BULLETINS
OF
AMERICAN
PALEONTOLOGY

*

VOL. XLIV

*

1962

Paleontological Research Institution
Ithaca, New York
U. S. A.

CONTENTS OF VOLUME XLIV

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PALEONTOLOGICAL RESEARCH INSTITUTION

1961-62

BULLETINS OF AMERICAN PALEONTOLOGY

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BULLETINS

OF

AMERICAN PALEONTOLOGY

Vol. 44

No. 199

STRATIGRAPHIC DISTRIBUTION OF MIDDLE TERTIARY LARGER FORAMINIFERA FROM SOUTHERN PUERTO RICO

By

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and

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May 10, 1962

Paleontological Research Institution
Ithaca, New York, U.S.A.

Library of Congress Catalog Card Number: GS 62-302

Printed in the United States of America

CONTENTS

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ABSTRACT

Nine species of larger Foraminifera from 27 localities from the middle Tertiary Juana Díaz and Ponce formations of southern Puerto Rico are discussed and illustrated. This fauna is compared with the one described from the San Sebastián formation of northern Puerto Rico. Correlation of these strata with others of the Caribbean and Gulf Coast areas is discussed, and the local stratigraphic ranges of the species are given. Supporting evidence for the recent placement of *Lepidocyclina yurnagunensis* in the subgenus *Eulepidina* by Cole is given.

INTRODUCTION

Although Galloway and Heminway (1941) briefly described and illustrated four species of Puerto Rican larger Foraminifera, the only systematic study to date was the one by Sachs (1959). Since that time additional material collected by the junior author and four samples kindly provided by E. A. Pessagno, Jr. of the University of California, Davis, California, have become available. Therefore, this study is a continuation of the previous reports to enlarge our knowledge of the larger Foraminifera in the southern middle Tertiary of Puerto Rico.

The figured specimens are deposited in the Sachs collection at the University of Florida, and will be presented eventually to the U.S. National Museum.

LOCALITIES

OP2342—Bluff on southwest bank of Río Jacaquas at bend, 2 km. in a straight line S-46°-W from the center of the town of Juana Díaz. Buff marlstone near top of Juana Díaz formation, just below contact with overlying Ponce limestone.

OP2639—Small bluff on west bank of Río Guyabal, 0.8 km. due west of Hacienda Luciana, northwest of the town of Juana Díaz. Alternating layers of limestone and marl in the lower part of the Juana Díaz formation.

OP2695—Km. 253.7 on highway PR132. Marl interbedded with fragmental limestone. Juana Díaz formation.

OP2696—Km. 255.2 on highway PR132. Buff marl. Juana Díaz formation.

PR300 —Cement company quarry, city of Ponce. Ponce limestone.

PR123 —Km. 254.8 on highway PR132. Buff marl. Juana Díaz formation.

PR124 —Km. 255.05 on highway PR132. Buff marl. Juana Díaz formation.

PR125 —Km. 255.1 on highway PR132. Buff marl. Juana Díaz formation.

PR126 —Km. 255.6 on highway PR132. Buff marl. Juana Díaz formation.

PR127 —Km. 256.1 on highway PR132. White marl. Juana Díaz formation.

PR128 —Km. 256.2 on highway PR132. Buff marl. Juana Díaz formation, probably near the top.

PR129 —Km. 256.35 on highway PR132. Hard white marl. Upper part of Juana Díaz formation.

PR130 —Km. 256.45 on highway PR 132. Buff marl. Upper part of Juana Díaz formation.

PR131 —West side of Quebrada del Agua Valley, 1.3 km. south of highway PR132. White marl. Lower part of lower Ponce limestone.

PR133 —Trail along Quebrada del Agua, 5 km. southeast of river crossing which is 1.8 km. south of highway PR132. White marl. Middle part of lower Ponce limestone.

PR134 —Trail along Quebrada del Agua, .9 km. southeast of locality PR133. Hard white marl. Middle part of lower Ponce limestone.

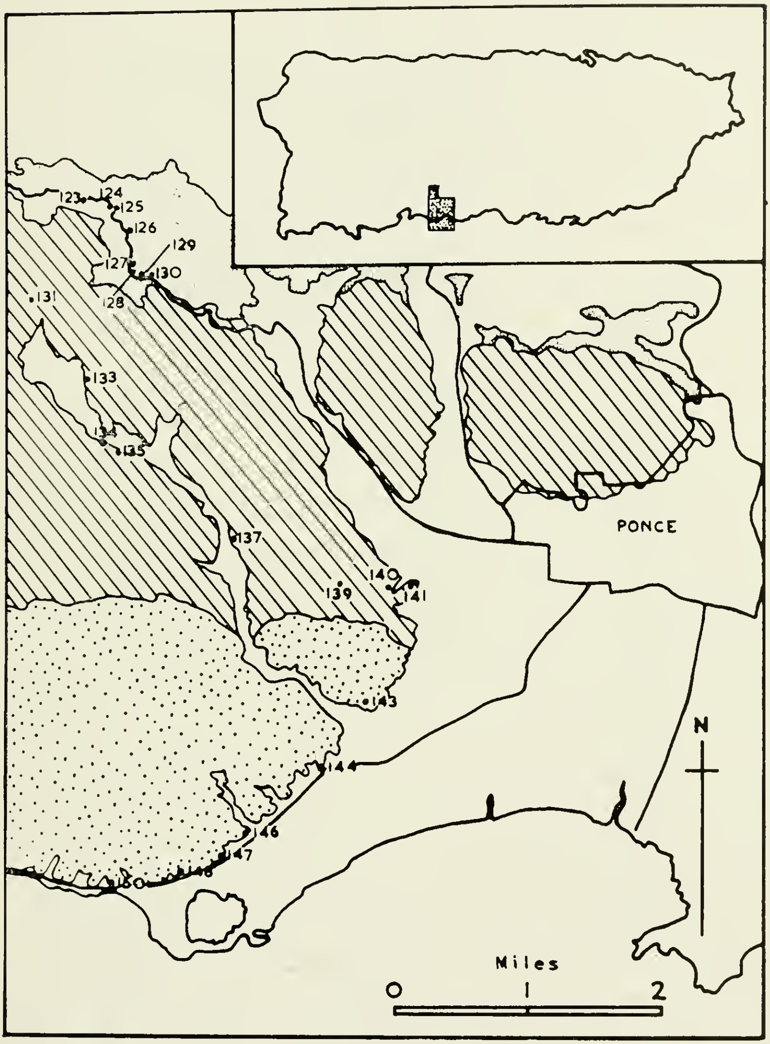
PR135 —Trail along Quebrada del Agua, 5.9 km. west of east edge of Peñuelas quadrangle and 2.5 km. north of the south edge of the quadrangle. Cream marl. Middle of lower Ponce limestone.

PR137 —Trail along Quebrada del Agua, 1.5 km. southeast of locality PR135. Cream marl. High lower Ponce limestone.

PR139 —3.3 km. west of east edge of Peñuelas quadrangle, and .95 km. north of south edge. White marl. High lower Ponce limestone.

PR140 —On a trail, .75 km. eastsoutheast of locality PR139. White marl. High lower Ponce limestone.

PR141 —2.3 km. west of east edge of Peñuelas quadrangle, and .9 km. north of south edge. Cream marl. High lower Ponce limestone.



Text figure 1. Location of samples PR123-PR150. Geological boundaries based on Zapp, Bergquist, and Thomas (1948). Fine stipple—Juana Díaz formation; diagonal lines—Ponce limestone, lower member; coarse stipple—Ponce limestone, upper member. Inset map of Puerto Rico shows the locality of the principal map.

PR143 —On a trail, 2.8 km. west of east edge of Punta Cuchara quadrangle and .5 km. south of north edge of the quadrangle. Cream marl. Lower part of upper Ponce limestone.

TABLE 1

Distribution of Species of Larger Foraminifera in the Juana Díaz and Ponce Formations of Southern Puerto Rico

	Juana Díaz formation												Ponce limestone														
													lower member									upper member					
	OP2639	OP2695	PR123	PR124	PR125	OP2696	PR126	PR127	PR128	PR129	PR130	OP2342	PR300	PR131	PR133	PR134	PR135	PR137	PR141	PR139	PR140	PR143	PR144	PR146	PR147	PR148	PR150
Camerina dia (Cole & Ponton)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X			X			?			
Heterostegina antillea Cushman			X					X								X											
Lepidocyclina (Lepidocyclina) conellei Lemoine & R. Douvillé			X	X																							
giroudi R. Douvillé	X	X	X			X						X									X						
waylandvaughani Cole		X																			X						
(Eulepidina) undosa Cushman	X	X																									
yurnagunensis Cushman	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X		X			X						
Miogypsina (Miogypsina) gunteri Cole		X																									
(Miolepidocyclina) panamensis (Cushman)																								X			

PR144 —Km. 19.3 on highway PR2. Cream marl. Middle of upper Ponce limestone.
PR146 —Km. 18.2 on highway PR2. Cream rubbly limestone. Upper part of upper Ponce limestone.
PR147 —Km. 17.7 on highway PR2. Cream rubbly limestone. High upper Ponce limestone.
PR148 —Km. 17.2 on highway PR2. Cream-pink rubbly limestone. Near top of upper Ponce limestone.
PR150 —Km. 16.2 on highway PR2. Cream-yellow rubbly limestone. Top upper Ponce limestone.

COMPARISON OF FAUNAS FROM NORTHERN AND SOUTHERN PUERTO RICO

As the Juana Díaz formation in the south has been assumed to be approximately the stratigraphic equivalent of the San Sebastián formation in the north (Woodring, 1943; Zapp, Bergquist and Thomas, 1948; Gordon, 1961), comparison of the fauna of larger Foraminifera from southern Puerto Rico with that of the San Sebastián formation from northern Puerto Rico described by Sachs (1959, p. 401) is of particular interest. If the species of larger Foraminifera are indicative, there appears to be an identity between the faunas of the northern and southern districts (Table 2) as only four species are geographically restricted. *Miogypsina* (*Miogypsina*) *antillea* and *Lepidocyclina* (*Lepidocyclina*) *asterodisca* were found only in the San Sebastián, and *Lepidocyclina* (*Eulepidina*) *yurnagunensis* and *Lepidocyclina* (*Lepidocyclina*) *waylandvaughani* occurred in the Juana Díaz. Furthermore, if *L. waylandvaughani* and *L. asterodisca* were eventually combined as suggested in the discussion of *L. waylandvaughani,* the number of restricted species would be reduced to two.

However, if the relative abundances of the various species are considered, a marked difference appears (Table 2). *Camerina dia* is abundant in the San Sebastián, and Juana Díaz formations; whereas *Heterostegina antillea,* abundant in the San Sebastián, is rare in the Juana Díaz and rarer in the Ponce. All of the species of *Lepidocyclina* found in the San Sebastián are common there, whereas, with the exception of *L. giraudi* and *L. yurnagunensis*, they are all exceedingly rare in the Juana Díaz and lower Ponce. *L. yurnagunensis* which was not found in the San Sebastián, is abundant throughout the Juana Díaz and common in two of the samples from the lower Ponce.

TABLE 2
Reported Geographic Distribution of Species of Larger Foraminifera from Puerto Rico

	Puerto Rico S*	N	Mexico	Florida	Cuba	Jamaica	Haiti	Antigua	Carriacou	Trinidad	Venezuela	Panama
Camerina dia (Cole & Ponton)	a	a		x	x		x		x	x		
Heterostegina antillea Cushman	r	c		x	x		x		x	x		
Lepidocyclina (Lepidocyclina) asterodisca Nuttall		c	x		x			x		x	x	x
canellei Lemoine & R. Douvillé	r	c	x		x	x	x	x	x	x	x	x
giraudi R. Douvillé	c	c	x	x	x	x	x	x	x	x		x
waylandvaughani Cole	r		x					x	x	x		x
(Eulepidina) undosa Cushman	r	c	x	x	x	x	x	x			x	x
yurnagunensis Cushman	a			x	x	x	x	x		x		x
Miogypsina (Miogypsina) antillea (Cushman)		r		x	x		x		x	x		x
gunteri Cole	r	r		x			x			x		x
(Miolepidocyclina) panamensis (Cushman)	r	c		x					x			x

*S = south coastal plain (San Sebastián formation)
N = north coastal plain (Juana Díaz, Ponce formations)
a = abundant c = common r = rare x = present, no quantitative significance

This contrast between the northern and southern middle Tertiary faunas of Puerto Rico has been remarked upon by workers in other groups of fossils. Meyerhoff (1933) noted that there is a significant contrast between the faunas of the north and south, as also did Zapp, Bergquist, and Thomas (1948). The work of Maury (1920) on the mollusks and of Coryell and Ohlsen (1929) on the corals demonstrated important dissimilarities between the northern and southern assemblages in these groups. Also, one of the present writers (W.A.G.) finds the same feature in his current studies of the smaller Foraminifera and the echinoids. These findings lend additional support to the suggestions of Meyerhoff (1933, p. 66 & map p. 69) and Woodring (1954, map p. 728) that an east-west land barrier separated the two ecologically distinct provinces of sedimentation in Puerto Rico during the middle Tertiary.

Table 2 shows the occurrence of the species of larger Foraminifera from Puerto Rico elsewhere in the Caribbean and Gulf Coast areas.

STRATIGRAPHY

The middle Tertiary rocks of Puerto Rico (Text fig. 1) occur in two main tracts, along the north and south coasts of the island respectively. The southern outcrops have been divided by Zapp, Bergquist, and Thomas (1948) into two principal formations of which the upper is subdivided into two members:

Ponce limestone { Upper member
Lower member
Juana Díaz formation

The Juana Díaz formation consists of pebble beds, sandy limestones, and calcareous clays, whereas the lower member of the Ponce limestone is composed principally of chalky limestones, above which occur dense crystalline limestones. The thicknesses of the three units are variable, and they may be facies equivalents of each other, in part. The maximum exposed thickness, about 4,500 feet, of these beds is west of the city of Ponce (Text fig. 1) where 24 samples were collected between Punta Cuchara and Peñuelas to provide a standard section. Eight of these samples contained no larger Foraminifera or only fragmentary material inadequate for positive identification.

In addition to this standard section, faunas were obtained from three other samples (OP2342, OP2639, PR300), but it was impossible to determine the exact positions of these samples relative to the standard section.

However, sample PR300 belongs to the lower member of the Ponce limestone, probably from the middle of that member. The other samples came from the Juana Díaz formation. Their estimated positions relative to the main sequence are indicated in Table 1.

In general, the best faunas were found in the samples from the Juana Díaz formation. Moderate or poor faunas were yielded by the Ponce limestone samples.

Sachs (1959, p. 400) noted the similarity between the fauna of the San Sebastián formation of northern Puerto Rico and the Bohio and Caimito formations of Barro Colorado Island, Panama Canal Zone, the *Lepidocyclina texana* horizon of the American Gulf Coast (Gravell and Hanna, 1937) and upper Oligocene formations of Trinidad (Vaughan and Cole, 1941, p. 28). Although it has been noted that the San Sebastián formation in the north and the Juana Díaz formation in the south of Puerto Rico were deposited in separate sedimentary provinces, the stratigraphic equivalence of these two formations is certain.

Furthermore, the presence of *Lepidocyclina* (*Eulepidina*) *undosa, L.* (*Lepidocyclina*) *canellei* and *Miogypsina* (*Miogypsina*) *gunteri* in both the San Sebastián and Juana Díaz formations indicates that these formations lie within the *Miogypsina* subzone of the *Eulepidina* zone (Cole, 1957, p. 35; 1958b, p. 220; Sachs, 1959, p. 403). It is therefore not surprising to find that there is also a close similarity between the fauna of the Juana Díaz formation and those of the Panama Canal Zone, Trinidad, and the American Gulf Coast.

In the Dale Mabry Field water well B in Leon County, Florida, Cole (1945, p. 24) reported *L. undosa* and *L. yurnagunensis* at a depth of 212.6 feet and *L. undosa, L. yurnagunensis,* and *L. parvula* (=*L. giraudi*) at a depth of 208-316.5 feet, both in the Suwannee limestone. These species of *Lepidocyclina* and *C. dia* are abundant in surface outcrops of the Suwannee limestone in northern Florida, and are considered to be Oligocene in age, whereas the downdip facies of the upper part of the Suwannee limestone in southern Florida is characterized by a *Miogypsina-Heterostegina* fauna similar to that of the *Lepidocyclina texana* horizon of Texas and Louisiana described by Gravell and Hanna (1937). However, Puri and Vernon (1959, p. 93) correlate this southern upper part of the Suwannee limestone with the Tampa limestone, considered to be Aquitanian (Woodring, 1957, p. 37).

Although the larger foraminiferal fauna from the Juana Díaz formation and the lower member of Ponce limestone indicates a close correlation with the *Lepidocyclina texana* horizon of the Gulf Coast, the problem of the exact stratigraphic age of the southern middle Tertiary formations of Puerto Rico is not resolved. Zapp, Berquist, and Thomas (1948) consider that they are middle Oligocene to lower Miocene, and that the Oligocene—Miocene boundary falls within the lower member of the Ponce. Woodring (1943) regarded the Juana Díaz formation as middle Oligocene and the Ponce as upper Oligocene to lower Miocene. Gordon (1961) concluded that the whole of the Puerto Rican middle Tertiary is referable to the Miocene, and that the upper part of the Ponce limestone is probably middle Miocene on the basis of the planktonic Foraminifera.

The entire problem of the Oligo-Miocene boundary in the Caribbean, and of the correct relationship of the New World mid-Tertiary to that of the Old World, is at present the subject of lively controversy and will not be considered further here.

DISCUSSION OF SPECIES

Family **CAMERINIDAE**

Genus **CAMERINA** Bruguière, 1792

Camerina dia (Cole and Ponton) Pl. 1, figs 2-4, 7; Pl. 2, fig. 2; Pl. 3. figs. 6,7

1930. *Operculinella dia* Cole and Ponton, Florida Geol. Sur., Bull. 5, p. 37.
1958. *Operculinoides dia* (Cole and Ponton), Cole, Bull. Amer. Paleont., vol. 38, No. 170, p. 198-200, pl. 22, figs. 1-3; pl. 24, fig. 5; pl. 25, figs. 3-13, 16.
1958. *Operculinoides dia* (Cole and Ponton), Cole, *idem*, p. 270, 271, pl. 34, figs. 2-4, 6, 9.
1959. *Operculina dia* (Cole and Ponton), Sachs, Bull. Amer. Paleont., vol. 39, No. 183, p. 404, 405; pl. 34, figs. 3, 4, 7, 12.

Remarks.—Two recent papers by Cole (1960a, 1961a) should be consulted for detailed discussions of the genus *Camerina* which is considered to include this species. Although Cole's studies were based primarily on Indo-Pacific species of this genus, the high degree of variability which he found within individual species has already been reported to occur in the Caribbean region. Sachs (1957, p. 107-113) demonstrated the variability in form exhibited by *Operculinoides bermudezi* (=*Camerina catenula*) and Cole (1958a p. 198-200) discussed variability in *C. dia.*

The variability of *C. dia* is further illustrated by the specimens studied in conjunction with this report. Figures 3, 7, 2, 4 of Plate 1 show the range from inflated specimens to appressed ones.

One poorly preserved specimen of a camerinid from sample PR146 has been tentatively identified as *C. dia*. Although this sample is considered to be Miocene in age, this identification is not considered to be sufficiently certain to warrant extension of the stratigraphic range to include the lower Miocene.

Genus **HETEROSTEGINA** d'Orbigny, 1826

Heterostegina antillea Cushman Pl. 3. fig. 1

1919. *Heterostegina antillea* Cushman, Carnegie Inst. Washington, Publ. 291, p. 49, 50, pl. 2, fig. 1b; pl. 5, figs. 1, 2.
1959. *Heterostegina antillea* Cushman, Sachs, Bull. Amer. Paleont. vol. 39, No. 183, p. 405, 406, pl. 34, figs. 1, 10; pl. 35, figs. 3-6, 10-12; pl. 36, fig. 8.

Remarks.—Specimens of *H. antillea* found in samples from the Juana Díaz and Ponce formations (Table 1) are typical of the species. Figure 1, Plate 3 of a median section of a specimen from the Juana Díaz formation illustrates the characteristic single undivided operculine chamber following the embryonic chambers.

Family **ORBITOIDIDAE**

Genus **LEPIDOCYCLINA** Gümbel, 1870

Subgenus **LEPIDOCYCLINA** Gümbel, 1870

Lepidocyclina (Lepidocyclina) canellei Lemoine and R. Douvillé Pl. 3, fig. 3

1904. *Lepidocyclina canellei* Lemoine and R. Douvillé, Soc. Geol. France, Mem., vol. 12, p. 20, pl. 1; pl. 3, fig. 5.
1952. *Lepidocyclina* (*Lepidocyclina*) *canellei* Lemoine and R. Douvillé, Cole, U. S. Geol. Sur., Prof. Pap, 244, p. 18-20, pl. 16, figs. 1-22; pl. 17, figs. 1-3 (references).

Remarks.—Specimens of *L. canellei* were found only in two samples from the Juana Díaz formation. Figure 3, Plate 3 of an equatorial section from loc. 124 illustrates the typical early arcuate and peripheral hexagonal equatorial chambers. This should be compared with figure 2 of Plate 3 of a closely related species, *L. giraudi* R. Douvillé. This species, in contrast to *L. canellei*, does not typically develop true hexagonal equatorial chambers.

Lepidocyclina (Lepidocyclina) giraudi R. Douvillé Pl. 1, figs. 6, 8, 11; Pl. 2, fig. 9; Pl. 3, figs. 2, 4, 9

1907. *Lepidocyclina giraudi* R. Douvillé, Soc. Geol. France, Bull., ser. 4, vol. 7, p. 305-311, pl. 10, figs. 9, 10, 15, 16.
1957. *Lepidocyclina* (*Lepidocyclina*) *giraudi* R. Douvillé, Cole, Bull. Amer. Paleont., vol. 38, No. 166, p. 41, 42, pl. 4, fig. 3; pl. 5, figs. 1, 2; pl. 6, figs. 1, 2, (references).

Remarks.—Cole (1957, p. 41) recently discussed the variability of this widely distributed and well-known species. The specimens from the south Coastal Plain of Puerto Rico are typical of the species. A number of vertical sections are illustrated here (Pl. 1, figs, 6, 8, 11) to further demonstrate variation from individuals with thin lateral chamber walls (fig. 6) to thick-walled ones with low lateral chambers (figs. 8, 11).

Lepidocyclina (Lepidocyclina) waylandvaughani Cole Pl. 1, figs. 5, 10

1928. *Lepidocyclina* (*Lepidocyclina*) *waylandvaughani* Cole, Bull. Amer. Paleont., vol. 14. No. 53, p. 21, pl. 4, figs. 1-8.

Remarks.—If figure 10, Plate 1 is compared with the illustration of a vertical section of *L. asterodisca* given by Sachs (1959, pl. 35, fig. 7) from the San Sebastián formation of northern Puerto Rico it will be seen that there are no features which will serve to separate them. The only difference between *L. waylandvaughani* and *L. asterodisca* is found in equatorial sections. *L. asterodisca* is rayed whereas *L. waylandvaughani* is not. There is apparently no difference in their stratigraphic range. Their geographic distribution is similar. These facts suggest that only a single species may be represented; however, additional study of these species is necessary before their proper relationship can be determined.

Subgenus **EULEPIDINA** H. Douvillé, 1911

Lepidocyclina (Eulepidina) undosa Cushman Pl. 1, fig. 9

1919. *Lepidocyclina undosa* Cushman, Carnegie Inst. Wash., Publ. 291, p. 65, pl. 2, fig. 1a.
1919. *Lepidocyclina gigas* Cushman, *idem,* p. 64, pl. 1, figs. 3-5; pl. 5, fig. 4.
1945. *Lepidocyclina* (*Eulepidina*) *undosa* Cushman, Cole, Florida Geol. Sur., Bull. 28, p. 43, 44, pl. 1, figs. 14, 15; pl. 2, fig. 8; pl. 8, fig. 7; pl. 11, fig. 8 (references).
1961. *Lepidocyclina* (*Eulepidina*) *undosa* Cushman, Cole and Applin, Contr. Cushman Found. Foram. Res., vol. 12, Pt. 4, p. 133, 134, pl. 7, fig. 12.

Remarks.—Specimens of *L. undosa* from two localities in the Juana Díaz formation (Table 1) are typical of the species. A vertical section of a selliform individual is illustrated (Pl. 1, fig. 9) to show the large eulepidine embryonic chambers and open lateral chambers in regular tiers.

The inclusion of *L.* (*Eulepidina*) *favosa* in the synonymy of *L. undosa* by Cole and Applin (1961, p. 133) is apt. At most localities in the Caribbean area, specimens formerly called *L. favosa* have been found associated with *L. undosa,* and it is certain that they represent only a single variable species. In addition, many workers have expressed an opinion that *L. gigas* represents the microspheric generation of this widely distributed Oligocene species (Vaughan, 1924, p. 799; Cole, 1952, p. 30; Cole and Applin, 1961, p. 134). However, to the knowledge of the senior author, the name *L. gigas* has not previously been formally recognized as being synonymous with *L. undosa.*

Grimsdale (1952, p. 240-244), in a study of Middle East Foraminifera, placed a large number of species, including *L. favosa,* in the synonymy of *L.* (*Eulepidina*) *ephippioides.* Although his analysis of the variability of this species is excellent and his arguments for including *L. favosa* in *L. ephippioides* are convincing, there are certain undesirable implications which could arise from such a union.

Grimsdale (1952, p. 423) clearly stated that the migration of *L. ephippioides* from Mexico to the Indo-Pacific occupied at least the entire Oligocene. However, in spite of his statement, the suggestion that individuals from such widely separated localities are conspecific will carry an implication of contemporaneity to some. This is highly undesirable. For this reason, *L. undosa* is retained provisionally as a distinct specific name representing Oligocene forms of the Americas.

Lepidocyclina (Eulepidina) yurnagunensis Cushman Pl. 1, fig. 1; Pl. 2, figs. 1, 3-8; Pl. 3, fig. 8

1919. *Lepidocyclina canellei* Lemoine and R. Douvillé, variety *yurnagunensis* Cushman, Carnegie Inst. Washington, Publ. 291, p. 57, pl. 12, figs. 7, 8.
1960. *Lepidocyclina* (*Eulepidina*) *yurnagunensis* Cushman, Cole, Micropaleontology, vol. 6, No. 2, p. 136, pl. 3, fig. 8.
1961. *Lepidocyclina* (*Eulepidina*) *yurnagunensis* Cushman, Cole and Applin, Contr. Cushman Found. Foram. Res., vol. 12, pt. 4, p. 134, pl. 7, fig. 13.
1961. *Lepidocyclina* (*Eulepidina*) *yurnagunensis* Cushman, Cole, *idem,* p. 143, pl. 9, figs. 2, 5; pl. 10, figs. 3, 4, 6; pl. 15, figs. 5, 6; pl. 16, figs. 2-6.

Remarks.—Recent papers by Cole (1960b, 1961b) and Cole and Applin (1961) should be consulted for a detailed discussion of the nomenclatorial history of this species.

Lepidocyclina (*Eulepidina*) *yurnagunensis* was the most abundant species of orbitoid Foraminifera recovered from both the Juana Díaz and Ponce formations. The variability of this species as seen in equatorial and vertical sections is demonstrated by figures 1, 3-8, Plate 2, and figure 8, Plate 3.

Although there is a possibility of confusing *L. yurnagunensis* with *L. tournoueri* and *L. vaughani* which superficially resemble it, these species are distinct.

If figures 1, 3, 5, 8, Plate 2 are compared with Cole's (1952, figs. 9, 10, pl. 19) illustrations of *L. tournoueri,* considerable similarity in equatorial sections will be noted. However, the equatorial chambers of *L. yurnagunensis* are dominantly rhombic and are arranged in a pattern of open crossed spirals whereas those of *L. tournoueri* are hexagonal near the periphery and are arranged in annuli.

Vertical sections of *L. vaughani* as illustrated by Cole (1952, figs. 6-10, pl. 21) resemble those of some of the Puerto Rican specimens of *L. yurnagunensis* (Pl. 2, figs. 4, 6; Pl. 3, fig. 8); however, the equatorial layer of *L. vaughani* is characteristically greatly expanded at the periphery whereas that of *L. yurnagunensis* is not.

Family **MIOGYPSINIDAE**

Genus **MIOGYPSINA** Sacco, 1893

Subgenus **MIOGYPSINA** Sacco, 1893

Miogypsina (Miogypsina) gunteri Cole

1937. *Miogypsina* (*Miogypsina*) cf. *M. irregularis* (Michelotti), Barker and Grimsdale, Ann. Mag. Nat. Hist., ser. 10, vol. 14, p. 163-166, pl. 5, figs. 4, 5, 7-10; pl. 7, figs. 2, 3.

1938. *Miogypsina* (*Miogypsina*) *gunteri* Cole, Florida Geol. Sur., Bull. 16, p. 42, 43, pl. 6, figs. 10-12, 14; pl. 8, figs. 1, 2, 4-9.

1957. *Miogypsina* (*Miogypsina*) *gunteri* Cole, Cole, Bull. Amer. Paleont., vol. 37, No. 163, p. 321, 322, pl. 26, figs. 1-4, 8, 9; pl. 27, fig. 1 (references).

Remarks.—A single specimen of *M. gunteri* was found in sample 123 from the lower member of the Juana Díaz formation.

Subgenus **MIOLEPIDOCYCLINA** A. Silvestri, 1907

Miogypsina (Miolepidocyclina) panamensis (Cushman) Pl. 3, fig. 5

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Remarks.—Rare specimens of *M. panamensis* were obtained from sample 146 from the upper member of the Ponce limestone. Figure 5, Plate 3 shows the subcentral embryonic apparatus surrounded by a well-developed coil of periembryonic chambers.

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PLATES

EXPLANATION OF PLATE 1

Figure Page

1. **Lepidocyclina (Eulepidina) yurnagunensis** Cushman.................. 16

Vertical section, X40, to show open lateral chambers, pillars, and equatorial layer which does not expand appreciably toward the periphery of the test.

2-4, 7. **Camerina dia** (Cole and Ponton).. 13

2-4. Transverse sections, X40, to show variation from appressed forms (fig. 2) to inflated ones (fig. 3).

7. Transverse section, X20, of a microspheric individual.

5, 10. **Lepidocyclina (Lepidocyclina) waylandvaughani** Cole................ 15

5. Vertical section, X20, introduced for comparison with the illustration given by Cole (1957, fig. 6, pl. 1).

10. Vertical section, X40, to show open lateral chambers which are not arranged in tiers.

6, 8, 11. **Lepidocyclina (Lepidocyclina) giraudi** R. Douvillé...................... 14

Vertical sections, X 40, to show variation from small, open-chambered individuals (fig. 6) to large individuals with slitlike lateral chambers. (fig. 8).

9. **Lepidocyclina (Eulepidina) undosa** Cushman............................... 15

Vertical section, X 20, of a large individual to show the eulepidine embryonic chambers and small tiered lateral chambers.

1, 4 from locality PR130
2, 5, 10 from locality PR140
3 from locality OP2342
6, 9 from locality OP2639
7 from locality PR124
8, 11 from locality OP2696

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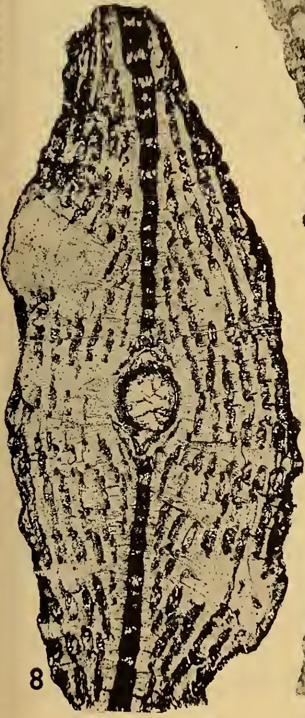

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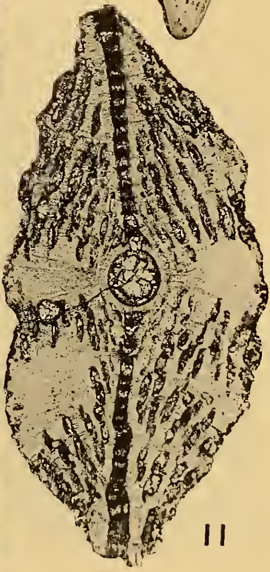

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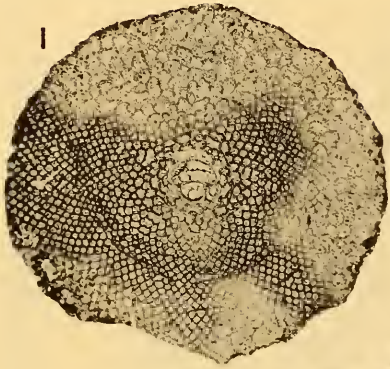

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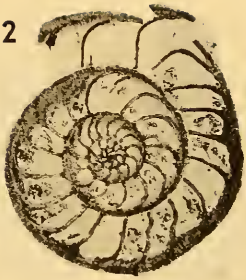

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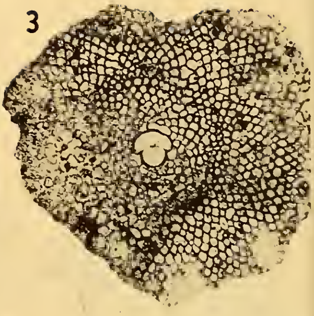

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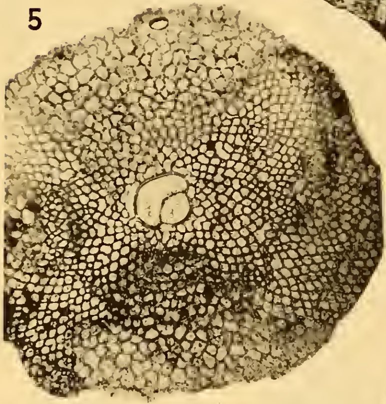

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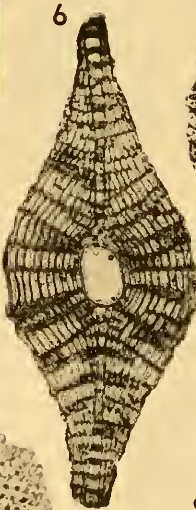

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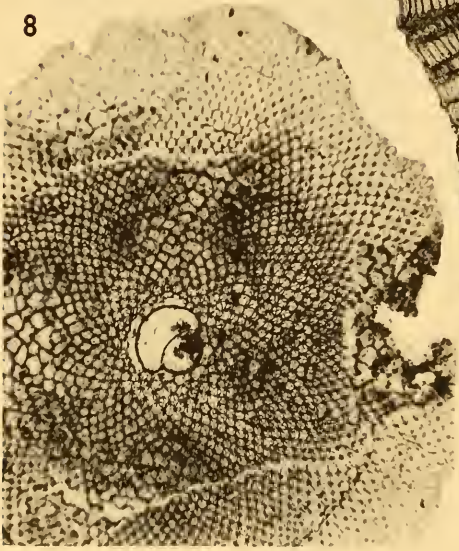

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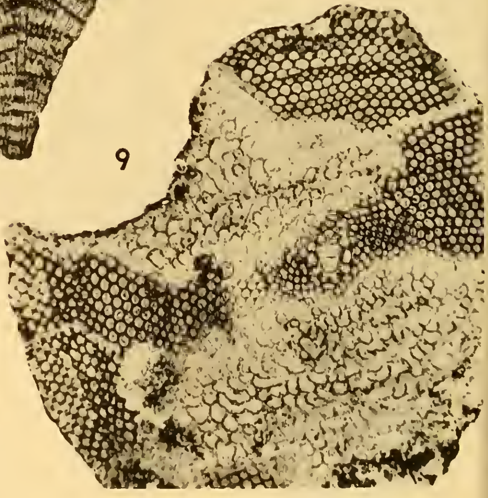

EXPLANATION OF PLATE 2

Figure Page

1, 3-8. **Lepidocyclina (Eulepidina) yurnagunensis** Cushman 16

1, 3, 5, 8. Equatorial sections, X20, to show the eulepidine embryonic chambers and rhombic equatorial chambers arranged in a pattern of open, crossed spirals.

7. Equatorial section, X40, of a specimen with nearly lepidocycline embryonic chambers. This illustration should be compared with that given by Cole (1945, fig. 6, pl. 6).

4, 6. Vertical sections, X20, to show open lateral chambers with thin walls.

2. **Camerina dia** (Cole and Ponton) 13

Median section, X20, to show the sharply recurved septa.

9. **Lepidocyclina (Lepidocyclina) giraudi** R. Douvillé 14

Equatorial section, X20, of a large individual showing early equatorial chambers which are arcuate, and peripheral ones which approach a hexagonal shape.

1, 9 from locality OP2696
2 from locality PR130
3 from locality PR125
4, 6, 8 from locality OP2695
5 from locality PR140
7 from locality OP2639

EXPLANATION OF PLATE 3

Figure — Page

1. **Heterostegina antillea** Cushman 14

Median section, X20, to show the single undivided operculine chamber following the embryonic chambers.

2, 4, 9. **Lepidocyclina (Lepidocyclina) giraudi** R. Douvillé........................ 14

Equatorial sections, figs. 2. 9, X20, fig. 4, X40, to show the predominantly arcuate shape of the equatorial chambers.

3. **Lepidocyclina (Lepidocyclina) canellei** Lemoine and R. Douvillé 14

Equatorial section, X20, to show early equatorial chambers which are arcuate and peripheral ones which are hexagonal.

5. **Miogypsina (Miolepidocyclina) panamensis** (Cushman)............ 17

Equatorial section, X40, to show the subcentral embryonic apparatus and the arrangement of the periembryonic coil.

6. 7. **Camerina dia** (Cole and Ponton) 13

Median sections, X20, of a megalospheric individual (fig. 6) and a microspheric individual (fig. 7) to show the sharply recurved septa.

8. **Lepidocyclina (Eulepidina) yurnagunensis** Cushman.................. 16

Vertical section, X20, of a large individual to show the open, thin-walled lateral chambers.

1 from locality PR123
2, 7-9 from locality OP2696
3 from locality PR124
4 from locality OP2639
5 from locality PR146
6 from locality PR140

1

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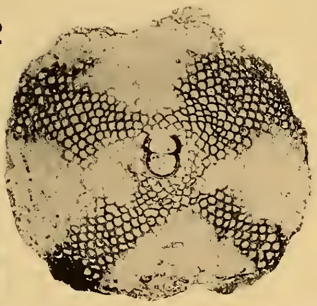

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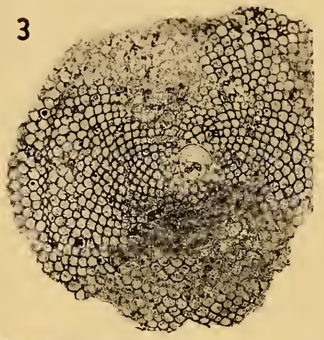

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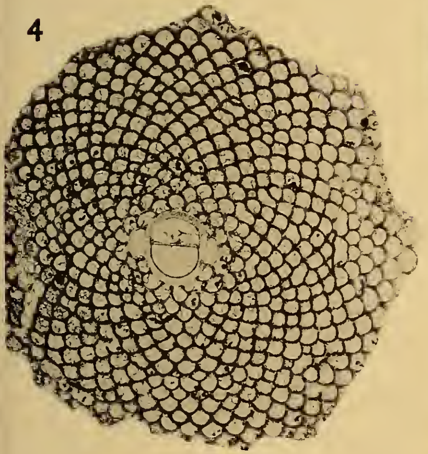

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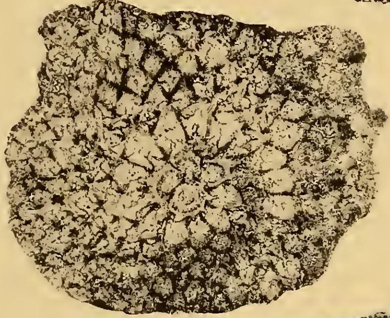

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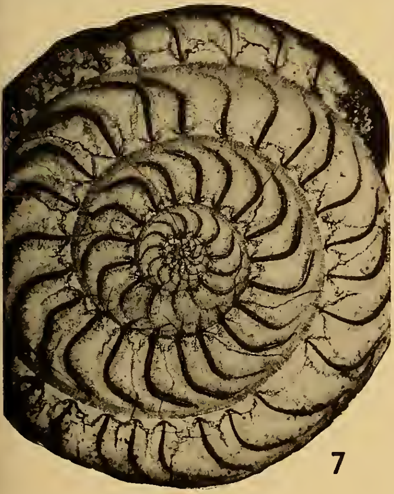

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EMBRYONIC CHAMBERS AND THE SUBGENERA OF LEPIDOCYCLINA

By

W. STORRS COLE
Cornell University

May 18, 1962

Paleontological Research Institution
Ithaca, New York, U.S.A.

Library of Congress Catalog Card Number: GS 62-303

Printed in the United States of America

CONTENTS

With No. 200 of the Bulletins of American Paleontology
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EMBRYONIC CHAMBERS AND THE SUBGENERA OF LEPIDOCYCLINA*

W. Storrs Cole
Cornell University, Ithaca, N. Y.

ABSTRACT

The development of multilocular embryonic chambers in *Lepidocyclina* (*Pliolepidina*) *pustulosa* H. Douvillé (American upper Eocene), in *Lepidocyclina* (*Eulepidina*) *vaughani* Cushman (American upper Oligocene), and in *Lepidocyclina* (*Eulepidina*) *radiata* (Martin) (Indopacific Miocene) is discussed and illustrated by new thin sections. Additional proof is given for placing certain species in the synonomy of *L. radiata.* The key (Cole, 1961, p. 143) to subgenera of the genus *Lepidocyclina* is reviewed and additional proof is given for placing the subgenus *Nephrolepidina* in the synonomy of *Eulepidina.* Finally, an outline of the stratigraphic and geographic distribution of the subgenera of *Lepidocyclina* and the probable evolution of these subgenera is given.

INTRODUCTION

This discourse is a continuation of earlier ones (Cole, 1960; 1961) in which the subgeneric classification of the genus *Lepidocyclina* was analyzed. Since those studies were completed, there has been the opportunity to prepare and examine about 400 additional specimens. Although many of these were studied by grinding to the equatorial plane through one surface of the specimen, all the critical specimens were made into thin sections. A selection of these completed thin sections was photographed and is illustrated on Plates 4-8.

It should be emphasized that this additional study did not produce any new concepts or any desire to revise the subgeneric classification proposed in the earlier articles. However, the new preparations do reinforce conclusions already stated, and these data should be available to other workers.

It is evident that many paleontologists tend to neglect the biology of species, depending upon form alone in developing classifications. Moreover, some of these paleontologists seemingly refuse to accept even a limited degree of plasticity or variation in individuals of a species. Such rigidity has led to the erection of many superfluous specific, subgeneric, and generic names. The literature has become clogged with these names, and basic reasoning has become so entangled in nomenclature that it is impossible to follow the evolution of groups of species through time and space with the emphasis on their biology.

This nomenclatural impasse ultimately will result in specimens from every locality being assigned to a new species and in many cases to a new genus. The basic fact that species are often widely distributed geo-

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* The cost of the printed plates was supplied by the William F. E. Gurley Foundation for Paleontology of Cornell University.

graphically and extend through time becomes submerged. Yet, the paleontologist should be acutely aware of the three dimensional aspects of the problems which he should attempt to solve. Paleontology and nomenclature are not synonymous words! Paleontology is biology, and biology in its broadest sense in which the time element is an important factor. Moreover, ecology and the influence of environment must be continually evaluated as an important factor in any complete paleontologic study.

Although the study of many groups of organisms is restricted by a scarcity of their remains, this is not the case in the study of larger Foraminifera. Those who work with this group of organisms do not have any excuse to confine their observations to a few specimens. There is a splendid chance to study variation, not only in a given population, but also in many populations at the same or other stratigraphic horizons.

There is not only an abundance of specimens with which to work, but also there is a large literature. Study of this group, to proceed in a rational direction, requires that many actual specimens be studied in detail, and that the observations which have been made in the past be fully understood.

The description of new species and new genera is meaningless, and, in fact, detrimental, unless the proper background has been obtained, not only through the examination of the literature, but also by actual observation on many specimens from as many localities as possible.

Thus, an attempt is made in this discourse to enlarge the knowledge of the biology of certain species and interrelate these observations into a system of useable nomenclature in which structures are correlated with the life history of the species. Structures are interpreted rather than accepted as empirical guideposts of a rigid classification.

The specimens used in this study are deposited temporarily in the Cole collection at Cornell University but will be transferred eventually to the U. S. National Musum.

LOCALITIES OF THE FIGURED SPECIMENS

Trinidad

Loc. 1—Vista Bella, San Fernando; upper Eocene; H. G. Kugler, collector, May 1932 (references: Cole, 1960, p. 133; 1961, p. 137).

Loc. 2-4—Soldado Rock; upper Eocene; H. G. Kugler, collector; 2, K 903; 3, K 3677; 4, K 3692 (for location: see map in Kugler, 1938, or Vaughan and Cole, 1941, pl. 2).

Grenada, Windward Islands

Loc. 5—Loose block from stream side near Clozier Bridge at 1135 feet above sea level on the Belvidere Road, Gouyave side; P. Martin-Kaye, collector, locality 4961; upper Eocene (reference: Cole, 1960, p. 133).

Panama Canal Zone

Loc. 6—Río Chilibrillo, 0.6 mile in direct line below bridge on road to Madden Airfield. Medium-grained somewhat calcareous and somewhat tuffaceous sandstone, about 1000 feet above the base of the Caimito formation (Oligocene); W. P. Woodring, collector, loc. 123 (references: Cole, 1953, p. 7; 1961, p. 137; Woodring, 1957, p. 119, no. 69).

Lau, Fiji

Loc. 7—Basal foraminiferal limestone, near western end of western lake, Oneata; altitude about 15 feet; H. S. Ladd collector; Tertiary *f*, Miocene; (references: Ladd and Hoffmeister, 1945, p. 189, locality L 466; Cole in Ladd and Hoffmeister, 1945, p. 274; Cole, 1960, p. 134; 1961, p. 138).

East Borneo

Loc. 8—Exact locality unknown; two microspheric specimens to which were attached by a clay matrix several, small, megalospheric specimens; accompanying label of the Rijks Geolog.—Mineralogisch Museum, Leiden, Holland, had in writing the name *Lepidocyclina luxurians* Tobler; gift of the late Helen Jeanne Plummer.

DEVELOPMENT OF MULTIPLE AND MULTILOCULAR EMBRYONIC CHAMBERS

Although the details of the life history of most species of Foraminifera are unknown, there are sufficient data available concerning those which are known to allow certain inferences to be made about the mechanism of reproduction in species, living and extinct, whose life histories have not been recorded in detail. Cole (1960, p. 134) suggested that "the life history of *Patellina corrugata* may have given a clue to the production of multiple embryonic chambers in certain of the larger Foraminifera."

Myers (1936, p. 138) in his well-documented study of *Spirillina vivipara* Ehrenberg wrote: "Tests having two or more initial chambers have been observed in a number of genera, and in many of these double tests the proloculi are in close proximity, later chambers being so arranged that monsters result, although occasionally a double test is found which appears to have normal symmetry. Such a condition is not surprising when we consider the common origin of their cytoplasm, and the close proximity of the developing young immediately following the multiple fission of the microspheric somatella . . ."

In the development of megalospheric individuals of *Patellina corrugata,* Myers (1943, p. 361) observed: "Protoplasmic differentiation accompanied by the secretion of a test around each nucleus results in twelve megalospheric young which now simultaneously part. Before the individuals of the new sexual generation break free from the multiple fission cyst each is provided with a calcified test consisting of a proloculum and a spiral chamber of about one and three-fourths whorls."

From observations of the kind cited Cole (1960, p. 135) concluded that under certain conditions, following some degree of protoplasmic differentiation around separate nuclei, separation did not occur. This resulted in the formation either of two or more separate, but perfectly formed sets of embryonic chambers, or embryonic chambers which are irregular, deformed, and multilocular.

Cassan and Sigal (1961, pl. 1, figs. 1-4) illustrated and described an equatorial section of a microspheric individual of *Orbitoides media* in which, in the peripheral zone, there are several perfectly formed sets of megalospheric embryonic chambers. In this case protoplasmic differentiation and the formation of some of the megalospheric young occurred within the test of the microspheric individual during asexual reproduction.

Although this incident is seemingly rare in the reproduction of the larger Foraminifera, it is significant when this observation is joined with others which have been made on the life histories of the Foraminifera. It does demonstrate that the megalospheric young do develop in close association with the microspheric individual which is reproducing. Moreover, protoplasmic differentiation during reproduction occurs in the peripheral zone, or outside of the test, and the individual nuclei within the differentiating protoplasmic mass are in close association.

Vaughan (1929, pl. 5, figs. 2-5), Cole and Gravell (1952, pl. 95, fig. 6) and Cole (1960, pl. 4, figs. 4, 5) illustrated discocyclinids from widely separated geographic areas which have multiple sets of perfectly formed megalospheric embryonic chambers. From the Miocene of Guam Island I have a specimen of *Cycloclypeus annulatus* Martin which has two perfectly formed sets of bilocular embryonic chambers in juxtaposition. Several specimens of *Lepidocyclina* are known with two sets of readily recognizable, bilocular embryonic chambers. Their occurrence and citations to the literature will be given in the section which follows.

This review establishes the fact that in the formation of the megalospheric young from a given microspheric parent under certain conditions two or more of the nuclei and the cytoplasm associated with each nucleus do not separate sufficiently to allow discrete individuals to form.

However, individuals which result from the association of two or more nuclei develop after the initial stage similar to those individuals which contain one nucleus. This is demonstrated by examination of equatorial and vertical sections of individuals with two or more sets of embryonic chambers. The internal structures beyond the embryonic chambers are the same as those in other specimens with a single set of embryonic chambers.

MULTIPLE AND MULTILOCULAR EMBRYONIC CHAMBERS IN *LEPIDOCYCLINA*

The first illustration of a specimen of *Lepidocyclina* with two separate, distinct, and perfect sets of embryonic chambers, known to me, is the one published by Zuffardi-Comerci (1929, pl. 9, fig. 22), and identified as "*Lepidocyclina sumatrensis* Brady (anomala)." In this same publication other specimens of *Lepidocyclina* with multilocular embryonic chambers are referred to a new species, *Pliolepidina amoentai* Zuffardi-Comerci (1929, pl. 8, figs. 1, 4, 6, 7, 8). Later, Caudri (1939, p. 228) placed *L.* (*Pliolepidina*) *amoentai* in the synonomy of *L. borneensis* Provale.

Cole (1960, p. 137; 1961, p. 139) demonstrated that *L. borneensis* was a synonym of *Lepidocyclina* (*Eulepidina*) *radiata* (Martin). The specimens illustrated by Zuffardi-Comerci as *L. sumatrensis* and *L. amoentai* have the same internal structures as specimens referred to *L.* (*E.*) *radiata,* and without question should be so identified.

H. Hodson (1926, pl. 7, figs. 4-6) illustrated under the name *L.* (*Polylepidina*) *mirandana* specimens from the District of Miranda, State of Zulia, Venezuela, with multilocular embryonic chambers. At this same locality she (p. 20) recorded specimens of *L. trinitatis* (=*L. pustulosa*).

Without question *L. mirandana* is another synonym of *L. pustulosa,* a relationship recognized by Van de Geyn and Van der Vlerk (1935, p. 239) when they stated that this species is "probably a teratological form of *L. trinitatis*" (=*L. pustulosa*).

L. Rutten (1928, p. 13) described *L.* (*Polylepidina*) *variabilis* from northwestern Peru stating "A single individual displayed an *Isolepidina*-like embr. app.; in all the others the embry. app. consisted of more than 2 chambers, while the number may rise to 11 . . ." His illustrations (figs. 13-15, pl. 1) and text figures 23 *a-h* demonstrate that this species is *L.* (*Pliolepidina*) *pustulosa.* The specimen (*his* fig. 14, pl. 1) has a single set of bilocular embryonic chambers, whereas the other two equatorial sections (*his* figs. 13, 15) have multilocular embryonic chambers of which several in the multilocular mass are of the bilocular type. Rutten's illustrations (figs. 13, 14, pl. 1) should be compared with figures 1, 5, Plate 7.

Vaughan (in Cushman, 1933, p. 284) wrote: "Prof. L. Rutten (1928) has described from 'probably Eocene' of Peru a species under the name *L.* (*Polylepidina*) *variabilis,* and he has been so kind as to send me specimens. This species is not *Polylepidina.* One horizontal section showed double embryonic chambers. . . . There is in this species both the doubling of chambers and 'gigantisme'. It is probable that *Multilepidina* Hanzawa is another instance of 'gigantisme' in *Lepidocyclina.*"

Van de Geyn and Van der Vlerk (1935, p. 247) correctly observed that *L. variabilis* was a synonym of *L. trinitatis* (=*L.* (*Pliolepidina*) *pustulosa*).

Rutten and Vermunt (1932, pl. 2, fig. 9; pl. 3, fig. 4) illustrated two specimens to which they gave the name *Lepidocyclina* (*Polylepidina*) *vanslobbeni* which have two distinct and regularly formed sets of embryonic chambers. At two of the localities from each of which single specimens of this species were found, they recorded the presence of specimens with multilocular embryonic chambers which were identified as *Pliolepidina tobleri.* Later, Vaughan and Cole (1941, p. 67) stated ". . . such a specimen from Curaçao has been given the specific name *vanslobbeni* by M. G. Rutten and Vermunt. The species should bear the name *L. pustulosa,* with *L. tobleri* recognized as a teratologic variant."

Although a complete search of the literature has not been made for other records of *Lepidocyclina* with two distinct and regularly formed sets of embryonic chambers, a sufficient number of publications have been reviewed to demonstrate that this kind of specimen is found only upon occasion.

However, if the concept that ". . . under certain conditions the megalospheric young may not 'simultaneously part'. Therefore, they will produce a multichambered embryonic apparatus" (Cole, 1960, p. 135) is correct, it should be possible to predict that in a given population of individuals, some of which have multilocular embryonic chambers, others will occur with two sets of regularly formed embryonic chambers if a sufficient number of specimens are sectioned.

As only three specimens with two sets of regular embryonic chambers have been reported to-date, the obvious conclusion is that such specimens are extremely rare, and one would be fortunate to encounter such a specimen. However, in the examination of specimens from Oneata, Lau, Fiji (loc. 7) a specimen with two sets (Pl. 4, fig. 1) was encountered. Unfortunately, these sets are not of the regular eulepidine type which other specimens from this locality possess. Although each set is irregular, they are separate and distinct. However, each set is similar to single sets encountered in other individuals (compare: fig. 1 with fig. 2, Pl. 4) from this same locality.

Inasmuch as the same variation in the shape and number of the embryonic chambers which occurred in specimens of *L. radiata* (Cole, 1960, pl. 1) from a single sample from Lau, Fiji, had been found in specimens of *L. vaughani* (Cole, 1961, pls. 12, 13) from a sample from the Oligocene of the Panama Canal Zone, a number of specimens from each of these localities was sectioned. Table 1 presents the data obtained.

Table 1.—Percentage comparison of regular and irregular embryonic chambers in two populations of *Lepidocyclina*

Kind of embryonic chamber	*L. vaughani* (Loc. 6) Number of specimens	%	*L. radiata* (loc. 7) Number of specimens	%
Bilocular	51	85.0	22	78.5
Trilocular	7	11.6	5	17.8
Multilocular	2	3.3	1	3.6
Totals	60	99.9	28	99.9

As the specimens of *L. vaughani* and *L. radiata* have a wide variation in the shape of the embryonic chambers, an attempt is made in Tables 2 and 3 to separate these specimens into groups based upon the shape of the embryonic chambers. The same specimens used in preparing Table 1 were analyzed.

Table 2.—Percentage of specimens of *L. vaughani* (loc. 6) in a single population arranged according to kind of embryonic chambers

Kind of embryonic chamber	Similar to:	number	%
Nephrolepidine (small)	Pl. 5, fig. 6	2	3.3
Nephrolepidine (large)	Pl. 5, figs. 1, 5; pl. 21, fig. 14, Cole, 1953	34	56.6
Eulepidine	Pl. 5, fig. 2; pl. 12, fig. 5, Cole, 1961	11	18.3
Trybliolepidine	pl. 12, fig. 6, Cole, 1961	4	6.6
Trilocular	Pl. 4, figs. 4, 5	7	11.6
Multilocular	pl. 12, fig. 4, Cole, 1961	2	3.3
Totals		60	99.7

Table 3.—Percent of specimens of *L. radiata* (loc. 7) in a single population arranged according to kind of embryonic chambers

Kind of embryonic chamber	Similar to:	number	%
Nephrolepidine	pl. 1, figs. 3, 8, Cole, 1960	7	25.0
Eulepidine	pl. 1, figs. 2, 7, Cole, 1960	7	25.0
Trybliolepidine	pl. 1, fig. 6, Cole, 1960	8	28.5
Trilocular	Pl. 4, fig. 2	5	17.8
Multilocular	pl. 1, fig. 1, Cole, 1960	1	3.6
Totals		28	99.9

Table 4 presents the occurrence of specimens of *L. pustulosa* with regular and irregular embryonic chambers from five localities in the Caribbean area. Fifty specimens were selected at random from each of these samples by my technician. Although he was able to exclude specimens of *Camerina, Asterocyclina,* and other genera which occurred in the samples, he did select specimens of *Helicolepidina.* Therefore, these are included in the table.

At two of the localities specimens of *L. pustulosa* with multilocular embryonic chambers were not found, and at the third locality only one specimen, illustrated as figure 6, Plate 7 was recovered. However, the other two localities had more specimens with multilocular chambers than those with bilocular chambers. Moreover, specimens of *L. pustulosa* with trilocular embryonic chambers similar to those encountered in *L. radiata* and *L. vaughani* have not been observed.

It should be emphasized that in the three species under discussion, specimens have been found in which two sets of multilocular chambers occur (see: for *L. radiata,* Cole, 1960, pl. 1, fig. 1; for *L. pustulosa,* Cole, 1960, pl. 2, fig. 7; and, for *L. vaughani,* Cole, 1961, pl. 12, fig. 4) Such specimens form from two protoplasmic masses, each of which contain several nuclei.

Specimens of *L. pustulosa* with regular bilocular embryonic chambers have little variation in the shape of these chambers, except in size, as shown by figures 1, 3, 4, 6, plate 2 (Cole, 1960) and by figures 3, 4, Plate 6 and figure 4, Plate 7. However, specimens of *L. radiata* and *L. vaughani* have bilocular embryonic chambers which vary from nephrolepidine through trybliolepidine (see: Tables 2 and 3).

Van der Vlerk (1924, p. 19) examined 253 specimens of *Lepidocyclina rutteni* of which he found 244 specimens with trybliolepidine embryonic chambers. The other nine specimens had nephrolepidine, eulepidine, and multilocular embryonic chambers. Although this population had a dominance of specimens with trybliolepidine embryonic chambers, the same variation observed in the populations of *L. radiata* and *L. vaughani* occurred.

Although there is not a sufficient number of specimens available for an analysis, it appears that localities such as those in the Tamavua Quarry at the head of Walu Bay, Vitilevu, Fiji (Whipple, 1934, p. 145) would yield a higher percentage of specimens of *L. radiata* with multiple embryonic chambers than those with bilocular embryonic chambers.

Table 4.—Percentage comparison of specimens of *L. pustulosa* and *Helicolepidina*

Species	Grenada		Trinidad		Soldado Rock					
	(loc. 5)		(loc. 1)		(loc. 2)		(loc. 3)		(loc. 4)	
	Number	%	Number	%	Number	%	Number	%	Number	%
L. pustulosa										
Bilocular embryonic chambers	11	22	10	20	37	74	48	96	7	14
Multilocular embryonic chambers	35	70	24	48	1	2				
Microspheric specimens	1	2	4	8						
H. nortoni	3	6	12	24	12	24	2	4	43	86

The data indicate that the number of individuals in a given population which have multiple embryonic chambers varies from zero to as high as 70 percent. Although a population may be found in which all the individuals have multiple embryonic chambers, the prediction may be made that such a locality will not be found.

Van den Abeele (1949, p. 764) described a new species, *Lepidocyclina* (*Multilepidina*) *wanneri* from Rembang, Java. These specimens have embryonic chambers which are similar to those of *L. radiata,* but the equatorial and lateral chambers are similar to those of *L. rutteni.* From localities closely associated stratigraphically with those from which *L. wanneri* was obtained, Van den Abeele identified *L. rutteni.*

All the evidence indicates that *L. wanneri* is a synonym of *L. rutteni,* as this name was applied to specimens in which multilocular embryonic chambers developed, but are otherwise identical with *L. rutteni.*

Van der Vlerk (1925, p. 24) described a species under the name *Lepidocyclina* (*Pliolepidina*) *stigteri* from Sg. Naintoepo, East Borneo. This species has multilocular embryonic chambers, but otherwise it is similar to *L. ephippioides* Jones and Chapman (=*L. formosa* Schlumberger) which is recorded from the same sample from which *L. stigteri* was recovered. Seemingly, *L. stigteri* represents specimens of *L. ephippioides* with multilocular embryonic chambers.

MECHANISM OF FORMATION OF MULTIPLE EMBRYONIC CHAMBERS

The specimen illustrated as figure 4, Plate 7 has regular bilocular embryonic chambers. This set was formed by a single nucleus and its associated cytoplasm. Figure 5, Plate 7 illustrates a specimen with a gigantic, multilocular, embryonic mass. However, at the lower left side of this mass there is a set of regular bilocular chambers, including associated periembryonic chambers, which are identical with those shown in figure 4, of this same plate. To the right of this set of regular bilocular chambers, there is another set of bilocular chambers which are slightly irregular. This set should be compared with the single set of slightly irregular embryonic chambers (pl. 14, fig. 5, Cole, 1961) published previously.

The large, irregular, multilocular chamber above these two bilocular sets in figure 5, Plate 7 is identical with the embryonic mass of such specimens as the one illustrated as figure 2, plate 15 (Cole, 1961).

This association within an embryonic mass of regular bilocular embryonic chambers in juxtaposition with gigantic multilocular chambers has been shown and discussed previously (Cole, 1960, p. 135, pl. 2, fig. 5; pl. 4, fig. 9).

The interpretation is that several nuclei were involved in formation of these embryonic masses. In the example under discussion (Pl. 7, fig. 5) two of these nuclei were in such a peripheral position that they were enabled to react normally and secrete bilocular embryonic chambers. However, several additional nuclei were so positioned that one irregular chamber was secreted by the relatively large mass of cytoplasm in which these nuclei were incorporated. However, in the three or so areas within this connected mass of cytoplasm in which the nuclei were, individual chambers were formed which correspond to the second chamber of the bilocular kind of embryonic chambers.

Thus, one can visualize a large mass of cytoplasm within which are three or four nuclei and on the border of which are two separate, but small, masses of cytoplasm each of which contained a single nucleus. As the masses reacted under the stimulus of the nuclei to secrete the initial and second chambers, the three distinct areas of this embryonic mass were formed.

Another specimen (fig. 6, Pl. 7) has two distinct sets of bilocular embryonic chambers. In the set to the right the initial chamber is nearly normal, whereas the second chamber is deformed. This deformation was caused by the growth of the initial chamber of the second set (upper left). The initial and second chamber of the second set are both strongly deformed.

The implication is that the set to the right formed slightly more rapidly than did the set to the upper left. Moreover, the set to the upper left was constrained by the development of the equatorial chambers developed by the more rapidly secreting protoplasm of the set to the right. At about this time either the nucleus responsible for the development of the set at the upper left was destroyed or fused with the nucleus responsible for the set of embryonic chambers at the right. From this time the specimen developed normal equatorial and lateral chambers similar in all respects to specimens which possess single sets of bilocular embryonic chambers.

Another specimen (Pl. 7, fig. 1) has a set of only slightly distorted bilocular chambers at the lower right above which occurs a large multilocular chamber. This multilocular chamber is similar to the one illustrated by figure 2, Plate 7 which does not have any bilocular set.

Several specimens have been found in which there is a trilocular embryonic mass (figs. 2, 4, 5, Pl. 4), and one specimen has been found with two separate, and distinct, trilocular masses (fig. 1, Pl. 4). The specimens illustrated as figures 4, 5, Plate 4 should be compared with figures 1, 5, Plate 5 which have bilocular embryonic chambers.

The specimens of *L. vaughani* (figs. 1, 5, Pl. 5) with bilocular embryonic chambers have large, elongate, periembryonic chambers on the periphery of the second chamber. The same elongate kind of periembryonic chambers occur on the periphery (top and bottom, figs. 4, 5, Pl. 4) of the trilocular embryonic apparati.

Thus, one can visualize the specimens with trilocular embryonic chambers starting with a mass of cytoplasm in which there are two nuclei. The irregular central chamber is secreted after which each nucleus, operating independently, causes the second (or embracing chamber in a bilocular embryonic set) to be formed. However, following this, the remainder of the test is constructed as if only one nucleus was involved from the start.

In a similar manner the specimen (fig. 1, Pl. 4) was formed by two separate discrete masses of cytoplasm, in each of which there were two nuclei.

In some populations there is a tendency to form multilocular embryonic masses which have a superficial regularity. Three specimens (figs. 1, 5, Pl. 6; fig. 3, Pl. 5) are illustrated in which there is a large central chamber which is bordered by three or more smaller chambers, but there are zones in which the wall of the large, central chamber is in contact with the equatorial zone (see: lower right and upper center, fig. 5, Pl. 6).

In this same series other specimens (fig. 9, pl. 1, Cole, 1961) have so many smaller chambers on the periphery of the central chamber that its wall is in contact with the equatorial zone only over small areas between the projecting, but almost complete, ring of smaller chambers.

Finally, other specimens (figs. A, B, pl. 22, Cole, 1945) have the large, central chamber surrounded by a complete ring of smaller chambers so that this large central chamber is not in contact with the equatorial layer.

Chambers of this kind are built from a small mass of cytoplasm in which there are a number of nuclei. In these cases the nuclei are so numerous that the entire periphery of the cytoplasm is so crowded by nuclei that the ring of second chambers becomes complete, thereby enclosing the large central chamber.

DISTRIBUTION AND ECOLOGY

Lepidocyclina (*Pliolepidina*) *pustulosa,* a species from the American upper Eocene with individuals with bilocular and multilocular embryonic chambers in association in single populations, is widely distributed from the Caribbean region to Peru. The other American species, *L.* (*Eulepidina*) *vaughani,* in which specimens with multilocular embryonic chambers are authenticated, occurs at numerous localities in the upper Oligocene of the Caribbean region. However, specimens of this species with multilocular embryonic chambers are known to-date only from one locality.

The Indopacific species, *L.* (*Eulepidina*) *radiata,* in which the presence both of bilocular and multilocular embryonic chambers is established, is distributed widely from Indonesia, the Philippine Islands, into Lau, Fiji. This species ranges from Tertiary *e* into Tertiary *f* (Miocene).

There are scattered records which show that other species of *Lepidocyclina,* such as *L. rutteni,* develop multilocular embryonic chambers. Cole (1944, pl. 16, fig. 10) illustrated a specimen of *L. ocalana* Cushman from the Ocala limestone of Florida which has irregular embryonic chambers suggestive of the trilocular kind found in comparative abundance in *L. vaughani* and *L. radiata.*

Although there is indication from the data available that the phenomenon of multilocular embryonic chambers is a common one in *L. pustulosa* and *L. radiata,* seemingly multilocular embryonic chambers do occur infrequently in several other species of *Lepidocyclina.* However, this phenomenon is common and wide spread only in *L. pustulosa* and *L. radiata.*

Inasmuch as multilocular embryonic chambers, even in the two species in which it is common, are known to occur irregularly, it is difficult to assess the basic cause. In a recent study Cole (1960, p. 135) wrote: "It is postulated that under certain ecologic conditions *Lepidocyclina pustulosa* and *L. radiata* form a multiple fission cyst with unusually thick walls in which disassociation of the gamonts is not possible at the proper instant, therefore the gamonts do not separate."

Although the specimens of *L. vaughani* with multilocular embryonic chambers occur at a single locality without associated species, specimens of *L. pustulosa* and *L. radiata* with multilocular embryonic chambers occur at localities with other species and genera.

The genera with which *L. radiata* is associated most commonly are *Camerina* and *Cycloclypeus.* Cole (1957, p. 750) stated concerning

Lepidocyclina-bearing sediments "The best estimate for depth of accumulation of such sediments would be around 25-40 fathoms . . . *Operculina* favors partly protected situations but is more tolerant of greater depth and lower temperature. *Cycloclypeus* flourishes at still greater depths but on the seaward slopes."

Kleinpell (1954, Table 1) recorded the smaller Foraminifera from locality 7 on Oneata, Lau, Fiji, the same locality at which *L. radiata* and *Camerina complanata* occur in abundance. Although he found few species, most of which are rare, he listed *Globigerina bulloides* as frequent.

Although the best indicator of probable depth is *Cycloclypeus,* the composition of the fauna at this locality is suggestive that the water was deeper than that at situations in which *Lepidocyclina* thrived normally. Thus, the postulate may be suggested that populations in which the number of specimens with multilocular embryonic chambers are high were living under marginal conditions. In such populations reproduction was upset which resulted in the formation of multilocular embryonic chambers in many individuals.

Conversely, this interpretation would explain the sporadic geographic and stratigraphic distribution of such specimens, particularly where they are numerous. *Lepidocyclina* in a normal depth environment would develop bilocular embryonic chambers with infrequently an occasional specimen with multilocular embryonic chambers. However, in the situations in which species of *Lepidocyclina* could manage to survive under marginal conditions specimens with multilocular embryonic chambers would be produced in some abundance.

The shape of the test of *L. radiata* (fig. 4, pl. 1, Cole, 1960) is similar to that of *L. vaughani* (figs. 6-10, pl. 21, Cole, 1953). The test has a small pronounced umbo bordered by a wide thin flange which consists mainly of the equatorial layer. This kind of test could not survive unbroken on bottoms in which there was any wave or current activity. However, it is admirably shaped to conform to deeper water sediments.

Some specimens of *L. radiata* have faint rays across the flange (fig. H, pl. 28, Cole, 1945), whereas other specimens (figs. 3, 6, pl. 19, Whipple, 1934) have strong surface rays. Whipple (1934, p. 148) found that specimens with the strong rays have bilocular embryonic chambers. Specimens with weak rays have either bilocular embryonic chambers or multilocular ones.

Cole (1961*a*, p. 392) suggested that "Stellate specimens of *L.* (*L.*)

canellei are associated commonly with abundant specimens of *Heterostegina,* and seemingly are developed in the situations which are optimum for the development of *Heterostegina.*" In this connection Cole (1961*a*, p. 391) noted that "The average depth at which *Heterostegina* occurred in the vicinity of Bikini and the Philippine Islands was 25 to 32 fathoms."

If these observations have any validity, the individuals of *L. radiata* with strong rays would be the ones from a shallower water environment, and those with weak rays or without rays would occupy the deeper water situation.

This analysis of test form may not be proof positive of the environment, but this theory does supplement and correlate with the observation that the specimens with multilocular embryonic chambers lived under adverse conditions for normal reproduction, in this case because of the depth of the water.

THE SPECIES WHICH ARE ILLUSTRATED

Although most of the specimens which are illustrated have been discussed, certain ones which are not mentioned have been introduced for completeness. This is particularly true of the vertical sections which do show the structure of the test but are not essential to the thesis of this discourse except to demonstrate that beyond the embryonic chambers the structure of the test is normal.

A summary of the species which are illustrated follows:

Lepidocyclina (*Pliolepidina*) *pustulosa* H. Douvillé
Pl. 5, fig. 4; Pl. 6, figs. 2-4; Pl. 7, figs. 1-6; Pl. 8, figs. 1, 2, 4-8
Lepidocyclina (*Eulepidina*) *radiata* (Martin)
Pl. 4, figs. 1-3; Pl. 5, fig. 3; Pl. 6, figs. 1, 5; Pl. 8, fig. 3
Lepidocyclina (*Eulepidina*) *vaughani* Cushman
Pl. 4, figs. 4, 5; Pl. 5, figs. 1, 2, 5, 6

COMMENTS ON LEPIDOCYCLINA BORNEENSIS

Provale (1909, p. 74) described under the name *Lepidocyclina tournoueri borneensis,* a species which has been recorded since that time from many Indonesian localities as *Lepidocyclina borneensis.* She illustrated four specimens, one of which is a vertical section, and the other three are equatorial sections. One of these equatorial sections (*her* pl. 3, fig. 17) has nephrolepidine embryonic chambers, another (*her* pl. 3, fig. 18) has trilocular embryonic chambers, and the third (*her* pl. 3, fig. 19) has multilocular embryonic chambers.

The specimen (*her* pl. 3, fig. 18) with trilocular embryonic chambers should be compared with the specimen from Oneata, Lau, Fiji, illustrated as figure 2, Plate 4, and the specimen (*her* pl. 3, fig .19) should be compared with the specimen from Borneo illustrated as figure 1, Plate 6. The only difference between any of the specimens, here assigned to *L. radiata,* and the types of *L. borneensis* is that most of the specimens from Fiji have slightly more elongate equatorial chambers, particularly in the peripheral zone.

However, the equatorial chambers of the specimens from Fiji near the center of equatorial sections are identical with those of *L. borneensis.* Moreover, the fundamental pattern of the equatorial chambers of the specimens from Fiji, even in the peripheral zone, is the same as that of *L. borneensis* except the chambers are more radially elongate.

Scheffen (1932, pl. 8, fig. 2) and others illustrated specimens of *L. borneensis* which have in the peripheral zone radially elongate equatorial chambers.

As the degree of elongation of equatorial chambers is known to vary within a given equatorial section, probably in response to the supply of food or some such factor, such a variation can not be used as a specific character.

Detailed analysis of the internal structure of specimens assigned previously to *L. borneensis* caused Cole (1960, p. 137) to consider *L. borneensis* a synonym of *L. radiata,* a conclusion which is still maintained.

L. borneensis has been long known (Van der Vlerk, 1928, p. 192) to range from Tertiary *e* into Tertiary *f* in Indonesia, but the types from Borneo are from Tertiary *e.* Provale (1909, p. 95) listed *Lepidocyclina formosa* (=*L. ephippioides*), a species seemingly confined to Tertiary *e,* from the type locality of *L. borneensis.*

L. radiata and *L. luxurians* (=*L. radiata*) were both recorded as Tertiary *e* species (Van der Vlerk, 1928, p. 199, 202), but Mohler (1949, p. 526) gave the stratigraphic range of *L. luxurians* as upper Tertiary *e* and lower Tertiary *f.*

Whipple (1934, p. 150) found *L. radiata* in Vitilevu, Fiji, in association with *Cycloclypeus annulatus,* a Tertiary *f* species, and Cole (1945, p. 275) assigned the localities in Lau, Fiji, at which *L. radiata* was found to Tertiary *f.*

Thus, under the several names (Cole, 1960, p. 137) which have been given to *L. radiata,* this species, as redefined, is one which in the Indo-pacific area has a stratigraphic range from Tertiary *e* into Tertiary *f*. Its exact stratigraphic position at a given locality can be determined only when it is accompanied by species with shorter stratigraphic ranges.

COMMENTS ON SOME MICROSPHERIC SPECIMENS

Large microspheric specimens, identified as *Lepidocyclina papulifera* H. Douvillé, were found in Lau, Fiji, (Cole, 1945, p. 295) in association with megalospheric specimens identified as *L.* (*Eulepidina*) *transiens* Umbgrove and *L.* (*E.*) *oneataensis* Cole. Later, Cole (1960, p. 137) suggested both of these species, based upon megalospheric specimens, were synonyms of *L. radiata* (Martin).

Inasmuch as the equatorial and lateral chambers of *L. papulifera* are the same as those of *L. radiata*, and at most localities in Lau, Fiji, only one megalospheric kind was found with the specimens indentified as *L. papulifera*, these microspheric specimens represent the sexual generation of *L. radiata*. Thus, *L. papulifera* H. Douvillé, 1916, is another synonym of *L. radiata* (Martin), 1880.

Van der Vlerk (1928, p. 201) reported that *L. papulifera* occurred with *L. radiata* at Rembang, Java. Whipple (1934, p. 150) recorded *L. papulifera* from Vitilevu, Fiji, in association with *L. radiata*. Yabe and Hanzawa (1929, p. 167) found *L. luxurians* (=*L. radiata*) in the Philippines, and illustrated (pl. 21, fig. 7) a part of a thin section with two megalospheric specimens of *L. luxurians* and a much larger microspheric specimen, identified questionably as *L. richthofeni*. This specimen is probably the same as similar microspheric specimens elsewhere which have been identified as *L. papulifera*.

Thus, it would appear that at most localities at which *L. radiata* has been found, it is either directly associated with microspheric specimens of the kind known as *L. papulifera*, or these specimens have been reported from adjacent beds to those in which *L. radiata* occurred. These occurrences may be accepted as additional proof that these microspheric specimens, known under the name *L. papulifera*, represent the sexual generation of *L. radiata*.

OBSERVATIONS ON THE SUBGENERIC CLASSIFICATION OF *LEPIDOCYCLINA*

There has been and continues to be confusion in the use of subgeneric names in *Lepidocyclina*. In part this has been the result of a lack of understanding of the life history of certain species. This is exemplified by the introduction of such subgeneric names as *Multilepidina.* Eames *et al* (1960, p. 680) wrote: "We redefine the relevant genera and restrict *Pliolepidina* to forms congeneric with *Multilepidina.*"

If the arguments advanced previously in this article, supported by abundant preparations, are accepted, the specimens with multilocular embryonic chambers can not be classified as a distinct, recognizable subgenus, restricted to a limited stratigraphic position. Instead, these multilocular specimens are only one form of species which belong to different subgenera and occur irregularly at different stratigraphic horizons.

Likewise, other authors seemingly are not cognizant of certain facts which have been well established in the literature and to which correct interpretations have been given. As such oversights add more confusion to an already involved understanding of the subgeneric definitions, a recent article by Chatterji (1961), in which he argued that complexity of the equatorial layer in the peripheral zone is restricted to, and, in part, characterizes *Trybliolepidina,* is discussed.

Cushman (1918, p. 96) proposed the subgeneric name *Multicyclina,* the type of which is *Lepidocyclina duplicata* Cushman, for those lepidocyclines ". . .differing from typical *Lepidocyclina* in the equatorial chambers which instead of being a single series become complex toward the periphery and may consist of several series." The types of *L. duplicata* are microspheric specimens obtained from USGS loc. 6523, two miles north of David, Panama. At this same locality Cushman (1918, p. 94) reported abundant specimens of *Lepidocyclina macdonaldi* Cushman ". . . occurring with *L. panamensis* and *L. duplicata.*"

In 1924 Vaughan (p. 796) suggested that *Lepidocyclina duplicata* was the microspheric generation of associated megalospheric specimens which Cushman had identified as *L. panamensis,* and he correctly assigned these microspheric and megalospheric specimens to the subgenus *Pliolepidina.* Later, Vaughan and Cole (1941, p. 66) demonstrated that *L. duplicata* and *L. panamensis* were synonyms of *L.* (*Pliolepidina*) *pustulosa* H. Douvillé, 1917. They (Vaughan and Cole, 1941, figs. 1-3, pl. 27) illustrated specimens from Trinidad with multiple equatorial chambers in the peripheral zone.

Yet, Chatterji (1961, p. 423), in spite of the long established proof of the occurrence of multiple equatorial chambers in *Pliolepidina,* wrote in defense of retaining the subgenus *Trybliolepidina* ". . .there are found several layers of equatorial chambers instead of a single layer as in *Nephrolepidina* and all other subgenera."

The phenomenon of peripheral multiple equatorial chambers not only occurs in species assigned to the subgenus *Pliolepidina,* but also in species assigned to other subgenera of *Lepidocyclina,* [for example, in L. (*Eulepidina*) *vaughani* (see: Cole, 1953, pl. 21, fig. 6, top; fig. 10), a species traditionally assigned to the subgenus *Nephrolepidina* until Cole (1961, p. 141) demonstrated that *Nephrolepidina* was a synonym of *Eulepidina*].

Another species, which has multiple equatorial chambers in the peripheral zone, is *L.* (*Pliolepidina*) *gubernacula* Cole (1953, pl. 8, fig. 14) from the upper Eocene of the Panama Canal Zone.

Moreover, Chatterji (1961, p. 422), in retaining *Trybliolepidina,* ignored the opinion of Grimsdale and Van der Vlerk (1959, p. 6) that ". . .*Trybliolepidina* is synonymous with *Eulepidina,* so *Trybliolepidina* should be rejected as a subgenus." Caudri (1934, p. 119) previously wrote: ". . .Tan and Van der Vlerk still regard the form of the nucleoconch as an important characteristic, on which the classification may be based, in other words, they both maintain *Trybliolepidina* as a subgenus. Tan's classification of subgenera is very loose as he lets the decision. . . depend upon the numerical majority of specimens with nephrolepidine or trybliolepidine nucleoconch within the species. . . apart from the want of accurancy of such a method of determination, it is undesirable to make use of such undecided characteristics in classification. . . In my opinion all the smaller nephrolepidine or trybliolepidine . . . belong to one group . . . "

Most of the specimens illustrated by Chatterji (1961) are identified incorrectly. Specimens designated *Lepidocyclina* (*Nephrolepidina*) *borneensis* Provale are not that species but are, without question, *Lepidocyclina* (*Eulepidina*) *sumatrensis* (Brady). The specimens identified as a new species, *L.* (*Trybliolepidina*) *raoi,* are *L.* (*Eulepidina*) *rutteni* Van der Vlerk.

In 1960 (Cole, p. 138) a reduction in the number of subgenera of *Lepidocyclina* was proposed. This was based on the assumption that the multilepidine kind of megalospheric embryonic chamber could be associated with the bilocular kind and that the nephrolepidine and eulepidine kinds were intergradational. Later, a key to the valid subgenera (Cole, 1961, p. 143) was given. This key was based on the shape of the embryonic chambers, the periembryonic chambers, and the equatorial chambers.

As the most radical departure from the more or less accepted traditional subdivision of *Lepidocyclina* into subgenera was the suppression of the subgeneric name *Nephrolepidina,* a brief discussion of the type species of *Eulepidina* follows, as the proposed classification placed *Nephrolepidina* in the synonomy of *Eulepidina.*

R. Douvillé, as early as 1907 (p. 53), noted and commented on the variable shape of the embryonic chambers of *L. dilatata,* the type of the subgenus *Eulepidina.* His drawings (text figs. 1, 2, 3, 8) show variation from the kind of embryonic chambers (fig. 6) accepted as eulepidine by later authors to trybliolepidine (fig. 1), and to nephrolepidine (fig. 8). Brönnimann (1940, pl. 6, figs. 6, 7) illustrated two specimens of *L. dilatata,* one of which (fig. 6) has eulepidine embryonic chambers, and another which (fig. 7) has nephrolepidine embryonic chambers. Thus, the type species of the subgenus *Eulepidina* conforms to *Eulepidina,* redefined (Cole, 1960, p. 138; 1961, p. 142).

In the proposed four-fold-classification of subgenera of *Lepidocyclina* a decision that may cause some confusion is the distinction between *Pliolepidina* and *Lepidocyclina, s. s.* Species of these subgenera have equal to subequal embryonic chambers which somewhat resemble each other.

However, the periembryonic chambers of *Pliolepidina* are large, distinct and easily observed in well-oriented equatorial sections (figs. 3, 4, Pl. 6), whereas the periembryonic chambers in *Lepidocyclina, s. s.* are always much smaller and are observed in most sections with difficulty. Additionally, all known species of *Lepidocyclina, s. s.* have equatorial chambers in the peripheral zone which are hexagonal. This kind of equatorial chamber does not occur in *Pliolepidina.*

If the key (Cole, 1961, p. 143) is used properly, species may be separated readily into four categories representing the evolutionary development within the genus *Lepidocyclina.* Moreover, the subgenera have validity in stratigraphic determinations. Thus, it is desirable on these two counts to maintain them.

The distinctive subgenus *Polylepidina* is confined to the American middle Eocene. *Pliolepidina* ranges in America from upper middle Eocene through the upper Eocene and is a modification of *Polylepidina* by a reduction of the distinct coil of large periembryonic chambers which characterize *Polylepidina.*

Pliolepidina in the American upper Eocene gave rise to such species as *Lepidocyclina chaperi* whose embryonic chambers, considered alone, vary from nephrolepidine (Cole, 1953, pl. 10, fig. 8) to eulepidine (Cole, 1953, pl. 10, fig. 10) to nearly lepidocycline, *s. s.* (Cole, 1953, pl. 10, fig. 4).

The *L. chaperi* kind of embryonic apparatus characterizes the basic lineage of the subgenus *Eulepidina* (*Nephrolepidina* and *Eulepidina* combined). This subgenus in the Americas extends from the upper Eocene to the top of the Oligocene.

Lepidocyclina, s. s. is an offshoot of the *Eulepidina* lineage developed in the American lower Oligocene and ranges from near the base of the American Oligocene into the lower Miocene.

Polylepidina and *Lepidocyclina, s. s.* are geographically restricted to the Americas, but *Pliolepidina* has been reported from the upper Eocene of Morocco (Bourcart and David, 1933, p. 48; Brönnimann, 1940, p. 37). The species which they described under the name *L.* (*Isolepidina*) *mauretanica* so closely resembles *L.* (*Pliolepidina*) *pustulosa* from the upper Eocene of the Carribbean region that it may prove to be a synonym of *L. pustulosa.*

All of the European and Indopacific species of *Lepidocyclina* in the Oligocene and Miocene, known to-date, belong to the subgenus *Eulepidina.* Certain of these European and Indopacific species have individuals, some of which have nephrolepidine embryonic chambers, whereas other individuals of the same species have eulepidine embryonic chambers. In addition, other populations occur in which all the individuals either have nephrolepidine or eulepidine embryonic chambers.

This same variation is found in populations in the Americas. But, the occurrences of "pure kinds" either of nephrolepidine or eulepidine embryonic chambers at certain localities does not invalidate the combination of these two subgenera. A sufficient number of species are known in which intergradation occurs to prove the correctness of this observation.

Although *Eulepidina* has embryonic chambers which are variable in shape, those of *Polylepidina, Pliolepidina,* and *Lepidocyclina, s. s.* are remarkably constant. However, one structure of the equatorial layer is not sufficient to determine the subgenus. The shape of the embryonic chambers is only suggestive. To this, must be coupled the size and arrangement of the periembryonic chambers and the shape of the equatorial chambers if the subgenus is to be identified correctly.

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PLATES

EXPLANATION OF PLATE 4

Figure Page

1-3. **Lepidocyclina (Eulepidina) radiata** (Martin) 35, 36

1. Part of an equatorial section, X40, of a megalospheric specimen with two, separate sets of trilocular embryonic chambers.

2. Part of an equatorial section, X20, of a megalospheric specimen with a single set of trilocular embryonic chambers.

3. Vertical section, X20, of a megalospheric specimen previously identified as *L. luxurians* Tobler.

4, 5. **Lepidocyclina (Eulepidina) vaughani** Cushman 36, 41, 44

4, 5. Parts of equatorial sections, X40, of megalospheric specimens with trilocular embryonic chambers.

1, 2. Loc. 7, (Miocene)
see text for locality descriptions.

3. Loc. 8, (Miocene).

4, 5. Loc. 6, (upper Oligocene).


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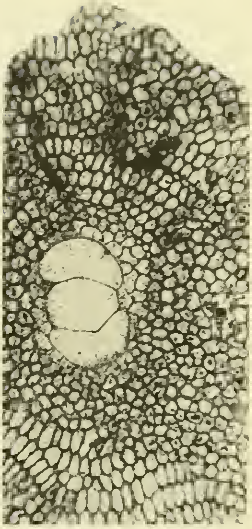
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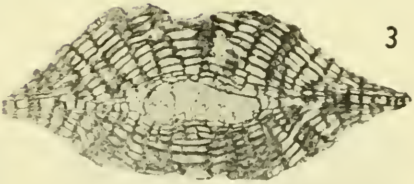
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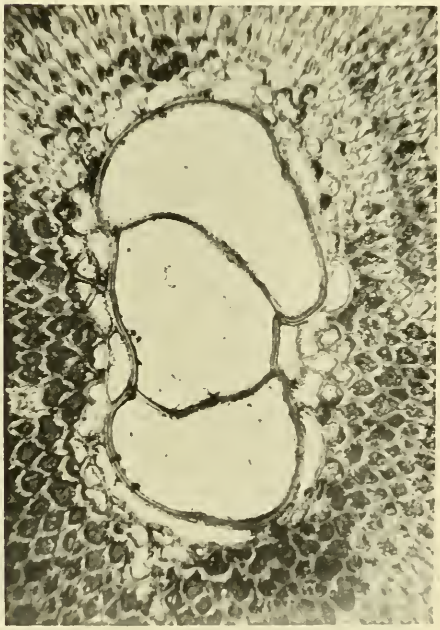
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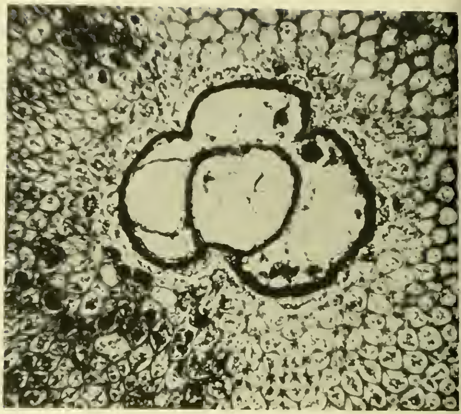

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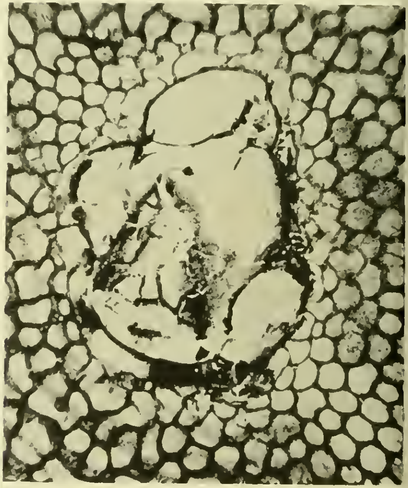

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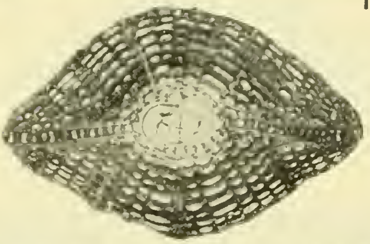

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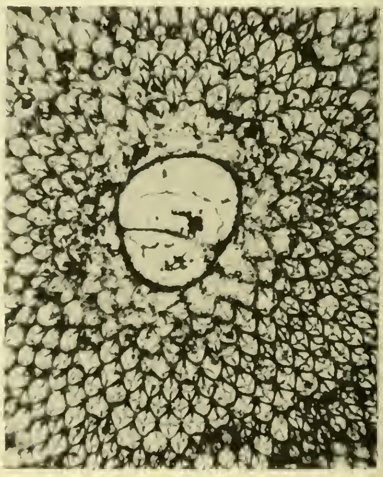


6

EXPLANATION OF PLATE 5

Figure Page

1, 2, 5, 6. **Lepidocyclina (Eulepidina) vaughani** Cushman..................36-41, 44

1. Part of an equatorial section, X40, of a megalospheric specimen with large, regular eulepidine embryonic chambers.
2. Part of an equatorial section, X40, of a megalospheric specimen with deformed eulepidine embryonic chambers.
5. Part of an equatorial section, X40, of a megalospheric specimen with large, slightly deformed embryonic chambers.
6. Part of an equatorial section, X40, of a megalospheric specimen with small eulepidine embryonic chambers in which the second chamber does not embrace the initial chamber.

