. canaliculata*, and treat *Globotruncana lapparenti* as a distinct species. They consider *R. linneiana* more compressed ventrally than *G. lapparenti*. The present author, however, considers *R. linneiana* conspecific with *G. lapparenti lapparenti* Brotzen emend. Bolli which is one of the more ventrally compressed subspecies of the '*lapparenti*' group. *G. lapparenti* is, therefore, a junior synonym of *R. linneiana*, and the subspecies of *G. lapparenti* should be considered subspecies of *R. linneiana*.

Occurrence. Globotruncana linneiana linneiana occurs commonly throughout the studied Culver Cliff section. Bolli's (1945, p. 230) specimens of *G. lapparenti lapparenti* (= *G. linneiana linneiana*) from Switzerland range from the Turonian to the Campanian. Bolli (1957, p. 53) indicates on his range chart that *G. lapparenti lapparenti* is restricted in Trinidad to Santonian and Campanian strata.

Globotruncana linneiana coronata Bolli

Plate 70, figs. 1*a–c*; Plate 72, figs. 3, 4

Rosalina linnei d'Orbigny, type 4 de Lapparent 1918, p. 4, fig. 1*g*.
Globotruncana lapparenti coronata Bolli 1945, p. 233, pl. 9, figs. 14–15; text-fig. 1, nos. 21–22.
Globotruncana lapparenti coronata Bolli, Cita 1948, p. 156, pl. 4, fig. 3.
Globotruncana lapparenti coronata Bolli, Mornod 1950, pp. 591–2, text-figs. 13*a–d*.

EXPLANATION OF PLATE 70

All illustrations ×72. Photographs retouched by author.

Fig. 1. *Globotruncana linneiana coronata* Bolli. 1*a*, dorsal view; 1*b*, side view; 1*c*, ventral view. *M. cor-anguinum* Zone, sample C47, P44607.

Fig. 2. *G. linneiana tricarinata* (Quereau). 2*a*, dorsal view; 2*b*, side view; 2*c*, ventral view. *B. mucronata* Zone, sample C10, P44606.

Fig. 3. *G. marginata* (Reuss). 3*a*, dorsal view; 3*b*, side view; 3*c*, ventral view. *A. quadratus* Zone (s.l.), sample C24, P44622.

Fig. 4. *G. rosetta* (Carsey). 4*a*, dorsal view; 4*b*, side view; 4*c*, ventral view. *A. quadratus* Zone (s.l.), sample C22, P44617.

Globotruncana lapparenti coronata Bolli, Hagn and Zeil 1954, pp. 43–44, pl. 3, fig. 4; pl. 7, figs. 1–3.

Description. Test free, very low trochospiral, dorsal side slightly convex to flat, ventral side moderately to slightly convex, evolute, umbilicate, 3 to 3½ whorls; equatorial periphery circular, slightly lobulate with 2 well-developed, subparallel, beaded keels, broadly spaced on early chambers, more closely spaced on final chambers; dorsal keel extends on to spiral surface of test as dorsal sutural ridge; ventral keel diverges to umbilical side of terminal chamber face forming ventral sutural ridge and then extends back along the umbilical margin as a slightly raised ridge; chambers angular truncate, 6 to 9 chambers in final whorl, uniformly and rapidly increasing in size; dorsal sutures distinct, oblique, strongly curved, raised, beaded; ventral sutures distinct, slightly oblique, curved, raised, beaded; umbilicus broad, deep, in well-preserved specimens covered by a complex tegillum with marginal accessory apertures; primary aperture interiomarginal, umbilical; wall calcareous, composed of radial calcite, uniformly perforate except for imperforate keels, peripheral area between keels, and tegilla; chamber surfaces weakly hispid; coiling predominantly dextral; 88 randomly selected specimens were all coiled dextrally; average maximum diameter 0·64 mm.

Remarks. *G. linneiana coronata* is larger and usually has more chambers than *G. linneiana linneiana* or *G. linneiana tricarinata*. The double keels of *G. linneiana coronata* are usually more closely spaced than those of the other two subspecies, and the chambers are more compressed ventrally than those of *G. linneiana tricarinata*.

Occurrence. *G. linneiana coronata*, although in abundance, is restricted in the samples studied to the *Micraster cor-anguinum* and *Micraster cor-testudinarium* Zones. Bolli's (1945) specimens of this subspecies from Switzerland were from Turonian, Coniacian, and Santonian beds. Cita (1948, p. 156) reports the range for *G. lapparenti coronata* in Italy as Turonian to Santonian.