3. **Lepidocyclina (Eulepidina) radiata** (Martin)..........................35, 36

Part of an equatorial section, X40, of a megalospheric specimen previously identified as *L. luxurians* Tobler with multilocular embryonic chambers.

4. **Lepidocyclina (Pliolepidina) pustulosa** H. Douvillé......................37

Vertical section, X20, of a megalospheric specimen with bilocular embryonic chambers.

1, 2, 5, 6. Loc. 6, (upper Oligocene)
see text for locality descriptions.

3. Loc. 8, (Miocene).

4. Loc. 1, (upper Eocene).

EXPLANATION OF PLATE 6

Figure Page

1, 5. **Lepidocyclina (Eulepidina) radiata** (Martin) 44

Parts of equatorial sections, X40, of megalospheric specimens with multilocular embryonic chambers previously identified as *L. luxurians* Tobler.

2-4. **Lepidocyclina (Pliolepidina) pustulosa** H. Douvillé 38, 44

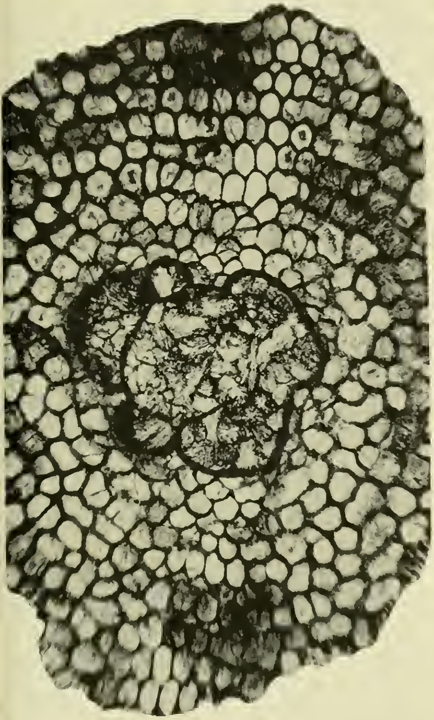
2. Part of an equatorial section, X40, of a megalospheric specimen with multilocular embryonic chambers.
3. Part of an equatorial section, X40, of a megalospheric specimen with normal size, bilocular embryonic chambers.
4. Part of an equatorial section, X40, of a megalospheric specimen with large, bilocular embryonic chambers.

1, 5. Loc. 8, (Miocene)
see text for locality descriptions.

2. Loc. 5, (upper Eocene).

3. Loc. 3, (upper Eocene).

4. Loc. 2, (upper Eocene).



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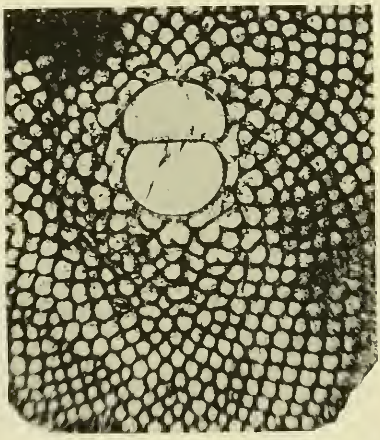

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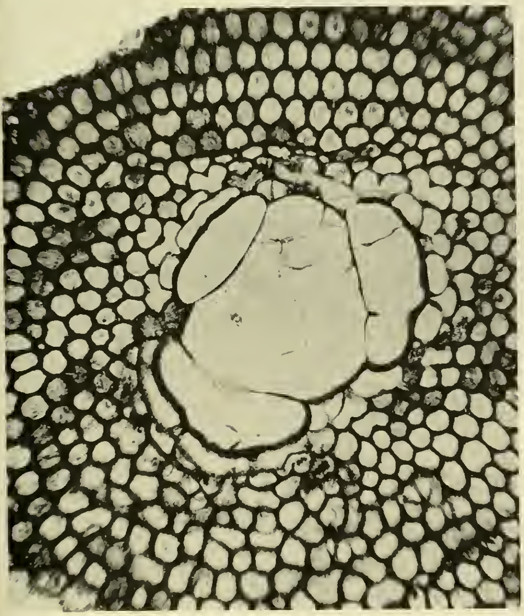

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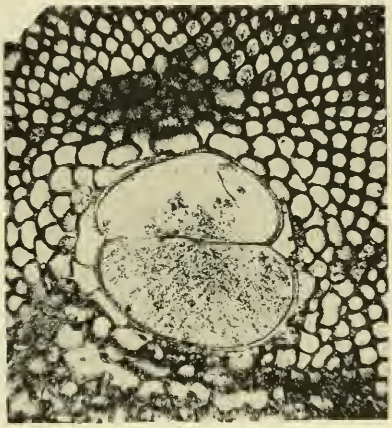

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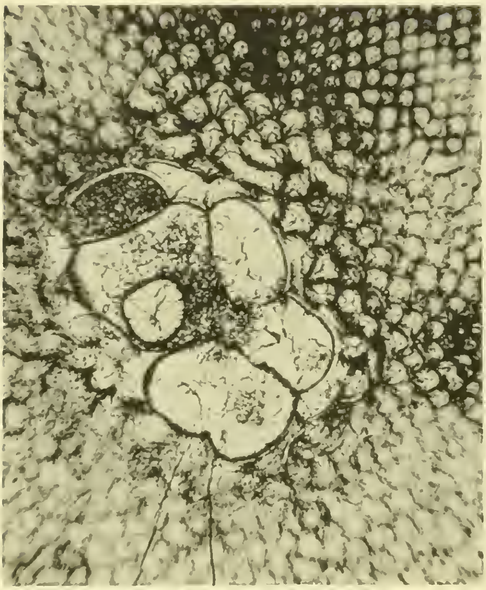

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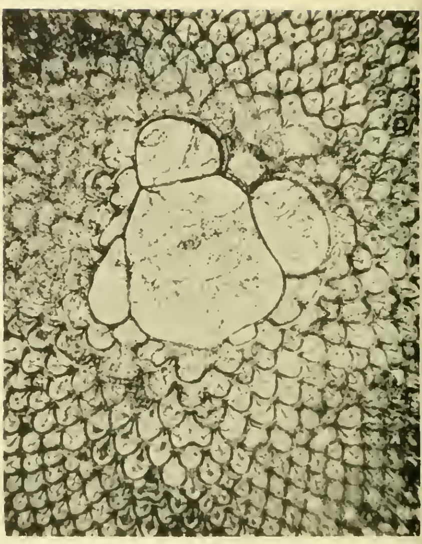

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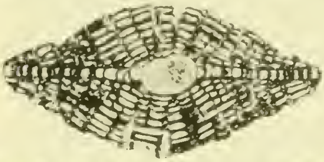

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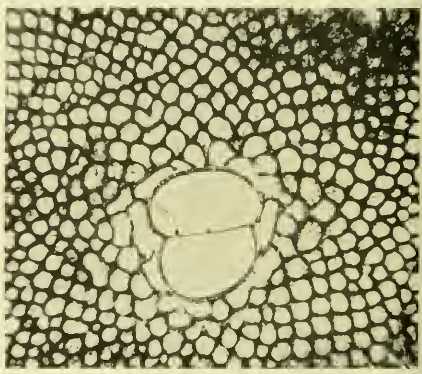

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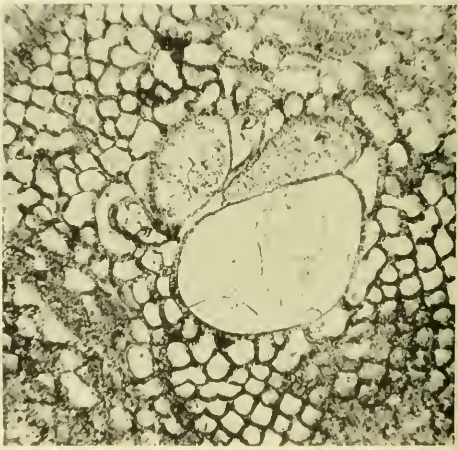


EXPLANATION OF PLATE 7

Figure		Page
1-6.	**Lepidocyclina (Pliolepidina) pustulosa** H. Douvillé	37-40, 44

1. Part of an equatorial section, X40, of a megalospheric specimen with multilocular embryonic chambers; especially note the slightly deformed, bilocular set at the lower right, and the multilocular mass at the upper left which is similar to the embryonic chambers of figure 2, this plate.
2. Part of an equatorial section, X40, of a megalospheric specimen with multilocular embryonic chambers.
3. Vertical section, X20, of a megalospheric specimen with bilocular embryonic chambers.
4. Part of an equatorial section, X40, of a specimen with bilocular embryonic chambers; compare these with the bilocular set at the lower left of figure 5, this plate.
5. Part of an equatorial section, X40, of a megalospheric specimen with two sets of bilocular embryonic chambers and an elongate, multilocular, embryonic chamber.
6. Part of an equatorial section, X40, of a megalospheric specimen with two separate sets of bilocular embryonic chambers, one of which (right side) is slightly deformed and the other (upper left) is badly deformed.

1, 2, 5. Loc. 1, (upper Eocene)
see text for locality descriptions.

3, 6. Loc. 2, (upper Eocene).

4. Loc. 3, (upper Eocene).

EXPLANATION OF PLATE 8

Figure Page

1, 2, 4-8. **Lepidocyclina (Pliolepidina) pustulosa** H. Douvillé........................44

1, 8. Parts of equatorial sections, X40, of megalospheric specimens with multilocular embryonic chambers which have bilocular embryonic chambers incorporated in parts of the periphery of the large central chamber.

2, 4, 5, 7. Vertical sections, X20, of megalospheric specimens with multilocular embryonic chambers to show variation in shape.

6. Vertical section, X20, of a megalospheric specimen with bilocular embryonic chambers.

3. **Lepidocyclina (Eulepidina) radiata** (Martin)..................................44

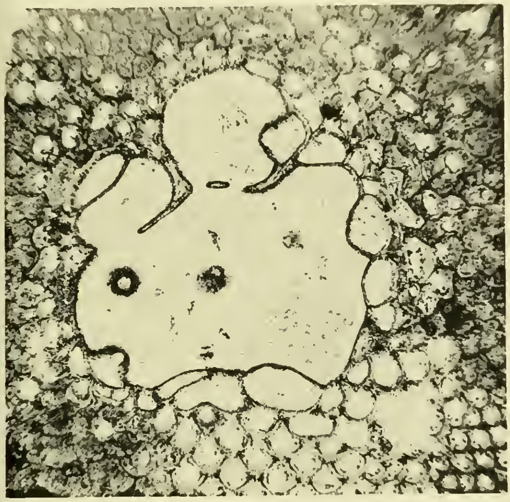
Vertical section, X40, of a small specimen previously identified as *L. luxurians* Tobler.

1, 8. Loc. 5, (upper Eocene)
see text for locality descriptions.

2, 4, 5, 7. Loc. 1, (upper Eocene).

3. Loc. 8, (Miocene).

6. Loc. 3, (upper Eocene).



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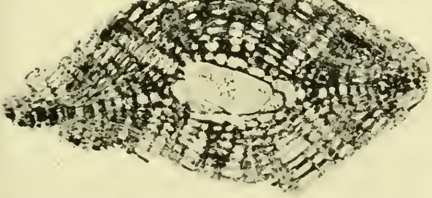

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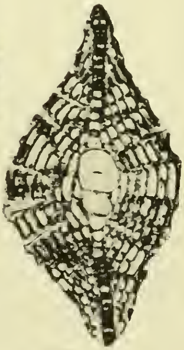

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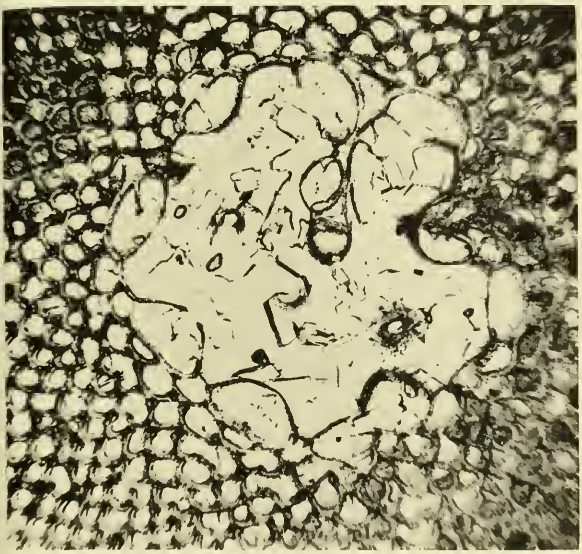

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NUMBER 201

1962

PALEONTOLOGICAL RESEARCH INSTITUTION
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Vol. 44

No. 201

THE DISTRIBUTION OF FORAMINIFERA OFF PARTS OF THE ANTARCTIC COAST

By

W. M. McKnight, jr.

August 27, 1962

Paleontological Research Institution
Ithaca, New York, U.S.A.

Library of Congress Catalog Card Number: GS 62-304

Printed in the United States of America

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THE DISTRIBUTION OF FORAMINIFERA OFF PARTS OF THE ANTARCTIC COAST

W. M. McKnight, Jr.

ABSTRACT

This study deals with the Foraminifera found in 28 cores collected from marine waters around Antarctica. One hundred thirty-three species of Foraminifera were identified and 18 additional species given letter designations. The species included 67 genera, many of which are confined to the Antarctic area.

Twenty species were tested statistically in an effort to ascertain their dependency on mean grain size, sorting of the sediment, water depth, and organic carbon. There were more species that tested significant to the standard deviation than any other parameter tested. The author interprets this as a dependency on current-supplied nutrients. Water depth seems to have little effect upon those species tested.

ACKNOWLEDGMENTS

The author is indebted to Dr. Lyman D. Toulmin, Professor of Paleontology at Florida State University, who directed the study, verified the identification of species, read the manuscript, and offered constructive criticisms. In addition, the author wishes to express gratitude to the United States Hydrographic Office for making available the sediment samples examined in this study. Financial support was given by the Antarctic Branch of the National Science Foundation, without which this study would not have been possible. Grateful acknowledgment is given Dr. H. G. Goodell for providing compilations of sediment characteristics and for valuable advice given in the statistical analysis of the data. Dr. S. K. Katti and Mr. Don Martin also materially aided the statistical analysis. The author is also indebted to Mr. C. H. Hickcox, Department Head of Centenary College of Louisiana, for furnishing a microscope for this study. Mrs. Roy K. Garman has drawn the foraminiferal illustrations, and for her work the author is deeply indebted. Thanks are expressed to Dr. Donn S. Gorsline, Dr. John K. Osmond, and Dr. H. G. Goodell for their constructive criticisms of the manuscript.

INTRODUCTION

PURPOSE

The purpose of this study is to examine the distribution of the Foraminifera found in 28 cores taken by the United States Navy. These cores were collected during the 1958-1959 International Geophysical Year as part of the Deep Freeze IV project. It is the author's intent to study the distribution of the Foraminifera with respect to the following five major factors of ecology: depth, temperature, salinity, sediment type, and geographic location. General consideration of surface and bottom currents are also to be considered.

LOCATION

The general area under investigation is contained south of the convergence around the continent of Antarctica, between water depths of 164 and 2,995 meters. Core samples were taken from the Ross Sea area, Weddell Sea area, off the Balleny Islands, off Wilkes Land, off Queen Maud Land, and adjacent to the Palmer Peninsula (Fig. 1 and Fig. 2). Table 1 gives the latitude, longitude, and water depth of each station.

PREVIOUS WORK IN THE AREA

THE CHALLENGER EXPEDITION, 1873-76

H. M. S. "Challenger", during its voyage around the world, visited parts of Antarctica in 1874. There were two deep-water sediment samples taken at longitude 79°49′E, latitude 65°42′S, in a depth of 1,675 fathoms; at longitude 94°47′ E, latitude 64°18′S, in 1,300 fathoms. These samples consisted of "mud with rocks and pebbles." H. B. Brady identified 40 species of Foraminifera from the 1,675 fathom sample.

THE GERMAN SOUTH POLAR EXPEDITION, 1901-03

The expedition's reports described Foraminifera found in collections made during the voyage of the "Gauss". The ship's route was to and from Antarctica via Kerguelen Island. Wiesner completed and published in 1931 the work started by Rhumbler on the material from this expedition. Wiesner did not include a map or a listing of the stations; however, Earland (1935) made an analysis of Wiesner's report in conjunction with an earlier report and stated,

> Of the 371 species and varieties, 216 were found on the Continental Shelf and Slope, and fifty-two others in the deep water of the Indo-Antarctic basin, but not on the slope. The balance are sub-Antarctic (Kerguelen, etc.), tropical (Cape Verde) and Pelagic.

THE SCOTIA EXPEDITION, 1903-04

The Scottish National Antarctic Expedition, 1903-04, under the direction of Dr. W. S. Bruce, took bottom samples from the Falk-

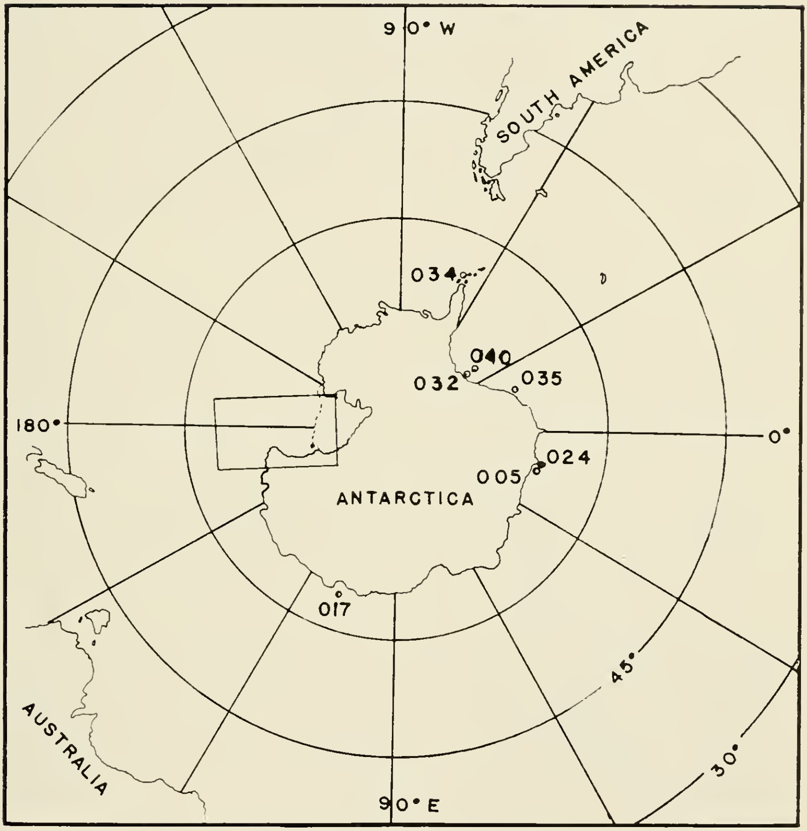

Figure 1. General Sample Locations.

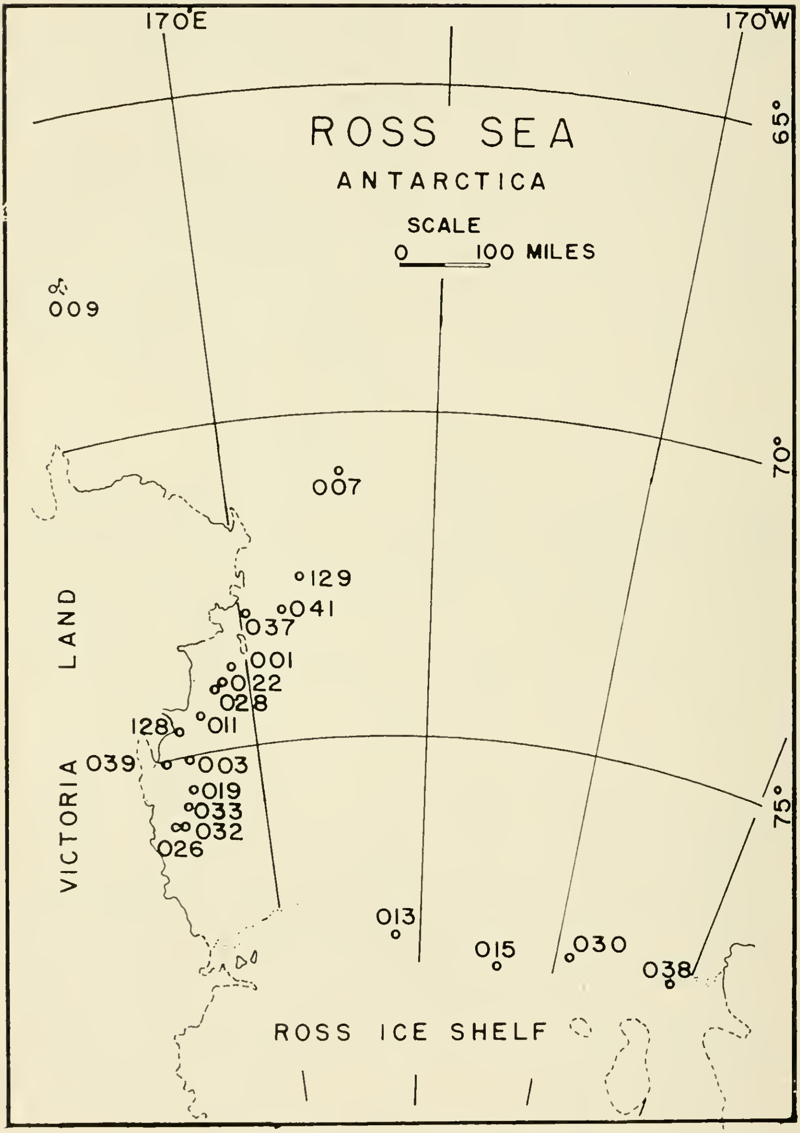

Figure 2. Ross Sea Sample Locations.

land Islands south through the South Orkneys and into the Weddell Sea. F. G. Pearcey (1914) published a report on the Foraminifera found in the expedition collections. He described a rich fauna of 267 species, 11 of which were new. Pearcey's report dealt with Foraminifera both inside and outside of the Antarctic area. He reported that the Antarctic fauna is richer south of 70°S in the Weddell area. Of the 267 species described in Pearcey's report, 83 were reported from the Antarctic area. Pearcey did not record any *Miliammina* or arenaceous species of *Miliolina,* using terminology frequently followed in older publications.

THE TERRA NOVA EXPEDITION, 1910

The Foraminifera in samples from the "Terra Nova" Expedition were studied and described in 1922 by F. E. Heron-Allen and Arthur Earland. This expedition dealt with that section of the Antarctic Ocean between New Zealand and the Ross Sea. It is difficult to establish a definite number of Antarctic species reported in this report, because of the vast extent of the Terra Nova area of investigation, but if the deep water stations from the outer edge of the New Zealand continental slope are assumed to represent Antarctic types, there are slightly more than 350 species reported.

THE AUSTRALASIAN ANTARCTIC EXPEDITION, 1911-14

Antarctic dredgings of the Australasian Expedition were taken between longitudes of 90°16′E and 145°35′E. The Foraminifera were identified by Frederick Chapman and Walter J. Parr. Their report described 342 species from the samples examined.

B. A. N. Z. ANTARCTIC RESEARCH EXPEDITION, 1929-31

During this expedition, 13 sediment samples were taken between the latitudes of 49°37′E and 138°28′E, in depths ranging from 177 to 1,718 meters. W. J. Parr identified 82 genera with 196 species and varieties. He found 77 arenaceous, 21 porcellaneous, and 98 perforate calcareous forms.

BAY OF WHALES, ROSS SEA, 1939

In 1939 A. S. Warthin, Jr. published a paper on the Foraminifera collected from a 1,680-foot sounding in the Bay of Whales (latitude, 78°34′S; longitude, 163°48′W.) He noted about 350 identifiable specimens representing 37 different species. Warthin found that only 7.2 per cent of the specimens collected were calcareous, with the bulk of the specimens being agglutinated forms.

The previous reports of the Antarctic area have been concerned with the description of species and provided only a vague picture of the ecology of the organisms.

DESCRIPTION OF ENVIRONMENTAL FACTORS

SALINITY

The surface salinity at the locations from which samples were taken ranged from 33.12 to 34.86 parts per thousand. It is the opinion of the author that this minor variation in surface salinity has little effect on planktonic forms of Foraminifera. The salinity at the bottom is even more uniform than the surface salinity. The bottom salinity ranged from 34.45 to 35.19 parts per thousand. This salinity range seems to be insufficient to effect the variations in the benthonic population. Phleger (1960) stated that salinity variations probably have little effect on assemblages in offshore water, because the variations are too slight to be ecologically significant.

The seasonal variation in salinity is negligible except possibly directly adjacent to melting ice masses in its effect on the distribution of the planktonic or benthonic forms of Foraminifera.

TEMPERATURE

The surface temperatures are relatively uniform with a range of –0.49°C to –1.89°C at the stations from which the cores were taken. The thermal structure of the Ross Sea is probably relatively unaffected by seasonal variations (U. S. Hydrographic Office, T. R. 29). Bottom temperatures range from 0.60°C to –1.94°C. This author believes that temperature variations exert an insignificant ecological control in this area. Comparison of Stations 129 and 128 with temperatures of 0.03°C and –1.89°C respectively indicates that Antarctic temperatures are not below minimum temperatures for repopulation, as both samples have high Foraminiferal Numbers.

Temperature can be used to distinguish the Antarctic Circumpolar Water Mass from the Ross Sea Water Mass. Sverdrup (1942) stated that Antarctic Circumpolar Water is characterized by salinities slightly above 34.70 parts per thousand and temperatures between 2°C and O°C.

CURRENTS

According to Deacon, 1937, the first observer to prove the existence of a bottom current in the Antarctic area was A. von Humboldt in 1814. Since Humboldt's study, work has been done by Brennecke, Drygałski, Schott, Deacon, and Mosby. At the present time little is know about the bottom current conditions in many areas of the Antarctic. The general bottom current pattern of the Weddell Sea is known, but only theoretical bottom currents of the Ross Sea have been reported.

The currents in the Antarctic area are known only generally. Surface currents in the Ross Sea area are generally clockwise, moving parallel to Victoria Land. In the Weddell Sea area the currents are also clockwise, moving in from the Princess Martha coast area south and parallel to the Filchner Ice Shelf, then turning northward.

This discussion will be mainly concerned with the Ross Sea area because of the sample concentration in this area. Deacon (1937) stated that his samples north of the Ross Sea indicated that there was no stream of bottom water sinking from the Ross Sea. For the purpose of this study, however, it is assumed that there is an eastward bottom current in the channel that parallels the Ross Ice Shelf (Fig. 4). In the vicinity of Ross Island the channel changes its trend to parallel Victoria Land (H. O. Chart 6636). The current is assumed to be deflected westward in the vicinity of Coulman Island, passing over Station 041 and between Stations 037 and 129. Station 129 has a bottom temperature of .03°C, with a maximum temperature of 0.57°C at a depth of 250 meters. These warmer temperatures are usually associated with Antarctic Circumpolar Water; at any rate, the temperature is warmer than that of the Ross Sea water. A study of available oceanographic data seems to support this pattern (Fig. 1).

SEDIMENT

MEAN GRAIN SIZE

The mean grain size is expressed in phi units in this study, which is the log negative to the base 2 of the particle diameter in mm. Particle size was measured by screening the sand-size particles and by using pipette analysis to obtain the distribution of particles between 62 and 0.5 microns. The mean grain size ranged from 0.087 to 0.003 mm., or 3.6 to 8.8 phi units in the samples used for Foraminiferal analysis (Table 3). In all cases silt and clay were present. The samples with large mean sizes usually contained a few granules or pebbles.

SORTING CO-EFFICIENT

The sorting has been expressed in terms of one standard deviation from the mean grain size. Sorting is expressed in terms of phi units. The standard deviation varied from 1.9 phi units to 5.4 phi units. The samples are considered poorly sorted, as can be seen by their standard deviations (Table 3).

ORGANIC CARBON

The Allison method was used to obtain the weight per cent organic carbon of the sediment (Allison, 1935, p. 311). The per cent organic carbon varied from .029 to 1.972 per cent in the samples used in this study (Table 3).

METHODS OF STUDY

SAMPLE COLLECTION

Samples were collected by the United States Navy Hydrographic Office as part of the International Geophysical Year 1958-1959, Deep Freeze IV project. This study was confined to samples taken using Phleger cores. A Phleger corer is a short-weighted tube with a clear plastic removable liner. The liner has a cross-sectional area of 9.6 cm^2. Original stratification is maintained, particularly in the surface layers (Phleger, 1951).

The distribution of samples was controlled by the course of the ships taking the samples and, therefore, followed no set sampling scheme, because sediment samples had a low priority and were taken coincidental to higher priority work. The sample locations are shown on Figures 1 and 2, with latitude and longitude given in Table 1.

LABORATORY PROCEDURE

In the laboratory each core was removed from its plastic liner and sliced into two-inch portions. These portions were placed into

DISTRIBUTION OF FORAMINIFERAL NUMBERS

STATION NUMBER	117	124	125	024	123	122	118	007	006	005	036	035	039	033	004	003	021	020	012	011	032	027	026	014	013	019	038	016	015	029	028	041	031	030	129	023	022	002	001	040	037	010	009	034	128
DEPTH (METERS)	995	2620	2620	2620	2450	2450	2450	2450	1670	1670	1281	1281	890	870	805	805	800	800	740	740	690	685	685	658	658	640	612	594	594	576	576	568	567	567	475	655	455	650	450	384	365	320	320	276	164
Globigerina pachyderma	.05		4.1	623	.04	2.4			1677	134	1.8				.02		.95	193				.15	.22		.35	.19		[illegible]						.08	1270	4.2				5.8	206	7.3	4.3		79.
G. bulloides			.04						165.								.12					.08					.03								175	1.2				.96	4.1	.11	.29		19.
G. conglomerata																	.03											.02						.08	20.	.37				.52					45.
Trochammina antarctica	.05									1.0		.32		4.3	.04	[illegible]	.03	.54			.61	.19	2.1		.07	1.5	2.3		1.2	.04		1.2		2.6			3.3			5.0					[illegible]
T. conica	.09			1.1			.06	.18		.09		.04		1.5		.10		1.1			.10	.19	.6			.42	.48		.48	.04		.33		.30	2.2		2.6		.41	.04		.03	.06		
Psammosphaera fusca	.05			.1								.21																							.24		.03			.06	.14				.33
P. parva	.05									.09		.09																				.03			.10					.15	.36				.66
Adercotryma glomeratum	.14		.02	.66													.05										.51		.11			.03		.38			.03			.82					
Recurvoides contortus	.05							.18		.40				.92		1.2					.25		.65			1.6				.04		.22			.02		1.9		.55		.89				
Reophax [illegible]	.33		.46	.14				.12												.09															2.2										
Jaculella acuta	.24			.25				.12		.53		2.1		.88		.36	.02	1.9			.05	.04				[illegible]	.03		1.2			.14		.38			4.5			.02	.46				
Haplophragmoides bradyi	.19						.03											.54								[illegible]	.09		.13					.08			.10								
Cyclammina pusilla	.05			.11				.42		.02		.09													.02		.06							.04											
Alveolophragmium wiesneri	.05			.66						.09		.02															.06		.06					.23						.04					
Cyclammina orbicularis	.24		.02	.98				.13		.34		.21																																	
Alveolophragmium subglobosum	.05			.08			.25			.16		.04																																	
Ammomarginulina ensis	.19			.03																																									
Angulogerina earlandi			.02			.12			55	5.8	1.5						.23	8.1				.34	.22		.02					.04				.11	173	1.2		.04		1.5	10.	42	12		43.
Eponides weddellensis			[illegible]	[illegible]		.06			82	22	.09						.6	72.							.55										30[illegible]	.71				.61	.23	5.6	2.3		180
Gyroidina neosoldanii			.32	.41					.04	.14																																			
Lagena fimbriata			.02	.46							.28																													.02					
Miliammina arenacea			.04									.13	.18	1.4		.05			11	.09	1.2	.11	90			93	.08		.45	.55		.73				.05	1.9	.04	2.9	.71		9.3	3.6	.08	
Cassidulina crassa				5.3		2.0			.11		.20						1.3	55.				.75	.6		1.2					.04		33		.08	532	1.1				2.1	1.8	.14	.12		61.
Cibicides refulgens				.30	.04	.12											.08	.94				.11	.11		.02									.08	129	1.1				2.1	12.	.17	.06		26.
Eponides tener				4.8					.7	1.7	.02				.02		.03	6.5				.04					.03							.04	2.2					.11		.25	.06		
Triloculina tricarinata				.03																															.02					.06					.17
[illegible] globosa caudigera				.06														.57																	2.2					.06	.06				
[illegible] ovicula				.22				.06		.21				.70		.03					1.1		90		.05	.37	.09		.25			.54		.19			1.6		.41	.65					2.6
Lagena, sp. D				.44														1.1																						.04					
Lagena alveolata separans				.08					.04																										.02										
L. globosa				.22					.15	.18	.04							1.6																	4.4	.15				.06			.03		2.6
L. mele				.22					.06																										.02	.01				.02					.50
L. [illegible]				.08					.04		.02																								27.					.04	.03				.17
Nonionella bradii				.22	.08				.11								.05	10.2				.04			.07									.04	18.					.67	.46	.08			50.
Parafissurina dorbignyana				.22		.03			.02								.09	1.1																	4.4										1.8
Pullenia subcarinata				.46	.04				15	.04																									29.						.23	.03			11.
[illegible]				.25						.15		.04		.11				.54					[illegible]				.06		.09			.27					1.8			.10	.03				
[illegible] glabra				.22			.25	.06					.04			10	.02	1.1				.19	.45				.12							.16			.10			2.8			.03		35.
Reophax pilulifer				.06				.06						.08		15		.03			.05		[illegible]				.08		.54			.08					1.5			.23	.09				
Pyrgo murrhina				.08																																				.02					
Parafissurina subcarinata				.22		.06			.06									.54												.08					24.	1.5				.67	.69				
Lagena squamosa ocellata									[illegible]									.03																	2.2										
L. meridionalis				.06					.09	.02								1.1							.02										8.9					.10		.03			
L. laevis				.03						.09																														.02					
[illegible]				.06								.09																	.03					.04			.03								
[illegible] tenuissima				1.1				.30		.91		13					.06	6.6				.22	.22		.05	.05	.56	[illegible]	.45			.03					.17			.21					
[illegible]				.36					.01																																	.25			.17
Haplophragmoides rotulatum				.16								.04																	.03					.45											
Entosolenia auriculata				.08														.54																											
Eggerella bradyi nitens				.03					.04	.02																																			
E. bradyi				.03					.01																																				
Lagena orbignyana				.03													.05	2.2																						.04					
L. nebulosa				.90					.01	.14	.02							1.6																											
Pullenia bulloides				.22					.02	.02													.11																						
Textularia c.f. catenata				.03					.02								.02								.02																				
Lagena [illegible]				.03																																									
L. apiculata				.03																																									
Laticarinina halophora				.68																																									
Globulina gibba				.08																																									
Sigmoilina umbonata					.04	.03																													98	1.2				.13	2.5				50.
Ehrenbergina glabra						.15			1.0		.02							5.6					[illegible]		.09										129	11.				.59	1.1				35.
Buliminella cochlea						.03																													.31						.23				
Entosolenia c.f. lineata						.03																													2.2	.20									
Pseudobulimina chapmani						.03																.04													42.					.04	.26				.66
Trochammina grisea										.11			.02	.35	.02	[illegible]					.05	.34	.22		.02	.28	.76		.28			.76		.41	6.7		.81		.07	5.3			.06		1.3
Cassidulina laevigata								.24	100								.02								.07																				
Haplophragmoides canariensis																1	.06	4.8					[illegible]				.03		.25			.08		.87	.05		1.9			.50	.03				5.3
Entosolenia, sp. A																		1.6																.04						.02					
Rhabdammina sp.																																.11		.08						.08					
Textularia antarctica										.09	.02	.02				.05	.02	.54			.10	.04	1.1			.23	1.3		1.2			.57		1.4			.94			.57					
Verneuilina minuta																					.05						.06		.08	.04		.03		.08			.17			.25					
Entosolenia earlandi									.20								.2	.54																	4.4					.08					.33
Nonionella, sp. A									[illegible]								.03	3.0				.04			.02										6.7					.25		.08	.03		11.
Patellina corrugata									[illegible]																		.03								18.	.01				.13					5.5
Virgulina davisi									14	.04							.05	17.		.71																				.13	.23				2.6
Lagena formosa									.07	.02																									.03					.02					
Cassidulinoides parkerianus									.04		.05																								.02	.25					.23				
Miliammina lata										.09				.29	.02	.20				.98	.05		1.9			.09	.12		.03	1.0		.76					.54	.02	1.7						
Lagena, sp. A										.09																									2.2					.02					2.6
Cibicides subhaidingerii										.21					.02																											.06			
Lagena hispidula									.02																																				
Bulimina aculeata										4.8																										.05						.03			
B. gibba										.02																																			
Astrononion, sp. A											.02							3.0				.04			.09										40.	.51				.23		.14	.09		42.
Nonion germanicus											.02						.08	8.3				.08		[illegible]	.16										13.	.35				1.4	.46	.50	.32		29.
Rhizammina horrida												.04						.03																			.03			.25					
Pyrgo depressa														.04																					.02					.02	.43	.03		.04	
Reophax spiculifer										.02																																			
Miliammina oblonga																.31						.19							.08									.02	1.0					.06	
Reophax dentaliniformis																.05		.03											.03			.05													
Lagena feildeniana																	.03	2.7																	.02										
Dentalina, sp. A																	.02																		.02										
Entosolenia, sp. B																		1.1																	2.2					.13					
E. botelliformis																		1.1																	.02							.03			.17
Glandulina antarctica																		.07													.02				.05					.06	.31				
Entosolenia kerguelenensis																		.03							.02															.08					
E. c.f. fissicarinata																																			4.4										
Cystammina pauciloculata																		1.7																	.02										
Nodosaria calomorpha																		1.6																											
Entosolenia lateralis																						.04													4.4					.04					5.5
Lagena squamosa-sulcata																									.02										15	.56				.06					1.3
L. catenulata																									.02			.02																	
Nodosaria sp.																									.02																				
Ammodiscus incertus																											.03													.08					
Bolivina earlandi																																			.02	.15				.06		1.0	.03		2.6
Cornuspira corticata																																			.57	.05					.37				.33
Discorbis c.f. globularis																																			38.					.15					.83
Entosolenia, sp. C																																			6.7					.17					.66
E. pseudauriculata																																			.21					.04					.66
Heronallenia wilsoni																																			2.2	.05									21.
Lenticulina antarctica																																			2.2	.01					.03				.17
L. asterizans																																			2.2	.15									.17
Polymorphina sp. A																																			2.2	.05									.17
Planispirinoides bucculentus																																			2.3	.01					.06				.17
Pyrgo elongata																																			.09					.02	.09				.17
Pyrgoella sphaera																																			2.3						.17				.17
Tubinella funalis																																			.07	.01					.23				1.3
Buliminella [illegible]																																			.55					.02	1.6		.03		
Lagena caudata																																			.42	.01									
Lenticulina altifrons																																			.09										
Pyrgo sp. A																																			.02					.02					
Robulus pliocaenicus																																			.02										.17
Triloculina rotunda																																			.02						.09				
Patellinoides depressa																																			2.2										
Parafissurina quadrata																																			.02										
Uvigerina sp. A																																			2.2										
Triloculina sp. A																																			.02										
Sigmorphina sp. A																																			.05										
S. subulata																																			.10										
Spirillina c.f. wrightii																																			.02										
Quinqueloculina sp. A																																			.02										
Rectoglandulina torrida																																			.02										
Lagena sp. B																																			.02										
Frondicularia pygmaea																																			.02										
Entosolenia nelsoni																																			4.5										
Dentalina c.f. communis																																			.02										
D. communis larva																																			.09										
Cruciloculina triangularis																																			2.2										
Cystammina galeata																																			.04										
Cibicides grossepunctatus																																			16.					.02					
Cassidulina crassa porrecta																																			29.					.10	.91				5.6
Lagena costata																																				.46									
Glomospira gordialis																																								.02					
Entosolenia annectens																																								.04					
Cornuspiroides profundum																																								.02	.03				
Entosolenia subformosa																																													2.8
Lagena texta																																								.08					
Delosina sutilis																																													.17
Entosolenia sp. D																																													5.3
Lagena sp. C																																											.03		

Figure 3. Distribution of Foraminiferal Numbers

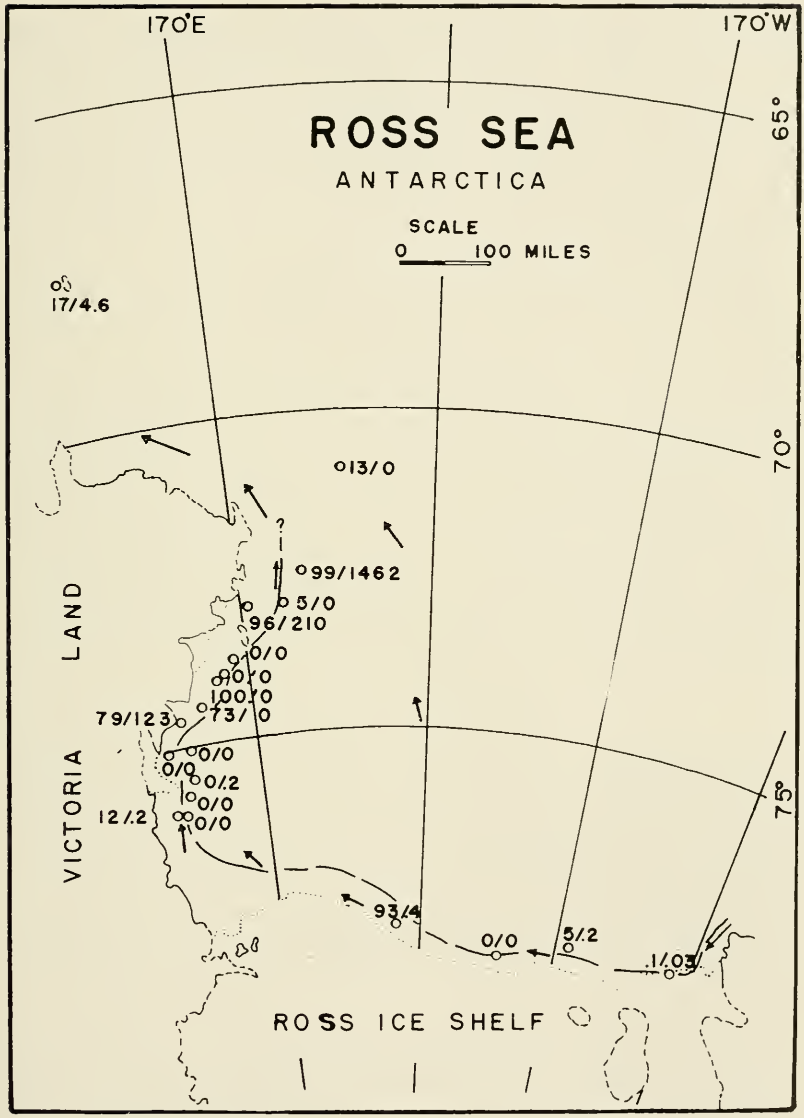

Figure 4. Current Map: «—Known surface currents; —Hypothesized bottom current; %Calcareous benthonic specimens/planktonic Foraminiferal Number.

envelopes and labeled for future use. Samples from 0-2 inches, 12-14 inches, 24-26 inches, and 36-38 inches of the core length were prepared for sedimentological and foraminiferal study. The particles larger than .062 mm. were then placed in carbon tetrachloride to concentrate the Foraminifera by floatation (Cushman, 1950, p. 27). After "floatation," the total sample was then examined and Foraminifera that did not float were also removed and placed on slides with those initially separated.

Total Foraminifera populations ranged from zero to hundreds of thousands of specimens per sample. Many of the concentrations had to be split into smaller fractions in order to get workable counts for the more abundant forms. The counts for the rare forms were obtained by their removal from the total concentrations of Foraminifera. This procedure was followed so that the rarer forms would not be overlooked. In order to divide large concentrations of Foraminifera into representative splits, a small microsplitter was used. This microsplitter was made by Sepor and consisted of 13 splitting surfaces. The splitter divided the sample into two statistically equal fractions. These fractions were further split until a workable number of specimens was obtained. The specimens were then mounted on 60 block group slides for identification and count.

IDENTIFICATION OF SPECIES

The identifications were made solely from written descriptions and figured specimens found in publications dealing with Recent Foraminifera. Specimens that could not be identified as to their specific level were identified as to genera, and a letter designation was then assigned to them. The lack of mounted holotype specimens for comparison decreases the accuracy of identification, but Dr. L. D. Toulmin verified the author's identification with reference to the literature.

QUANTITATIVE METHODS

Many writers use the per cent method of presenting data on populations; however, this method gives no indication as to the abundance of the species in the sediment. For this reason the Foraminiferal Number was used in this study. The Foraminiferal Number is defined as the number of specimens occurring in one gram of sediment. The Foraminiferal Number is assumed to represent the abundance of the species relative to the rates of deposition at or near the site of collection of the samples. No information is available as to the living assemblage at or near the site of collection, as the samples were not preserved or stained with protein stains. No data are available concerning rates of deposition in the Antarctic area covered by this study. Phleger (1960) used living-dead ratios of benthonic Foraminifera to obtain relative rates of deposition and cited earlier uses by other workers, but for this study Phleger's method cannot be used for the reason stated above.

STATISTICAL ANALYSIS

The statistical analysis used in this study has related the foraminiferal data to some of the parameters of the environment, using multiple regression and analysis of variance. The assumption made in this statistical scheme is that observation y can be expressed as various functions of known variables $x_1, x_2, x_3 \ldots x_n$ with the residual errors distributed normally and independently around the initial mean and with a constant variance. The regression of y on any single x_i is linear and has constant slope when the other variables $x_i + 1, x_i + n$ are constant; also that the slope of y versus x_i is the same for all other choices of variables. The model is then stated:

$$y_\alpha = a_1x_1 + a_2x_2 + a_3x_3 + \ldots a_i + x_i + e_\alpha$$

The x values take on successive known values for y. In this study x_1 = mean phi grain size, x_2 = organic carbon per cent, x_3 = water depth, and x_4 = the standard deviation of the sediment. The author chose 20 species based on most common frequency of occurrence and abundance, which became successive y_α's in the analysis. The estimation of $a_1, a_2 \ldots a_i$ was made using the method of least squares, which minimizes the sum of the squares of deviations:

$$\sum_{\alpha} (y_\alpha - a_1x_{1\alpha} - a_2x_{2\alpha} - \ldots a_ix_{i\alpha})^2$$

When this is done for all cases of y_2 and the equations differentiated with respect to a, a series of "normal" equations are created, which may be solved simultaneously.

The digital computer was used to solve these "normal" equations in conjunction with matrix techniques. The parameters x_1, x_2, x_3 and x_4 were solved for 20 stations and 20 species of Foraminifera on an individual basis. The author did not test certain parameters of the environment such as temperature, salinity, dissolved oxygen, clay mineralogy, and detrital mineralogy because in the area studied they had no apparent effect on distributions of the Foraminifera.

Regression analysis was performed on each species tested versus each of the four parameters—organic carbon (x_2), mean phi grain size (x_1), standard deviation of the sediment (x_4), and water depth (x_3). Combinations of $x_1 + x_2 + x_3 + x_4$, $x_1 + x_2 + x_3$, and $x_1 + x_2$ were also tested.

The format for the analysis of variance of the parameters in combination follows:

Source	Degrees of Freedom	Sum of squares due to regression (SSR)	Mean Square (MS)	f^s Ratio
$x_1+x_2+x_3+x_4$	4	Computed	SSR/4	MS_4/MSE
$x_1+x_2+x_3$	3	Computed	SSR/3	MS_3/MSE
x_1+x_2	2	Computed	SSR/2	MS_2/MSE
x_1	1	Computed	SSR/1	MS_1/MSE
Error	16	Computed	SSE/16	
Total	20	(SSE)		

The analysis of variance for each species versus each parameter taken singly is as below:

Source	Degrees of Freedom	Sum of squares due to regression (MS)	Mean Square
x_1	1	Computed	MS_1/SSE
Error	19	Computed	
Total	20	(SSE)	

The results of the analyses are given in Table 5. The designations used were as follows: (a) not significant at the 95% level of significance (NS); (b) significant at the 95% level (*); (c) significant at the 99% level of significance (**).

DISCUSSION OF DATA

GENERAL COMPARISON TO ARCTIC AREA

One hundred thirty-three species of Foraminifera were identified from the Deep Freeze IV cores studied. Eighteen additional species were given letter designations. The species included 67 genera, many of which were believed to be confined to the Antarctic area; however, some of the species have almost universal distributions in the deeper areas of the oceans of the world.

Little or no variation in form of any given species was noted when comparing specimens from the Weddell and Ross Seas. There were, however, some species from the Ross Sea that were not observed in samples from the Weddell Sea area; the reverse was also found to be true.

It is of interest to note that at least 12 species of Foraminifera are common to the Antarctic area and to the Arctic area off Ellesmere Islands, studied by Green (1960). Many forms in the Antarctic have comparable forms in the Arctic areas. The Antarctic seems to have a richer fauna than is found in the Arctic. One explanation for the rich bottom fauna of the Antarctic area is that the Antarctic waters have a large supply of nutrients due to the turnover of the water supplying the bottom.

ROSS SEA AREA

FORAMINIFERAL ASSEMBLAGE IN SURFACE SEDIMENT

Within the Ross Sea area 30 species of benthonic Foraminifera belonging to 20 genera may or may not be found to be relatively common and widely distributed. Of these benthonic Foraminifera *Trochammina, Reophax, Haplophragmoides, Textularia,* and *Miliammina* are among the most noteworthy. Representatives of these genera are found at all depths and environments within the Ross Sea except for a few anomalous areas that will be discussed later.

The most common benthonic species of the Ross Sea mentioned above are: *Trochammina antarctica, T. conica, T. glabra, T. grisea, Adercotryma glomeratum, Recurvoides contortus, Jaculella acuta, Haplophragmoides bradyi, H. canariensis, Cyclammina pusilla, Alveolophragmium wiesneri, Angulogerina earlandi, Miliammina arenacea, M. lata, M. oblonga, Cassidulina crassa, Cibicides refulgens, Eponides tenera, Hormosina ovicula, Nonionella bradyi, Reophax distans, R. pilulifer, R. nodulosus, R. dentaliniformis, Textularia tenuissima, T. antarctica, Ehrenbergina glabra, Verneuilina minuta, Astronion* sp. *A,* and *Nonion germanicus.*

The planktonic Foraminifera in the Ross Sea area include *Globigerina bulloides, G. conglomerata,* and *G. pachyderma,* assuming that *G. pachyderma* is planktonic rather than benthonic. This study revealed no definite evidence concerning the question of whether *G.*

pachyderma is planktonic or benthonic. It was treated as a planktonic form, but the author reserves the right to reverse his stand in the light of any new evidence. Takayasu Uchio (1960) gave a good comprehensive discussion of this question.

In 13 of the 19 surface core samples from the Ross Sea, arenaceous forms dominated (Table 4, Fig. 5). This phenomenon seemed to have no correlation with mean grain size, organic carbon, standard deviation of the sediment, or water temperature. Four of the six samples with high contents of calcareous forms were located in a water depth of less than 600 meters. The exceptions were samples 011 and 013, which are at depths of 740 and 658 meters, respectively (Fig. 5). It is of interest to note that the dominately calcareous populations showed a general increase in per cent calcareous specimens with decreasing organic carbon (Fig. 6).

The surface portions of the cores yielded two distinct populations—one group with less than 13 per cent calcareous benthonic specimens by count, and the other group with over 73 per cent calcareous benthonic specimens. There were no surface samples from cores that had intermediate mixtures of calcareous and arenaceous forms.

One possible explanation for the distribution is the presence of a bottom current with high arenaceous or low calcareous Foraminiferal percentages passing over the stations. This bottom current moves eastward into the channel that trends approximately parallel to the Ross Ice Shelf, then changes its trend in the vicinity of Ross Island and moves parallel to Victoria Land. It passes over Stations 038, 030, 015, north of Station 013, and continues its journey eastward until it passes over Station 032. The current then changes its course to a northwestward direction, passing over Stations 026, 033, 019, and 003, moving close to land in Terra Nova Bay and passing over Station 039. It then moves back seaward, missing Station 128 and possibly barely passing over Station 011. The bottom current then continues its trend over Stations 028, 022, and 001, trending westward around Coulman Island over Station 041 and between Stations 129 and 037 (Figure 4). The bottom water at Station 129 is Antarctic Circumpolar water and not Ross Sea water (Table 2). The hypothesized bottom current continues its northward move-

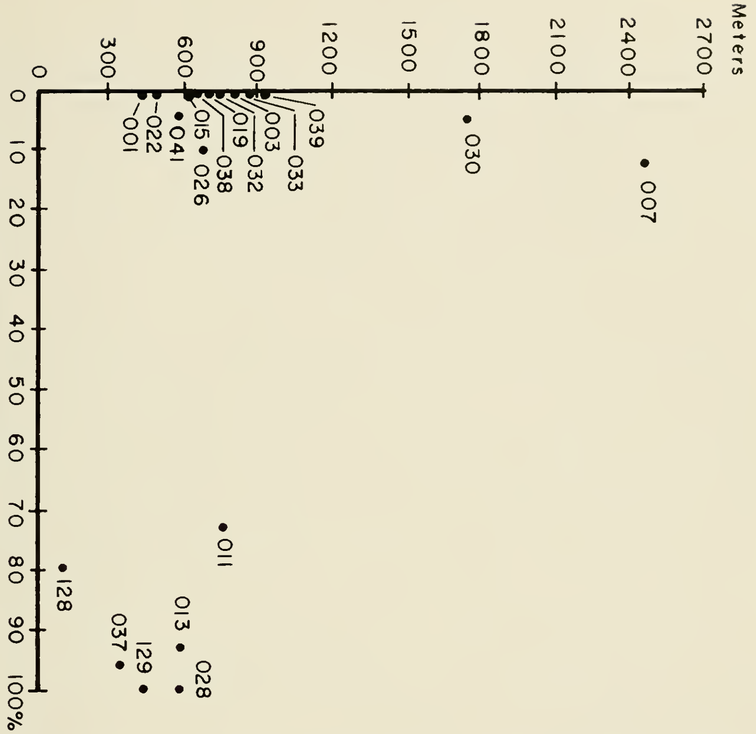

Fig. 5 -- Ross Sea Surface Sediment
Depth vs. % Calcareous Specimens (Benthos)

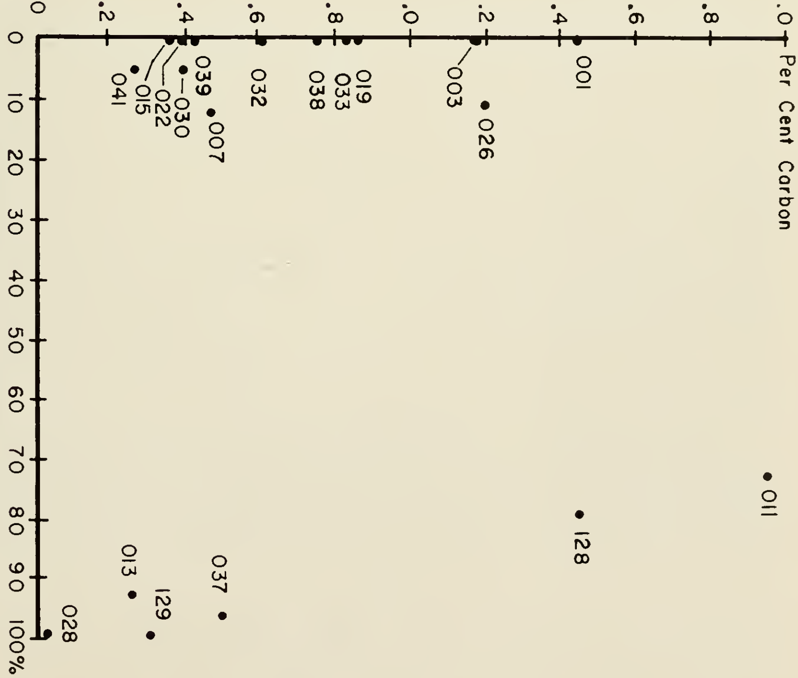

Fig. 6 -- Ross Sea Surface Sediment
Carbon vs. % Calcareous Specimens (Benthos)

ment downslope and out of the Ross Sea area. The bottom currents of the Ross Sea have little known about them as yet, because no bottom currents have been taken, to the author's knowledge, with the exception of one set of observations from Moubray Bay. There the current flowed out of Moubray Bay on the eastern side at a rate of 0 to 2.7 knots (U. S. Navy Hydrographic Office, 1957). Dr. D. S. Gorsline has used σ^t values and confirmed the current mentioned above (personal communication).

This writer believes the calcareous, benthonic populations to be in areas of little or no bottom current and the arenaceous populations to be in areas of either greater depths or bottom currents. The samples from the Ross Sea with high benthonic Foraminiferal Numbers as high as 30 are Stations 128, 129, and 037 (Table 4). These stations all have high percentages of calcareous forms. These high Foraminiferal Numbers are probably due to lack of deposition in these areas (Fig. 2). Deposition in the Antarctic area is due to melting of the ice which is transported by currents. If little ice is transported over the three stations mentioned above, the rates of deposition of clastic material would be slow, giving an apparent increase in organic production. The result would be the high Foraminiferal Numbers that are found.

The Ross Sea area generally shows a decrease in the number of foraminiferal species with water depth and distance from land (Fig. 3). This is a reverse situation from that generally found off the Atlantic Coast, eastern Pacific Coast, and the Gulf of Mexico, (Bandy and Arnal, 1960). Distance from land in the Ross Sea seems to have no direct bearing on abundance of Foraminifera in the samples studied. Dating of sediments within the Ross Sea has not yet been undertaken but will be done in the near future by Dr. J. K. Osmond of Florida State University (personal communication). The results of these studies should aid in establishing rates of deposition within the Ross Sea. This information should be of extreme value in the interpretation of the foraminiferal distribution in the Ross Sea.

The *Globigerina* of the Ross Sea decrease seaward in Foraminiferal Number to zero in the previously mentioned channel that parallels the edge of the sea (Fig. 4). The author believes this is due to their removal by bottom currents in the channel. Assuming that

Globigerina is planktonic, individuals would be swept out of the area by the surface and bottom current as they settled toward the bottom. Station 129 has the highest *Globigerina* Foraminiferal Number in the Ross Sea. This station is covered by Ross Sea water in the surface layers of its water column, but its subsurface water is Antarctic Circumpolar water. Station 041 has no *Globigerina*, while Station 037 has many. This helps to support the hypothesis of a bottom current moving through the area between Stations 037 and 129. Following this line of reasoning, Stations 001, 022, 028, 011, 039, 003, 033, 032, and 015 all help support the hypothesis of a bottom current because of their complete lack of *Globigerina* (Fig. 4). Station 123, with high *Globigerina* counts, is completely outside the influence of the hypothesized current. Stations 019, 026, 030, and 038 all have small *Globigerina* counts even though they are thought to be in the area of bottom currents. This might be expected, as the hypothesized bottom currents would not be expected to remove all planktonic forms.

FORAMINIFERA OF THE SUBSURFACE OF ROSS SEA SEDIMENTS

This study included the 12-14" portions of 10 cores in the Rose Sea area. The samples are 002, 023, 029, 016, 027, 012, 004, 008, 014, and 031 (Table 1). Without age dates it is impossible to place these subsurface portions of the cores into any particular part of geologic time and, due to the uniformity of sediment within these cores and lack of any given layers for correlation, the subsurface portions of the cores cannot be precisely correlated with each other on a time basis. The only basis for correlation of these assemblages is depth below the depositional interface. There is no way, in this area, to use planktonic Foraminifera to indicate a cooler or warmer time period because the forms present in the surface and subsurface portions of the cores are cold-water forms, and no warm-water forms are found (Phleger, 1960).

The subsurface samples contained the same typical species as the surface samples, with a few exceptions; *Adercotryma glomeratum*, *Haplophragmoides bradyi*, *Alveolophragmium wiesneri*, *Cyclammina pusilla*, *Hormosina ovicula*, *Reophax distans*, *Reophax nodulosus*, *Reophax dentaliniformis*, and *Haplophragmoides canariensis* do not occur in the lower portions of the cores. It is of interest to note that all the above-mentioned forms are arenaceous species. With the exception of Samples 023, 029, and 027, all samples showed a marked decrease in the number of Foraminifera species found with depth in the core. Except for Stations 007, 028, and 011 all cores showed an increase in the per cent of calcareous specimens found with depth in the cores. Decrease in calcareous specimens at Stations 011 and 028 is probably because of the small number of Foraminifera found to represent the total population. In the subsurface of Station 011, the only Foraminifera found were representatives of *Miliammina arenacea,* with a Foraminiferal Number of 0.11. At Station 028 the surface sample was represented by one specimen of *Glandulina antarctica,* giving the surface per cent calcareous benthos a value of 100 per cent. After eliminating these two stations, all stations except 007 in the Ross Sea show an increase in per cent calcareous benthonic specimens with depth in the core (Table 4). There is more than one possible explanation for this increase in per cent calcareous specimens. The arenaceous forms may not have completed their migration to the Ross Sea area when the lower portions of the cores were being deposited. At the time the sediments in the upper part of the cores were being deposited, the arenaceous forms dominated in many parts of the Ross sea and included *Adercotryma glomeratum, Haplophragmoides bradyi, Alveolophragmium wiesneri, Cyclammina pusilla, Hormosina ovicula, Reophax distans, Reophax nodulosus, Reophax dentaliniformis,* and *Haplophragmoides canariensis.* Another explanation for the higher percentages of calcareous forms in the lower portions of the Ross Sea cores could be a climatic change which influenced the water masses, causing changes in the foraminiferal distributions. At present too little is known about the relationship of water masses on calcareous versus arenaceous foraminiferal distribution to state what this climatic change could have been. A possibility, however, might have been a cooling of the Antarctic area, causing an ice shelf to build out from Victoria Land to the vicinity of Stations 011, 028, 022, and 001. This would have been an extension of Newnes Ice Shelf and could not have extended southward much past Station 011. Station 128 is fairly uniform in its foraminiferal assemblage; even though quantitative work was not done on the lower portions of this core, it was observed for foraminiferal content. Station 022 could not have been as near the hypothesized ice shelf, as its foraminiferal distribution was not influenced as much as the other stations in this area. In fact, Station 022 had an increase from 20 to 30 in the number of species found here with depth in the core. It also is the only station of the four mentioned in this area that had planktonic Foraminifera present.

WEDDELL SEA AREA

FORAMINIFERAL ASSEMBLAGE IN SURFACE SEDIMENT

Within the Weddell Sea area 37 species of benthonic Foraminifera belonging to 22 genera were found in at least two of three cores observed from this area (Fig. 1). The most common genera were *Trochammina, Psammosphaera, Angulogerina, Eponides, Entosolenia, Lagena, Nonion, Virgulina,* and *Nonionella.*

The benthonic species that appeared in two or more stations are: *Trochammina antarctica, T. conica, T. glabra, Psammosphaera fusca, P. parva, Jaculella acuta, Alveolophragmium wiesneri, Angulogerina earlandi, Eponides weddellensis, E. tenera, Miliammina arenacea, Cassidulina crassa, Cibicides refulgens, Entosolenia globosa caudigera, E.* sp. *A, E. earlandi, E.* sp. *B. E. kerguelenensis, Lagena* sp. *D, L. alveolata separans, L. meridionalis, Nonionella bradyi, N.* sp. *A, Reophax distans, R. pilulifer, Parafissurina subcarinata, Textularia tenuissima, T. antarctica, Ehrenbergina glabra, Haplophragmoides canariensis, Virginulina davisi, Astrononion* sp. *A, Nonion germanicus, Rhizammina horrida,* and *Glandulina antarctica. Globigerina pachyderma* is the dominate species of planktonic Foraminifera in this area; however, *G. bulloides* and *G. conglomerata* do occur.

In two of the three samples studied from the surface sediment of the Weddell Sea area arenaceous specimens outnumbered the calcareous specimens (Fig. 3, Table 4). The sample distribution of the Weddell Sea area is not complete enough to make any conclusive statements as to the control of the foraminiferal distribution by environmental factors but indicates that there is a decrease in the number of species with depth.

FORAMINIFERAL DISTRIBUTION IN SUBSURFACE SEDIMENT

The 12-14" portions of two cores from the Weddell Sea area were analyzed for foraminiferal distributions. These cores were Stations 020 and 035, with samples numbered 021 and 036 respectively. It is interesting to note that the following species were found in the surface portions of the cores but did not occur in the subsurface portions: *Trochammina conica, Psammosphaera fusca, P. parva, Alveolophragmium wiesneri, Miliammina arenacea, Entosolenia globosa caudigera, E.* sp. *A, E.* sp. *B, E. kerguelenensis, Lagena* sp. *D, L. meridionalis, Reophax distans, R. pilulifer, Parafissurina subcarinata, Nonion germanicus, Rhizammina horrida,* and *Glandulina antarctica.* Of the 16 species mentioned above, only 2—*Alveolophragmium wiesneri* and *Reophax distans*—likewise occur in the subsurface of the Ross Sea. The addition of species to the upper portions of the Weddell Sea area differs greatly from the addition of species in the upper portions of the Ross Sea cores. The difference mentioned is that only 7 of the 16 species occurring in the surface, but not the subsurface of the Weddell Sea area, are arenaceous species. In the Ross Sea all nine species that were added are arenaceous forms.

QUEEN MAUD LAND

FORAMINIFERAL ANALYSIS IN SURFACE AND SUBSURFACE SEDIMENT

Two cores were taken off Queen Maud Land for study in this report (Fig. 1). These cores yielded 24 benthonic species that were common to at least two sections studied. There were 17 genera represented, 10 of which were arenaceous forms.

The benthonic species that appeared in two or more samples are: *Trochammina conica, Jaculella acuta, Cyclammina pusilla, C. orbicularis, Alveolophragmium wiesneri, A. subglobosum, Angulogerina earlandi, Eponides tenera, E. weddellensis, Gyroidina neosoldanii, Cassidulina crassa, Hormosina ovicula, Lagena globosa, L. meridionalis, L. nebulosa, L. formosa, Pullenia subcardinata, P. bulloides, Reophax distans, Textularia tenuissima, Eggerella bradyi nitens, Ehrenbergina glabra,* and *Virginulina davisi* (Fig. 3). There were only two planktonic species—*Globigerina pachyderma* and *G. bulloides*—in the cores from this area.

Seven species were present in the surface portions of the cores that were not present in the subsurface of the two cores studied from this area. *Alveolophragmium wiesneri* and *Reophax distans* were not found in the subsurface of any of the cores studied. *Hormosina ovicula* occurred in the surface of the Ross Sea sediment and the Queen Maud Land sediment but not in the subsurface of these cores. *Jaculella acuta, Textularia tenuissima,* and *Lagena laevis* occurred in the surface sediments of the Queen Maud Land cores but not in the subsurface portions of the cores.

The surface portions of cores 005 and 024 indicate that the foraminiferal assemblages are more alike between surface portions of the two cores than their corresponding subsurface portions. The percentages of calcareous benthonic specimens were lower in the deeper of the two stations, with station 005 being in the 90-per cent or higher range throughout the core, while Station 024 ranged from approximately 80 to 42 per cent calcareous benthos (Table 4).

WILKES LAND

FORAMINIFERAL ASSEMBLAGE FROM SURFACE SEDIMENT

One sample was taken off Wilkes Land in 2,995 meters of water (Fig. 1). This sample contained 14 benthonic species representing 10 genera (Fig. 3). All benthonic species at this station were found to be arenaceous forms. The reason for this is most probably related to depth, as all other known parameters of the environment show no reason why there should not be calcareous forms present. The bottom temperature, –32°C, is only slightly warmer than Ross Sea temperature; therefore, temperature as the control of arenaceous forms does not seem to be of any significance in this area. The only planktonic form present in the sediment at Station 017 was *Globigerina pachyderma*.

PALMER PENINSULA

FORAMINIFERAL ASSEMBLAGE FROM SURFACE SEDIMENT

One core was taken at a depth of 274 meters from the Palmer Peninsula area for this study (Fig. 1). The only species it yielded were *Miliammina arenacea, M. oblonga,* and *Pyrgo depressa* (Fig. 3). The author believes that the rates of deposition in this area are fairly rapid, accounting for the small Foraminiferal Number of 0.2 at Station 034; however, it is probable that the rate of production of Foraminifera in this area is also fairly slow.

AGE OF ANTARCTIC SEDIMENTS

The sediments under study are probably no older than Pleistocene. The sediments from three cores taken by J. L. Hough from the Ross Sea were dated by W. D. Urry (Hough, 1950). Age determinations were made, using the "per cent of equilibrium method" involving uranium, ionium, and radium (Urry, 1942). The three cores were located at a latitude of 68°26′S, longitude 179°35′W; latitude of 69°12′S, longitude 179°34′E; and latitude of 70°17′S, longitude 178°23′W (Fig. 2). The lengths of the cores were 228 cm., 260 cm., and 242 cm., respectively. The date determined for the bottom of the cores by Urry was 420,000 to 460,000 years for the 228 cm. core, 172,000 years for the 260 cm. core, and about 1,000,000 years for the 242 cm. core. Urry had to extrapolate all dates older than 300,000 years with his method, so considerable error is possible for the oldest dates. If the rates of deposition of the cores in this study are similar to the area studied by Hough, no material older than Pleistocene were penetrated, as the longest core studied here is only 98 cm. long.

T. Uchio dated surface sediment from off Wilkes Land, latitude 68°19.2′S, longitude 31°21.2′E, using the carbon 14 method (Uchio, 1960). He found this to be a pre-modern sediment with an age of 5,490 (plus or minus 370) years. No subsurface dates were made in this study.

There was no indication from the foraminiferal assemblages found in this study that anything older than Pleistocene was penetrated.

DEPTH BOUNDARIES OF BENTHONIC FORAMINIFERA

A foraminiferal depth assemblage in the Antarctic area is difficult and possibly impractical to determine due to the complexity of water characteristics and currents in the area. Two stations of comparable depth can have completely different bottom waters, giving rise to different benthonic assemblages. This is illustrated by samples 022 and 129, at depths of 455 and 475 meters respectively. The bottom water at Station 022 is Antarctic bottom water, while Station 129 has Antarctic Circumpolar water covering the sea floor. Arenaceous forms dominate at Station 022, whereas calcareous forms

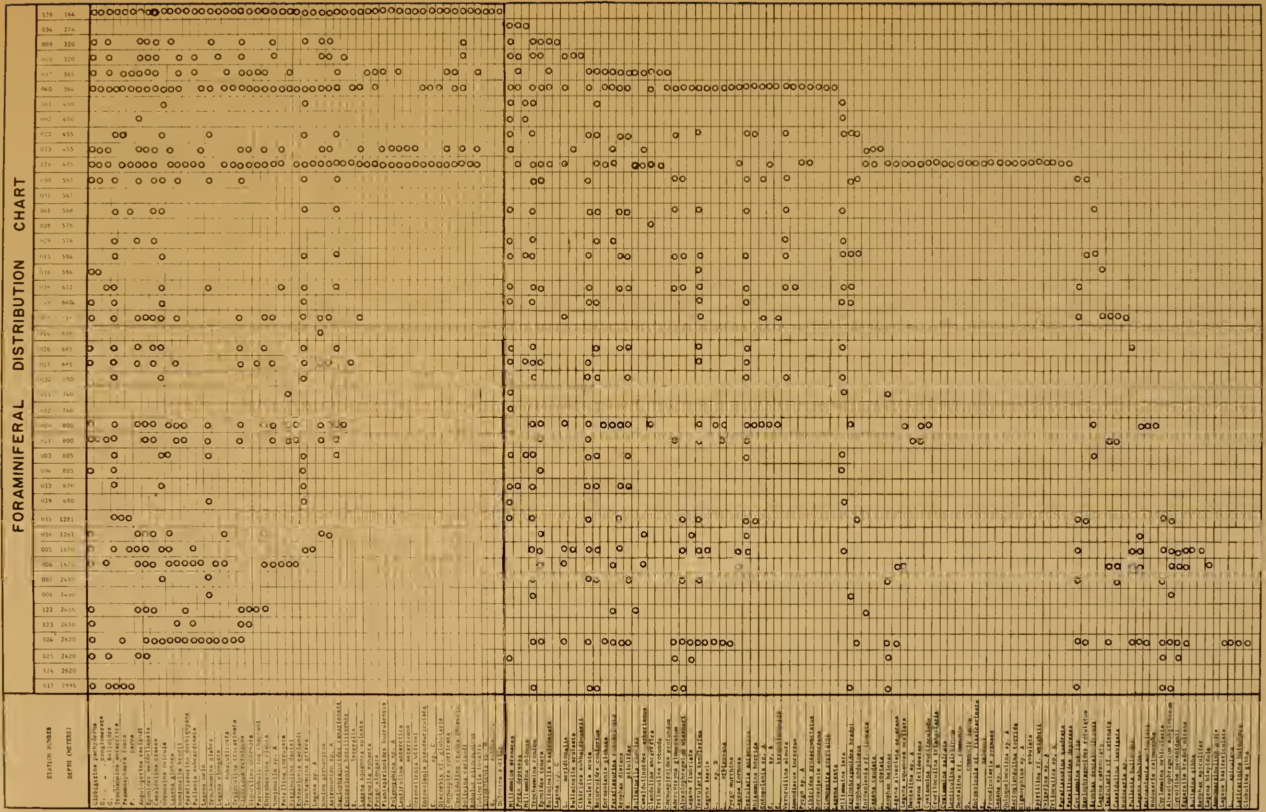

Figure 7. Foraminiferal Distribution Chart

dominate at Station 129. Station 129 has about 100 times as many specimens per gram as does Station 022 (Table 4). The lack of a continental shelf in this area also complicates zonation because of the ease with which contamination of species from shallower depths takes place. The distribution of sample locations in this study does not follow a pattern that lends itself to a depth assemblage study.

Three depth assemblages with boundaries at 850 meters and 2,000 meters was established in the Lutzow Holm Bay area (Uchio, 1960). No samples were available shallower than 350 meters in Uchio's study; therefore, his depth assemblages may have been incomplete.

The shallowest sample taken in this study is at a depth of 164 meters; therefore, any existing assemblages shallower than this were not observed. Due to the meager coverage of any given area only tentative depth assemblages are established in this study. These tentative depth assemblages seem to have boundaries at approximately 164 (?) meters, 384 meters, and 475 meters. No sharp foraminiferal depth assemblage based on minimum occurrence alone was found below 475 meters in the cores observed (Fig. 7).

Assemblage I (depth 164 to 475 meters)
Important species are:

Bolivina earlandi
Cornuspira corticata
Heronallenia wilsoni
Lenticulina antarctica
L. asterizans
Polymorphina sp. A
Planispirinoides bucculentus
Pyrgo elongata
Pyrgoella sphaera
Tubinella funalis

Assemblage II (depth greater than 384 meters)
Important species are:

Adercotryma glomeratum
Textularia tenuissima
T. antarctica
Entosolenia sp. B.

Assemblage III (475 meters or greater)

Important species are:

Reophax helenae
Dentalina communis larva
Entosolenia nelsoni
Sigmomorphina subulata
Patellinoides depressa

There are no sharp breaks in foraminiferal assemblages below approximately 475 meters.

RESULTS OF STATISTICAL ANALYSIS

The statistical analysis to compare 20 different most common Foraminifera to certain parameters of their environment was tested at the 95% and 99% levels of significance. This is not meant to prove or disprove a dependency on each specific parameter, but it indicates the relative association with each parameter. Certain stations were eliminated from the analysis: (a) Stations 009, 017, and 034 were eliminated because they were isolated and had no stations located near them for comparison; (b) Station 129 was eliminated because a convergence between Ross Sea Water and Antartcic Circumpolar Water over this station caused extremely high foraminiferal numbers that would decrease any significance of other nearby stations; (c) Stations 128 and 037 were eliminated because they also had extremely high foraminiferal numbers that would have masked the other adjacent stations, causing them to have little weight in the analysis, even if significance were present; (d) Station 028 was eliminated because only one specimen was found in the sample.

The following Foraminifera of those tested were independent of water depth, standard deviation, per cent organic carbon, or mean phi grain size: *Angulogerina earlandi*, *Cassidulina crassa*, *Trochammina glabra*, *Ehrenbergina glabra*, *Nonion germanicus*, *Nonionella bradii*, and *Cibicides refulgens*.

Trochammina antarctica was significant at the 95% level for a combination of $x_1x_2x_3x_4$, with x_4 testing significant at the 99% level and x_2 at the 95% level. X_4 probably weighted the $x_1x_2x_3x_4$ combination into significance at the 95% level, as $x_1x_2x_3$ alone showed no significance at the 95% level.

Trochammina conica tested significant at the 95% level for $x_1x_2x_3x_4$, $x_1x_2x_3$, and x_4, x_3, and x_2. Mean phi grain size seemed to have no effect on distribution for this species.

Jaculella acuta tested significant at the 99% level for only one parameter, namely that of standard deviation of the sediment.

Eponides weddellensis tested significant at the 95% level for the standard deviation of the sediment.

Eponides tenera showed significance at the 95% level for $x_1x_2x_3$, x_4 and x_3. Water depth probably gave just enough support to the x_1x_2 combination to bring them into significance.

Hormosina ovicula was significant at the 95% level for $x_1x_2x_3x_4$, $x_1x_2x_3$, x_1x_2, and x_3, x_1. It also was significant at the 99% level for x_4 and x_2. This was the only Foraminifera tested that showed significance to all four parameters tested.

Reophax distans showed significance at the 95% level for standard deviation of the sediment.

Textularia tenuissima tested significance at the 95% level for per cent organic carbon.

Textularia antarctica tested significant at the 99% level for $x_1x_2x_3x_4$, $x_1x_2x_3$, x_1x_2, and x_4. It also tested significant at the 95% level for x_2. Evidently *T. antarctica* is most effected by combinations of the four parameters tested or perhaps other indirect factors controlling these parameters.

Haplophragmoides canariensis was significant at the 95% level for the standard deviation of the sediment.

Miliammina lata showed significance at the 95% level for $x_1x_2x_3$, x_1x_2, and at the 99% level for x_2. It is possible that a false impression is given in this instance with a strong x_2 weighting the combinations into significance.

Miliammina arenacea showed significance at the 95% level for $x_1x_2x_3x_4$, $x_1x_2x_3$, x_1x_2, x_4 and x_1. It also tested significant at the 99% level for x_2.

Recurvoides contortus tested significant at the 95% level for x_1x_2 and x_4. It also tested significant at the 99% level for x_2.

It is of interest to note that only two species tested as significant at the levels tested with mean phi grain size. Both the species mentioned are arenaceous forms. The organic carbon had eight forms showing significance, all of which were arenaceous. Unexpected were the results obtained that dealt with water depth. Only two arenaceous and one calcareous forms tested showed any relationship to water depth. The characteristic that one would think had the least to do with foraminiferal distributions showed 10 forms testing significant to it; that is, the standard deviation of the sediment. Ten Foraminifera tested significant to this parameter, eight of which were arenaceous forms, although after some consideration of the results obtained from the standard deviation, the author suspects that currents are the major control of the standard deviation of the sediments and also of the nutrients which support the benthonic Foraminifera tested. Thus, while the standard deviation of the sediment appears to control these distributions, actually both the foraminiferal distributions and the standard deviation of the sediment are dependent upon a third and untested parameter: the currents. It is possible that many of the other species tested also show effects of parameters not tested which are actually operating in common with those tested.

CONCLUSIONS

The purpose of this study has been to examine the distribution of Foraminifera found in 28 cores taken by the United States Navy as a part of the Deep Freeze IV project. It has been the author's intent to compare this distribution with water depth, temperature, salinity, sediment type, geographic location, and general consideration of currents. Major conclusions of this study are:

1. Water depth had little affect on the distribution of Foraminifera tested.
2. Temperature can be disregarded in the Antarctic area as a major ecologic control, as most stations represent isothermal conditions.
3. Salinity has little, if any, effect on foraminiferal distributions because salinity variations are minute.
4. Mean phi grain size has little effect on foraminiferal distributions.

5. Organic carbon seems to affect some of the arenaceous forms, but none of the calcareous forms tested showed any dependency to this parameter.
6. The standard deviation of the sediment probably represents a current control for the Foraminifera tested and was the most significant parameter tested.

LIST OF GENERA AND SPECIES

This list is prepared alphabetically by genera and species. The asterisk following the name indicates that the name was used by this author. The number after the name is the number assigned to the individual by this writer.

*Adercotryma glomeratum**—15
*Alveolophragmium subglobosum**—16
*Alveolophragmium wiesneri**—17
Ammodiscus gordialis—14
*Ammodiscus incertus**—13
Ammomarginulina ensis—18
Angulogerina angulosa—125
*Angulogerina earlandi**—125
Articulina funalis—36
Astrononion sp. A*—98
Augusticarinata—79
Biloculina depressa—43
Biloculina elongata—42
Biloculina murrhina—44
Biloculina sphaera—45
*Bolivina earlandi**—123
Bolivina punctata—123
Bolivina punctata arenacea—25
*Bulimina aculeata**—104
Bulimina baccata—105
Bulimina chapmani—101
Bulimina elegans—105
Bulimina fusiformis—105
*Bulimina gibba**—105

ANNOTATED SYNONYMY

The species are listed in taxonomic rather than alphabetical order. Statements are made for some species, giving general geographic and depth distributions for the samples that were available to the author. Figure 3 gives the Foraminiferal Number and sample occurrence of each species.

Family **ASTRORHIZIDAE**

1. **Rhabdammina** sp. Pl. 9, fig. 1

This species was represented in three samples—two from the

Ross Sea and one from the Weddell Sea. It is rare at all three stations.

Family **RHIZAMMINIDAE**

2. **Rhizammina horrida** Chapman and Parr Pl. 9, fig. 2

Rhizammina horrida Chapman and Parr, 1937, p. 165, pl. X, fig. 47.

This species was found in four samples ranging in depth from 384 to 1,281 meters. It was rare at each station from which it was observed.

Family **SACCAMMINIDAE**

Subfamily **PSAMMOSPHAERINAE**

3. **Psammosphaera fusca** Schulze Pl. 9, fig. 3

Psammosphaera fusca Schulze, 1875, p. 113; Brady, 1884, p. 249, pl. 18, fig. 1; Wiesner, 1931, p. 79, pl. IV, fig. 32-33; Heron-Allen and Earland, 1932, p. 327, pl. VIII, fig. 1-4; Parr, 1950, p. 256.

The specimens are composed of coarse rock and quartz sand grains, giving the test a rough and odd shape. I have followed Parr's example in not trying to distinguish between *P. fusca* and *P. irregularis* Wiesner, and *P. testudinaris* Rhumbler. Depth seems to have little effect on this species in area studied, and it is probably distributed almost universally in the Antarctic area, based on known locations of its existence.

4. **Psammosphaera parva** Flint Pl. 9, fig. 4

Psammosphaera parva Flint, 1899, p. 268.

This species is similar to *P. fusca,* except for size and texture, the *P. parva* being much smaller and smaller grains composing the test.

Family **HYPERAMMINIDAE**

Subfamily **HYPERAMMININAE**

5. **Jaculella acuta** Brady Pl. 9, fig. 5

Jaculella acuta Brady, 1884, pl. XXII, fig. 14-18.

This species was a common form; however, it occurred in fragments and some specimens might well have belonged in another group, but positive identification could not be made on these fragments, and they were all placed in this species. Our samples reveal a depth range of 365 to 2,995 meters.

Family **REOPHACIDAE**
Subfamily **REOPHACINAE**

6. **Hormosina ovicula gracilis** (Earland) Pl. 9, fig. 6

Reophax distans var. *gracilis* Earland, 1933, v. 7, p. 76, fig. 21.
Hormosina ovicula var. *gracilis* (Earland), 1934, v. 10, p. 85, pl. III, fig. 2.

This is a widely distributed species, found between 164 and 2,620 meters. It is most probably universally distributed in the Antarctic area.

7. **Reophax dentaliniformis** Brady Pl. 9, fig. 7

Reophax dentaliniformis Brady, 1884, v. IX, p. 293, pl. XXX, fig. 21-22; Heron-Allen and Earland, 1922, T. N., p. 94; Parr, 1950, p. 266.

This species has a wide distribution in the Antarctic area; however, my values for abundance are not too reliable, as the specimens were mostly fragments. The Deep Freeze IV depth range for this species is 568 to 805 meters.

8. **Reophax distans** Brady Pl. 9, fig 8

Reophax distans Brady, 1884, p. 296, pl. XXXI, fig. 18-22; Wiesner, 1931, p. 90, pl. IV, fig. 104-105; Earland, 1934, p. 83; Chapman and Parr, 1937, p. 147; Parr, 1950, p. 266.

The chambers of the specimens were separated in all but two cases. This species seems to have a wide distribution in the Antarctic area. The samples reveal a depth range of 365 to 2,620 meters for this species, with a maximum abundance of 1.8 chambers per gram at station 022.

9. **Reophax helenae** Rhumbler Pl. 9, fig. 9

Reophax helenae (under *R. cylindricus*) Wiesner, 1931, p. 90, pl. IX, fig. 103.
Reophax helenae Parr, 1950, p. 266, pl. 4, fig. 13.

I have made thin sections of two specimens, and my observations agree with Parr's in that the internal wall is composed of small quartz grains rather than sponge spicules. I have followed Rhumbler and Parr in their decision to make this a separate species rather than a variation of *R. cylindricus*. The chambers are distinctly separated in my specimens. They ranged in depth from 475 to 2,995 meters in our samples.

10. **Reophax nodulosus** Brady Pl. 9, fig. 10

Reophax nodulosus Brady, 1884, p. 294, pl. XXXI, fig. 1-9; Wiesner, 1931, p. 91, pl. IX, fig. 108; Parr, 1950, p. 267.

Based on other reports, this is a common Antarctic form and is typical wherever found in the area. It ranged in depth in this area from 455 to 2,620 meters, and is rare at all five stations from which it came.

11. **Reophax pilulifer** Brady Pl. 9, fig. 11

Reophax pilulifera Brady, 1884, p. 292, pl. XXX, fig. 18-20.
Reophax pilulifer Heron-Allen and Earland, 1922, p. 93; Earland, 1934, p. 80, pl. ii, fig. 10, 36; Parr, 1950, p. 267.

This is a widely distributed Antarctic form but is seldom abundant. It ranged in depth from 365 to 2,620 meters, being recorded in 13 samples. Both sexual and asexual forms occur at most of the stations from which it was observed.

12. **Reophax spiculifer** Brady Pl. 9, fig. 12

Reophax spiculifera Brady, 1879, p. 54, pl. IV, fig. 10-11; Brady, 1884, p. 295, pl. XXXI, fig. 16-17.
Reophax spiculifer Wiesner, 1931, p. 91, pl. IX, fig. 113; Parr, 1950, p. 269.

R. spiculifer is rare from almost all stations from which it has been reported by other authors. The Deep Freeze IV samples yielded only one specimen of this species. It came from station 005, off Queen Maud Land, in 1,670 meters of water.

Family **AMMOSISCIDAE**
Subfamily **AMMODISCINAE**

13. **Ammodiscus incertus** (d'Orbigny) Pl. 9, fig. 13

Operculina incertus d'Orbigny, 1839, p. 49, pl. VI, fig. 16-17.
Ammodiscus incertus Brady, 1884, p. 330, pl. XXXVIII, fig. 1-3; Heron-Allen and Earland, 1932, p. 342, pl. VIII, fig. 18-20; MacFadyen, 1933, p. 83; Earland, 1934, p. 96.

This species was found at two stations—040 and 038. Its depth range was 384 to 612 meters in the Deep Freeze IV samples. It was rare at both stations at which it was found, one was adjacent to the ice shelf of the Weddell Sea, and the other was adjacent to the Ross Ice Shelf.

14. **Glomospira gordialis** (Jones and Parker) Pl. 9, fig. 14

Trochammina squamata var. *gordialis* Jones and Parker, 1860, p. 304.
Ammodiscus gordialis Brady, 1884, p. 333, pl. XXXVIII, fig. 7-9.
Glomospira gordialis Heron-Allen and Earland, 1932, p. 343, pl. VIII, fig. 21-22; Earland, 1934, p. 97.

One specimen was found in sample 040 at a depth of 384 meters within the Weddell Sea.

Family **LITUOLIDAE**
Subfamily **HAPLOPHRAGMIINAE**

15. **Adercotryma glomeratum** (Brady) Pl. 9, fig. 15

Lituola glomerata Brady, 1878, v. 1, p. 433, pl. 20, fig. 1.
Haplophragmoides glomeratus Earland, 1936, p. 35, n. 72.
Adercotryma glomeratum Loeblich and Tappan, 1952, p. 141.

This species was found by Wiesner, Earland, Chapman, and Parr in the Antarctic area. Specimens were found off Kerguelen in 150 meters of water and off the Tasmania in dredgings from 122 to 155 meters. Wiesner's species were from 3,400 meters of water in the Antarctic area. It is curious that W. J. Parr did not find any specimens in the Antarctic area in his B. A. N. Z. Antarctic report, as it seems to have a wide distribution in the Antarctic area. The depth range in my samples was from 384 to 2,995 meters, with maximum abundance of .82 at station 040, at a depth of 384 meters.

16. **Alveolophragmium subglobosum** (G. O. Sars) Pl. 10, fig. 16 a, b

Lituola subglobosa G. O. Sars, 1872. p. 253.
Haplophragmium latidorsatum Brady, 1884, p. 307, pl. XXXIV, fig. 7, 8, 10.
Haplophragmoides subglobosum Cushman, 1910, p. 105; Parr, 1950, p. 271.
Labrospira subglobosum Hoglund, 1947, p. 144.
Alveolophragmium subglobosum Barker, 1960, pl. 34, fig. 7, 8, 10.

This species had a depth range of 1,281 to 2,995 meters in my samples and was found from the Ross Sea, off Wilkes Land, and Queen Maud Land. On the basis of the locations in which it was found, it is assumed that it had a wide distribution in the deeper Antarctic areas. At no station was it abundant.

17. **Alveolophragmium wiesneri** (Parr) Pl. 10, fig. 17 a, b

Trochammina trullissata Brady, 1884, p. 342, pl. XI, fig. 14-15.
Haplophragmoides trullissata Cushman, 1910, p. 100, text-fig. 148.
Labrospira wieiner Parr, 1950, p. 272, pl. IV, fig. 25-26.
Alveolophragmium wiesneri Barker, 1960, p. 82, pl. 40, fig. 14-15.

Loeblich and Tappan, in 1953, have shown that *Labrospira* Hoglund is a synonym of *Alveolophragmium* Tachedrina. Parr's description of this form is more than ample. The depth range within the Deep Freeze IV samples was 384 to 2,995 meters; however, it seems to be slightly more prevalent in the deeper samples. It was found in the Ross Sea, Weddell Sea, off Wilkes Land, and off Queen Maud Land, indicating that it has a wide distribution.

18. Ammomarginulina ensis Wiesner Pl. 10, fig. 18

Ammomaraginulina ensis Wiesner, 1931, p. 97.

This species was first thought to be confined to the Antarctic area, but records now show it to be found at Tasmania and off the Great Barrier Reef, Queensland. In the Deep Freeze IV samples it was found only in the two deepest samples, 024 and 017, which are located off Wilkes Land and off Queen Maud Land. It was rare at both localties.

19. Haplophragmoides bradyi (Robertson) Pl. 10, fig. 19

Trochammina robertsoni Brady, 1887, p. 893.
Trochammina bradyi Robertson, 1891, p. 388.
Haplophragmoides bradyi Phelger, 1960, p. 73, pl. 3, fig. 23.

The Deep Freeze IV samples reveal a depth range of 455 to 2,995 meters for this species. It has a wide geographic distribution within the Antarctic area, but at no station is it abundant.

20. Haplophragmoides canariensis (d'Orbigny) Pl. 10, fig. 20

Nonionina canariensis d'Orbigny, 1839, p. 128, pl. ii, fig. 33-34.
Haplophragmium canariense Brady, 1884, p. 310, pl. XXXV, fig. 1-5.
Haplophragmoides canariensis Wiesner, 1931, p. 95, pl. II; Chapman and Parr, 1937, p. 139; Parr, 1950, p. 270.

This species is widely distributed in the Antarctic area. The Deep Freeze IV samples show a depth range of 164 to 805 meters for this species. It is most abundant at station 020, with a Foraminiferal Number of 4.8.

21. Haplophragmoides cf. rotulatum (Brady) Pl. 10, fig. 21 a, b

Haplophragmium rotulatum Brady, 1881, p. 50; Brady, 1884, p. 306, pl. XXXIV, fig. 5-6.

For this species the samples show a depth range of 594 to 2,620 meters, with observations from the Ross Sea, Weddell Sea, and off Queen Maud Land.

22. Recurvoides contortus Earland Pl. 10, fig. 22

Haplophragmoides scitula Wiesner, 1931, p. 96, pl. XII, fig. 141.
Haplophragmoides scitulum Earland, 1933, n. 112, pl. III, fig. 11-12.
Recurvoides contortus Earland, 1934, p. 91, pl. X, fig. 7-19; Chapman and Parr, 1937, p. 138, pl. IX, fig. 34; Parr, 1950, p. 273.

Typical examples are found at all stations at which this species occurs. The depth range in the Deep Freeze IV samples for this species is 365 to 2,995 meters. It has a wide geographic distribution in the Antarctic area.

Subfamily **LITUOLINAE**

23. **Cyclammina orbicularis** Brady Pl. 10, fig. 23

Cyclammina orbicularis Brady, 1884, p. 353, pl. XXXVII, fig. 17-19; Wiesner, 1931, p. 97, pl. XIII, fig. 149; Earland, 1936, p. 39, pl. I, fig. 27-28.
Cyclammina orbicularis var. *asellina* Wiesner, 1931, p. 97, pl. XIII, fig. 150.

The variation *asellina* was not separated in this report; however, a few specimens did occur. The samples observed revealed this species to exist between depths of 1,281 and 2,995 meters from off Queen Maud Land, Weddell Sea, and the Ross Sea.

24. **Cyclammina pusilla** Brady Pl. 11, fig. 24 a, b

Cyclammina pusilla Brady, 1884, p. 353, pl. XXXVII, fig. 20-23; Wiesner, 1931, p. 97, pl. XIII, fig. 151; Earland, 1936, p. 39, pl. I, fig. 25-26; Parr, 1950, p. 273.

This is a widely spread form in the Antarctic area, with a depth range of 612 to 2,995 meters in our samples. It is most common in sample 007, with a frequency of .42 specimens per gram.

Family **TEXTULARIIDAE**

Subfamily **TEXTULARIINAE**

25. **Textularia antarctica** (Wiesner) Pl. 11, fig. 25

Bolivina punctata var. *arenacea* Heron-Allen and Earland, 1922, p. 133, pl. IV, fig. 21-22.
Pseudobolivina antarctica Wiesner, 1931, p. 99, pl. XXI, fig. 257-258, pl. XXIII, stereo-fig. C.
Textularia antarctica Earland, 1934, p. 116, pl. IV.

This is a common, widely distributed Antarctic form, being found in sixteen samples between 384 and 1,670 meters of water depth.

26. **Textularia** cf. **catenata** Cushman Pl. 11, fig. 26

Textularia catenata Cushman, 1911, p. 23, fig. 39-40; Earland, 1935, p. 115, pl. IV, fig. 44-47.

This is a rare form, being represented by only one specimen at each of four stations between 658 and 2,620 meters of water depth. The geographic distribution of the samples indicates that it is widely spread in the Antarctic area.

27. **Textularia tenuissima** Earland Pl. 11, fig. 27

Textularia elegans Lacroix, 1932, p. 8, fig. 4, 6.
Textularia tenuissima Earland, 1933, p. 95, pl. III, fig. 21-30; Earland, 1934, p. 115; Chapman and Parr, 1937, p. 151, pl. X, fig. 43; Parr, 1950, p. 276.

This species is widely distributed in the Antarctic area and has been reported from widely dispersed areas over the world. It ranged in depth from 384 to 2,620 meters and was observed in 16 samples. It is most common at station 024, at a depth of 2,620 meters.

Family VERNEUILINIDAE

28. **Verneuilina minuta** Wiesner Pl. 11, fig. 28

Verneuilina minuta Wiesner, 1931, p. 99, pl. 13, fig. 155; Earland, 1934, p. 119, pl. V. fig. 22-26.

This species was found in eight samples, ranging in depth from 384 to 690 meters. It was rare at all stations at which it was observed. All observations were confined to the Ross Sea, except for sample 040, which came from the Weddell Sea.

Family VALVULINIDAE
Subfamily EGGERELLINAE

29. **Eggerella bradyi** (Cushman) Pl. 11, fig. 29

Verneuilina pygmaea Brady, 1884, p. 385, pl. XLVII, fig. 6.
Verneuilina bradyi Cushman, 1911, p. 54.
Eggerella bradyi Cushman, 1933a, p. 33.

This form of *E. bradyi* is rare and was confined to two samples off Queen Maud land. The depths of these samples were 1,670 and 2,620 meters.

30. **Eggerella bradyi nitens** (Wiesner) Pl. 11, fig. 30

Verneuilina bradyi Cushman var. *nitens* Weisner, 1931, p. 99, pl. XIII, fig. 154; Earland, 1934, p. 118, pl. V, k, fig. 19-21.
Eggerella bradyi var. *nitens* Cushman, 1937, p. 53, pl. V, fig. 20; Parr, 1950, p. 281.

This form is almost as wide as it is long. The typical measurements of my specimens are .6 mm. long and .5 mm. in diameter. The typical grayish forms are present in my samples. This species has a fairly wide distribution in the Antarctic area but is generally rare. Specimens of this species were confined to samples off Queen Maud Land in my cores.

Family **SILICINIDAE**
Subfamily **RZEHAKININAE**

31. **Miliammina arenacea** (Chapman) Pl. 11, fig. 31 a, b

Miliolina oblonga (Montagu) var. *arenacea* Chapman, 1916, p. 59.
Miliolina oblonga var. *arenacea* Heron-Allen and Earland, 1922, p. 66.
Miliammina oblonga Heron-Allen and Earland, 1929, p. 41-42.
Miliammina arenacea Earland, 1934, p. 110; Parr, 1950, p. 253.

This species is common in the Antarctic area. The depth range is of little value as this species has been reported from many depths.

32. **Miliammina lata** Heron-Allen and Earland Pl. 11, fig. 32 a, b

Miliolina agglutinans Chapman, 1916, p. 58, pl. I, fig. 6.
Miliammina lata Heron-Allen and Earland, 1929, p. 253, pl. I, fig. 13-17; Earland, 1933, p. 93, pl. III, fig. 17; Earland, 1934, p. 111; Parr, 1950, p. 253, pl. III, fig. 4.

Earland and Parr have observed that *M. lata* is absent from many stations from which *M. arenacea* has been described; however, the species are frequently found in association with each other. The reported observations of *M. lata* are from a depth range of 177 to 474 meters in Parr's area; however, Earland in 1934 described them from 4,517 meters. In our samples this species ranges from depths of 450 to 1,670 meters.

33. **Miliammina oblonga** Heron-Allen and Earland Pl. 11, fig. 33 a, b

Miliammina oblonga Heron-Allen and Earland, 1929, p. 41; MacFadyen, 1933, p. 92; Earland, 1934, p. 111.

Earland stated that depth seems to have little effect on *M. oblonga,* as he found it present with a depth range of 50 to 4,517 meters. In my samples it ranges from depths of 274 to 805 meters.

Family **MILIOLIDAE**

34. **Quinqueloculina** sp. A Pl. 12, fig. 34, a, b, c

Observation of this species is based on one specimen from station 129.

35. **Sigmoilina umbonata** Heron-Allen and Earland Pl. 12, fig. 35

Sigmoilina umbonata Heron-Allen and Earland, 1922, p. 71, pl. I, fig. 7-8.

This species was found in both the Ross Sea and the Weddell

Sea between the depths of 164 and 2,450 meters. It was by far the most common at station 128, with a Foraminiferal Number of 50.

36. **Tubinella funalis** (Brady) Pl. 12, fig. 36

Articulina funalis Brady, 1884, p. 186, pl. 13, fig. 6-17.
Tubinella funalis Wiesner, 1931, p. 109, pl. I, fig. 6; Earland, 1934, p. 51; Parr, 1950, p. 289; Loeblich and Tappan, 1955, p. 19; Barker, 1960, pl. 13, fig. 6-11.

This is a widely distributed but fairly rare form. It was confined to the Ross Sea samples in the Deep Freeze IV sediments. It occurred in four samples ranging in depths from 164 to 475 meters. Its maximum abundance was 1.3 specimens per gram in sample 128.

37. **Triloculina** sp. A Pl. 12, fig. 37 a, b

This species was represented by one specimen from station 129.

38. **Triloculina rotunda** d'Orbigny Pl. 12, fig. 38 a, b

Triloculina rotunda d'Orbigny, 1826, p. 299.

39. **Triloculina tricarinata** d'Orbigny Pl. 12, fig. 39

Triloculina tricarinata d'Orbigny, 1826, p. 299; Chapman and Parr, 1937, p. 134; Parr, 1950, p. 294.
Miliolina tricarinata Brady, 1884, p. 165, pl. III, fig. 17; Heron-Allen and Earland, 1922, p. 66.

This is a rare form in the Antarctic area. It was found in four Deep Freeze IV samples, ranging in depth from 164 to 2,620 meters.

40. **Cruciloculina triangularis** d'Orbigny Pl. 12, fig. 40 a, b

Cruciloculina triangularis d'Orbigny, 1839, p. 72.
Miliolina tricarinata var. *crucioralis* Wiesner, 1931, p. 105.
Triloculina triangularis Parr, 1950, p. 295.

I disagree with authors who think that the distinct aperture of this species is not worthy of a generic distinction, and I choose to maintain D'Orbigny's full name for this species. In previous reports this species has been reported from the Falkland Islands, South Georgia, and the area covered by Parr, 1950. In all previous reports it has been of rare occurrence, and my samples confirm these observations, with sample 129 being the only sample with any specimens.

41. **Pyrgo** sp. A Pl. 13, fig. 41

Two specimens of this species—one from the Ross Sea and one from the Weddell Sea—occurred in our samples. The depth ranged from 384 to 475 meters.

42. **Pyrgo elongata** (d'Orbigny) Pl. 13, fig. 42

Biloculina elongata d'Orbigny, 1826, p. 298.
Pyrgo elongata Chapman and Parr, 1937, p. 136.

This species was not reported by Parr but was found in four samples ranging in depths from 164 to 475 meters. One specimen was found in the Weddell Sea area, but the others came from beneath the Ross Ice Shelf.

43. **Pyrgo depressa** (d'Orbigny) Pl. 13, fig. 43

Biloculina depressa d'Orbigny, 1826, p. 298.
Pyrgo depressa Earland, 1934, p. 46; Chapman and Parr, 1937, p. 135; Parr, 1950, p. 297.

The *Pyrgo depressa* is large in the Antarctic area. It probably is universally distributed in the area but is rare in some areas. The depth range in our samples was 274 to 805 meters.

44. **Pyrgo murrhina** (Schwager) Pl. 13, fig. 44

Biloculina murrhina Schwager, 1866, p. 203, pl. IV; Wiesner, 1931, p. 110, pl. XVII, fig. 195.
Pyrgo murrhina Chapman and Parr, 1937, p. 136; Parr, 1950, p. 297.

The depth range in Antarctica, from previous records, is 385 to 3,410 meters, but this is based on three samples. This species occurred in two samples from depths of 384 to 2,620 meters. A total of four specimens was found.

45. **Pyrgoella sphaera** (d'Orbigny) Pl. 13, fig. 45

Biloculina sphaera d'Orbigny, 1839, p. 66.
Miliolinella sphaera Wiesner, 1931, p. 107, pl. XV, fig. 177.
Pyrgoella sphaera Cushman and White, 1936, p. 90; Parr, 1950, p. 299.
Planispirina sphaera Heron-Allen and Earland, 1932, p. 322, pl. IV, fig. 41-42; Earland, 1934, p. 51, pl. IX, fig. 2.

The forms I observed were typical, confirming other persons' observations of this fact. It ranged in depth from 164 to 475 meters, with a maximum occurrence of 2.3 specimens per gram at station 129. All observations of this species were from the Ross Sea area.

Family **OPHTHALMIDIIDAE**
Subfamily **CORNUSPIRINAE**

46. **Cornuspira corticata** Chapman and Parr Pl. 13, fig. 46 a, b

Cornuspira involvens Heron-Allen and Earland, 1922, p. 74.
Cornuspira involvens var. *corticata* Chapman and Parr, 1937, p. 128, pl. IX, fig. 32.
Cornuspira corticata Parr, 1950, p. 284.

This species has been recorded from various Antarctic areas under the name *Cornuspira involvens;* however, I have chosen to accept Parr's decision that this species is different from *C. involvens.* The Deep Freeze IV samples reveal it from a depth range of 165 to 475 meters. It was most abundant at station 129, with a concentration of .57. Specimens were not found outside the Ross Sea beyond the Ballenys Islands in our samples.

47. **Cornuspirinoides profundum** Stschdrina Pl. 13, fig. 47 a, b

Cornuspirinoides profundum Stschdrina, 1946, p. 147.

The identification of this species is subject to doubt, as I had no types with which to compare my specimens, but Stschdrina's figures and descriptions closely fit my specimens, one each from station 037 and 040, at a depth of 365 and 384 meters respectively.

48. **Planispirinoides bucculentus** (Brady) Pl. 13, fig. 48 a, b

Miliolina bucculenta Brady, 1884, p. 170, pl. CXIV, fig. 3.
Miliolinella subrotunda var. *trigonina* Wiesner, 1931, p. 107.
Planispirinoides bucculentus Parr, 1950, p. 287, pl. VI, fig. 1-6, text-fig. 1-5.

This species was first described from the North Atlantic as *Miliolina bucculenta* by Brady; however, Parr made thin sections of individuals from the Antarctic and North Atlantic areas and found the initial stage to be a "*Cornuspira*-like" stage. This report follows Parr's descriptions on the basis of external character. Thin sections were not made of this individual by this author. It occurred in four samples, all from the Ross Sea between depths of 164 and 475 meters.

Family **TROCHAMMINIDAE**
Subfamily **TROCHAMMININAE**

49. **Trochammina conica** Earland Pl. 13, fig. 49 a, b

Trochammina conica Earland, 1935, p. 104, pl. III.

This is a common Antarctic form. It is found between 320 and 2,995 meters in almost all areas. It was observed in 24 samples.

50. **Trochammina glabra** Heron-Allen and Earland Pl. 13, fig. 50 a, b

Trochammina glabra Heron-Allen and Earland, 1932, p. 344.

This species was observed in 15 samples, ranging in depths from 164 to 2,620 meters. It was most common at station 128, with a Foraminiferal Number of 35.

51. **Trochammina grisea** Earland Pl. 14, fig. 51 a, b

Trochammina grisea Earland, 1935, p. 104, pl. III.

This species occurred in twenty samples, ranging in depths from 164 to 1,730 meters. It was typical at all stations from which it was observed.

52. **Trochammina antarctica** Parr Pl. 14, fig. 52 a, b

Trochammina antarctica Parr, 1950, p. 280, pl. V, fig. 2-4.

This species is believed to be confined to the Antarctic area; however, it is widely distributed. It is found in 21 samples between depths of 164 and 2,995 meters. It is common at most stations from which it was observed.

53. **Cystammina** cf. **galeata** (Brady) Pl. 14, fig. 53 a, b

Trochammina galeata Brady, 1884, p. 344, pl. 40, fig. 19-23.
Cystammina galeata Barker, 1960, p. 82, pl. 40, fig. 19-23.

Specimens of this species were confined to sample 129, at a depth of 475 meters, and numbered only two. The test is almost totally cement with only a few quartz grains.

Subfamily **AMMOSPHAEROIDININAE**

54. **Cystammina pauciloculata** (Brady) Pl. 14, fig. 54

Trochammina pauciloculata Brady, 1884, p. 344, pl. XLI, fig. 1-2.
Cystammina pauciloculata Earland, 1934, p. 106; Chapman and Parr, 1937, p. 159; Parr, 1950, p. 280; Barker, 1960, pl. XLI, fig. 1-2.

This species seems to have a fairly wide distribution in the Antractic area, considering the distribution of the areas from which it has been reported. It occurred in only two samples in the Deep Freeze IV sediments, both were from the Ross Sea.

Family **LAGENIDAE**
Subfamily **NODOSARINNAE**

55. **Robulus pliocaenicus** (Silvestri) Pl. 14, fig. 55

Cristellaria sp. Brady, 1884, pl. 69, fig. 5.
Polymorphina pliocaena Silvestri, 1898, p. 234, pl. 4, fig. 3.
Robulus pliocaenicus Thalmann, 1932, p. 252.

This species is represented by two specimens, both from the Ross Sea. It was obtained from samples 128 and 129, with depths of 164 and 475 meters respectively.

56. **Lenticulina (Robulus) altifrons** Parr Pl. 14, fig. 56

Lenticulina (Robullus) altifrons Parr, 1950, p. 323, pl. XI, fig. 12.

This species was described from the Tasmanian area. In the Deep Freeze IV samples, it was confined to sample 129 within the Ross Sea area, with a Foraminiferal number of .09.

57. **Lenticulina antarctica** Parr Pl. 14, fig. 57

Cristellaria gibba Wiesner, 1931, p. 114.
Lenticulina (Robulus) antarctica Parr, 1950, p. 323, pl. XI, fig. 11 a, b.

Comparing data from other Antarctic reports indicates that this is probably the most common species of *Lenticulina* in the Antarctic area. It was observed in four samples, all from the Ross Sea, in our sediments. Its depth range in our samples is 164 to 475 meters.

58. **Lenticulina (Robulus) asterizans** Parr Pl. 14, fig. 58

Lenticulina (Robulus) asterizans Parr, 1950, p. 322, pl. XI, fig. 9-10.

This species is confined to the Antarctic area. Parr's statement, "The contrast between the heavy, radial sutures and the transparent chamber walls is very striking" sums up the description well. It was found in three samples from the Ross Sea between depths of 164 and 475 meters.

59. **Frondicularia** cf. **pygmaea** Sidebottom Pl. 14, fig. 59

Frondicularia pygmaea Sidebottom, 1907, p. 5, fig. 27.

The Deep Freeze IV samples revealed only one specimen of this species. The observation was from station 129, at a depth of 475 meters within the Ross Sea.

60. **Dentalina** sp. A Pl. 14, fig. 60

Two specimens of this species were found—one from the Ross Sea and one from the Weddell Sea.

61. **Dentalina** cf. **communis** (d'Orbigny) Pl. 15, fig. 61

62. **Dentalina communis larva** (Earland) Pl. 15, fig. 62

Nodosaria communis d'Orbigny var. *larva* Earland, 1934, p. 167.

This species was confined to station 129 in the Ross Sea and had a concentration of .09 specimens per gram.

63. **Nodosaria** sp. Pl. 15, fig. 63

This species is represented by one broken fragment in sample 013.

64. **Nodosaria calomorpha** Reuss Pl. 15, fig. 64

Nodosaria calomorpha Reuss, 1866, p. 129, pl. 1, fig. 15-19; Brady, 1884, pl. 61, fig. 23-27; Heron-Allen and Earland, 1922, p. 168, n. 387.
Dentalina translucens Parr, 1950, p. 328, pl. XI, fig. 25.

I think Parr's *D. translucens* is a form of *N. calomorpha*, and I have retained *N. calomorpha* for my specimens. It occurred in one sample, 020, from the Weddell Sea, but in the sample it has a Foraminiferal Number of 1.6.

Subfamily **LAGENINAE**

65. **Lagena** sp. A Pl. 15, fig. 65

Specimens placed here ranged in the samples from 164 to 1,670 meters in depth. It was most abundant at station 128, with a Foraminiferal Number of 2.6.

66. **Lagena** sp. B Pl. 15, fig. 66

This is a rare form, probably related to *Entosolenia fissicarinata* (Parr). It has a little sharper angle, considering the aperture as the apex. The specimen had no entosolenian tube, and the surface of the test was coarsely perforate, but in overall shape and size it was nearly identical to *E. fissicarinata*, especially in keel construction. Its only occurrence was at station 129.

67. **Lagena** sp. C Pl. 15, fig. 67

This species, consisting of one specimen, was confined to station 009.

68. **Lagena** sp. D Pl. 15, fig. 68

This species was found in three samples—two samples from the Weddell Sea and one from off Queen Maud Land. It was most abundant at station 020, with a Foraminiferal Number of 1.1.

69. **Lagena** sp. E Pl. 15, fig. 69 a, b

This specimen is probably one of the *L. trigona* subspecies.

70. **Lagena alveolata separans** Sidebottom Pl. 15, fig. 70 a, b

Lagena alveolata Brady var. *separans* Sidebottom, 1912, p. 425, pl. 21, fig. 5; Earland, 1936, p. 44, pl. 1, fig. 43-44.

This subspecies of *L. alveolata* was not reported to be present in Parr's Antarctic samples; *semisculptra* was reported. It was observed from three stations—two from off Queen Maud Land and one from the Ross Sea. It was most abundant at station 024, with three representatives. The depth range was 475 to 2,620 meters.

71. **Lagena apiculata** (Reuss) Pl. 15, fig. 71

Oolina apiculata Reuss 1851, p. 22, pl. 2, fig. 1
Lagena apiculata Earland, 1934, p. 142, pl. VI, fig. 36.

This species had one representative, which was found at station 024, at a depth of 2,620 meters.

72. **Lagena basireticulata** Earland Pl. 15, fig. 72 a, b

Lagena basireticulata Earland, 1934, p. 143, pl. VII, fig. 39-40.

Earland's species were all from deep water (4,344 to 3,713 meters), both inside and outside the Antarctic convergence line. The samples revealed one specimen which came from 2,620 meters' depth at station 024.

73. **Lagena catenulata** (Williamson) Pl. 15, fig. 73

Entosolenia catenulata Williamson, 1858, p. 12, pl. 1, fig. 29.
Lagena (Entosolenia) catenulata Wiesner, 1931, p. 116, pl. 18.

The Deep Freeze IV samples revealed two specimens of this species, both being from the Ross Sea between the depths of 594 and 658 meters.

74. **Lagena caudata** (d'Orbigny) Pl. 15, fig. 74 a, b

Oolina caudata d'Orbigny, 1839, p. 19, pl. V, fig. 6.
Lagena caudata Heron-Allen and Earland, 1932, p. 365, pl. X, fig. 9; Parr, 1950, p. 301, pl. VIII, fig. 2.

My specimens differ from the types, in that the costae are weaker. Specimens were observed to vary from no costae to fairly pronounced costae. This species was found in two samples from the Ross Sea, between the depths of 455 and 475 meters.

75. **Lagena costata** (Williamson) Pl. 16, fig. 75

Entosolenia costata Williamson 1858, p. 9, pl. I, fig. 18.
Lagena costata Heron-Allen and Earland, 1932, p. 369, pl. X, fig. 19-24.

This species was found in one sample—023. It was fairly common, having a Foraminiferal Number of .46.

76. **Lagena elongata** (Ehrenberg) Pl. 16, fig. 76

Miliola elongata Ehrenberg, 1845, p. 317.
Lagena elongata Brady, 1884, p. 457, pl. LVI, fig. 29; Heron-Allen and Earland, 1932, p. 363; Parr, 1950, p. 299.

This species has been reported to be rare in the Antarctic area. It was found in four samples from the Deep Freeze IV project. The depths ranged from 164 to 2,620 meters. It was most common at station 024, with a Foraminiferal Number of .36.

77. **Lagena feildeniana** Brady Pl. 16, fig. 77

Lagena feildeniana Brady, 1878, p. 434; Brady, 1884, p. 469, pl. 58, fig. 38-39.

This species was found in three samples—two samples from the Weddell Sea and one from the Ross Sea. It was most common at station 020, with a Foraminiferal Number of 2.7.

78. **Lagena fimbriata** Brady Pl. 16, fig. 78

Lagena fibriata Brady, 1884, p. 486, pl. LX, fig. 26.
Lagena (*Entosolenia*) *fimbricata* Wiesner, 1931, p. 122, pl. XIX, fig. 232.
Fissurina fimbriata Parr, 1950, p. 307; Barker, 1960, pl. 60.

This species was found from the Weddell Sea and off Queen Maud Land. It is represented in a total of four samples.

79. **Lagena formosa** Schwager Pl. 16, fig. 79

Lagena formosa Schwager, 1866, p. 206, pl. 7, fig. 1; Brady, 1884, p. 480, pl. 60, fig. 18-19.
Fissurina formosa var. *augusticarinata Parr,* 1950, p. 313, pl. IX, fig. 8.

My specimens differ from Parr's description and figure in that mine have the notch in the keel at the base of the test, similar to those described by Cushman in 1933, and Parr's have no notch. It was found in four samples, between depths of 384 and 1,670 meters.

80. **Lagena globosa** (Montagu) Pl. 16, fig. 80

Vermiculum globosum Montagu, 1803, p. 523.
Lagena globosa Brady, 1884, p. 452, pl. 56, fig. 2.
Oolina globosa Parr, 1950, p. 302; Barker, 1960, pl. 56, fig. 2.

This species was found between the depths of 164 and 2,620 meters in our samples but was most common at station 129, at a depth of 475 meters, with a Foraminiferal Number of 4.4.

81. **Lagena hispidula** Cushman Pl. 16, fig. 81

Lagena laevis Brady, 1884, p. 455, pl. LVI, fig. 10-11.
Lagena hispidula Cushman 1913a, p. 14, pl. 56, fig. 10-11; Heron-Allen and Earland, 1932, p. 364; Earland, 1934, p. 152, pl. VI, fig. 58-60; Parr, 1950, p. 300.

This species is represented by one specimen from sample 006, at a depth of 1,730 meters.

82. **Lagena laevis** (Montagu) Pl. 16, fig. 82

Vermiculum laeve Montagu, 1803, p. 524.
Lagena semistriata Brady, 1884, pl. LVII, fig. 17.
Lagena laevis Barker, 1960, p. 118, pl. 57, fig. 17.

This species was found in three samples—two samples from off Queen Maud Land and one from the Weddell Sea; it was rare at all three stations.

83. **Lagena melo** (d'Orbigny) Pl. 16, fig. 83

Oolina melo d'Orbigny, 1839, p. 19.
Lagena melo Heron-Allen and Earland, 1932, p. 370, pl. X, fig. 25-27; Parr, 1950, p. 303.

This species has been reported from the Kerguelen Islands and the vicinity of the Falkland Islands in previous reports. Our samples reveal a depth range of 164 to 2,620 meters.

84. **Lagena meridionalis** Wiesner Pl. 16, fig. 84

Lagena gracilis Brady, 1884, p. 464, pl. 58, fig. 19.
Lagena gracilis var. *meridionalis* Wiesner, 1931, p. 117.
Lagena meridionalis Loeblich and Tappan, 1953, p. 59.

This species is widely distributed, with specimens from the Weddell Sea, Ross Sea, and off Queen Maud Land. The depths of the samples from which it came range from 320 to 2,620 meters.

85. **Lagena nebulosa** Cushman Pl. 16, fig. 85

Lagena laevis Brady, 1884, p. 455, pl. 56.
Lagena laevis (Montagu) var. *nebulosa* Cushman, 1923, p. 29, pl. 5, fig. 4-5.
Lagena nebulosa Barker, 1960, pl. 56.

This species was found in five samples from the Weddell Sea and off Queen Maud Land. It ranged in depth from 800 to 2,620 meters.

86. **Lagena orbignyana** (Seguenza) variation A Pl. 16, fig. 86

This is of the *L. orbignyana* group, but the variation is not known to the author and it might well represent a new subspecies. It was found in four samples from the Weddell Sea and off Queen Maud Land, with a depth range of 384 to 2,620 meters. It was most abundant at station 020, with a Foraminiferal Number of 2.2.

87. **Lagena squamosa ocellata** Wiesner Pl. 16, fig. 87

Lagena squamosa (Montagu) var. *ocellata* Wiesner, 1931, p. 118.

This species was reported from three stations—one from the Ross Sea, one from the Weddell Sea, and one off Queen Maud Land.

88. **Lagena squamosasulcata** Heron-Allen and Earland Pl. 16, fig. 88

Lagena squamosa-sulcata Heron-Allen and Earland, 1922, p. 151, pl. V, fig. 15, 19; Wiesner, 1931, p. 119, pl. XXIII, fig. H; Earland, 1934, p. 162, pl. VII, fig. 26-28; Chapman and Parr, 1937, p. 74.
Oolina squamososulcata Parr, 1950, p. 304.

This species was found in five samples, four being from the Ross Sea and one from the Weddell Sea. It ranged in depth from 164 to 658 meters in our samples.

89. **Lagena subacuticosta** Parr Pl. 16, fig. 89

Lagena sulcata Parker and Jones, 1865, p. 351.
Lagena acuticosta Brady, 1884, p. 464, Wiesner, 1931, p. 117.
Lagena subacuticosta Parr, 1950, p. 302, pl. VIII, fig. 3.
Lagena apiopleura Loeblich and Tappan, 1953, p. 59.

This is one of the most common species of *Lagena* in the Antarctic area. I have chosen to accept Mr. W. J. Parr's species name here rather than Mr. Wiesner's identification. Specimens of this species were observed from seven samples, being located in the Ross Sea, Weddell Sea, and off Queen Maud Land. It was most typical and abundant from station 129, with a Foraminiferal Number of 27.

90. **Lagena texta** Wiesner Pl. 16, fig. 90

Lagena texta Wiesner, 1931, p. 121, pl. XIX, fig. 230.
Fissurina texta Parr, 1950, p. 309.

The reported depth range of this species so far is 193 meters to a depth of 540 meters. In our samples only four specimens were found, all from station 040, at a depth of 384 meters in the Weddell Sea.

Family **POLYMORPHINIDAE**
Subfamily **POLYMORPHININAE**

91. **Globulina gibba** (d'Orbigny) Pl. 16, fig. 91

Polymorphina (*Globulina*) *gibba* d'Orbigny, 1826, p. 266, fig. 63.
Globulina gibba (d'Orbigny), Thalmann, 1932, p. 306; Parr, 1950, p. 332.

I have one specimen that has been placed in this species. It is located off Queen Maud Land in sample 024, at a depth of 2,620 meters.

92. **Glandulina antarctica** Parr Pl. 17, fig. 92 a, b

Glandulina rotundata Wiesner, 1931, p. 115.
Glandulina laevigata Wiesner, 1931, p. 115.
Glandulina antarctica Parr, 1950, p. 334, pl. XII, fig. 8, 9 a, b

Both megalospheric and microspheric forms are present in the samples which yield this species. This species was reported by Parr from the Antarctic, Kerguelen, and Tasmania areas. The depth range in our samples is 365 to 800 meters for this species. It was found in the Ross Sea and the Weddell Sea.

93. **Rectoglandulina torrida** (Cushman) Pl. 17, fig. 93

Polymorphinidae torrida Cushman, 1923, p. 65.
Rectoglandulina torrida Barker, 1960, p. 128.

This species had one representative in our Antarctic samples and was found in sample 129.

94. **Polymorphina** sp. A Pl. 17. fig. 94

Specimens of this species were from three stations, all from the Ross Sea between depths of 164 and 475 meters. It is rare except for station 129 which had 2.2 specimens per gram.

95. **Sigmomorphina** sp. A Pl. 17, fig. 95

This species is represented by two specimens, both from station 129, at a depth of 475 meters in the Ross Sea.

96. **Sigmomorphina subulata** Chapman and Parr Pl. 17, fig. 96

Sigmomorphina subulata Chapman and Parr, 1937, p. 77, pl. VII, fig. 10; Parr, 1950, p. 334.

Previous reports of this species report it from a longitude of 49° 41′ E to 89° 49′ E and from depths ranging from 300 to 456 meters. In our samples it occurred in the Ross Sea at station 129, from a depth of 475 meters and had a Foraminiferal Number of .10.

Family **NONIONIDAE**

97. **Nonion germanicus** (Ehrenberg) Pl. 17, fig. 97 a, b

Nonionina germanicum Ehrenberg, 1840, p. 23, pl. 2, fig. 1.
Nonion germanicum Cushman, 1939, p. 22, pl. V, fig. 31-32.
Nonion germanicus Parr, 1950, p. 370.

This species has been reported to be rare at each station from which it was previously reported; however, station 020 had a Foraminiferal Number of 8.3, station 129 a Foraminiferal Number of 13, and station 128 a Foraminiferal Number of 29. Its depth range in our samples was 164 to 1,281 meters.

98. **Astronion** sp. A Pl. 17, fig. 98

This species had a depth range of 164 to 1,281 meters in the Deep Freeze IV samples, with a fairly wide geographic distribution.

99. **Nonionella bradii** (Chapman) Pl. 17, fig. 99 a, b

Nonionina (?) *scapha* Brady, 1884, p. 730, pl. CIX, fig. 6.
Nonionina scapha var. *bradii* Chapman, 1916, p. 71, pl. V, fig. 42.
Nonionella bradii Parr, 1950, p. 371.

This species seems to be most abundant in the Ross Sea; however, it has been reported from the elevated slopes of Mt. Erebus, B.A.N.Z. Antarctic area, and the Australian Antarctic area. In our samples it occurred in 13 samples, between the depths of 2,620 and 164 meters.

100. **Nonionella** sp. A Pl. 17, fig. 100

This species ranged in depths from 164 to 1,670 meters. It seems to be widely distributed in the Antarctic area, with observations from ten samples from the Ross Sea, Weddell Sea, and off Queen Maud Land.

Family **BULIMINIDAE**

Subfamily **TURRILININAE**

101. **Pseudobulimina chapmani** (Heron-Allen and Earland) Pl. 18, fig. 101 a, b

Bulimina chapmani Heron-Allen and Earland, 1922, p. 130, pl. 4.
Robertina chapmani Wiesner, 1931, p. 124, pl. 20.
Pseudobulimina chapmani Earland, 1934, p. 134, pl. 6.

The depth range of this species in the Deep Freeze IV samples is 164 to 2,450 meters, but it is more common in our area at depths less than 500 meters. Its maximum and most typical occurrence was at station 129, at a depth of 475 meters, with a Foraminiferal Number of 42.

102. **Buliminella basicostata** Parr Pl. 18, fig. 102

Buliminella elegantissima var. *seminuda* Brady, 1884, p. 403, pl. L, fig. 23-24.
Buliminella basicostata Parr, 1950, p. 336, pl. XII, fig. 11-12.
Buliminella madagascariensis Cushman and Parker, 1947, p. 61.

This species was not reported from the Antarctic by Parr, 1950. It was found in four samples, with a depth range of 320 to 475 meters. Specimens were found in the Ross Sea area and the Weddell Sea. It was most abundant at station 129, with a Foraminiferal Number of .55.

103. **Buliminella cochlea** Wiesner Pl. 18, fig. 103

Buliminella elegantissima var. *cochlea* Wiesner, 1931, p. 124, pl. XIX, fig. 237.
Buliminella cochlea Parr, 1950, p. 325, pl. XII, fig. 10.

The Deep Freeze IV specimens of this species had a depth range of 365 to 2,450 meters, but at none of the three stations at which it was found was it abundant. The three stations are all located in the Ross Sea.

Subfamily BULIMININAE

104. **Bulimina aculeata** d'Orbigny Pl. 18, fig. 104

Bulimina aculeata d'Orbigny, 1826, p. 269, pl. 11, fig. 128; Brady, 1884, p. 406, pl. LI, fig. 7-9; Parr, 1950, p. 337.

Parr observed this species in only one station, which had a depth of 1,718 meters. The depth range in the Deep Freeze IV samples was 320 to 1,670 meters, but it was most abundant at station 005, with a Foraminiferal Number of 4.8. It was also found in two other samples, 010 and 023, but was represented by 1 and .4 specimens, respectively.

105. **Bulimina gibba** Fornasini Pl. 18, fig. 105

Bulimina elegans Brady, 1884, p. 398, pl. L, fig. 1-4.
Bulimina gibba Fornasini, 1901, p. 378.
Bulimina fusiformis Fornasini, 1901, p. 377.
Bulimina baccata Cushman and Parker, 1940, p. 14, pl. 3, fig. 1-6.

This species is represented by one specimen, which was found at station 005, at a depth of 1,670 meters, off Queen Maud Land.

106. **Entosolenia** sp. A Pl. 18, fig. 106

Specimens of this species were found in the Ross and Weddell Seas, with the highest concentration—1.6 specimens per gram of sample—being at station 020.

107. **Entosolenia** sp. B Pl. 18, fig. 107

This form is related to *E. lateralis* (Cushman). The entosolenian tube extends almost to the bottom of the chamber, with a slight flare at the bottom of the tube. The shape is a little more elongate than *E. lateralis*. It was found in the Ross Sea and Weddell Sea.

108. **Entosolenia** sp. D Pl. 18, fig. 108

Specimens of this species were confined to one sample, 128, in the Ross Sea.

109. **Entosolenia** sp. C Pl. 18, fig. 109

Specimens of this species are found in the Ross and Weddell Seas between depths of 164 and 475 meters in the Deep Freeze IV samples.

110. **Entosolenia annectens** (Burrows and Holland) Pl. 18, fig. 110

Lagena annectens Burrows and Holland, 1895, p. 203, pl. 7, fig. 11; Fornasini, 1901, p. 50, text-fig. 4; Heron-Allen and Earland, 1932, pl. X, fig. 40-44.

This species is confined to the Weddell Sea in the Deep Freeze IV samples and is represented by two specimens from station 040.

111. **Entosolenia auriculata** (Brady) Pl. 18, fig. 111

Lagena auriculata Brady, 1881, p. 61.

This species is represented from one core from the Weddell Sea and one core from off Queen Maud Land.

112. **Entosolenia botelliformis** (Brady) Pl. 19, fig. 112

Lagena botelliformis Brady, 1884, p. 454, pl. 56, fig. 6.
Oolina botelliformis Barker, 1960, pl. 56, fig. 6.

Specimens of this species were found in the Ross and Weddell Seas. It was most abundant in the Weddell Sea sample 020, at a depth of 800 meters, with a Foraminiferal Number of 1.1. Its depth range in our samples was 164 to 800 meters.

113. **Entosolenia earlandi** (Parr) Pl. 19, fig. 113

Lagena biancae Heron-Allen and Earland, 1932, p. 372, pl. X, fig. 35-39.
Fissurina earlandi Parr, 1950, p. 306, pl. VIII, fig. 8 a, b.

This species has been reported from the Falkland Islands, Kerguelen Islands, and the Antarctic area. In our samples it was found off Queen Maud Land, in the Weddell Sea, and within the Ross Sea.

114. **Entosolenia** cf. **E. fissicarinata** (Parr) Pl. 19, fig. 114 a, b

Fissurina fissicarinata Parr, 1950, p. 309, pl. VIII, fig. 11 a, b.

This species has been reported from the Antarctic and Kerguelen areas. This species is probably related to *Lagena marginata* "var." *fissa* Heron-Allen and Earland and *E. cushmani* Wiesner. In our samples it was confined to sample 129, but it was common in this sample with a Foraminiferal Number of 4.4.

115. **Entosolenia globosa caudigera** (Wiesner) Pl. 19, fig. 115

Lagena (*Entosolenia*) *globosa* var. *caudigera* Wiesner, 1931, p. 119.
Oolina globosa Parr, 1950, p. 302.

This species was found in samples between the depths of 365 and 2,620 meters in our sediments. It was most common at station 129, with a Foraminiferal Number of 2.2.

116. **Entosolenia kerguelenensis** (Parr) Pl. 19, fig. 116

Lagena staphyllearia Brady, 1884, p. 474, pl. LIX, fig. 8-11.
Fissurina kerguelenensis Parr, 1950, p. 305, pl. VIII, fig. 7.

My specimens of *E. kerguelenensis* are the same as Parr's in form except in size. The Antarctic specimens described by Parr are much larger than those that I have observed. Specimens were observed both in the Ross and Weddell Seas.

117. **Entosolenia lateralis** (Cushman) Pl. 19, fig. 117

Lagena lateralis Cushman, 1913, p. 9.
Ellipsolagena lateralis Wiesner, 1931, p. 126.
Parafissurina lateralis Parr, 1950, p. 316.

This species was first described by Cushman from a depth of 905 fathoms off Japan. Wiesner described it from Antarctica and Parr described it from Antartica and the Kerguelen area. Deep Freeze IV samples reveal it between depths of 164 and 685 meters, being most common at station 128, at a depth of 164 meters, with a Foraminiferal Number of 5.5.

118. **Entosolenia** cf. **lineata** Williamson Pl. 19, fig. 118

Entosolenia lineata Williamson, 1848, p. 18.
Lagena (*Entosolenia*) *lineata* Wiesner, 1931, p. 119, pl. XXIII, fig. G.

This species was confined to the Ross Sea in the Deep Freeze IV samples.

119. **Entosolenia nelsoni** (Heron-Allen and Earland) Pl. 19, fig. 119

Lagena stelligera var. *nelsoni* Heron-Allen and Earland, 1922, p. 148; Earland, 1934, p. 163.
Lagena nelsoni Parr, 1950, p. 307, pl. VIII, fig. 9.

I have chosen not to retain the original name but rather to follow Parr's changes, except for changing to *Entosolenia*. This unusual form seems to be confined to the Antarctic area, as the only records are in synonymy. In the Deep Freeze IV samples, it was confined to sample 129, but it had a concentration of 4.5 in this sample.

120. **Entosolenia pseudauriculata** (Earland) Pl. 19, fig. 120

Lagena pseudauriculata Earland, 1934, p. 158.

This species was found in the Ross and Weddell Seas, between the depths of 164 and 475 meters. It was not common at any of the three stations from which it was observed.

121. **Entosolenia subformosa** (Parr) Pl. 19, fig. 121

Fissurina subformosa Parr, 1950, p. 313, pl. IX, fig. 9 a, b.

This species was described and named on the basis of one specimen occurring at a latitude of 65° 48′ S, longitude of 53° 16′ E, at a depth of 193 meters. My specimens are confined to one sample in the Ross Sea, sample 128, at a depth of 164 meters. This species evidently has a wide geographic distribution within the shallower depths.

Subfamily **VIRGULININAE**

122. **Virgulina davisi** Chapman and Parr Pl. 19, fig. 122

Virgulina schreibersiana Brady, 1884, p. 414, pl. 52, fig. 1, 2.
Virgulina davisi Chapman and Parr, 1937, p. 88, pl. VIII, fig. 15.

This species ranged in depth from 164 to 1,670 meters, being most common off Queen Maud Land in sample 006.

123. **Bolivina earlandi** Parr Pl. 19, fig. 123

Bolivina punctata Earland, 1934, p. 132, pl. VI, fig. 5-7; Chapman and Parr, 1937, p. 92, pl. VIII, fig. 16.
Bolivina earlandi Parr, 1950, p. 339, pl. XII, fig. 16.

This species is believed to be confined to the Antarctic area and has a wide distribution in the area, but at no station yet observed has it been reported in abundance. In station 128 it was most abundant, with 2.6 specimens per gram of sample. In the Deep Freeze IV samples it had a depth range of 164 to 475 meters. It was found in the widely separated areas of the Ross and Weddell Seas.

Subfamily **UVIGERININAE**

124. **Uvigerina** sp. A Pl. 19, fig. 124

This species was confined to sample 129 in the Ross Sea area.

125. **Angulogerina earlandi** Parr Pl. 20, fig. 125 a, b

Angulogerina angulosa Cushman, 1927, p. 69; Chapman and Parr, 1937, p. 97.
Uvigerina angulosa Heron-Allen and Earland, 1932, p. 397, pl. XII, fig. 32-39.
Angulogerina earlandi Parr, 1950, p. 341, fig. 21, pl. XII.

This species has a wide variation in its forms. It varies from closely spaced costae to almost smooth. Heron-Allen and Earland have found the long, tapering forms to represent the megalospheric form and the short, broad forms represent the microspheric forms. I have accepted Mr. Parr's species, so I have not retained the older name, *Angulogerina angulosa*. It had a depth range of 164 to 2,620 meters in the Deep Freeze IV samples with a wide geographic distribution.

126. **Delosina sutilis** Earland Pl. 20, fig. 126

Delosina complexa Wiesner, 1931, p. 123, pl. XXI, fig. 254.
Delosina sutilis Earland, 1934, p. 129, pl. V, fig. 1-8.

Records of this species were confined to the Antarctic area until 1950, when Parr reported this species from the Kerguelen area. Only one sample had a representative of this species, and it was based on one specimen; that was sample 128, which is found in the Ross Sea at a depth of 164 meters.

Family **ELLIPSOIDINIDAE**

127. **Parafissurina dorbignyana** (Wiesner) Pl. 20, fig. 127

Lagena orbignyana Chapman, 1916, p. 66, pl. IV, fig. 29.
Ellipsolagena dorbignyana Wiesner, 1931, p. 127, pl. XXIV, fig. P.
Parafissurina valida Parr, 1950, p. 320, pl. X, fig. 21.

I have retained Wiesner's species for this individual in lieu of *P. valida* (Mathes), as proposed by Parr, as I did not read Matthes' paper. In the Deep Freeze IV samples this species ranges from depths of 164 to 2,620 meters and is most abundant in sample 129, with a Foraminiferal Number of 4.4.

128. **Parafissurina quadrata** Parr Pl. 20, fig. 128

Parafissurina quadrata Parr, 1950, p. 316, pl. 9, fig. 20 a, b.

Parr described this species from the Tasmanian area. One specimen of this species was found in sample 129 from the Ross Sea.

129. **Parafissurina subcarinata** Parr Pl. 20, fig. 129

Parafissurina subcarinata Parr, 1950, p. 318, pl. X, fig. 9 a-c.

This species is rare in previous reports and has not, to my knowledge, been reported from outside the Antarctic area. Its maximum abundance was at station 129, with a Foraminiferal Number of 24. The Deep Freeze IV samples show a depth range of 365 to 2,620 meters for this species.

Family **ROTALIIDAE**
Subfamily **SPIRILLININAE**

130. **Spirillina** cf. **wrightii** Heron-Allen and Earland Pl. 20, fig. 130

Spirillina wrightii Heron-Allen and Earland, 1930, p. 181; Earland, 1935, p. 180, pl. VIII.

This species was not observed by Parr. In our samples it was represented by one eroded specimen from station 129 within the Ross Sea.

Subfamily **DISCORBINAE**

131. **Patellina corrugata** Williamson Pl. 20, fig. 131 a, b

Patellina corrugata Williamson, 1858, p. 46, pl. 3, fig. 86-89; Heron-Allen and Earland, 1932, p. 406; Chapman and Parr, 1937, p. 102; Barker, 1960, p. 178.
Patellina antarctica Parr, 1950, p. 352, pl. XIII, fig. 19-21.

Chapman and Parr first stated in their report of 1937 that *P. corrugata* was present in Antarctica. Parr then stated in 1950 that:

> The large number of specimens of the same form from the present dredgings has convinced me that it is not Williamson's species. It is considerably larger, more depressed, with concave sides dorsally, more widely spaced septa, and a thin, wide, marginal keel.

I have found specimens fitting Parr's description; however, I have also found specimens from the same core more closely resembling *P. corrugata* with intermediate forms being present. I am retaining *P. corrugata* for this report.

132. **Patellinoides depressa** Heron-Allen and Earland Pl. 20, fig. 132

Patellinoides depressa Heron-Allen and Earland, 1932, p. 408, pl. XIII, fig. 30-33.

This species was found in only one sample—129—with a Foraminiferal Number of 2.2.

133. **Discorbis** cf. **globularis** (d'Orbigny) Pl. 20, fig. 133 a, b

Rosalina globularis d'Orbigny, 1826, p. 271, pl. XIII, fig. 1-2.
Discorbis globularis Earland, 1934, p. 180; Parr, 1950, p. 353.

In the Antarctic area the species is large and irregularly formed. The placement of specimens in this species is of slight doubt. The depth range in our samples was 164 to 475 meters. It was most common in station 128, with .83 specimens per gram of sample. The three stations which revealed specimens of this species were from the Ross Sea.

134. **Heronallenia wilsoni** (Heron-Allen and Earland) Pl. 21, fig. 134 a, b

Discorbina wilsoni Heron-Allen and Earland, 1922, p. 206.
Heronallenia wilsoni Chapman and Parr, 1931, p. 236.

This species has been reported from the Antarctic, South Georgia, and Falkland areas. The Deep Freeze IV samples reveal it from three samples, all from the Ross Sea area between depths of 164 and 475 meters. It is most abundant at station 128 with a Foraminiferal Number of 21.

135. **Gyroidina neosoldanii** Brotzen Pl. 21, fig. 135 a, b, c

Rotalia soldanii Brady, 1884, p. 706, pl. CVII, fig. 6-7; Earland, 1934, p. 189.
Gyroidina neosoldanii Brotzen, 1936, p. 158.
Gyroidina soldanii Parr, 1950, p. 360.

I have used Brotzen's species rather than *G. soldanii* d'Orbigny, because the Antarctic forms seem to fit this description best. The depth range for this species is 1,670 to 2,620 meters in our samples. It was most abundant at station 024, with a Foraminiferal Number of .41.

Subfamily **ROTALIINAE**

136. **Eponides tenera** (Brady) Pl. 21, fig. 136 a, b

Truncatulina tenera Brady, 1884, p. 665, pl. XCV, fig. 11.
Eponides tenera Cushman, 1954, p. 359.
Pseudoeponides tenera Parker, 1954, p. 530.

The depth range of this species in the Deep Freeze IV samples is 320 to 2,620 meters. It was found in all areas except the Palmer Peninsula and off Wilkes Land which are represented by stations 034 and 017, respectively.

137. **Eponides weddellensis** Earland Pl. 21, fig. 137 a, b

Eponides weddellensis Earland, 1936, p. 57, fig. 65-67.

This species has a depth range of 164 to 2,620 meters in the Deep Freeze IV samples. It has a wide geographic distribution in the Antarctic area.

Family **CASSIDULINIDAE**
Subfamily **CASSIDULININAE**

138. **Cassidulina crassa** d'Orbigny Pl. 21, fig. 138

Cassidulina crassa d'Orbigny, 1839, p. 56, pl. 7, fig. 18-20; Wiesner, 1931, p. 131, pl. XXI, fig. 259; Heron-Allen and Earland, 1932, p. 357, pl. IX, fig. 26-33; Parr, 1950, p. 343.

The specimens from the Antarctic area are large, typical forms with a depth range of 164 to 2,620 meters in the Deep Freeze IV stations. Its geographic distribution seems to be universal in the Antarctic area, but it was in greatest abundance at station 129, with a Foraminiferal Number of 532.

139. **Cassidulina crassa porrecta** Heron-Allen and Earland Pl. 21, fig. 139

Cassidulina crassa porrecta Heron-Allen and Earland, 1932, p. 358.
Cassidulinoides porrecta Parr, 1950, p. 344, pl. XII, fig. 26.

I follow Heron-Allen and Earland's classification of this species rather than Mr. Parr's. Parr described some forms that terminate with a rectilinear series of chambers, but my samples do not have this type of specimen. The Deep Freeze IV samples have a depth range of 164 to 475 meters with specimens from both the Ross and Weddell Seas. Station 129 has the greatest abundance with 29 specimens per gram.

140. **Cassidulina laevigata** d'Orbigny Pl. 21, fig. 140 a, b

Cassidulina laevigata d'Orbigny, 1826, p. 282, pl. XV, fig. 4-5; Parr, 1950, p. 343.

Although this species has been noted as rare in previous reports of the Antarctic area, Deep Freeze IV sample 006 had a concentration of 100 per gram. This species had a depth range in our samples of 658 to 2,450 meters. It is curious to note that it is not a frequent form with the exception of sample 006, which is the 12-14″ portion of a core off Queen Maud Land. The upper portion of the core, sample 005, had no specimens of this form.

141. **Cassidulinoides parkerianus** (Brady) Pl. 22, fig. 141

Cassidulina parkerianus Brady, 1884, p. 432, pl. LIV, fig. 11-16; Heron-Allen and Earland, 1932, p. 359, pl. IX, fig. 22-25.

Cassidulinoides parkerianus Thalmann, 1932, p. 302; Parr, 1950, p. 344, pl. XII, fig. 25.

This species is always rare in Antarctic material in which it is found. The depth range for our samples is 365 to 1,670 meters. It is of interest to note that three cores revealed this species in the 12-14″ portion but not in the 0-2″ portion. The Deep Freeze IV samples revealed it to exist in the Ross and Weddell Sea and off Queen Maud Land.

Subfamily **EHRENBERGININAE**

142. **Ehrenbergina glabra** Heron-Allen and Earland Pl. 22, fig. 142 a, b

Ehrenbergina hystrix Brady var. *glabra* Heron-Allen and Earland, 1922, p. 140, pl. V, fig. 1-6; Wiesner, 1931, p. 132, pl. XXII, fig. 262; Earland, 1934, p. 139.

Ehrenbergina glabra Chapman and Parr, 1937, p. 84; Parr, 1950, p. 344.

I have conformed to Chapman and Parr's decision to raise *glabra* to a specific level, as specimens from Antartica are more closely related to *E. pupa* than *E. hystrix;* however, *E. pupa* does not occur in my samples. This species is widely distributed and abundant in some areas. The depth range in our samples is 165 to 2,620 meters, with the greatest abundance between 455 and 800 meters. Sample 129 had 129 species per gram of sample.

Family **CHILOSTOMELLIDAE**
Subfamily **ALLOMORPHINELLINAE**

143. **Pullenia bulloides** (d'Orbigny) Pl. 22, fig. 143 a, b

Sphaeroidina bulloides d'Orbigny, 1826, p. 267.
Pullenia bulloides Cushman and Todd, 1943, p. 13; Parr, 1950, p. 346.

This species has not been reported from the Antarctic area in previous reports. Parr reported it in the Tasmanian area represented by two specimens. In our sediments, however, it occurred in four samples, with a maximum occurrence of .22 specimens per gram of sediments at station 024.

144. **Pullenia subcardinata** (d'Orbigny) Pl. 22, fig. 144 a, b

Nonionina subcarinata d'Orbigny, 1839, p. 28, pl. 5, fig. 23-24.
Pullenia subcardinata Heron-Allen and Earland, 1932, p. 403, pl. XIII, fig. 14-18; Earland, 1934, p. 179; Parr, 1950, p. 347.
Pullenia quinqueloba Cushman and Todd, 1943, p. 11.

This species is of common occurrence in the Antarctic area and has a wide distribution. It is found also in the Kerguelen area. Parr stated that *P. subcarinata* is replaced by *P. quinqueloba* in the Australian area. In the Deep Freeze IV sediments it occurred in eight samples, with a maximum occurrence of 29 specimens per gram at station 129.

Family **GLOBIGERINIDAE**
Subfamily **GLOBIGERININAE**

145. **Globigerina bulloides** d'Orbigny Pl. 22, fig. 145 a, b

Globigerina bulloides d'Orbigny, 1826, p. 277; Parr, 1950, p. 365.

This species is rare at the station from which it has been reported in previous reports; however, sample 006 has a Foraminiferal Number of 165, sample 129 a number of 175, and sample 128 a number of 19. Its distribution is almost universal in the Antarctic area.

146. **Globigerina conglomerata** Schwager Pl. 22, fig. 146 a, b

Globigerina dutertrei Schwager, 1866, p. 255, pl. 7, fig. 113; Brady, 1884, p. 592, 601, pl. LXXXI, fig. 1.
Globigerina conglomerata Cushman, 1927, p. 172; Parr, 1950, p. 366; Barker, 1960, pl. LXXXI, fig. 1.

This species was not reported from the Antarctic area by Parr.

147. **Globigerina pachyderma** (Ehrenberg) Pl. 22, fig. 147 a, b

Aristerospira pachyderma Ehrenberg, 1873, p. 386, pl. 1, fig. 4.
Globigerina pachyderma Heron-Allen and Earland, 1932, p. 401, pl. XIII, fig. 9-13; Chapman and Parr, 1937, p. 112; Parr, 1950, p. 366; Barker, 1960, pl. CXIV, fig. 19.

This is a widely spread Antarctic form. It is found in both the Arctic and Antarctic areas at high latitudes. It is the most abundant foraminiferal form at many of the stations.

Family **ANOMALINIDAE**

Subfamily **ANOMALININAE**

148. **Laticarinina halophora** (Stache) Pl. 23, fig. 148 a, b

Robulina halophora Stache, 1864, (see Reference).
Pulvinulina pauperata Brady, 1884, p. 696, pl. CIV, fig. 3-11; MacFadyen, 1933, p. 129.
Laticarinina halophora Barker, 1960, p. 214, pl. 104, fig. 3-11.

In our samples this species was confined to one core taken off Queen Maud Land at a depth of 2,620 meters. It was found in the 0-2″ portion and the 24-26″ portion of the core.

Subfamily **CIBICIDINAE**

149. **Cibicides grossepunctatus** Earland Pl. 23, fig. 149 a, b, c

Cibicides grossepunctatus Earland, 1934, p. 184, pl. VIII, fig. 39-41; Parr, 1950, p. 364, pl. XV, fig. 6.

This species has been found to be most abundant by previous workers in depths from 160 to 500 meters. In the Deep Freeze IV samples it was found in two samples—040 and 129—from the Weddell and the Ross Seas, respectively. It was rare in sample 040 and common in sample 129, with a Foraminiferal Number of 16.

150. **Cibicides refulgens** Montfort Pl. 23, fig. 150 a, b

Cibicides refulgens Montfort, 1808-10, p. 122.
Truncatulina refulgens Heron-Allen and Earland, 1922, p. 207.
Cibicides refulgens Barker, 1960, pl. 92, fig. 7-9.

This is the most common form of *Cibicides* in the Antarctic area, and specimens reach large sizes wth thick tests. The samples observed showed it throughout the depths available for study, but maximum concentrations were found between depths of 164 and 475 meters. It probably has universal distribution even though the one sample from the Palmer Peninsula did not reveal any specimens.

151. **Cibicides subhaidingerii** Parr Pl. 23, fig. 151 a, b

Truncatulina haidingerii Brady, 1884, p. 663, pl. XCV, fig. 7.
Cibicides subhaidingerii Parr, 1950, p. 364, pl. XV, fig. 7.

This species has not been reported from the Antarctic area, but the Deep Freeze IV samples revealed it to exist off Queen Maud Land and within the Ross Sea. It was rare at the three stations in which it was found.

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APPENDIX

Table 1.—Sample Locations

IBM	HYDRO.	LATITUDE	LONGITUDE	DEPTH IN METERS
001	GLP-16	73-46.7 S	169-09 E	450
002	GLP-16			
003	GLP-9	75-15 S	165-55 E	805
004	GLP-9			
005	GLP-26	69-11.5 S	16-46 E	1670
006	GLP-26			
007	GLP-23	70-53 S	175-22 E	2430
008	GLP-23			
009	SI-10	67-23 S	164-24 E	320
010	SI-10			
011	GLP-13	74-25.1 S	167-00.3 E	740
012	GLP-13			
013	PC-3	78-02 S	178-10 E	658
014	PC-3			
015	2-58	78-24 S	175-50 W	594
016	2-58			
017	SI-15	64-47.5 S	109-42.5 E	2995
018	GLP-27	68-57.2 S	14-35.5 E	2620
019	GLP-8	75-30 S	165-44 E	640
020	ED-PC-3	77-40 S	41-05 W	800
021	ED-PC-3			
022	GLP-15	73-58.5 S	168-29 E	455
023	GLP-15			
024	GLP-22	71-44.5 S	174-24 E	2100
025	GLP-27			
026	GLP-6	76-04 S	164-18 E	685
027	GLP-6			
028	GLP-14	74-11 S	168-01 E	576
029	GLP-14			
030	PH-1	78-28 S	168-55 W	567
031	PH-1			
032	GLP-5	76-11.6 S	164-46 E	690
033	GLP-7	75-46.4 S	165-15 E	870
034	PC-6	65-13 S	64-14 W	274
035	PC-1	71-55 S	15-35 W	1281
036	PC-1			
037	GLP-19	72-55.8 S	170-17.7 E	365
038	GLP-1	78-18 S	160-20 W	612
039	GLP-10	75-00 S	164-35 E	890
040	PC-2	74-40 S	35-30 W	384
041	GLP-20	72-53 S	172-10 E	568
122	GLP-23			
123	GLP-23			
124	GLP-24			
128	GLP-12	74-39 S	165-52 E	164
129	SI-4	72-30 S	173-25 E	475

Table 2—Water Characteristics

IBM	Bottom Salinity 0/00	Surface Salinity 0/00	Bottom Temp. C°	Top Temp. –C°
001	34.93	34.82	–1.93	–1.83
003	34.93	34.60	–1.91	–1.72
005	34.68	33.62	0.18	–1.74
007	34.81	34.37	0.13	–1.55
009	34.67	33.86	0.46	–1.61
011	35.19	34.83	–1.92	–1.63
013	34.82	34.34	0.74	0.59
015	34.82	33.92	–1.19	–0.49
017	34.69	33.12	–0.32	–1.24
019	34.97	34.72	–1.90	–1.75
020	34.74	33.98	–1.89	–1.75
022	34.88	34.76	–1.94	–1.72
024	34.73	33.88	–0.18	–1.70
026	34.90	34.88	–1.89	–1.86
028	34.90	34.76	–1.93	–1.76
030	34.58	34.10	–1.68	–1.74
032	34.89	34.79	–1.90	–1.80
033	34.92	34.81	–1.92	–1.81
034	34.49	33.24	0.60	–1.11
035	34.68	33.71	0.42	–1.43
037	34.87	34.42	–1.90	–1.70
038	34.52	34.41	–1.83	–1.56
039	34.93	34.77	–1.91	–1.58
040	34.45	33.94	–1.78	–1.50
041	34.82	34.36	–1.90	–1.72
128	34.90	34.86	–1.89	–1.89
129	34.70	34.33	0.03	–1.76

Table 3.—Sediment Characteristics

IBM	Inch in Core	Mean Phi	Stand. Dev.	Organic Carbon Per cent	Weight of Sample
001	00-02	8.1	2.4	1.460	14.675
002	12-14	4.9	4.5	0.522	51.801
003	00-02	8.0	2.5	1.189	19.203
004	12-14	8.0	3.1	0.435	44.469
005	00-02	6.6	3.5	0.551	43.767
006	12-14	7.5	3.6	0.261	54.356
007	00-02	7.9	2.6	0.466	16.633
008	12-14	8.4	2.3	0.481	31.887
009	00-02	3.4	5.0	0.464	34.610
010	12-14	6.3	2.4	0.233	36.003
011	00-02	7.9	2.4	1.972	11.275
012	12-14	3.1	3.4	1.182	26.143
013	00-02	0.5	5.4	0.277	43.411
014	12-14	0.7	5.4	0,321	67.355
015	00-02	0.3	5.4	0.379	35.416

016	12-14	0.5	5.3	0.394	59.440
017	00-02	−2.3	4.6	0.773	21.156
018	00-02	0.3	5.2	0.350	39.490
019	00-02	0.0	5.1	0.861	21.516
020	00-02	0.0	5.1	0.379	29.772
021	12-14	0.6	5.1	0.729	65.108
022	00-02	−0.1	4.8	0.393	29.729
023	12-14	−1.4	4.7	0.029	79.196
024	00-02	0.4	5.3	0.291	36.563
025	12-14	−1.7	4.5	0.087	49.841
026	00-02	−0.2	5.0	1.219	08.937
027	12-14	0.1	5.2	0.306	26.841
028	00-02	−3.4	5.0	0.087	43.609
029	12-14	−0.0	5.1	1.138	23.472
030	00-02	−3.6	5.6	0.394	26.520
031	12-14	8.8	1.9	0.583	40.661
032	00-02	6.8	3.1	0.612	19.655
033	00-02	6.3	3.7	0.835	22.769
034	00-02	8.1	2.0	0.806	24.860
035	00-02	5.8	3.7	0.388	46.733
036	12-14	4.7	3.2	0.345	56.150
037	00-02	3.1	4.6	0.503	34.994
038	00-02	6.8	4.3	0.777	33.098
039	00-02	4.0	3.3	0.420	48.813
040	00-02	2.0	3.2	0.230	47.704
041	00-02	3.7	2.7	0.287	36.922
122	24-26	6.8	3.2	0.124	32.812
123	36-38	7.6	2.6	0.565	28.111
124	24-26	6.1	2.8	0.435	41.553
128	00-02	5.0	3.2	1.472	6.047
129	00-02	1.7	2.8	0.298	57.766

Table 4. — Foraminiferal Numbers

IBM	Total Foraminiferal Numbers	Benthonic Foraminiferal Numbers	Planktonic Foraminiferal Numbers	Number of Species
001	7.04	7.04	0	7
002	.12	.12	0	4
003	5.46	5.46	0	13
004	.14	.12	.02	6
005	178.68	44.68	134.00	35
006	1875.00	33.00	1842.00	33
007	1.92	1.92	0	12
008	.59	.59	0	4
009	23.24	18.63	4.59	18
010	25.58	18.17	7.41	21
011	.97	.97	0	4
012	.11	.11	0	1
013	2.97	2.62	.35	23
014	.01	.01	0	1
015	7.59	7.59	0	20

016	.41	.04	.37	4
017	1.82	1.77	.05	15
019	5.85	5.66	.19	12
020	422.10	229.00	193.10	43
021	4.80	2.98	1.10	26
022	23.50	23.50	0	20
023	46.98	40.69	6.29	30
024	649.48	24.77	624.71	51
025	5.06	.91	4.15	10
026	10.79	10.57	.22	19
027	3.26	3.03	.23	21
028	.02	.02	0	1
029	1.87	1.87	0	9
030	7.84	7.68	.16	24
031	0	0	0	0
032	3.61	3.61	0	11
033	14.39	14.39	0	10
034	.20	.20	0	3
035	3.61	3.61	0	16
036	4.10	2.30	1.80	14
037	246.90	36.80	210.10	37
038	6.75	6.72	.03	22
039	.53	.53	0	4
040	39.07	31.79	7.28	72
041	6.76	6.76	0	19
122	5.06	2.66	2.4	12
123	.24	.20	.04	5
124	3.10	.41	2.69	11
128	850.70	682.70	123.00	52
129	3237.50	1772.00	1462.	86

Table 5. — Statistical Data

Name	$x_1+x_2+x_3+x_4$	$x_1+x_2+x_3$	x_1+x_2	x_4	x_3	x_2	x_1
Trochammina antarctica	*	NS	NS	**	NS	*	NS
T. conica	*	*	NS	*	*	*	NS
Jaculella acuta	NS	NS	NS	**	NS	NS	NS
Angulogerina earlandi	NS	NS	NS	NS	NS	NS	NS
Cassidulina crassa	NS	NS	NS	NS	NS	NS	NS
Eponides weddellensis	NS	NS	NS	*	NS	NS	NS
E. tenera	NS	*	NS	*	*	NS	NS
Hormosina ovicula	*	*	*	**	*	**	*
Reophax distans	NS	NS	NS	*	NS	NS	NS
Trochammina glabra	NS	NS	NS	NS	NS	NS	NS
Textularia tenuissima	NS	NS	NS	NS	NS	*	NS
Ehrenbergina glabra	NS	NS	NS	NS	NS	NS	NS
Textularia antarctica	**	**	**	**	NS	*	NS
Haplophragmoides canariensis	NS	NS	NS	*	NS	NS	NS
Miliammina lata	NS	*	*	NS	NS	**	NS
Nonion germanicus	NS	NS	NS	NS	NS	NS	NS
Recurvoides contortus	NS	NS	*	*	NS	**	NS
Miliammina arenacea	*	*	*	*	NS	**	*
Nonionella bradyi	NS	NS	NS	NS	NS	NS	NS
Cibicides refulgens	NS	NS	NS	NS	NS	NS	NS

PLATES

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1.	**Rhabdammina** sp. Side view; X 60	98
2.	**Rhizammina horrida** Chapman and Parr Side view; X 65	99
3.	**Psammosphaera fusca** Schulze Side view; X 22	99
4.	**Psammosphaera parva** Flint Side view; X 35	99
5.	**Jaculella acuta** Brady Side view; X 50	99
6.	**Hormosina ovicula gracilis** (Earland) Side view; X 95	100
7.	**Reophax dentaliniformis** Brady Side view; X 40	100
8.	**Reophax distans** Brady Side view; X 60	100
9.	**Reophax helenae** Rhumbler Side view; X 40	100
10.	**Reophax nodulosus** Brady Side view; X 50	100
11.	**Reophax pilulifer** Brady Side view; X 50	101
12.	**Reophax spiculifer** Brady Side view; X 85	101
13.	**Ammodiscus incertus** (d'Orbigny) Side view; X 140	101
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15.	**Adercotryma glomeratum** (Brady) Side view; X 190	102


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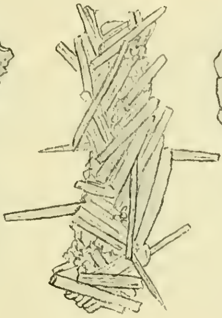
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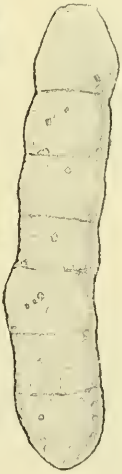
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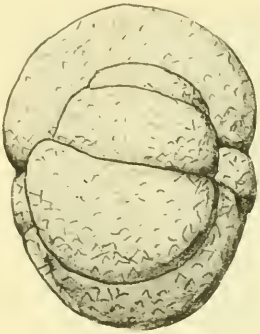

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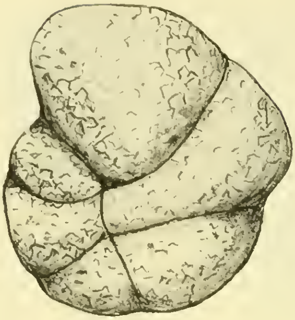

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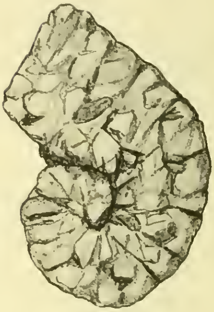

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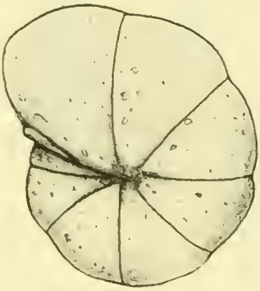

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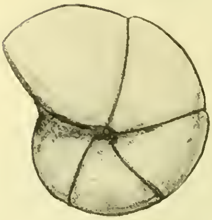

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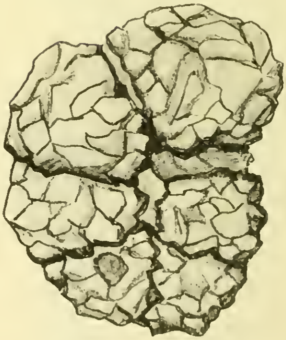

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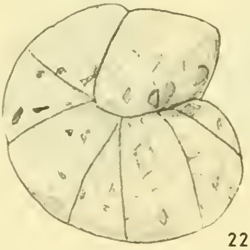

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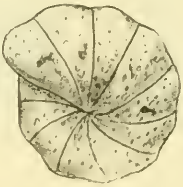

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19.	**Haplophragmoides bradyi** (Robertson) Side view; X 180	103
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26.	**Textularia** cf. **catenata** Cushman Side view; X 185	104
27.	**Textularia tenuissima** Earland Side view; X 100	105
28.	**Verneuilina minuta** Wiesner Side view; X 135	105
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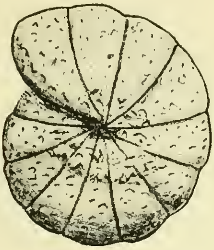
32.	**Miliammina lata** Heron-Allen and Earland a, b. Opposite sides; X 140	106
33.	**Miliammina oblonga** Heron-Allen and Earland a, b. Opposite sides; X 65	106



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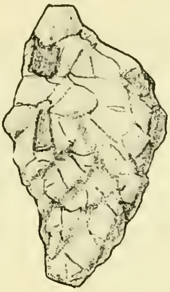

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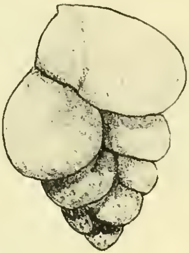

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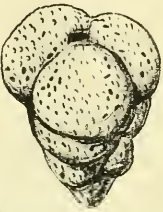

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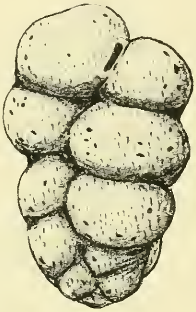

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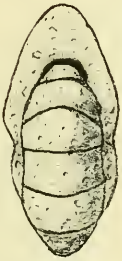

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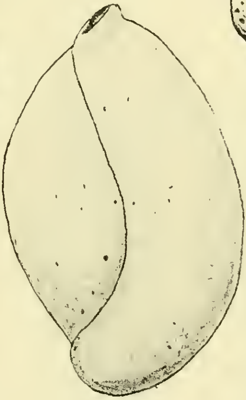

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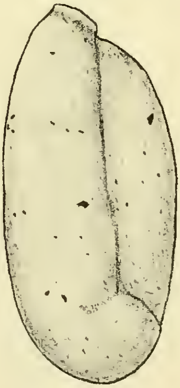

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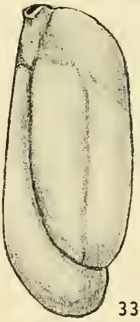

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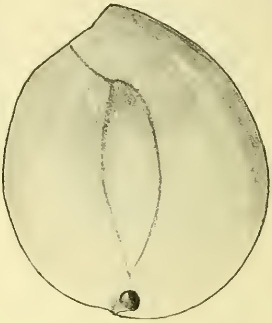
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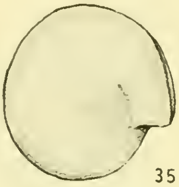
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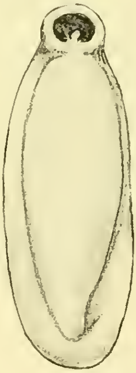
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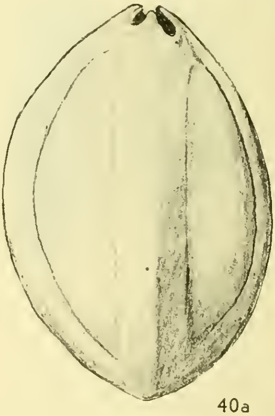
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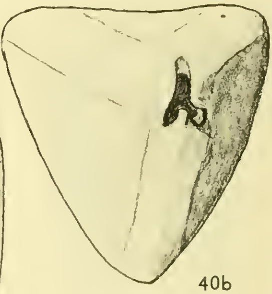
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Explanation to Plate 12

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35.	**Sigmoilina umbonata** Heron-Allen and Earland Side view; X 130	106
36.	**Tubinella funalis** (Brady) Side view; X 100	107
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42.	**Pyrgo elongata** (d'Orbigny) Front view; X 55	108
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46.	**Cornuspira corticata** Chapman and Parr a. Apertural view; b. Side view; X 35	109
47.	**Cornuspiroides profundum** Stschdrina a. Apertural view; b. Side view; X 35	109
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49.	**Trochammina conica** Earland a. Apex view; b. Apertural view; X 125	109
50.	**Trochammina glabra** Heron-Allen and Earland a. Ventral view; b. Dorsal view; X 165	110


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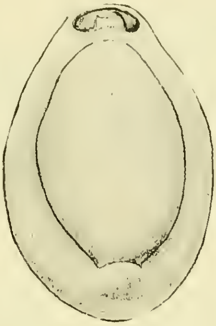
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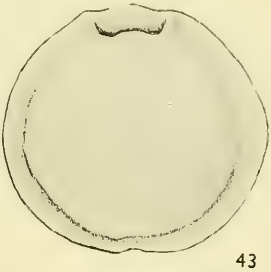
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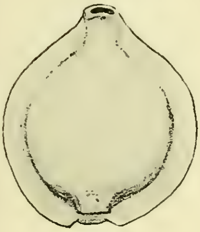
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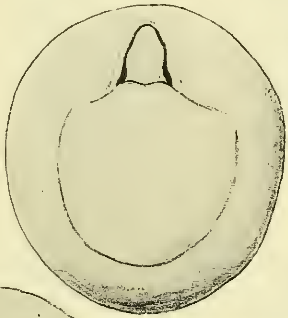
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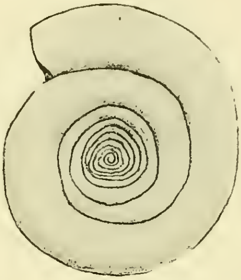
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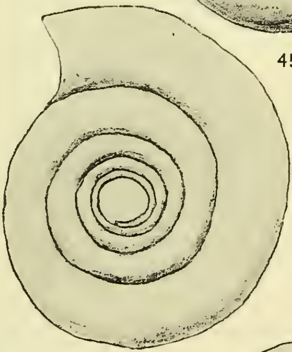
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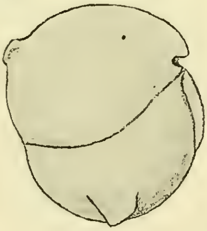
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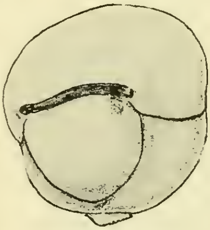
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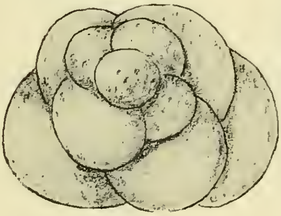
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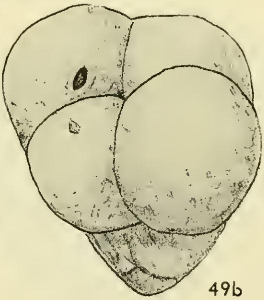
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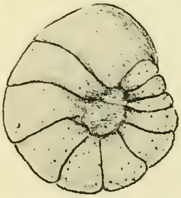
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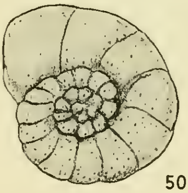
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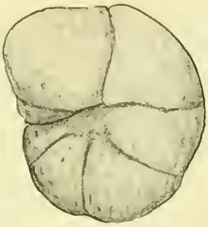
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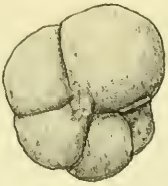
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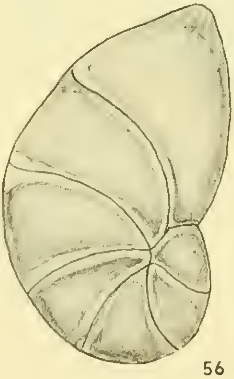
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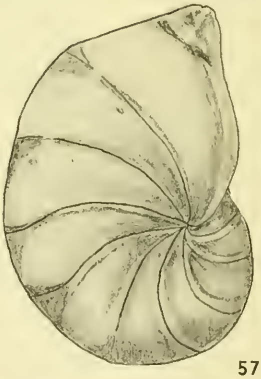
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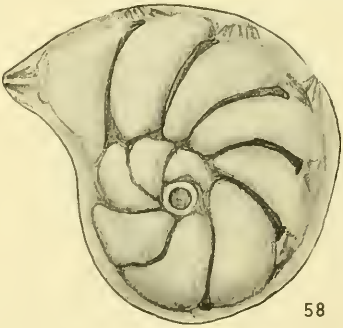
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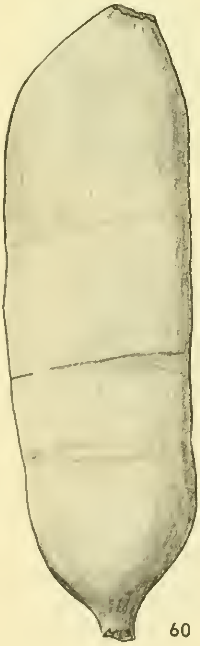
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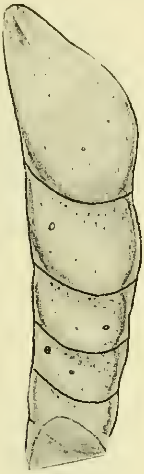
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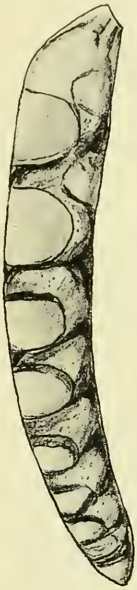
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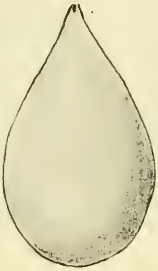
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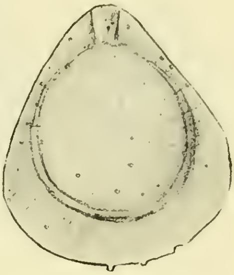
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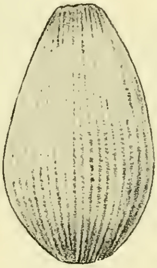
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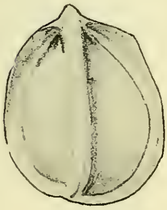
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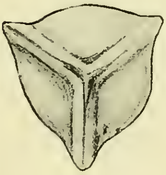
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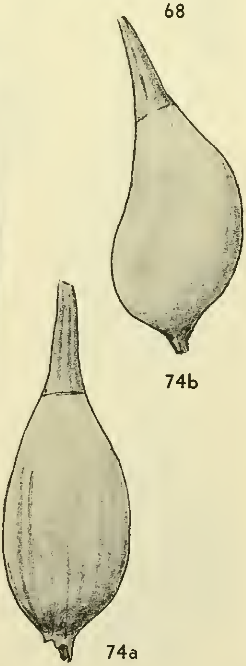
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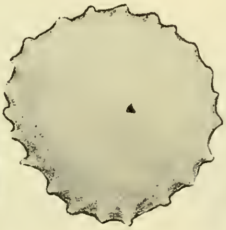
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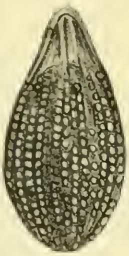
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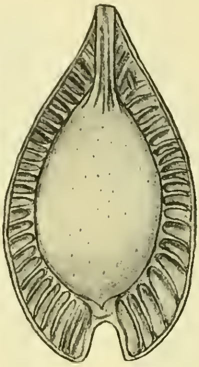
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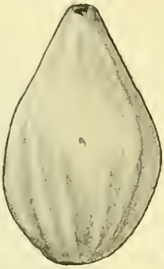
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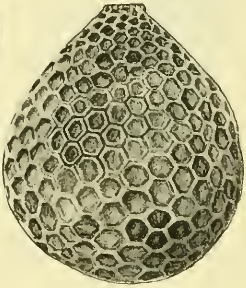
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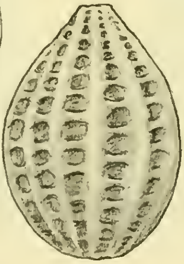
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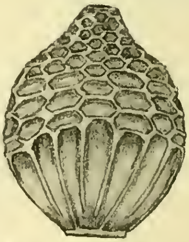
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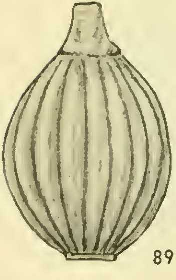
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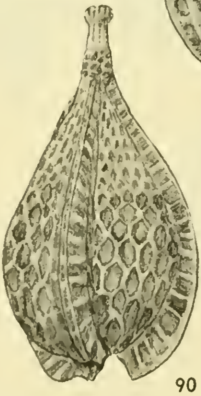
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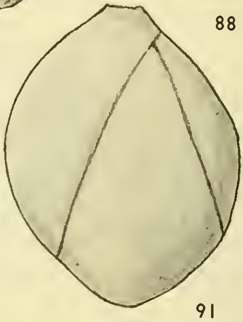
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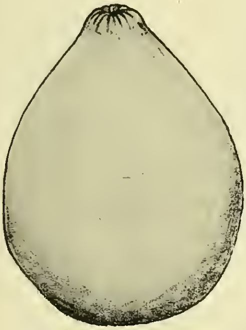
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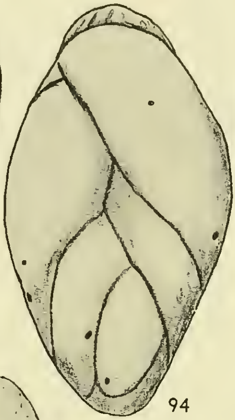
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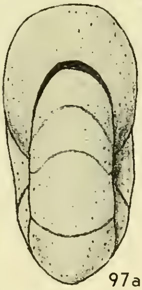
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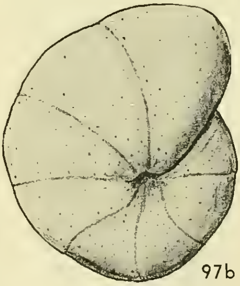
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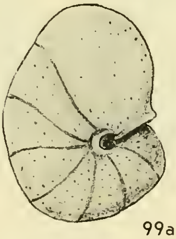
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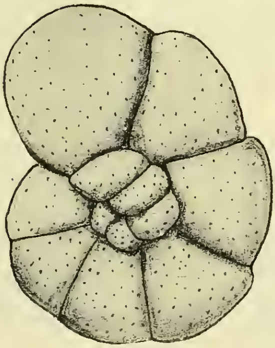
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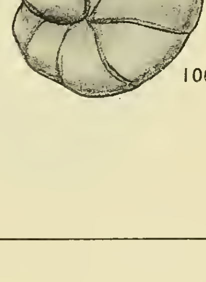
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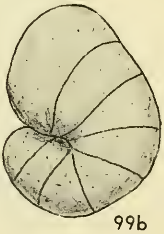
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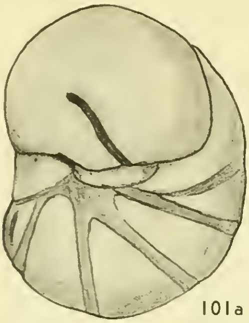

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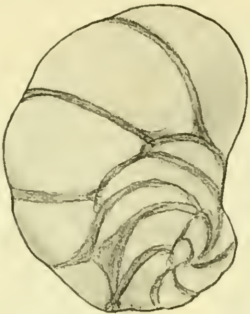

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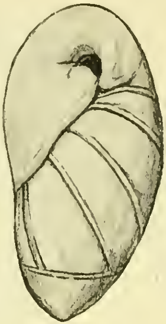

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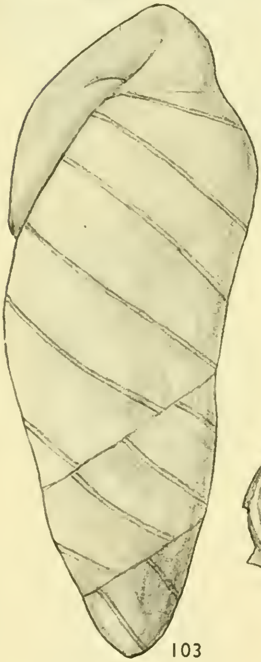

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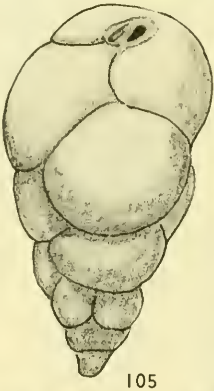

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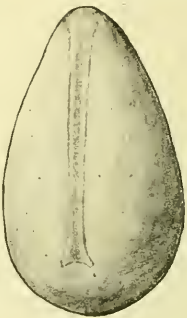

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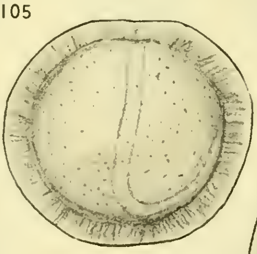

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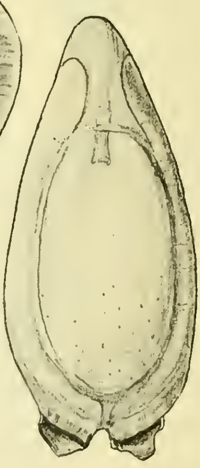

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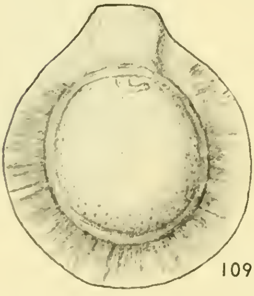

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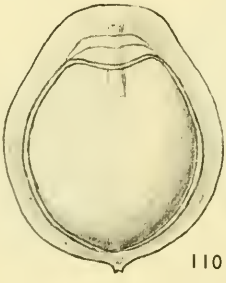

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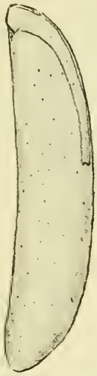
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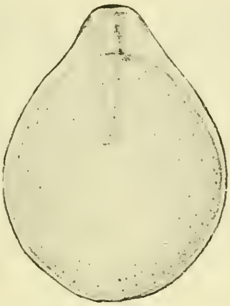
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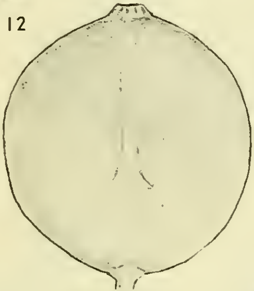
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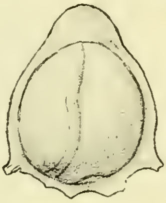
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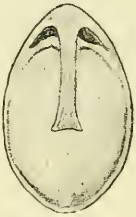
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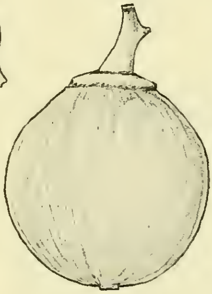
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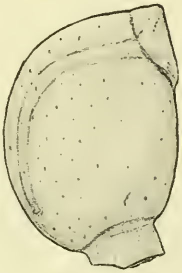
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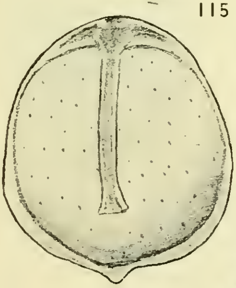
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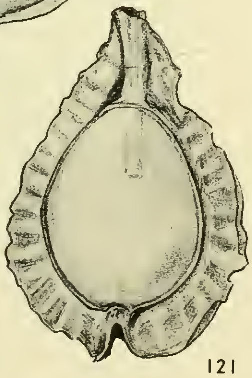
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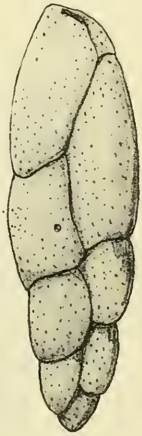
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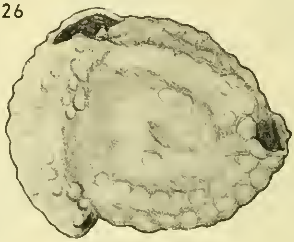
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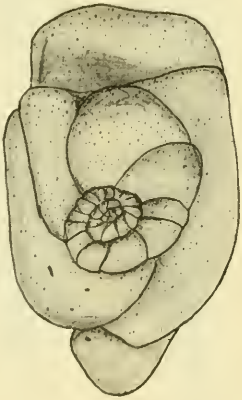
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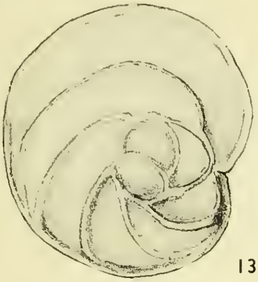

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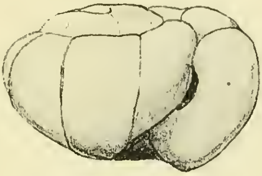

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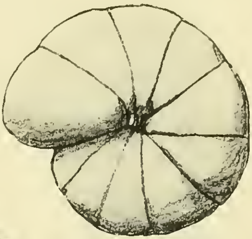

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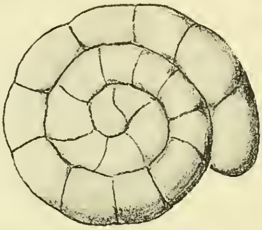

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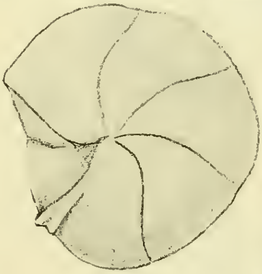

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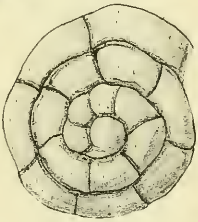

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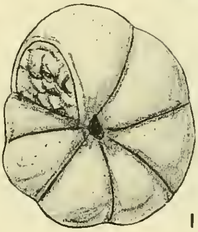

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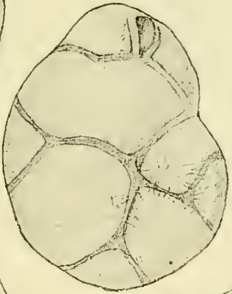

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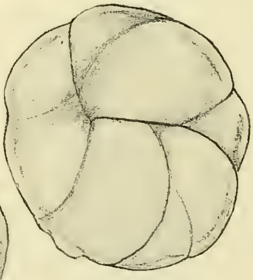

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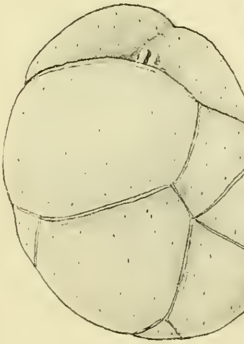

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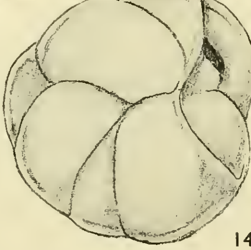

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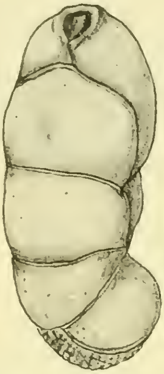
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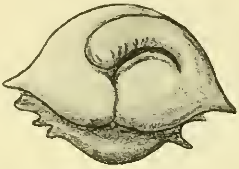
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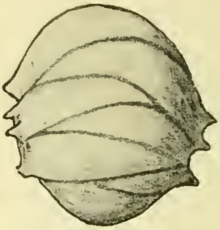
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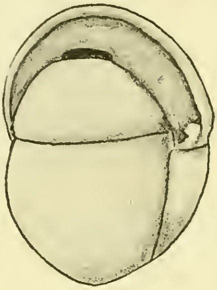
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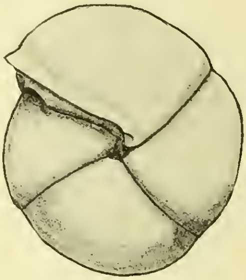
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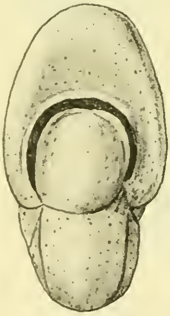
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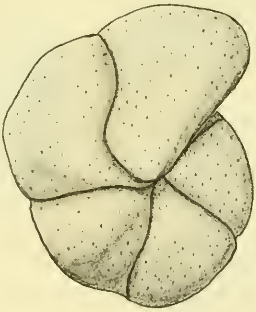
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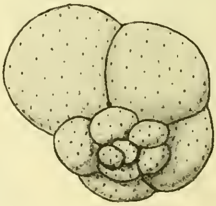
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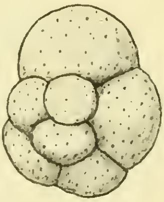
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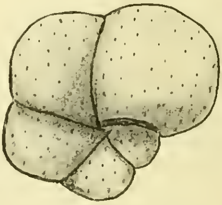
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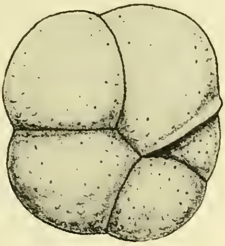
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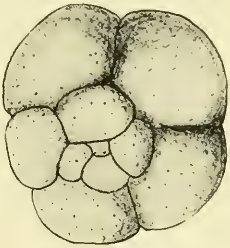
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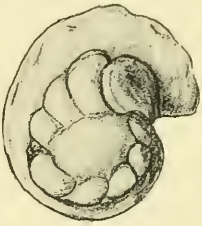
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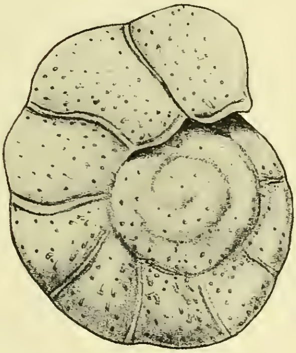
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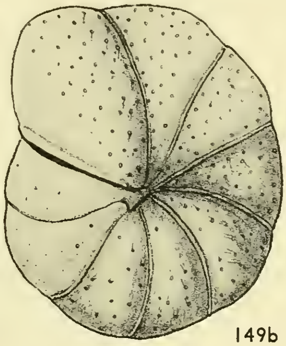
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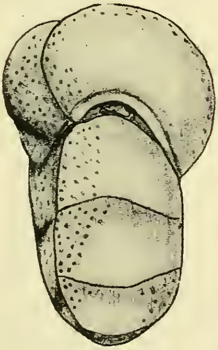
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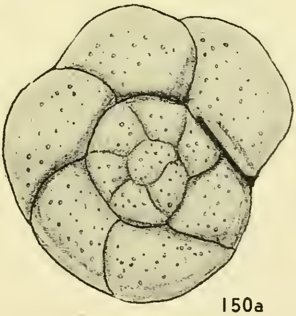
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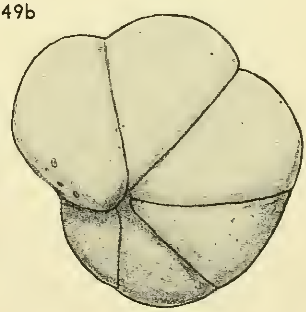
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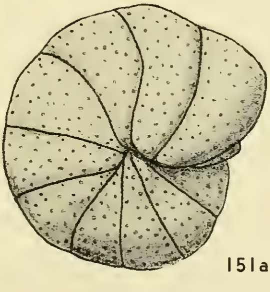
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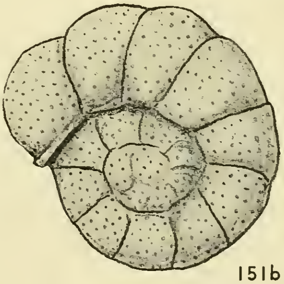
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VOL. XLIV

NUMBER 202

1962

PALEONTOLOGICAL RESEARCH INSTITUTION
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BULLETINS
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Vol. 44

No. 202

THE PALEOZOIC EUMALACOSTRACA OF NORTH AMERICA

By

H. K. BROOKS
University of Florida

November 12, 1962

Paleontological Research Institution
Ithaca, New York, U.S.A.