Globotruncana linneiana tricarinata (Quereau)

Plate 70, figs. 2*a–c*

Pulvinulina tricarinata Quereau 1893, pl. 5, fig. 3*a*.
Rosalina linnei (d'Orbigny), type 2 de Lapparent 1918, p. 4, figs. 1*b*, *d*, *e*, *f*; p. 5, figs. 2*d*, *n*.
Globotruncana linnei (d'Orbigny), Renz 1936 (part), p. 19, pl. 6, figs. 28–30; pl. 8, fig. 7.
Globotruncana linnei tricarinata (Quereau), Vogler 1941, pl. 23, figs. 22–31.
Globotruncana lapparenti tricarinata (Quereau), Bolli 1945, pp. 232–3, pl. 9, fig. 13; text-fig. 1, nos. 19, 20.
Globotruncana canaliculata (Reuss), Cushman 1946 (part), p. 149, pl. 61, figs. 18*a–c*.
Globotruncana lapparenti tricarinata (Quereau), Cita 1948, pp. 157–8, pl. 4, figs. 4*a–c*.
Globotruncana lapparenti tricarinata (Quereau), Hagn and Zeil 1954, pp. 42–43, pl. 6, figs. 6–7.

Description. Test free, very low trochospiral, dorsal side slightly convex to flat, ventral side moderately to slightly convex, evolute, umbilicate, 3 to 3½ whorls; equatorial periphery circular, lobulate with 2 well-developed, broadly spaced, subparallel, beaded keels; dorsal keel diverges slightly to dorsal side extending on to spiral surface of test as dorsal sutural ridge; ventral keel diverges to umbilical side of terminal chamber face forming ventral sutural ridge and then extends back along umbilical margin as a slightly raised ridge; chambers angular truncate, ventrally inflated, 6 chambers in final whorl uniformly increasing in size; dorsal sutures distinct, oblique, strongly curved, raised, beaded; ventral sutures distinct, slightly oblique, curved, flush to slightly raised, beaded; umbilicus broad, deep, in well-preserved specimens covered by a complex tegillum with marginal accessory apertures; primary aperture interiomarginal, umbilical; wall calcareous, composed of radial calcite, uniformly perforate except for imperforate keels, peripheral area between keels, and tegilla; chamber surfaces weakly hispid; coiling predominantly dextral; 140 of 142 specimens selected at random coiled dextrally; average maximum diameter 0·54 mm.

Remarks. G. linneiana tricarinata differs from *G. linneiana linneiana* in being ventrally more convex. The chambers of *G. linneiana tricarinata* are ventrally inflated while the chambers of *G. linneiana linneiana* are more compressed.

Occurrence. This subspecies is very rare in the *Micraster cor-anguinum* Zone and occurs commonly in the *Actinocamax quadratus* Zone (s.l.) and the *Belemnitella mucronata* Zone at Culver Cliff. Bolli (1945) records the range of *G. lapparenti tricarinata* (= *G. linneiana tricarinata*) in Switzerland as Turonian to Maestrichtian, and Cita (1948, p. 157) also reports a Turonian to Maestrichtian range for *G. lapparenti tricarinata* in Italy. Bolli (1957, p. 53), however, lists on a range chart a more restricted range of Campanian to L. Maestrichtian for *G. lapparenti tricarinata* in Trinidad.

Globotruncana marginata (Reuss)

Plate 70, figs. 3*a–c*; Plate 72, figs. 7, 8*a–c*

Rosalina marginata Reuss 1845, p. 36, pl. 13, fig. 68.
Rosalina marginata Reuss, Reuss 1854, p. 59, pl. 26, fig. 1.
Globigerina marginata (Reuss), Loetterle 1937, pp. 44–45, pl. 7, fig. 3.
Globotruncana linnei bulloides Vogler 1941, p. 287, pl. 23, figs. 32–39.
Globotruncana lapparenti bulloides Vogler, Bolli 1945, pp. 231–2, text-fig. 1 (17–18); pl. 19, fig. 12.
Rosalinella marginata (Reuss), Schijfsma 1946, p. 97, pl. 7, figs. 10*a–c*.
Globotruncana marginata (Reuss), Cushman 1946, p. 150, pl. 62, figs. 1–2.
Globotruncana marginata (Reuss), Hagn 1953, p. 93, pl. 8, fig. 10; text-figs. 10, 11.
Globotruncana marginata (Reuss), Hagn and Zeil 1954, pp. 46–47, pl. 2, fig. 4; pl. 7, figs. 5, 6.
Globotruncana marginata (Reuss), Frizzell 1954, p. 129, pl. 20, fig. 24.
Globotruncana marginata (Reuss), Edgell 1957, p. 114, pl. 2, figs. 4–6.

Description. Test free, very low trochospiral, slightly biconvex, evolute, umbilicate, 2½ to 3 whorls, equatorial periphery nearly circular, lobulate, with 2 weakly to fairly well-developed, closely spaced, finely beaded, keels; dorsal keel diverges obliquely on

EXPLANATION OF PLATE 71

All illustrations ×72. Photographs retouched by author.

Fig. 1. *Globotruncana culverensis* sp. nov., holotype. 1*a*, dorsal view; 1*b*, side view; 1*c*, ventral view. *M. cor-anguinum* Zone, sample C46, P44602.

Fig. 2. *G.* cf. *ventricosa* White. 2*a*, dorsal view; 2*b*, side view; 2*c*, ventral view. *A. quadratus* Zone (s.l.), sample C27, P44616.

Fig. 3. *G. rugosa* (Marie). 3*a*, dorsal view; 3*b*, side view; 3*c*, ventral view. *B. mucronata* Zone, sample C10.

Fig. 4. *G. concavata* (Brotzen). 4*a*, dorsal view; 4*b*, side view; 4*c*, ventral view. *M. cor-anguinum* Zone, sample C42, P44615.

to spiral side of test forming a sutural ridge in early portion of test, on later chambers dorsal keel does not always coincide precisely with dorsal sutures; ventral keel, sometimes more weakly developed than dorsal keel, diverges to umbilical side of terminal chamber face commonly coinciding with ventral sutures of early chambers, on later chambers ventral keel usually does not coincide precisely with ventral sutures and often ventral keel is not completely visible on the umbilical side of test because of embracing nature of chambers, ventral keel extends back along umbilical margin as a slightly raised, indistinct ridge; chambers inflated, slightly truncate, elongate in direction of coiling, overlapping, 5 to 6 chambers in final whorl uniformly increasing in size, chambers often added in slightly oblique position; sutures of late chambers distinct, slightly oblique, curved, usually depressed, rarely raised; sutures on early chambers distinct, slightly oblique, curved, slightly raised or flush, finely beaded; umbilicus broad, deep, in well-preserved specimens covered by a complex tegillum with marginal accessory apertures; primary aperture interiomarginal, umbilical; wall calcareous, composed of radial calcite, uniformly perforate except for imperforate keels, peripheral area between keels, and tegilla; surface weakly hispid; coiling predominantly dextral; 185 of 190 specimens selected at random coiled dextrally; average maximum diameter 0·54 mm.

Remarks. Because of the inadequacy of Reuss's original description and illustration, there has been much confusion as to the nature of *G. marginata*. Bolli *et al.* (1957, p. 46) have discussed some of the problems arising from the poorly known type and have designated a specimen originally illustrated by Reuss (1845, pl. 13, fig. 68) which most closely corresponds to the original written description as the lectotype. The illustration of the designated lectotype, however, is very small and does not show the morphology necessary to recognize the species. Cushman (1946, p. 150), after examining specimens of *G. marginata* from the collections of Reuss in Dresden, Vienna, and Cambridge, reported that they were all in agreement and figures (op. cit., pl. 62, figs. 1*a–c*) a specimen of *G. marginata* from Reuss's Cambridge collection.

Occurrence. *G. marginata* is fairly abundant in the studied samples from Culver Cliff and occurs from the *M. cor-testudinarium* Zone to the lower part of the *Belemnitella mucronata* Zone. The specimen proposed by Bolli *et al.* (1957, p. 46) as the lectotype of *G. marginata* is from the Turonian of Bohemia. Edgell (1957, p. 114) states that within the Carnarvon Basin of North-western Australia, *G. marginata* appears to be restricted to beds of Santonian and Campanian age.

Bolli's hypotype (1945, pl. 9, fig. 12) of *Globotruncana lapparenti bulloides* has been examined by the present author at the Geological Institute, University of Zurich, and is believed to be a slightly oblique section of *G. marginata*. Bolli (op. cit.) reports the range of *G. lapparenti bulloides* in Switzerland as Turonian to L. Santonian.

Globotruncana rosetta (Carsey)

Plate 70, figs. 4*a–c*

Globigeria rosetta Carsey 1926, p. 44, pl. 5, figs. 3*a–c*.
Globotruncana rosetta (Carsey), Brönnimann and Brown 1956, p. 545, pl. 21, figs. 11–13.

Description. Test free, very low trochospiral, dorsal side slightly convex, ventral side strongly convex, evolute, umbilicate, 2½ to 3 whorls; equatorial periphery circular, slightly lobulate with a single dichotomous or 2 very closely spaced, beaded keels on the early chambers and a single keel on final chambers; dorsal keel extends on to spiral side of test as dorsal sutural ridge; ventral keel extends on to umbilical side of test and along umbilical margin as a slightly raised ridge; chambers hemispherical, 6 to 7 chambers in final whorl uniformly increasing in size; dorsal sutures distinct, oblique, strongly curved, raised, beaded; ventral sutures distinct, oblique, curved, slightly raised or flush; umbilicus moderately broad, in well-preserved specimens covered by a complex tegillum with marginal accessory apertures; primary aperture interiomarginal, umbilical; wall calcareous, not examined in thin section; surface weakly hispid; all of limited number of specimens coiled dextrally; average maximum diameter 0·54 mm.