Library of Congress Catalog Card Number: GS 62-305

Printed in the United States of America

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THE PALEOZOIC EUMALACOSTRACA of NORTH AMERICA

H. K. Brooks
University of Florida

ABSTRACT

It has been assumed that the Paleozoic eumalacostracan Crustacea had morphological characteristics consistent with representatives of the extant "primitive" taxa, the Mysidacea and Syncarida. Morphological study of the American fossils proves this belief to be correct only for the Syncarida. The species with a carapace, though displaying morphological trends in the structure of the exoskeleton toward various established taxa, are distinguished not only by an unexpected combination of characteristics previously not known to exist in the same animal, but by some features known only in Recent Crustacea believed to be more primitive than Eumalacostraca. A complete revision of the classification with new genera and species: *Anthracaris,* n.g. (type species: *Anthrapalaemon gracilis* Meek and Worthen); *Mamayocaris jepseni,* n.g., n.sp.; *Pseudotealliocaris,* n.g. (type species: *Tealliocaris caudafimbriata* Copeland); *Anthracophausia strongi,* n.sp.; *Archaeocaris graffhami,* n.sp.; *Acadiocaris,* n.g.; (type species: *Palaeocaris novascotica* Copeland) and *Palaeosyncaris dakotensis,* n.g., n.sp.; new families: Eocarididae, Palaeopalaemonidae, Anthracophausiidae, Pygocephalidae, Tealliocarididae, Notocarididae, Anthracocarididae; new orders: Eocaridacea, Palaeostomatopoda, Anthracocaridacea, and a new superorder, Eocarida, is required.

Tagmosis of the body, modification of the exopod of the second antennae as a squama, jointing of the thoracic pereiopods, development of a caudal fan through modification of the sixth pair of abdominal appendages as uropods, and reduction of the furca and median telson spine distinguish Eumalacostraca. These are characteristics of the nektonic "caridoid facies" superimposed upon a benthonic crustacean. The most ancient eumalacostracans reported in the literature are classified as syncarids. Re-interpretation and new discoveries prove these Devonian fossils are caridoid Malacostraca. True syncarids first occur in Upper Mississippian strata.

Recent Euphausiacea are specialized pelagic descendants of the most ancient Eumalacostraca. Decapods and the several orders of peracarids evolved from this stock in the late Paleozoic. Primitive morphological characteristics and the fossil record establish stomatopods and syncarids as a more ancient derivative which differentiated in the Devonian or early Mississippian.

INTRODUCTION

Despite the interest that has been shown in crustacean evolution, there has never been a critical morphological study of the Paleozoic Eumalacostraca.

Malacostraca are Crustacea with eight somites in the thoracic tagma and six or seven somites in the abdomen, the first antennae are biramous (rarely triramous), and the female gonopores are associated with the fifth thoracic somite and the male gonopores are associated with the eighth thoracic somite. Two primary subdivisions of this taxon are recognized; they are the Series Phyllocarida and the Series Eumalacostraca. Characteristics of the Eumalacostraca are: the exopod of the second antennae is developed as a scale, the thoracic appendages are jointed (not foliaceous), there are six (not seven), abdominal somites, and the appendages of the sixth abdominal somite are developed as uropods. The most diagnostic character of the Eumalacostraca is the reduction of the furca and median spine on the telson which is replaced functionally by the caudal fan composed of the uropods and the body of the telson. The Recent Phyllocarida, the Leptostraca, have a carapace adductor muscle. This was probably absent in some of the extinct Archaeostraca, but proof is lacking that these Paleozoic fossils are truly malacostracans.

In the present study all fossil species from the United States are re-examined and described in detail. Specimens of only two of the Canadian species were received for direct examination; however, this work is comprehensive of all known American species. In the course of investigation, representative specimens of contemporaneous fossils from Europe, Africa, and Brazil have been studied, and information obtained has been synthesized into the discussion of interrelationships of the genera and the evolution of the Eumalacostraca.

Hundreds of excellent specimens in the ironstone concretions from the Pennsylvanian deposits of northern Illinois have been collected since the last American study (Packard, 1886) in which morphological interpretation of the Paleozoic Eumalacostraca was the primary objective. There are also many undescribed specimens from other deposits from Devonian to Permian in age that have accumulated in museum collections during the past 100 years. Dr. Percy E. Raymond, knowing of the great need for a biological study of these fossils, encouraged me to begin the work in 1948. As this study has progressed, morphology of the fossils has been compared with that of extant animals.

Knowledge of nearly the complete skeletal morphology of the basic types of Paleozoic Eumalacostraca represented by species in the Mazon Creek concretions has been realized in this work. Previous investigators failed to take advantage of the exquisite details preserved in the ironstone concretions because they neglected to prepare the fossils. The specimens are natural molds filled with soft flaky kaolin which must be removed before the fossils can be studied to advantage (compare photographs of unprepared and prepared specimen, Plate 29, figs. 1, 2). Mineral materials filling the molds were removed under a binocular microscope with a needle sharpened to a chisel point and held in a pin vise. The cleaned specimens are difficult to study because they are concave impressions of the external morphology of the animals. Rubber latex, preferably red, has been used to duplicate the original form of the animal. No details are lost in the reproductions; the rubber duplicates minute setae and even the texture of the matrix. Not only is it easier to study the fossil as reproduced in positive relief, but superior photographs can be obtained if the red latex casts are covered by a thin film of ammonium chloride.

All available collections in the United States have been studied in pursuance of this investigation. The Peabody Museum at Yale University contains specimens that surpass, in numbers and preservation, the materials of the other museums. Specimens in principal museum collections are as follows: Peabody Museum, Yale University, 1711; U.S. National Museum, 99; Chicago Natural History Museum, 212; Museum of Comparative Zoology, Harvard University, 76; Illinois State Museum, 22, and Princeton University, 184. Types and specimens of rare species in other collections are referred to in the text.

It has been assumed that the Paleozoic Eumalacostraca had morphological characteristics consistent with representatives of the extant "primitive" taxa, the Mysidacea and the Syncarida (Woodward, 1907 b; Peach, 1908; and Calman, 1896, 1911 b, 1932 a and b). Re-study of the fossils from Mazon Creek proves this belief to be correct only for the Syncarida. Once the morphology of the basic types of Paleozoic Eumalacostraca is established, it is possible to re-interpret the species represented less adequately by compressions from other deposits. This study results in the recognition of four new genera. From the morphological characteristics discovered, it is evident that a complete revision of the classification is required. New families, orders and a new superorder must be proposed for the systematic classification of the known Paleozoic Eumalacostraca.

ACKNOWLEDGMENTS

Many have contributed by their cooperation in providing

materials for study. Dr. G. A. Cooper and Mr. Henry Roberts of the U.S. National Museum, Drs. Harry B. Whittington and W. D. I. Rolfe of the Museum of Comparative Zoology at Harvard, Drs. Carl O. Dunbar and Karl M. Waage of the Peabody Museum, Yale University, Dr. Eugene S. Richardson, Jr. of the Chicago Natural History Museum, Dr. Harold Scott of the University of Illinois, Dr. Thorne Deuel of the Illinois State Museum, Dr. J. W. Wells of Cornell University, Dr. F. D. Holland, Jr. of the University of North Dakota, Dr. Carl Branson of the Oklahoma Geological Survey, Dr. Charles Collinson of the Illinois Geological Survey, Dr. Norman Newell of the American Museum of Natural History, Dr. Horace G. Richards of the Academy of Natural Science of Philadelphia, and Dr. Alfred Fischer of Princeton University have been most cooperative in lending collections for study.

Rare Recent specimens of the Tasmanian mountain shrimp, *Anaspides tasmaniae* Thomson, have been received for morphological study from Mr. Edgar F. Riek, Canberra, Australia. A specimen of the deep sea shrimp, *Gnathophausia gracilis* Suhm, was obtained for dissection from Dr. W. D. Clarke of the Scripps Institution of Oceanography. Dr. Elizabeth Deichmann of the Museum of Comparative Zoology has made available many specimens for my reference.

To expedite completion of this work a "Science Faculty Fellowship" was granted by the National Science Foundation for the academic year 1961-62. Sigma Xi, National Academy of Sciences (Bache Fund), Florida State Museum, and the Department of Geology, College of Arts and Sciences, University of Florida have granted funds to pay for the engraving of the many plates.

I am especially indebted to Dr. Frank M. Carpenter who has patiently supervised this study over many years. Drs. Carpenter, Robert R. Shrock, Harry B. Whittington, J. H. Welsh, Katherine V. W. Palmer, and Kenneth E. Caster have generously contributed editorial assistance.

EXPLANATION OF MORPHOLOGICAL TERMINOLOGY

Terminology in carcinological works varies slightly from taxon to taxon. Because the Paleozoic Eumalacostraca display morphological trends of differentiation toward all the modern types, the terms herein used are not completely in accord with those of any one author; a single term must be employed consistently for the same homologue. Terms have been chosen based upon usage, descriptive appropriateness, and brevity. They have been selected from those used by Sars (1885, p. 3-6), Calman (1909), Hansen (1925, p. 83-89), Tattersall and Tattersall (1951, p. 13-28), and Snodgrass (1956).

Theoretical implication in morphological terminology cannot be completely avoided. For example, the carapace mantle originates ontogenetically as a fold of the integument at the posterior margin of the cephalon. Some authors (*i.e.*, Borradaile and Potts, 1958, p. 350) would differentiate the head shield from the carapace by the position of the cervical groove and term the complete cephalothoracic structure the dorsal shield. This introduces an error. The dorsal musculature of the two posterior cephalic appendages, the first and second maxillae, originates posterior to the cervical groove; thus this cannot be used as a criterion for division. The prominent sulcus that traverses the cephalic shield is a homologous structure throughout the Eumalacostraca. In the Syncarida it can be seen to be associated with the mandibles. The term mandibular sulcus should be abandoned unless it is to be employed only for the anterior sulcus on those Crustacea, *e.g.*, *Acanthotelson* and *Palaeopalaemon,* in which the cephalic sulcus bifurcates into an anterior branch and the cervical groove. Consistent with classical usage, the complete dorsal shield of the cephalothorax is termed a carapace in this work. In those forms without the thoracic mantle, the cephalic shield is an appropriate name for the dorsal skeletal covering of the head.

Tagmosis in the Eumalacostraca does not depart from a basic plan. Five pairs of appendages are borne on the head; they are first antennae, second antennae, mandibles, first maxillae, and second maxillae. The stalked compound eyes are not homologous with appendages. In this work a practical scheme has been followed and the somites are correlated with the appendages they bear. Thus the cephalic tagma is considered to consist of five somites, the thorax eight somites and the abdomen six somites and a telson. The adult eumalacostracan body is composed of a total of 19 appendage-bearing somites and a telson which may bear a furca and a median articulated spine. These somites have been indicated by Roman numerals on the morphological drawings. It is true that cephalization has occurred in some Recent eumalacostracans such that one or two thoracic somites have been incorporated into the cephalic tagma, *e.g., Anaspides* and *Gammarus,* or fusion has occurred between the telson and the last abdominal somite, *e.g., Bathynella* and *Tanais.* The appendages of the fused somites are an infallible criterion for their identification.

Structures that appear in embryonic and larval stages of some Recent eumalacostracans should be given special consideration in the study of the Paleozoic fossils. They are: a seventh abdominal somite and a furca and median spine on the telson. The seventh abdominal somite and the furca are significant because it is believed the ancestral malacostracan had these characteristics, as does the Recent Leptostracan, *Nebalia.* Manton (1928, p. 446) reported the presence of a seventh abdominal somite as "represented in the embryo (*Hemimysis lamornae*) by a pair of mesoblastic somites and a ganglion, although in the adult it is completely fused with the sixth segment." She (1928, p. 446-447) dismissed the furca on the embryo of *Hemimysis* as "purely ectodermal and does not appear to be a pair of appendages . . ." Evidence of a seventh abdominal somite is not present on any of the Paleozoic primitive Eumalacostraca so it is doubtful that Manton's observations are of phylogenetic significance. On the other hand, all fossils except the syncarids have a pair of furcal lobes and a median spine on the telson. A furca is known in adult Recent Eumalacostraca only on euphausids and the syncarids of the Order Bathynellacea. The median spine is known only in the adults of euphausids. Gurney (1942, p. 116-123) noted the occurrence of these structures of the telson in ontogenetic stages of the Eumalacostraca and concluded they are relics of a "primitive form of telson preserved from a predecapod ancestor." The paleontological evidence presented herein proves his deduction.

It has been assumed that the primitive crustacean leg had a sympod with three joints because the sympod of the first antennae of all Crustacea typically consists of three joints, and three joints are allegedly present on the thoracic legs of species of taxa other than the Copepoda. It is only in the copepods that bifurcation into two rami, an endopod and an exopod, characteristically occurs at the third joint. Some authors have interpreted a precoxal joint on many Crustacea where one does not exist. Embryological evidence (Heegard, 1946, p. 2-4) and the discovery of only a single joint in the sympod of the primitive appendages of *Hutchinsoniella* (Saunders, 1957, p. 120-124), *Spelaeogriphus* (Gordon, 1957, figs. 21-26), and *Thermosbaena* (Siewing, 1957, p. 258) have emphasized the need for a re-evaluation of concepts of interpretation of the crustacean limb. In the Paleozoic fossils only one joint could be distinguished in the sympod of the species with a carapace.

The articulation of greatest flexure of the thoracic endopod is consistent in position. This "knee" is the articulation between the fourth and fifth joints of the leg, the merus and carpus, in those forms that have two joints in the sympod. There are a few exceptions in Recent Crustacea where fusion or additional joints have been introduced to complicate the primitive plan. However, Hansen (1925, p. 89) was correct in believing the "knee" is of the greatest importance in determining the homology of the joints of the endopod.

For purposes of homologous comparison between the different Eumalacostraca, the syncarid appendages are most useful (Text Plate 1). The thoracic appendages are biramous with the exopod arising from the second discreet joint. The elusive theoretical precoxal joint has not been seen. From the basal joint, the coxa, two lobate, membranous epipods originate. The exopod arises from the second joint, the basis, and consists of a stipe and a flagellum. The endopod is divided into five joints; they are: ischium, merus, carpus, propodus and dactylus. The "knee" is between the merus and carpus. Three joints are distal to it.

Appendages of the Paleozoic syncarids have an identical structure. The Paleozoic eumalacostracans with a carapace are believed to have had thoracic appendages of comparable structure but with only one joint in the sympod. So that the numbering system employed herein for the joints of the thoracic appendages would indicate homologous parts, the single sympod joint of these Crustacea has been indicated as the second leg joint though it represents both the coxa and the basis.

For morphological comparative purposes, drawings of the skeletal structure of the Recent syncarid, *Anaspides tasmaniae* Thomson are presented (Text Pl. 1 and Text Pl. 14, fig. b). Except for the absence of a carapace, marsupium, and furcal lobes and a median spine on the telson, this species portrays the morphological features of the fossil Crustacea to be described. The skeletal features of the cephalothorax of a primitive Recent lophogastrid mysidacean, *Gnathophausia gracilis* Suhm, with a carapace are shown in Text Pl. 14, fig. c. The abbreviations and symbols employed on these figures and throughout this work are:

A,	opening of otocyst
Abd,	abdomen
An,	anus
Ant,	antenna, (1 Ant and 2 Ant)
As,	antero-lateral spine
B,	branchial area of carapace
brC,	brancial chamber
Bs,	branchiostegal spine
C,	cardiac region of carapace
Cp,	carapace
Cps,	cephalic shield
Cs,	cardiac spine
cvg,	cervical groove
Dblr,	doublure
E,	eye
Endpd,	endopod
Endt,	endite
Eppd,	epipod
Epst,	epistome
Expd,	exopod
F,	foramen (with appropriate prefix)
Fl,	flagellum
G,	gastric region of carapace
gnL,	gnathic lobe of mandible
Gpr,	gonopore
Gs,	gastric spine
H,	hepatic region of carapace
Hs,	hepatic spine
K,	"knee" between merus and carpus
Lm,	labrum
Md,	mandible
mol,	molar process of mandible
Mx,	maxilla (1 Mx and 2 Mx)
Mxpd,	maxillipod
Npr,	nephropore
O,	ocellus
Os,	supraorbital spine

Ostg,	oostegite
Pa,	ocular papilla
Pgn,	paragnath
Pl,	pleural lobe of tergite
Plp,	palp
Plpd,	pleopod
Prpd,	pereiopod
R,	rostrum
S,	antennal scale or exopod, squama
Sp,	sternal process
Sr,	seminal receptacle
St,	sternum
Sy,	sympod, protopod
T,	tergite
Tel,	telson
telS,	telson spine
telL,	telson lobe, furcal lobes
Urpd,	uropod
1 . . . 8	thoracic appendages
1 . . . 7	joints of thoracic appendages
I . . . XIX	body somites

In the descriptions, observation of morphological detail is substantiated by reference to specific fossils on which the feature is best displayed. Citations of the institution in which the specimens are preserved have been abbreviated. They are:

CMNH	Chicago Museum of Natural History
ClMNH	Cleveland Museum of Natural History
CU	Columbia University, New York
GSC	Geological Survey of Canada, Ottawa
ISMNH	Illinois State Museum of Natural History, Springfield
MCZ	Museum of Comparative Zoology, Harvard University
PU	Princeton University
PY	Peabody Museum, Yale University
USNM	United States National Museum
UI	University of Illinois, Urbana
UO	University of Oklahoma, Norman

DESCRIPTIONS OF THE PALEOZOIC EUMALACOSTRACA

SPECIES WITH A CARAPACE

Until recently the most ancient authentic eumalacostracans reported in the literature were classified as syncarids and, therefore, supposedly lacked a carapace. They are *Palaeocaris destinezi* Van Straelen, 1943, from the Upper Devonian of Belgium and *Palaeocaris cuylerensis* Wells, 1957, from the Middle Devonian of New York. Morphological evidence is indicative of the caridoid facies for these species and the new genus, *Devonocaris,* was proposed for them (Brooks, 1962 a). In the same paper a specimen with the carapace preserved was described from the Middle Devonian of Germany. This new crustacean, *Eocaris oervigi* (Text Pl. 9, fig. e), has its closest affinities with *Palaeopalaemon newberryi* Whitfield (1880) from the Upper Devonian of Ohio.

Though the carapace provides the best diagnostic characteristics for definition of genera, its absence from poorly preserved fossils is negative evidence. Because of this, several fossils are in need of reinterpretation. Not only were the "Devonian syncarids" incorrectly interpreted, but *Belotelson magister* Packard (1886 a) from the Pennsylvanian of Illinois, has characteristics of the caridoid Crustacea. On the other hand, *Squillites spinosus* Scott (1938) from the Upper Mississippian of Montana is obviously a syncarid. It and an associated new genus are the most ancient eumalacostracans known without a carapace. *Anthracocaris scotica* (Peach) from the Mississippian of Scotland (Calman, 1932 b) and a contemporaneous species from Canada have a reduced carapace comparable to that of the Spelaeogriphacea and Tanaidacea.

Because the Paleozoic Eumalacostraca have not been adequately studied, diversion from objective description is sometimes necessary to evaluate the validity, significance, and theoretical implication of new observations. Without doing this, it would be impossible to interpret the fossils accurately.

The species with a carapace, though displaying morphological trends in the structure of the exoskeleton toward the various modern eumalacostracan taxa, are distinguished not only by an unexpected combination of characteristics previously not known to exist in the same animal, but by some features previously known only in Recent Crustacea believed to be more primitive than the Eumalacostraca. Therefore in the descriptive portion of this study no attempt has been made to arrange the genera systematically. The basic division is between those that are known or believed to have had a carapace and those that do not. Because of the inadequacy of many of the fossils, the species with better preservation, in which the morphology can be more completely determined, are described first. Genera that are closely related are grouped together. Otherwise the arrangement is, more or less, from youngest to oldest.

A complete systematic revision of the Paleozoic Eumalacostraca is presented after all the basic morphological types are redescribed.

Genus **ANTHRACARIS,** new genus

The singular nature of the species described as *Anthrapalaemon gracilis* by Meek and Worthen is herein proven. The species has affinities with the fossils assigned to *Pygocephalus* Huxley (1857) and its synonym *Anthrapalaemon* Salter (1861); however, it is distinguished (Text Pl. 2) by the presence of a pair of spines on the hepatic region of the carapace, the sympod of the first thoracic appendage is not unlike those succeeding. There are large endites on the sympods of both the first and second thoracic appendages, the endopod of the third thoracic appendage is not fully developed as a pereiopod, and there is an absence of oostegites. A large seminal receptacle is present on the last thoracic sternite of the females of both genera. The generic name *Anthracaris* is proposed to distinguish this crustacean; the incongruity of which was noted by Packard (1885 b) in proposing the family Anthracaridae. From the many excellent specimens now available in the concretions from Mazon Creek, Illinois, the type species, *Anthrapalaemon gracilis* Meek and Worthen, will be described in detail.

A comma is inserted in the synonymy in place of repetition of the original author's name.

Anthracaris gracilis (Meek and Worthen), 1865 Pls. 29-43; Pl. 44, fig. 4; Text Pl. 2; Text Pl. 3, figs. a-c

Anthrapalaemon gracilis Meek and Worthen, 1865, p. 50-51.
Anthrapalaemon gracilis, Meek and Worthen, 1866, p. 406-408, pl. 32, fig. 4.
Anthrapalaemon gracilis, Meek and Worthen, 1868 b, p. 554, figs. a, b.
Anthrapalaemon gracilis, White, 1884, p. 180, pl. 38, figs. 8, 9.
Anthrapalaemon gracilis, Packard, 1885 b, p. 880-881.
Anthrapalaemon gracilis, Packard, 1886 c, p. 135-140, pl. 7, figs. 3, 3 a, 4, 4 a 5, 6.
Anthrapalaemon gracilis, Van Straelen, 1931, p. 24.

Because the genus is monotypic, the description of the specimens must replace the specific diagnosis.

Description of the specimens.—One hundred eighty-three ironstone concretions containing specimens of this species have been studied, of which three are from the collection of Worthen.[1]

Two specimens, not counterparts, have been labeled types; one is at the University of Illinois, X-343 (ISMNH 11124) and the other is in the Illinois Geological Survey collections (ISMNH 3067). At the time Meek and Worthen's original study was made only one specimen was available. This was poorly illustrated by an engraving (1866, pl. 32, fig. 4). The description of the species was revised by Meek and Worthen (1868 b) after several specimens had been received. Restorations based on the composite information from all of the specimens were presented in wood cuts (1868 b, p. 554, figs. a, b), but they refer to no single specimen. Only one specimen in the Worthen collection can be considered a primary type and this is the holotype. The specimen which has been mislabeled as a type in the collections of the University of Illinois, X-343 (ISMNH 11124, Pl. 30, fig. 4) bears no resemblance to the specimen drawn by Meek and Worthen. It is probable that the specimen from the Illinois Geological Survey (ISMNH 3067, Pl. 30, fig. 1) is the holotype. The general shape, the size, and the poor preservation of the caudal extremity conform to the description, measurements, and illustration originally presented; however, many details well portrayed by this specimen were not mentioned or illustrated in the 1865 and 1866 papers.

All four of the specimens figured by photographs in Packard's (1886 c, pl. 7, figs. 3, 3 a, 4, 4 a, 5, 6) work are in the collections of the U.S. National Museum. They are catalogued as USNM 38843. Better photographs of two of these plesiotypes are presented (Pl. 30, figs. 3, 5).

Preservation of most of the specimens is suggestive of a relatively stiff unmineralized chitinous exoskeleton. In all cases, the skeletal materials have deteriorated. If the exoskeleton was mineralized during life, it is doubtful the skeletal remains could be distorted, as many of the specimens have been, without rupture. Sternal features are impressed onto the dorsal surface of the carapaces of

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[1] Note: Upon retiring as State Geologist of Illinois, Worthen withdrew his collection from the Illinois State Museum. They were listed and offered for sale by his heirs, see Worthen and Worthen, 1889. Most of the specimens are now in the collections of the University of Illinois.

many of the specimens, *e.g.*, Pl. 31, fig. 1. This is a characteristic of fossil insects, arachnids and other arthropods with chitinous exoskeletons lacking mineral reinforcement. Considerable wrinkling of two specimens is illustrated (Pl. 32, fig. 2; Pl. 41, fig. 1).

During deterioration of the chitinous materials of some of the specimens, a complex pattern of fractures (Pl. 32, fig. 1) was produced resulting in a reticulate pattern. That this mosaic of both the carapace and the tergites of the abdomen is not a feature of the original exoskeleton is proven by its absence on many of the specimens, by the negative relief of the reticulate pattern, and by inconsistency and asymmetry of design.

Another feature of preservation that may be confused with original structure of the exoskeleton is small mammilla-like protrusions on the dorsal surface of the carapace. They are conspicuous near the lateral margins of only a few specimens. Lack of a pattern of distribution and the unsymmetrical occurrence on the left and right sides of the specimens prove their fortuitous nature. From examination of the nodules it was determined that the "mammillae" correlate with sites of soft ochreous material. Their origin is related to small crystals of pyrite that have weathered.

Statistical analysis of this species has been complicated by distortion of the fossils. Most specimens are preserved in a dorsal-ventral position and have undergone considerable compression. Only five percent of the specimens are preserved on their sides in the position that Glaessner (1929) argued represent positions assumed by exuviae, *e.g.*, PY 19998 (Pl. 35, fig. 4). That they are remains of cadavers and not exuviae is suggested by detrital fillings of the alimentary canal. If some of the fossils were exuviae, the sample would not be representative of the original population. Significant dimensions have been determined with a vernier caliper and recorded for all specimens on which plausible measurements could be made. For some features this represented a small percentage of the total sample.

The parameters measured are the ones that can be reliably determined most frequently on the fossils. The body length is the total length from the anterior margin of the carapace at the base of the rostrum to the suture at the base of the median telson spine.

The length of the carapace was measured in the sagittal plane and does not include the rostrum. The position of the cervical groove is reported as the distance forward from the posterior edge of the carapace in the sagittal plane. Rostrum length, in the few cases that its complete length could be determined, was measured from the tip to the anterior edge of the carapace. The maximum width was measured as the greatest breadth at a position about one-half way back on the carapace. The anterior width was taken as the distance across the carapace at the base of the antero-lateral spines and the posterior width as the interval across at the postero-lateral angles. The length of the antero-lateral spines was measured from the anterior edge of the carapace to the pointed tip. Serrations on the branchiostegal keel were recorded for only those specimens on which the total number could be seen.

Measurements and proportions of representative specimens, including the alleged "types" are given in Text Plate 3, fig. d. Statistical analysis based on the total number of observations of each parameter (N), maximum size (Max), minimum size (Min), mode (Mo), median (Me), arithmetic mean (Ma), and standard deviation (S) is included in the table for characteristics of value in defining the species.

Anthracaris gracilis was a small crustacean. The maximum body length measured was 37 mm. (PY 19937) and the minimum was 16 mm. (PY 19983, Pl. 35, fig. 2). When the body length in percentage frequency is plotted graphically in millimeters, and a line graph drawn, size groupings of units of 3 mm. are evident (Text Pl. 4, fig. a). What appears to be an arithmetic progression is actually a geometric progression with a value of about 1.1. This progression may represent stages of growth. For larval and immature Crustacea, the increase in size of each moult is by a factor of about 1.25 (Brooks' rule, Teissier, 1960, p. 541), but the rate of growth decreases as maturity is reached. The low value suggests we are dealing with mature individuals.

The data plotted as a histogram (Text Pl. 4, fig. a), using class intervals of 3 mm. of body length, show a distribution skewed toward the larger sizes. This is normal for adult populations of invertebrate animals and reflects their growth and mortality. The clustering of the observations about a single mode with a value of 31 mm. indicates only one species was represented in the population. It also proves that there was no sexual dimorphism in size.

The carapace is the part of the animal most frequently found and upon which most of the fossil genera have been characterized. No single specimen reveals all of the features of the carapace. The restorations (Text Pl. 2, 3, fig. a) are composites based especially upon the specimens figured on Plates 31 to 35. Most of the specimens have been spread laterally. The least compressed is PY 19941 (Pl. 33, fig. 2) in which the body depth is about one-half the width of the carapace. Though this is somewhat less than the original relationship, the animals were definitely applanated.

Because of deformation, the most reliable measurement of the carapace is its length. Its mode value is 14.5 mm. but the variation is skewed (Text Pl. 4, fig. c). Due to deformation and inaccuracies in size determination, no growth stages could be detected. The mode of the proportion of the carapace length to the body length is 0.5; however, the median and arithmetic mean value of 0.46 is a more reliable index of the original relationship. The maximum width of the carapace is about nine-tenths its length. The maximum and anterior widths of the carapace and the rostrum length are plotted against the length of the carapace in Text Plate 4, fig. b. The line ($Y = 0.6 X$) about which the values of the anterior width to length are distributed has a lower slope and is divergent from that of the line of the anterior width of the carapace ($Y = 0.9 X$). Though the geometric growth rates for both width measurements are constant with relation to the carapace length, the relationship between the two dimensions is allometric. In practically all specimens the posterior width of the carapace is the same as the anterior width.

It has been assumed in studies of related genera that the apparent margins were the true lateral edges of the carapace. What appears to be the margins are branchiostegal pleural keels. Ventral to the keel the carapace is abruptly underfolded. The ventral edges lie against the flanks of the thoracic somites just above the coxa of the legs to form a crablike branchial chamber. A doublure is unmistakably present on PY 19989 and MCZ 5229 (Pl. 35, fig. 1; Pl. 41, fig. 1).

The pleural keels are serrate anteriorly. The small denticles diminish in size posteriorly and the posterior two-thirds of the keel is smooth. Only 26 specimens are preserved so that all serrations can be counted. About one-third of the specimens have eight denticles but the range is from five to eleven. One would expect the number to be fixed or to increase with growth, but no relationship with size exists (Text Pl. 4, fig. d). Though most specimens have equal numbers of serrations on the left and right keels, some individuals have them unequally developed; for example, PY 19932 (Pl. 31, fig. 1) has eight denticles on the left side and ten on the right.

The lateral keels are produced into acute spines at the antero-lateral angles of the carapace. When well preserved their tips are pointed as on PY 19932 (Pl. 31, fig. 1). Exact measurements are difficult to obtain, but in the best specimens their length is about one-eleventh to one-twelfth the length of the carapace.

The anterior margin of the carapace is best displayed by PY 19993 and PY 20003 (Pl. 34, fig. 1; Pl. 32, fig. 1). Immediately inward from the antero-lateral spines, the margin is recessed and then projects slightly forward to a central portion of about one-half the width of the carapace. This portion of the anterior border is straight and at right angles to the axis of the plane of symmetry. From this, the rostrum arises abruptly through an arc of small radius.

At the center of the anterior margin of the carapace a long spinelike rostrum projects anteriorly. It is well preserved in PY 19993, PY 20003 (Pl. 34, fig. 1; Pl. 32, fig. 1) and in PY 19928 (Pl. 35, fig. 3) which presents a side view. The rostrum arises in the mid-dorsal line about a quarter of the distance back on the carapace through anterior development of a mid-dorsal keel. The rostrum in cross section is in the form of an inverted T consisting of a central keel and lateral flanges. The central keel has its greatest development just anterior to where the margin of the carapace gives way to the lateral flanges. The transverse flanges are widest at the base. The keel and flanges taper to a point anteriorly with the extremity slightly upturned. No trace of serrations on the dorsal keel or the flanges was observed. From the margin of the carapace to the tip of the rostrum is slightly over one-half the length of the carapace. In PY 19992 it is 0.58 and in PY 19993 it is 0.59 of the carapace length. For the eight specimens in which this proportion could be determined, the mode, median, and arithmetic mean were 0.60.

The features of the dorsal surface of the carapace are: a posterior mid-dorsal keel, transverse cervical groove, marginal pleural flanges, a pair of gastric spines and a pair of hepatic spines. The mid-dorsal keel is a raised reinforced line. It arises midway back on the carapace posterior to the hepatic eminences. The cervical groove divides the carapace transversely. The groove is situated forward on the carapace at a distance of three-quarters of its length. From the mid-dorsum, the groove extends anteriorly and laterally. Though it appears to bifurcate into anterior and posterior prongs on some specimens, it terminates at the site of apparent splitting. The supposed anterior and posterior prongs are the division between the pleural flanges and the arched main body of the carapace. That the anterior and posterior furrows do not exist is well shown by PY 20003, PY 19996, and PY 19975 (Pl. 32, fig. 1; Pl. 36, fig. 1; Pl. 32, fig. 2). Compression has caused furrows to develop in some specimens at the juncture between the central and lateral regions of the dorsal surface of the carapace.

A pair of prominent spines is situated on the protocephalic portion of the carapace, vide PY 20003 and PY 19988 (Pl. 32, fig. 1; Pl. 33, fig. 1.). In the morphological terminology of Recent Malacostraca, these are referred to as gastric spines. Posterior to the cervical groove a pair of spines arise through development of ridges. It is common to refer to similarly situated structures as hepatic spines. The position and ridgelike nature of the bases of the hepatic spines are shown by PY 19975 and PY 19941 (Pl. 32, fig. 2; Pl. 33, fig. 2).

The posterior margin of the carapace is usually not well preserved. It can be seen on PY 19941 and PY 19975 (Pl. 33, fig. 2; Pl. 32, fig. 2). The border seemingly fitted closely around the tergite of the first abdominal somite, though in most specimens the posterior lateral angles have been spread by compression resulting in a posterior flare of the carapace. The posterior margin was originally highly arched. When viewed from above it is slightly arcuate being concave forward. This concavity is accentuated in compressed specimens. As is the case with all crustacean carapaces, its edges are reinforced.

That the carapace was not fused with the posterior thoracic somites is shown by several specimens lying on their side in such orientation that their free unattached nature is manifest by the carapace being displaced upward away from the thorax, vide PY 19928 (Pl. 35, fig. 3). The granular undersurface of the carapace can be seen on PY 19928 (Pl. 40, fig. 2). It also shows that the thoracic somites retained their identity. Lack of fusion is further proven by the freely jointed sternites which are commonly separated in the fossils as on PY 19947 (Pl. 40, fig. 3).

Features that may be mistaken for characteristics of the carapace are especially well shown by the dorsal surface of PY 19932 (Pl. 31, fig. 1). In this specimen the sternites of the thorax have been impressed against the undersurface of the carapace. The outlines of the sternites are expressed as transverse ridges. The raised central portion of the carapace upon which the ventral features are reflected is bounded laterally by distinct lines. The lines bordering the raised area are an outline of the thorax, especially the sternum, and have been produced through compression. These features have been mistaken (Salter, 1861, and Rhodes and Wilson, 1957) as characteristics of the carapace of the species of *Pygocephalus* (= *Anthrapalaemon*) (Text Pl. 6, figs. b, c). Compare the raised area on the carapace of *A. gracilis* with the thoracic sternites of the same specimen (Pl. 31, figs. 1, 2). For the normal aspect of the carapace in which the sternal features have not been superimposed see the carapaces of PY 20003 and PY 19975 (Pl. 32, figs. 1, 2).

The surface of the carapace of typical individuals is believed to have been without ornamentation. Under magnification the smooth impressions of the surface texture are finely granulate. This is especially well shown by specimens CMNH 28125 and MCZ 5206 in which impressions of the original carapace surface are superbly preserved. The mammillae on the marginal flanges of PY 19932 are due to crystals of weathered pyrite; however, the tubercles distributed over most of the dorsal surface of the carapace of PY 19975 (Pl. 32, fig. 2) may be authentic ornamentation. If so, this is a variant as this specimen differs in no other way from typical specimens of *A. gracilis*.

The skeletal features of the head are remarkably well preserved on some of the specimens of *A. gracilis*. The sensor region of the head, the protocephalon, bears a pair of stalked compound eyes and two pairs of antennae. Three additional somites are fused into the cephalic tagma. These gnathic somites bear the mandibles and two pairs of maxillae.

The ventral skeleton of the protocephalon can be seen on many specimens but is decipherable on only a few. A composite drawing of the ventral aspect of the head with all the appendages removed, except the mandibles, is presented in Text Pl. 3, fig. b. The ventral plate of the protocephalon, or epistome, with foramina for a pair of stalked eyes and two pairs of antennae are shown as seen on USNM 38842-200[11] (Pl. 44, fig. 4). First antennae are seen to originate from the protocephalon on PY 19931 (Pl. 40, fig. 1). In this specimen the portion from which the first antennae arise is separated from the portion bearing the second antennae. The separation has occurred along a suture which can be seen on USNM 38842-200[11], PY 20022 (Pl. 42, fig. 1) and USNM 38843 (Pl. 39, fig. 1).

Just anterior to the labrum is a transverse prominence joined to the second antennal "sternite" of the epistome by a suture. In Pl. 40, fig. 1, the relationship of this to the mandible articulation is shown. The strong development of the epistome corresponds to a similar development in Recent decapods, *e.g.*, *Cambarus longulus* Girard, in which a supralabral ridge exists to support the secondary articulation of the mandible.

It is easy to mistake portions of the peduncle of the first antennae for eyes as did Meek and Worthen in their original study. Both stalked eyes are present on PY 19694 but are too poorly preserved to photograph. A stalked eye is present on the left side of PY 19993 (Pl. 34, fig. 1). Doubts of the validity of interpretation of these indefinite remains are dispelled by the presence of the foramina on USNM 38842-200.[11] Also, stalked eyes are well preserved on a closely related genus to be described below, see Pl. 44, figs. 2, 3.

The thick basal peduncle, sympod, of the first antennae consisting of three segments is commonly preserved, *vide* PY 20022 (Pl. 42, fig. 1). The flagella are more rarely present. All or part of both the outer and inner flagella are preserved in PY 19931, 19936, 19939, 19944, 19945, 19988, 19990, 19998, 20001, 20003, 20013 and MCZ 5224. PY 19988 (Pl. 33, fig. 1) has the sympod and portions of both flagella preserved. The basal joint of the peduncle is long, and the two distad joints are short and about equal in length. A row of setae originates on the inner margins of these joints. Their presence in life is indicated by a row of about ten setal sockets on the inner edge of both short joints of PY 19996 and PY 20000. Some of these sockets can be seen in the photograph of PY 20022 (Pl. 42, fig. 1). The inner flagellum is short, being about one-sixth the length of the animal. It consists of 18 annuli of equal length but of diminishing diameter. The length of the outer flagellum is about one-third the length of the animal. In specimen PY 19932 (Pl. 31, figs. 1, 2), 64 annuli of equal length constitute the tapering flagellum.

The second antennae are present on many of the specimens; especially good are USNM 38843, MCZ 5229, PY 19929, PY 19931, PY 19932, PY 19988, PY 19993, and PY 20022 which are figured (Pl. 39, fig. 1; Pl. 41, fig. 1; Pl. 43, fig. 1; Pl. 40, fig. 1; Pl. 31, fig. 1; Pl. 43, fig. 2; Pl. 34, fig. 1; Pl. 42, fig. 1). On none of these is the appendage complete. The sympod consists of two joints. The basal joint is short and wide with a ventral medial sharp lobe which obscures the relationship of the next segment. This relationship is shown by PY 20022 (Pl. 42, fig. 1). Only a rectangular free portion of the second segment, to which is articulated a flattened, squamate exopod, is visible on most specimens. Articulated to the mesad base of the second segment is an endopod consisting of three segments and a long flagellum. The exopod (PY 19988, Pl. 33, fig. 1) has a straight lateral edge which is reinforced by a ridge that terminates in a spine. The shape of the antennal scale is best seen in PY 19930 and PY 19948. The main body of the scale is a flat inner lobe which bears a marginal row of setae (PY 19929, Pl. 43, fig. 1). The basal segments of the endopod are robust and of about equal length. The flagellum is about the length of the body. In PY 18856, which is 22 mm. long, the flagellum is 19 mm. in length. The basal annulus of the flagella of the first and second antennae is significantly larger than those succeeding.

The ventral skeletal structure of the head posterior to the mouth is poorly known. Two small lobelike structures that may be fortuitous scraps or true paragnaths were discovered on the counterpart of USNM 38842-200.[11] They are of an acceptable shape, are correctly situated, and arise from a small skeletal element posterior to the mouth.

The body of the left mandible is remarkably well preserved on PY 19931 (Pl. 40, fig. 1). The biting processes are unknown except that the incisor lobe was serrate as seen in PY 19936 (Pl. 42, fig 2). The three small joints present on some specimens, *e.g.*, PY 19929 (Pl. 43, fig. 1), in the position of a mandibular palp, are the terminal portions of the first maxillipeds. The structure of the mandibular palp is unknown.

A most unusual feature of the mandible of these Crustacea with biramous thoracic appendages is the articulation with the epistome as seen on PY 19931 (Text Pl. 3, fig. c). This well-developed articulation lateral to the labrum is secondary and is characteristic of decapods.

Among the jumble of remains on the fossils of structures which originally supported the mandibles posteriorly, one can sometimes imagine that maxillae can be seen. Under close scrutiny the decipherable structures always prove to be remains of the maxillipeds. If maxillae were present, they would be obscured from view by the large endites of these thoracic appendages. The structures on fossils of *Tealliocaris* interpreted as maxillae by Peach (1908, pl. 1, fig. 7 a) (Text Pl. 7, fig. c) need to be critically re-examined.

The thorax is covered dorsally and laterally by the carapace. Though the carapace and thorax were probably not adnate, nothing is known of the tergites of the eight somites forming this tagma. Between the pleural development of the carapace and the body, branchial chambers were present. Nothing is known of the gills.

The sternites and their corresponding pairs of biramous appendages are well preserved on some of the specimens. The eight sclerites of the sternum are shown by USNM 38843 (Pl. 39, fig. 1). The sternites were sclerosed more than the other skeletal parts. The first thoracic sternite appears to be a small triangular sclerite with a pronounced medial ridge. This is not the complete structure but a reinforced portion between foramina for the legs, vide PY 19936

(Pl. 37, fig. 1); its complete shape is transverse with bridges anterior and posterior to each foramen. The seven succeeding sclerites have a central heavily sclerotized portion in bold relief. The raised portion of each sternite is quadrilateral with acute postero-lateral angles. The anterior sternites have a raised medial keel. The sternites become progressively wider placing the foramina for the legs farther apart. The foramina for the legs are surrounded by the marginal recessed portion of the sternites (PY 19936, Pl. 37, fig. 1). Thoracic somites are subequal in length as shown by the sternites. Each sternite is reinforced anteriorly and posteriorly by infolded edges at the intersegmental suture. The sternal sclerites of some of the specimens have been pulled apart suggesting a membranous articulation, see PY 19947 and PY 19971 (Pl. 40, fig. 3; Pl. 36, fig. 2). The thoracic somites were not fused and there was no endophragmal skeleton.

There are two variations of the eighth sternite. On PY 20022 (Pl. 42, fig. 1) this sclerite is not unlike the seventh except for its greater length and convex posterior. At least one-half of the specimens with this skeletal part preserved have an enlarged medial pouch (PY 19947, Pl. 40, fig. 3; USNM 38843, Pl. 39, fig. 1). This structure, which originally was nearly circular, has a large aperture facing slightly to the posterior. The structure is reminiscent of the sperm receptacle of the syncarids and eryonid decapods. The annulus ventralis of other decapods, when present, is on the seventh sternite of the females. The structure must be a sperm receptacle. It is too small for an egg pouch. Though male gonopores are associated with the eighth somite in Eumalacostraca, this is an unlikely male organ.

Evidence of other sexual characters were sought in vain. Female gonopores did not open on the sternite of the fifth somite as there is no trace of them on the many excellent specimens which show this sclerite. It must be assumed that the female gonopores opened on the sympod of the fifth pair of thoracic appendages and the male gonopores on the sympod of the eighth pair of appendages as in Recent decapods.

Eight pairs of thoracic appendages are present on PY 20022 (Pl. 42, fig. 1) and USNM 38843 (Pl. 39, fig. 1). The first two pairs are differentiated as maxillipeds, the third is incipiently modified, and the last five pairs are long, slender pereiopods, vide PY

19993 (Pl. 34, fig. 1), PY 20005 (Pl. 34, fig. 2), PY 19953 (Pl. 38, fig. 2), and PY 19988 (Pl. 33, fig. 1).

On several of the specimens parts of the first two pairs of appendages are present. They must be interpreted with caution to avoid misapprehension as it is not always obvious they originate from the first two thoracic somites. It is also unknown to what degree the maxillae had degenerated to foliaceous lobes. Especially confusing are the large lobate endites which arise from the sympod of the maxillipeds and embrace the gnathic structures as on USNM 38843 (Pl. 39, fig. 1). At first it was believed the lobes and segments of appendages shown by PY 19929 (Pl. 43, fig. 1), PY 19988 (Pl. 43, fig. 2), PY 19960 (Pl. 41, fig. 2), and PY 19971 (Pl. 36, fig. 2) were maxillae, but in all cases, the morphology of these parts conforms to the known structure of the first two pairs of thoracic appendages.

The maxillipeds of *A. gracilis* are most unusual. The sympod consists of a single joint. From the mesad side a simple large endite arises. The endite on the first appendage is produced into a blade-like lobe which is twice the size of that of the second; otherwise, the two maxillipeds are similar. Only four joints make up the endopod. They are shown in the restoration (Text Pl. 2). Exopods which may be associated with these appendages can barely be detected on the right side of MCZ 5229 (Pl. 41, fig. 1).

Except for the smaller size of the appendages of the third thoracic somite, the remaining six pairs of endopods are similar. There is a distinct specialization for only the posterior five pairs to function as pereiopods. This tendency toward becoming a decapod is apparent in many specimens, vide PY 19953 (Pl. 38, fig. 2) and PY 20005 (Pl. 34, fig. 2).

The two rami of the thoracic leg arise from a short stout sympod. A precoxa cannot be fused into the pleura associated with each appendage as Hansen (1925, p. 138) has claimed is the case with decapods. The simple, unmodified foramina for the thoracic legs have been discussed and illustrated. Only one joint can be distinguished in the sympod of *A. gracilis*. The single large joint is produced mesad and forward into small endites. These are particularly well shown by USNM 38843 (Pl. 39, fig. 1).

The endopod conforms to the basic structure of the malacostracan leg. It has five joints, an ischium, merus, carpus, propodus, and terminal dactylus. The "knee" is between the merus and the carpus. For the proportional development of these joints see the photograph of PY 19953 (Pl. 38, fig. 3) and the restoration.

The exopods are always poorly preserved, but fragmentary evidence of their existence is found on many specimens. Remains of the annulate flagellum are unmistakable. The setiferous annulate portion of the exopod is particularly well preserved on PY 19979 (Pl. 39, fig. 2). The flagellum and the basal unjointed stalk of the exopod are both present on the fourth thoracic appendages of PY 20022 (Pl. 42, fig. 1).

Except by analogy, only the digestive tract is known of the internal anatomy. The gut of many of the specimens has been filled with detrital sediment of the same general nature as the entombing matrix. As shown by PY 19998 (Pl. 35, fig. 4) there is an expansion of the gastric region in the cephalothorax to form a simple undivided stomach. The posterior intestine is a simple tube which terminates on the ventral side of the telson as shown by PY 19993 (Pl. 34, fig. 1).

The abdomens of most of the specimens are preserved in a dorso-ventral position and are extended, but a few have their abdomens reflexed. A gentle flexure as shown by the specimens preserved on their sides (*vide* Pl. 34, fig. 2; Pl. 35, figs. 3, 4; Pl. 38, fig. 2) seems to be normal.

The tergites of the second to fifth abdominal somites are similar except for a slight decrease in size posteriorly. This can be seen in the photograph of PY 19993 (Pl. 34, fig. 1) and PY 19928 (Pl. 35, fig. 3). The first tergite is never well preserved (PY 19983, Pl. 35, fig. 2). If it were not for the sternites, there would be no conclusive proof of its existence on the specimens of *A. gracilis* studied. The tergites are highly arched as shown by PY 19996 (Pl. 36, fig. 1). Ventrally they are produced into pleural lobes with an acutely pointed apex (PY 19931, Pl. 39, fig. 3). The tergite of the sixth abdominal somite is distinguished only by the marginal modification of the pleural plate and the postero-lateral margins to accommodate the uropods.

Sternites of the first five abdominal somites are narrow sclerotized bars which are expanded near their juncture with the tergites where there are foramina for the swimmerets. These structures are shown by USNM 38843 (Pl. 39, fig. 1) and MCZ 5229 (Pl. 41, fig. 1). The ventral membranous surface of the abdomen between the sternites is partially preserved on USNM 38843. The appendages of the first five abdominal somites are unknown, but from their foramina (Pl. 42, fig. 1) they must have been small swimmerets.

The appendages of the sixth abdominal somite are large uropods. These contribute to the formation of a caudal fan. As shown by PY 19932 (Pl. 31, fig. 1), PY 19993 (Pl. 34, fig. 1) and PY 19996 (Pl. 36, fig. 1) these appendages have a large, one-jointed sympod, a bladelike exopod, and a lobate endopod. The outer margin of the exopod is strongly sclerotized and is produced into a spine. This marginal spine extends beyond the position of the oblique suture that separates the lobe of the blade into two unequal parts. The true shape of the endopod as a simple lobe can be seen only on the ventral counterpart of PY 19932 (Pl. 31, fig. 2). Marginal setae are remarkably well preserved on nearly all of the specimens figured. No evidence of statocysts or other sensory organs in the uropods is present.

The flattened body of the telson is more or less pentagonal. From its broad base, the lateral margins flare slightly and terminate in small spines. Small furcal lobes arise inward to the lateral spines. Two additional pairs of small spines are present inward to the furcal lobes on the postero-lateral margins. The inward pair are marginal to the articulation of the medial spine. A similar fixed spine is present on the telson in the sagittal plane and projects over the articulation. The shape and proportion of these features are displayed by PY 19996 (Pl. 36, fig. 1) and PY 19932 (Pl. 31, fig. 1). Situated mid-ventrally on the body of the telson is the anus.

Synopsis.—A new monotypic genus, *Anthracaris,* is established for a pygocephalomorph crustacean with a broad applanated carapace distinguished by having a pair of hepatic spines. The most significant differences from *Pygocephalus* are the absence of oostegites and the shape of the sympods of the thoracic appendages. Thought the thoracic legs are biramous and their sympods consist of only one joint, this crustacean displays many characteristics of the eryonid decapods. There is a secondary articulation between the mandible and the epistome, the endopods of the first two pairs of thoracic legs are modified as maxillipeds, and the third is incipiently modified. There is a seminal receptacle on the eighth sternite of the females. The genus has retained the primitive furcal lobes and median spine on the telson. Specific criteria of *A. gracilis* are the characteristics of the specimens described.

Stratigraphic occurrence.—Francis Creek shale, Carbondale formation, Alleghany series (Westphalian), Pennsylvanian in Mazon Creek nodules.

Localities.—Grundy and Will counties, Illinois.

Collections.—The best collection is the S.S. Strong collection at Yale University. Other collections are in the Chicago Museum of Natural History, Illinois State Museum of Natural History, University of Illinois, Illinois Geological Survey, U.S. National Museum, and the Museum of Comparative Zoology.

Holotype.—ISMNH 3067 in the collection of the Illinois Geological Survey is the holotype. Y-343 in the collection of the University of Illinois is mislabelled. The plesiotypes studied by Packard are catalogued as No. 38843 in the collection of the U.S. National Museum.

Genus **MAMAYOCARIS**, new genus

A single compressed specimen of a pygocephalomorph was discovered in 1956 by S. H. Mamay of the U.S. Geological Survey in the Vale formation of Permian age south of Abilene, Texas. Its superficial appearance and the marginal branchiostegal serrations of the carapace are characteristics it possesses in common with species of *Anthracaris* and *Pygocephalus*. Through the courtesy of Donald Baird of Princeton University, a large number of specimens, some with better carapaces, representing the same species were brought to my attention. They are from the Opeche formation of Permian age near Rapid City, South Dakota. From these specimens it was determined that the new species differs in several significant characteristics from the known Pennsylvanian and Permian genera.

The only Permian pygocephalomorphs previously known were

Notocaris Broom (1931) from South Africa and *Paulocaris* Clarke (1920) (= *Pygaspis* Beurlen, 1934, and *Liocaris* Beurlen, 1931) from Brazil. Hitherto, pygocephalomorphs have not been reported from strata younger than Westphalian, Middle Pennsylvanian, in the Northern Hemisphere. The new genus is named *Mamayocaris* in recognition of the important paleontological discovery of S. H. Mamay.

Paulocaris has the mid-dorsal carina on the carapace developed into a short prominent crest. The carina is unknown on *Notocaris* and is subdued to the point of being almost undetectable on *Mamayocaris*. The extended compressed carapaces of *Paulocaris* have a greater width than length. On *Mamayocaris* the length and width are approximately equal, whereas on *Notocaris* the width is less than the length. Both southern hemispheric genera differ from *Mamayocaris* by having the abdomen reduced and flexed under the cephalothorax in a crablike manner.

The new genus has its closest phylogenetic relationships with *Pygocephalus* and *Anthracaris*. It (Text Pl. 5) is distinguished by the absence of a pair of hepatic spines, indistinctness of the mid-dorsal carina, shortness of the antero-lateral spines and the more posterior course of the cervical groove on the carapace. The cornea of the stalked compound eyes is abnormally large and the shape of the telson is subtriangular. The seminal receptacle and marsupium on the females are not known. The endopods of the thoracic legs display a decapodous tendency for reduction of the first three pairs to maxillipeds as on *Anthracaris*. The sympods of these legs are more like those of *Anthracaris* than *Pygocephalus*.

The genus is monotypic, represented only by *Mamayocaris jepseni*.

Mamayocaris jepseni, new species — Pl. 44, figs. 1-3; Pl. 45, fig. 5; Text Pl. 5

This species is characterized by the shortness of the antero-lateral spines, smoothness of the carapace, and existence of only five inconspicuous serrations on the anterior portion of the branchiostegal keels. The individuals of this species are comparatively small. Of the 47 specimens on which measurements of the carapace could be made, the largest was 10.2 mm. in length and the smallest was 7.5 mm. The mode and median were 8.5 mm.

Description of the specimens.—The holotype, USNM 133393 (Pl. 44, figs. 1-3), is preserved as a carbonized compression of low relief in a light-gray siliceous mudstone. The details of the dorsal surface of the carapace cannot be seen, but otherwise the specimen is remarkable for the many morphological features of the body and appendages preserved.

The length of the body of the holotype, telson spine not included, is 19.0 mm. and the length of the carapace is 9.7 mm. Thus, about fifty percent of the length of the animal's body was covered by the carapace. On the paratypes from South Dakota the ratio is fifty to fifty-one percent and the carapace length to width ratio is 0.9 to 1.0.

Remains of about 164 individuals on a slab of limestone and four on pieces of fine red sandstone are paratypes. The limestone is thinly laminated. The more nearly pure calcite layers are light tan in color, but because of the many layers of red, detrital partings, the rock appears reddish-brown. The specimens are all dorso-ventral compressions of low relief. Both dorsal and ventral surfaces and impressions of these surfaces are present. Except for the natural impression of the dorsal features of the carapace, the preservation is extremely poor. However, two specimens do reveal characteristics of the telson that would otherwise remain unknown. No residue of the original organic skeletal material remains. The form of the compressed exoskeletons has been duplicated with an earthy calcite. Few of the specimens are of complete animals.

Features of the carapace can be seen on several of the paratypes, *e.g.*, PU 83463 a (Pl. 45, fig. 5). They have the same small antero-lateral spines and the five small inconspicuous serrations of the branchiostegal keel as the holotype (Pl. 44, fig. 3). The surface of the carapace is smooth. A dorsal carina is conspicuous on all pygocephalomorphs from the Pennsylvanian. In this species it is barely detectable. There is a pair of gastric spines, but there are no hepatic spines. Only the base of the rostrum was seen. On the many specimens with this feature, none was complete. The course of the cervical groove on the carapace is more posteriorly oriented than on any other Upper Paleozoic crustacean. Near the mid-dorsum, where it diminishes and terminates, each lateral sulcus is directed toward the posterior.

As far as known, the body and appendages have the same structural plan as *Anthracaris.* It is only on the holotype that their morphology is decipherable (Pl. 44, figs. 2, 3).

Eyes and portions of both pairs of antennae are the only features of the head exposed. The first antenna is believed to be like that of *A. gracilis.* The scape of the scale, a process of the second joint of the sympod of the second antenna, has its distal end transversely oblique to the outer margin. Whereas the absence of the blade of the squama is a feature of preservation, this is not. The flagellum of the second antenna is nearly as long as the animal.

The left eye on this fossil is the best preserved stalked compound eye known on Paleozoic caridoid fossils. The faceted cornea forms a large hemisphere (Pl. 44, fig. 3). The juncture with the stalk is straight.

Except for lacking the mid-ventral longitudinal ridge on the thoracic sternites, the eight sclerites are not distinctive. Absence of a medial keel is not due to preservation as the sternites can be studied both as compressions and external impressions (Pl. 44, figs. 2, 3). The paratypes also have no keel. On none of the specimens is there evidence of a seminal receptacle on the eighth sternite.

The last five thoracic appendages are beautifully preserved on the right side of the holotype. The basal shaft and the annulate flagellum of the exopod are present on both counterparts of the fourth thoracic appendage. A flagellum just forward of this is present on one counterpart (Pl. 44, fig. 2). This must have had its origin on the third appendage. Joints of the endopods of the five pereiopods are remarkably well preserved; however, the small dactylus is present only on the seventh leg (Pl. 44, fig. 2). The "knee" portion of the third thoracic appendage can be seen. As in *A. gracilis,* this endopod is smaller than those of the succeeding appendages. Because the other appendages are identical to those of *A. gracilis,* it is assumed the third pair of endopods were incipiently modified as maxillipeds.

The Texas specimen is the only pygocephalomorph fossil with the tergite of the first abdominal somite well displayed. The sclerotized part is less than half the length of the typical abdominal tergites. It can be seen in the photographs of counterpart a (Pl. 44, figs. 1, 3). The apex of the pleural lobes of the tergites of abdominal somites two to five are sharper than on *A. gracilis,* and the anteroventral margins are straight. The tergite of the sixth abdominal somite is not well preserved; neither are the telson and uropods of the caudal fan. What can be seen of the telson on this specimen is not distinctive; however, on paratype PU 83463 a (Pl. 45, fig. 5), the telson is subtriangular with the furcal lobes articulated closer to its base than on *A. gracilis.* The rami of the uropods and the furcal lobes are fringed with setae. There is a broad triangular spine articulated medially on the telson.

Synopsis.—*Mamayocaris jepseni* is the only pygocephalomorph crustacean known from Permian deposits of the Northern Hemisphere. *Notocaris tapscotti* (Woods) (Woods, 1923, Broom, 1931) from the Upper Dwyka shales of Kimberly, South Africa, and *Paulocaris pachecoi* Clarke (1920) from the Iraty shales of Brazil are the only other Permian species known. *Pygaspis brasiliensis* Beurlen, *P. quadrata* Beurlen (1934) and *Liocaris huenei* Beurlen (1931) from the same deposits as *Paulocaris* are believed to be synonyms. The genera from the Southern Hemisphere differ from *Mamayocaris* by having the abdomen slightly reduced and flexed under the cephalothorax. The new genus is closely related to *Anthracaris* but is readily distinguished by the absence of hepatic spines, indistinct dorsal carina, and the more posterior course of the cervical groove. The hemispherical cornea of the compound stalked eyes is abnormally large. The appendages are similar in structure to those of *Anthracaris.* It is unknown if seminal receptacles or oostegites exist on the females. The telson is subtriangular with the furcal lobes being articulated nearer the base of the telson than they are on *Anthracaris.* The species is characterized by its small size and by five inconspicuous branchiostegal serrations.

Stratigraphic occurrence.—Holotype is from the Vale formation, Clear Fork group, Leonardian series, Permian System. It was associated with remains of terrestrial plants, palaeoniscoid fish, amphibians and reptiles. The only other invertebrates are rare estherian fossils. The stratigraphy and paleoecological condition of this deposit have been summarized by Wilson (1953). The paratypes from the contemporaneous Opeche formation were found in association with palaeoniscoid fishes in a lagoonal deposit.

Collections.—The holotype, USNM 133393, was collected by S. H. Mamay in a quarry six miles southwest of Lawn, Texas, on the property of C. O. Patterson in the southern part of Taylor County, S.W. 1/4 of S. 436 of the M.P. King survey. The 168 paratypes, PU 83463, were collected by G. L. Jepsen with financial support from the Scott Fund, Princeton University. They are from the State Cement Quarry, three miles west of Rapid City, South Dakota.

Types.—The holotype is No. 133393 in the collection of the U.S. National Museum. There are 168 paratypes catalogued as No. 83463 in the collection of Princeton University. The better specimens have been assigned alphabetical suffixes, a to k.

Genus **PYGOCEPHALUS** Huxley, 1857

The name of this genus is indicative of the difficulty Huxley had in interpreting the three original specimens which presented the ventral skeletal structure of this crustacean. Outlines of the carapace were not present. All that he had to work with were the thoracic sternities, the cephalic and thoracic appendages; and on all specimens the abdomens were reflexed upon themselves. Upon deciding the end with the flagella was anterior, he noticed the similarities of the structures present to those of the Recent *Mysis.* It is unfortunate that *Pygocephalus* has been restricted to fossils that present only the ventral skeleton. There is no question but that *Anthrapalaemon* Salter (1861) with a carapace is the dorsal surface of the same species and that *Necroscilla* Woodward (1879) is a poorly preserved abdomen.

Woodward (1907 b) was the first to note the many common characteristics observed on specimens referred to both *Anthrapalaemon* and *Pygocephalus,* but he failed to realize the taxonomic significance. Other authors (Peach, 1908, p. 37, Copeland, 1957 b, p. 43) noted the close generic association and Beurlen (1930, p. 126) suggested they should be synonymized. When it is obvious that these two genera are different parts of the same animal, perpetuation of their use is absurd. *Anthrapalaemon* Salter, 1861, must be suppressed as a junior synonym of *Pygocephalus* Huxley, 1857. The type species is *P. cooperi* Huxley.

Pygocephalus (Text Pl. 6) is distinguished by the absence of a pair of hepatic spines on the carapace and massive development of the sympods of the first two thoracic appendages. It is believed that the females had six or seven pairs of oostegites and a seminal receptacle on the eighth sternite.

Pygocephalus dubius (Milne-Edwards), 1840 Pl. 38, fig. 1; Text Pl. 6

Apus dubius Milne-Edwards, 1840, *in* Prestwich, p. 491, pl. 41, fig. 9.
Pygocephalus cooperi Huxley, 1857, p. 363, pl. 13, figs. 1, 3.
Anthrapalaemon grossarti Salter, 1861, p. 530, text figs. 1-4.
Anthrapalaemon (*Palaeocarabus*) *dubius,* Salter, 1861, p. 532, figs. 6, 7 a, 7 b.
Palaeocarabus russellianus Salter, 1863 b, p. 520, figs. 1, 2.
Anthrapalaemon (*Palaeocarabus*) *hilliana* Dawson, 1877, p. 56-57, fig. 1.
Anthrapalaemon (*Palaeocarabus*) *hillianum,* Dawson, 1878, Appendix, p. 55, fig. 10.
Necroscilla wilsoni Woodward, 1879, p. 551-552, pl. 26, fig. 3.
Anthrapalaemon parkeri Woodward, 1907 a, p. 568.
Pygocephalus cooperi, Woodward, 1907 b, p. 400-406, figs. 1, 2, pl. 18, figs. 1-6.
Pygocephalus (*Anthrapalaemon?*) *parkeri,* Woodward, 1907 b, p. 406-407, fig. 2.
Anthrapalaemon russellianus, Peach, 1908, p. 29-39, pl. 4, figs. 1-7.
Anthrapalaemon hillianus, Bell, 1922, p. 162, pl. 1, fig. 10.
Pygocephalus cooperi, Beurlen, 1930, p. 442, fig. 61.
Anthrapalaemon dubius, Van der Heide, 1951, p. 26-37, pl. 3, figs. 4, 5, pl. 4, figs. 2-10, pl. 5, figs. 1-10, pl. 6, figs. 1-5.
Anthrapalaemon dubius, Rhodes and Wilson, 1957, p. 1159-1165, text figs. 1, 2.
Anthrapalaemon dubius, Copeland, 1957 b, p. 42, pl. 10, figs. 3-6, pl. 11, figs. 2, 3.
Anthrapalaemon sp. Copeland, 1957 b, p. 43, pl. 21, fig. 2.
Pygocephalus cooperi, Copeland, 1957 b, p. 43, 44, pl. 10, fig. 1, pl. 11, fig. 1.
Pygocephalus cf. *cooperi,* Copeland, 1957 b, p. 44, pl. 10, fig. 2.

The systematics of the many species that have been referred to *Anthrapalaemon* and *Pygocephalus* needs critical review. However, for the present we must rely on the work of Van der Heide (1951) and Rhodes and Wilson (1957) on the European carapaces referred to *Anthrapalaemon*. They synonymized all of the European species and *Anthrapalaemon hillianus* Dawson from Nova Scotia. Peach (1908, p. 31) called attention to variations in the number of marginal serrations as a product of preservation; thus, the serrations are not a reliable specific criterion. This and the variations in distribution and density of the tuberculate ornamentation of the carapaces preserved as impressions in black shale are unreliable bases for differentiating species. Rhodes and Wilson (1957, p. 1161-1164) attempted to prove by a statistical analysis of the size frequency and other parameters of the British specimens that only one species should be recognized.

The systematics of *Pygocephalus dubius* is further complicated by the paleontological practice of recognizing form genera. *Necroscilla* Woodward, 1879, is an abdomen. *Anthrapalaemon* Salter, 1861, has been used for those Crustacea showing the dorsum, particularly the carapace. On the other hand, *Pygocephalus* Huxley, 1857, has been used for classification of remains presenting the ventral aspect of the exoskeleton. Species assigned to these genera have been defined on different distinguishing characteristics. In the proven absence of reliable differences, there is no recourse but to synonymize at this time. The synonymy presented above includes only those taxonomic contributions relative to the classification of the Canadian fossils. More complete synonymies can be found in the works of Van Straelen (1931, p. 23-26, p. 32-35), Van der Heide (1951) and Rhodes and Wilson (1957).

Morpholoy.—The morphological description presented below is not restricted to the specimens examined. For many details I have had to rely upon published illustrations of specimens of *Anthrapalaemon* and *Pygocephalus*. The only previous studies worthy of note are those of Woodward (1907 b, *Pygocephalus cooperi*) and Peach (1908, *Anthrapalaemon russellianus*). A composite restoration of *Pygocephalus dubius* is presented in Text Plate 6. Features shown by discontinuous line have not been seen in this study. Their authenticity is supported in the literature cited.

There are many variations due to preservation of the fossils. The figures of the carapace drawn by Rhodes and Wilson (1957, text fig. 2) and reproduced herein (Text Pl. 6, figs. b, c) are incorrect in several respects because they failed to differentiate original features from those produced by fossilization. The "raised central area" is a compressional reflection of the thorax, particularly that of the sternal skeleton. They also believed the cervical groove gave rise to anterior and posterior branches which separated lateral margins of the carapace. As in *Anthracaris,* this is not an original feature (compare photographs of GSC 12813, Copeland, 1957 b, pl. 10, fig. 4, to that of GSC 12821, pl. 10, fig. 6).

The dorsal characteristics of the carapace of *Pygocephalus dubius* from the Canadian deposits are well preserved on GSC 12821 (Copeland, 1957 b, pl. 10, fig. 6). The compressions are spread laterally such that they are as wide as long (GSC 12821 is 18 mm. long). Measurements on the nine specimens in the MCZ collection on which the length could reliably be made ranged from 7 to 17 mm. The mode is 12 mm. The lateral margins of the carapace are broadly curved. As Peach has noted this is a branchiostegal keel and not the true ventral edges of the carapace. The marginal keels are armed with serrations. They are conspicuous anteriorly; some European specimens have denticles of equal size along the complete length of both edges. The antero-lateral angles of the carapace are produced as spines. Inward from the spines, the anterior margin is not so deeply recessed as in *Anthracaris.* Though most drawings of this species show a short rostrum, it is nearly one-half the carapace length on GSC 12821. A prominent mid-dorsal carina extends forward from the posterior margin for two-thirds the length of the carapace to the cervical groove. The groove does not cross the mid-dorsum. Each lateral branch arises lateral to the termination of the carina. A pair of ridges on the gastric area of the carapace gives rise to spines which project anteriorly. No eminences of any sort are present in the hepatic region. Relative preservation of the tubercular ornament is evident, but there may have been considerable original variation. The better preserved European specimens often have the carapace completely covered with strong tubercles (*vide, Anthrapalaemon russellianus,* Peach, 1908, pl. 4, fig. 1), but on the Canadian fossils the tubercles are subdued with the larger papillae just posterior to the cervical groove and scattered posteriorly on either side of the dorsal part of the carapace.

The ventral aspect of the cephalon is poorly known. Copeland (1957 b) has figured specimens from Canada identified as *Pygocephalus cooperi* (GSC 12811, pl. 10, fig. 1; GSC 12810, pl. 10, fig. 2; GSC 12858, pl. 11, fig. 1). Though extremely poorly preserved, it is probable that these specimens are of the same species as those from England and Scotland. As shown by Woodward (1907 b) and Peach (1908), the two pairs of antennae do not differ from those of *Anthracaris gracilis*. The sympod, including the stipe for the exopodal scale, and the basal joint of the endopod of the second antennae can be seen on MCZ 6718 (Pl. 38, fig. 1). Peach's (1908, p. 34, pl. 4, fig. 2, 3) notation of large stalked compound eyes is of doubtful authenticity. Except for a plate on MCZ 6718 that may be a portion of the labrum, no other features of the head are known.

The description of the ventral structures of the thorax that follows is based largely on MCZ 6718 (Pl. 38, fig. 1) from the Upper Carboniferous of England. The sympods of the first pair of thoracic appendages are produced as large, massive rounded lobes and extend forward. The ischium and merus of the endopod can be seen arising laterally. Though shortened, these joints are no less robust than those of the succeeding pereiopods. The sympods of the second pair of thoracic appendages extend to the mid-ventral line and though massive, lack the anterior extensions of the preceding pair. The endopod of these appendages appears to differ in no respect from the typical pereiopod. All five joints of this ramus can be distinguished. The basal stalk and flagellum of the exopod can be seen arising from the sympod of the fifth appendage. Woodward observed seven similar biramous pereiopods on the specimens he figured (1907 b, pl. 18, figs. 1, 4).

The sympods of thoracic appendages three to eight are subquadrate in shape. The peculiar anterior shoulder may have been for the support of oostegites.

Only seven sternites are evident on the Canadian and British specimens. If present, the sternal sclerite of the first thoracic somite was reduced as on *Anthracaris*. It is obscured on all specimens by the massive sympods of the first and second pairs of appendages. The last sternite of MCZ 6718 is badly deformed, but is larger and has a transverse bulge. It lacks a seminal receptacle. Woodward (1907 b, pl. 18) called attention to sexual differences in a specimen of *Pygocephalus*. The specimens like that of MCZ 6718 he correctly interpreted as males. He showed that some specimens have six or seven large platelike imbricating endites, oostegites, to form a marsupium. That the oostegites are not always preserved on the females is proven by the specimen figured by Woodward on plate 18, figure 3. The sternites of this specimen are not covered by the marsupium, but it is evidently a female as the last sternite has a large circular pouch clearly figured. It is comparable to the seminal receptacle on specimens of *Anthracaris gracilis*. Woodward misinterpreted this as a "doubtful (anal?) plate displaced." The poorly preserved remains designated as male genital papillae by Peach (1908, pl. 4, fig. 2) must also be relics of such a chamber.

The presence of a seminal receptacle on the last thoracic sternite is most peculiar in that Woodward (1907 b, pl. 18, figs. 3, 5) has proven the females to have oostegites forming a marsupium. These are characteristics that previously were believed to be mutually exclusive. The seminal receptacle is a feature of syncarids and decapods whereas oostegites are restricted to the peracarids.

The gills mentioned and figured by Peach (1908, p. 35, pl. 4, figs. 3, 4) are of doubtful authenticity.

The dorsum of a poorly preserved abdomen from Canada has been figured by Copeland (GSC 12812, 1957 b, pl. 10, fig. 5). Superior specimens are figured by Woodward (1907 b) and Peach (1908). The abdomen is about the same length as the cephalothorax. Only five tergites, a pair of uropods and the telson have been figured. As in *Anthracaris,* the first abdominal tergite must have been reduced as it has not been observed. Furcal lobes are present on the telson. The median spine has a broad base, but narrows rapidly and is sharply pointed.

It is believed that *Amphipeltus paradoxus* Salter (1863 a, p. 75) and *Diplostylus dawsoni* Salter (1863 a, p. 76) may also be synonyms of this species. They will be discussed later.

Synopsis.—The recognition of three form genera for the dorsal and ventral side of the same species and its abdomen is an indefensible paleontological practice; therefore, *Anthrapalaemon* and *Necroscilla* are suppressed as synonyms of *Pygocephalus*. Valid criteria remain to be presented for distinguishing the many species previously assigned to these genera. Thus *Anthrapalaemon hillianus* Dawson from the Maritime Provinces of Canada is best classified at this time as *Pygocephalus dubius* (Milne-Edwards). Further study will probably prove it to be worthy of recognition as a subspecies.

The genus is distinguished from *Anthracaris* by the absence of a pair of hepatic spines on the carapace, and by the massive development of the sympods of the first two thoracic appendages. The females had six or seven pairs of oostegites forming a marsupium. It is proven that the females of both genera had large seminal receptacles on the sternite of the eighth thoracic somite.

Stratigraphic occurrence.—Westphalian, Pennsylvanian. Copeland reports specimens from the Riversdale, Cumberland and Pictou groups in Nova Scotia.

Localities.—England, Scotland, Netherlands, Belgium, France, Nova Scotia, and United States(?). For the many localities in Canada that these fossils have been collected, see Copeland (1957 b, p. 42-44). (Note: A single poorly preserved specimen (MCZ 5322) of the sternum of a pygocephalomorph was collected by Donald Baird from below the upper Freeport coal, Alleghany series at the Linton mine dump near the mouth of Yellow Creek, Jefferson County, Ohio. In that it lacks a median keel, it is probably *Pygocephalus* rather than *Anthracaris.*)

Collections.—The best collections of American specimens are in the museum of the Geological Survey of Canada, Ottawa, Museum of Comparative Zoology, Harvard University, and the Department of Geology at Princeton University.

Type.—The holotype of *Apus dubius* Milne-Edwards is No. 54398 in the collection of the Geological Survey Museum, London, England. The repository of Dawson's type for *Anthrapalaemon hillianus* is unknown.

Genus **PSEUDOTEALLIOCARIS,** new genus

Because the carapaces of some poorly preserved Pennsylvanian fossils from Nova Scotia have a median and two pairs of lateral carinae they were assigned by Copeland (1957 b, p. 44-47) to the genus *Tealliocaris,* a pygocephalomorph genus known only from Mississippian strata of Scotland (Peach, 1908, p. 9-27) and France (Carpentier, 1913, p. 344-345). The carapaces of the specimens from

Canada are produced laterally by the development of large branchiostegal keels, and there are long pointed antero-lateral spines. These are characteristic features of the other Pennsylvanian genera and not *Tealliocaris*. In common with *Tealliocaris*, the new genus has carinae on the carapace and the abdominal tergites, a small embossed area at the base of the rostrum, and a subtriangular telson. Furcal lobes and a median spine are present on the telson of *Pseudotealliocaris*. However, the thoracic sterna are devoid of sternal processes. A drawing of the carapace of *Pseudotealliocaris* and a restoration portraying the known morphological features of *Tealliocaris* are presented in Text Plate 7. The type species is *Tealliocaris caudafimbriata* Copeland (1957 b, p. 44).

Pseudotealliocaris caudafimbriata (Copeland), 1957 Text Pl. 7, fig. b

Tealliocaris caudafimbriata Copeland, 1957 b, p. 44, pl. 12, fig. 3.
Tealliocaris barathrota Copeland, 1957 b, p. 45-46, pl. 13, figs. 2-6, pl. 14, figs. 2, 3, 1 text fig.
Tealliocaris belli Copeland, 1957 b, p. 46-47, pl. 12, fig. 4.
Anthracophausia sp. Copeland, 1957 b, p. 47, pl. 14, fig. 1.

Copeland (1957 b) used such characteristics in his specific diagnosis of the three species named as "a distinct posterior swing of the thoracic shield and in lacking crenulations interior to the carapace ridges," "Carapace shield-shaped, strongly wrinkled and pitted with seven well-developed dorsal keels," and "having large, wrinkled first uropods and is much larger in size." Fossils of animals with chitinous exoskeletons always present great noninnate variations such as these due to deformation and varying retention of skeletal parts, particularly when they are preserved as compressions, carbon films, and impressions in shale.

The length of the holotype of *Tealliocaris caudafimbriata* is 13.5 mm., and the length of the carapace is 6.7 mm. The length given for *T. barathrota* is 16 mm. and for *T. belli* is 26 mm. At this time there is no valid basis for recognition of more than one species in the genus *Pseudotealliocaris*. Its characteristics are those of the specimens figured by Copeland.

Description of the specimens.—I have not had access to the specimens in the Geological Survey of Canada collections that were available to Copeland, but it is apparent from his figures that the specimens have been badly misinterpreted. It was possible to determine the following characteristics from his photographs.

The carapace covers 46 to 48 percent of the length of the body, telson spine not included. The telson is about one-third the length of the carapace. As preserved, the carapaces have a maximum width only slightly less than the length.

The true ventral edges of the carapace cannot be seen because of pronounced branchiostegal keels as on *Anthracaris*. The margins of these keels are either finely serrate or are granulate (GSC 10384, Copeland, 1957 b, pl. 13, fig. 6), and there is a pair of long, sharp antero-lateral spines. The frontal margin of the carapace has an antennal re-entrant. As far as can be determined, the rostrum was of moderate length. It arises from a parabolically shaped embossed development of the gastric region of the carapace (GSC 10384, *op. cit.,* GSC 12785 c, pl. 13, fig. 4). The peripheral margin of this area has been wrinkled on some of the compressions. This, Copeland 1957 b, p. 45, text fig.) has termed a "gastric fold". A mid-dorsal carina and two lateral pairs of carinae are present posterior to the cervical groove which Copeland (1957 b, p. 44, 45) has misinterpreted as a "cervical fold". The first pair of lateral carinae is developed anterior of the cervical groove as crests. These terminate as gastric spines. The complete dorsal surface is covered by a fine pitting.

The antennae and other appendages of the cephalothorax are too poorly portrayed for interpretation. The sternites of the thoracic tagma are the same shape as on all other pygocephalomorphs. There are no sternal processes (GSC 12785 d, Copeland, 1957 b, pl. 13, fig. 5) as on the species of *Tealliocaris*. No evidence of a seminal receptacle is present on *Pseudotealliocaris*.

The six abdominal tergites are poorly preserved on several specimens. They have one or more longitudinal carinae dorsally on the tergites and their pleural lobes are pointed.

The holotype of *Tealliocaris caudafimbriata* (Copeland, 1957 b, GSC 10382, pl. 12, fig. 3) has retained both rami of the uropods. Each ramus has a strongly sclerotized median ridge from which there is a radiating structure. The specimens referred to *Anthracophausia* sp. (Copeland, 1957 b, GSC 12783, pl. 14, fig. 1) show only the axial structure of the uropod rami. The subtriangular telson is displayed on GSC 12782 (Copeland, 1957 b, pl. 14, fig. 3). Copeland (1957 b, p. 46) referred to "two swimmerettes on each side of the telson behind the uropods." These are the furcal lobes. There are two small fixed spines at the lateral edge of the narrow transverse tip of the body of the telson, between which a median articulated spine must have originated.

Synopsis.—A new genus, *Pseudotealliocaris,* is established for the three Pennsylvanian species from Nova Scotia previously referred to *Tealliocaris.* These pygocephalomorph crustaceans do have longitudinal carinae on the carapace and abdominal tergites and the telson is subtriangular; however, the carapace is produced laterally as branchiostegal keels which terminate anteriorly as long sharp spines. The surface of the carapace of *P. caudafimbriata* is punctate and the marginal keels are either granulate or finely serrate. Two species are suppressed as synonyms.

Stratigraphic occurrence.—Copeland reported specimens from the Casco group, Westphalian, Pennsylvanian.

Localities.—Copeland (1957 b) cited localities near Parrsboro, Mabou River, and Creignish, N.S., Canada.

Collections.—The few specimens that have been discovered are numbers 10381, 10382, 10384, 12782, 12783, 12784 and 12785 a-d in the Museum of the Geological Survey of Canada.

Holotype.—No. 10382 in the collections of the Geological Survey of Canada is the holotype of *Tealliocaris caudafimbriata.*

Genus **ANTHRACOPHAUSIA** Peach, 1908

Anthracophausia dunsiana Peach, 1908, p. 61-67, pl. 9, figs. 1-15.
Anthracophausia traquairi (Peach), Peach, 1908, p. 67-69, pl. 10, figs. 1-5.
Anthracophausia sp. Carpentier, 1913, p. 348, pl. 4, fig. 10.
Anthracophausia, Van Straelen, 1931, p. 23.

The generic name selected for these Upper Paleozoic Crustacea is most appropriate as far as superficial resemblances to the Recent euphausids are concerned. Peach (1908, p. 62, pl. 9, figs. 2-4) presented reliable evidence that the carapace was not fused with the posterior thoracic segments, but this primitive characteristic is to be expected of the ancestral euphausids. Most disconcerting, however, is the presence of a marsupium on the females of the closely related contemporaneous fossil *Crangopsis* (Peach, 1908, p. 74, pl. 11, fig. 14). *Anthracophausia* and *Crangopsis* are distinguished only by the length of their rostra; consequently they both must be classified together but not as genuine members of the Order Euphausiacea.

Anthracophausia is a prawnlike crustacean which is consistently found as lateral compressions. Its chitinous carapace is thin and smooth and is approximately one-third the total length of the animal. A short, spikelike rostrum arises mid-dorsally on the anterior and its base grades imperceptibly into the anterior margin of the carapace. A cervical groove is faintly distinguishable. The margins of the carapace are reinforced by an unusually narrow band. These generic characteristics will be amplified in the morphological discussion.