Remarks. In the original description of *G. rosetta*, Carsey (1926, p. 44) did not mention the presence of a double keel and presented no illustration of a peripheral view of this specimen. Brönnimann and Brown (1956, p. 546), however, state: 'Examination of the holotype of *Globotruncana rosetta* (Carsey), in the Carsey Collection at the University of Texas, reveals that it possesses two keels in the early chambers of the last whorl which are very close together. In the ante- and penultimate chambers the keels join.'

In the light of Brönnimann and Brown's re-examination of the holotype, it is necessary to critically re-examine all specimens referred in the literature to *G. rosetta* (Carsey).

Occurrence. Specimens of *G. rosetta* (Carsey) are very rare, found only in samples C22 and C24 from the *Actinocamax quadratus* Zone (s.l.). Brönnimann and Brown (op. cit., p. 546) report the range of this species as Campanian to Maestrichtian.

Globotruncana rugosa (Marie)

Plate 71, figs. 3*a–c*

Rosalinella rugosa Marie 1941, p. 241, pl. 35, fig. 340.
Globotruncana rugosa (Marie), Hagn 1953, pl. 8, fig. 13.

Description. Test free, trochospiral, moderately biconvex, evolute, umbilicate, $2\frac{1}{2}$ to 3 whorls, equatorial periphery subcircular, weakly lobulate with 2 well-developed, widely to closely spaced, beaded keels; dorsal keel diverges on to spiral side of final whorl as strongly raised sutural ridges, but not apparent on dorsal side of early whorls; ventral keel extends on to umbilical side of test not precisely coinciding with ventral

EXPLANATION OF PLATE 72

Figs. 1, 2. *Globotruncana fornicata* Plummer. 1, axial section, P44596, $\times$ 112. 2, axial section, P44597, $\times$ 112. Both specimens from *A. quadratus* Zone (s.l.), sample C22.

Figs. 3, 4. *G. linneiana coronata* Bolli. 3, axial section, $\times$ 112. *M. cor-anguinum* Zone, sample C47, P44600. 4, axial section, $\times$ 112. *M. cor-anguinum* Zone, sample C46, P44599.

Fig. 5. *G. linneiana linneiana* (d'Orbigny), $\times$ 112. Axial section. *M. cor-anguinum* Zone, sample C46, P44601.

Fig. 6. *G. cretacea* (d'Orbigny), $\times$ 112. Axial section. Keels are not usually apparent in thin section. *B. mucronata* Zone, sample C10, P44598.

Figs. 7, 8. *G. marginata* (Reuss). 7, axial section, P44595, $\times$ 112. 8*a*, axial section, P44595, $\times$ 112; 8*b*, peripheral portion of final chamber showing perforate and imperforate parts of test wall, $\times$ 750 approx.; 8*c*, lower half of same portion of test wall using polarized light showing radial wall structure of both perforate and imperforate parts of test, $\times$ 1400 approx. Both specimens from *M. cor-anguinum* Zone, sample C46.

sutures then extends back along umbilicus as fairly prominent ridge; chambers strongly curved, truncate, inflated ventrally, latest 1 to 4 chambers often depressed dorsally, 5 to 6½ chambers in final whorl uniformly increasing in size; dorsal sutures of final 1 to 1½ whorls distinct, strongly curved, beaded, raised; early dorsal sutures indistinct, depressed, slightly oblique; ventral sutures distinct, depressed, slightly oblique; umbilicus broad, deep, in well-preserved specimens covered by a complex tegillum with accessory apertures; primary aperture interiomarginal, umbilical; wall calcareous, composed of radial calcite, perforate except for imperforate keels, peripheral area between keels, and tegilla; surface of initial 1 to 2 whorls weakly rugose, final whorl coarsely hispid; coiling predominantly dextral; 28 of 30 specimens selected at random coiled dextrally; approximate maximum diameter 0·54 mm.

Remarks. Globotruncana rugosa appears to have evolved from *G. fornicata* Plummer in the Lower *Belemnitella mucronata* Zone. Consequently, the earliest forms of *G. rugosa* are quite similar to *G. fornicata*. Typical specimens of *G. rugosa*, however, differ from *G. fornicata* in: (1) being ventrally more convex, (2) having an early rugose surface, (3) usually having more broadly spaced keels without the distinctive 'cone in cone' arrangement of *G. fornicata*, and (4) having chambers less strongly curved. *G. rugosa* somewhat resembles *G. linneiana tricarinata* (Quereau) but is more convex dorsally, and the dorsal surface of the early chambers is rugose compared to the finely hispid chamber surface of *G. linneiana tricarinata*. Dr. Pierre Marie has kindly compared specimens of *G. rugosa* from Culver Cliff with the holotype of *G. rugosa* and has confirmed the identification of this species.

Occurrence. In the studied samples *G. rugosa* is restricted to the *Belemnitella mucronata* Zone and is most abundant in the uppermost sample, no. C10. Marie's type for *G. rugosa* is from the *Belemnitella mucronata* Zone of the Paris Basin.

Globotruncana cf. *ventricosa* White

Plate 71, figs. 2*a–c*

Cf. *Globotruncana canaliculata* var. *ventricosa* White 1928, p. 284, pl. 38, figs. 5*a–c*.
Cf. *Globotruncana ventricosa* White, Bolli 1957, p. 57, pl. 13, figs. 4*a–c*.

Description. Test free, very low trochospiral, dorsal side flat to slightly convex, ventral side strongly convex, evolute, umbilicate, about 2½ whorls, equatorial periphery circular, weakly lobulate with 2 well-developed, closely spaced, beaded keels; dorsal keel diverges on to spiral side of test as dorsal sutural ridge; ventral keel diverges to umbilical side of terminal chamber face usually not coinciding precisely with ventral suture and usually not completely visible on ventral side of test, ventral keel then extends back along umbilical margin as a slightly raised ridge; chambers angular, ventrally inflated, 5 to 5½ chambers in final whorl somewhat irregularly increasing in size; dorsal sutures distinct, oblique, strongly curved, raised, beaded; ventral sutures distinct, nearly radial, slightly curved, depressed; umbilicus moderately broad, deep, covered by a complex tegillum with marginal accessory apertures; primary aperture interiomarginal, umbilical; wall calcareous; wall structure not examined in thin section; chamber surfaces coarsely hispid becoming less hispid with growth; all of limited number of specimens coiled dextrally; average maximum diameter 0·58 mm.

Remarks. See remarks under *Globotruncana concavata* (Brotzen). The limited number of forms referred to *Globotruncana* cf. *ventricosa* from the Isle of Wight have more broadly curved chambers than the holotype of *G. ventricosa* and only 5 chambers in the final whorl instead of the usual 6 or 7. These forms, however, appear quite similar to Bolli's (1957, pl. 13, figs. 4*a–c*) excellent illustrations of *G. ventricosa*, although his specimens have smooth chamber surfaces compared to the hispid surfaces of the specimens from the Isle of Wight.

These forms are also similar to *Globotruncana bollii* Gandolfi. The keels on the specimens from the Isle of Wight are much more strongly developed and wider spaced, however, than those of *G. bollii*.

Occurrence. This species is very rare in the studied samples and was found only in samples C22 and C27 from the *Actinocamax quadratus* Zone (s.l.). Bolli (op. cit., p. 57) states that *G. ventricosa* appears to be restricted to the Upper Santonian and Campanian.