The type species, *A. dunsiana* Peach (1908, p. 61-67, pl. 9, fig. 11-15), is from the Cementstone group, Tuedian, Mississippian of Scotland. The specimens identified by Copeland (1957, p. 47, pl. 14, fig. 1) as being congeneric are not representatives of this genus. The presence of carinae on the abdominal tergites prove they are specimens of *Pseudotealliocaris caudafimbriata,* a species found at the same collecting locality.

Only two specimens have been collected from Mazon Creek, Illinois; one lacks its counterpart. These fossils portray innate characteristics distinguishing them as representing a new species. It is the first authentic record of this genus from North America and from the Pennsylvanian System.

Anthracophausia strongi, new species Pl. 48, figs. 1-3; Text Pl. 8, fig. f

Though much like the type species, the specimens from Illinois have two distinguishing characteristics. The rostrum is straight and sharply pointed and is easily distinguished from the arched falciform structure of the Scottish species. The pleural lobes of the abdominal tergites narrow to a sharp apex on *A. dunsiana.* They are broadly rounded on the new species.

The average size of *A. dunsiana* is given as 30 to 40 mm. Its associate, *A. traquairi,* is 80 to 100 mm. in total length. Part of this greater length is due to an unusually long rostrum. The Pennsylvanian species from Illinois is estimated to have been 25 to 30 mm. long. The length from the anterior of the carapace to the base of the telson is 21 mm. on PY 18884 and 20 mm. on PY 18821. Respectively, the measurements of lengths of the following features on these specimens are: rostrum, 2.8 mm. and 2.5 mm.; carapace, 7.7 mm. and 6.5 mm.; sixth abdominal somite, 3 mm. and 2.5 mm.; and the telson of the latter is 4 mm. in length.

Description of the specimens.—The compressions in the Mazon Creek nodules leave much to be desired for morphological interpretation. The chitin has disintegrated and form is discernible only from impressions. Nothing that could not be confirmed on the specimens has been drawn on the restoration (Text Pl. 8, fig. f).

The carapace is a thin, smooth, chitinous shield that wrapped closely around the thorax (PY 18884, Pl. 48, fig. 3, and PY 18821, Pl. 48, figs. 1, 2). A cervical groove is faintly perceptible and extends obliquely downward from a position mid-dorsally about one-third the length of the carapace from its front. There is a faint mid-dorsal keel (PY 18884). The posterior edge is deeply emarginated dorsally and the large lateral lappets on the sides are broadly rounded. The stout, sharply pointed rostrum is reinforced at its base by a low median keel. The lateral flanges grade imperceptibly into the carapace and the orbital notches. The complete marginal edges of the carapace are reinforced by a narrow rim.

Only partial remnants of the antennae and the mandibular palps have been seen. However, the orbital notches of the carapace and the hollowed-out portion of the peduncle of the first antennae substantiate belief in the original existence of a pair of stalked eyes. There can be little doubt that the large compound eyes figured by Peach (1908, pl. 9, figs. 1-4, 10-12) are authentic.

Three joints of the peduncle of one of the first pair of antennae are present on both specimens. The basal joint has its proximal dorsal surface hollowed out comparable to the "eye sockets" in some of the Recent Crustacea. Distad, this joint becomes cylindrical and extends beyond the tip of the rostrum. The second and third are short. Peach (1908, pl. 9, figs. 1, 3) illustrated two short flagella on each of the first antennae of the species he studied.

Both fossils have enough of the sympod and exopodal scale of a second antenna remaining to justify acceptance of their caridoid nature as illustrated by Peach (1908, pl. 9, fig. 3).

The right counterpart of PY 18821 (Pl. 48, fig. 1) has three joints of a slender, diminutive appendage preserved. Because all eight thoracic appendages are distinguishable as pereiopods, they cannot be the remains of a maxilliped. Similar small, slender three-jointed appendages were seen by Peach (1908, pl. 9, fig. 4). They can only represent a mandibular palp. Neither the body of the mandibles nor the maxillae have been seen.

Peach believed the first pair of thoracic appendages had the endopods modified as massive maxillipeds whereas the seven succeeding pairs were constructed alike. All eight pairs are similar on PY 18821 and PY 18884. The five jointed endopods are slender. The three joints beyond the knee together are equal in length to the two proximal joints. The vagueness of the sympods and exopods makes it impossible to correctly portray these structures. Peach encountered the same difficulty. *Crangopsis socialis* Salter close relative of *Anthracophausia Crangopsis socialis* Salter, (Peach, 1908, pl. 10, fig. 11) is restored as having a typical flagellate exopod. *C. rhodesi* Peach (1908, pl. 11, fig. 14) is shown with a marsupium. These structures may have been similarly developed on *Anthracophausia.* The luminous organs and gills reported by Peach (1908, p. 65, p. 69) are unequivocally rejected.

The course of the intestinal tract is clearly impressed on both specimens by detrital fillings of the intestine as is also true of the species from Scotland.

The six somites of the abdomen are covered by subequal tergites. The third, which provides the principal flexure of the abdomen, is the longest and has the greatest depth. The pleural processes are bluntly rounded. I have no basis for addition or subtraction from Peach's (1908, p. 65) description of sexually dimorphic pleopods.

Remnants of the single joint of the sympod and both rami of the uropods and a side view of the telson are preserved on PY 18821 (Pl. 48, fig. 1). For details we must rely upon the restoration presented by Peach (1908, pl. 9, fig. 9) of the caudal fan of *A. dunsiana.* It is reproduced herein (Text Pl. 8, fig. e). The uropods are typically caridoid with furcal lobes and a fixed median plate on the telson. There can be no doubt that the telson of the Recent Euphausiacea has been derived from such a structure.

Synopsis.—Anthracophausia has morphological characteristics suggesting relationships to the Euphausiacea. Particularly significant are the eight pairs of unmodified biramous thoracic appendages, with long slender endopods and the structure of the telson. A noneuphausid characteristic is the lack of fusion of the carapace with the thoracic somites. It is inferred that a marsupium may have been present as one has been reported on a closely related genus.

The new species is distinguished from *A. dunsiana* Peach by the shape of a stout wedgelike rostrum and the rounded margins of the abdominal pleural lobes.

Stratigraphic occurrence.—Francis Creek shale, Carbondale formation, Alleghany series (Westphalian), Pennsylvanian in the Mazon Creek nodules.

Locality.—Mazon Creek, Grundy County, Illinois.

Collection.—Two specimens are in the Peabody Museum, Yale University. Both were collected by S. S. Strong.

Types.—Holotype is PY 18821 (counterparts a and b) and the paratype is PY 18884. They are in the type collection of the Peabody Museum at Yale University.

Genus **BELOTELSON** Packard, 1886

Because the elements of the caudal fan preserved on fossils of this crustacean are styloid, it was originally assigned with the syncarid genus *Acanthotelson*. The type species is *Acanthotelson magister*.

This caridoid crustacean must have originally had a carapace though it is unknown. The genus is best distinguished by the narrow, spikelike shape of the telson which is unique among Crustacea with large abdomens. The terminal one-quarter of the telson appears to be separated from the main body of the telson by a restriction in width and an articulation. As on the broader telson of *Anthracophausia,* this may be the site of origin of the furcal lobes.

Belotelson magister (Packard), 1886 Pl. 52, figs. 1-4; Text Pl. 9, figs. b, e

Acanthotelson? magister Packard, 1886 a, p. 127, pl. 1, fig. 2, pl. 2, figs. 4, 5.
Belotelson magister, Packard, 1886 a, p. 128.
Belotelson magister, Van Straelen, 1931, p. 13.

This large, prawnlike fossil with a styloid telson and a narrow bladelike exopod of the uropods has no known parallel among Paleozoic Crustacea. Description of the specimens is presented as a specific diagnosis.

Description of the specimens.—Only three specimens of this rare crustacean are available for study; two of these are Packard's types. The specimen upon which Packard described the species was collected by J. C. Carr at Mazon Creek. This is number 38844 (401 a and b) in the collections of the U.S. National Museum. A supplementary note by Packard was appended to his text prior to publication in which a brief description is given of an additional specimen collected by R. D. Lacoe from the subsurface mines near Braidwood in Will County, Illinois. This plesiotype, USNM 38844 (401 c), is better preserved; hence the uniqueness of the species was verified and the generic name, *Belotelson,* proposed. Among the hundreds of Mazon Creek concretions examined in this study, only one additional specimen was discovered. It is number 888 of the Chicago Museum of Natural History.

The specimens are poorly preserved compressions with little relief. Disintegration of the chitin of the exoskeleton has resulted in a reticulate pattern of cracks. As far as known, the original surface texture of the integument was smooth.

The holotype (Pl. 52, fig. 2, 3) presents a dorsal aspect of the abdomen and telson with only fragments of the two pairs of antennae remaining of the anterior position of the body. The plesiotype of Packard (Pl. 52, fig. 1) has its flexed abdomen compressed laterally, but the remains of both pairs of antennae are oriented in the plane of bedding. The new specimen has only the posterior abdominal somites and part of the caudal fan preserved.

Packard recognized two pairs of antennae, but his presentation is confused. The first pair of antennae has a peduncle of three segments; the second and third together are about equal to the length of the stout basal joint. Two flagella from one and the inner flagellum of the other are all that can be detected of the first antennae on the holotype. These are the long antennae mentioned by Packard. The rami are unequal, but a statement as to their true length is not justified.

The basal portions of the second pair of antennae are present. The sympod appears to consist of a single large segment, but there is some indication on the fossils of a second. This joint, if it exists, is not produced as a scape for the antennal scale as is typical in the other Paleozoic Eumalacostraca. The squamate exopod is best seen on the holotype (Pl. 52, fig. 4). The endopod consists of two joints and a flagellum. Compressions of a long stout joint of the left and right appendages are present on both specimens. It is three times longer than the terminal joint from which the flagellum originates. Traces of the flagellum consist of two basal annuli on the left antenna of the plesiotype. Shrinkage cracks have fragmented the integumental remains of the antennal joints. This misled Packard into interpreting them as six annuli of a flagellum.

Little, if any, displacement of parts has occurred in the plesiotype; therefore, the distance between the base of the antennae and the first abdominal segment is a valid measure of the length of the cephalothorax. The combined length of the head and thorax is believed to have been one-third that of the abdomen. The discrepancy between the estimated total length of the two specimens, *i.e.,* 72 mm. and 82 mm., exclusive of the antennae and telson given by Packard, is due to deformation of the holotype when it was a decaying cadaver.

If a carapace originally existed, it left no trace in either specimen.

Remnants of five slender thoracic pereiopods are present on the plesiotype. Though only two joints distad of the "knee" can be distinguished, there may have been three. The number of pereiopods and their position are suggestive of specialization toward a decapodous adaptation.

The features of the abdomen and telson were given by Packard as the characteristics of the species and genus. The development of the abdomen conveys an impression of a prawnlike decapod. The second and the last somites were the longest. The skeletal remains in the holotype have been spread laterally exaggerating its true width. The laterally compressed abdomen of the plesiotype presents the tergite and pleural lobes in their true perspective. The first abdominal segment is smaller than the second. The abdomen then tapers to the sixth segment. All except the last abdominal segment bear pleural lobes. Developed mid-dorsally on the sixth abdominal tergite is a carinate ridge.

Details of the abdominal appendages are not known except for the uropods, though obscure relics of pleopods are present on the second abdominal somite of the plesiotype. Superficially the uropods resemble those of *Acanthotelson.* From a stout basal joint, a bladelike ramus arises. Whereas the exopods are straight and spikelike in *Acanthotelson,* they are narrow blades in *Belotelson.* The outer edge of the exopod is nearly straight except the extremity which bends slightly outward. The inner margin is much less strongly chitinized and is curved throughout most of its length. The endopods are not known. The scapulate remains of the rami of the uropods are present on all three specimens. These sclerotized structures may not be representative of the complete exopods. It is common for only the outer edge of the lobes of the uropods to be strongly fortified as in Recent species of *Panulirus* and the Paleozoic species of *Anthracophausia.* Thus the inner more membranous lobes of the exopods may have been destroyed as were the endopods.

From a broad base the telson narrows rapidly and then extends as a spine. At a position about three-quarters of its length it narrows. The tip of the spinelike telson is an articulated process. The abrupt narrowing at the articulation may indicate the position of origin of a caudal furca.

Synopsis.—Morphological information is too meager for adequate definition of *B. magister;* nevertheless, the details of its morphology clarified above prove that it is not a syncarid. Absence of a carapace on the three poor fossils that have been collected is negative evidence. It does not prove that such a structure was not present in life. In fact, lack of preservation of the cephalothorax may be an argument for a protective dorsal shield. Inadequate fossilization of this part of the body is common among caridoid fossil Crustacea. The decapodous adaptive trend of the thoracic pereiopods and the large size of the abdomen relative to the estimated length of the cephalothorax are the only criteria on which we can rely. Until proven otherwise, *Belotelson magister* Packard must be classified with the Paleozoic Malacostraca with a carapace.

The abdominal tergites, particularly that of the sixth abdominal somite, and the scapulate outer sclerotized portions of the rami of the uropods in *Palaeomysis* (Peach, 1908, pl. 8, figs. 13, 14) and *Anthracophausia* (Peach, pl. 9, figs. 9, 11) superficially resemble those of *Belotelson;* however, the greater width of the telson distinguishes these genera.

Stratigraphic occurrence.— Francis Creek shale, Carbondale formation, Alleghany series (Westphalian), Pennsylvanian in Mazon Creek nodules.

Localities.—Grundy and Will counties, Illinois.

Types.—Holotype and plesiotype, USNM 38844.

Genus **ARCHAEOCARIS** Meek, 1872

The carapace, six abdominal tergites, telson, and a three jointed "leg-like appendage" were mentioned by Meek (1872) in the original description of the fossils for which the generic name, *Archaeocaris,* was provisionally established. A relationship with the Recent cumaceans was suggested for these Lower Mississippian Crustacea (1872, 1875). Ortmann (1897) superficially examined several excellent specimens and noted four free thoracic tergites underlying the carapace. This led him to believe *Archaeocaris* was a synonym of *Crangopsis* and an affinity with the Mysidacea was postulated. If either Meek or Ortmann had closely examined the specimens before them, they would have discovered features of the Stomatopoda. The following description is based on the holotype and paratypes of Meek and the plesiotypes of Ortmann. No additional specimens of this species are known to have been collected.

The cephalothorax of *Archaeocaris* is one-third the body length. The carapace is without ornament. There is no mid-dorsal carina or transverse sulcus. Articulated to the carapace is a platelike rostrum. The endopods of some of the thoracic appendages are clustered forward under the cephalothorax. These subchelate appendages are believed to be pairs two to five. The six somites of the abdomen are large and their pleurae are truncated. Rami of the caudal fan are broad blades and the telson is spatulate.

Perimecturus (Peach, 1908, p. 39-53) and *Archaeocaris* have several characteristics in common. For purposes of comparison, I have taken the liberty of preparing a restoration of *P. elegans* Peach (Text Pl. 8, fig. c). It is a composite of the characters illustrated in Peach's (1908, pl. 6, figs. 2-6) work. Features of special note on *Perimecturus* are the articulated rostrum, four free thoracic somites, shallowness of the small carapace, large abdomen, and the biramous nature of the three posterior thoracic legs. Peach figured flagellate exopods but mistook remains of the jointed endopods for a brood pouch (1908, pl. 6, fig. 2), and the broad lobes shown on *P. pattoni* as a "broodpouch" are probably the remains of pleopods (1908, pl. 6, fig. 9). The differences in the structure of the anterior thoracic appendages from those of *Archaeocaris* (Text Pl. 8, fig. a) are believed to be due to incompleteness or misinterpretation of the Scottish fossils.

Whereas *Perimecturus* has narrow, hastate, uropod rami, the species of *Archaeocaris* have broad caridoid lobes. The genera differ also in that *Perimecturus* has carinae on the carapace and the abdominal tergites and spines are present on the outer margin of the exopod of the uropods.

In addition to the type species, *A. vermiformis* Meek, a new species is herein described from the Upper Mississippian of Oklahoma. *Perimecturus fraiponti* Van Straelen (1922) from the Westphalian of Belgium should be assigned also to *Archaeocaris;* thus, the known stratigraphic range of the genus is Lower Mississippian to Middle Pennsylvanian.

Archaeocaris vermiformis Meek, 1872 Pl. 45, figs. 1-4; Pl. 46, figs. 1-3; Pl. 53, fig. 5; Text Pl. 8, fig. a

Archaeocaris vermiformis Meek, 1872, p. 335-336.
Archaeocaris vermiformis, Meek, 1875, p. 321-322, pl. 18, fig. 7.
Crangopsis vermiformis, Ortmann, 1897, p. 283-289.
Archaeocaris vermiformis, Van Straelen, 1931, p. 71.

A. fraiponti (Van Straelen) and the new species from Oklahoma are too poorly known for adequate specific characterization at this time. If it were not for the uniform small size of *A. vermiformis* and massiveness of its mandible, it would be impossible to distinguish it from the new species to be described from Oklahoma.

Description of the specimens.—The specimens are preserved in gray phosphatic concretions. Not only is there a concentric structure of the phosphatic material around the fossils, but with few exceptions, the skeletal remains have not been compressed. The interior spaces of the skeletons are filled with radiating calcite crystals with small amounts of pyrite and glauconite; therefore, the concretions are believed to be syngenetic. Original exoskeletal material is preserved with degradation of only the organic base. It is now a brittle, gray to brown, translucent substance. Evidently, the exoskeleton was impregnated by calcareous material in life.

Twenty-five specimens, some with counterparts, have been studied. Measurement of body length could be made on 13 of these. The range was from 16 mm. to 25 mm. One-half the specimens measured were between 24 and 25 mm. long, rostrum and telson not included. On no specimen that the body length could be determined, is the carapace complete. For the six specimens on which the length of the carapace could be estimated with reasonable accuracy, it was one-third the body length. The holotype (USNM 27126, Pl. 46, fig. 1) has a body length of 22 mm., carapace length of 7.5 mm. (estimated) and the length of the second abdominal tergite is 2.4 mm. A plesiotype (PU 1597 $^{d}/4$) with a body length of 25 mm. has a rostrum 1.1 mm. long, carapace 8 mm. long (estimated) and telson 5 mm. long.

The carapace covers the head and thorax, but in all specimens its posterior is broken. Its features are best seen on PU 1597 $^{d}/3$ (Pl. 45, fig. 1) and PU 1597 $^{d}/1$ (Pl. 46, fig. 2). The carapace has its greatest depth posterior and it becomes very shallow anteriorly. There is no antero-lateral angle; rather, there is a curvature and rapid narrowing of the carapace immediately behind the rostrum. The free margins are bordered by a narrow rim. A triangular rostral plate articulates with the carapace (PU 1597 $^{d}/3$, Pl. 45, fig. 2). Its length is equal to its basal width. The anterior apex is rounded. Carinae are absent from the rostrum as well as from the carapace.

The carapace seems to have been fused with four thoracic somites. On no specimen can more than four free tergites be seen (PU 1597 $^{d}/2$, Pl. 46, fig. 3). The tergite of the eighth thoracic somite is twice the length of the fifth.

Of the cephalic appendages, only the right mandible was seen on PU 1597 $^{d}/5$ (Pl. 45, fig. 4). From the condyle, it widens into the stout body of the mandible. The anterior is nearly straight whereas two bulges of the posterior are separated by a transverse sulcus. There is a strong posteriorly directed gnathic process. The palp and molar process were not seen. Among Recent Crustacea, it is only in the Stomatopoda that one finds the mandible comparably developed (Text Pl. 8, fig. d).

The remains of the thoracic appendages are clustered together making it difficult to interpret their structure; nevertheless, four pairs of subchelate appendages can be distinguished, each with six joints. The proximal joint is short and dorso-ventrally oriented (PU 1597 $^d/5$, Pl. 53, fig. 5). This is probably equivalent to the complete sympod. An elongate forward projecting joint, probably the ischium, articulated with this. Those of three legs can be seen on PU 1597 $^d/2$ (Pl. 46, fig. 3). The next leg joint is short and projects inwardly (PU 1597 $^d/3$, Pl. 45, fig. 1). The knee is at the distal articulation of this element, the merus, beyond which there are three joints. Two stout broad joints (PU 1597 $^d/3$, Pl. 45, fig. 1; PU 1597 $^d/1$, Pl. 46, fig. 2; and PU 1597 $^d/2$, Pl. 46, fig. 3) are oriented ventro-posteriorly. The mesad margin of the most distal of the two, the propodus, is armed with a row of small conical spines (PU 1597 $^d/1$, Pl. 46, fig. 2) much as on the "palm" of *Chloridella.* A dactylus opposes the propodus to form a subchela. It can be seen on PU 1597 $^d/1$ (Pl. 46, fig. 2) and PU 1597 $^d/5$ (Pl. 45, fig. 4). It is believed that these four pairs of raptorial legs are the second to fifth appendages. This interpretation is based on their position and by analogy with the Recent stomatopods. The new species from Oklahoma has traces of additional thoracic legs that may have been pereiopods.

Peach (1908, p. 38-46) claimed the thoracic appendages of *Perimecturus* were biramous and bore oostegites on females. The three basal joints of the four pairs of clustered appendages portrayed (1908, pl. 6, fig. 2 a) are identical in structure to those seen on *Archaeocaris.* It is believed the spatulate joint shown by Peach is a fragment of the carpus and is not the terminus of the leg. Restudy of the specimen of *Perimecturus* is required before conclusive interpretation of the legs of this genus is possible.

The abdomen is enormous relative to the size of the cephalothorax (USNM 27126, Pl. 46, fig. 1). It is believed the first abdominal somite was somewhat larger than the other five which are subequal in length. The abdomen narrows and decreases in depth posteriorly. The pleurae of each tergite are broad lobes which have their ventral margin truncate. The ventral edge originates through an anterior curvature of small radius.

Only the appendages of the sixth abdominal somite, the uropods, are known (PU 1597 ^{d}/4, Pl. 45, fig. 3). The sympod of the uropod is long and narrow and it is believed the two rami were lobate. The remains are too incomplete to determine if the exopod consisted of two joints, a characteristic feature of the Recent stomatopods.

The telson is spatulate. Its basal portion is highly arched and there is a mid-dorsal carina. There is suggestive, but inconclusive, evidence of furcal lobes and a median articulated spine.

Synopsis.—Most of the morphological characteristics of *Archaeocaris vermiformis* that can be determined are those of the Stomatopoda. They are the relatively large size of the abdomen, small carapace not fused with last four thoracic tergites, articulated rostrum, shape of mandible, and the presence of four pairs of subchelate thoracic appendages. In common with the caridoid Paleozoic fossils, it has a single joint in the sympod of the thoracic legs and furca and a median spine on the telson. It is believed that *Archaeocaris* and *Perimecturus* are closely related.

Stratigraphic occurrence.—New Providence fm., Kinderhookian, Lower Mississippian.

Locality.—Linietta Springs, Junction City, Boyle Co., Kentucky.

Collections.—Holotype and seven paratypes (13 pieces) are catalogued as 27126 in the collection of the U.S. National Museum. Twenty-seven pieces representing 18 individuals are in the collections of Princeton University, 1597 d. The specimens herein figured have been assigned suffixes.

Archaeocaris graffhami, new species Pl. 47, figs. 1-4; Text Pl. 8, fig. b

A single specimen of a large species of *Archaeocaris* was discovered in the Caney shale of Upper Mississippian age in Oklahoma. Size alone is a poor basis for distinguishing species of fossils and except for the relatively small size of the mandible, all characters that can be determined are identical to those of *A. vermiformis*. In the new species the mandible is much less massive, *i.e.*, *A. vermiformis* $\frac{\text{(mandible width) } 0.9 \text{ mm.}}{\text{(body length) } 21 \text{ mm.}} = .043$, whereas on Oklahoma specimen $\frac{0.8 \text{ mm.}}{35 \text{ mm.}} = .023$. Until better specimens of *A. graffhami* are collected, the species is characterized by the weaker development of the mandible. A diagrammatic drawing of the fossil, with parts labeled, is presented in Text Pl. 8, fig. b. The species is named in honor of its collector, Allen Graffham.

Description of the specimens.—Though the exoskeleton is fortified with calcareous materials, it is badly crushed. The fossil is nearly flat. Within the tan argillaceous limestone matrix, the fossil lies obliquely oriented in a more or less dorso-lateral position. This slanted position in connection with compressional spreading has greatly exaggerated the apparent depth of the animal.

Neither extremity of the fossil has been retained; however, the distance from the anterior of the carapace to the base of the telson is estimated to be 35 mm. The following lengths were also determined: head and thorax, 12.0 mm.; seventh thoracic somite, 1.0 mm.; eighth thoracic somite, 2.0 mm.; abdomen 23.0 mm.; first abdominal somites, 3.6 mm. each.

The carapace is broken away beyond the fourth thoracic somite leaving four tergites uncovered. The small shallow shield is unornamented. A cervical groove, carina and sulcus were not seen. Its anterior and lateral margins are too poorly preserved for accurate delimitation. The rostrum is unknown.

Only the body of a mandible with the peculiar transverse sulcus of the type species can be seen of the cephalic appendages.

The four exposed thoracic somites gradually increase in size posteriorly. The tergite of the eighth thoracic somite is more than twice the width of the fifth.

A congeries of small thoracic appendages is clustered forward under the carapace. No interpretation of structure of these appendages is possible. That the appendages of the last somites are different is proven by remains of legs of larger size which apparently extended ventrally. A short proximal and a long distal joint of the eighth and a single joint of the seventh are exposed (Pl. 47, fig. 1).

The abdomen constitutes two-thirds of the animal's length. A portion of its great depth is due to compressional expansion of the tergites, but there can be no doubt that it was enormously developed. The first abdominal tergite is about one-half again as long as the five subequal tergites succeeding it. The tergites are smooth. The truncated free ventral edges are rectilinear except for an anterior curvature. They are reinforced by a narrow rim.

It is unfortunate that the important taxonomic characteristics of the element of the caudal fan are not more clearly visible. The uropods and telson have been crushed together. The uropods have a relatively long sympod. The blade of the exopodal joint is broad (Pl. 47, fig. 3). The telson was wide at the base and evidently was longer than the uropods. Nothing more is known.

Stratigraphic occurrence.—Delaware Creek member, Caney shale, Chesterian, Mississippian.

Locality.—N.W. 1/4, Section 27, T. 3 N., R. 6 E., Pontotoc County, Oklahoma.

Collector.—Allen Graffham of Ardmore, Oklahoma.

5879 *Types.*—The holotype is number 5849 in the Museum of Comparative Zoology at Harvard University. The less complete counterpart is number 4411 in the Paleontology Collection of the University of Oklahoma.

Genus **ACADIOCARIS**, new genus

Palaeocaris novascotica Copeland (1957 a, p. 596) from the Mississippian deposits of Nova Scotia has many characteristics in common with a Pennsylvanian species from Scotland, *P. landsboroughi* Peach (1908, p. 55, 56). Both have only 12 free postcephalic somites exposed. Calman (1932 b) recognized the phylogenetic significance of another Scottish species, *P. scotia* Peach, which also has the first two thoracic somites obscured by a short carapace, and he established a new genus, *Anthracocaris*. The Canadian species is the first American representative of these Paleozoic tanaidacean-like Crustacea, but it cannot be assigned to Calman's genus, as Rolfe (1962, p. 549) suggested. It is conspicuously distinguished by the elements of the caudal fan.

Though I have not seen the specimens described by Copeland, it is apparent from the photographs presented (1957 a, pl. 67, fig. 4; pl. 68, figs. 1-9) that his morphological characterizations are incorrect, *e.g.*, (p. 596-597) "Thoracic segments . . . each with . . . a pair of long uniramous limbs, limbs equal to one-third the length of the body, each three-jointed, proximal segment the longest, nonchelate" and "Abdominal segments . . . having a pair of short, three-jointed uniramous limbs; last abdominal segments slightly longer than wide, with no limbs, bearing the telson and uropods." Not only do the photographs disprove his proportions and interpretation of jointing of the legs, but the uropods are the "limbs" of the sixth abdominal somite!

Acadiocaris has only 12 postcephalic somites evident on the fossils illustrated. This means that the first two thoracic somites are either fused with the head or they are covered by a short carapace as in *Anthracocaris*. The new genus differs by having a spatulate telson very much like that of *Palaeocaris*. The uropods are distinguished by being relatively narrow blades. The endopods of the thoracic appendages are shorter and stouter than those of *Palaeocaris*. In this respect they are comparable to those of *Palaeosyncaris*.

The type species is *Palaeocaris novascotica* Copeland.

Acadiocaris novascotica (Copeland), 1957

Palaeocaris novascoticus Copeland, 1957 a, p. 596-597, pl. 67, fig. 4; pl. 68, figs. 1-9.
Palaeocaris novascotica, Rolfe, 1962, p. 549.

Morphological interpretations herein presented are based upon the photographs published by Copeland. When the fossils preserved as carbonized compressions are restudied, a more detailed description will be possible.

The carapace and six exposed thoracic somites are equal to four-sevenths the length of the body (1957 a, pl. 68, figs. 6, 9). The carapace, including the head shield, is equal to one-sixth the body length. Copeland presented no measurements. If the indicated enlargements of the photographs are correct, the holotype, GSC 13316, is 10 mm. long, telson not included. The length of GSC 13323 is 7 mm. and GSC 13320 is 8 mm.

Morphology.—A small carapace covers the head and the two anterior thoracic somites. It is best displayed (Copeland, 1957 a, pl. 68, fig. 6) on GSC 13320. A small portion of the second thoracic somite extends from under the carapace on this specimen. Other details of the carapace cannot be determined.

The first antennae are excellent on three of the specimens figured. The three joints of the peduncle are stout. They are distinguished by being subequal in length with the second being the shortest. The internal flagellum is about one-half the length of the outer ramus. Copeland made the contradictory statement "second pair of antennae uniramous, protopodite with three podomeres, bearing a setate rectangular basal scale and a slender flagellum equal to half the length of the body." If a scale is present, the appendage is not uniramous. The scale cannot be seen on the photographs, but he appears to be correct in his observation that the endopod consists of three joints and a long flagellum.

Remains of five of the thoracic appendages are beautifully preserved on the left side of the holotype, GSC 13316, (Copeland, 1957 a, pl. 68, figs. 1, 2). The endopods are short and stout and are less than one-fourth the length of the body. Even in the small photographs published (X 4), the dactylus, propodus, carpus and merus are clearly evident on the posterior leg. The long merus above the knee is best seen on the two preceding legs. The shape of these joints is typical. There is no reason to believe that the basal joint of the endopod, the ischium, and the joints of the sympod are not present. No proof is presented by Copeland that the thoracic legs are "uniramous". Close scrutiny of the specimen will probably reveal vestiges of the ischium, sympod, and the exopod.

The abdominal somites decrease in size, but are subequal in length except the sixth abdominal somite which is twice as long as the others. The tergites of body somites 14 to 18 have their pleurae anteriorly rounded with a blunt point at their post-lateral angle (GSC 13323, Copeland, 1957 a, pl. 68, fig. 9). Relics of the pleopods shown on the same photograph do not corroborate the statement that these appendages were "three-jointed uniramous limbs".

The uropods as shown on GSC 13321 (Copeland, 1957 a, pl.

68, fig. 7) characterize this genus. The sympod is small. The exopod is long and bladelike. The slight convexity of its outer margin terminates at a position equal to two-thirds the length of the ramus where a transverse suture on the blade separates a narrowing terminal lobe. The length and width of the endopod are the same as those of the exopod.

The telson is spatulate (Copeland, 1957 a, pl. 68, fig. 7) with its greatest width near the base. No articulated furcal structures are associated. At least the terminal edge of the telson bore stout bristles. There are suggestions on the photograph that the lateral margins were also armed.

Synopsis.—This crustacean, previously referred to *Palaeocaris,* has a carapace covering the first two thoracic somites. It differs from *Anthracocaris scotica* in the narrow lobate shape of the rami of the uropods. According to Peach (1908, pl. 8, figs. 1, 5) the telson of this species has accessory structures.

The likeness of *P. landsboroughi* Peach (pl. 8, fig. 8-10) to the Canadian fossil must be acknowledged. The uropods are remarkably similar. If *P. landsboroughi* does not have furcal lobes on the telson, the species are congeneric. *Acadiocaris novascotica* is minute and lacks dorsal crests on the thoracic and abdominal tergites.

Stratigraphic occurrence.—Horton group (Upper), Osagean, Lower Mississippian.

Locality.—Core from drill hole one mile south of Hillsboro, Inverness County, N.S., Canada.

Collector.—W. A. Bell.

Types.—Holotype is No. 13316, and paratypes are Nos. 13317-13324 in the collection of the Geological Survey of Canada.

Genus **PALAEOPALAEMON** Whitfield, 1880

The materials available to Whitfield (1880) at the time this genus was established are much poorer than one would suspect from the description or the figure (1891, pl. 12, fig. 20). The "specimen" he presented as a carapace, six abdominal tergites and caudal fan, are natural molds of scraps of three separate individuals. The pereiopods and pleopods mentioned are not present on any of the syntypes.

There is a note with the syntypes at Columbia University that James Hall of the New York State Museum made impressions for a study that was published later (Hall and Clarke, 1888, p. 203). This "plastotype" is a composite of the syntypes with missing parts crudely restored. Because of the inaccurate interpretation of *Palaeopalaemon,* it has frequently been referred to in the literature as an Upper Devonian decapod.

Though there are differences in ornament between the syntypes and the two additional specimens now available from the Chagrin shale (= Erie shale of Whitfield) east of Cleveland, there is no reason to believe that two species are represented. The two syntypes displaying the ornament pattern on the carapace have a pattern of anastomosing fine ridges whereas one of the additional specimens recently collected has a pattern of minute papillae. Another has a subdued ornament that is intermediate. For morphological interpretation, a specimen from the Lower Mississippian of Kentucky has proven most useful. The latter specimen has the characteristic anastomosing pattern of the syntypes on its carapace. The restoration presented in Text Pl. 9, fig. a, shows only the features distinguished on these specimens. Specimens of an additional species, *P. iowensis* Walter from the Lower Mississippian of Iowa, have been of little use in the interpretation of the morphology of this genus.

Palaeopalaemon was shrimplike; however, the cephalothorax is only slightly shorter than the abdomen. None of the thoracic tergites is believed to have been normally exposed at the broad dorsal posterior re-entrant of the carapace. The carapace has its greatest depth just anterior to the postero-lateral curvature. Its depth decreases gradually anteriorly where the carapace becomes unusually shallow. The most distinctive characteristics of this genus are the mid-dorsal and lateral pair of longitudinal carinae, narrow anterior doublure, bifurcating cephalic sulcus and an oblique shoulder on the dorsum of the carapace. Anterior to the cephalic sulcus, the lateral carinae become prominent crests and terminate as spines. A rostrum was probably present. The peduncles of the first pair of antennae are abnormally large. It is believed the thoracic appendages were biramous, but only the long slender endopods have been observed.

They are all pereiopods. The last somite is longer than the five preceding abdominal somites, the tergites of which have rounded pleural lobes. Of the abdominal appendages, only the uropods are known. They have a short single-jointed sympod. The single exopod that has been studied is subtriangular with the greatest width distad.

The type species is *Palaeopalaemon newberryi* Whitfield from the Upper Devonian and Lower Mississippian.

Palaeopalaemon newberryi Whitfield, 1880 Pl. 49, figs. 1-3; Pl. 50, figs. 1-8; Pl. 51, fig. 5; Text Pl. 9, fig. a

Palaeopalaemon newberryi Whitfield, 1880, p. 41-42, (fig. in author's separates).
Palaeopalaemon newberryi, Hall and Clarke, 1888, p. 203-205, pl. 30, figs. 20-23.
Palaeopalaemon newberryi, Whitfield, 1891, p. 571, pl. 12, figs. 19-21.
Palaeopalaemon newberryi, Whitfield, 1893, p. 461, pl. 8, figs. 19-21.
Palaeopalaemon newberryi, Beurlen, 1930, p. 443, fig. 63.
Palaeopalaemon newberryi, Van Straelen, 1931, p. 30.

The only criterion justifying recognition of two species of *Palaeopalaemon* is the ornament on the carapace. On *P. newberryi* there is an anastomosing network of ridges or small papillae whereas on *P. iowensis* the carapace is smooth but punctate. No significant morphological differences have been determined and those presented by Walter (1917, p. 122, 123) are erroneous. Of the two species, *P. newberryi* is somewhat smaller.

Description of the specimens.—The specimens from Ohio are preserved in dark gray, argillaceous, siderite concretions from the black Chagrin shale. None of the specimens displays any compressional distortion. The more complete specimen from the Lower Mississippian of Kentucky is preserved in a gray phosphatic concretion. It is deformed despite the fact that these concretions are believed to be syngenetic. The remains of the exoskeletons from both deposits appear to have originally been impregnated with mineral matter.

The only specimen with the elements of the cephalothorax and abdomen articulated is MCZ 5880 (Pl. 49, fig. 3; Pl. 51, fig. 5). On this specimen the carapace is 22 mm. long and the body length, telson not included, is estimated to be 50 mm. One of the syntypes is a natural mold of an incomplete carapace. From this (CU 5514), it is estimated that the carapace was 21 mm. long. Two other specimens without the abdomen preserved have been found. Their carapace lengths are 19 mm. and 18 mm.

The restored carapace figured in drawings by Hall and Clarke (1888, pl. 30, fig. 20) and Whitfield (1891, pl. 12, fig. 20) closely resembles the cast (Pl. 50, fig. 8) made from the natural mold believed to be a syntype (CU 5541, Pl. 50, fig. 4). Because both extremities of this specimen are incomplete and the longitudinal carinae have been exaggerated by deformation, the description that follows will be based upon C1MNH 7628 (Pl. 50, figs. 5, 7) and MCZ 6563 (Pl. 50, fig. 1). The lateral flaps of the carapace have their greatest depth posteriorly. Broadly rounded lobes extend posteriorly below the re-entrant of the postero-dorsal margin. A narrow thickened rim borders the posterior edge of the carapace. A keel that originates at the postero-lateral curvature of the carapace develops into a flexure anteriorly such that the free ventral anterior margin is bent under to form a narrow doublure. There are three longitudinal carinae, a mid-dorsal and a dorso-lateral pair. They are interrupted in the vicinity of the cephalic sulcus. There is no trace of the mid-dorsal ridge for a short distance; it then increases greatly in height and massiveness anteriorly as if it were to give rise to a rostrum. However, a rostrum has not been observed. The lateral pair of carinae are interrupted for a short distance by the transverse cephalic sulcus; they increase in amplitude near the anterior of the carapace and it is believed they terminated in gastric spines. The anterior portion of all carapaces examined were too poorly preserved for positive interpretation. A prominent shoulder projects obliquely backwards across the dorsum of the hepatic portion of the carapace from the interruption of the lateral carina by the cephalic sulcus. From its origin at the ventral flexure to the position of the lateral carina, the cephalic sulcus is a simple groove. Above this, it divides into two prongs; one bends anteriorly and the other associated with the shoulder extends obliquely backward. Near its postero-dorsal termination the posterior branch diverges dorsally away from the shoulder. It terminates without intersecting the mid-dorsal carina. This branch of the cephalic sulcus is the cervical groove.

The ornament on the carapace of *Palaeopalaemon* is a specific criterion. On the two pieces of the carapace represented by the syntypes (CU 5514, Pl. 50, fig. 4 and CU 6174, Pl. 50, fig. 2) there is a system of anastomising fine ridges oriented in an antero-ventral to postero-dorsal direction. This pattern is also present on the specimens from the Lower Mississippian (MCZ 5880, Pl. 49, figs. 1-3; Pl. 51, fig. 5). Two additional specimens from the same stratigraphic horizon as the syntypes, the Chagrin shale, display a variation from this pattern. On C1MNH 7628 (Pl. 50, fig. 7) the ornament is a fine papillae whereas a subdued intermediate ornament is present on MCZ 6563 (Pl. 50, fig. 1).

The remains of both pairs of antennae that have been seen are only peculiar in the gigantic size of the peduncle of the first antennae. Only one enormous segment of this appendage has been observed (C1MNH 7628, Pl. 50, fig. 7; CU 5514, Pl. 50, fig. 8, and MCZ 5880, Pl. 51, fig. 5). It must be the basal joint of the three-jointed peduncle. Remains of the two flagella were not seen. Fragments of the sympod, scale and endopods, both joints and annuli, of the second antennae are present on MCZ 5880 (Pl. 51, fig. 5). The scale is better seen on a specimen of *P. iowensis,* MCZ 5106 (Pl. 51, fig. 1). 5186 The small jointed structure above the scale but associated with it is not the base of a first antenna as interpreted by Walter (1917, p. 121, pl. 5 a, fig. 1). It is the basal jointed section of the endopod of a second antenna.

Though reported by Walter (1917, p. 121), authentic eyes have not been observed on either species of this genus.

A badly preserved mandible is present on MCZ 5880 (Pl. 49, figs. 2, 3). There is a long mandibular body with a single apical condyle. As far as can be seen, the incisor and molar processes are typical. No remains of the palp are present. Posterior and ventral to the mandible is a congeries of small appendage parts. Some are the remains of jointed rami whereas others are foliaceous. These are, no doubt, the remains of the two pairs of maxillae.

It is presumed the carapace was not fused with the thoracic somites. The only evidence presented by the fossils bearing on this is the disarticulated and displaced nature of the sternites. The scraps of the sternites (MCZ 5880, Pl. 49, figs. 1-3) suggest broad transverse sclerites as on the pygocephalomorphs.

There are remains of five anterior thoracic endopods with minute scraps of two additional legs on the right side on MCZ 5880 (Pl. 49, fig. 3). From their position it is believed the sixth pair of legs are the appendages not represented. All of the legs were developed as long slender pereiopods. There is no reason to believe that any of them were modified for raptorial purposes. Walter (1917, p. 122) mistakenly interpreted the large joints of the peduncle of the first antennae as the bases of an enormous pair of thoracic legs. Evidence of exopods and oostegites are lacking. This is probably due to a deficiency of the fossils.

Six abdominal somites can be distinguished on MCZ 5880 (Pl. 51, fig. 5). The first five tergites are subequal and the last is about half again longer (CU 6714, Pl. 50, fig. 6). They bear the same ornament as the carapace. The pleurae are distinguished from those of other Paleozoic Crustacea by being broadly rounded (CU 6174, Pl. 50, fig. 2, and MCZ 5880, Pl. 51, fig. 5).

The only abdominal appendages seen were the uropods and these are on one of the isolated fragments constituting the syntypes (CU 6714, Pl. 50, figs. 3, 6). The figure and description presented by Whitfield (1891, p. 461, pl. 8, figs. 20, 21) of the caudal fan are wrong. There is a short stout sympod. Only one of the two rami is preserved, and it is a subtriangular lobe with the greatest width near its extremity. Its distal edge is broadly rounded. A branching ridged ornament is evident on this, the exopod. Nothing of the telson is known.

Synopsis.—*Palaeopalaemon newberryi* has morphological characteristics consistent with those of other caridoid Paleozoic Eumalacostraca. The carapace is distinguished by the branching of the cephalic sulcus, dorsal oblique shoulder posterior to the cervical groove, a dorsal and a pair of lateral carina, and a small doublure on the carapace. In common with *Eocaris* (Brooks, 1962 a) (Text Pl. 9, fig. e) the peduncle of the first antenna is abnormally large; however, the pleurae of the abdominal tergites are rounded and the exopod of the uropod is a broad subtriangular lobe. The ornament is a specific criterion.

Stratigraphic occurrence.—Chagrin shale member, Ohio shale (= Erie shale), Upper Devonian, and the New Providence fm., Kinderhookian, Lower Mississippian.

Collecting localities.—The syntypes are from near Leroy, Lake County, Ohio; C1MNH 7628 was collected in Stebbins Gulch, Lake County, Ohio; MCZ 6563 was collected near Painesville, Lake County, Ohio, and MCZ 5880 was collected at Blue Mound west of Junction City, Boyle County, Kentucky.

Types.—Three fragmentary syntypes and a vial of 18 small rock fragments are in the collection of Columbia University. They are catalogued as 5514, 6174, and 6714. Artificial "plastotypes" are present in the collection of the New York State Museum (4607) and the U.S. National Museum.

Palaeopalaemon iowensis Walter, 1917 Pl. 51, figs. 1-4

Palaeopalaemon newberryi, Whitfield, 1892, p. 237-238.
Palaeopalaemon newberryi, Weller, 1900, p. 69.
Palaeopalaemon iowensis, Walter, 1917, p. 119-123, pl. 5 a, figs. 1-4.
Palaeopalaemon iowensis, Van Straelen, 1931, p. 30.

This species is distinguished by having a smooth exoskeleton with small pits rather than an ornament in relief, and the individuals are larger. Morphologically the two species assigned to this genus are identical.

Description of the specimens.—Only three specimens have been closely examined. There is one fragmentary species with the carapace, portions of the second antennae and a pereiopod preserved in the Museum of Comparative Zoology. Two other specimens with portions of the carapace preserved are in the collections of the U.S. National Museum. The holotype and several fair specimens in the collections of Iowa State University have been subjected to only cursory examination. When these specimens are made available to me for proper study it is believed that many important morphological features of this genus will be clarified.

The species are preserved in silty, gray, carbonate concretions. The remains have been protected from compressional forces by the syngenetic concretions. The skeletal material is now light grayish-brown and has a bright natural polish. Two of the carapaces are estimated to have had a carapace length of 26 mm. On another it is 31 mm. long. The carapace of the specimen figured as the holotype by Walter is 36 mm. in length.

Morphological characteristics of the carapace that can be determined are exactly as described for *P. newberryi.* That the lateral carinae are developed as gastric spines forward of the cephalic sulcus is proven by USNM 141319. The surface is smooth and polished and all specimens display a fine punctation.

One specimen has the antennal scale partially preserved (MCZ 5106, Pl. 51, figs. 1, 2). Its outer margin is reinforced and is slightly concavely curved. The blade of the scale is a broad lobe. The joints above the scale are the basal portion of the endopod of the same appendage and are not remains of a first antenna as Walter interpreted similar structures on the holotype.

Only one fragment of a leg is present on the specimens studied. The joint is long, slender and round (MCZ 5106, Pl. 51, fig. 4). The pits on it must have been the sites of origin of setae.

Synopsis.—Palaeopalaemon iowensis is characterized by its large size and the punctation of the smooth exoskeleton. Morphologically it is identical to *P. newberryi.* None of the morphological distinctions presented by Walter are valid.

Stratigraphic occurrence.—Kinderhook shale, Kinderhookian, Lower Mississippian.

Collecting locality.—All specimens are from Kaskade Creek at the southwestern edge of Burlington, Iowa.

Collections.—The original specimen of Whitfield has not been located. The holotype and several additional specimens are in the collections of Iowa State University. The specimens described above are in the collections of the U.S. National Museum (141319) and the Museum of Comparative Zoology (5106).

Genus **DEVONOCARIS,** Brooks, 1962

A single poorly preserved specimen from the Middle Devonian deposits of New York is of special interest in that it is one of the two most ancient eumalacostracan fossils known. The specimen was originally described as *Palaeocaris? cuylerensis* Wells. Not only is the species not congeneric with *Palaeocaris,* but it has none of the attributes of a syncarid.

The telson of *Devonocaris* has no known parallel. It is spade-shaped. Though it is nearly rectangular, its margins are slightly convex. Its posterior extremity is as wide as its base. A broad median ridge arises from the arched basal portion and extends the remaining length of the blade. The basal two-thirds of each lateral margin is reinforced by a rib.

All known morphological features are shown on the drawing (Text Pl. 9, fig. d). They will be discussed below in the description of the type species, *Palaeocaris? cuylerensis* Wells (1957). *Palaeocaris destinezi* Van Straelen (1943) is believed to be congeneric.

Devonocaris cuylerensis (Wells), 1957 Pl. 53, figs. 2, 4; Text Pl. 9, fig. d

Palaeocaris? cuylerensis Wells, 1957, p. 983, 984; pl. 125, figs. 1-4.
Devonocaris cuylerensis, Brooks, 1962 a, in press.

The description of the fossil with measurements was presented by Wells as the specific criteria for distinguishing this species. Morphological reinterpretation requires that new parameters be established. Measurements are as follow: length of body to the base of the telson, 16.8 mm.; cephalothorax, 7.8 mm.; abdomen, 9.0 mm.; telson, 2.7 mm.; length of sixth thoracic somites, 0.6 mm.; length of abdominal somites one to six, 1.5 mm.; and the maximum width of the telson is 1 mm. The fossil appears to have been subjected to very little, if any, lateral spreading, thus it is worthy of note that the first abdominal somite is 2.5 mm. and the last is 1.6 mm. wide.

Description of the specimen.—The holotype, Cornell University 40020, is preserved as a dorso-ventral compression of low relief in a black shale matrix. A carbonaceous residue of part of the chitinous exoskeleton remains. Some fine-grained pyritization has occurred. No other fossils are known.

Remains of the cephalothorax are fragmentary. Except for relics of the narrow tergites of the posterior thoracic somites, the dorsal elements of the exoskeleton were broken away in collecting. Remains of a carapace were undoubtedly destroyed. Vague traces of appendages can be seen. A long basal joint of the peduncle of both first antennae are present. Traces of their extremities are too poorly preserved for interpretation. By holding the specimen at the proper angle relative to the light source, the right exopodal scale can be clearly seen. It is a narrow lobe fringed with setae. The other appendages are vaguely visible when the specimen is wet with alcohol. The only statement that can be made is that the remains of the thoracic legs have definite forward orientation.

Six abdominal somites constitute slightly more than one-half the body length. All are subequal in length, but they narrow posteriorly.

Wells mistook the lateral portions of the blade of the telson for the endopods of the uropods. The uropods which arise from the sixth abdominal somites have a small sympod. The sclerotized outer margins of the exopods have left clear impressions. The membranous extremity and inner margin are poorly defined. Vague suggestive remains indicate both the exopod and endopod were lobate.

The body of the telson is the best preserved and the most diagnostic portion of the fossil. It is spade-shaped with a slight convex curvature of its lateral margins. The axial ridge that extends the length of the blade misled Wells into believing that the lateral portions were the endopods of the uropods. He interpreted only the arched base upon which the intestinal filling terminates as the telson. Inward from the lateral margins are strengthening ridges. These diminish in height but increase in width posteriorly. They originate near the basal margin of the telson and extend for three-fourths of its length. At their distad termination, the ridges have arched somewhat inwardly. Indeterminate remains posterior to the body of the telson are probably vestiges of the furcal elements. They seem to have been lobate.

Synopsis.—The eumalacostracan nature of the above described remains cannot be doubted. Being from the Middle Devonian, this is the most ancient record of this taxon from North America.

Lack of a carapace on the fossil is negative evidence and proves nothing. The general appearance of the remains is that of a caridoid crustacean. No syncarid is known with the thoracic endopods normally disposed in a forward arrangement; moreover, the relatively large size of the telson negates such a taxonomic assignment.

The genus is characterized by the shape of its large telson. In *Devonocaris destinezi* (Van Straelen), the distal extremity of the telson is narrower than at its base, whereas on *D. cuylerensis* the widths are equal.

Stratigraphic occurrence.—Windon member of Moscow formation, two feet below base of Tully limestone, Hamilton group, Tioughniogan stage (Givetian stage of Europe). Middle Devonian.

Locality.—Quarry 1.5 miles northwest of DeRuyter, Madison County, New York.

Collector.—J. W. Wells.

Type.—Holotype, Cornell University, No. 40020.

SPECIES WITHOUT CARAPACE

The only fossil Malacostraca from strata of North America previously correctly interpreted as lacking a carapace are *Acanthotelson stimpsoni* and *Palaeocaris typus.* Though hundreds of excellent specimens representing both of these species are present in museum collections, these Crustacea from the Pennsylvanian Mazon Creek nodules of Illinois are poorly known. Rare specimens of *Palaeocaris* are also known from the Pennsylvanian of Nova Scotia. *P. novascotica* (Copeland, 1957 a), a Mississippian species from Canada, has a short carapace and has been redescribed herein as *Acadiocaris novascotica.* The alleged Devonian species, *P. cuylerensis* Wells (1957), is the type species of a new caridoid genus, *Devonocaris* (Brooks, 1962 a). *Belotelson,* a prawnlike Pennsylvanian crustacean, likewise has been discussed with the eumalacostracans with a carapace. On the other hand, *Squillites,* an alleged Mississippian stomatopod, is a true syncarid and will be described below.

Misconceptions of the morphology of the Paleozoic syncarids have been perpetuated for nearly a century. The taxon Syncarida was originally proposed as a suborder on the basis of Packard's (1886 a) study of *Acanthotelson.* At the time of Meek and Worthen's last study (1868 b) and Packard's revision, the most closely analogous Recent Crustacea known were the isopods and amphipods. The principal diagnostic characteristic of *Acanthotelson,* and thus the Syncarida, as presented by Packard was loss of the first thoracic tergite through fusion. This error has remained uncorrected until now. With the discovery of the Recent "Tasmanian mountain shrimp", *Anaspides,* which has the first thoracic somite fused with the head, Calman (1896) established the Syncarida as an order.

Related Recent forms have been discovered and the taxonomic category redefined to also include the fossil and extant genera with eight thoracic tergites. It is interesting that *Acanthotelson,* the original syncarid, was placed in the incertae sedis in the most recent treatise on these Crustacea (Siewing, 1959, p. 102).

Acanthotelson has fallen from grace, not because it is aberrant but because of misinterpretation and ignorance. It will be discussed first because of its historical significance. It must be re-established as the basic syncarid type.

Genus **ACANTHOTELSON** Meek and Worthen, 1865

This genus is endemic to the Pennsylvanian deposits of Illinois. Its raptorial thoracic appendages and general body form are comparable to those of *Uronectes* (Text Pl. 11, fig. b), but it is readily distinguished by the shortness of the sixth abdominal somite and by the styliform rami of its uropods and its hastate telson.

Three restorations of this genus have been published. They were drawn by Meek and Worthen (1868 b), Packard (1886 a) and Fritsch (1901). The first was the most accurate, but even this did an injustice to these remarkable fossils. Dorsal, ventral, and lateral views have been drawn (Text Pl. 10, Text Pl. 11, fig. a) of *Acanthotelson stimpsoni* based upon knowledge gained from this study.

The genus is monotypic being represented only by *A. stimpsoni.* All specimens are from Mazon Creek nodules. Over 1200 individuals are now present in various museum collections making this the most abundant fossil malacostracan to be found in this or any other Paleozoic deposit.

Acanthotelson stimpsoni Meek and Worthen, 1865 Pls. 54-59, Text Pl. 10; Text Pl. 11, fig. a

Acanthotelson stimpsoni Meek and Worthen, 1865, p. 47.
Acanthotelson stimpsoni, Meek and Worthen, 1866, p. 401-404, pl. 32, figs. 6, 6 a-f.
Acanthotelson eveni Meek and Worthen, 1868 a, p. 27.
Acanthotelson stimpsoni, Meek and Worthen, 1868 b, p. 549, fig. 1.
Acanthotelson eveni, Meek and Worthen, 1868 b, p. 551, 4 figs.
Acanthotelson stimpsoni, Brocchi, 1880, p. 10, pl. 1, fig. 11.
Acanthotelson stimpsoni, White, 1884, p. 176-177, pl. 37, figs. 4, 5.

Acanthotelson eveni, White, 1884, p. 177-178, pl. 38, figs. 4-7.
Acanthotelson stimpsoni, Packard, 1886a, p. 123-127, pl. 1, figs. 1-3; pl. 2, figs. 1-3.
Eileticus anthracinus Scudder, 1890, p. 420-421, pl. 38, fig. 5.
Eileticus aequalis Scudder, 1890, p. 421, pl. 38, figs. 6-9.
Acanthotelson stimpsoni, Calman, 1896, p. 799, pl. 2, fig. 16.
Acanthotelson sp. Fritsch, 1901, p. 74, fig. 398.
Acanthotelson stimpsoni, Smith, 1909, p. 575, fig. 62.
Acanthotelson stimpsoni, Vanhöffen, 1916, p. 146, fig. 12.
Acanthotelson eveni, Vanhöffen, 1916, p. 148.
Acanthotelson sp. Vanhöffen, 1916, p. 148, fig. 14.
Eileticus aequalis, Pruvost, 1919, p. 89-91, fig. 23.
Acanthotelson eveni, Van Straelen, 1931, p. 11-12.
Acanthotelson stimpsoni, Van Straelen, p. 12.
Eileticus aequalis, Vandenberghe, 1960, fig. 1 b.

Meek and Worthen established three species. They are: *Acanthotelson stimpsoni* (1865), *A. inaequalis* (1866) and *A. eveni* (1868 a). Packard synonymized *A. eveni* believing that these larger more robust individuals were adults of *A. stimpsoni.* Most authors have been unaware that *A. inaequalis* is equivalent to *Palaeocaris typus* Meek and Worthen. Not only does Vanhöffen (1916) redefine all three species, but one additional species, based on an inaccurate restoration by Fritsch (1901), is recognized but left unnamed. Though closely related species do sometimes exist in the same ecological niche, it is the exception. Especially in paleontology, one must be cautious in recognizing sympatric species. Though the statistical analysis of the size of the individuals (Text Pl. 12, fig. c) of the population is not a typical distribution, it shows a continuum and there is absolutely no morphological basis for justifying differentiation of the larger individuals as belonging to a separate species.

Description of specimens.—The holotype, UI X-346 (ISMNH 1118) (Pl. 54, fig. 4) is in the collections of the University of Illinois. Another specimen designated as the type of *A. eveni* (UI X-344) is the result of a curatorial error.

Four hundred twenty-three specimens of *Acanthotelson stimpsoni* were prepared and studied in detail. An additional 792 specimens in the S. S. Strong collection were superficially examined for features not present on those already studied. All occur in ironstone concretions from Mazon Creek and the adjoining strip mines in Grundy and Will counties, Illinois.

Of the specimens that have been collected, about fifty percent are large, robust individuals of the type previously termed *A. eveni*. Meek and Worthen were impressed in the original study by the fact that all specimens were lateral compressions. This was fortuitous. Sixty-three percent of the population sample now known are oriented in a dorsal-ventral position with their pereiopods outspread.

Some of the larger individuals of this species retain much of their original relief; however, many specimens are badly compressed. From this it may be presumed that the chitinous exoskeletons of the larger individuals were strong; however, there is no evidence of fortification with mineral matter. In all specimens the surface texture of the skeletal elements is smooth. Impressions of bristles, spines, and setal sockets are commonly preserved on the appendages.

Three divisions of the body can be distinguished. There are no rudiments of a carapace. Previous observations to the contrary, all eight thoracic somites are separate and distinct. Thus the cephalic tagma bears a pair of stalked compound eyes and five pairs of appendages, the first antennae, second antennae, mandibles and two pairs of maxillae. The thorax consists of eight distinct somites each of which bears a pair of appendages. It is known that the last six pairs are biramous. The six abdominal somites bear biramous appendages of which the last pair are modified as uropods. The telson lacks any trace of furcal rami.

Only the combined length of the head and thorax, exclusive of rostrum, and the body length, exclusive of rostrum and telson, could be measured with enough accuracy to merit mathematical analysis. However, measurements of the length of the rostrum, length of head exclusive of rostrum, length of thorax, length of abdomen, and length of the telson and body length are presented for the holotype and other representative specimens (Text Pl. 11, fig. c).

The length of the body was determined on all specimens whereon this measurement could be made or estimated with reasonable accuracy. When these data were plotted graphically, a binodal curve was obtained suggesting a composite of two population samples with modes at 22 mm. and 33 mm. It was noticed that larger individuals were considerably more abundant in all but the S. S. Strong collection at Yale. A random sample of 216 specimens from this collection was used as the most representative sample of the population not prejudiced by a collecting factor, since Strong was paid for each specimen irrespective of size and preservation. Using this sample, a reasonably normal curve for the size frequency was obtained (Text Pl. 12, fig. c). It has the following values: Max = 55 mm., Min = 12 mm., Mo = 28 mm., Me = 28 mm., Ma = 29 mm., and a standard deviation of 8 mm.

The size frequency of the population is unusual in the abundance of individuals larger than the mode. Two percent are twice as large. The great range in size is disturbing, but we must not be misled into believing the species is dimorphic or that two species are represented. These hypotheses were thoroughly tested statistically and by careful scrutiny of the specimens for distinguishing criteria before they were abandoned. Though data are not available on undisturbed populations of the American lobster, *Homarus americanus,* it is known that some individuals attain gigantic size relative to those commonly caught. It is believed *A. stimpsoni* had a comparable longevity. Thus the size frequency distribution of the population is of paleocological not taxonomic significance.

The combined length of the head and thorax is greater than that of the abdomen. Forty-five observations of the ratio of the combined length of head and thorax to body length (less telson) gave the following values: Mo = 0.60, Me = 0.59, Ma = 0.59 and S = 0.04.

Compared to other Crustacea the head of *A. stimpsoni* is relatively small. Though it represents five fused appendages bearing somites, its length is slightly less than one and one-half the length of the typical thoracic somite.

The dorsal cephalic shield is well preserved on many specimens (MCZ 5210, Pl. 55, fig. 1; PY 19842, Pl. 56, fig. 1, and PY 19902, Pl. 57, fig. 3). It is less well preserved on those specimens that are lateral compressions. The lateral restoration (Text Pl. 11, fig. a) is based principally on PY 19834, PY 19849, PY 19867, and PY 19835. The cephalic shield is produced mid-dorsally into a small triangular rostrum as shown on PY 19902 (Pl. 57, fig. 3). Other specimens on which the complete rostrum remains are PY 19644,

PY 19692, PY 19842, PY 19844, PY 19877, PY 19878 and PY 19904. From these, it appears to be about one-fifth the length of the head. Two transverse grooves divide the shield. The anterior groove crosses the dorsal portion of the shield whereas the posterior groove is divided into two separate parts. From its dorso-lateral origins at the posterior of the head, it extends forward on either side for about one-third the length of the cephalon. It then follows a course obliquely downward terminating anterior to the mandible articulation (PY 19842). This is the cervical groove. The anterior and posterior grooves merge just above the mandibular articulation. Posterior to this position, the depth of the head becomes equal to that of the succeeding somites. A narrow flange borders the cephalic shield on its ventral and anterior margins and extends onto the rostrum.

The eyes and cephalic appendages are exceptionally well preserved on some of the specimens, however, ventral views of the head structure are poor. The foramina for the eyes and, in some cases, for the antennae can be seen on the epistome (PY 19842, Pl. 56, fig. 1). The simple epistome posterior to the foramina for the second antennae is preserved on PY 19839 (Pl. 57, fig. 2). This specimen also shows the mandible articulation. If remains of a labrum exists on any of the specimens it is the triangular process anterior to the mandibles on PY 19854 (Pl. 59, fig. 1).

Stalked compound eyes extend from their base beneath the rostrum. Many specimens display one or both of the eyes and they are present on specimens studied by Meek and Worthen and by Packard. They failed to recognize them on their unprepared specimens. Even the faceted cornea is preserved on PY 19902 (Pl. 57, fig. 3).

The sympods of the first pair of antennae are also well displayed on this specimen. The three joints are even better preserved on PY 19842 (Pl. 56, fig. 1). Setal sockets on the inner margins of all three joints can be seen on PY 19842 (Pl. 56, fig. 1) and PY 19854 (Pl. 59, fig. 1). On the distal joint the row of setae are small and close together. The second joint had four or five larger setae and there were five or six on the basal joint. The annulate rami are both present on PY 19903, PY 19713, and PY 19906. The outer flagellum, the exopod, is about one-third the length of the body (11 mm. / 33.4 mm. on PY 19887 and 10 mm. / 34 mm. on PY 19904) and is composed of approximately 54 annuli. On PY 19842 the small inner flagellum is 4.5 mm. long and is made up of 18 annuli. The endopod is approximately one-third the length of the outer flagellum or equal to one-ninth the length of the body of the animal.

The endopod of the second antenna has three basal joints and a long flagellum. Such endopods are present on many specimens but are particularly good on MCZ 5210 (Pl. 55, fig. 1). The flagellum is nearly as long as the length of the body and telson combined. It appears normally to have been trailed lateral to the body. Setal sockets can be seen on all three of the massive basal joints on PY 19854 (Pl. 59, fig. 1). The antennal sympod seems to have been reduced to a single joint. It is the second joint of the sympod which is produced as a stipe for the antennal scale that is usually preserved on the other species. No trace of this joint or the exopod was detected. A single, short, robust sympodal joint is readily distinguished on PY 19867 (Pl. 59, fig. 6). On the ventral side of the example mentioned, a prominent nephropore is present. In all other syncarids known, the excretory glands are associated with the second maxillae on the adult animals.

The mandibles are unusually massive with a strong incisor lobe, vide PY 19839 (Pl. 57, fig. 1). The body of the mandible had only one articulation. The extended condyle articulated with the exoskeleton of the head just posterior to the cervical groove (PY 19839, Pl. 57, fig. 2). From the broad anterior bench on the body of the mandible a palp originated. The basal joint of this structure is preserved on PY 19725, PY 19664 and PY 19867 (Pl. 59, fig. 6). The longer second joint of both the left and right palp is preserved on PY 19854 (Pl. 59, fig 1).

A lobate structure between the mandible and the first maxillae can be seen on PY 19839 (Pl. 57, fig. 1). This may be one of the paragnaths.

The two pairs of maxillae can be distinguished only on the laterally oriented specimens. A three-jointed endopod of the first maxillae can be seen on PY 19835 and PY 19839 (Pl. 57, fig. 1).

The only relic of the second maxillae is the basal joint of the endopod on PY 19839. A three-jointed endopod is not uncommonly retained on the second maxillae of the lower Eumalacostraca, but it is unusual for it not to be aborted on the first. The endites which are always the most conspicuous elements of the maxillae on Recent Malacostraca are unknown in this genus.

Both Meek and Worthen and Packard interpreted the thorax as having only seven tergites. They overlooked the first tergite which is reduced to a narrow collar overlapping the posterior border of the head (MCZ 5210, Pl. 55, fig. 1; PY 19902, Pl. 57, fig. 3). The next three tergites are progressively larger and the last four are of equal size. The fourth tergite, which is the longest, overlaps both anteriorly and posteriorly. A ridge borders the anterior portion of each of the last four tergites which imbricate posteriorly. The surface of the exoskeleton is smooth, and there are no spines or processes. Even the pleural borders are not developed; they are abruptly truncated.

The sternites were observed only on PY 19847 (Pl. 59, fig. 3). These sclerites are greatly reduced. However, there are wide flanges or epemera between the legs and tergite. This is best seen on PY 19846.

The last five pairs of thoracic appendages were equally developed whereas the first are greatly reduced and the endopods of the second and third are modified as large raptorial structures. All except the single small pair of maxillipeds are displayed by PY 19867 (Pl. 54, fig. 3). The normal stance was with the pereiopods extended laterally (MCZ 5210, Pl. 55, fig. 1, PY 19744, Pl. 58, fig. 1) and the raptorial appendages extended forward (PY 19842, Pl. 56, fig. 1).

The typical biramous pereiopod has a sympod of two joints, lobate exopod and epipods, and a five-jointed endopod. The coxa and basis of the sympod are shown on PY 19854 (Pl. 59, fig. 1), but their existence is definitely proven by PY 19707 (Pl. 58, fig. 3), PY 19867 (Pl. 54, fig. 3), MCZ 5233, and PY 19875.

Laminate blades are associated with the thoracic appendages (PY 19884, Pl. 59, fig, 9). It can be seen that most of these are exopods (PY 19640, Pl. 55, fig. 2). A flagellum does not exist. What appears to be annuli on some specimens is the margin of the exopod blade divided by setal sockets. This interpretation is verified by PY 19839. The exopod blade has a short stalk and articulates with the basis. The six posterior thoracic appendage (PY 19711 and PY 19640) are biramous and it is probable the two preceding were likewise.

There appears to be more than one blade per appendage on PY 19884 and PY 19640 (Pl. 55, fig. 2). We may be seeing left and right exopods; however, since they are of unequal size it is believed the extra lamillae are epipods which arose from the coxa.

The endopods are shown in the photographs of PY 19867 (Pl. 54, fig. 3) and PY 19744 (Pl. 58, fig. 2). The small terminal dactylus can be seen on PY 19744 and PY 19707 (Pl. 59, fig. 5). Setal sockets are present on the joints of the endopod of these specimens. Bristles on the carpus and merus are best seen on PY 19849. The "knee" of the five-jointed endopod is between the merus and carpus.

The second pair of thoracic appendages were modified as large raptorial legs (USNM 38845, Pl. 54, fig. 2). The third pair is intermediate in size but is also raptorial (PY 19813, and PY 19842, Pl. 56, fig. 1). They are known to be biramous. The dactylus of both pairs of appendages has heavy curved spikelike claws (PY 19844, Pl. 54, fig. 1; MCZ 5224, Pl. 59, fig. 7). The two distal claws are much longer and stouter than the other five. The propodus and carpus also had spines (PY 19744, Pl. 58, fig. 2). These are reduced to heavy bristles on the third pair of appendages.

Evidence of the first pair of thoracic appendages is uncertain, but joints of a small appendage are present on PY 19653 (Pl. 59, fig. 2) and MCZ 5210. It is believed the endopod retained five joints.

Only two things were learned of the internal anatomy from the fossils. From the position of nephropores on the second antennae, the position of the excretory glands is established and a detrital filling of the intestinal tract on one specimen (PY 19744, Pl. 58, fig. 2) shows a simple stomach and intestine.

No sexual differences were detected.

All six of the abdominal somites are subequal in length. In other fossil syncarids the pretelson somite is considarably longer than the others. Many of the fossils have the tergites of the abdomen spread more than the thoracic tergites, *i.e.*, MCZ 5210 (Pl. 55, fig. 1). This is due to their greater depth because of the development of pleural lobes. The abdominal somite actually tapered in width posteriorly.

The typical abdominal tergite does not differ significantly from those of the thorax in dorsal aspect (PY 19842, Pl. 56, fig. 2). A lateral bulge acting as a fulcrum between the tergites is conspicuous on the last thoracic somite as well as those of the abdomen. The pleural lobes are, however, distinctive. The ventral margins of the plates are curved throughout, but the arc of least radius is posterior. The posterior marginal arc is armed with five spines with the ventral spine the most strongly developed. The posterior margin of the fifth abdominal tergite is serrated completely across. Unusually large spines rise above the dorsal articulation of the sympods of the uropods with the sixth abdominal somite (Pl. 55, fig. 1). The mid-dorsal posterior margin of this tergite bears eight denticles arranged in a central group of four separated by a gap from two lateral denticles. The main body of this somite narrows to the width of the telson; however, the width of the flanks is maintained to accommodate the sympods of the uropods.

The sternites of the five anterior abdominal somites are relatively wide. The foramina on the sclerites for the appendages are large. Though not shown by the photograph of PY 19817 (Pl. 59, fig. 4), there is a bridge posterior to the insertion of the appendage. The sternite of the pretelson somite covers nearly its complete ventral surface (PY 19866).

Many specimens have traces of swimmerets, but they are rarely well enough preserved for structural interpretation. The single jointed sympods for all five of the left appendages are present on PY 19692. These and the poorly preserved rami can be seen on all but the first abdominal somite of PY 19867 (Pl. 54, fig. 3). The outer and inner branches are both unjointed laminae. The bladelike exopod shown on PY 19846 (Pl. 59, fig. 8) is setiferous on the straight outer margin as well as on the thinner curved inner edge. The restorations of Meek and Worthen and of Packard show the wrong proportional development. The rami of the swimmerets are at least four times longer than the short, stout sympod. The rami are definitely not annulate as shown by Fritsch.

The uropods provide the most distinctive characteristic of this genus. The single jointed sympod articulated dorsally and ventrally with the sixth abdominal somite such that these appendages could be moved only laterally. Both rami are reduced to long, curved, slender blades. The inner blade is more strongly arched near its tip. Being thin, both branches are strengthened dorsally and ventrally by raised medial ridges. The total length of the uropods is equal to that of the telson or one-fourth of the length of the body of the animal.

The uropods are well preserved on MCZ 5210 (Pl. 55, fig. 1). Both branches are setiferous. Except for the inner margin of the exopods, the setal rows are interrupted by stout spines. These stout bristles are equal in length to the fine setae. Eight to ten setae are present between each spine (PY 19842 and PY 19653).

From an arched broad base the telson becomes a thin, narrow spike. The spikelike terminal three-fourths of the telson is strengthened by a mid-dorsal ridge. Its borders are armed with spines and setae arranged as on the branches of the uropods.

Synopsis.—Only one species of *Acanthotelson* can be distinguished in the population sample from the Francis Creek shale at Mazon Creek and the adjacent strip mines. Most of the external morphology of this crustacean is now known and has been presented in the restorations. In common with *Uronectes,* it has raptorial appendages but is easily distinguished by the shortness of the sixth abdominal somite and the styliform uropods and telson. Of great phylogenetic significance is the discovery of a nephropore on the basal joint of the second antennae.

Stratigraphic occurrence.—Francis Creek shale, Carbondale formation, Alleghany Series (Westphalian), Pennsylvanian in the Mazon Creek nodules.

Localities.—Grundy and Will counties, Illinois.

Collections.—The best collection is the S. S. Strong collection at Yale University. Other collections are in the Chicago Museum of Natural History, Illinois State Museum, U.S. National Museum and the Museum of Comparative Zoology.

Types.—The holotype is in the University of Illinois collection, X-346 (ISMNH 1118). All of the plesiotypes figured by Packard are in the collection of the United States National Museum, USNM 38845.

Genus **PALAEOCARIS** Meek and Worthen, 1865

This genus was established upon specimens from the Pennsylvanian deposits at Mazon Creek, Illionis. The type species, *Palaeocaris typus,* was described by Meek and Worthen (1865, 1866 and 1868 a, b) and was re-described by Packard (1886 b). Despite the studies of these distinguished paleontologists, the only reliable morphological description of this genus is by Calman (1911 b, 1932 a) based upon closely related species from England, *P. praecursor* (Woodward) and *P. retractata* Calman. His limited materials were inadequate for accurate interpretation of several morphological features.

Restorations of *Palaeocaris typus* have been attempted by Meek and Worthen (1868 b) and by Packard (1886 b, pl. 3, fig. 1). The restorations presented herein (Text Pl. 13, Text Pl. 12, fig. a) illustrate all morphological characters seen on the fossils.

The most distinctive characteristics of the genus are as follow: the first five thoracic tergites are imbricated forward, the large sixth tergite overlaps both adjoining tergites, the last two tergites imbricate posteriorly, and pleural lobes are present on these as well as on the abdominal tergites. The rami of the uropods are lobate blades. The endopod is three-fourths as long as the exopod. The telson is spatulate. The caudal fan of *Uronectes* is similar, but this genus is readily distinguished by a pair of large thoracic raptorial appendages. The pereiopods of *Palaeocaris* are unusually long and slender. The first pair is reduced. These and other morphological features will be clarified with reference to the large number of specimens of *P. typus* now available.

Palaeocaris typus Meek and Worthen, 1865 Pls. 60-64; Text Pl. 12, fig. a; Text Pl. 13

Acanthotelson inaequalis Meek and Worthen, 1865, p. 48.
Palaeocaris typus Meek and Worthen, 1865, p. 49.
Acanthotelson inaequalis, Meek and Worthen, 1866, p. 403, p. 32, fig. 7.
Palaeocaris typus, Meek and Worthen, 1866, p. 405, pl. 32, figs. 5, 5a-d.
Palaeocaris typus, Meek and Worthen, 1868 a, p. 28.
Palaeocaris typus, Meek and Worthen, 1868 b, p. 552, 2 figs.

Palaeocaris typus, Brocchi, 1880, p. 9, pl. 1, figs. 8-10.
Palaeocaris typus, White, 1884, p. 179-180, pl. 38, figs. 1-3.
Palaeocaris typus, Packard, 1886 b, p. 129-133, pl. 7, figs. 1-2.
Palaeocaris typus, Packard, 1889, v. 24, p. 213.
Palaeocaris typus, Calman, 1896, p. 796, p. 2, fig. 15.
Palaeocaris typus, Smith, 1909, p. 570, text figs. 56-58.
Palaeocaris typus, Vanhöffen, 1916, p. 141, fig. 5.
Acanthotelson inaequalis, Vanhöffen, 1916, p. 147.
Palaeocaris typus, Siewing, 1959, p. 100.
Palaeocaris typus, Rolfe, 1962, p. 548-549.

Palaeocaris typus is a synonym of *Acanthotelson inaequalis.* Through the latter has page priority, Meek and Worthen suppressed it in favor of *P. typus* upon which the genus was described (1868 b, p. 562, footnote). Because the name *A. inaequalis* has never been used correctly and *P. typus* is an established name, the decision of the first revisor should be accepted. The species is characterized by having no transverse striae on its thoracic and abdominal tergites and by the presence of small spines completely across the posterior margins of all abdominal tergites.

Description of specimens.—Two hundred eighty-six specimens of *Palaeocaris typus* from the Mazon Creek nodules were prepared. An additional 482 specimens were given cursory examination to discover features not previously discovered on the prepared specimens. For morphological study, the best specimens are in the collections of the Peabody Museum, Yale University, the U.S. National Museum, and the Museum of Comparative Zoology.

Holotypes of *Acanthotelson inaequalis* and *Palaeocaris typus* figured by Meek and Worthen have not been located. They may ultimately be discovered in the collections of the Illinois Geological Survey or the University of Illinois. The 12 plesiotypes studied by Packard are in the collections of the U.S. National Museum. The best specimen is refigured herein (USNM 38850, Pl. 62, fig. 2).

MCZ 5192 and CMNH 29405 are the only specimens that have retained their original relief. All other specimens are deformed by compression (PY 19731, Pl. 63, fig. 1). The chitinous exoskeletal sclerites were undoubtedly much less firm than those of the associated crustacean species. The original skeletal material has disintegrated. Unless otherwise indicated, the descriptions and photographs are of rubber molds of the natural impressions.

The surface texture of the exoskeleton was completely smooth. The fine spines across the posterior margin of the abdominal tergites are the only skeletal frill. The appendages and telson were setiferous.

The majority of the specimens are lateral compressions. This contrasts with the preferential dorsal-ventral orientation of *Acanthotelson.*

The three primary divisions of the body are the head, thorax, and abdomen. Eight separate thoracic somites are present; however, the tergites and appendages of the first are reduced. The head has prominent stalked compound eyes and consists of five fused appendages bearing somites. There is no rudiment of a carapace. The abdomen consists of six somites and a simple, flattened, spatulate telson. The most conspicuous body division back of the head is at the sixth postcephalic somite from which the tergites overlap toward either extremity.

The small size of the individuals and state of preservation make it impossible to obtain precise measurements for statistical analysis for all but the length of the body less the telson. It was found the most reliable relationships could be determined on a few select specimens. For example, the length of the head and thorax to the body length as defined above was consistently 0.58 on the specimens on which these measurements could be most accurately determined. On the other specimens there was a great range in this proportion. By selecting the best fossils for measurements, a statistical error is avoided. Meaurements of representative specimens are presented in Text Plate 11, figure c. Where pertinent, proportions will be presented in the morphological description.

The size frequency distribution within the sample is shown graphically in Text Plate 12, figure b. The maximum size was 35 mm. and the minimum size was 12 mm. The median and mode are at 22 mm. The distribution is skewed toward the upper sizes. This is normally exhibited by fossil populations. The standard deviation of 4.5 mm. about the arithmetic mean of 21 mm. reflects a strong central tendency.

The cephalic tagma of five fused somites is the same length as the sixth thoracic tergite and the sixth abdominal tergite. Each contributes one-ninth of the length of the body.

The dorsal cephalic shield is undivided dorsally (CMNH 29405, Pl. 61, fig. 1), but a shallow groove arises on the sides just anterior to the mandibles. It diminishes upward and no trace is to be found beyond a faint longitudinal groove. This groove arises at the posterior margin of the shield (MCZ 5197, Pl. 60, fig. 2). The cephalic shield attains the full depth of the body posterior to the mandibular groove. It rapidly diminishes in depth anteriorly with its ventral edge facing forward at an angle of about forty-five degrees to the axis of the animal's body. An antero-lateral angle of about 90 degrees is formed by an abrupt curvature of the margin of the shield. What is equivalent to the anterior margin in other syncarids is recessed through a broad arc to form a large orbital notch. Between the orbital notches, the carapace projects slightly forward as a truncated plate. This supraorbital plate is strengthened at either side, but it is not developed as a typical rostrum (CMNH 29405, PY 19767 and PY 18823).

A bridge of the epistome projects forward of the dorsal shield below the foramina for the eyes (CMNH 29405, Pl. 61, fig. 1). This condition is unknown in other adult syncarids but is recapitulated in the development of the stalked eyes of *Anaspides tasmaniae* (Thomson) (Hickman, 1937, p. 24, pl. 6, figs. 40-43).

Eye stalks are present on PY 18850, PY 19715, PY 19731 (Pl. 63, fig. 1), PY 19736, PY 19750, PY 19795, PY 19812, PY 19823 (Pl. 63, fig. 2), and USNM 38851-404f. The peduncle is short and stout. This accounts for the large ocular orbit. An unexpected feature is the prominent peracarid-like papillae clearly present on both eye stalks of PY 19823 (Pl. 64, fig. 5). Its existence is further validated on PY 19765. The cornea of the eye was not seen.

Both pairs of antennae are articulated ventral to the epistomal bridge. A strongly sclerotized plate between the first antennae is preserved on many specimens, *i.e.,* PY 19775 (Pl. 61, fig. 3), PY 19783 (Pl. 62, fig. 3), and USNM 38851-404p (Pl. 62, fig. 1). This sclerite is a distinct division of the epistome. As in some of the other primitive Eumalacostraca, it is interpreted as a rudiment of the sternite of the first antennal somite. The ventral skeletal portion of the epistome associated with the second antennae is poorly preserved on USNM 38851-404p. The mouth is shielded anteriorly by a sclerotized labrum which is expanded near its extremity (PY 19812, Pl. 61, fig. 4), much like that of *Anaspides*.

Remnants of the first antennae are present on a great many specimens. The three-jointed sympod is best preserved on PY 19783 (Pl. 62, fig. 3; Pl. 64, fig. 3). The stout basal joint is equal to the combined length of the other two joints. The terminal joint is only slightly longer than the second. Two rows of setal sockets are present on the basal joint of PY 19783 (Pl. 64, fig. 3). Setae can be seen on the second and third joints of this specimen. Portions of both flagella are present on several specimens. The length of the inner flagellum is about one-fifth the length of the body of the animal. It is believed that the other flagellum was about a third the body length (PY 19736 and PY 18917).

Despite the excellent preservation of portions of the second antennae on PY 19812 and PY 19783, the basal joint is unknown. The endopod arises near the base on the mesad side of a large joint that extends as a stipe for the antennal scale. By homology, this joint is the second joint of the sympod. Though a careful search was made, the first joint was not seen on any of the fossils. The exopod is a lobate squama. Its outer margin is not produced as a spine, but is slightly convex and bears setae as does the curved inner margin and broadly rounded tip. Three joints of subequal length and a long flagellum form the endopod. Setae on the mesad side of these joints can be seen on PY 19783 (Pl. 62, fig. 3). The length of the flagella of this pair of antennae is equal to the body length (PY 19705).

The mandible articulates with the cephalic shield posterior to the cervical groove (MCZ 5197, Pl. 60, fig. 2). Though the body of the mandible is large, it is not so stout as that of *Acanthotelson*. As in the Recent *Anaspides,* the shoulder anterior to the incisor lobe was the site of origin of a palp. The short isolated joint seen on PY 19775 (Pl. 61, fig. 3) is the same shape as the basal palp joints observed on Acanthotelson. The longer second joint is known (PY 19812, Pl. 61, fig. 4).

The basal joint of one of the first pair of maxillae is well preserved on PY 18855 and is identical to those seen on specimens of *A. stimpsoni.* The terminal joint is only poorly preserved on PY 19786, but there is a good ventral view of two joints of the second maxilla. The lateral compression of PY 19755 (Pl. 62, fig. 4) has remains of both pairs of maxillae preserved. The ventral skeletal sclerite supporting these appendages is shown by USNM 38851-404 p (Pl. 62, fig. 1).

Though the first thoracic somite is greatly reduced in length, all eight tergites remain freely articulated. Somites two through eight are subequal in length as shown by the margin of the tergites; however, they appear unequal dorsally because of imbrication. Mid-dorsally the sixth tergite is twice as long as the typical somite. This is because it overlaps both anteriorly and posteriorly. Tergites anterior to this imbricate forward. The first forms a collar extending upon the head shield. All tergites succeeding the sixth articulate in the normal manner.

The pleural lobes of this genus provide a distinguishing criterion that can be seen on most of the fossils. The anterior margin of the tergite gives way to the free pleural lobes through a broad arc. The posterior margin remains nearly straight. At the intersection of these edges the apex of the pleural plate is blunted (PY 19755, Pl. 60, fig. 1).

At least seven of the thoracic legs were biramous and there is definite proof of epipods. All endopods except the first are not uncommonly preserved (PY 19731, Pl. 63, fig. 1). There are five joints. The knee is between the merus and carpus. The pereiopods are slender. Successive pairs increased slightly in length posteriorly. The two joints of the sympod can be seen on USNM 38841-404. These and the ischium are particularly good on PY 18858 and PY 19750 (Pl. 60, fig. 3).

The blades of the exopod with their peduncle are present on many specimens (vide PY 19765, Pl. 63, fig. 4; MCZ 5197, Pl. 60, fig. 2; Pl. 62, fig. 6). Evidence of the setae which originally fringed the blades can be seen on these specimens in the form of setal sockets. Packard thought the exopods were jointed and Calman mistook the setal sockets for sutures of annuli. Seven exopods are preserved on both sides of USNM 38851-404. The exopod of the first thoracic leg is unknown.

The exopod arises from the basis. A tubular structure which must be the base of an exipod is seen to originate on the basal joint, the coxa, of the sympod above the exopod on the seventh thoracic appendage of PY 19731. Similar tubular structures are present on PY 19779, PY 19781 (Pl. 62, fig. 5), PY 19783, and PY 19765 (Pl. 63, fig. 4). On PY 19756 stalks are present above the exopods on both the seventh and eighth thoracic appendages. The lamellae of the exipods were not preserved. This would be expected if their integument was as thin as on the Recent syncarids. On *P. typus* the exopods extend between the pleural lobes of the tergites. It is probable that the sclerotized cylindrical stalks developed because of this.

This first pair of thoracic legs is reduced to less than half the size of the succeeding legs. Some of the joints can be seen on PY 19858, PY 19766 and USNM 38851-404f. The merus on PY 19755 (Pl. 62, fig. 4) is about half the length of the homologous joint on the normal pereiopod.

The thoracic sternites were nearly as long as their somites. Foramina for the legs are set wide apart leaving a more heavily sclerotized central plate. They are ornamented mid-ventrally by a small mound (PY 19775).

Detrital intestinal fillings are common on the fossils of this species. Fossils of *P. typus* are distinguished by impressions of longitudinal striations which reflect a ridge and groove structure of the interior of the intestine (PY 19750, Pl. 60, fig. 3). Some of the fillings extend through the thorax and abdomen into the base of the telson. The striations are restricted to internal molds of the posterior portion of the gut.

Six abdominal tergites, uropods, and the telson are present on most specimens. The first five abdominal tergites are subequal in length with pleural lobes like those of the thoracic tergites. The abdominal tergites are distinguished by a fringe of fine spines completely across the posterior border. The abdomen narrows gradually in width. The sixth abdominal tergite is slightly over half again as long as those preceding. As the main body of this somite rapidly narrows to the width of the telson, its anterior width is maintained by the development of marginal flanges. Each flange extends posteriorly beyond the main body of the somite for about one-quarter of its length. Their post-lateral angle is produced as a spine lateral to the sympod of the uropod (PY 19729, Pl. 64, fig. 4).

The ventral surface of each abdominal somite is nearly covered by a sternite. Foramina for the paired appendages are located laterally near the posterior border. Between the legs each sternite is strengthened by a slight crest (USNM 38851-404z, Pl. 63, fig. 3). The ventral sclerotized surface of the sixth abdominal somite is shown by PY 18917 and PY 19729 (Pl. 64, fig. 4). On this sternite there is a deep mid-ventral recession of the posterior edge.

Swimmerets were present on the first five abdominal somites. These can be seen on PY 19731 (Pl. 63, fig. 1). Their structure is similar to that of *A. stimpsoni.* The sympod is composed of a single stout joint (PY 19750, Pl. 60, fig. 3). It gives rise to two rami. They are blade-shaped and, as indicated by setal sockets, were fringed with setae (PY 19731, Pl. 63, fig. 1).

CMNH PE-2511 is incomparable for the preservation of the elements of the caudal fan. Both dorsal and ventral impressions make it possible to determine the true shape of both rami of the uropods as well as see the distribution of the fringing setae. Though not preserved on this specimen, the single joint of the sympod is excellent on PY 19917 and PY 19729 (Pl. 64, fig. 4). The lateral margin of the exopod is slightly convex. This sclerotized margin appears to be devoid of spines or bristles except for three terminal spines which arise anterior to the position of the transverse suture which divides the blade of the exopod. But in addition to the spines there are eight small inconspicuous bristles on the lateral margin (PY 19729, Pl. 64, fig. 4). The articulated terminal lobe is semicircular in shape. The margin of the terminal lobe and the slightly concave inner margin of the blade are fringed with setae. From the dorsal articulation with the sympod a prominent ridge extends the length of the blade. The endopod is more lobate and its complete free margin is fringed with setae. The lateral margin is convex whereas the inner edge is nearly straight. The endopod is only three-fourths as long as the exopod. Its tip extends barely to the transverse suture on the outer ramus.

The telson is spatulate with the basal axis dorsally arched to accommodate the intestine (USNM 38851-404v). It is widest near the base beyond which it gradually narrows. The tip is broadly curved. As shown by CMNH PE-2511 (Pl. 64, fig. 1) its margin was fringed with setae. The length of the telson on all specimens determined was equal to one-sixth the length of the body.

Synopsis.—Though the head shield is distinctive, the genus can most readily be distinguished by the shape of the pleural lobes of the thoracic and abdominal tergites, the large sixth thoracic tergite which overlaps those of both adjoining somites, forward imbrication of the first five thoracic tergites, and the shape of the blades of the uropod and the spatulate telson. Small spines are present completely across the posterior margin of all the abdominal tergites on *P. typus* and *P. praecursor* (Woodward). In both of these species the pereiopods are long and slender. The tergites of *P. praecursor* are, however, transversely striated. Species that might be confused with *P. typus* are *P. vandergrachti* Pruvost (1922, p. 147-150) and *P. retractata* Calman (1932 a, p. 541), but these do not have the spinose frill on the abdominal tergites.

Stratigraphic occurrence.—Francis Creek shale, Carbondale formation, Alleghany series (Westphalian), Pennsylvanian in Mazon Creek nodules.

Localities.—Grundy and Will counties, Illinois.

Collections.—The largest collection is in the Peabody Museum, Yale University. Other large collections are in the U.S. National Museum, Chicago Museum of Natural History, and the Museum of Comparative Zoology.