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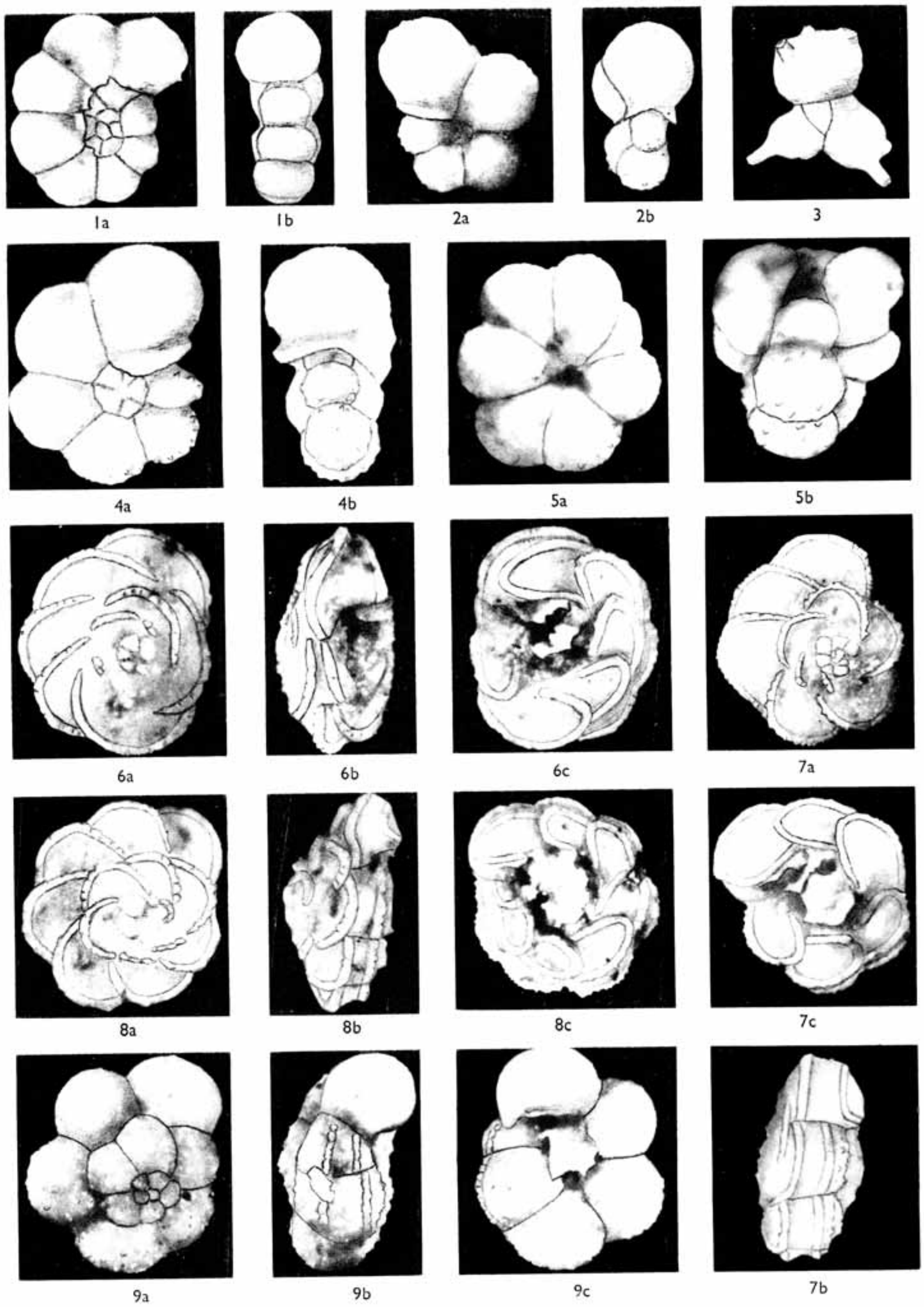

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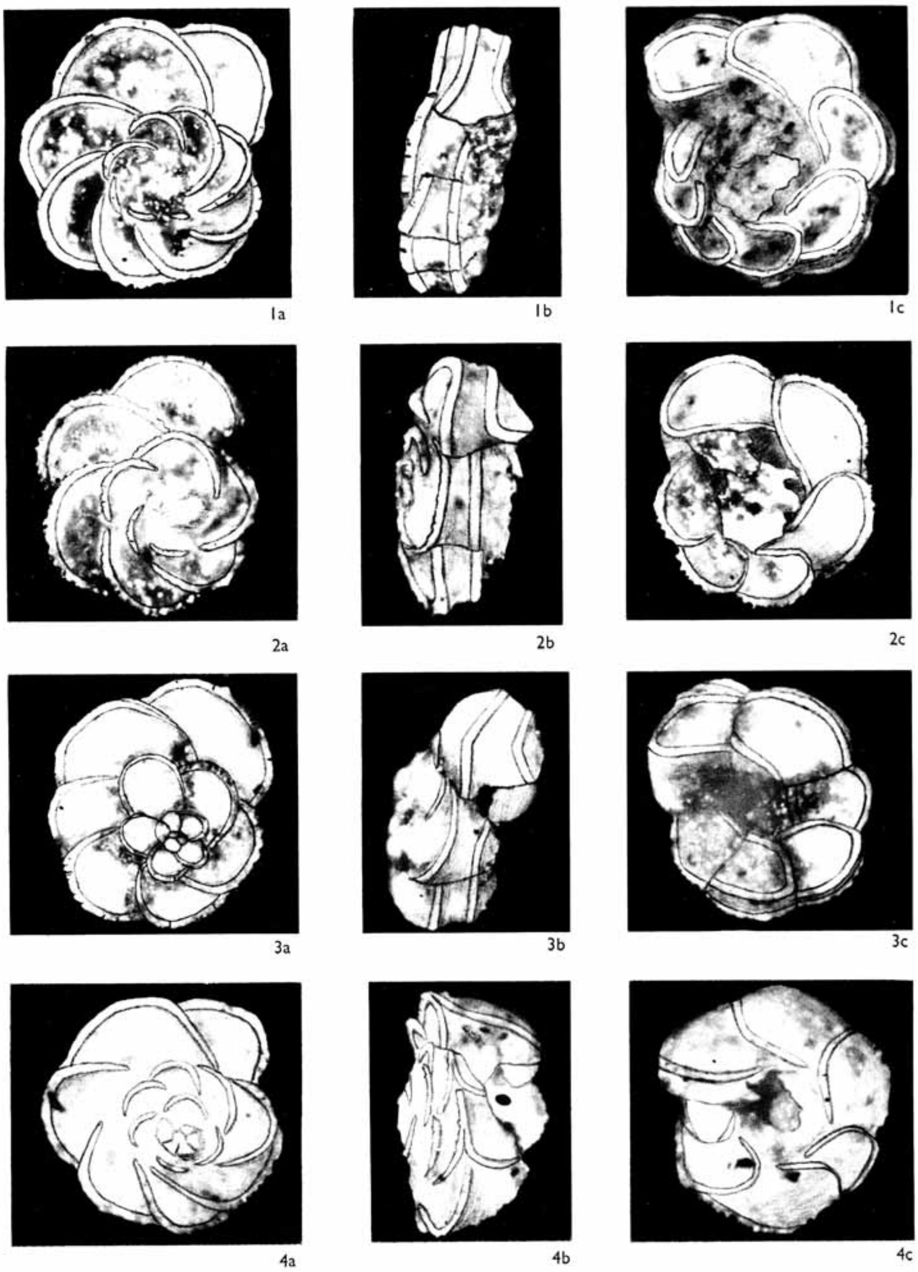

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4a 4b 4c

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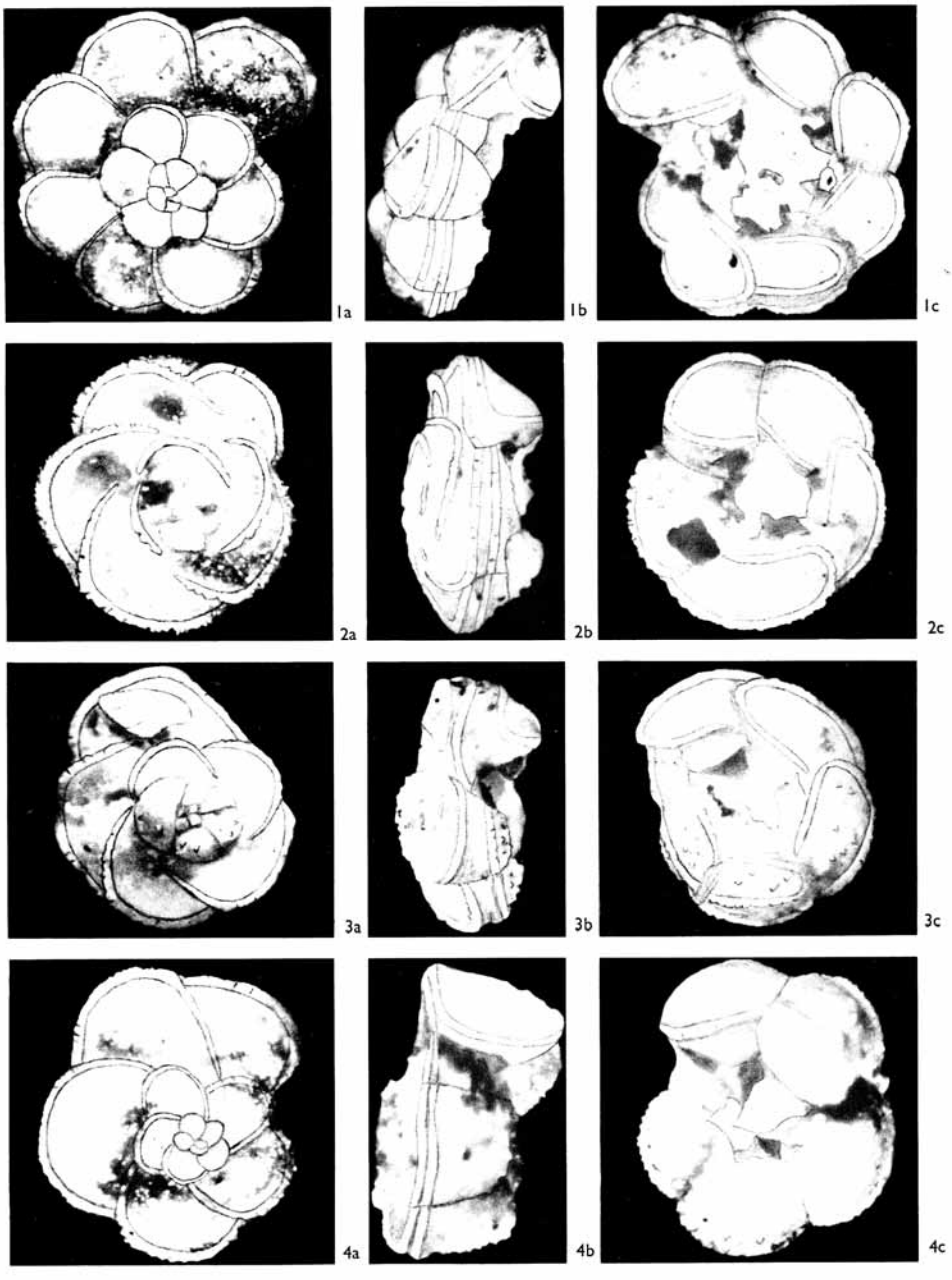