Types.—Holotypes of *P. typus* and *Acanthotelson inaequalis* are misplaced or lost. Packard's (1886 b) 12 plesiotypes are in the collection of the U.S. National Museum, 38850.

Palaeocaris canadensis, new species Pl. 65, figs. 1, 2

Palaeocaris sp. Copeland, 1957 a, p. 595, pl. 67, fig. 5.
Palaeocaris cf. *typus* Meek and Worthen, Copeland, 1957 b, p. 47, pl. 15, fig. 1

Counterparts of an excellent specimen in the Museum of Comparative Zoology, MCZ 5435, represent an unnamed Pennsylvanian syncarid from Canada. In that Copeland has previously identified the specimen as *Palaeocaris typus?*, the characterless specimens figured by him are herein considered to be synonymous.

All the basic morphological elements that can be determined on the Canadian specimens have their counterpart on *P. typus*. Whereas *P. typus* is without ornamentation of any nature on the thoracic tergites, the new species has two pronounced transverse grooves on each tergite, thoracic as well as abdominal. These markings are readily distinguished from the features resulting from compression of the imbricated margins of the tergites. Transverse ornament is characteristic of many of the Paleozoic syncarids. Two other species of *Palaeocaris* are so distinguished. *Palaeocaris burnetti* Woodward (1881) has eight to ten subparallel striae crossing each tergite from side to side and *P. praecursor* Woodward (1908) has three to four.

Description of specimen.—The fossil is preserved as a compression of low relief in black shale. One counterpart is negative impression; the other retains the carbonized remains of the chitinous exoskeleton. The specimen is broken, and the abdomen beyond the second tergite was not collected. The combined length of the head and thorax is 7.8 mm. With the same body proportions as *P. typus,* the body length of the new species would be 13.5 mm.

The cephalic shield has a pair of dorso-lateral protuberances near the posterior margins (Pl. 65, fig. 2). Neither the shape of the shield nor the position of the cervical groove is distinctive. Remains of antennae are too poor to warrant comment.

The thorax has eight tergites characterized by transverse grooves. The sixth tergite is the widest and it overlaps both adjacent tergites. Imbrication is as on *P. typus*. The maximum length of the sixth tergite is 1.0 mm, the length of the third is 0.7 mm. and the length of the first is 0.5 mm.

Pleurae of the thoracic somites cannot be seen on the fossil.

Remnants of legs are preserved on the right side of the specimen. The fifth and seventh endopods are long and slender with the joints developed in the manner normal for the genus. Setae can be seen on the carpus and propodus. Mineral fillings of the tubular remains of the epipods are present on the legs of somites three to six (Pl. 65, figs. 1, 2). On the counterpart they can be seen in negative relief on legs two to eight.

The tergites of the first two abdominal somites have the two characteristic transverse grooves. The pleurae are badly crushed, but their shape can be seen on the compression. It is a pointed lobe. There is a possibility the anterior curvature is not so convex as on *P. typus.*

Copeland (1957 b, p. 47) characterized the caudal fan as follows, "Caudal appendage showing one pair of setate, elongate swimmerettes on either side of the elongate blunted telson plate. Telson with numerous coarse setae ending posterior to the swimmerettes." His figure (1957 b, pl. 15, fig. 1) shows the rami of the uropods poorly preserved. The telson has the typical spatulate shape and is fringed by bristles.

Synopsis.—A new syncarid, *Palaeocaris canadensis,* is described from the Pennsylvanian deposits of Nova Scotia. The species is small in size and characterized by two transverse grooves on each postcephalic tergite.

Stratigraphic occurrence.—The holotype is from the Riversdale group. Specimens figured by Copeland are from the Pictou group. Both are Westphalian, Pennsylvanian.

Localities.—Holotype is from the headland at confluence of Ramshead and Diligent rivers, south of Diligent River, Cumberland Co., N.S., Canada. The specimens previously described are from Clifton and Glace Bay, N.S., Canada.

Collector.—Donald Baird, Princeton University.

Holotype.—The single specimen studied, MCZ 5435, is in the Museum of Comparative Zoology, Harvard University.

Genus **PALAEOSYNCARIS,** new genus

A beautiful fossil syncarid was discovered in a four inch drill core of the Heath shale of Upper Mississippian-Lower Pennsylvanian age from the subsurface of North Dakota. The specimen was obtained from a depth of 8170 to 8180 feet. It missed being damaged by the drill only two sixteenths of an inch. From the counterparts it is possible to determine most of the significant morphological features which prove it to represent a new genus and species.

In many respects, the fossil resembles the specimens described as *Praeanaspides praecursor* by Woodward (1908). Reassignment of

Woodward's species to *Palaeocaris* by Calman (1911 b) must be considered tenuous. The syntypes were large individuals on which the pleurae of the thoracic tergites were short and blunt. All tergites had multiple transverse striae. The new species from North Dakota also has these characteristics but is different in that the posterior margin of the large pleural lobes of the abdominal tergites is coarsely serrate. Whereas the posterior margins of the pleural lobes of Woodward's Pennsylvanian specimens were straight, those of the new genus are rounded. The lateral margins of the exopod of the uropods and the free edge of the telson of the specimen from North Dakota are armed with distinctive small spines, not bristles. Irrespective of the validity of *Praeanaspides,* there is no doubt that a new genus must be established for classification of the new species described below.

Palaeosyncaris dakotensis, new species Pl. 65, figs. 3, 4; Pl. 66, figs. 1-3; Text Pl. 14, fig. a

The body of the specimen is 24.5 mm. and the telson is 4 mm. in length. Lengths of the tagmata are as follow: head, 3.5 mm.: thorax, 10.5 mm.; and abdomen (*sans* telson), 11 mm. It is believed the proportional development and the transverse ornament on the tergites are distinctive of this species.

Description of the specimen.—The specimen is preserved as a compression in a black shale. Remnants of the chitinous exoskeleton remain on one of the counterparts. The other is an impression. Associated specimens of *Pseudoestheria* sp., ostracods, and *Anthraconaia*-like pelecypods are partially pyritized. The exoskeleton is oriented such that its left ventral side is bent under. Exposed are the dorsal and right lateral portions of the fossil. Even compensating for the great exaggeration in body depth due to compressional spreading, the animal was considerably more robust than any of the species of *Palaeocaris.*

The head is the most poorly preserved portion of the fossil. Nothing except the length of the head shield can be determined. However, stalked compound eyes and all elements of both antennae are remarkably well displayed. The peduncle of the eye is relatively long and slender. The hemispherical cornea is comparatively small for a syncarid.

The peduncle of the first antenna consists of three joints. The basal joint is equal in length to both of the others (Pl. 66, fig. 2). There are remains of both annulate rami. These flagella are fragmentary, but appear to have been somewhat longer than those of *Palaeocaris*. Sockets for the origin of fine setae are preserved along the distad margin of several of the annuli. This is the only fossil syncarid known to have setigerous flagella. It is a characteristic of the Recent Syncarida.

The second antennae (Pl. 65, fig. 3) have the typical elements. The second joint of the sympod, the major part of which serves as a stipe for the scale, is unusually stout. The antennal scale is small, lobate, and fringed with setae. The flagellum is setiferous and apparently not of great length.

Of the other cephalic appendages only the body and incisor lobe of the mandibles are distinguishable. The body of the mandible is not so large as the mandibles of *Palaeocaris* and *Acanthotelson*.

The thorax consists of eight somites. The tergite of the first is reduced to a narrow band, but it is free and definitely is not fused with the cephalon. The second tergite is narrower than the six subequal thoracic tergites succeeding. From the fossil it is impossible to be certain if there was forward imbrication of the anterior tergites. They appear to all overlap to the posterior. Irregular, transverse striae cross each tergite and terminate upon the pleurae. Typically there are three, but some of the posterior thoracic tergites have four. The pleurae of the anterior tergites are short. The free ventral margin is transverse with the anterior and posterior rounded. The pleural lobes become progressively longer and more oblique. The eighth lobe is pointed.

The thoracic legs are remarkably well preserved except for the epipods and exopods of which no trace remains. The sympod consists of two short joints as can be distinguished on the third, fifth, sixth and seventh appendages. The five joints of the endopod can also be seen on these pereiopods. The legs are much shorter and stouter than those of *Palaeocaris*. Only scraps of the first thoracic endopod are present and reduction in size is indicated. The second appendage is not unlike the typical posterior pereiopods; however, the third seems to be somewhat longer and more heavily constructed.

There was a tendency for the development of large raptorial appendages in the Paleozoic Syncarida, *e.g., Acanthotelson* and *Uronecetes.* Though not distinctly specialized, the third thoracic endopod of *Palaeosyncaris* appears to have been incipiently modified.

The first five abdominal tergites are of subequal length whereas the sixth abdominal tergite is nearly twice as long. The abdominal tergites are characterized by having large pleural lobes and four transverse striae. The ventral margin of each lobe was heavily chitinized and produced as a posterior spine. The free posterior edge of the lobe dorsal to the spine was convexly curved and armed with long pointed teeth (Pl. 66, fig. 3). The sixth abdominal segment lacks pleural lobes. Pleopods are unknown. Only the single jointed sympod and the lobate exopod of the uropods are partially preserved (Pl. 65, fig. 4). Spines on the convex outer margins of the exopod are more abundant and rigid than on any other syncarid.

The telson is spatulate with a broad base. Distinctive rigid spines are borne on the postero-lateral and rounded terminal portion of its margin.

Synopsis.—The new genus, *Palaeosyncaris,* has blunt pleurae on the anterior thoracic tergites. These change posteriorly to the longer pointed pleural lobe of the eighth thoracic somite. Large pleural lobes with a ventro-posterior spine and a convex, serrated posterior margin are distinctive of the first five abdominal somites. Whereas the other Paleozoic syncarids have their uropods and telson armed with setae or bristles, the rigid, pointed processes on this genus are best designated as spines. The pereiopods are relatively short and massive. The third pair is somewhat large and may have been incipiently modified as raptorial appendages. The general aspect of the fossil gives the impression of a creature with a more massive body than that of the other syncarids. It is believed the transverse ornament on the tergite is a specific criterion as are the relative proportions of the body.

Stratigraphic occurrence.—Heath shale, Upper Mississippian-Lower Pennsylvanian.

Locality.—Subsurface from core approximately 8170 to 8180 feet in Casimer Duletski No. 1, Tennessee Gas Transmission Company, N.W. 1/4, N.W. 1/4, Sec. 16, T. 139 N., R. 99 W., west southwest of Dickinson, Stark Co., North Dakota.

Holotype.—One counterpart is in the collection of the University of North Dakota, Grand Forks, North Dakota, and the other is in the collection of the U.S. National Museum, No. 143409.

Genus **SQUILLITES** Scott, 1938

The author of this name clearly expressed the intention that the name was proposed to discriminate a distinct genus for a Mississippian crustacean from Montana. The name was selected because it was believed the fossil was closely related to *Squilla,* a Recent stomatopod. Herein, this relationship is disproven.

Squillites is characterized by having 14 free post-cephalic somites. Eight thoracic somites contribute as much to the length of the animal as do the six abdominal somites. There is no carapace. The first thoracic tergite is narrow and overlaps onto the posterior of the head. Most distinctive are the similar sternites of all post-cephalic somites. They are relatively wide with rounded lateral margins. The rami of the uropods are spatulate and fringed with setae. The massive telson is wedge-shaped and armed with stout bristles.

The type species is *S. spinosus* Scott, 1938. The genus is monotypic.

Squillites spinosus Scott, 1938 Pl. 53, figs. 1, 3; Text Pl. 14, fig. d

Squillites spinosus Scott, 1938, p. 508-510, 2 figs.
Squillites spinosus, Berry, 1939, p. 467.

Re-interpretation of the specimen invalidates the original definition. After the morphological analysis, characterization of the species will be summarized in the synopsis. A restoration is impossible but a diagrammatic drawing of the specimen is presented with the parts labeled (Text Pl. 14, fig. d.)

Description of specimen.—This small crustacean is preserved as dorsal and ventral impressions in a black shale matrix. The chitinous exoskeletal compression has disintegrated. Not having previously worked with fossil Malacostraca, it is a tribute to Scott that he distinguished so many morphological features correctly. The specimen is most confusing until one realizes the specimen is twisted. The front portion of the animal presents the right side, whereas the posterior is a left dorso-lateral view. Ventral features have been impressed into the dorsal integument where it is preserved. Except for the left pleurae of the sixth and seventh thoracic somites, the dorsal skeleton is missing for the third to the seventh. Though dorsal and ventral structures are superimposed, one counterpart (Pl. 53, fig. 1) portrays the dorsal feature best, whereas the other shows the ventral (Pl. 53, fig. 3).

Measurements are as follow: length of body, 7.8 mm.; length of head, 1.1 mm.; length of thorax, 3.3 mm.; and the width of the eighth sternite is 1.1 mm. Widths of other features presented by Scott (1938, p. 510) are of no significance as their great width is due to compressional spreading.

The head shield is poorly preserved. Its length is equal to slightly less than one-seventh the length of the complete body. It appears that the mid-dorsal edge of the carapace projected forward. The extent to which a rostrum was developed is unknown.

A composite of parts exists in front of the cephalic shield. Only the three flagella that extend beyond this complex are interpretable. The two long flagella with large annuli are probably the endopods of the second antennae. Because of equivalency in size of the annuli, it is doubted that the less complete one is the remains of a first antenna as believed by Scott. Vague remains of a minute flagellum exist between the two larger flagella. This is all that is known of the first antenna.

The eight thoracic somites are free and not covered by a carapace. A narrow tergite overlaps the posterior margin of the head. The second thoracic tergite is twice as wide. It also imbricates forward. Tergites three to five are not preserved. The sixth and seventh are represented only by their left pleura. The eighth is complete and the true shape of the pleura is shown. It is bluntly pointed. The postero-lateral angle of this lobe results from a broad curvature of the antero-ventral edge.

All eight thoracic sternites can be distinguished on both counterparts. The first is reduced in size. On the fossil, it is displaced posteriorly and is associated with the second tergite. The lengths of the succeeding thoracic ventral sclerites are longer. A rounding of the lateral margins of these strongly sclerotized plates is a singularlity. Foramina for the legs can clearly be seen on the seventh sternite.

A clue to interpretation of the abdomen is found in the remains of the eighth thoracic somite. Both tergal and sternal features are clearly superimposed. Not only are the lateral extremities of the sternite strongly expressed on the fossil, but the right pleura is bent under in such a way that the tergite appears to have three longitudinal ridges. These are the "prominent knobs, one median and two laterals" mentioned by Scott (1938, p. 508-509). No ornament of any type was seen.

The dorsal and ventral skeletal features of the six abdominal somites are as described for the thorax. They are all of subequal length. The sternites narrow posteriorly. Foramina for the appendages are clearly evident on some of the sternites. Except for the large uropods arising from the sixth abdominal somite, no post-cephalic appendages were detected. The basal sympodal joint of the uropods gives rise to two long spatulate rami. Both the exopod and endopod have a median keel. A fringe of setae surrounds the outer as well as the inner margins of the two lobes.

The telson appears to have been a heavy wedge-shaped body. Accessory furcal structures are not present. It is believed the complete free margin was armed with heavy bristles. Evidence for these is found in the large sockets at the edge of the telson.

Synopsis.—Scott recognized that this crustacean lacked a carapace. However, because of spreading of the abdomen, its relatively enormous appearance on the fossil misled him to believe it was a stomatopod. Actually the thorax and the abdomen are about the same length. Using the width of the abdominal sternites as a criterion, the abdomen was of normal width and diminished in size posteriorly.

The true affinity of this crustacean is with the Syncarida. Not only are all eight thoracic somites free, but the tergites of at least the first and second imbricate forward. This is an irrefutable criterion peculiar to the Syncarida in Crustacea. Lack of articulated furcal processes on the telson is of less significance.

The peculiarity of the sternites with their rounded lateral extremities and the massive wedge-shaped telson are generic characteristics. Lack of ornamentation and the proportional development of the various morphological parts will probably prove to be the basis for specific distinction.

Stratigraphic occurrence.—Heath shale, Big Snowy group, Chesterian, Mississippian.

Locality.—Two miles south of Heath, Fergus County, Montana in Spring Creek on the north flank of the Big Snowy Mountains.

Collector.—Harold W. Scott.

Type specimen.—Counterparts of holotype are X-1219 in the University of Illinois collections.

IDENTITY OF AMPHIPELTUS, DIPLOSTYLUS, AND EILETICUS

Three genera of fossil arthropods from North America are in need of restudy; they are *Amphipeltus* Salter, *Diplostylus* Salter, and *Eileticus* Scudder. From evidence now available, I believe the first two are abdomens of *Pygocephalus dubius* (Milne-Edwards), and that *Eileticus* is a myriapod as originally reported, through specimens subsequently assigned to this genus are species of the syncarids, *Acanthotelson* and *Palaeocaris.*

Salter (1863 a, p. 75-78) established *Amphipeltus paradoxus* and *Diplostylus dawsoni* for two fossil crustacean abdomens. The first fossil, which also has the cephalothorax poorly preserved, is allegedly from the Devonian rocks near St. John and the second is from the Coal Measures at Joggins, Nova Scotia. It is mentioned that fragments of a fern and *Cardiocarpon* occur on the same slab of black glossy shale as the holotype of *A. paradoxus. Cardiocarpon* is a Pennsylvanian seed. Though Dawson (1862), the collector, claimed the specimen was collected from Devonian strata, the presence of *Cardiocarpon* and the similarity of the abdomen of the figured specimen to that of *Diplostylus dawsoni* (Salter, 1863 a, figs. 6, 11) makes this determination highly improbable. The specimen (having five tergites bearing pleural spines directed backward) which was later figured by Matthews (1895, pl. 2, fig. 6) from the Little River Group of Devonian age, represents a different type of arthropod. It is certainly not an isopod as Matthews claimed. Until proven otherwise, Salter's two genera must be considered as synonyms and they are probably incorrectly interpreted abdomens of

Pygocephalus dubius (Milne-Edwards), a crustacean known to occur in the Pennsylvanian strata of Nova Scotia.

The holotype of *Eileticus anthracinus* Scudder (1882, p. 178-189) is a typical myriapod from the Pennsylvanian concretions from Mazon Creek, Illinois. The unmistakable broad labrum of the Archipolypoda is present on the specimen originally illustrated. By later figuring poor specimens of *Acanthotelson stimpsoni* Meek and Worthen (USNM 38004) as an additional example of *Eileticus anthracinus* and as specimens of a new species, *E. aequalis*, Scudder (1890, p. 420-421, pl. 38, figs. 5-9) (USNM 37996) misled European paleontologists. Pruvost (1919, p. 89) recognized the syncarid nature of these later specimens and thus classified *Eileticus, Acanthotelson* and *Pleurocaris* in the family Acanthotelsonidae. Recently Vandenberghe (1960, p. 690-692) synonymized *Pleurocaris* Calman (1911 a, p. 156-160) as a junior synonym of *Eileticus*. The new species he proposed, *E. pruvosti*, from the Saint-Etienne Basin of France is too poorly illustrated for positive determination, but it is probably a species of *Palaeocaris*. It should be noted that his observations, that the first thoracic somites are incorporated into the cephalic tagma and that the abdomen has seven somites, are erroneous. As in *Palaeocaris*, there is the typical eumalacostracan segmentation of the tagmata, *i.e.*, five cephalic, eight thoracic and six abdominal somites. He simply placed the division between the tagmata incorrectly. Adding further to the confusion, a new family, Eileticidae, and a new subfamily, Anacanthotelsonidae, were proposed. He also reduced Acanthotelsonidae Cockerell (incorrectly attributed to Pruvost) to subfamily rank. Not being aware of the incorrectness of the premises upon which Vandenberghe's classification of the Paleozoic Syncarida was based, Rolfe (1962, p. 550) revised the family and subfamily names. The taxonomy of both authors must be rejected, and *Eileticus anthracinus* Scudder remains a valid name for a species of Pennsylvanian myriapod.

STRATIGRAPHIC OCCURRENCE AND PALEOCOLOGY

The stratigraphic occurrence of fossil arthropods with skeletons not fortified with mineral matter is extremely sporadic. Many types of arthropods have evolved and become extinct without leaving any trace of their existence. The Euphausiacea must have existed throughout Mesozoic and Cenozoic time, but no fossils are known.

For an example of the extent to which ecological factors and selective preservation influence the stratigraphic occurrence of fossil arthropods, and the misconceptions that have resulted, one has only to cite the fossil record of the limuloids (Brooks, 1957, p. 896). Recent *Limulus* and its congeners are marine animals (Waterman, 1953), though in the breeding season they migrate to the beaches. They invade lagoons, estuaries, swamps, and sometimes wander for considerable distances up rivers. Undoubtedly, the Tertiary, as well as the Mesozoic limuloids, had similar habits. It is interesting to note that there is not one occurrence of their remains preserved in typical marine sediments. Remains of limuloids are found in association with trachaeophytes in fresh to brackish water, lagoonal and swamp deposits, and in sediments that contain evidence of supersalinity. The one example in which they occur in a marine deposit is the lagoonal Solnhofen limestone of Bavaria. This is a Jurassic back reef deposit in which marine organisms, including several genera of decapods with chitinous skeletons otherwise unknown as fossils, are associated with terrestrial animals, *i.e.,* insects, arachnids, and vertebrates. Their fossil record is a paradox unless one realizes the stratigraphic occurrence is the result of selective preservation and special environmental conditions under which the remains were preserved. In the sea, the normal habitat, their chitinous exoskeletons were destroyed.

The species of *Archaeocaris* and *Palaeopalaemon* are the only fossil Paleozoic Eumalacostraca with fortified skeletons, and they were originally weakly mineralized. Their remains are found in sideritic and phosphatic concretions in marine deposits. The single specimen not from a concretion, *Archaeocaris graffhami,* was collected from a light tan, calcareous shale associated with abundant goniatites and remains of other marine animals with shells. The Mesozoic and Tertiary lobsters with a larger more heavily fortified chitinous exoskeleton have left a record that is not much better than that of their Paleozoic counterparts (Brooks, 1957, p. 896). Their fossil record consists mostly of the strong chelae, and these are rare.

In the normal marine environment chitin is rapidly destroyed by fungi and bacteria. It is only where biological and physiochemical factors have favored their preservation that the chitinous Paleozoic eumalacostracan remains are found. These are the anaerobic conditions in marine and lagoonal environments wherein biological activity is arrested in organic rich muds. Supersaline and fresh water environments also favored their preservation. The other condition indicated by the fossil record is that of a lagoon which has fluctuated from fresh to salt water conditions.

The oldest eumalacostracan fossils are found in the Devonian and these are uncommon. The known world record is eight specimens. Two species are from the Upper Middle Devonian. They are *Eocaris oervigi* Brooks (1962 a) from the Givetian of Western Germany and *Devonocaris cuylerensis* (Wells) from the Moscow formation of New York. Both are known from single poorly preserved fossils. Directly associated with *Eocaris* in a gray siltstone are fish remains and an archaeostracan, *Montecaris lehmanni* Jux. Typical marine invertebrate fossils also occur in the same formation (Jux, 1960). The Moscow formation in which *Devonocaris* occurs is a black marine shale. Only two additional species of Devonian Eumalacostraca are known. They are *Devonocaris destinezi* (Van Straelen) from a subgraywacke of Belgium and *Palaeopalaemon newberryi* Whitfield from the Upper Devonian black shales of Ohio. The same American species is also known from a phosphatic concretion from the Lower Mississippian of Kentucky.

In Mississippian strata eumalacostracan fossils become more abundant. Most occur as compressions in black carbonaceous shales associated with scraps of plants, fish, and miscellaneous fossils which have led paleontologists to infer a fresh-water habitat. However, the relatively rare species of *Archaeocaris* and *Palaeopalaemon* are found in unquestionably marine deposits. Most of the Mississippian fossils have been collected from Scotland (Peach, 1908). A few are known from France (Carpentier, 1913). Less than 30 specimens have been collected in North America. *Anthracocaris* (Calman, 1932 b) from Scotland and *Acadiocaris* redescribed above from Nova Scotia were originally reported as syncarids (Peach, 1908, Copeland, 1957 a). Both genera have a short carapace and are thus not syncarids.

Syncarids made their first appearance in the uppermost Mississippian of North Dakota and Montana in a black shale. *Palaeosyncaris* is associated with estherians, *Anthraconaia*-like pelecypods and "fresh water ostracods." *Squillites* occurs in a facies of the same formation with more characteristics of being marine.

With both syncarids and pygocephalomorphs occurring in the black shales and ironstone concretions associated with Pennsylvanian coal deposits, eumalacostracan fossils are no longer uncommon. *Anthracaris, Pygocephalus, Anthracophausia, Pseudotealliocaris, Belotelson, Acanthotelson* and *Palaeocaris* occur in strata of Pennsylvanian age in North America. Though hundreds of some of these animals have been collected, only *Palaeocaris* is represented by more than one American species. This is further evidence of the inadequacy of the paleontological record.

The presence of plant remains, *Anthraconaia,* merostomes, arachnids, insects, myriapods, estherians, and fish, have been deceptive in environmental arguments. A common fossil in all of these deposits is *Spirorbis,* a sedentary, tubicolous, marine polychaete. Other marine fossils also occur but tend to be overlooked by those who have a preconceived interpretation. Mazon Creek concretions contain excellent specimens of marine gastropods, amphineurans and pectenoid clams. One trilobite has been collected (Richardson, 1956, p. 59). The deposit is at the margin of the Pennsylvanian marine embayment into northern Illinois.

In the infancy of geology, plant remains and estherians were used as criteria for fresh-water conditions of deposition of Upper Paleozoic strata. The occasional presence of insects, arachnids, myriapods, and amphibian remains gave further weight to the argument. However, one has only to cite the occurrence of terrestrial animals in the Jurassic Solnhofen limestone to demonstrate the need for caution. Actually a complete re-evaluation is needed of the habitat and conditions of preservation of all the alleged "fresh water faunas" from Paleozoic rocks. The only reliable evidence will be obtained by geochemical studies. Could it be that the Upper Paleozoic estherians were marine or at least euryhaline? It is known that the Devonian species were marine (Raymond, 1946).

If one were blindly to accept the criteria presently used as evidence, we could only conclude that aquatic arthropods with chitinous exoskeletons colonized the fresh-water environment during the Carboniferous and were restricted to it in the Permian. It is my opinion that the Mazon Creek fossiliferous deposit is lagoonal in origin. Its salinity may have fluctuated and the lagoon may have been fresh for short periods of time. It is also possible that the Crustacea were euryhaline and tolerated the freshened conditions. That they were not marine organisms cannot be upheld merely because of "scientific" tradition. The absence of their skeletal remains in normal fossiliferous marine deposits is negative evidence caused by selective preservation. It is absurd to perpetuate as fact, paleoecological interpretations based upon circular reasoning and negative evidence.

Some of the Permian syncarids and pygocephalomorphs may have lived in fresh water as their normal habitat, but this is improbable. The deposits in which the single Permian specimen from Texas occurs (Wilson, 1953) may be fresh water in origin, but the specimens of the same species, *Mamayocaris jepseni,* from the Opeche formation of South Dakota were collected from a lagoonal deposit. Beurlen has called attention to the fact that the syncarids and pygocephalomorphs from the Permian of Brazil are found associated with a marine fauna (1931, p. 46-49). It is obvious that he would like to believe they were fresh-water animals so he concludes the environment was "at least not completely marine".

A criterion for interpreting the feeding habits of the most ancient Eumalacostraca is found in the fossils of the Pennsylvanian syncarids, *Acanthotelson* and *Palaeocaris,* which lived in the same habitat and were similarly preserved. *Acanthotelson* was primarily a rapacious carnivore as indicated by the modification of its anterior thoracic legs. The fossils of the more generalized *Palaeocaris typus* have detrital fillings of the intestinal tract whereas, with one exception, those of the associated carnivore do not. The size frequency distribution of the individuals in the statistical sample of the two species may also be of ecological significance (Text Pl. 12, figs. b, c). The population of *Acanthotelson* is skewed with some individuals attaining sizes twice that of the mode, whereas *Palaeocaris* has a size distribution with the mode skewed toward the larger sizes typical of paleontological samples of scavengers, microphagous feeders and herbivores. The population of *Acanthotelson* has its modern correlation in the Recent carnivorous lobsters. In Recent slime- and detritus-feeding crustaceans large amounts of sediment are taken in with the food. Thus, one can only conclude that *Palaeocaris* fed on bottom detritus. If this criterion can be extened to the other Paleozoic fossils, then *Devonocaris, Tealliocaris, Anthracaris* and most of the other eumalacostracans were bottom scavengers. As further evidence in support of the argument, fossils of *Archaeocaris* and *Perimecturus,* the rapacious stomatopod-like Paleozoic crustaceans are the other exceptions to having casts of the intestinal tract. With their subchelate raptorial appendages, large abdomens, and short carapaces these creatures, by Dollo's (1910) principle of form and function, are believed to have been carnivores and to have had burrowing habits such as do the Recent stomatopods.

Evidence for the feeding habits of the Paleozoic Eumalacostraca is inconclusive, but it is a mistake to accept dogmatically the postulate that the ancestral Eumalacostraca were filter feeders (Cannon and Manton, 1927; Dennel, 1937). Notwithstanding the nauplius type "primitive" mandibles of the Mystacocarida, which may represent an example of phylogenetic neoteny, the typical crustacean jaw is a biting triturating structure. If filter feeding is the primitive mode of obtaining food, the evolution of the crustacean mandible is a singular exception to Darwinian theory. From the multiplicity of filtering methods that exist in the Crustacea (Dahl, 1956), it is safe to assume that filter feeding is a secondarily acquired adaptation. The evidence presented above indicates that primitive crustaceans, and thus the archaeotype of the Malacostraca, were bottom living omnivorous scavengers that fed predominately on detritus.

The shrimplike bodies of *Eocaris, Devonocaris, Anthracophausia, Palaeopalaemon,* and *Belotelson* are the only exceptions in the Paleozoic Eumalacostraca of North America to being adapted as predominantly bottom living creatures. The large abdomen relative to the length of the cephalothorax in this caridoid type of crustacean is indicative of nektonic habits. Another analogy of interest is the crablike pygocephalomorphs from the Southern Hemisphere. These benthonic homeomorphs have the abdomen reduced and flexed under the body.

The stratigraphic occurrence of the fossils from North America are summarized diagrammatically in Text Plate 15. The teilzones of the American Eumalacostraca are plotted in relation to the known biozones of the genera.

PHYLOGENETIC RELATIONSHIPS AND THE CLASSIFICATION OF THE PALEOZOIC EUMALACOSTRACA

In the older papers on fossil eumalacostracans from the Paleozoic, most authors classified the species with a carapace as decapods. The single exception was Huxley (1857, p. 368), who recognized some of the homologies between *Pygocephalus* and the Mysidacea but even he later (1877) referred to its synonym, *Anthrapalaemon,* as a "Macrourous Decapod Crustacean". Woodward (1907 b) figured and described a peracarid marsupium composed of oostegites on *Pygocephalus.* In the following year Peach (1908) published his monographic study on the Upper Paleozoic Eumalacostraca from Scotland in which oostegites also were proven to exist on *Tealliocaris.* He envisioned that a marsupium was present on all other contemporaneous genera. In his text, Peach repeatedly compared the morphological features of *Tealliocaris* with those of the Recent Lophogastridae. Phylogenetic theory at the time advocated the primitiveness of the Lophogastridae and Peach enthusiastically believed the paleontological record supported the theory.

Peach (1908, p. 6) classified the syncarids as "Anaspidae", *Perimecturus* in a new family Perimecturidae, and *Tealliocaris, Pseudogalathea, Anthrapalaemon* and *Pygocephalus* as Lophogastridae in the "Mysid Group" and *Anthracophausia* and *Crangopsis* in the family Euphausiidae of the "Euphausid Group" of the Schizopoda.

Though subsequent authors have correctly separated the Syncardia, the mysidacean classification for the other fossils has been perpetuated and extended to include *Crangopsis* and *Anthracophausia* (Van Straelen, 1931, p. 23-36; Piveteau, 1953, p. 318). The reason for classification of these genera with the peracarid order was the marsupium on *Crangopsis* figured by Peach (1908, pl. 11). Until recently, little attention has been given to the order

Pygocephalomorpha established by Beurlen (1930, p. 452, 1931, p. 44-46) to distinguish those Paleozoic fossils with a carapace. He mentions *Palaeopalaemon, Anthrapalaemon, Pygocephalus,* and *Paulocaris* without giving an adequate definition of the new taxon.

The classification of the Recent Eumalacostraca has remained essentially unmodified for over 50 years. This is a tribute to Calman's (1904) understanding of the systematic relationships of these Crustacea. Four divisions, *i.e.,* superorders, are recognized. They are the Syncarida, Peracarida, Eucarida, and Hoplocarida. Recently Siewing (1957, p. 268) proposed an additional taxon, the superorder Pancarida, for the Thermosbaenacea represented by two unique genera discovered subsequent to Calman's work.

The Paleozoic eumalacostracan fossils with a carapace described in this paper have a puzzling combination of morphological characteristics not consistent with the definition of any one of the Recent superorders. They are unique in that all have biramous thoracic appendages with a single joint in the sympod and furcal lobes and a median spine on the telson; however, structural trends toward all the basic eumalacostracan types are displayed. *Tealliocaris* with a brood pouch, no seminal receptacle and with sternal processes may be related to the stock from which the Mysidacea arose. On the other hand, *Anthracaris* lacks oostegites, has a seminal receptacle on the last thoracic sternite of females, and has a secondary articulation between the mandible and the epistome. These are characteristics of decapods! The problems in classification are best exemplified by *Pygocephalus* which not only has a peracarid marsupium, but the seminal receptacle diagnostic of syncarids and decapods. All of these Paleozoic genera have the carapace extended laterally, and it is apparent they belong to one phyletic group. These and the genera *Pseudotealliocaris, Pseudogalathea, Mamayocaris, Notocaris,* and *Paulocaris* are herein considered to represent the order Pygocephalomorpha (Beurlen, 1930, emended). They have the cephalothorax and abdomen of subequal length, or the abdomen is reduced. They were the Paleozoic benthonic eumalacostracans.

The nektonic caridoid facies with a shortened cephalothorax is represented in the Paleozoic by *Eocaris, Devonocaris, Palaeopalaemon, Crangopsis,* and *Anthracophausia. Palaeopalaemon* is distinguished by the thorax being only slightly reduced in length. It is also of phylogenetic significance for another reason. There is an incipient branchiostegal development of the pleurae of the carapace, and it may have been from such a morphological type that the Pygocephalomorpha evolved. *Eocaris, Devonocaris,* and *Palaeopalaemon* have in common unusually large first antennal sympods. In this study oostegites have not been seen on any of these genera, but Peach (1908, p. 74) claimed they were present on *Crangopis*. This needs reinvestigation. Absolute criteria that prevent the above genera from being classified as Euphausiacea are the single joint of the thoracic sympod and the carapace not being fused with the thoracic somites. The order Eocaridacea is proposed for their classification. Recent euphausids have retained the primitive telson and are probably specialized pelagic descendants of this primitive eumalacostracan order.

Even more astonishing than the phylogenetic trends indicated above is the evolutionary significance of *Archaeocaris* and *Perimecturus*. They are either remarkable homeomorphs of stomatopods or are their ancestors. These fossils have a short cephalothorax covered by a shallow carapace that is fused with four anterior thoracic tergites and the rostrum is articulated at its base. The abdomen is enormously developed and it is known that the thoracic appendages two to five on *Archaeocaris* are subchelate. Whereas the three posterior subchelate appendages of the true stomatopods are reduced, all four are subequally developed on the Paleozoic fossils, therefore the order Palaeostomatopoda is proposed for their classification.

Fossils representing the Syncarida were known prior to the discovery of extant species. The Syncarida was originally defined by Packard (1885 a) to include only the Pennsylvanian fossil, *Acanthotelson stimpsoni* from Illinois. At the time of Meek and Worthen's last description (1868 b) and Packard's revision the most closely analogous extant crustaceans without a carapace were the Isopoda and Amphipoda. The principal diagnostic characteristics of *Acanthotelson* and thus the Syncarida, as presented by Packard, were the absence of a carapace and loss of the first thoracic tergite thorugh fusion. Though reduced, the first tergite is present as it is on all other Paleozoic syncarids from the Northern Hemisphere.

With the discoverey of the Recent "Tasmanian mountain shrimp", *Anaspides tasmaniae* (Thomson, 1893), Calman (1896) established the Syncarida as an order. These extant crustaceans with biramous thoracic appendages and no carapace have the first thoracic somite incorporated into the head, and the females do not have a marsupium. The taxon was extended by Calman to include other fossils, such as *Palaeocaris,* which were known to have the first thoracic somite freely articulated. Subsequently several Recent genera have been discovered. In his later classification of these Crustacea, Calman (1904, p. 159) raised the Syncarida to division rank, *i.e.,* superorder.

The attempts that have been made to establish a systematic classification of the fossil syncarids have been unsuccessful (Chappuis, 1915; Cockerell, 1916; Siewing, 1959; Vandenberghe, 1960; Rolfe, 1962) because of misinterpretation and lack of morphological information. Now that it is known that all the Paleozoic syncarids from the Northern Hemisphere have eight free thoracic somites as do the aberrant extant subterranean Bathynellacea, a workable classification is possible. The Bathynellacea have the telson and last abdominal somite fused together, a furca is present, and the pleopods are reduced or absent. Thus they differ from the Paleozoic syncarids from the Northern Hemisphere. In a separate paper dealing with the two authentic anaspidacean fossils known, *Clarkecaris* (Mezzalira, 1952) from the Permian of Brazil and *Anaspidites* (Brooks, 1962 b) from the Triassic of Australia, I have revised the families and orders of the Syncarida. A new order, Palaeocaridacea, was established for the Paleozoic syncarids that have eight free thoracic somites and the telson devoid of a furca (Brooks, 1962 b). Though the ocellus has not been detected, it may have been present on one or more species of the genera included in this taxon. Primitive charactertistics discovered that are not present on extant species of the orders Bathynellacea and Anaspidacea are ocular papillae on the eye stalks of *Palaeocaris typus* and nephropores for antennal glands on the basal joint of the second antennae of *Acanthotelson stimpsoni.*

Evolution of the three orders of syncarids has been discussed separately (Brooks, 1962 b). The most primitive syncarids known are the extant Bathynellacea which have eight separate thoracic somites, no seminal receptacle on the females, and a furca on the telson. The Palaeocaridacea differentiated and thrived during the Upper Paleozoic. From the Palaeocaridacea, the Anaspidacea evolved in the Southern Hemisphere during the Permian. On *Clarkecaris* from Brazil a vestige of the first thoracic somite can be seen though it is incorporated into the head, whereas on the Triassic fossil from Australia, *Anaspidites,* it has lost its identity within the cephalic tagma as is the condition in the Recent *Anaspides, Paranaspides, Koonunga,* and *Micraspides.*

Until more is known of the morphology of *Anthracocaris* (Calman, 1932 b) and *Acadiocaris,* n.g., which have a short carapace, we must accept the suggestion of Calman that they are related to the Peracarida. They could be ancestral tanaidaceans as mentioned or related to the Spelaeogriphacea. Both of these peracarid orders have a short carapace covering only the anterior thoracic somites. There are only two unique diagnostic characteristics of the peracarids. These are a lacinia mobilis on the mandible and a marsupium formed of oostegites on the females. It is only the oostegites that we may expect to find preserved on the fossils. If they are present, a peracarid relationship would be proven. The fossils cannot be considered true tanaidaceans even if oostegites prove to be present since these peracarids have the telson fused with the last abdominal somite. Members of the Superorder Pancarida, *i.e., Thermosbaena* and *Monodella* of the order Thermosbaenacea, also have a short carapace and must not be neglected in an analysis of the phylogenetic relationships of the fossils. In the females of the Pancarida the carapace functions as a dorsal marsupium. Also, it is a remote possibility that *Anthracocaris* and *Acadiocaris* are an ancestral stage in the evolution of the Syncarida, or they may not be closely related to any extant taxon. A new order, Anthracocaridacea, is definitely justified by the known morphological features of the fossils, but proof of its relationships with the Peracarida, Pancarida, and the Syncarida must await further discovery. The order Anthracocaridacea is tentatively assigned to the Peracarida.

Several genera of inadequately known Paleozoic arthropods have been referred to the isopods. Because of the previous misinterpretation of *Acanthotelson,* it has been postulated that a relationship exists between the Syncarida and the Isopoda (Nicholls, 1929, Calman, 1934, Glaessner, 1957 a). This interpretation is not supported by comparative morphology nor the fossils when they are correctly interpreted.

Necrogammarus salweyi Woodward (1871 b) from the Silurian of England, *Praearcturus gigas* Woodward (1871 a) from the Devonian of England, "*Amphipeltus paradoxus*" of Matthews (1895) from the Devonian of Nova Scotia, *Oxyuropoda ligioides* Carpenter and Swain (1908) from the Devonian of Ireland, and *Camptophyllia ethringhami* and *C. fallax* Gill (1924) from the Pennsylvanian of England have been interpreted as isopods. Van Straelen (1931, p. 86) was correct in removing them from serious consideration as representative of any of the Malacostraca. They may be related to the Arthropleurida, an order of Trilobitomorpha. The interpretation of *Palaeocrangon problematicus* (Schlotheim) from the Permian of Germany and England as an isopod has recently been revived by Glaessner (1957 b). Superficial resemblances between these fossils and the phreatoicoids may be misleading. Proof of phylogenetic relationship is lacking on these poorly known fossils.

The Permo-Triassic time was a critical interval in the evolution of the modern eumalacostracan types, but except for the syncarids, fossils are rare in these deposits. *Schimperella beneckei* and *S. kessleri* Bill (1914, p. 310-322) from the Triassic of France are the oldest authentic mysidaceans. Antiquity of the Mysidacea will be extended to the Pennsylvanian if *Anthracomysis rostrata* Van Straelen (1922, p. M39-M40) from Belgium proves to belong to this taxon. Several genera of primitive decapods occur in Triassic strata. They represent the primitive extant families Peneidae and Eryonidae as well as two extinct families, the Glypheidae and the Pemphicidae. Rapid differentiation of modern decapod types occurred in the Jurassic. Though *Anthracaris* from the Pennsylvanian has some characteristics of the eryonid decapods, it is a pygocephalomorph. The only Paleozoic fossil that may be a true decapod is *Palaeopemphix sosiensis* Gemmellaro (1892, p. 19-20) and related species from the Permian of Sicily. The carapaces figured by Gemmellaro (pl. 4, figs. 1-9) have cervical, post-cervical, and branchiocardiac sulci comparable to those of *Pseudoglyphea spinosus* and *Pseudopemphix alberti* (Glaessner, 1960, p. 41, fig. 19) from the Triassic. Two species of true isopods have been reported from the Triassic of Europe (Van Straelen, 1931, p. 42, 47). They are *Anhelkocephalon handlirschi* Bill and *Isopodites triasinus* (Picard). Several genera are represented in the Jurassic. The survey of Triassic Eumalacostraca is completed with mention of *Anaspidites* (Brooks, 1962 b) from Australia. It is a true anaspidacean syncarid.

Siewing (1956) has made a detailed study of the comparative anatomy of the extant eumalacostracan types. A wealth of information is employed in the consideration of their interrelationships and his interpretation of the phylogenetic relationship is not likely to be challenged. Both the Syncarida and Hoplocarida are believed to have evolved early in the phylogenetic differentiation of the Eumalacostraca. This conclusion is supported by the fossil record. There is definitely no relationship between the syncarids and isopods. The only evidence for interpretation of the interrelationships and evolution of the Peracarida is comparative anatomy of the Recent species. Siewing's interpretations of the Recent orders of Eumalacostraca are herein accepted but placed in relation to the fourth dimension and the paleontological record (Text Pl. 16). It should be noted that the Decapoda may be polyphyletic. The Penaeidae may have evolved from the Eocaridacea whereas the Eryonidae probably evolved from the Pygocephalomorph. It is likely that the actual ancestral stock for the majority of the decapod types is unknown.

By establishing a new order of syncarids, the Palaeocaridacea, it is possible to logically classify the Paleozoic syncarids. The problem of classification of the Paleozoic Eumalacostraca with a carapace is more difficult. As has been demonstrated, a vertical (phylogenetic) classification for these animals consistent with the taxa established for Recent Crustacea is impossible. Divergent evolution toward modern morphological types can be distinguished, but there is no proof that the Paleozoic species are truly ancestral. Some may be homeomorphs as a result of convergent or parallel evolution. Some of the fossils are too inadequately known for a strict phylogenetic classification and some represent extinct divergent stocks, but most significantly, their inclusion in modern taxa would require revision and redefinition of established taxonomic units. A vertical classification would be detrimental in that it would obscure the tenuousness of the inferred phylogenetic relationships. It is believed a horizontal classification is the only possible systematic solution. Thus, a new superorder, the Eocarida, is proposed for the extinct orders Eocaridacea, Pygocephalomorpha, and Palaeostomatopoda which have a carapace that is not fused with the thorax, biramous thoracic appendages with a single joint in the sympod, and with furcal lobes and a median spine on the telson. The females may or may not have a marsupium and a seminal receptacle or they may have both.

The resulting classification of the Paleozoic fossils, in which new orders and families are diagnosed is:

Class **CRUSTACEA** Pennant, 1777

Subclass **MALACOSTRACA** Latreille, 1802

Series **EUMALACOSTRACA** Grobben, 1892

Superorder **EOCARIDA,** new superorder

Order **EOCARIDACEA,** new order

Length of thorax reduced, caridoid facies.

Family **EOCARIDIDAE,** new family

Large peduncle of first antennae, no carinae or doublure on carapace.

Genus **EOCARIS** Brooks, 1962

Genus **DEVONOCARIS** Brooks, 1962 (Incertae sedis)

Family **PALAEOPALAEMONIDAE,** new family

Peduncle of first antennae large, carinae and an incipient branchiostegal keel on carapace.

Genus **PALAEOPALAEMON** Whitfield, 1880

Family **ANTHRACOPHAUSIIDAE,** new family

Proximal joint of peduncle of first antennae has hollowed out "eye sockets", no carinae or branchiostegal keels on carapace.

Genus **ANTHRACOPHAUSIA** Peach, 1908

Genus **CRANGOPSIS** Salter, 1863

Genus **BELOTELSON** Packard, 1886 (Incertae sedis)

Genus **PALAEMYSIS** Peach, 1908 (Incertae sedis)

Genus **ANTHRACOMYSIS** Van Straelen, 1922 (Incertae sedis)

Order **PALAEOSTOMATOPODA**, new order

Carapace shallow with articulated rostrum, four posterior thoracic somites freely articulated, thoracic somites two to five subchelate and subequal in size.

Family **PERIMECTURIDAE** Peach, 1908

With characteristics of the order.

Genus **PERIMECTURUS** Peach, 1908

Genus **ARCHAEOCARIS** Meek, 1872

Order **PYGOCEPHALOMORPHA** (Beurlen, emended), 1930

Branchiostegal development of the pleurae of the carapace, cephalothorax and abdomen equal in length, or the abdomen is reduced.

Family **PYGOCEPHALIDAE**, new family

Carapace with antero-lateral spines.

Genus **PYGOCEPHALUS** Huxley, 1857

Genus **ANTHRACARIS**, new genus

Genus **MAMAYOCARIS**, new genus

Genus **PSEUDOTEALLIOCARIS**, new genus

Family **TEALLIOCARIDIDAE**, new family

Carapace without antero-lateral spines, and thoracic sternites with sternal processes.

Genus **TEALLIOCARIS** Peach, 1908

Genus **PSEUDOGALATHEA** Peach, 1882 (Incertae sedis)

Family **NOTOCARIDIDAE**, new family

Abdomen reduced and reflexed under thorax.

Genus **NOTOCARIS** Broom, 1931
Genus **PAULOCARIS** Clarke, 1920

Superorder **PERACARIDA** Calman, 1904
Order **ANTHRACOCARIDACEA,** new order (Incertae sedis)

Carapace covering only first two thoracic somites, articulation between sixth abdominal somite and telson not fused.

Family **ANTHRACOCARIDIDAE,** new family

With characteristics of the order.

Genus **ANTHRACOCARIS** Calman, 1932

Genus **ACADIOCARIS,** new genus
Superorder **SYNCARIDA** (Packard), 1885
Order **PALAEOCARIDACEA** Brooks, 1962

Eight free thoracic somites, stalked compound eyes, normal pleopods and no caudal furca.

Family **PALAEOCARIDIDAE** (Siewing), 1959

None of the thoracic endopods modified as raptorial appendages, rami of uropods lobate and telson spatulate.

Genus **PALAEOCARIS** Meek and Worthen, 1865

Synonyms: *Nectotelson* Brocchi, 1880; *Palaeorchestia* Zittle, 1882; *Gasocaris* Fritsch, 1901.

Genus **SQUILLITES** Scott, 1938
Genus **PALAEOSYNCARIS,** new genus

Family **URONECTIDAE** Cockerell, 1916

Endopods of second thoracic appendages raptorial, rami of uropods lobate and telson spatulate.

Genus **URONECTES** Bronn, 1850

Family **ACANTHOTELSONIDAE,** Cockerell, 1916

Second and third thoracic appendages raptorial, rami of uropods and the telson styloid.

Genus **ACANTHOTELSON** Meek and Worthen, 1865

Family **PLEUROCARIDIDAE** (Chappuis), 1915

None of the thoracic appendages specialized for raptorail purposes, large thoracic pleurae, rami of uropods and the telson styloid.

Genus **PLEUROCARIS** Calman, 1911

Order **ANASPIDACEA** (Calman), 1904

First thoracic somite incorporated into cephalic tagma, seminal receptacle, no furca.

Family **ANASPIDIDAE** Thomson, 1894

Exopods on thoracic appendages one to seven, endopods of pleopods reduced, stalked compound eyes.

Genus **ANASPIDITES** Brooks, 1962

Family **KOONUNGIDAE** Sayce, 1908

No scale on second antennae, eyes sessile, last two thoracic limbs are uniramous and the pleopods are all uniramous, except the first two in males which are copulatory organs. No fossils known.

Family **CLARKECARIDIDAE** Brooks, 1962

Vestige of suture between head and first thoracic somite, sigmoidal anterior sulcus on cephalon, long spinelike abdominal pleurae.

Genus **CLARKECARIS** Mezzalira, 1952

Order **BATHYNELLACEA** (Chappuis), 1915

Eight free thoracic somites, telson fused with sixth abdominal somite, furca, pleopods reduced or absent, no seminal receptacle.

Family **BATHYNELLIDAE** Chappuis, 1915

No fossils known.

Superorder **EUCARIDA** Calman, 1904
Order **DECAPODA** Latreille, 1802
Family **GLYPHEIDAE** Winckler, 1883
Genus **PALAEOPEMPHIX** Gemmellaro, 1892

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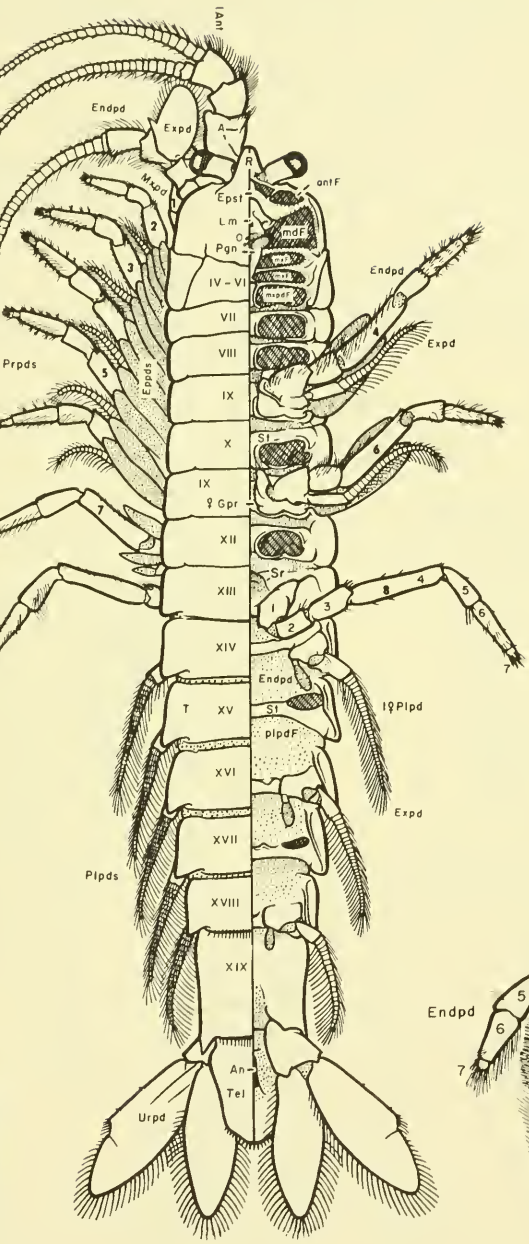
PLATES

Explanation of Text Plate 1

Page

Anaspides tasmaniae (Thomson) 170

Dorsal and ventral skeletal morphology of the left side diagrammatically drawn; X 5. Representative appendages have greater enlargement.



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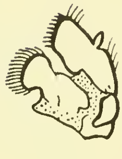

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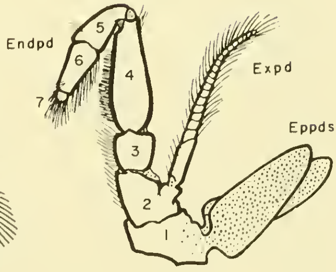

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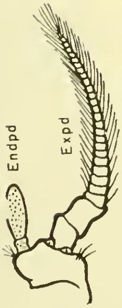

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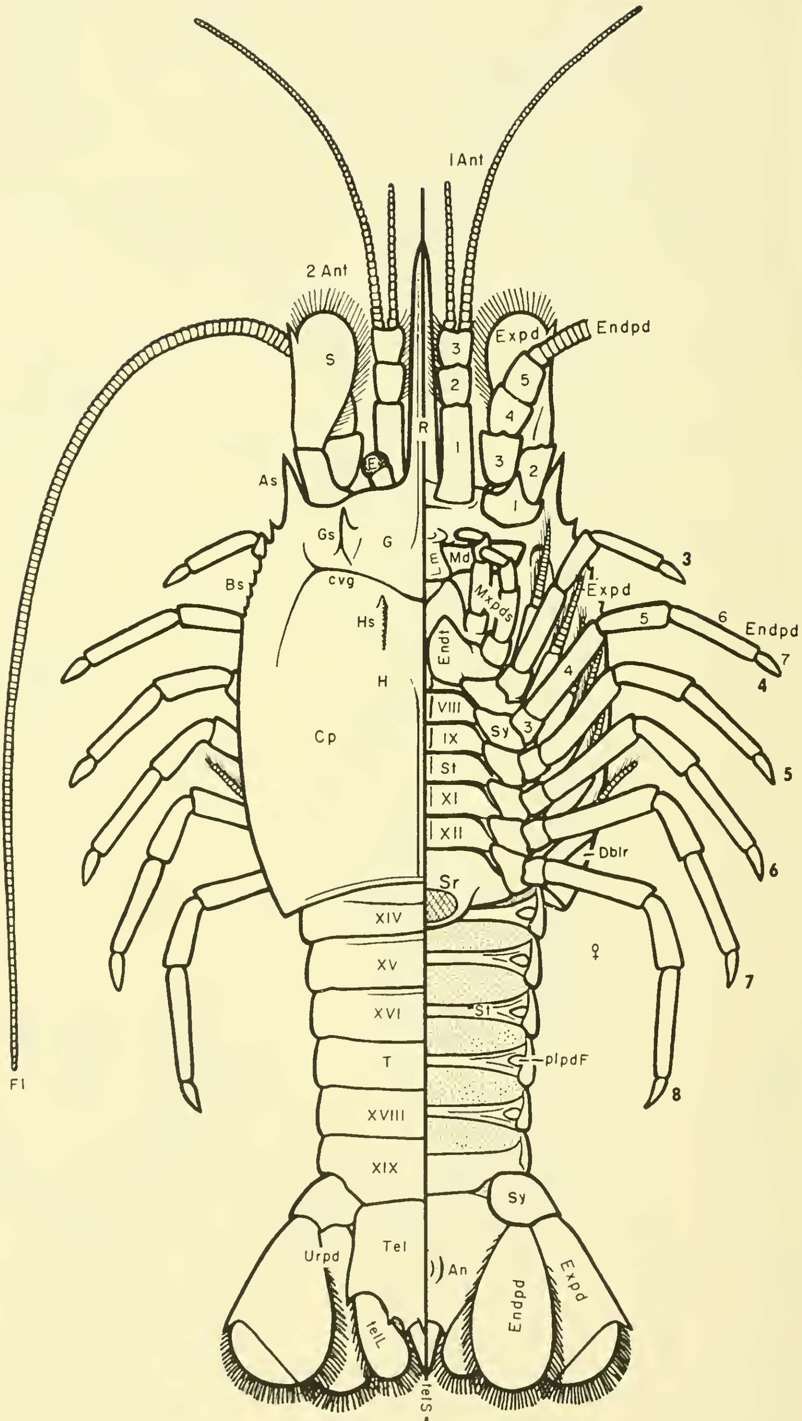
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Explanation of Text Plate 2

	Page
Anthracaris gracilis (Meek and Worthen) Dorsal and ventral skeletal morphology of the left side diagrammatically drawn; X 3.5.	173

Explanation of Text Plate 3

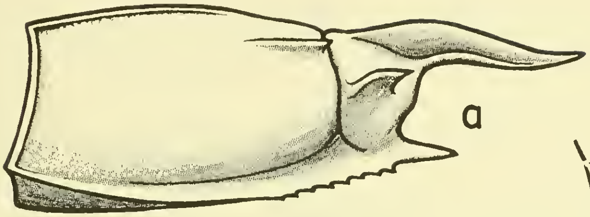
Figure Page

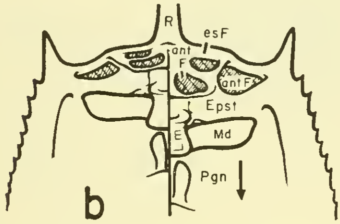
a. **Anthracaris gracilis** (Meek and Worthen) 173
Restoration of carapace; X 3.5.

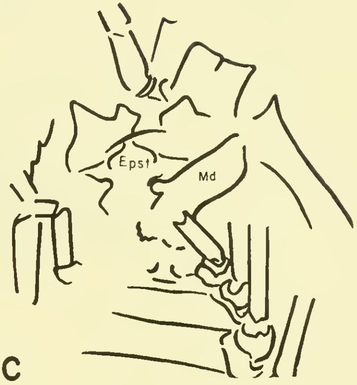
b. **A. gracilis** 173
Ventral skeletal features of the anterior portion of the head; X 4.5. The right side has been displaced posteriorly to show the shape and position of the foramina.

c. **A. gracilis** 173
Diagrammatic drawing of ventral skeletal features of PY 19931; note the secondary articulation between the mandible and the epistome.

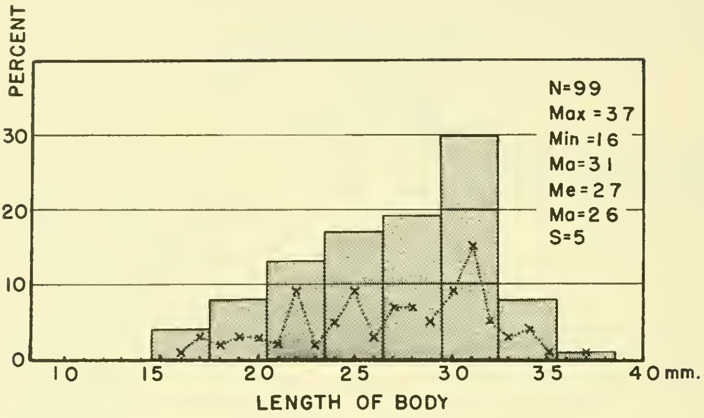
d. Table of measurements in millimeters of representative specimens of *A. gracilis* and their proportions. The results of statistical analysis of observations of the total sample are shown at the right.







d	REPRESENTATIVE SPECIMENS										STATISTICAL ANALYSIS						
	ISMNH 3067	UI X-343	USNM 38843	PY19932	PY19933	PY19936	PY19937	PY19983	PY19993	PY19996	N	Max	Min	Mo	Me	Ma	S
LENGTH OF BODY	24	32	22	26	33		37	17	31	31	99	37	11	31	27	26	5
LENGTH OF CARAPACE	12	16	12	11	15	18	15	8	14	13	64	18	8	14	14	13	1.6
CERVICAL GROOVE				7	11	13	10	6	10	10							
LENGTH OF ROSTRUM							10		8	8							
CARAPACE MAX. WID.	11	14	10	9	12	16		7	12	13							
CARAPACE ANT. WID.	8	12	7	6	9	10		6		10							
CARAPACE POST. WID.	9	12	8	7	9	10			9	10							
LENGTH OF A.-L. SPINE	1	1	1	1.3	1.5	2		0,7									
SERRATIONS	5	6	5	8	7			8		8	35	11	5	7	8	8	2
PROPORTIONS																	
CARAPACE LENGTH: BODY LENGTH	.50	.51	.55	.43	.45		.41	.48	.44	.42	45	.52	.39	.50	.46	.46	.04
CARAPACE MAX. WID.: CARAPACE LENGTH	.92	.85	.83	.82	.78	.90		.88	.89	1.0	51	1.1	.68	1.0	.92	.90	.10
CERVICAL GROOVE: CARAPACE LENGTH				.64	.74	.73	.73	.76	.78	.77	32	.84	.64	.74	.75	.75	.04
ROSTRUM LENGTH: CARAPACE LENGTH							.57		.59	.58	8	.80	.35	.60	.60	.60	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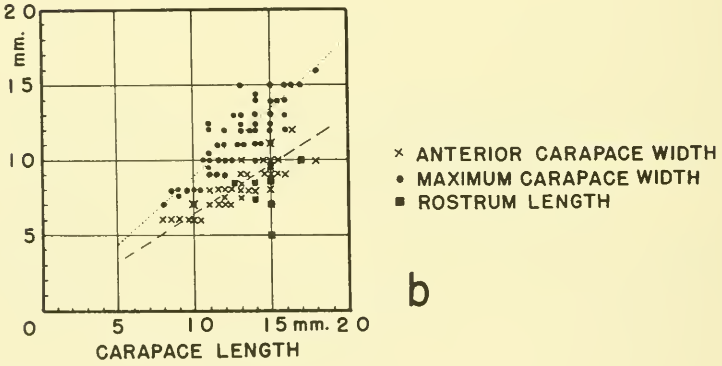
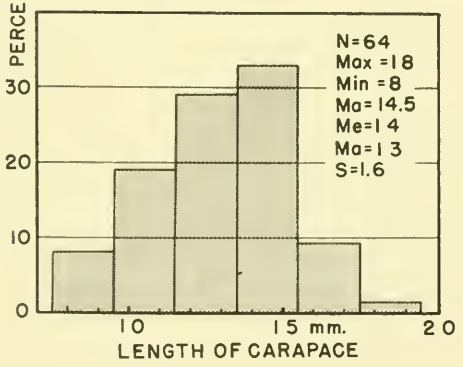
20
10
0
N=99
Max =37
Min =16
Ma=31
Me=27
Ma=26
S=5
10
15
20
25
30
35
40 mm.
LENGTH OF BODY

a


20
mm.
15
10
5
0
5
10
15 mm. 20
CARAPACE LENGTH
× ANTERIOR CARAPACE WIDTH
• MAXIMUM CARAPACE WIDTH
■ ROSTRUM LENGTH

b

c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20
10
0
N=64
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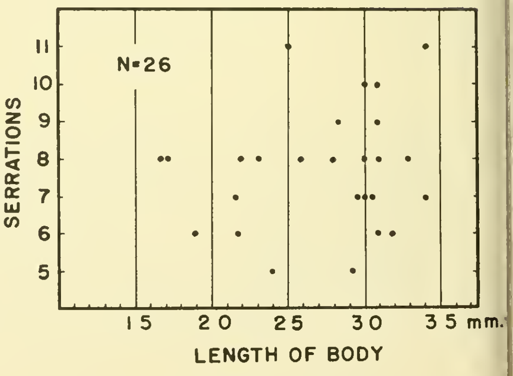
Min =8
Ma= 14.5
Me=14
Ma=13
S=1.6
10
15 mm.
20
LENGTH OF CARAPACE

d


N=26
SERRATIONS
11
10
9
8
7
6
5
15
20
25
30
35 mm.
LENGTH OF BODY

Explanation of Text Plate 4

Figure

a. Size frequency of the length of the body to specimens of *Anthracaris gracilis* (Meek and Worthen) presented as a histogram and a line graph. Statistical parameters for the population are given at the right.

b. Anterior width of the carapace, maximum width of the carapace and the length of the rostrum of specimens of *A. gracilis* plotted relative to the length of the carapace of each individual as a scatter diagram to show allometric relationships.

c. Size frequency of the length of the carapace of specimens of *A. gracilis* presented as a histogram. Statistical parameters for the population are given at the right.

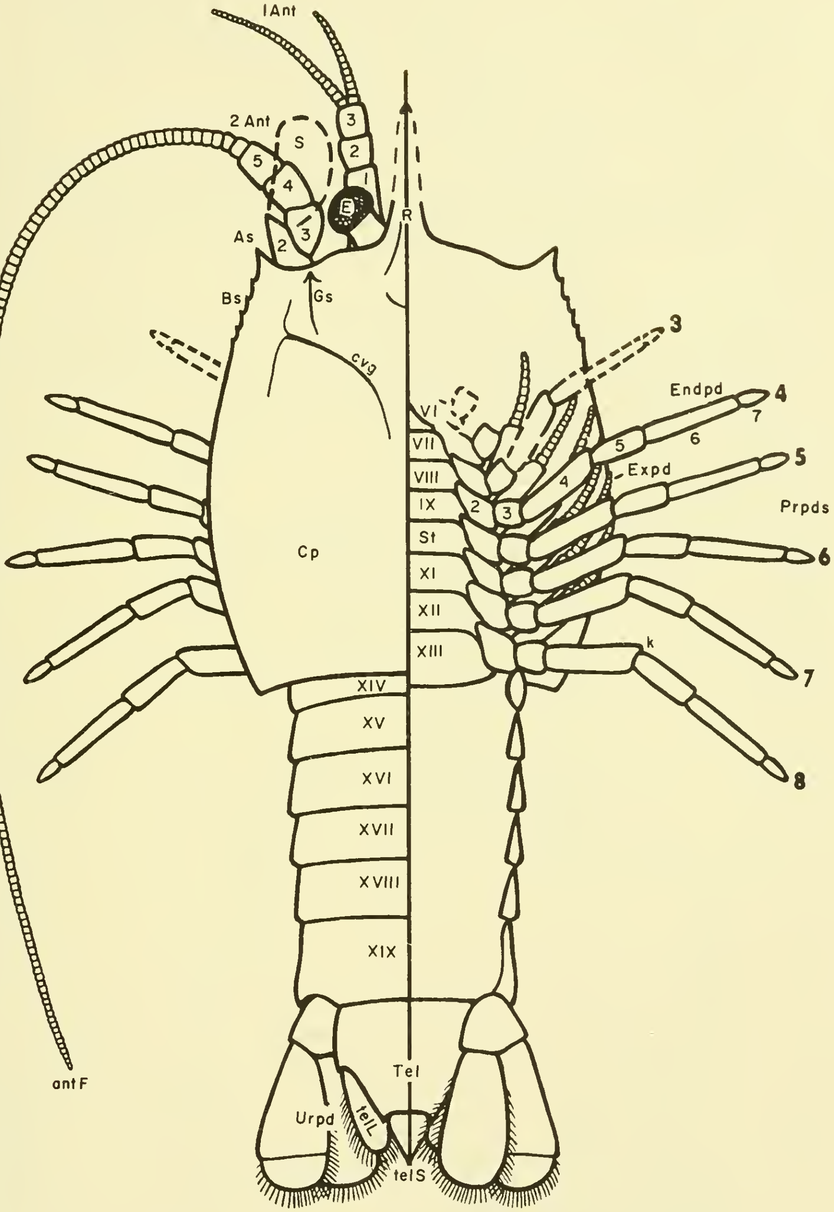
d. Scatter diagram showing variation in number of serrations relative to the body length of specimens of *A. gracilis.*

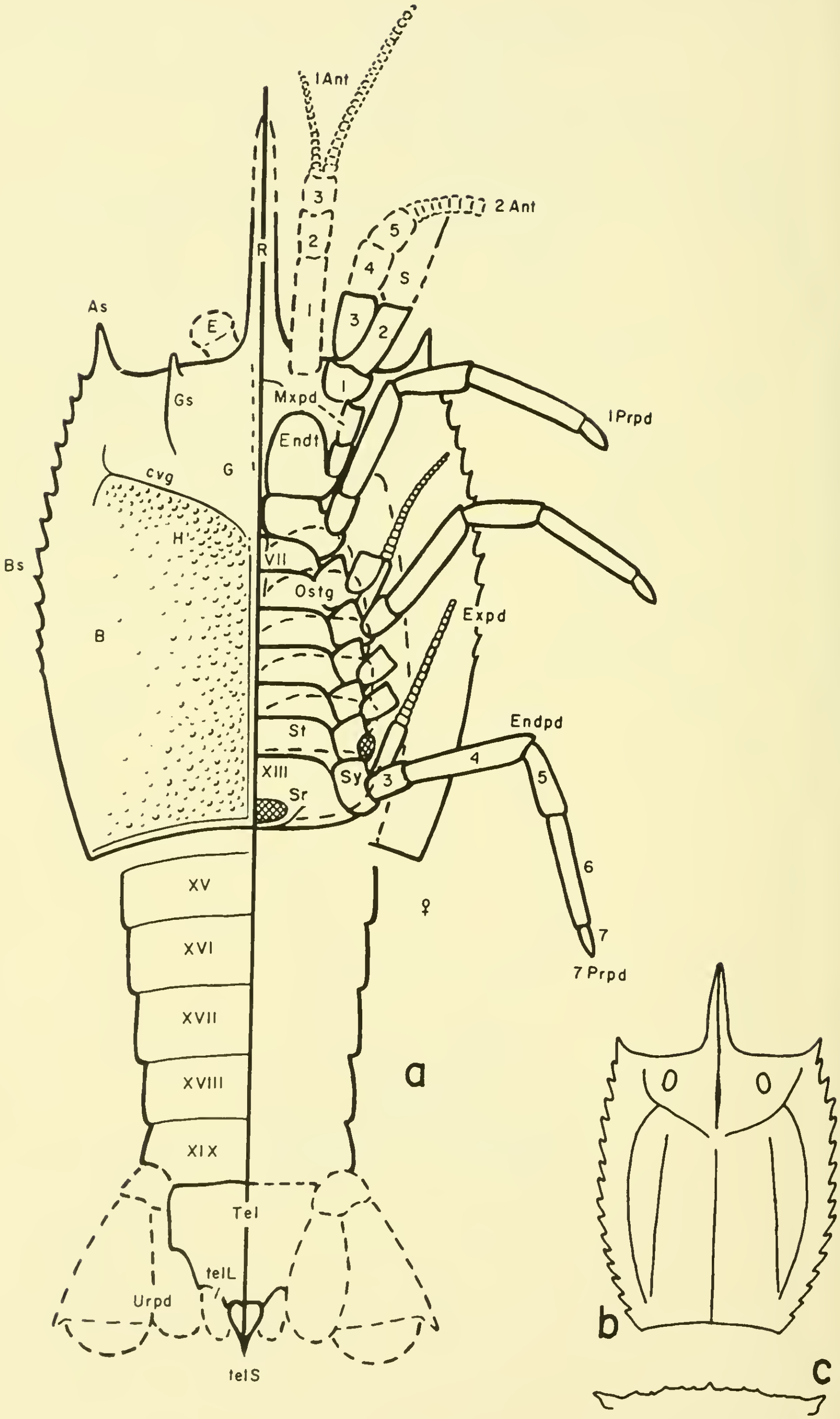
Explanation of Text Plate 5

Page

Mamayocaris jepseni n.g., n. sp. 189
Dorsal and ventral skeletal morphology of the left side diagrammatically drawn; X 6.

Text Plate 5


1Ant
2 Ant
S
3
2
1
5
4
3
2
E
R
As
Bs
Gs
cvg
3
Endpd
4
7
6
5
Expd
5
Prpds
6
7
8
k
VI
VII
VIII
IX
St
XI
XII
XIII
4
2
3
Cp
XIV
XV
XVI
XVII
XVIII
XIX
Tel
Urpd
telL
telS
antF


1Ant
3
2
1
R
2 Ant
5
4
S
3
2
1
As
E
Gs
Mxpd
1Prpd
Endt
cvg
G
H
VII
Bs
Ostg
Expd
B
Endpd
St
XIII
Sy
3
4
5
Sr
6
XV
♀
XVI
7
7 Prpd
XVII
a
XVIII
XIX
Tel
telL
Urpd
telS
b
c

Explanation of Text Plate 6

Figure		Page
a.	**Pygocephalus dubius** (Milne-Edwards)	194
	Dorsal and ventral skeletal morphology of the left side diagrammatically drawn. The oostegites shown by discontinuous lines would normally obscure the sternum in adult females; X 5.	
b.	**P. dubius**	194
	Drawing of carapace by Rhodes and Wilson (1957, text fig. 2).	
c.	**P. dubius**	194
	Median transverse section of carapace as interpreted by Rhodes and Wilson (1957, text fig. 2).	

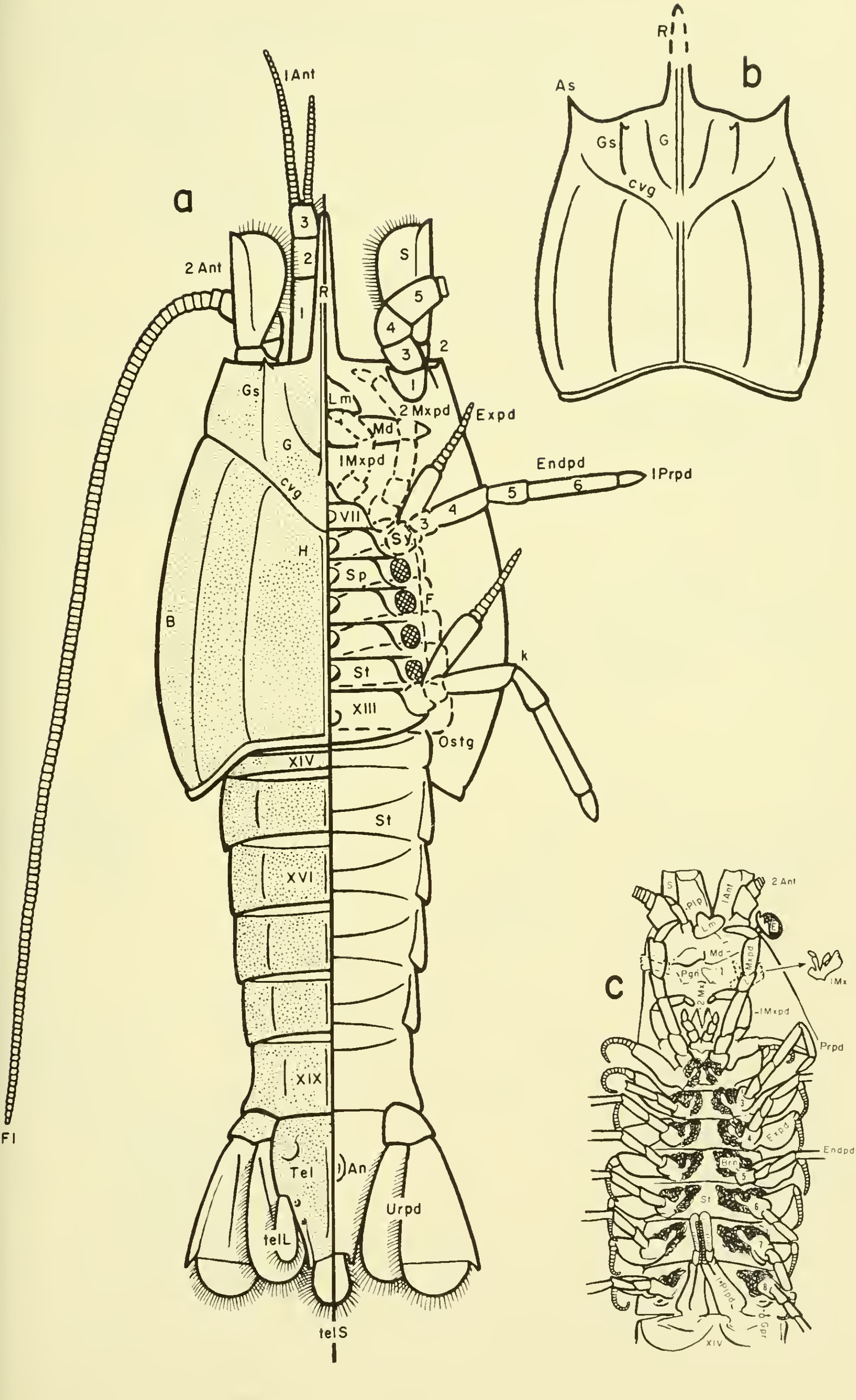
Explanation of Text Plate 7

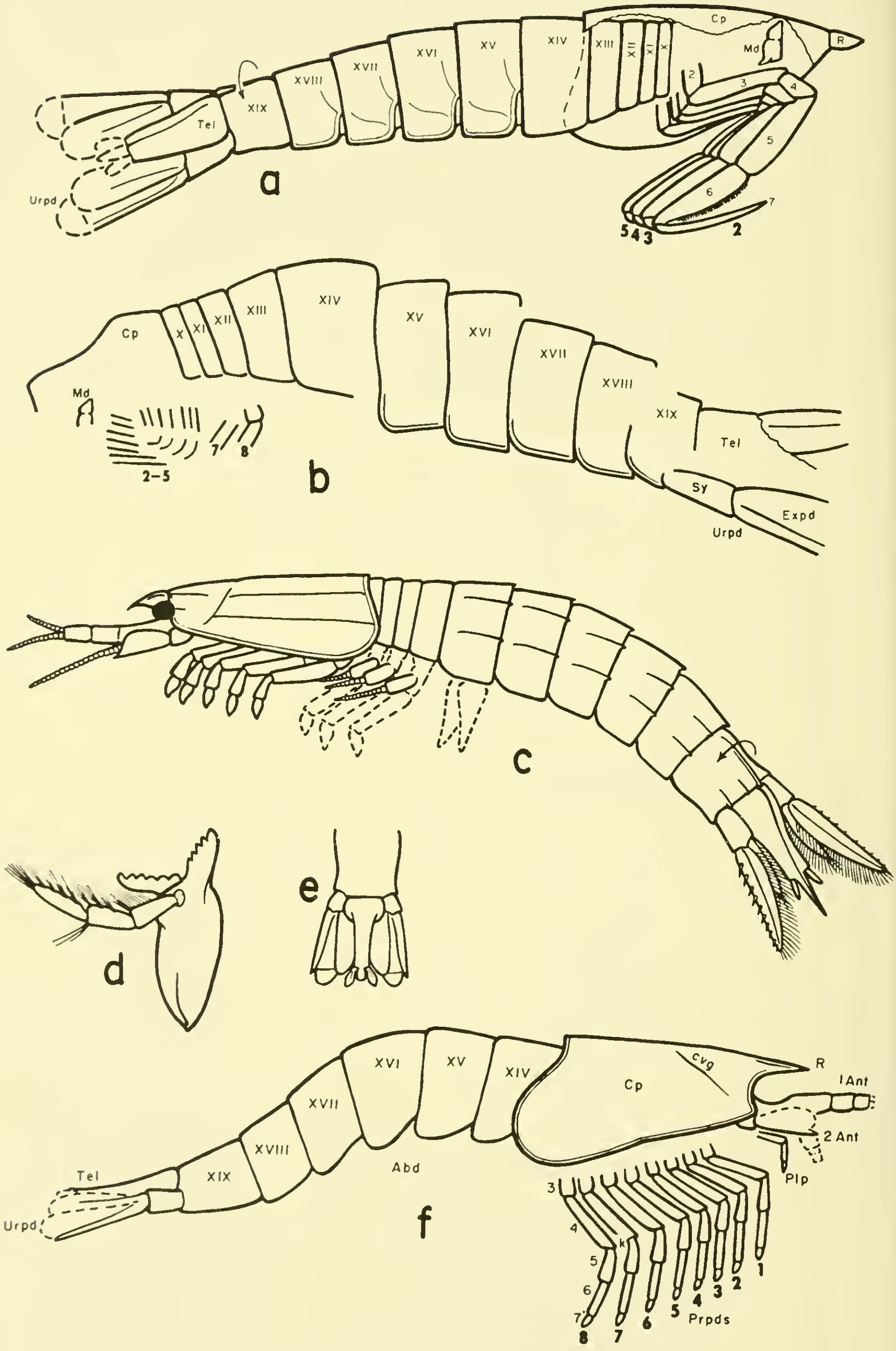
Figure — Page

a. **Tealliocaris loudonensis** Peach 200
Dorsal and ventral skeletal morphology of the left side diagrammatically drawn; X 5. The oostegites shown by discontinuous lines would obscure the sternum in adult females.

b. **Pseudotealliocaris caudafimbriata** (Copeland) ... 200
Dorsal features of the carapace; X 3.

c. **Tealliocaris loudonensis** Peach 200
Ventral features of cephalothorax as interpreted by Peach (1908, pl. 1, fig. 7 a) redrawn and simplified.


a
1 Ant
2 Ant
3
2
1
R
S
5
4
3
2
1
Gs
G
Lm
2 Mxpd
Md
Expd
1 Mxpd
Endpd
5
6
1 Prpd
4
3
cvg
VII
Sy
H
Sp
F
B
St
k
XIII
Ostg
XIV
St
XVI
XIX
Tel
An
Urpd
telL
telS
Fl
b
R
As
Gs
G
cvg
c
S
Plp
1 Ant
2 Ant
Lm
E
Md
Pgn
1
Mxpd
2
1 Mx
2 Mx
1 Mxpd
Prpd
3
4
Expd
Endpd
Brn
5
St
6
7
8
1 Plpd
Gpr
XIV

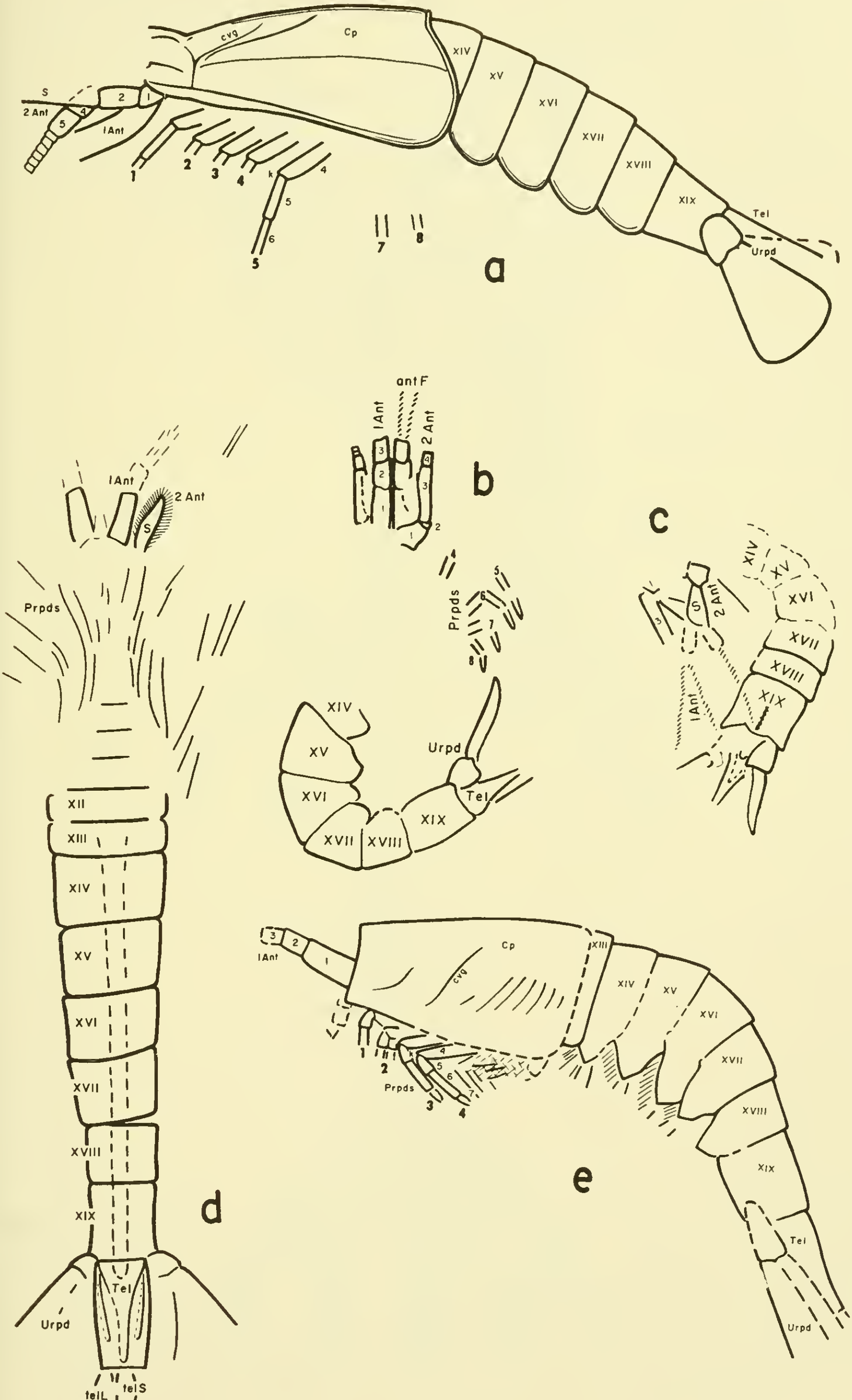

Cp
Md
R
XIX
XVIII
XVII
XVI
XV
XIV
XIII
XII
XI
X
2
3
4
5
6
7
Tel
Urpd
a
5 4 3
2
Cp
X
XI
XII
XIII
XIV
XV
XVI
XVII
XVIII
XIX
Md
2–5
7
8
b
Tel
Sy
Urpd
Expd
c
d
e
R
cvg
Cp
1 Ant
2 Ant
XIV
XV
XVI
XVII
XVIII
XIX
Abd
Tel
Urpd
f
Plp
3
4
5
6
7
k
8
7
6
5
4
3
2
1
Prpds

Explanation of Text Plate 8

Figure		Page
a.	**Archaeocaris vermiformis** Meek Lateral restoration with portion of carapace removed to show known morphology of cephalothrax; X 3.5.	211
b.	**A. graffhami,** n. sp. Diagrammatic drawing of holotype with morphological features identified; X 2.7.	214
c.	**Perimecturus elegans** Peach Restoration based on characters illustrated by Peach (1908, pl. 6, figs. 2-6); X 2.	211
d.	Mandible of Recent specimen of **Chloridella empusa** (Say)	213
e.	Caudal fan of **Anthracophausia dunsiana** Peach (1908, pl. 9, fig. 9).	203
f.	**Anthracophausia strongi,** n. sp. Lateral restoration; X 4.	203

Explanation of Text Plate 9

Figure	Page
a. **Palaeopalaemon newberryi** Whitfield Lateral restoration; X 2.	221
b. **Belotelson magister** Packard Diagrammatic drawing of Packard's plesiotype, USNM 38844; X 1.	206
c. **B. magister** Packard Diagrammatic drawing of the holotype, USNM 38844; X 1.	206
d. **Devonocaris cuylerensis** (Wells) Diagramatic drawing of holotype, Cornell Univ. 40020; X 5.	227
e. **Eocaris oervigi** Brooks Diagrammatic drawing of holotype, Ar27335 in Swedish Museum of Natural History; X 3.	172


a
S
2 Ant
1 Ant
cvg
Cp
1
2
3
4
5
6
7
8
k
XIV
XV
XVI
XVII
XVIII
XIX
Tel
Urpd
b
ant F
1 Ant
2 Ant
Prpds
Urpd
Tel
XIV
XV
XVI
XVII
XVIII
XIX
c
S
2 Ant
1 Ant
XIV
XV
XVI
XVII
XVIII
XIX
d
1 Ant
2 Ant
S
Prpds
XII
XIII
XIV
XV
XVI
XVII
XVIII
XIX
Tel
Urpd
telL
telS
e
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Cp
cvg
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XIV
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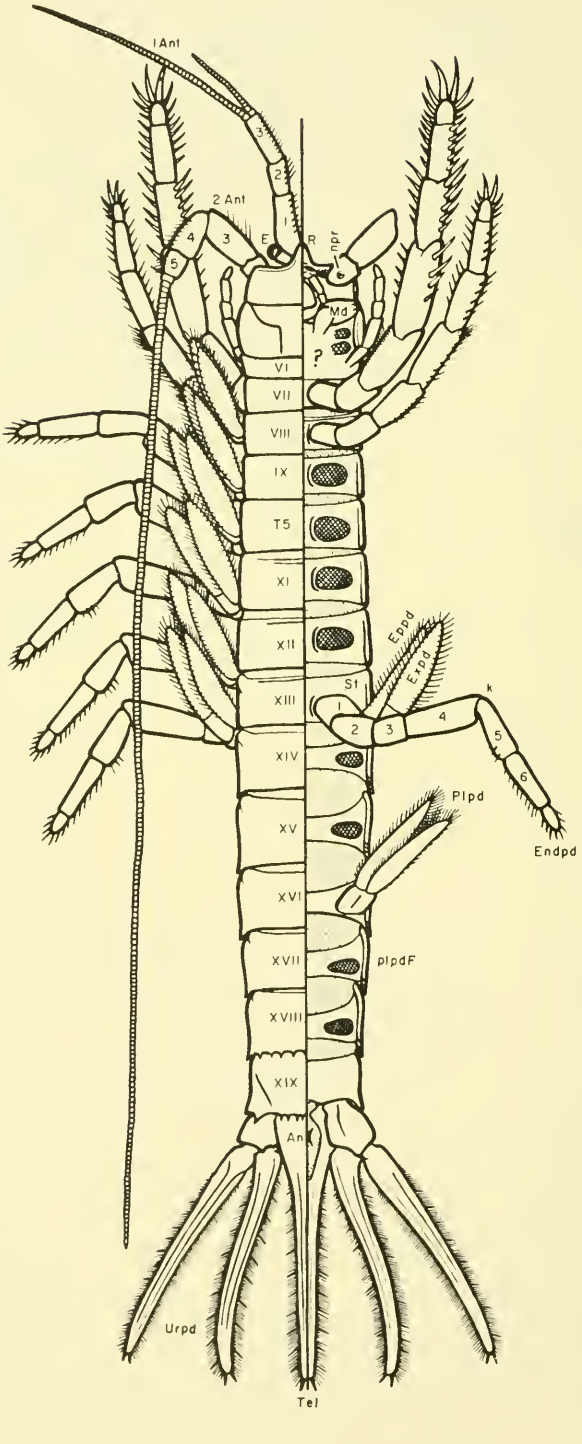
XVI
XVII
XVIII
XIX
Prpds
Tel
Urpd


1Ant
3
2
1
2 Ant
4
3
5
E
R
npr
Md
?
VI
VII
VIII
IX
T5
XI
XII
XIII
XIV
XV
XVI
XVII
XVIII
XIX
An
Eppd
Expd
St
k
1
2
3
4
5
6
Endpd
Plpd
plpdF
Urpd
Tel

Explanation of Text Plate 10

	Page
Acanthotelson stimpsoni Meek and Worthen Dorsal and ventral skeletal morphology of the left side diagrammatically drawn; X 4.	230

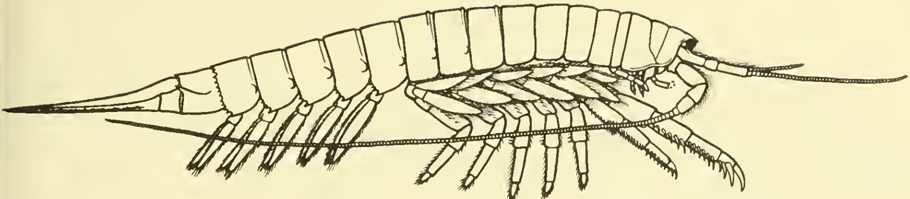
Explanation of Text Plate 11

Figure — Page

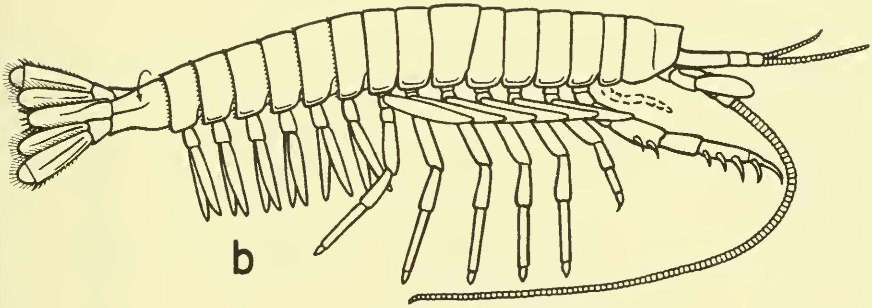
a. **Acanthotelson stimpsoni** Meek and Worthen — 230
Lateral restoration; X 2.

b. **Uronectes fimbriatus** (Jordan) — 230
Lateral restoration based upon specimens in the Museum of Comparative Zoology; X 3.

c. Table of measurements in milimeters of representative specimens of *Acanthotelson stimpsoni* Meek and Worthen and *Palaeocaris typus* Meek and Worthen.