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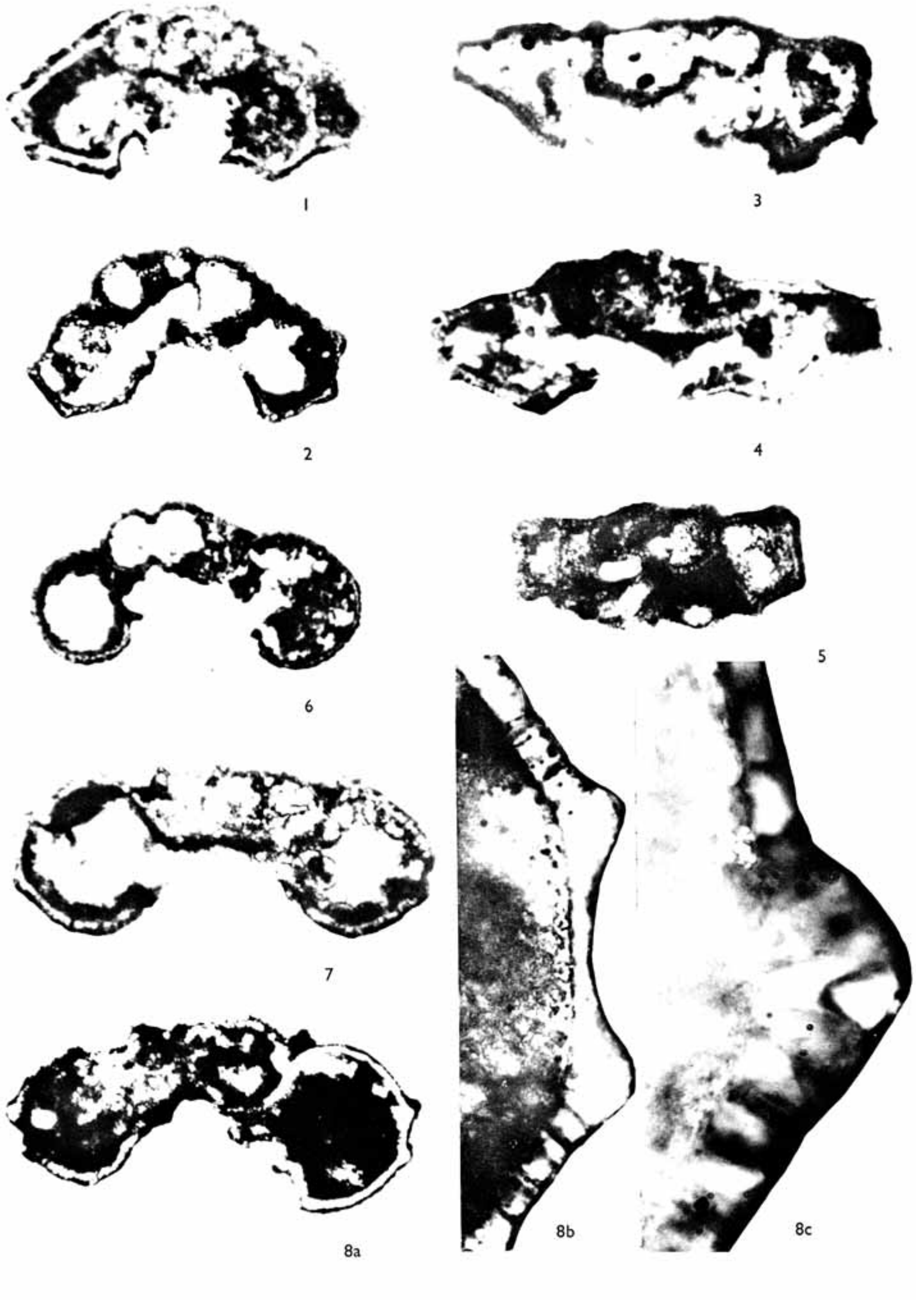

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