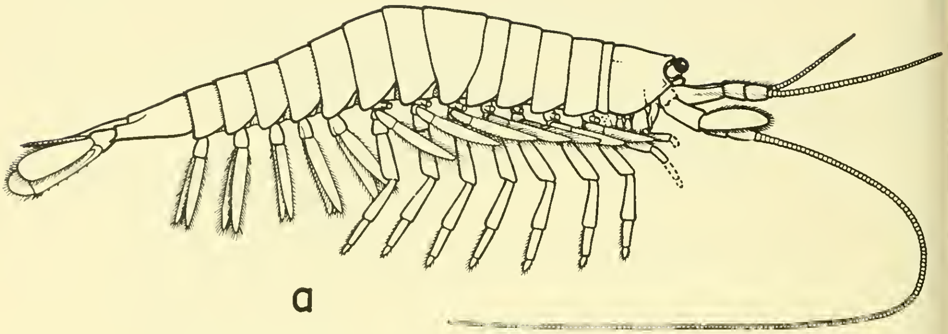


a



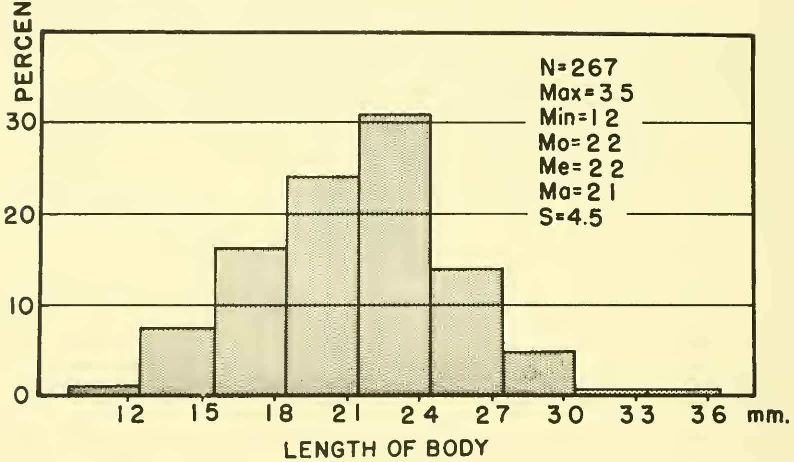
b

c	*Acanthatelsan stimpsani*							*Palaeacaris typus*							
	UI X-346	PY19842	MCZ 5210	PY19821	CMNH 4611	PY19867	PY19898	USNN 38850	MCZ 5197	PY19731	PY19734	PY19755	PY18850	PY19728	PY19734
LENGTH OF BODY	31	53	21	12	31	28	28	18	20	22	23	18	20	19	23
LENGTH OF HEAD	3	5	2.5	1.6	3.4	3	3.2	2.8	2	2.1	2.5	2.1	2.3	2.2	2.5
LENGTH OF THORAX	17	27	10	6	17	14	18	8.7	8.2	10.0	11.0	8.1		8.7	10.6
LENGTH OF 6th TH. T.	2.0	3.8	1.7	1.4	2.2	1.9	2.0	2.8	1.9	2.3	2.4	2.1	2.3	1.8	2.4
LENGTH OF 2nd ABD. T.	2.2	3.7	1.7	1.4	1.9	1.9	2.0	1.2	1.0	1.1	1.3	0.7	1.7	1.3	1.3
LENGTH OF 6th ABD. T.	2.2	3.8	2.0	1.4	2.0	1.5	2.3	2.3	1.7	2.3	2.3	2.3	2.3	2.0	2.3
LENGTH OF TELSON	8.0		7.2			8.0	8.6	3.5			3.7	3.2	4.5	3.1	3.2



a

b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Mo=22
Me=22
Ma=21
S=4.5
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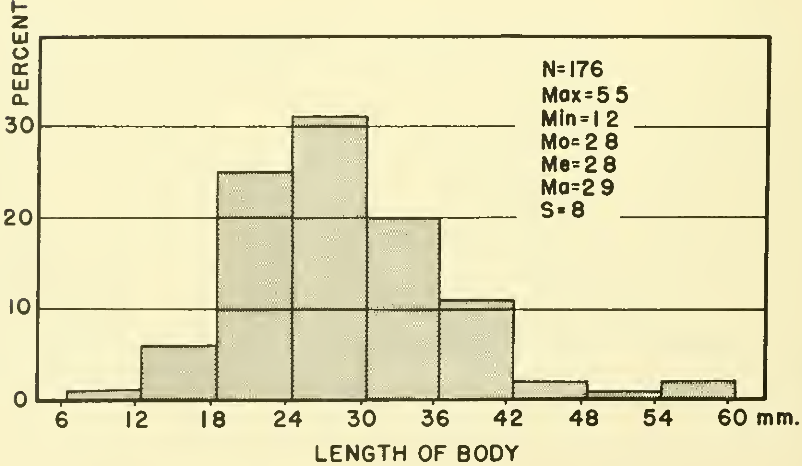
10
20
30
12
15
18
21
24
27
30
33
36 mm.
LENGTH OF BODY

c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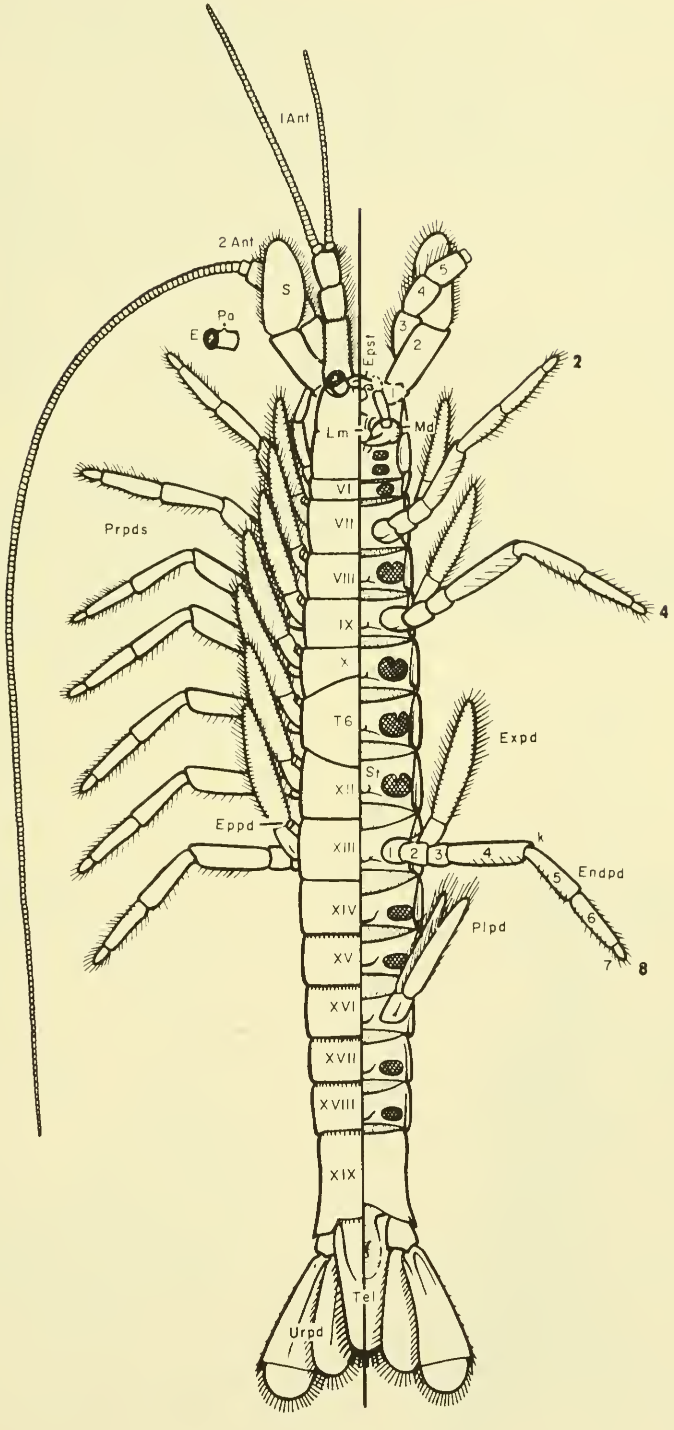
0
10
20
30
6
12
18
24
30
36
42
48
54
60 mm.
LENGTH OF BODY

Explanation of Text Plate 12

Figure	Page
a. **Palaeocaris typus** Meek and Worthen .... Lateral restoration; X 3.	240
b. Histogram of size frequency of the length of the body of specimens of *Palaeocaris typus* Meek and Worthen.	
c. Histogram of size frequency of the length of the body of specimens of *Acanthotelson stimpsoni* Meek and Worthen.	

Explanation of Text Plate 13

	Page
Palaeocaris typus Meek and Worthen Dorsal and ventral skeletal morphology of the left side diagrammatically drawn; X 5.	240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2 Ant
S
Pa
E
Epst
1
2
3
4
5
2
Lm
Md
VI
VII
Prpds
VIII
IX
4
X
T6
Expd
St
XII
Eppd
XIII
1
2
3
4
k
5
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XIV
Plpd
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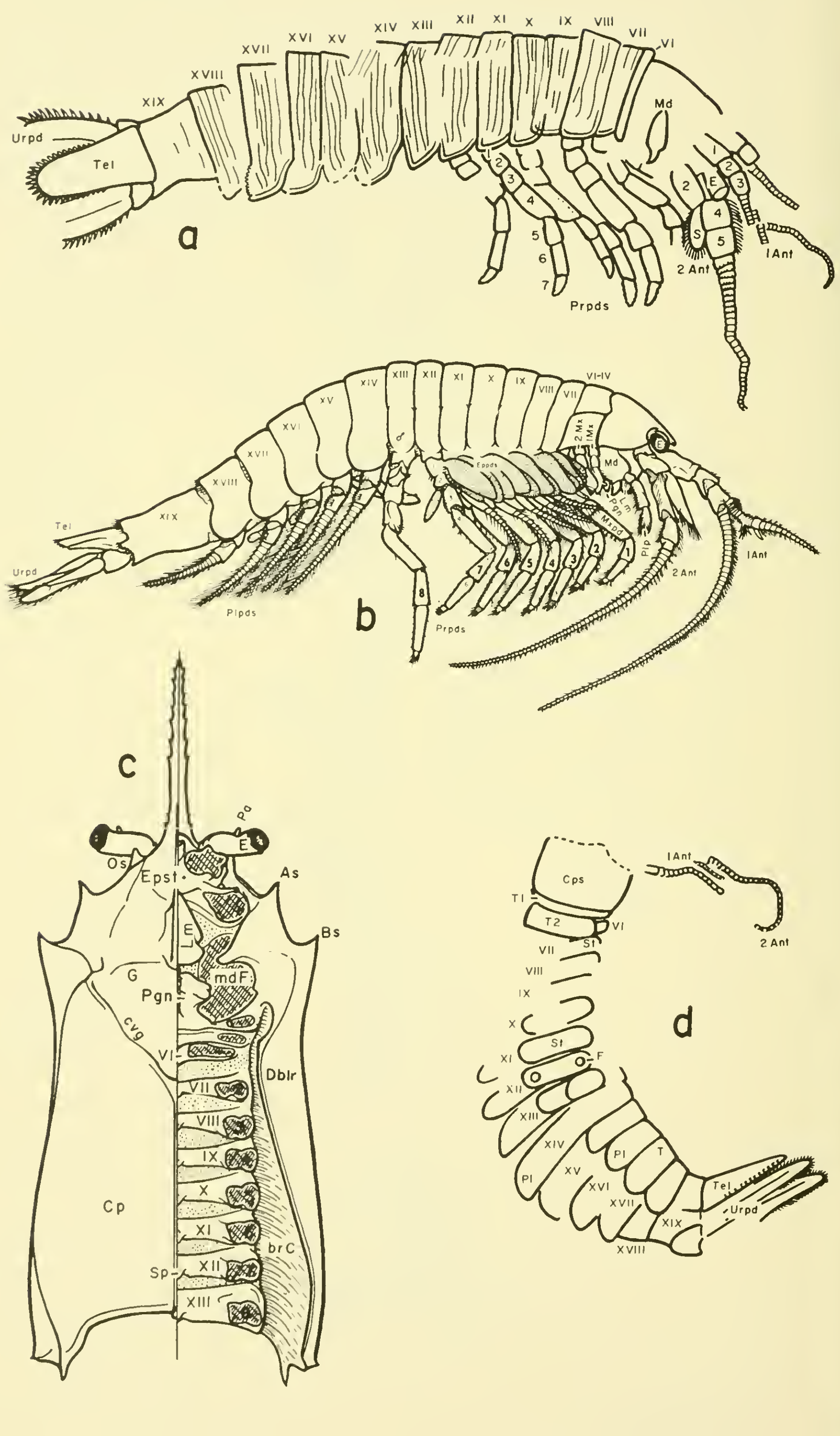
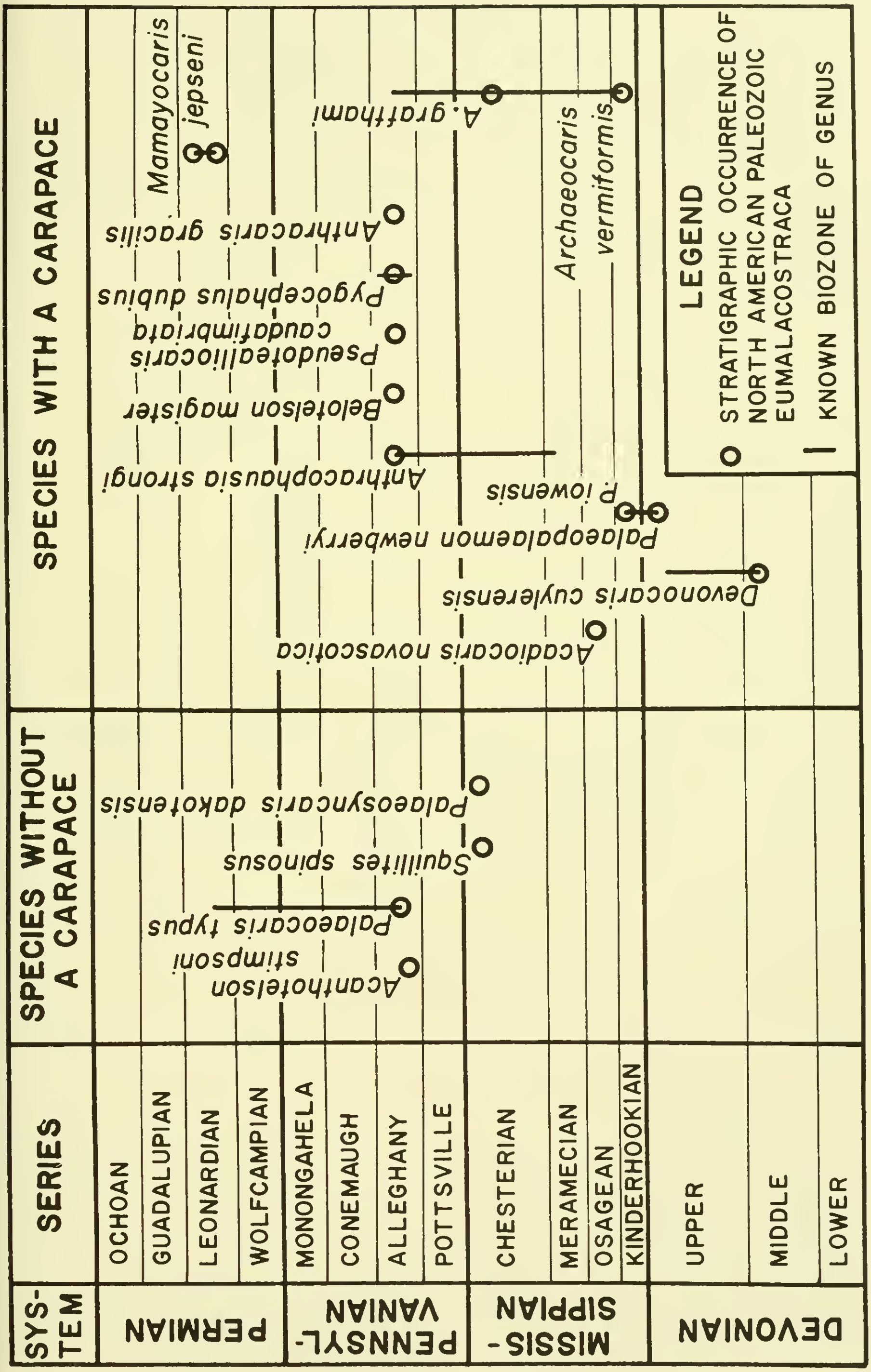
XV
7
8
XVI
XVII
XVIII
XIX
Tel
Urpd

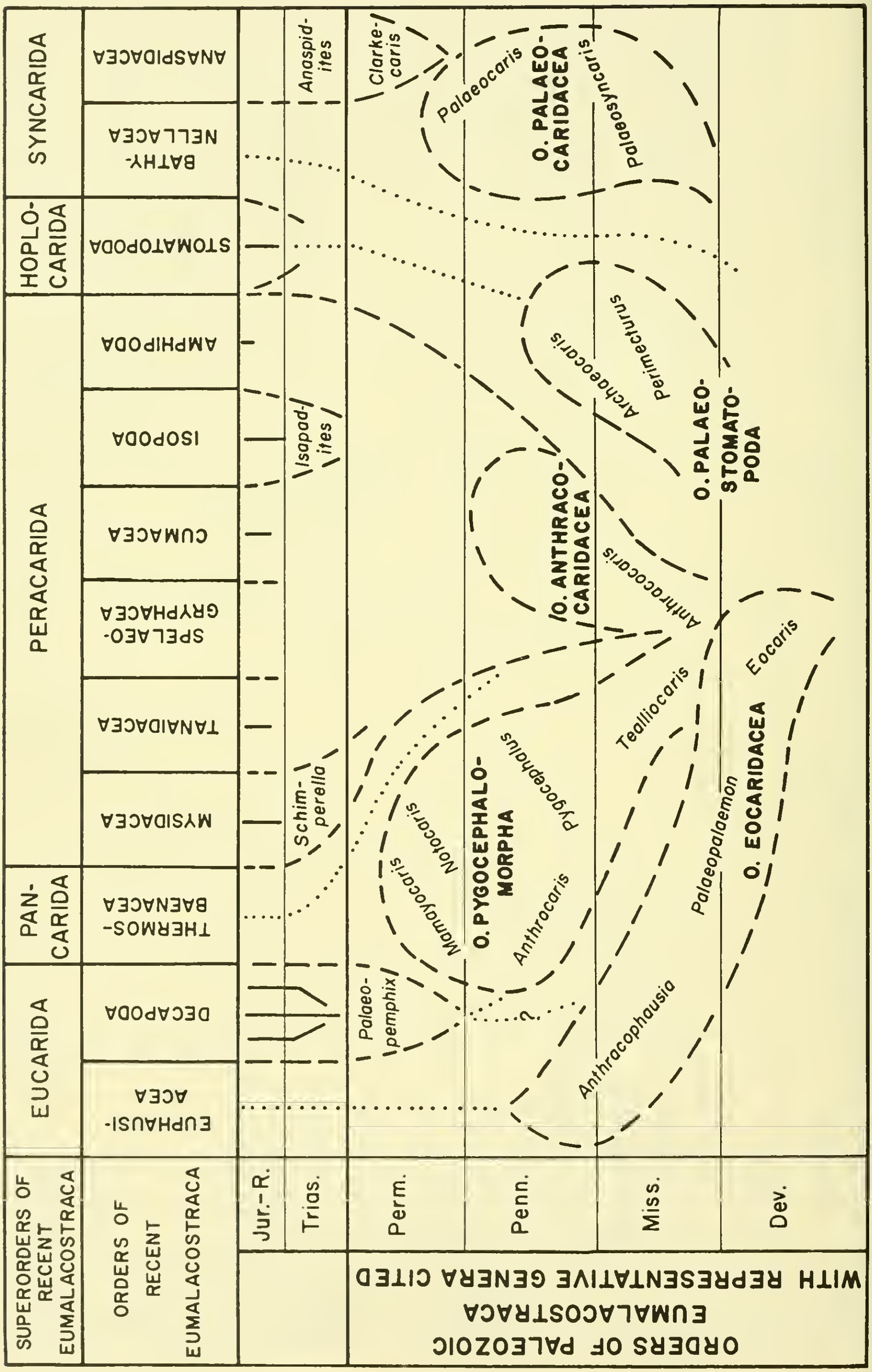

a
XIX
XVIII
XVII
XVI
XV
XIV
XIII
XII
XI
X
IX
VIII
VII
VI
Md
Urpd
Tel
1
2
3
4
5
6
7
E
S
2 Ant
1 Ant
Prpds
b
VI-IV
2 Mx
1 Mx
Eppds
E
Md
Lm
Pgn
Mxpd
Plp
8
Plpds
Prpds
c
Pa
E
Os
Epst
As
Bs
G
Pgn
mdF
cvg
Dblr
brC
Cp
Sp
d
Cps
T1
T2
St
F
Pl
T
Tel
Urpd

Explanation of Text Plate 14

Figure	Page
a. **Palaeosyncaris dakotensis,** n.g., n. sp. Diagrammatic drawing of the holotype; X 2.	251
b. **Anaspides tasmaniae** (Thomson) Skeletal morphology of Recent syncarid shown in lateral view; X 3.	170
c. **Gnathophausia gracilis** Suhm Dorsal and ventral skeletal morphology of cephalothorax of Recent lophogastrid mysidacean with appendages removed; X 3.	170
d. **Squillites spinosus** Scott Diagrammatic drawing of holotype; X 8.	254

Explanation of Text Plate 15


SYSTEM
SERIES
SPECIES WITHOUT A CARAPACE
SPECIES WITH A CARAPACE
PERMIAN
OCHOAN
GUADALUPIAN
LEONARDIAN
WOLFCAMPIAN
PENNSYLVANIAN
MONONGAHELA
CONEMAUGH
ALLEGHANY
POTTSVILLE
MISSISSIPPIAN
CHESTERIAN
MERAMECIAN
OSAGEAN
KINDERHOOKIAN
DEVONIAN
UPPER
MIDDLE
LOWER
Acanthotelson stimpsoni
Palaeocaris typus
Squillites spinosus
Palaeosyncaris dakotensis
Acadiocaris novascotica
Devonocaris cuylerensis
Palaeopalaemon newberryi
P. iowensis
Anthracophausia strongi
Belotelson magister
Pseudotealliocaris caudafimbriata
Pygocephalus dubius
Anthracaris gracilis
Mamayocaris jepseni
Archaeocaris vermiformis
A. graffhami
LEGEND
○ STRATIGRAPHIC OCCURRENCE OF NORTH AMERICAN PALEOZOIC EUMALACOSTRACA
| KNOWN BIOZONE OF GENUS


ORDERS OF PALEOZOIC EUMALACOSTRACA WITH REPRESENTATIVE GENERA CITED
SUPERORDERS OF RECENT EUMALACOSTRACA
ORDERS OF RECENT EUMALACOSTRACA
Jur.-R.
Trias.
Perm.
Penn.
Miss.
Dev.
SYNCARIDA
ANASPIDACEA
BATHYNELLACEA
HOPLOCARIDA
STOMATOPODA
PERACARIDA
AMPHIPODA
ISOPODA
CUMACEA
SPELAEOGRYPHACEA
TANAIDACEA
MYSIDACEA
PANCARIDA
THERMOSBAENACEA
EUCARIDA
DECAPODA
EUPHAUSIACEA
Anaspidites
Clarkecaris
Palaeocaris
O. PALAEOCARIDACEA
Palaeosyncaris
Archaeocaris
Perimecturus
O. PALAEOSTOMATOPODA
Isopadites
O. ANTHRACOCARIDACEA
Anthracocaris
Eocaris
Tealliocaris
Schimperella
Pygocephalus
Notocaris
Mamayocaris
O. PYGOCEPHALOMORPHA
Anthracaris
Palaeopalaemon
O. EOCARIDACEA
Palaeopemphix
?
Anthracophausia

Explanation of Text Plate 16

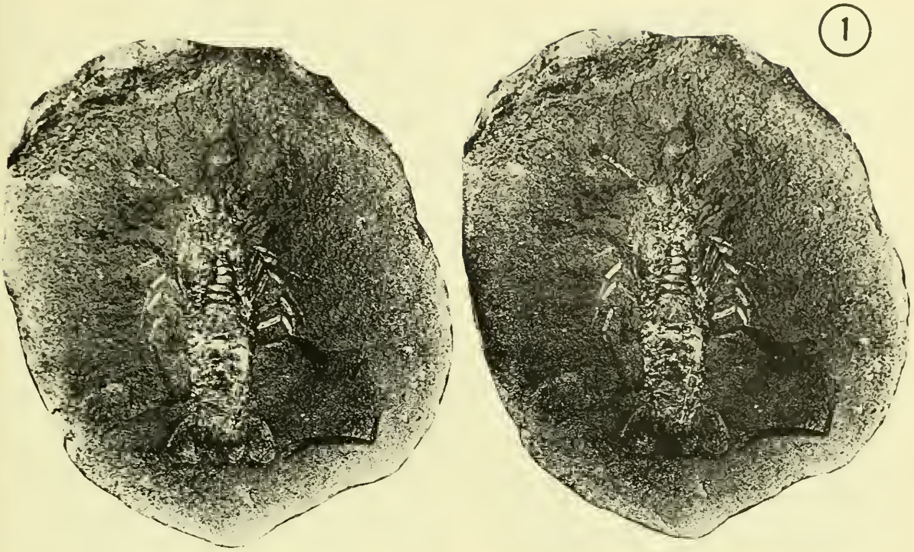
	Page
Diagram of the phylogenetic relationships of the Paleozoic Eumalacostraca	264

Explanation of Plate 29

Figure		Page
1.	**Anthracaris gracilis** (Meek and Worthen)	173

Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19988. Ventral surface of specimen with natural mold partially filled with kaolin, X 1, stereograph.

2. Same specimen but of rubber cast made after preparation, X 2.5, stereograph.



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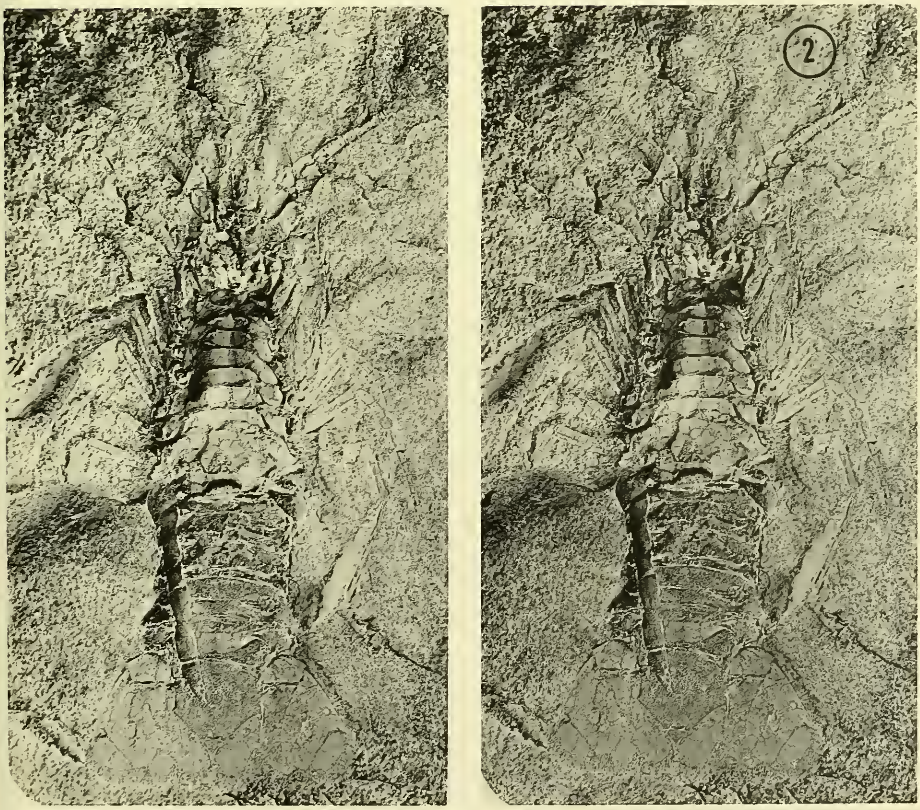

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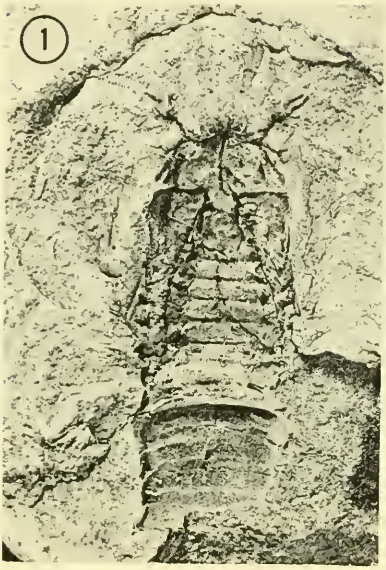
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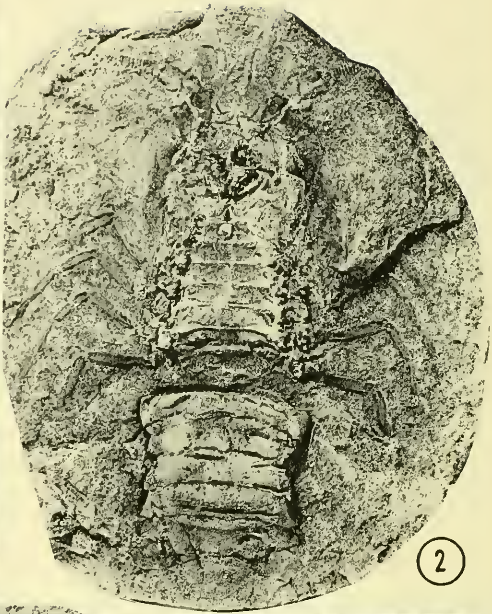
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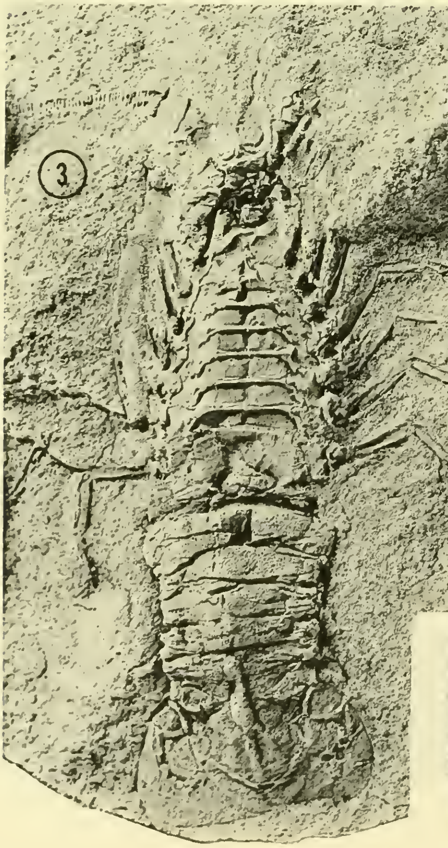
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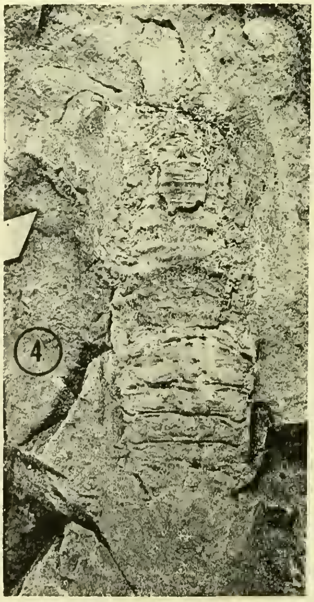

④


⑤

Explanation of Plate 30

Figure Page

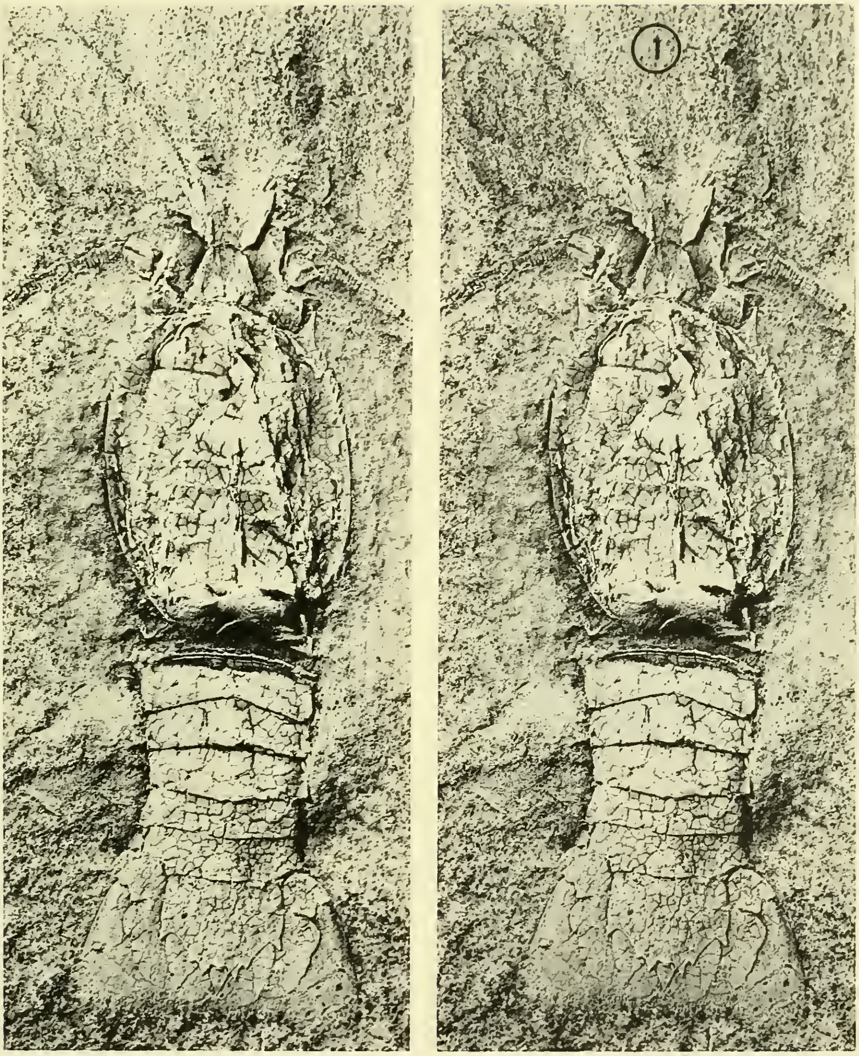
1. **Anthracaris gracilis** (Meek and Worthen) 173
   Francis Creek shale, Pennsylvanian, Mazon, Creek, Grundy Co., Ill., Ill. Geol. Survey (ISMNH 3067), holotype, X 3.
2. Counterpart, X 3.
3. **A. gracilis** 173
   Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., USNM 38843, plesiotype of Packard (1886 c, pl. 7, fig. 4), X 3.
4. **A. gracilis** 173
   Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., UI X-343, (ISMNH 11124), X 2.
5. **A. gracilis** 173
   Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., USNM 38843, plesiotype of Packard (1886 c, pl. 7, fig. 3 a), X 2.

Explanation of Plate 31

Figure Page

1. **Anthracaris gracilis** (Meek and Worthen) 173
Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19932, rubber cast, X 4, stereograph.

2. Counterpart, rubber cast, X 3.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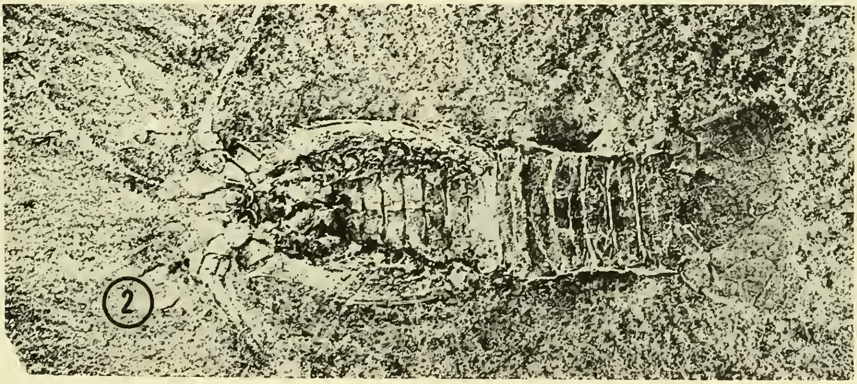
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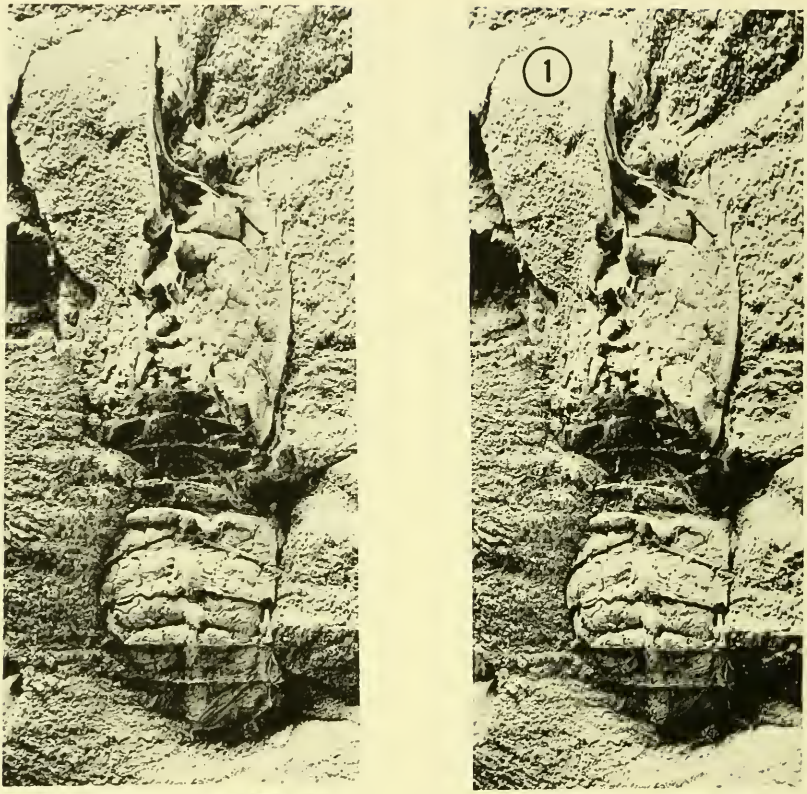

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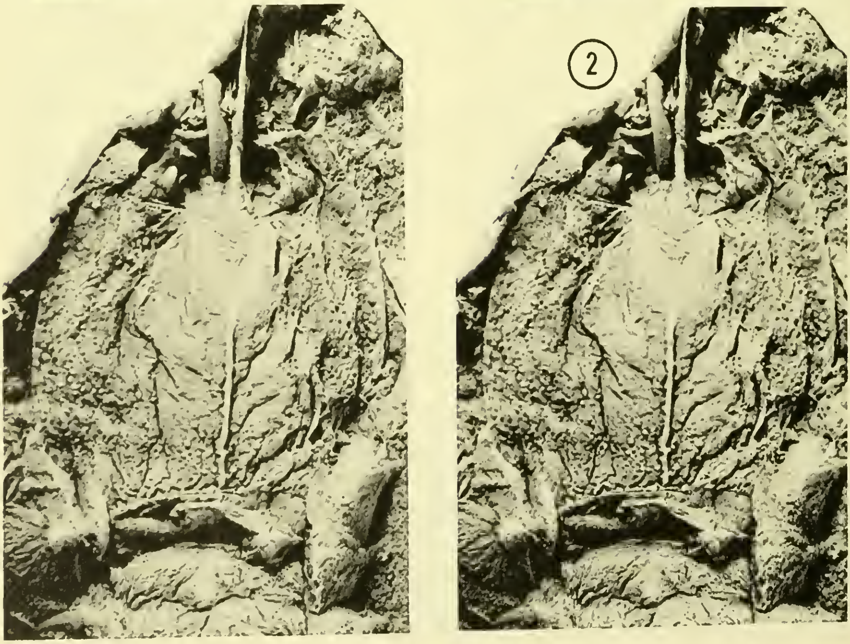

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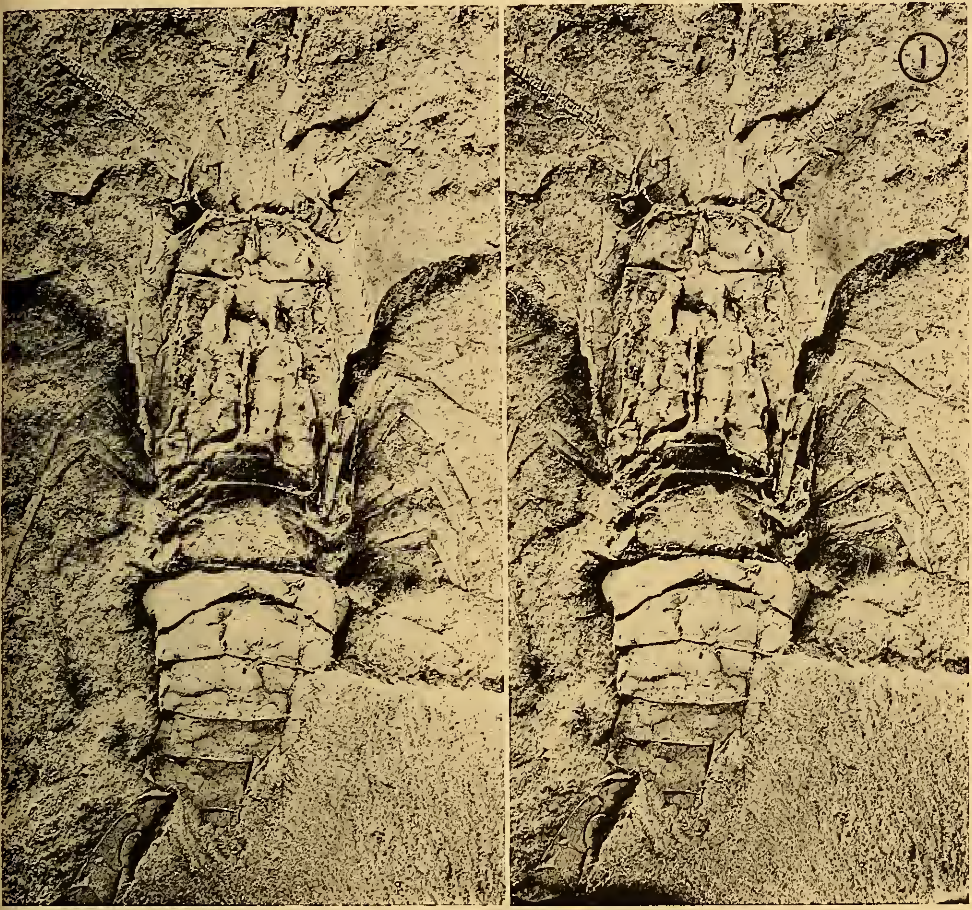
Explanation of Plate 32

Figure	Page
1. **Anthracaris gracilis** (Meek and Worthen)	173
Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 20003, rubber cast, X 3, stereograph.	
2. **A. gracilis**	173
Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19975, rubber cast, X 4, stereograph.	

Explanation of Plate 33

Figure	Page
1. **Anthracaris gracilis** (Meek and Worthen) .... Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19988, rubber cast, X 3, stereograph.	173
2. **A. gracilis** .... Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19941, X 4, stereograph.	173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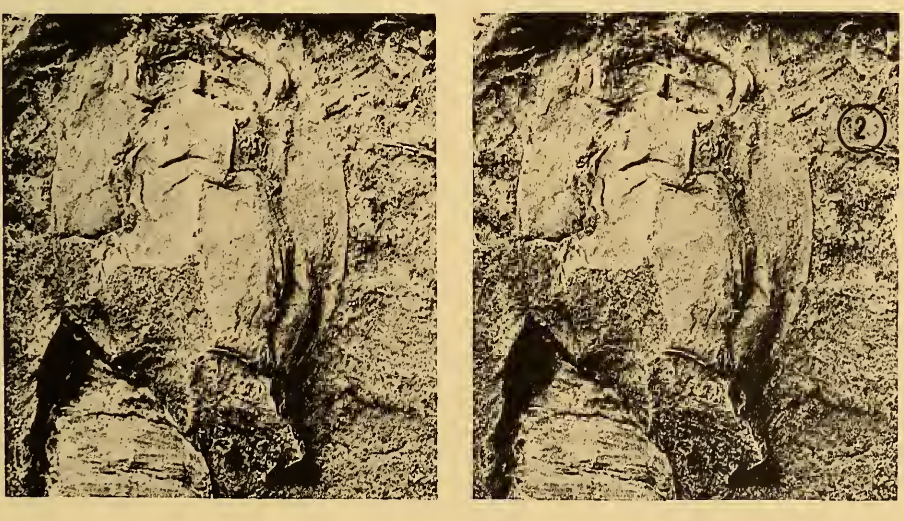
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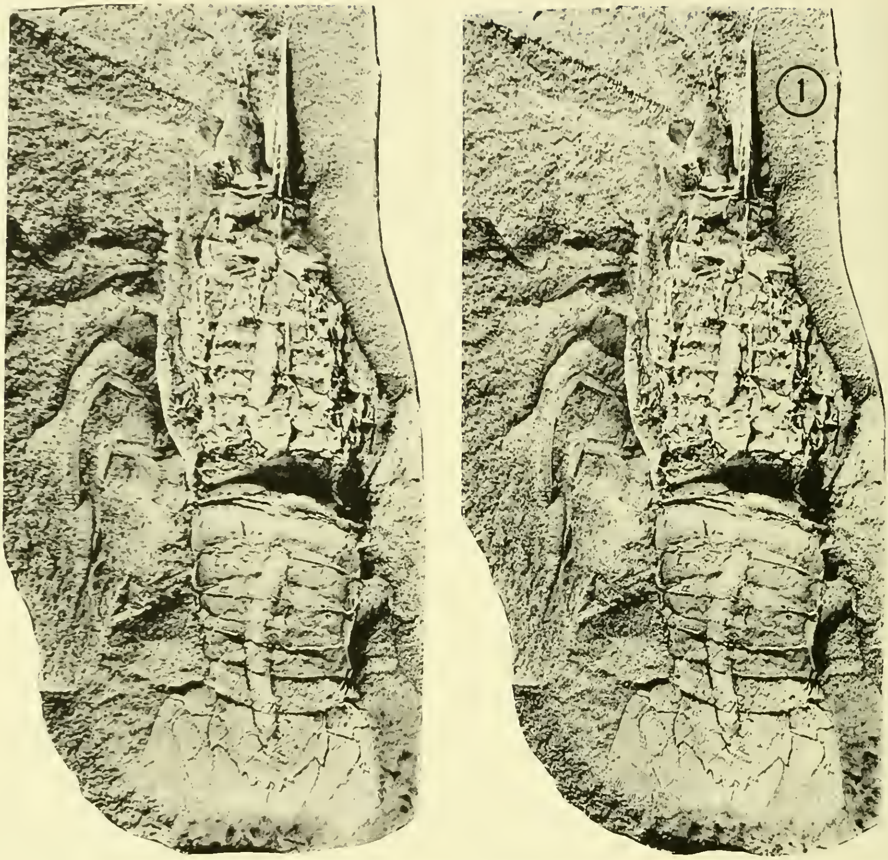

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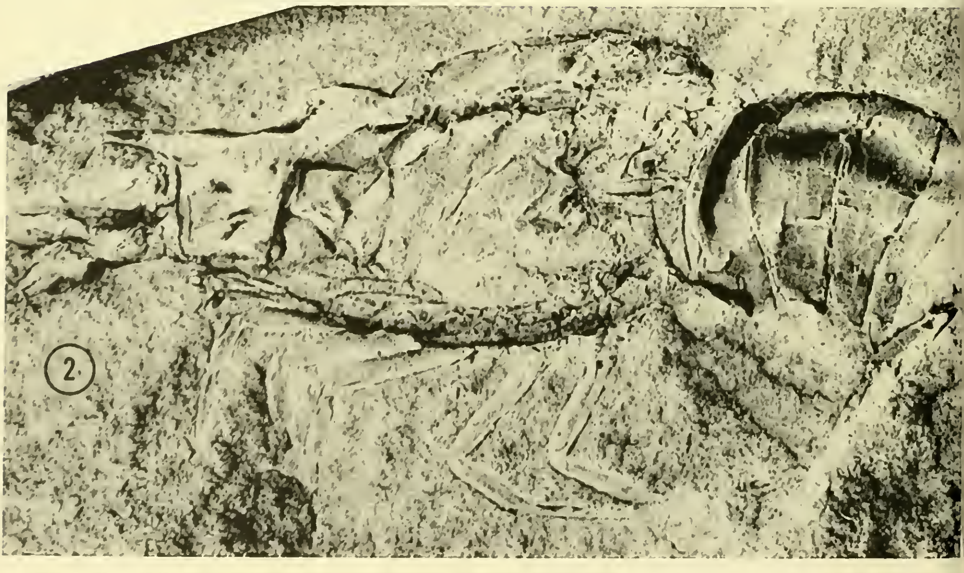

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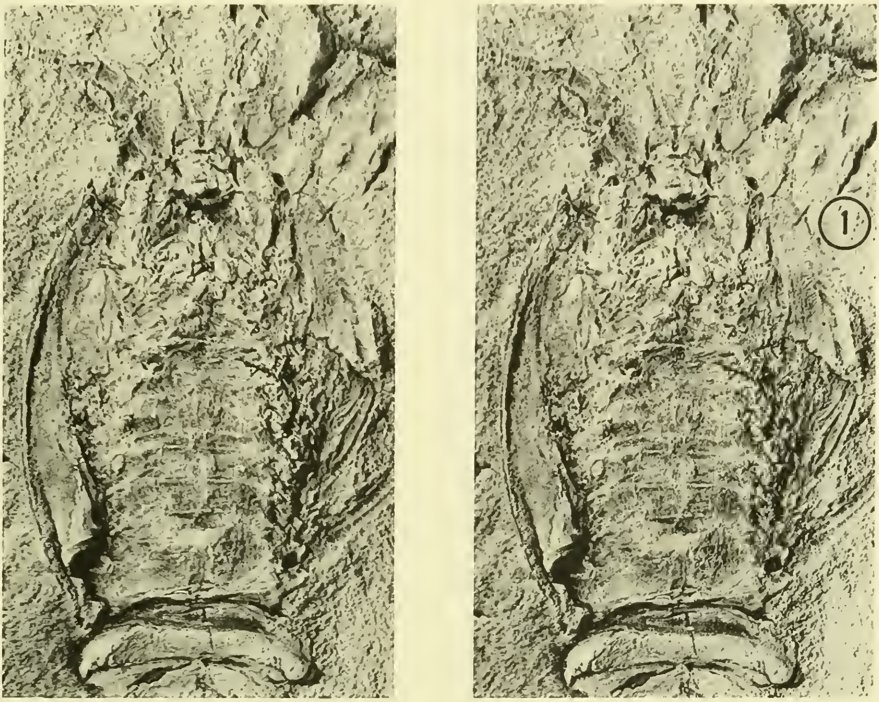
Explanation of Plate 34

Figure	Page
1. **Anthracaris gracilis** (Meek and Worthen) .... Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19993, rubber cast, X 3, stereograph.	173
2. **A. gracilis** .... Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 20005, X 6.	173

Explanation of Plate 35

Figure	Page
1. **Anthracaris gracilis** (Meek and Worthen)	173
Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19989, rubber cast, X 3, stereograph.	
2. **A. gracilis**	173
Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19983, rubber cast, X 4.	
3. **A. gracilis**	173
Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19928, rubber cast, X 2.	
4. **A. gracilis**	173
Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19998, X 2.	



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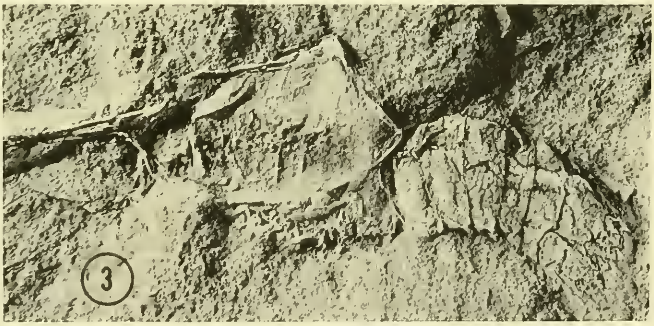

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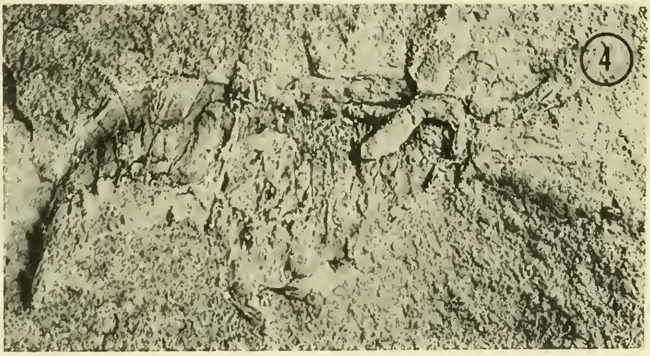

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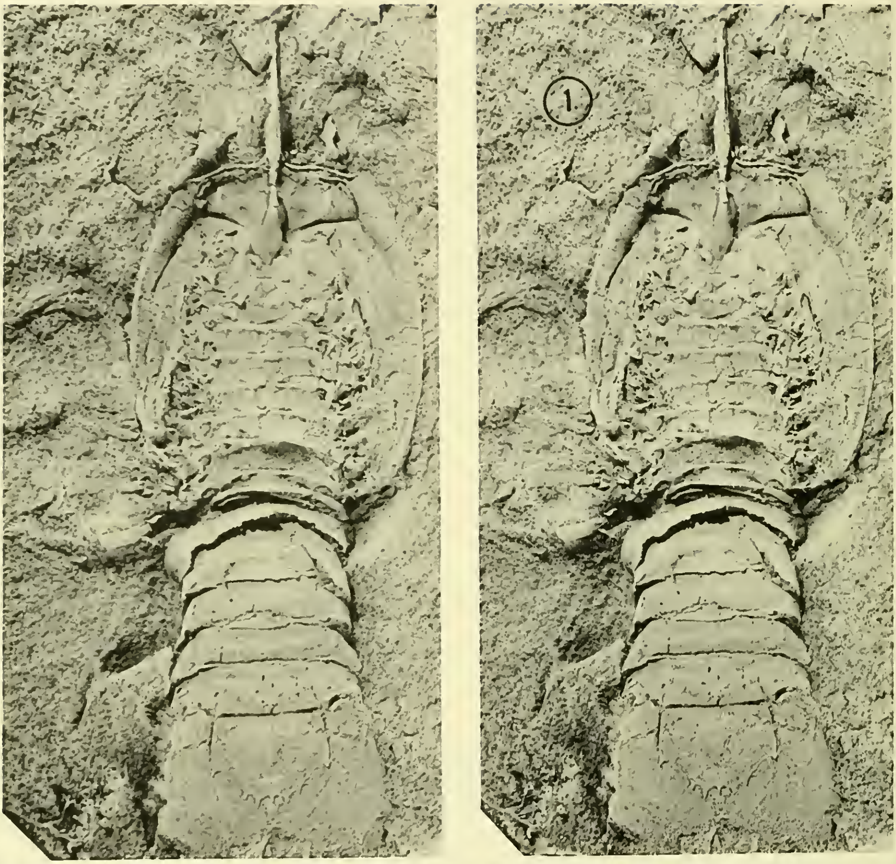

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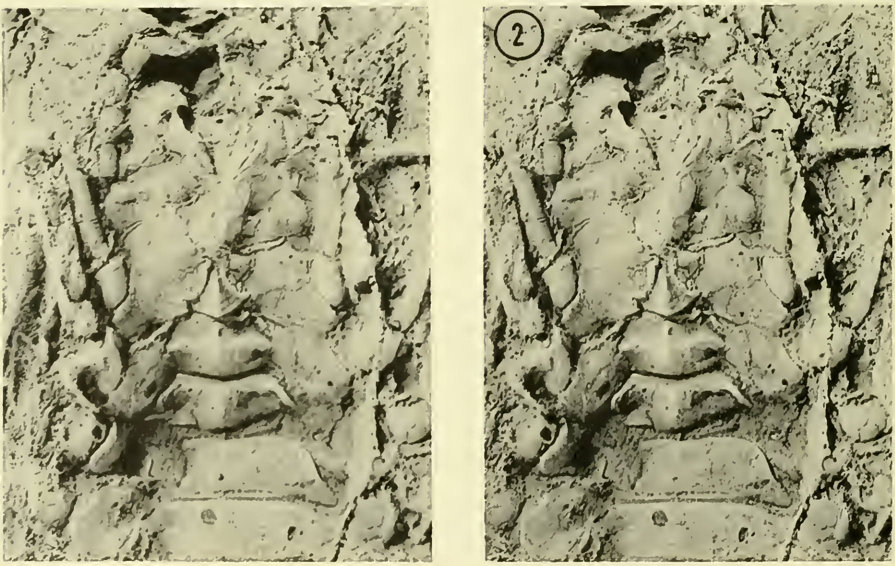

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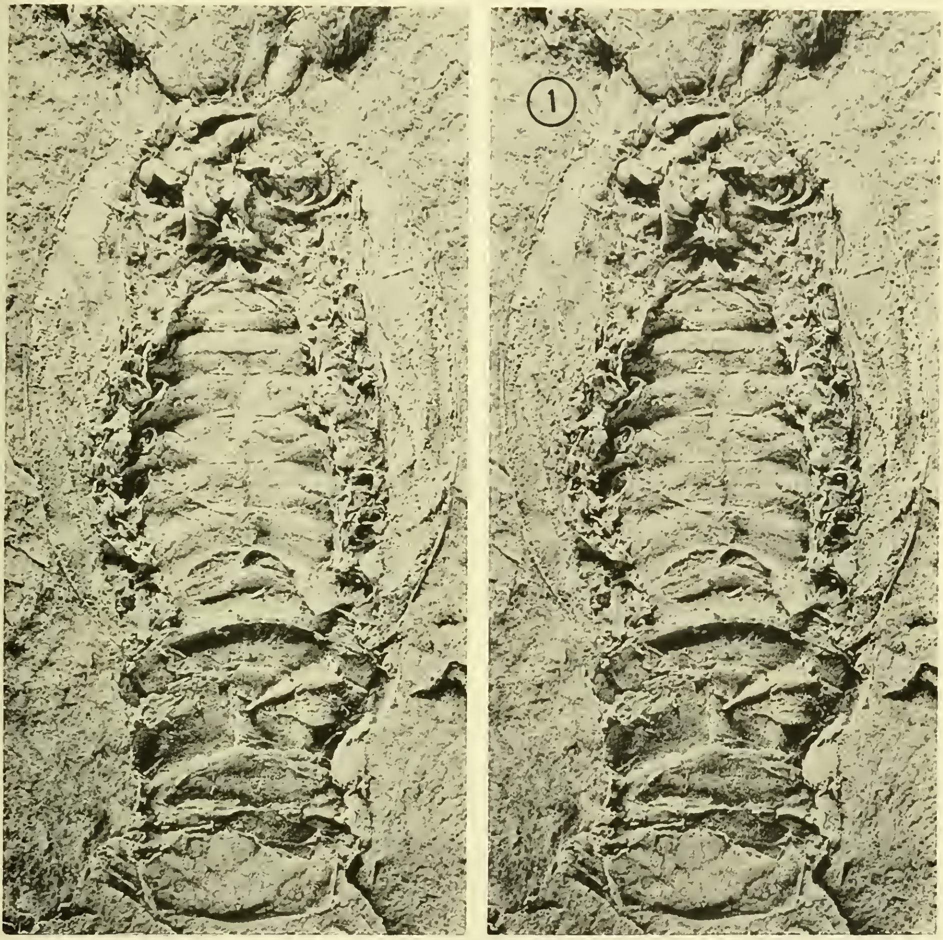
Explanation of Plate 36

Figure	Page
1. **Anthracaris gracilis** (Meek and Worthen) .... 173 Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19996 rubber cast, X 3, stereograph.	173
2. **A. gracilis** .... Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19971, rubber cast, X 9, stereograph.	173

Explanation of Plate 37

Figure		Page
1.	**Anthracaris gracilis** (Meek and Worthen) .... Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19936, rubber cast, X 4, stereograph.	173
2.	**A. gracilis** .... Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19987, rubber cast, X 4, stereograph.	173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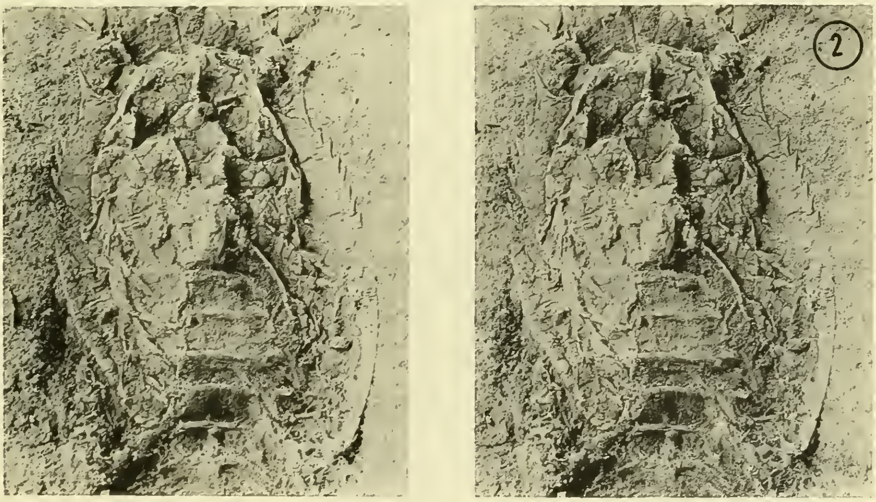
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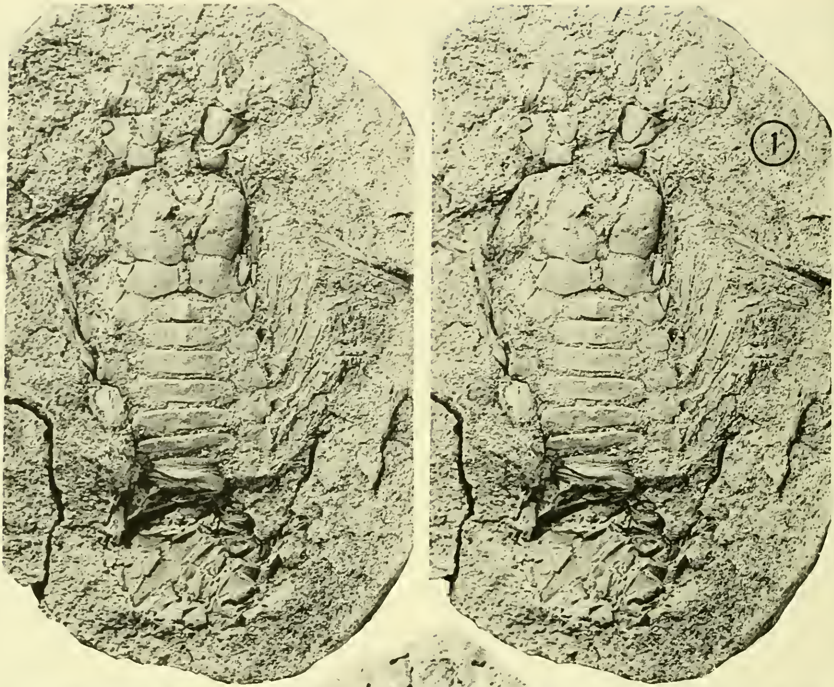
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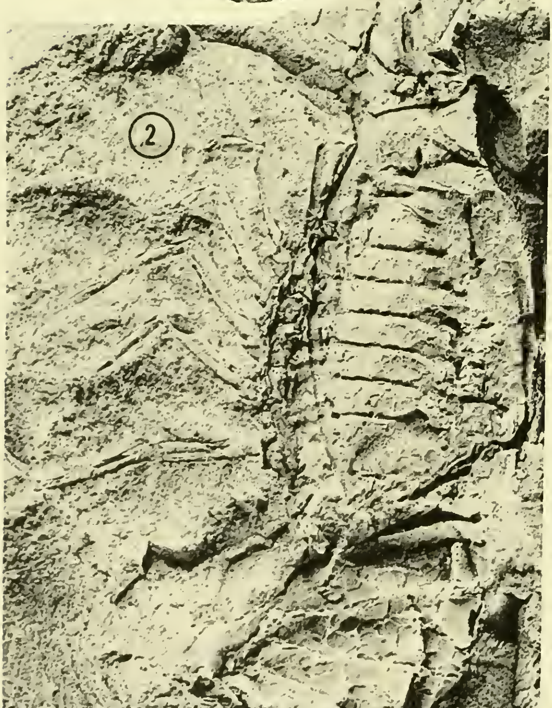
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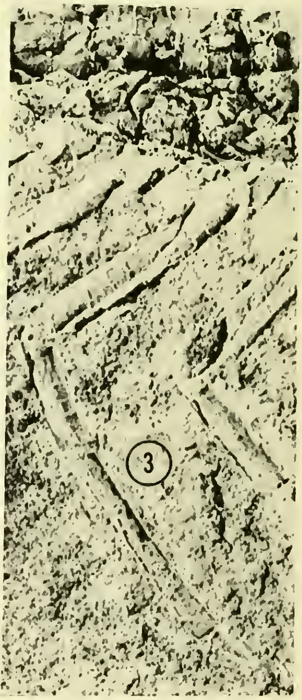
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Explanation of Plate 38

Figure		Page
1.	**Pygocephalus dubius** (Milne-Edwards) Pennsylvanian, England, MCZ 6718, X 4, stereograph.	194
2.	**Anthracaris gracilis** (Meek and Worthen) Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19953, X 4.	173
3.	Enlargement of photograph of same specimen showing the endopods, X 8.	

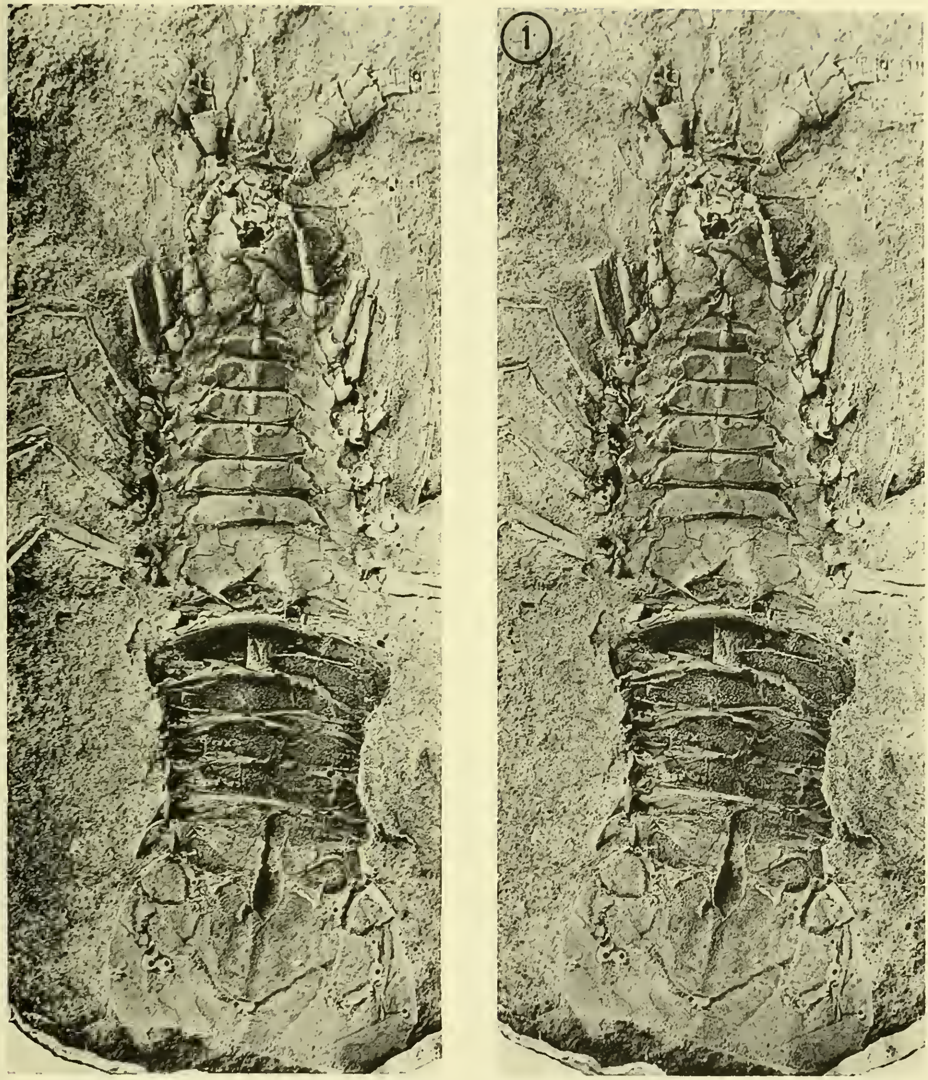
Explanation of Plate 39

Figure Page

1. **Anthracaris gracilis** (Meek and Worthen) 173
Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., USNM 38843, rubber cast, X 9, stereograph.

2. **A. gracilis** 173
Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19979, exopods, X 10.

3. **A. gracilis** 173
Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19931, rubber cast of abdominal pleurae, X 5.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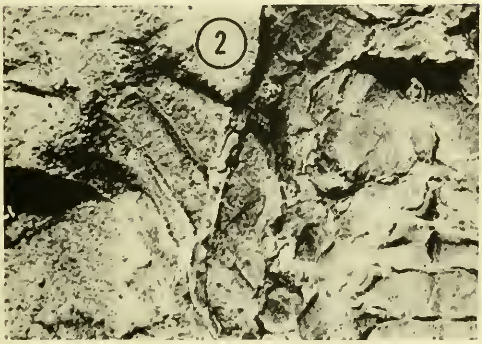
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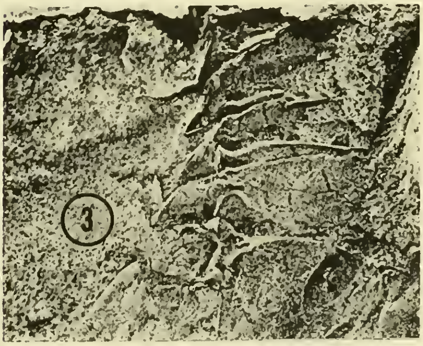
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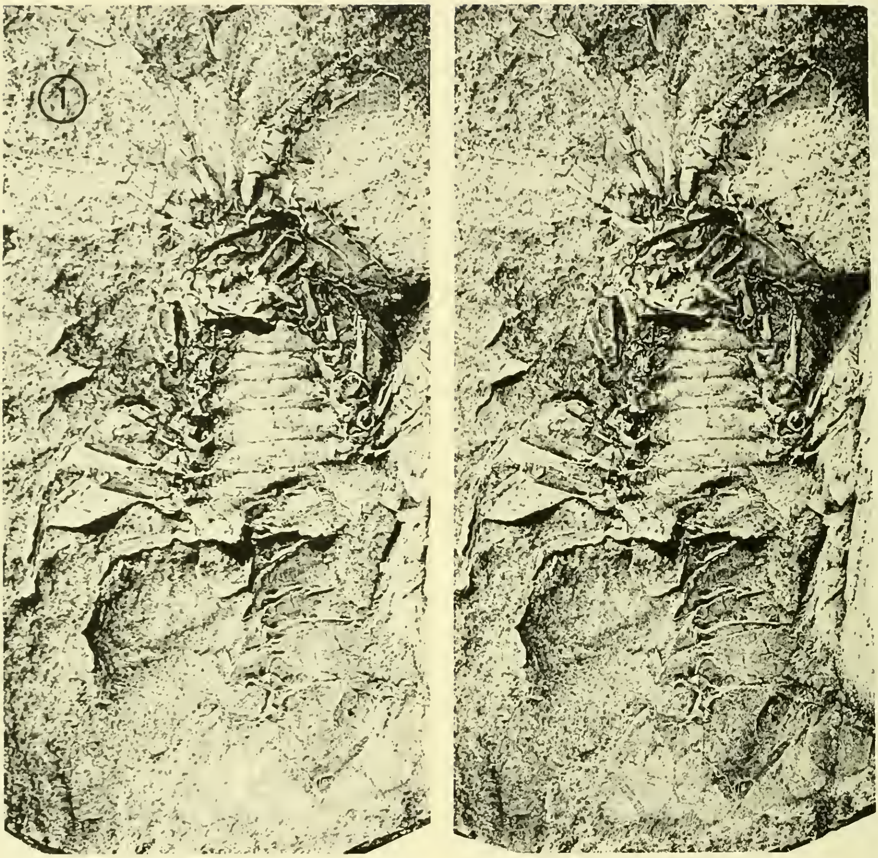
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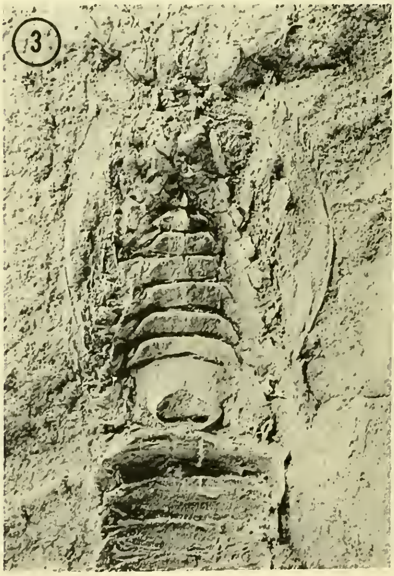
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Explanation of Plate 40

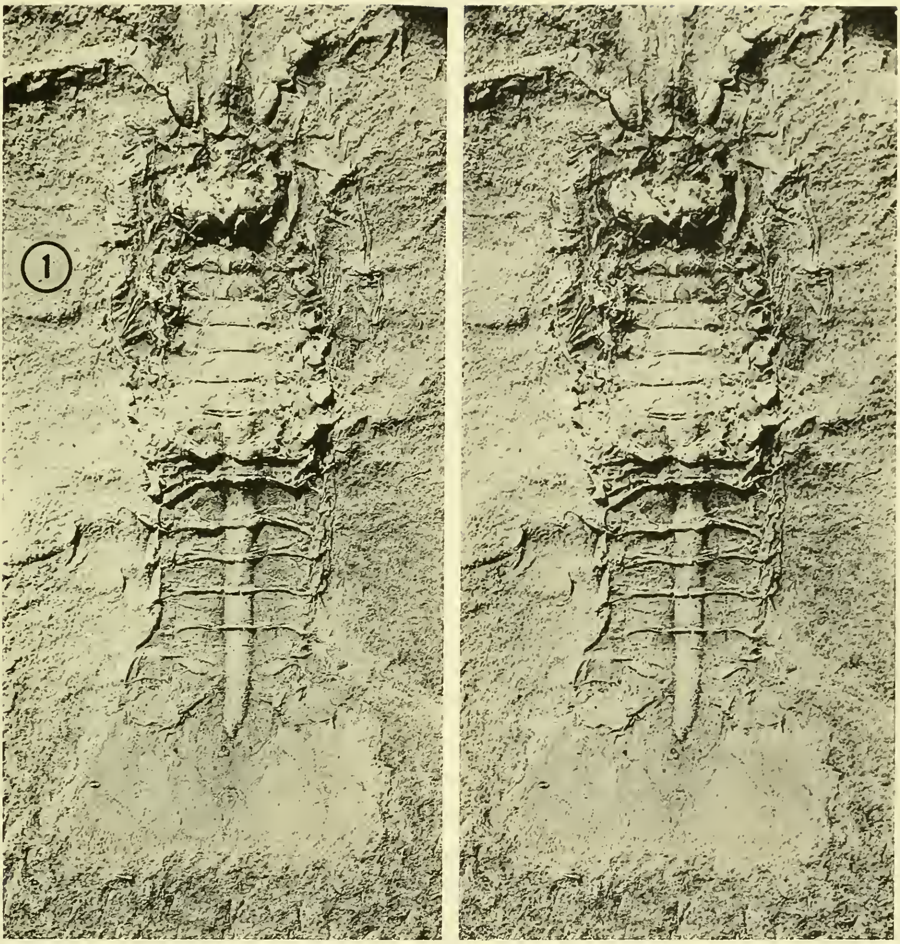
Figure	Page
1. **Anthracaris gracilis** (Meek and Worthen) Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19931, rubber cast, X 4, stereograph.	173
2. **A. gracilis** Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19928, rubber cast of cephalothorax, X 3.	173
3. **A. gracilis** Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19947, rubber cast of ventral surface showing sternites and seminal receptacle, X 4.	173

Explanation of Plate 41

Figure Page

1. **Anthracaris gracilis** (Meek and Worthen) 173
   Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., MCZ 5229, rubber cast, X 4, stereograph.

2. **A. gracilis** 173
   Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19960, rubber cast of structures associated with the mouth, X 8, stereograph.



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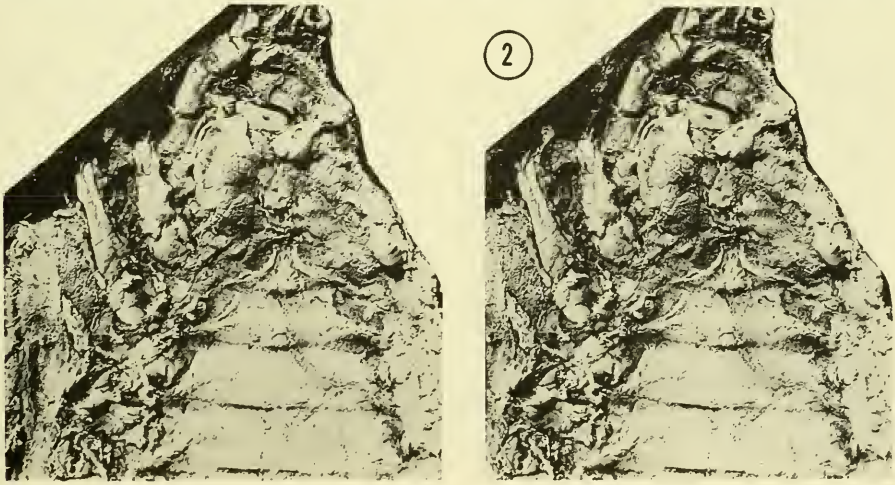

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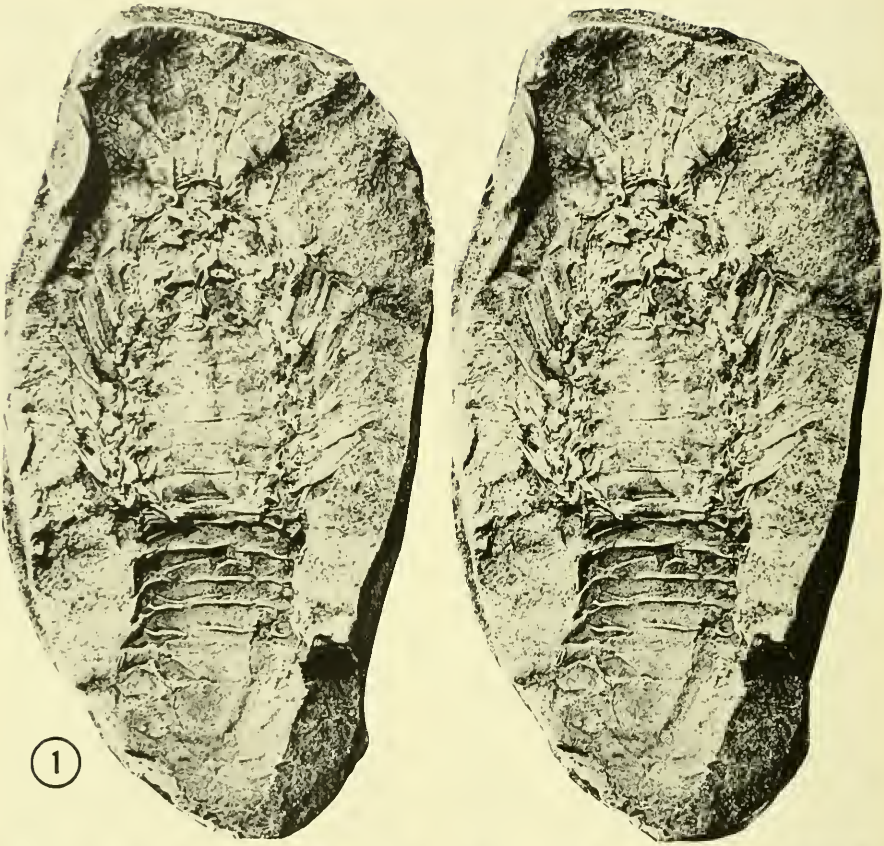

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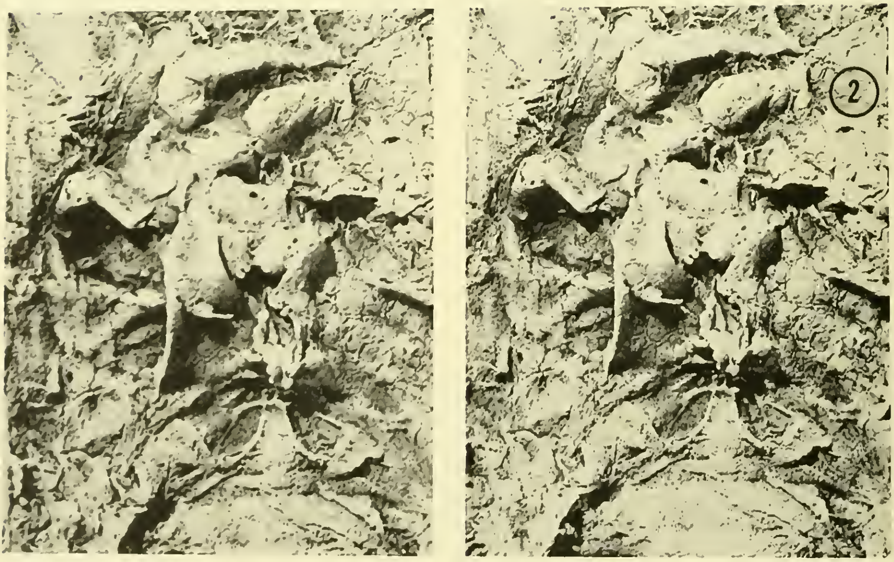

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Explanation of Plate 42

Figure Page

1. **Anthracaris gracilis** (Meek and Worthen) 173
   Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 20022, rubber cast, X 3.5, stereograph.

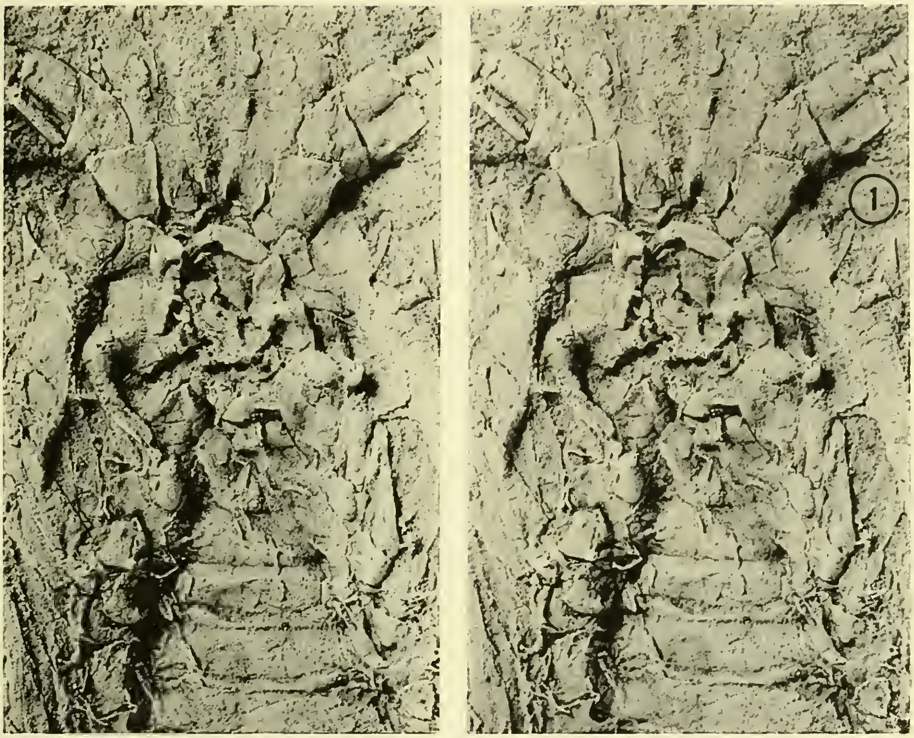
2. **A. gracilis** 173
   Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19936, rubber cast of structures associated with the mouth, X 8, stereograph.

Explanation of Plate 43

Figure Page

1. **Anthracaris gracilis** (Meek and Worthen) 173
Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19929, rubber cast of ventral structure of cephalothorax X 7, stereograph.

2. **A. gracilis** 173
Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19988, rubber cast of ventral structure of cephalothorax, X 6, stereograph.



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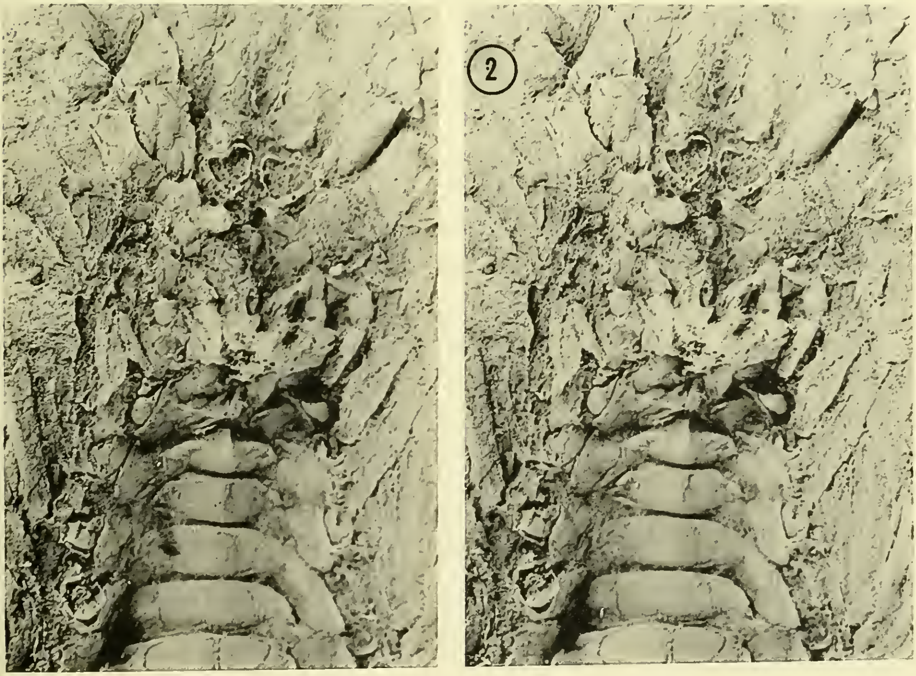

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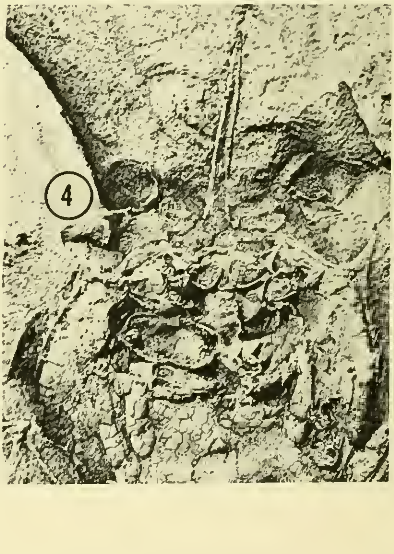
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Explanation of Plate 44

Figure		Page
1.	**Mamayocaris jepseni,** n.g., n.sp.	189
	Vale fm., Permian, Taylor Co., Texas, USNM 133393, abdominal pleurae, X 5.	
2.	**Mamayocaris jepseni**	189
	Vale fm., Permian, Taylor Co., Texas, USNM 133393, holotype, X 6.	
3.	Counterpart of holotype, X 5.	
4.	**Anthracaris gracilis** (Meek and Worthen)	173
	Francis Creek, Grundy Co., Ill., USNM 38842, rubber cast of ventral features of head, X 5.	

Explanation of Plate 45

Figure Page

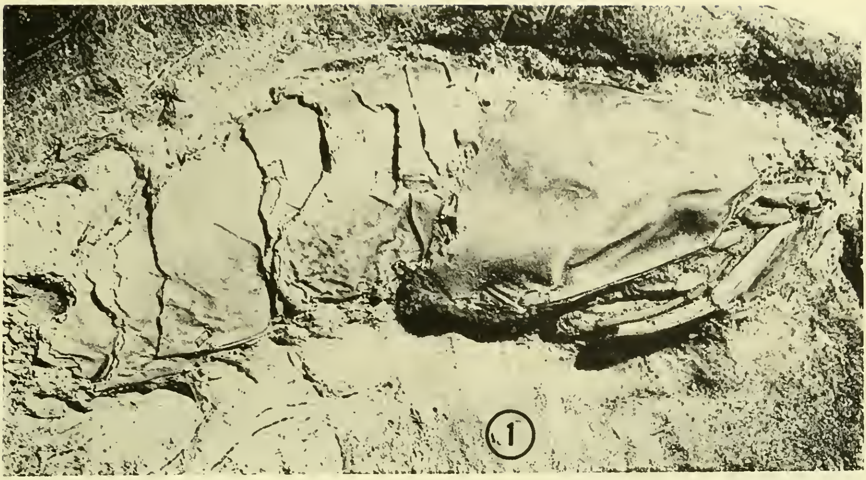
1. **Archaeocaris vermiformis** Meek 211
New Providence fm., Mississippian, Linietta Springs, Boyle Co., Ky., PU 1597 $^{d}/3$, X 6.

2. **Archaeocaris vermiformis** 211
New Providence fm., Mississippian, Linietta Springs, Boyle Co., Ky., PU 1597 $^{d}/3$, articulated rostrum, X 10.

3. **Archaeocaris vermiformis** 211
New Providence fm., Mississippian, Linietta Springs, Boyle Co., Ky., PU 1597 $^{d}/4$, caudal fan, X 5.

4. **Archaeocaris vermiformis** 211
New Providence fm., Mississippian, Linietta Springs, Boyle Co., Ky., PU 1597 $^{d}/5$, mandible, X 10.

5. **Mamayocaris jepseni,** n.g., n.sp. 189
Opeche fm., Permian, Rapid City, S.D., PU 83463 a, paratype, X 7.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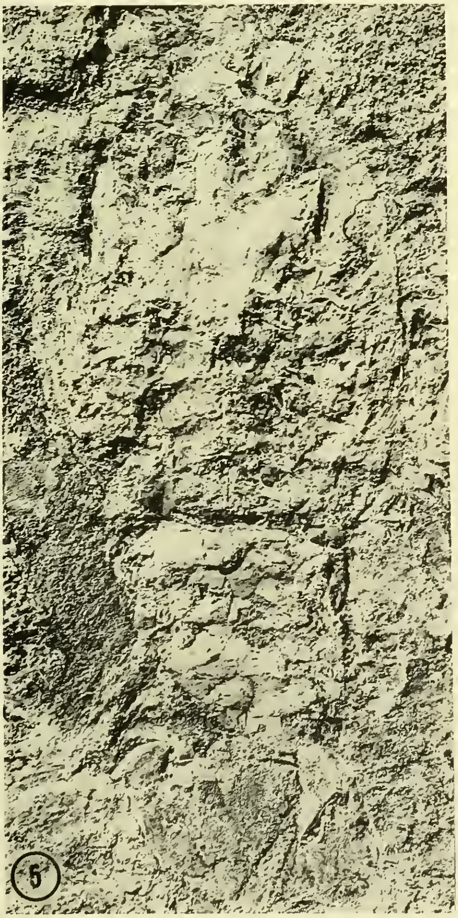
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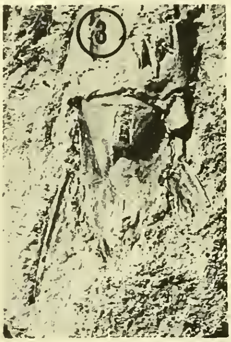
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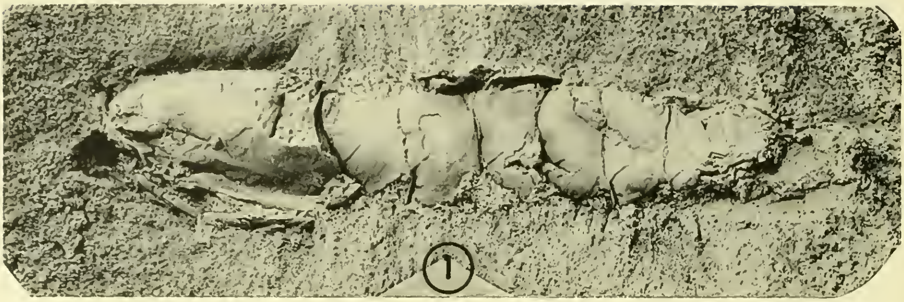
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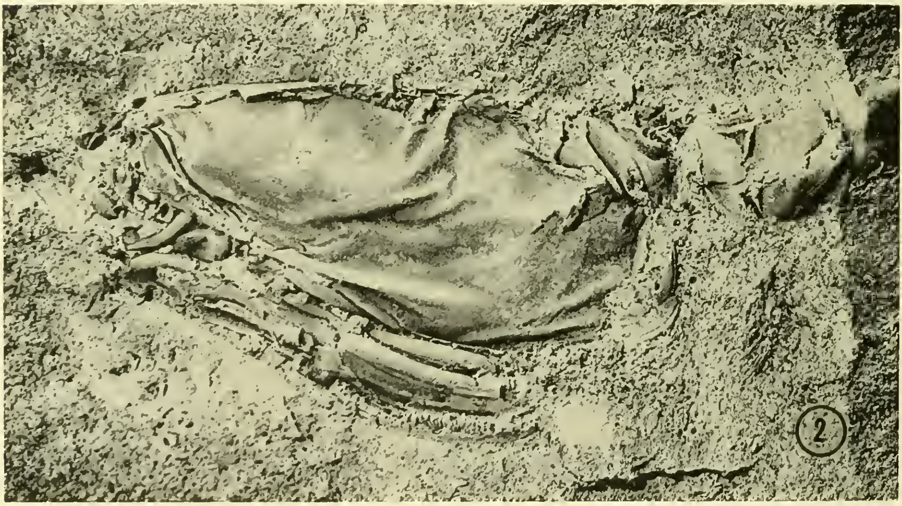
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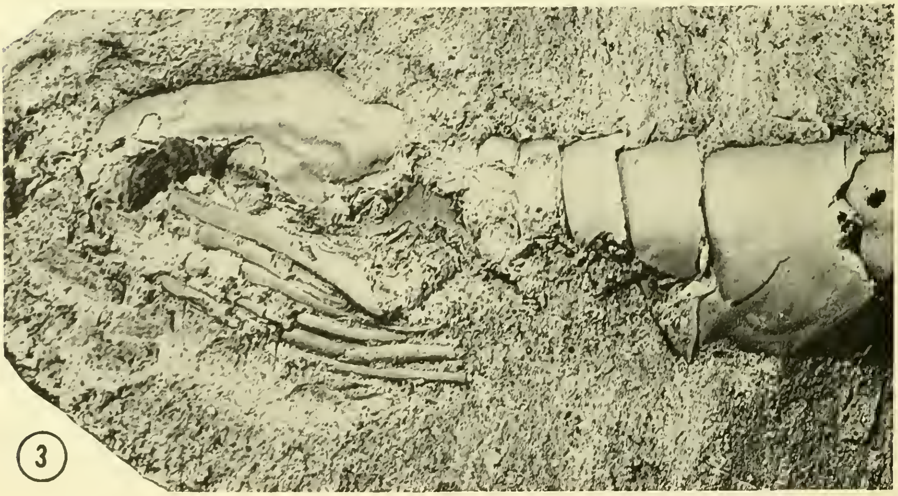
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Explanation of Plate 46

Figure Page

1. **Archaeocaris vermiformis** Meek ... 211
New Providence fm., Mississippian, Linietta Springs, Boyle Co., Ky., USNM 27126, holotype, X 4.

2. **Archaeocaris vermiformis** ... 211
New Providence fm., Mississippian, Linietta Springs, Boyle Co., Ky., PU 1597 ^{d}/1, X 8.

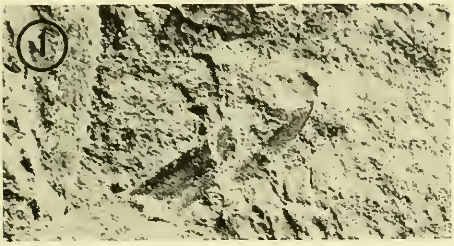
3. **Archaeocaris vermiformis** ... 211
New Providence fm., Mississippian, Linietta Springs, Boyle Co., Ky., PU 1597 ^{d}/2, X 8.

Explanation of Plate 47

Figure Page

5879

1. **Archaeocaris graffhami,** n. sp. 214
   Caney shale Mississippian, Pontotoc Co., Okla., MCZ 5849, remnants of posterior thoracic legs. X 10.
2. **Archaeocaris graffhami,** n. sp. 214
   Caney shale, Mississippian, Pontotoc Co., Okla., MCZ 5849, holotype, X 4.
3. Caudal fan of holotype, X 10.
4. Counterpart of holotype UO 4411, X 4.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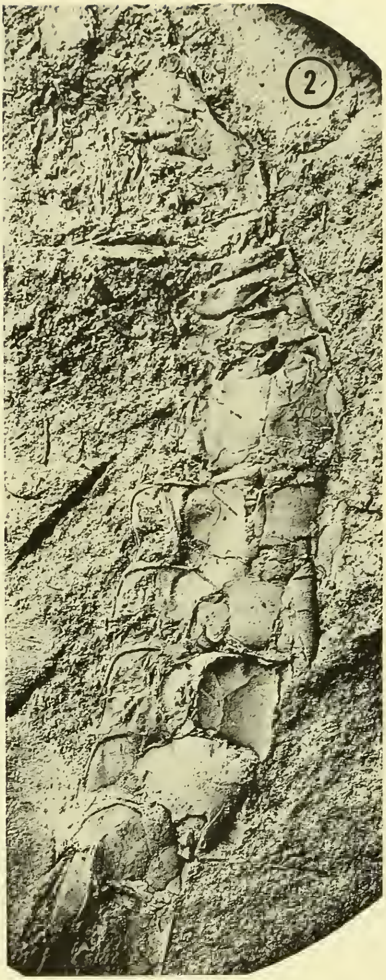
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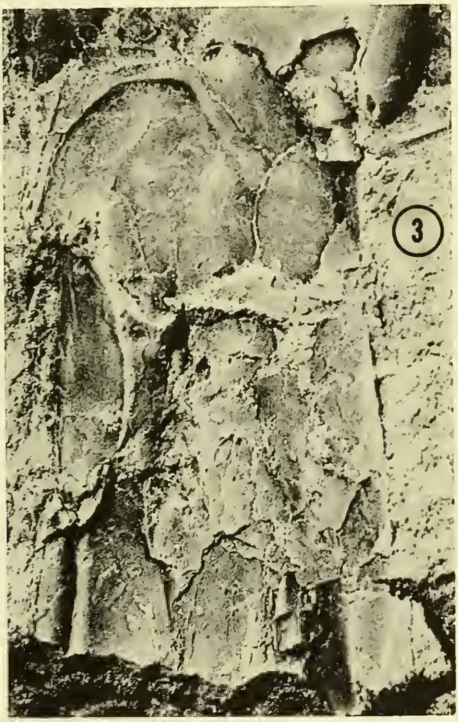
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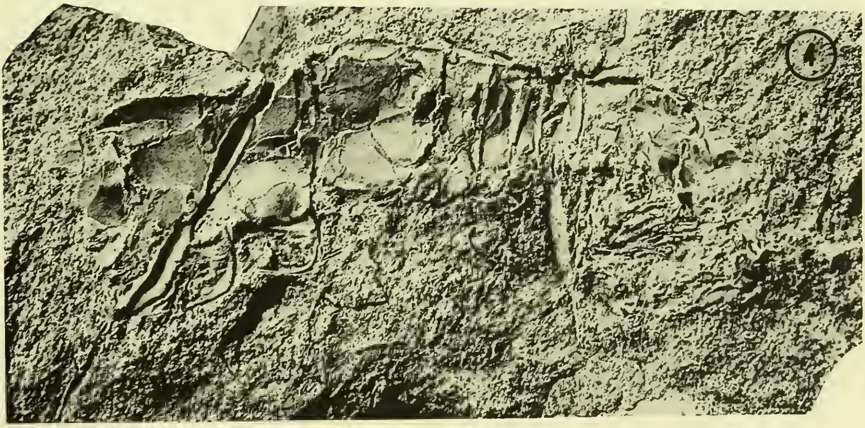
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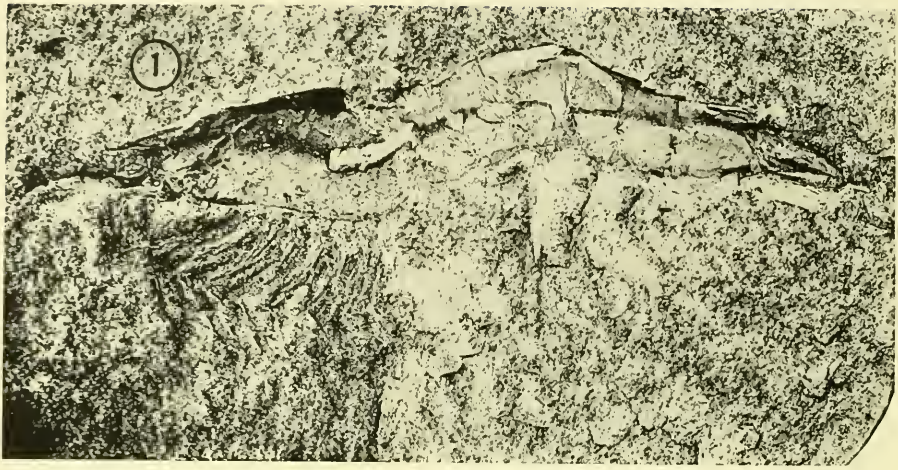
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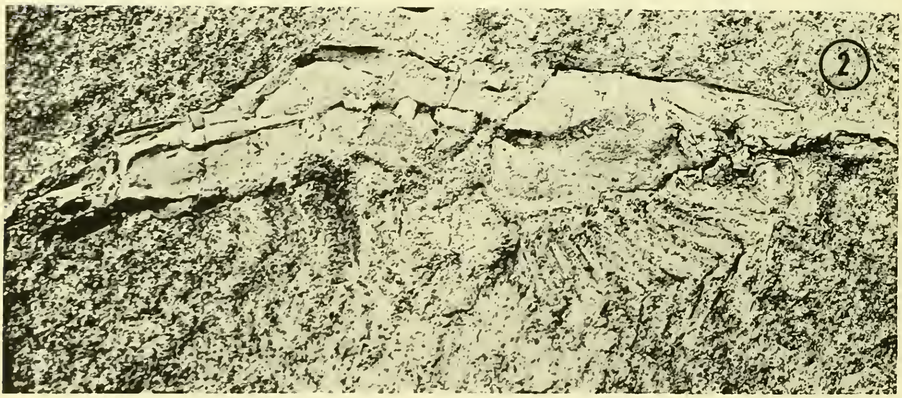
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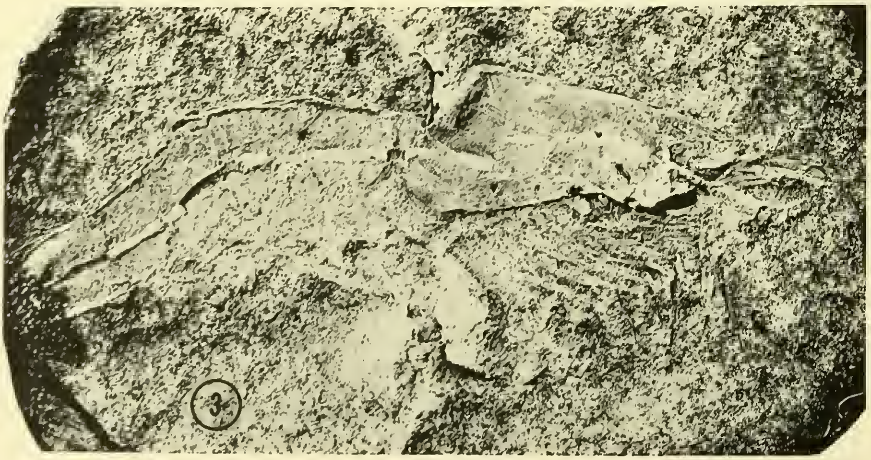
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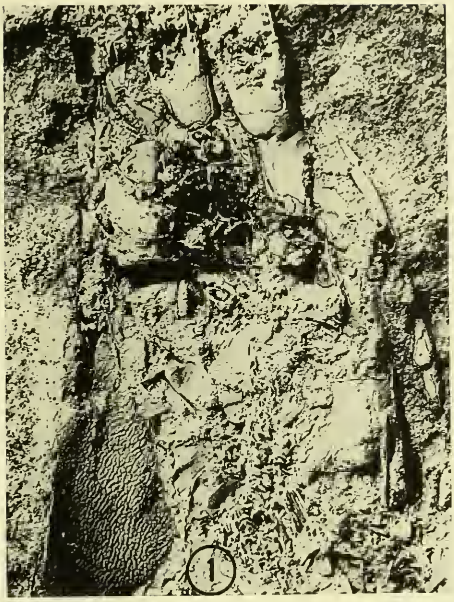
Explanation of Plate 48

Figure Page

1. **Anthracophausia strongi,** n. sp. 203
   Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 18821, holotype, X 4.
2. Counterpart of holotype, X 4.
3. **Anthracophausia strongi** 203
   Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 18884, paratype, X 4.

Explanation of Plate 49

Figure	Page
1. **Palaeopalaemon newberryi** Whitfield New Providence fm., Lower Mississippian, Junction City, Ky., MCZ 5880, X 4.	221
2. Counterpart, X 4.	
3. Same specimen, X 2, stereograph.	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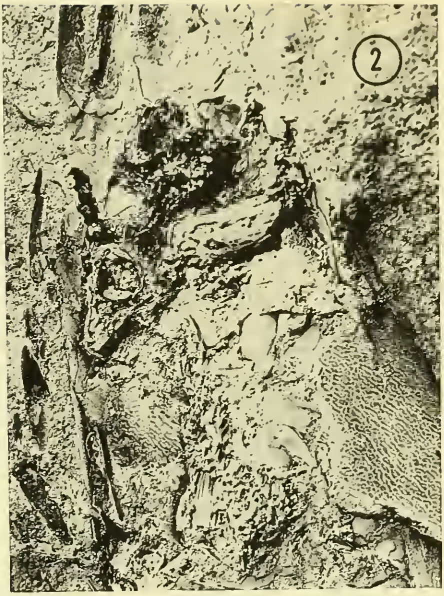
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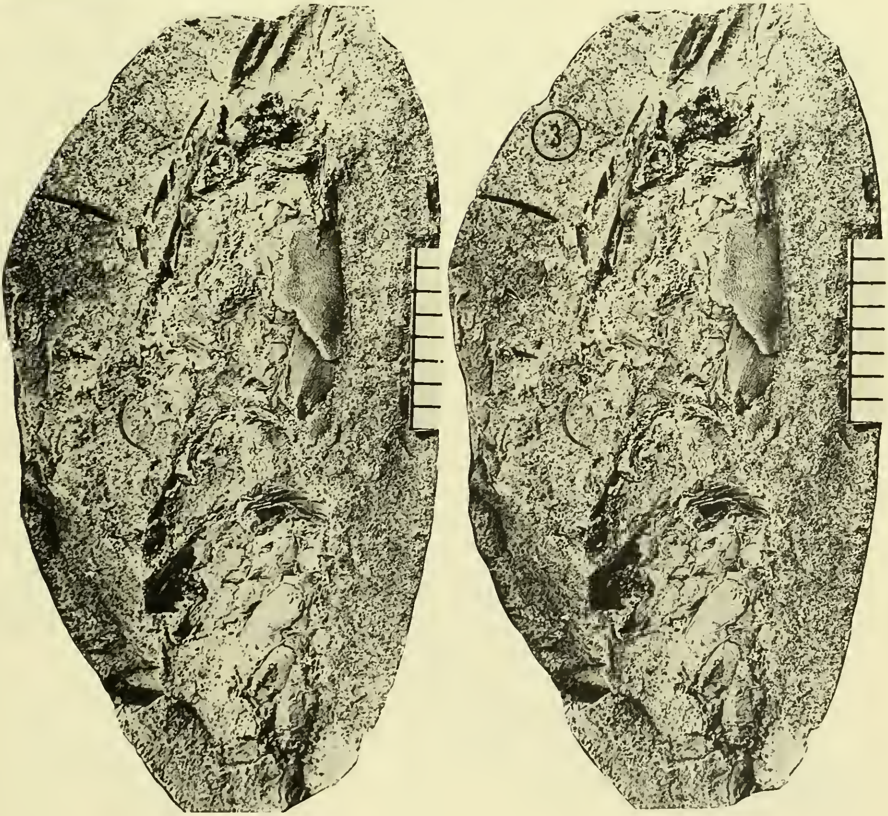
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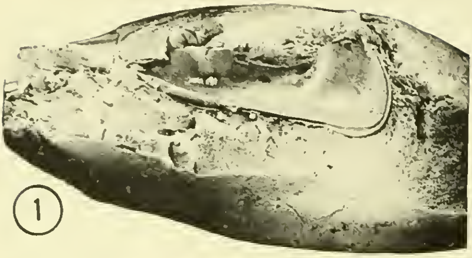
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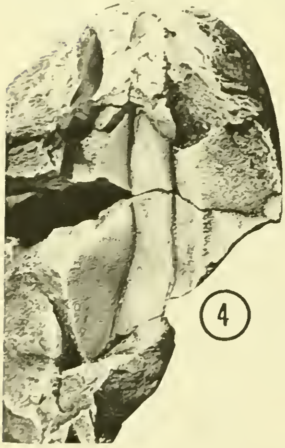
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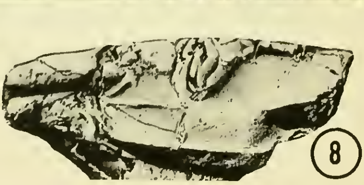
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Explanation of Plate 50

Figure Page

1. **Palaeopalaemon newberryi** Whitfield 221
Chagrin shale, Devonian, Painesville, Lake Co., Ohio, MCZ 6563, X 2.

2. **Palaeopalaemon newberryi** 221
Chagrin shale, Devonian, Leroy, Lake Co., Ohio, CU 6174, syntype (posterior of carapace and two abdominal tergites), X 5.

3. **Palaeopalaemon newberryi** 221
Chagrin shale, Devonian, Leroy, Lake Co., Ohio, CU 6714, syntype (caudal fan), X 6.

4. **Palaeopalaemon newberryi** 221
Chagrin shale, Devonian, Leroy, Lake Co., Ohio, CU 5514, syntype (carapace), X 2.

5. **Palaeopalaemon newberryi** 221
Chagrin shale, Devonian, Stebbins Gulch, Lake Co., Ohio, ClMNH 7628, dorsal view of carapace and pair of large basal joints of first antennae, X 3.

6. Rubber cast of CU 6714 (fig 3), X 5.

7. **Palaeopalaemon newberryi** 221
Chagrin shale, Devonian, Stebbins Gulch, Lake Co., Ohio, ClMNH 7628, lateral view of carapace and basal joint of first antennae, X 6.

8. **Palaeopalaemon newberryi** 221
Chagrin shale, Devonian, Leroy, Lake Co., Ohio, CU 5514, rubber cast of syntype, X 2.

Explanation of Plate 51

Figure Page

1. **Palaeopalaemon iowensis** Walter 225
Kinderhook shale, Mississippian, Burlington, Iowa, MCZ, 5106, 5186
joint of sympod of first antenna and exopodal scale of second antennae, X 5.

2. Same specimen, dorsal view of carapace, X 2.

3. Same specimen, lateral view of carapace, X 2.

4. Same specimen, joint of pereiopod, X 10.

5. **Palaeopalaemon newberryi** Whitfield 221
New Providence fm., Mississippian, Junction City, Ky., MCZ 5880, X 2, stereograph.


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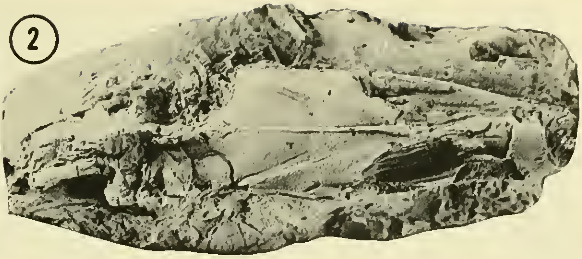
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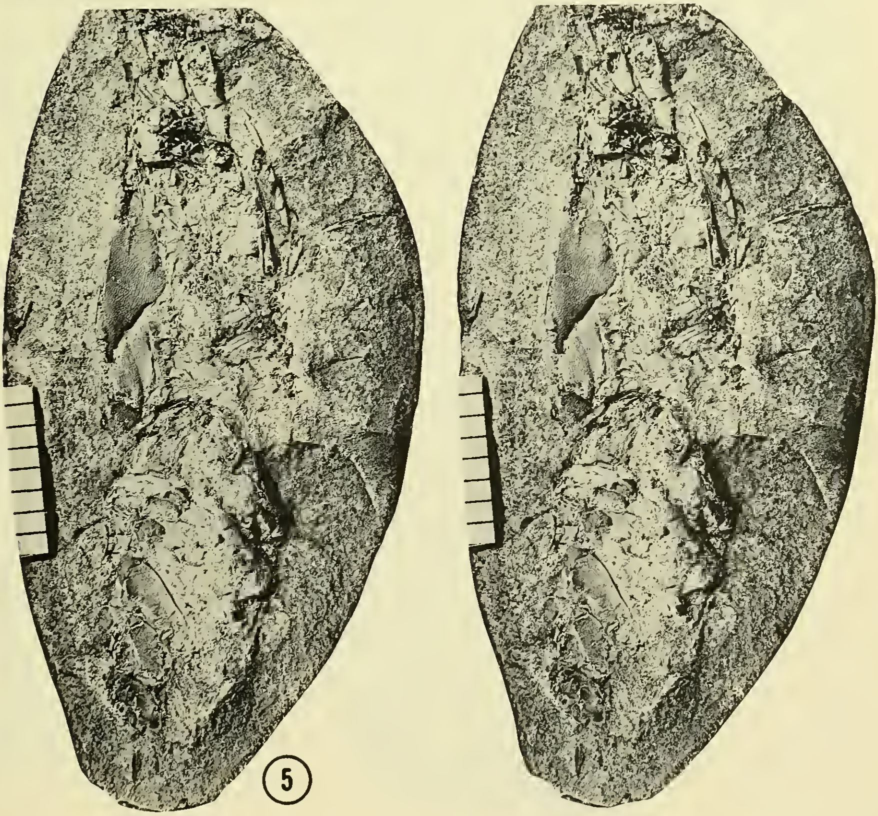
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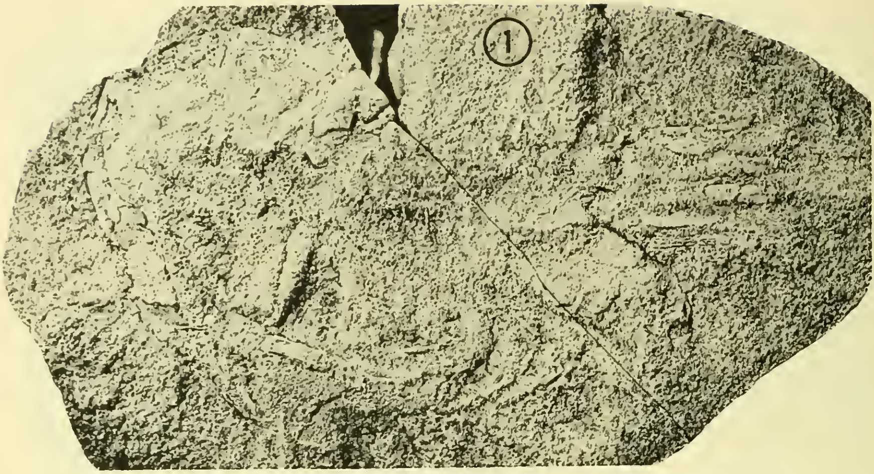
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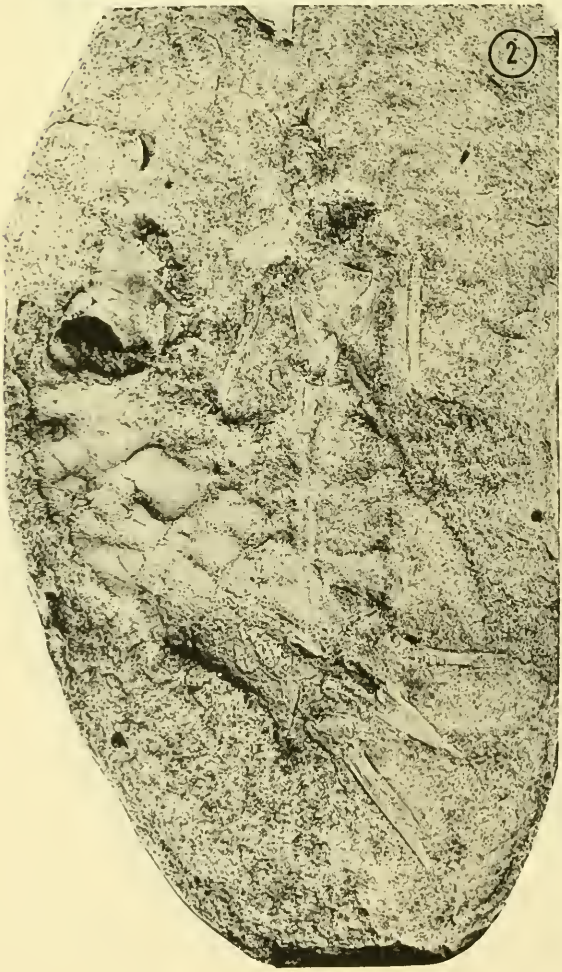
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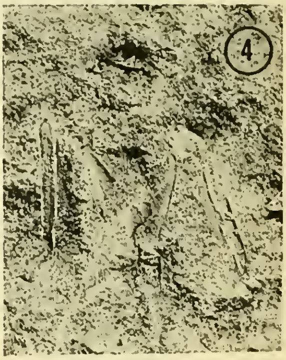
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Explanation of Plate 52

Figure		Page
1.	**Belotelson magister** Packard Francis Creek shale, Pennsylvanian, Braidwood, Will Co., Ill., USNM 38844, Packard's (1886 a) plesiotype, X 1.5.	206
2.	**Belotelson magister** Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., USNM 38844, holotype, X 2.5.	206
3.	Counterpart of holotype, X 1.	
4.	Remains of cephalic appendages on counterpart of holotype, X 2.5.	

Explanation of Plate 53

Figure Page

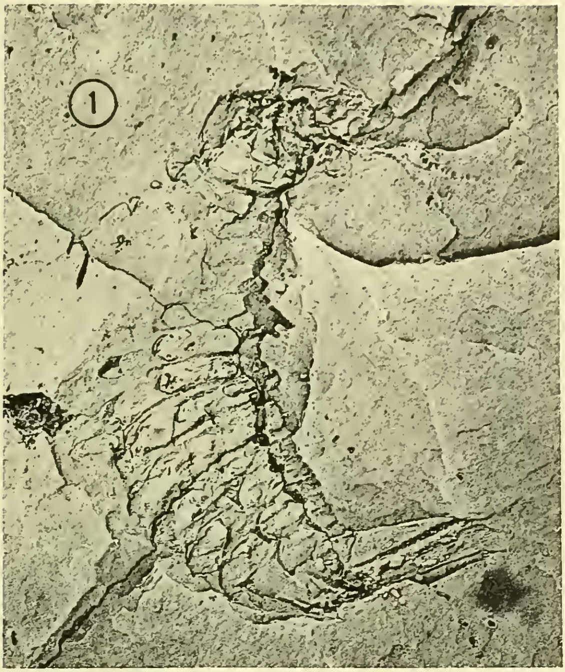
1. **Squillites spinosus** Scott 254
   Heath shale, Mississippian, Heath, Montana, UI X-1219, holotype, X 10.

2. **Devonocaris cuylerensis** (Wells) 227
   Moscow fm., Devonian, DeRuyter, New York, Cornell Univ. 40020, X 8.

3. **Squillites spinosus** 254
   UI X-1219, counterpart of holotype, X 10.

4. **Devonocaris cuylerensis** 227
   Telson of holotype, X 15.

5. **Archaeocaris vermiformis** Meek 211
   New Providence fm., Mississippian, Linietta Springs, PU 1597 d/5, sympods of thoracic appendages X 10.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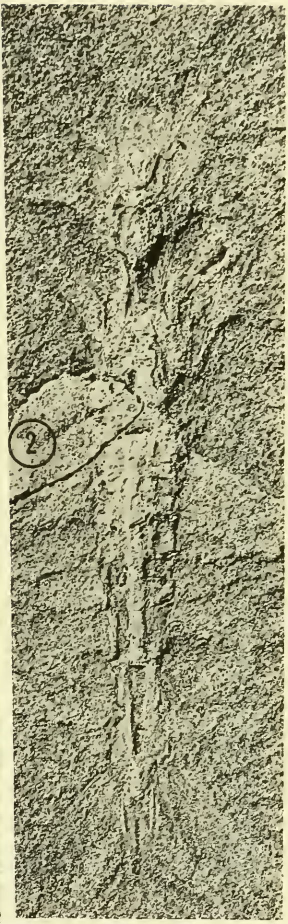
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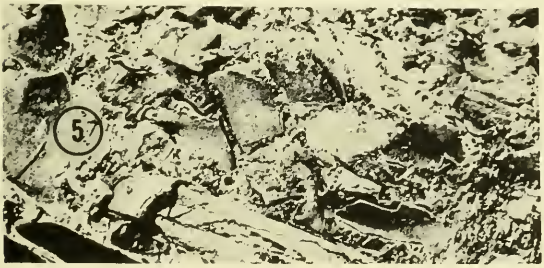
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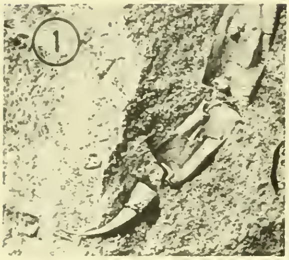
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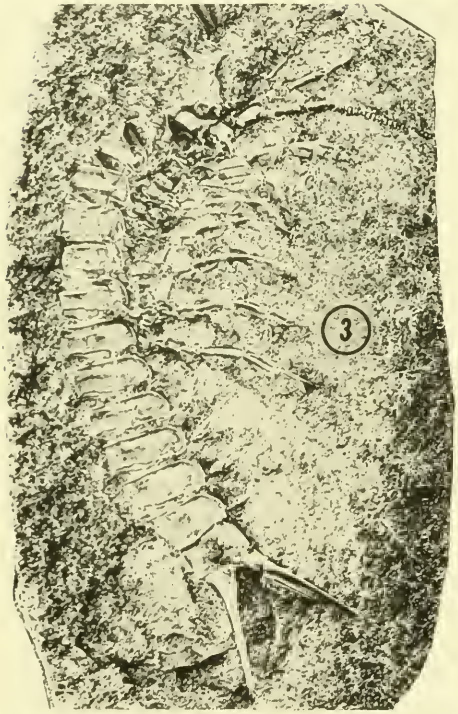
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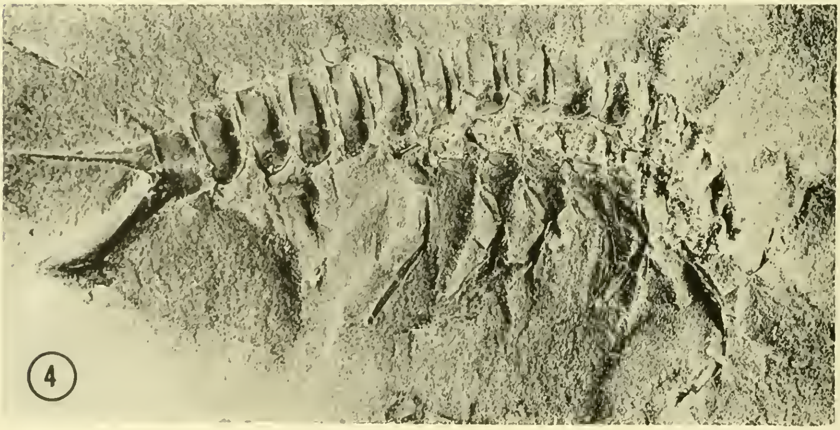
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Explanation of Plate 54

Figure Page

1. **Acanthotelson stimpsoni** Meek and Worthen 230
Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19844, distal joints of raptorial appendage, X 5.

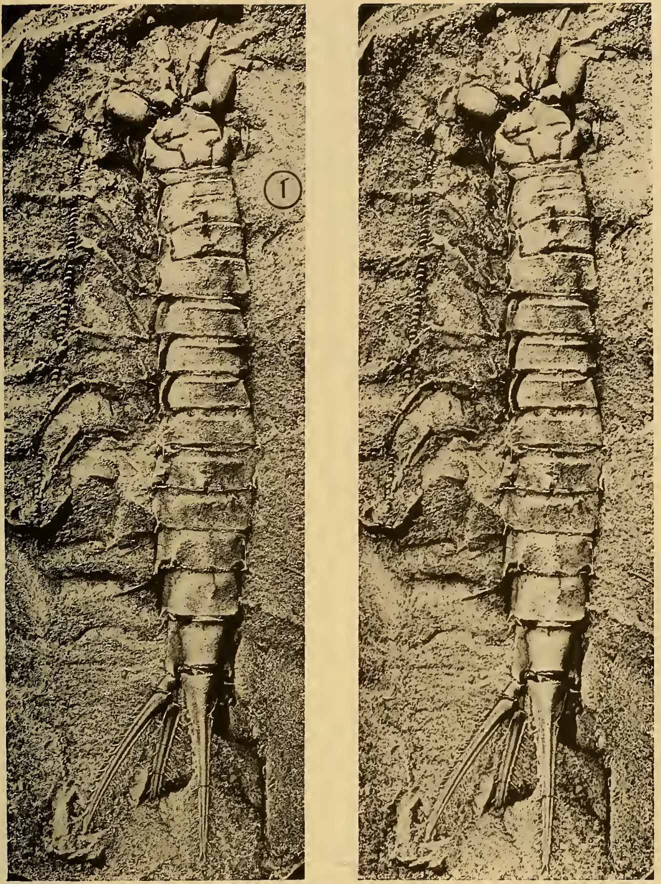
2. **Acanthotelson stimpsoni** 230
Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., USNM 38845, plesiotype of Packard (1886 a, pl. 2, fig. 1), X 2.5.

3. **Acanthotelson stimpsoni** 230
Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19867, X 3.

4. **Acanthotelson stimpsoni** 230
Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., UI X-346 (ISMNH 1118), holotype, X 3.

Explanation of Plate 55

Figure	Page
1. **Acanthotelson stimpsoni** Meek and Worthen Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., MCZ 5210, rubber cast, X 5, stereograph.	230
2. **Acanthotelson stimpsoni** Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19640, rubber cast of epipods and exopods, X 10.	230



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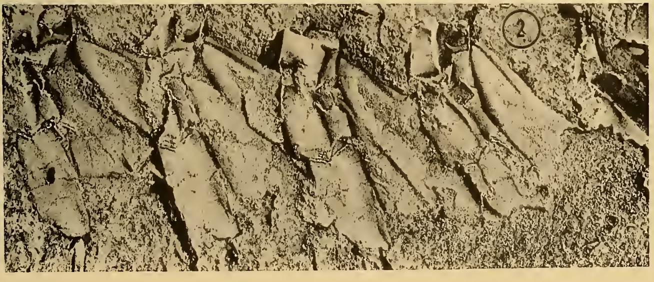

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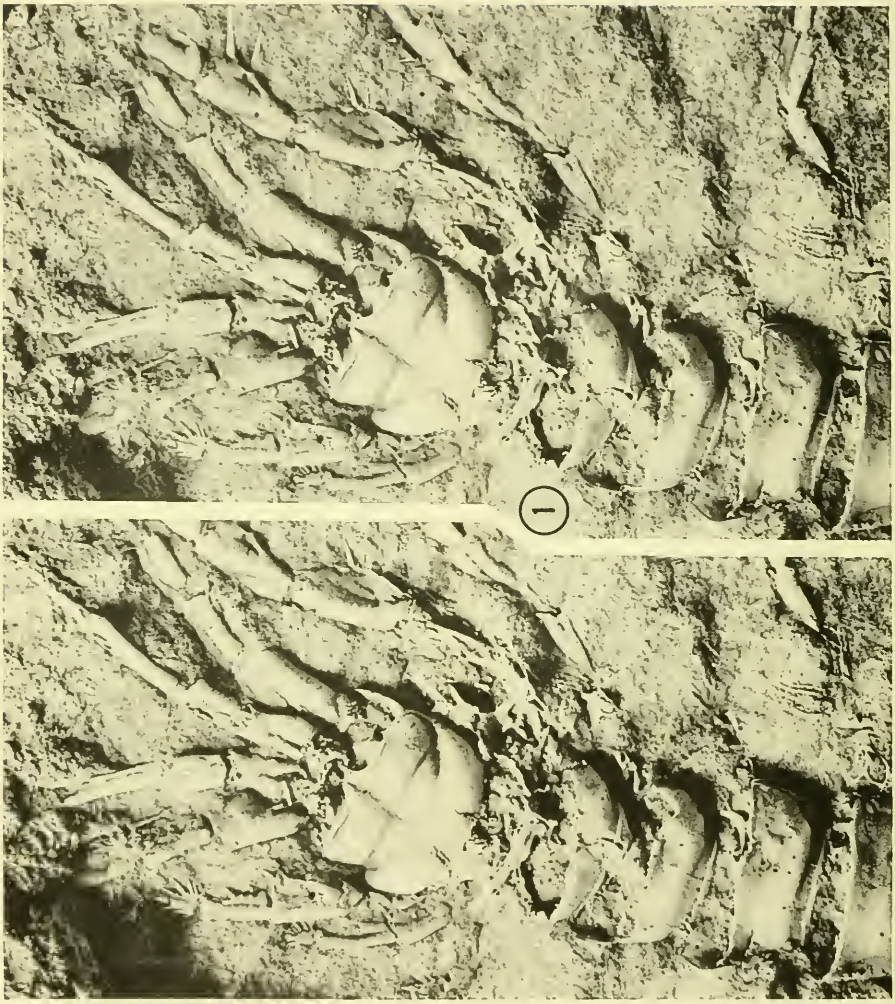

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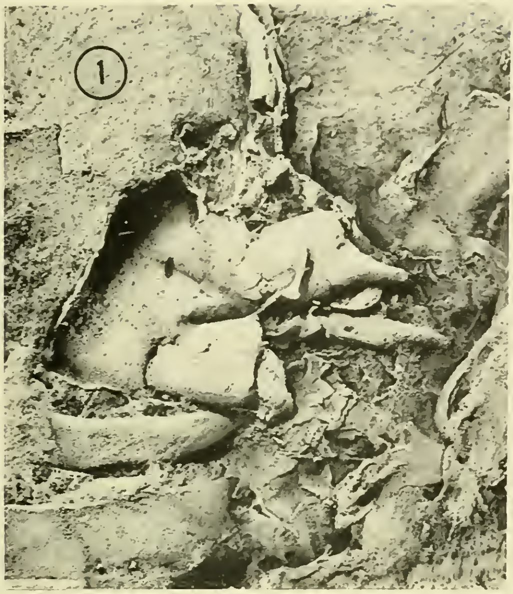
Explanation of Plate 56

Figure		Page
1.	**Acanthotelson stimpsoni** Meek and Worthen Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19842, rubber cast, X 5, stereograph.	230
2.	Posterior of same specimen, rubber cast, X 5.	

Explanation of Plate 57

Figure		Page
1.	**Acanthotelson stimpsoni** Meek and Worthen Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19839, rubber cast of head showing mandible, paragnath and first maxilla, X 10.	230
2.	Counterpart of same specimen, rubber cast showing condyle of mandible, X 10.	
3.	**Acanthotelson stimpsoni** Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19902, X 5, stereograph.	230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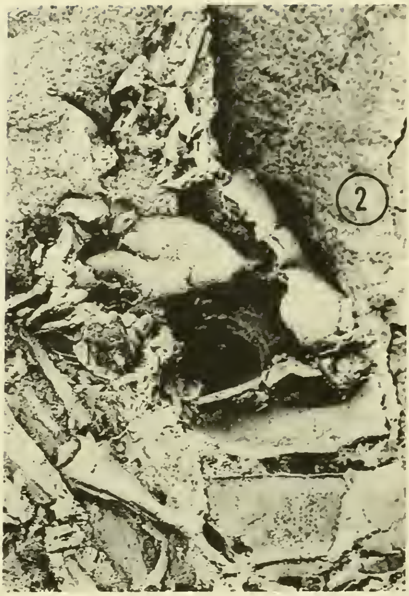
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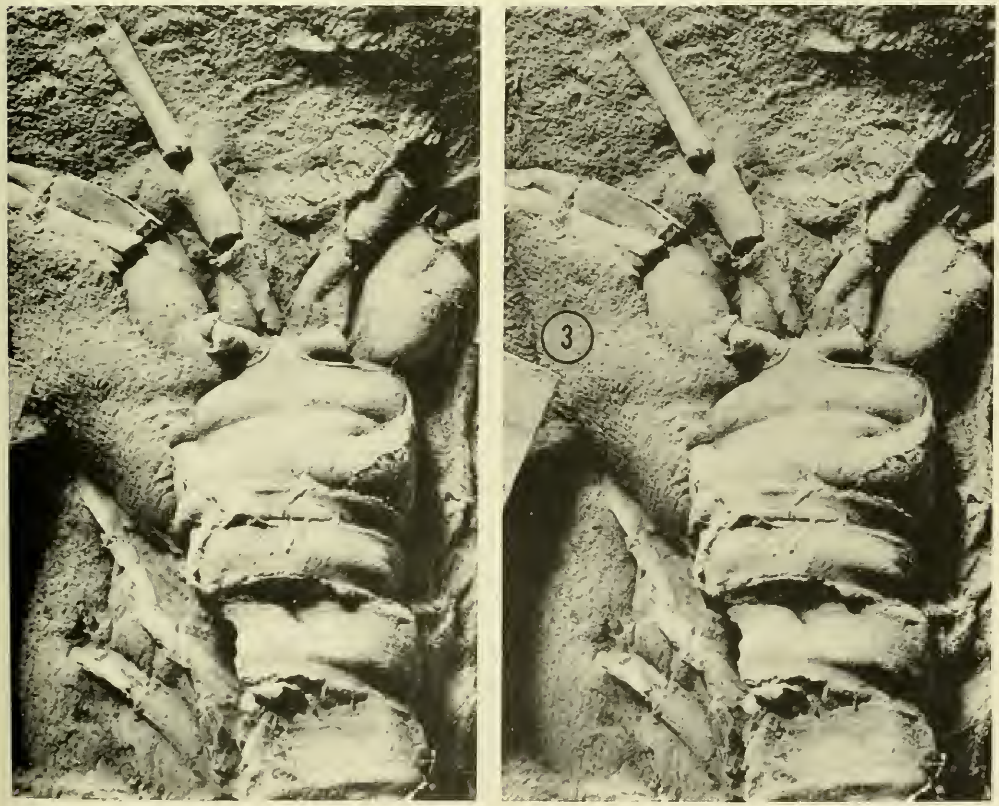
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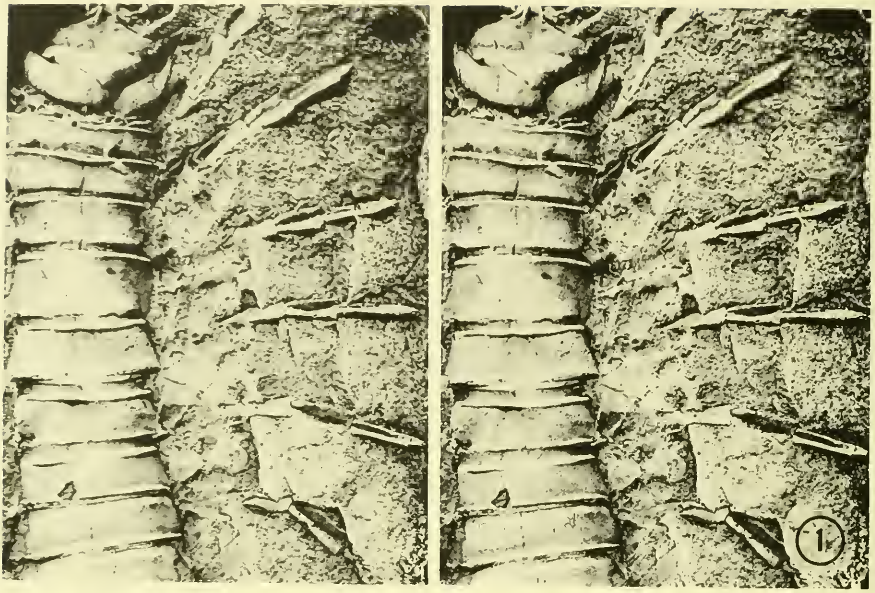
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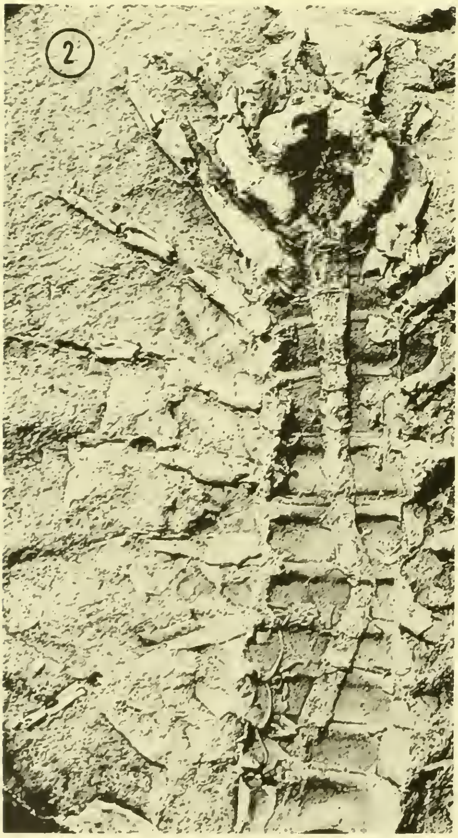
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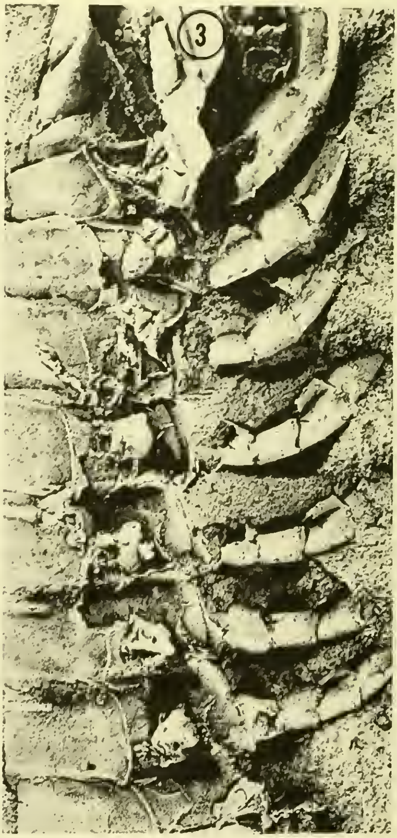
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Explanation of Plate 58

Figure		Page
1.	**Acanthotelson stimsoni** Meek and Worthen Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19744, rubber cast, X 5, stereograph.	230
2.	Counterpart of same specimen, rubber cast, X 5.	
3.	**Acanthotelson stimpsoni** .... Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19707, rubber cast showing sympods of thoracic appendages, X 10.	230

Explanation of Plate 59

Figure Page

1. **Acanthotelson stimpsoni,** Meek and Worthen 230
Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19854, rubber cast, X 10.

2. **Acanthotelson stimpsoni** 230
Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19653, rubber cast showing remains of first thoracic appendage, X 10.

3. **Acanthotelson stimpsoni** 230
Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19847, rubber cast showing thoracic sternites, X 10.

4. **Acanthotelson stimpsoni** 230
Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19817, abdominal sternites, X 6.

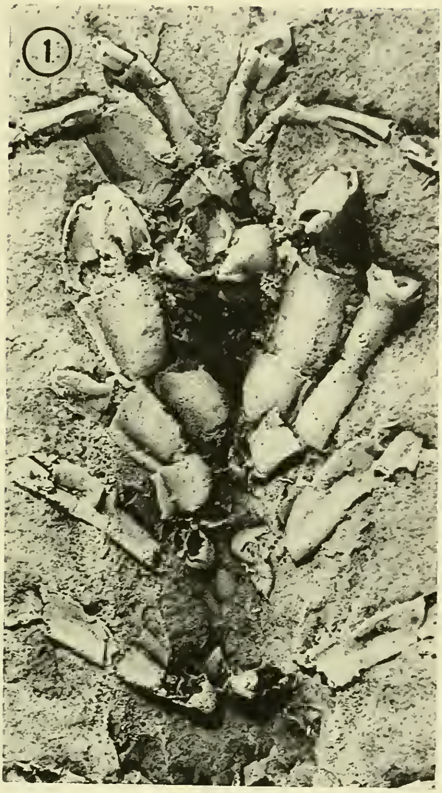
5. **Acanthotelson stimpsoni** 230
Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19707, rubber cast showing terminal joints of pereiopods, X 10.

6. **Acanthotelson stimpsoni** 230
Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19867, rubber cast showing mandible and sympod of second antenna (note nephropore), X 20.

7. **Acanthotelson stimpsoni** 230
Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., MCZ 5224, rubber cast of dactylus of second thoracic endopod, X 10.

8. **Acanthotelson stimpsoni** 230
Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19846, rubber cast of exopod of pleopod, X 10.

9. **Acanthotelson stimpsoni** 230
Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19884, rubber cast of epipods and exopods, X 6.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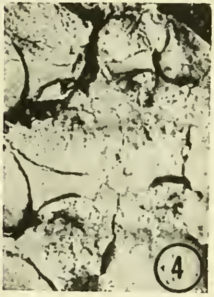
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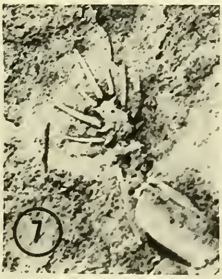
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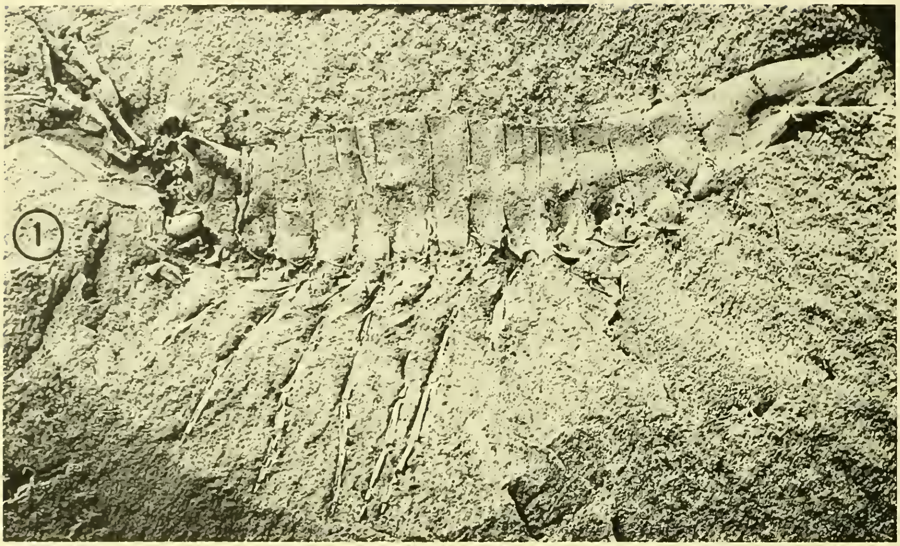
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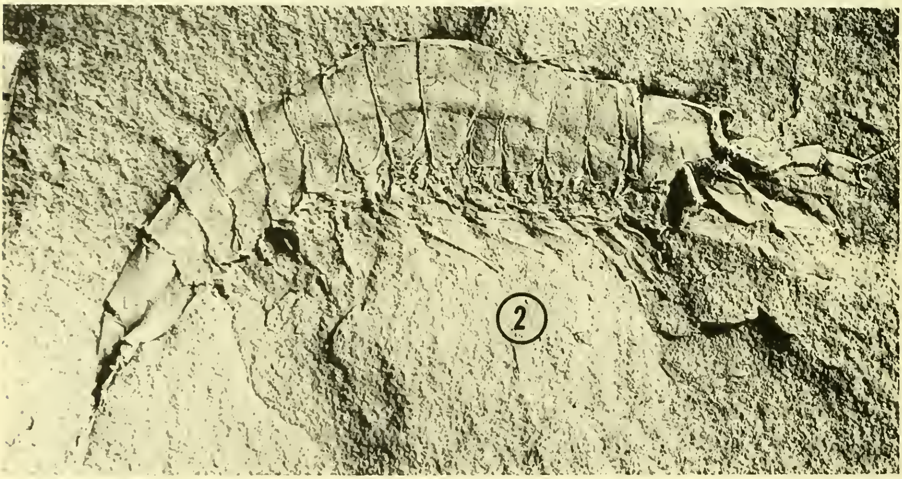
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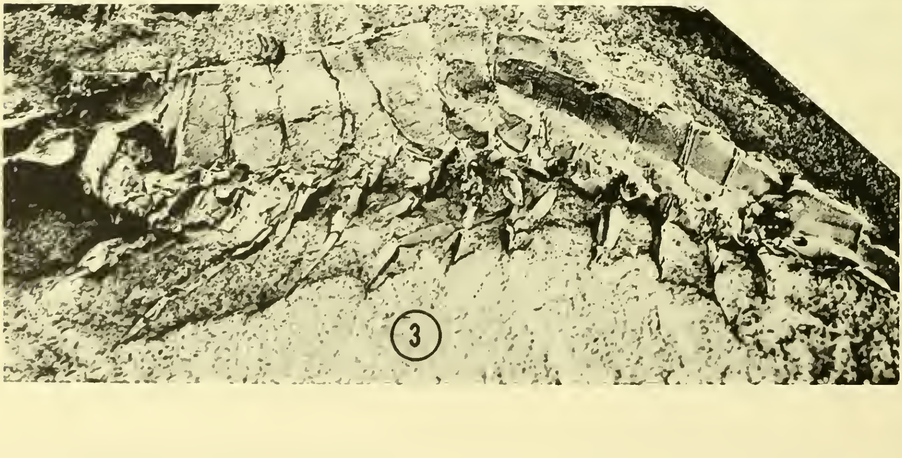
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Explanation of Plate 60

Figure Page

1. **Palaeocaris typus** Meek and Worthen 240
Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill.,
PY 19755, rubber cast, X 4.5.

2. **Palaeocaris typus** 240
Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill.,
MCZ 5197, rubber cast, X 6.

3. **Palaeocaris typus** 240
Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill.,
PY 19750, rubber cast, X 5.

Explanation of Plate 61

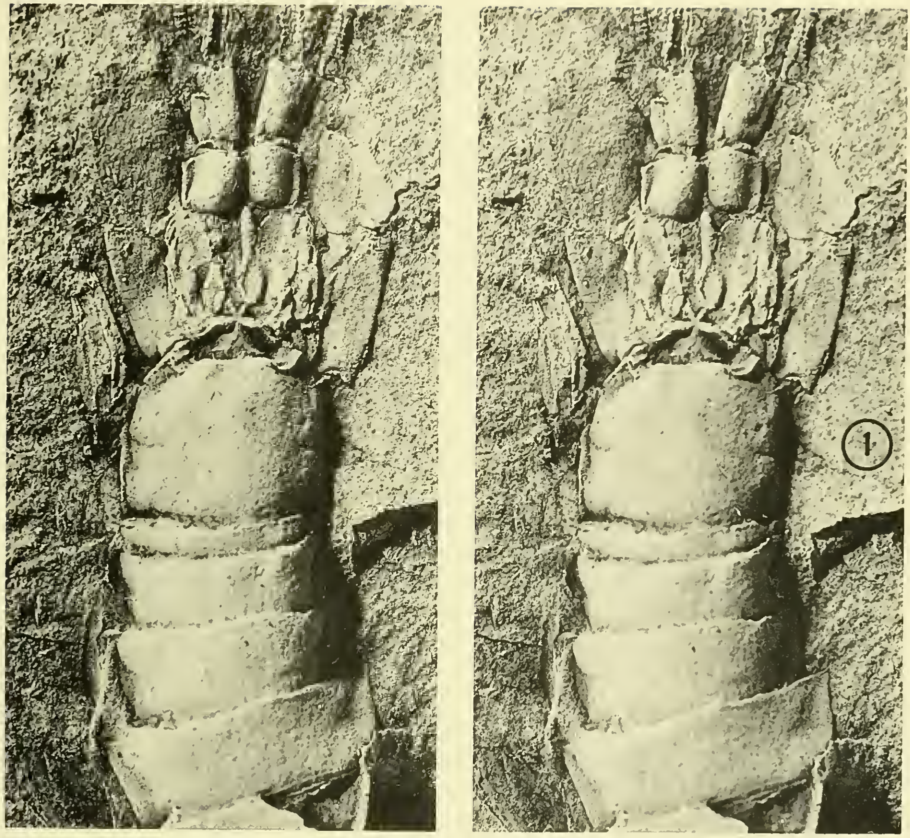
Figure Page

1. **Palaeocaris typus** Meek and Worthen 240
Francis Creek shale, Pennsylvanian, Braidwood, Will Co., Ill., CMNH 29405, rubber cast, X 10, stereograph.

2. **Palaeocaris typus** 240
Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19786, rubber cast, X 5.

3. **Palaeocaris typus** 240
Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19775, rubber cast showing epistome and basal joint of mandibular palp, X 20.

4. **Palaeocaris typus** 240
Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19812, rubber cast of labrum and second joint of mandibular palp, X 10.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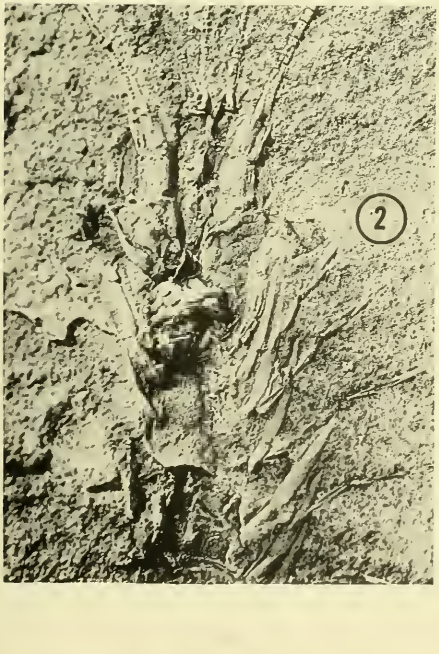
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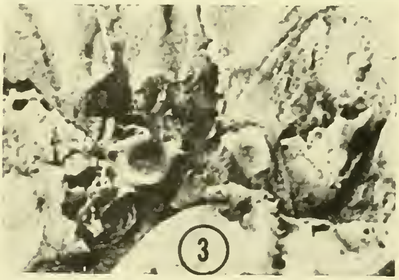
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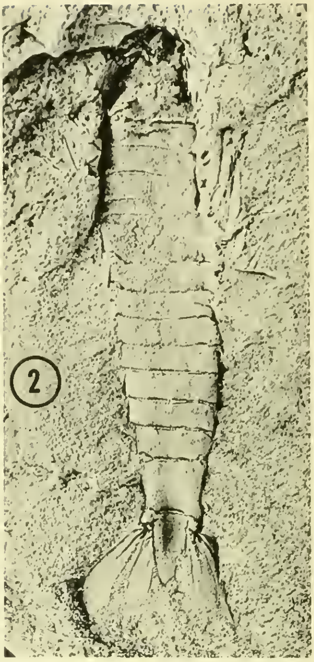
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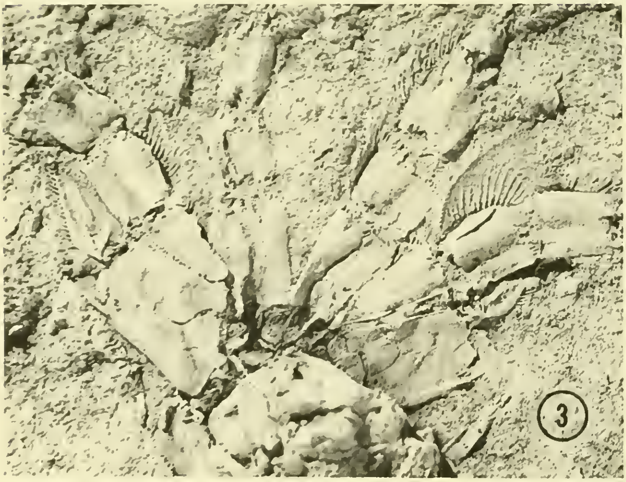
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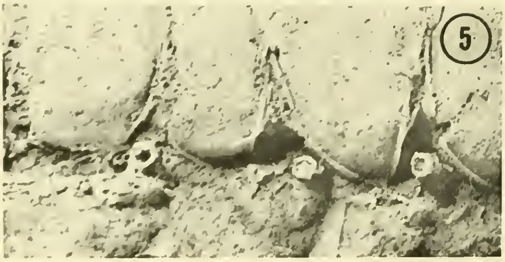
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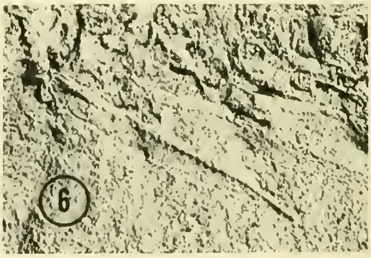
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Explanation of Plate 62

Figure		Page
1.	**Palaeocaris typus** Meek and Worthen Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., USNM 38851, rubber cast of ventral structures of head, X 20.	240
2.	**Palaeocaris typus** Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., USNM 38850, plesiotype of Packard (1886 b, pl. 8, fig. 2), X 3.	240
3.	**Palaeocaris typus** Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19783, rubber cast of basal portion of antennae, X 10.	240
4.	**Palaeocaris typus** Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19755, rubber cast of anterior portion of fossil showing mandible, first and second maxillae, first thoracic endopod and an exopod, X 10.	240
5.	**Palaeocaris typus** Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19781, rubber cast of thoracic pleurae and bases of the epipods, X 20.	240
6.	**Palaeocaris typus** Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., MCZ 5197, rubber cast of exopods, X 10.	240

Explanation of Plate 63

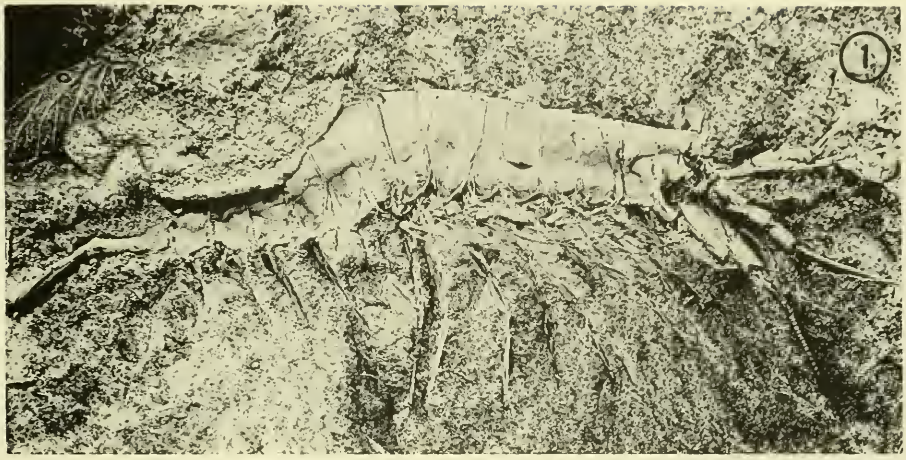
Figure Page

1. **Palaeocaris typus** Meek and Worthen 240
   Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19731, rubber cast, X 4.

2. **Palaeocaris typus** 240
   Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19823, rubber cast of dorsal features of head (note stalked eyes), X 10.

3. **Palaeocaris typus** 240
   Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., USNM 38851, rubber cast of abdominal sternites, X 10.

4. **Palaeocaris typus** 240
   Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19765, rubber cast showing epipods and exopods, X 10.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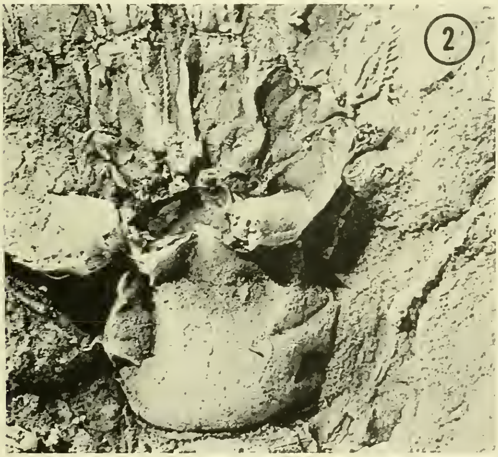
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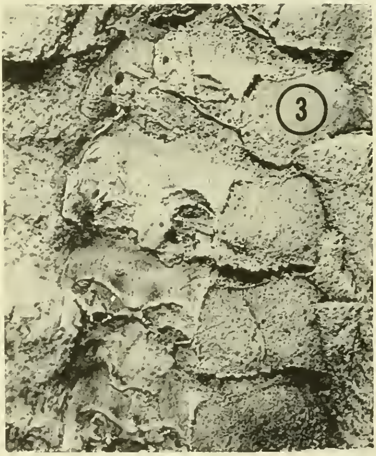
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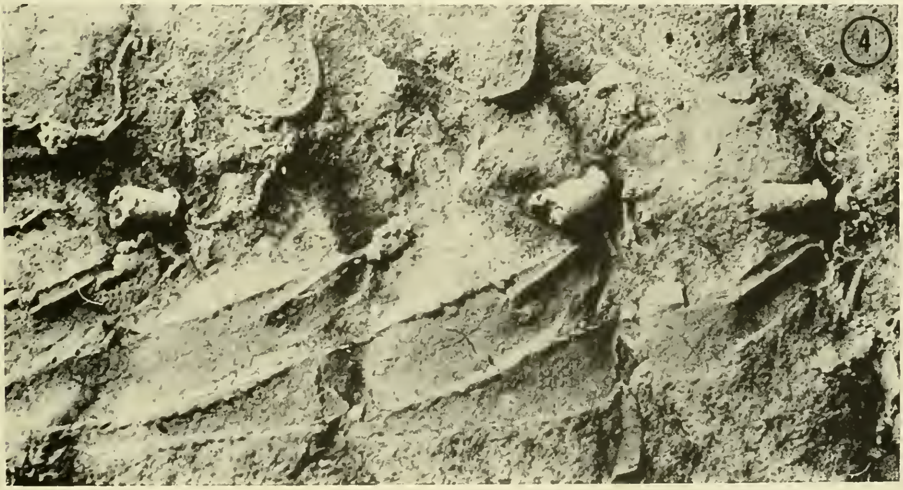
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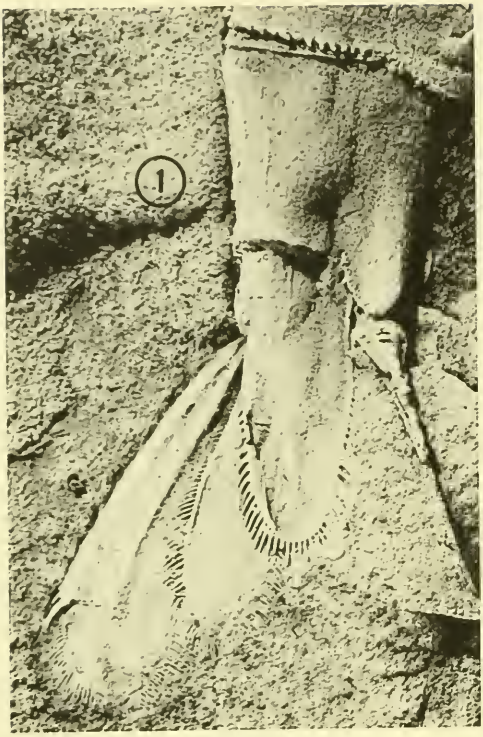
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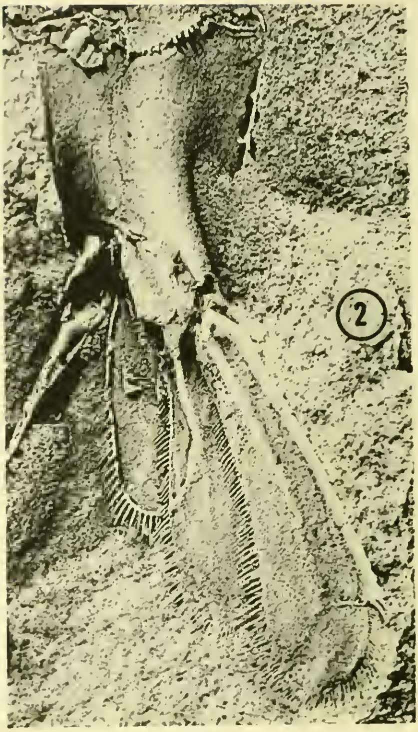
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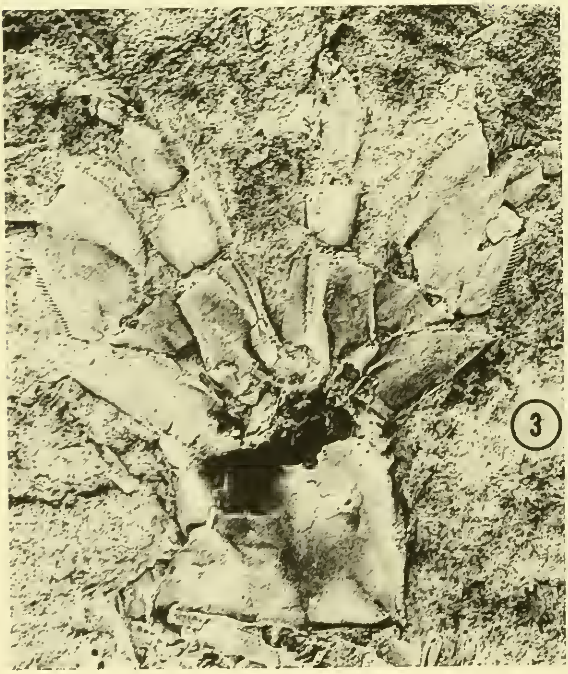
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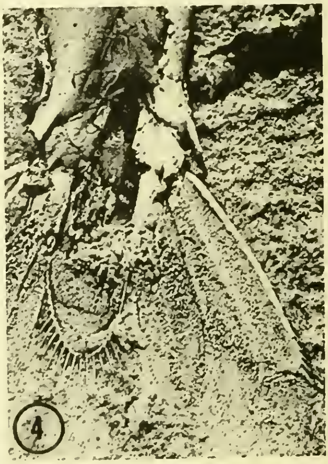
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Explanation of Plate 64

Figure Page

1. **Palaeocaris typus** Meek and Worthen 240
   Francis Creek shale, Pennsylvanian, Braidwood, Will Co., Ill., CMNH PE-2511, rubber cast of sixth abdominal somite and caudal fan, X 10.
2. Counterpart of same specimen, X 10.
3. **Palaeocaris typus** 240
   Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19783, rubber cast of first and second antennae, X 10.
4. **Palaeocaris typus** 240
   Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19729, rubber cast of sixth abdominal somite and caudal fan, X 5.
5. **Palaeocaris typus** 240
   Francis Creek shale, Pennsylvanian, Mazon Creek, Grundy Co., Ill., PY 19823, rubber cast of eye stalk (note papilla), X 15.

Explanation of Plate 65

Figure		Page
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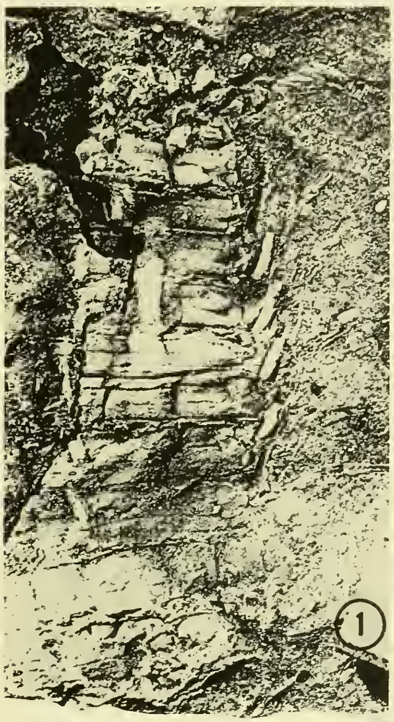
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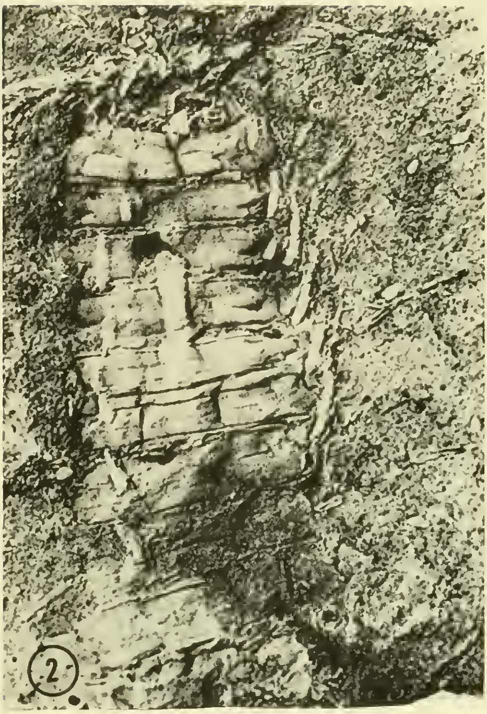
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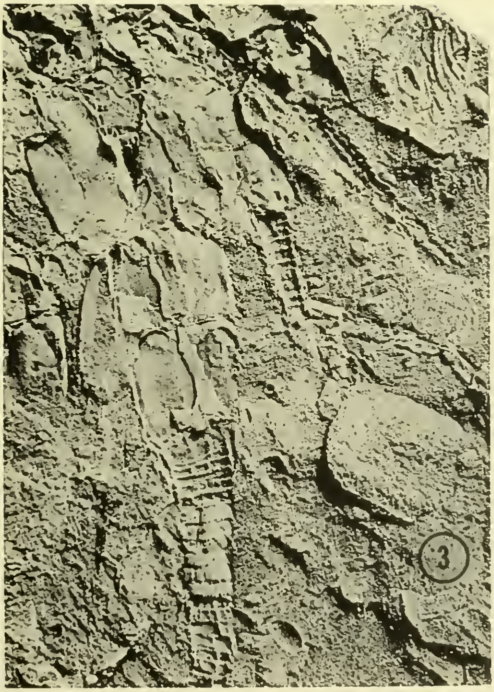
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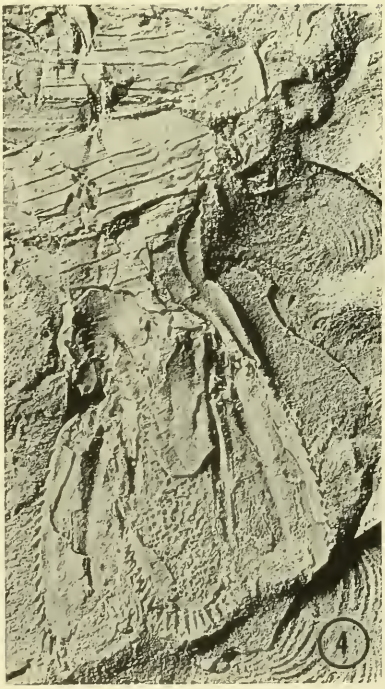
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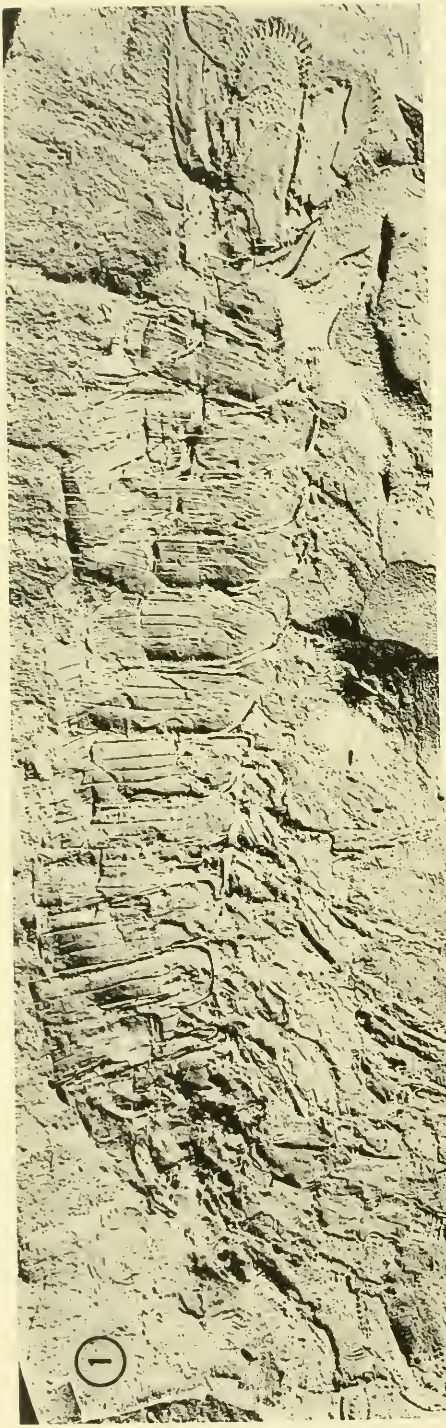
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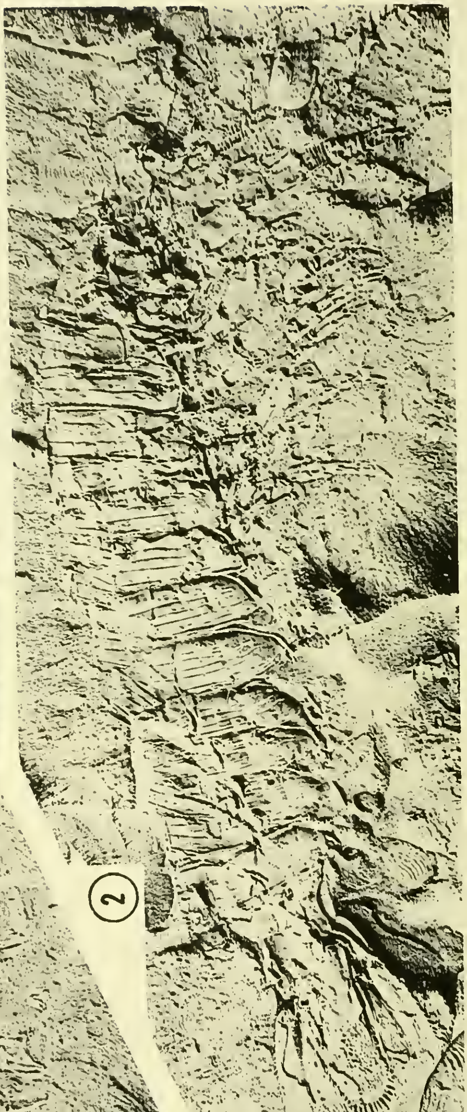
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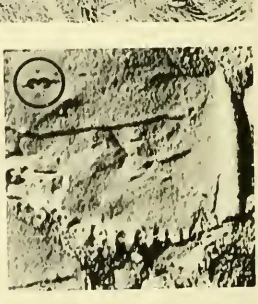
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NUMBER 203

1962

Paleontological Research Institution
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BULLETINS

OF

AMERICAN PALEONTOLOGY

Vol. 44

No. 203

ASTEROCYCLINA FROM NEW ZEALAND AND THE CHATHAM ISLANDS

By

W. Storrs Cole
Cornell University

November 16, 1962

Paleontological Research Institution
Ithaca, New York, U.S.A.

Library of Congress Catalog Card Number: GS 62-306

Printed in the United States of America

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ASTEROCYCLINA FROM NEW ZEALAND AND THE CHATHAM ISLANDS*

W. Storrs Cole
Cornell University

ABSTRACT

Larger Foraminifera of the genus *Asterocyclina* from two localities in New Zealand and four localities in the Chatham Islands are discussed and illustrated. *Asterocyclina speighti* Chapman is a valid species occurring in New Zealand and the Chatham Islands in sediments which are dated as probably middle to upper Eocene. Two late Eocene species of *Asterocyclina* occur at a higher horizon in the Totara limestone. *Asterocyclina* to date is the only genus of larger Foraminifera known to have invaded the New Zealand area in the Eocene.

INTRODUCTION

Although the occurrence of discocyclinids in the Eocene of New Zealand has been known since 1928 when Speight (p. 413) recorded the presence of *Orthophragmina* at a locality on the Eyre River, the only illustrations of these fossils which have been published are those given by Chapman (1932). Unfortunately, his descriptions and illustrations are not sufficiently detailed to enable one to recognize with certainty the species which he identified and described.

Chapman (1932, p. 483) from the collection sent him by Speight identified seven species of Eocene larger Foraminifera, two of which he described as new species. The species recognized by Chapman (1932) with his notations of their frequency of occurrence follow:

Assilina leymeriei (d'Archiac and Haime)—a single transverse section and "another was found in the rock debris" (p. 484).

Heterostegina reticulata Rutimeyer—"occasional small specimens" (p. 485)

Discocyclina speighti Chapman, n. sp.—"common" (p. 485)

D. novaezelandiae Chapman, n. sp.—"rare" (p. 485)

D. dispansa (Sowerby)—"fairly abundant" (p. 485)

D. archiaci (Schlumberger)—"frequent" (p. 486)

Asterocyclina stellata (d'Archiac)—"abundant" (p. 486)

Chapman (1932, p. 487) concluded that "The age of this foraminiferal fauna is distinctly Eocene, and from the presence of *Assilina,* indicates a basal horizon of the Lutetian (Middle Eocene)."

Later, Finlay (1946, p. 239) studied additional specimens from the vicinity of the Eyre River. He noted that all the specimens in these collections were *Asterocyclina.* Finlay (1946, p. 239) wrote:" . . . it is

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*The cost of the printed plates has been furnished by the William F. E. Gurley Foundation for paleontology of Cornell University.

possible that all his (Chapman) specimens were broken Asterocyclinas; it is even quite possible that the two specimens he identified as *Assilina* were also badly preserved *Asterocyclina,* central fragments of which are also almost certainly his *'Heterostegina reticulata'*." Finlay (1946, p. 240) concluded ". . . it seems to be the safest course in the meantime to regard all the Eyre River Orbitoids as *Asterocyclina speighti* (Chap.)," a conclusion which is confirmed by this study.

In addition, Finlay (1946, p. 240) recorded the occurrence of *Asterocyclina* at Fortification Hill in the Oamaru area. He studied and listed the species of smaller Foraminifera which were associated with the *Asterocyclina* on the Eyre River and at Fortification Hill and concluded (p. 242) ". . . *Asterocyclina* occurs at two quite different levels in New Zealand, the upper being topmost Eocene, while the Eyre River lower level can hardly be any higher than Lower Eocene, and is probably well down in that."

However, Finlay was well aware that the stratigraphic range usually assigned to *Asterocyclina* elsewhere is middle and upper Eocene. He (Finlay, 1946, p. 240) stated concerning the occurrence of *Asterocyclina* at Fortification Hill: "This is just where *Asterocyclina* is to be expected, and it fits in perfectly with the age ideas already developed from the smaller Foraminifera." On the other hand, he expressed some doubt concerning the age of the *Asterocyclina* zone at the localities on the Eyre River as he wrote ". . . the small forms accompanying *speighti* at the Eyre River tell a very different story."

Finlay (1946, p. 240, footnote) reconciled the occurrence of *Asterocyclina speighti* in association with lower Eocene smaller Foraminifera in New Zealand by quoting Senn (1940, p. 1559) who wrote "In Europe the first appearance of *Asterocyclina* occurs in the Ypresian." Senn based his statement on the ranges given by Douvillé (1922, p. 84). Neumann (1958, p. 21, table 2) recorded only one species of *Asterocyclina* in the Ypresian of the Aquitaine basin, but noted (p. 119) that it becomes abundant in the Lutetian.

Although *Asterocyclina* is known from the lower Eocene of Europe, elsewhere it is most common in the middle and upper Eocene. Thus, its occurrence in the lower Eocene of New Zealand, if this stratigraphic assignment is correct, would indicate a rapid dispersal of *Asterocyclina* which seemingly originated in the European area during the Paleocene.

Recently, Hornibrook (1958, p. 27; table 1) summarized the foraminiferal zones recognized in New Zealand. *Asterocyclina speighti* is assigned to the Mangaorapan stage (lower Eocene). Discocyclinidae are reported from the Kaiatan stage, and the last occurrence of *Asterocyclina* in New Zealand is recorded from the succeeding Runangan stage. These two stages are equivalent to the European upper Eocene. Three stages in which discocylinids have not been found intervene between the Mangaorapan stage and the Kaiatan stage.

In addition to the two occurrences of *Asterocyclina* in New Zealand R. F. Hay, A. R. Mutch, and W. A. Watters in a geological survey of the Chatham Islands discovered several localities at which *Asterocyclina* occurred. Their report on these islands is in press as a bulletin of the New Zealand Geological Survey. The limestones in which these *Asterocyclina* occur have been dated by means of small Foraminifera as Paleocene and middle to upper Eocene.

Larger Foraminifera in the New Zealand area have not been studied in detail, therefore, Dr. N. de B. Hornibrook, senior micropaleontologist of the New Zealand Geological Survey, wrote me to ascertain if I would be interested in studying the collection of *Asterocyclina.* I acknowledge my indebtedness to Dr. Hornibrook for supplying stratigraphic and other data concerning the collection which he sent.

The specimens upon which this study was based will be returned to the New Zealand Geological Survey to be filed in their collections.

LOCALITIES

New Zealand

Loc. 1—F 5048. White Creek, one and one half miles east of Eyre River; collector, R. Speight (references: Chapman, 1932, p. 483; Finlay, 1946, p. 240; Macpherson, 1946, p. 165).

2—Fortification Hill, Oamaru; Totara limestone (reference: Hornibrook, 1961, p. 169).

Chatham Islands

3—Pitt Island, 40 chains at 71° from Trig Waihere at 971 feet.

4—Limestone at top of narrow isthmus connecting Whenuataru Peninsula with main part of island on northwest side of Pitt Island.

5—Waikato Point, west shore of Te Whanga lagoon, Chatham Island.

6—Boulder of limestone from Red Bluff, Petre Bay, on west shore of Chatham Island.

DISCUSSION AND DESCRIPTION OF SPECIES

New Zealand

Eyre River Locality

Numerous matrix-free specimens from locality 1 on the Eyre River were sent. All of these specimens are *Asterocyclina* and without question represent the species which Chapman (1932, p. 485) named *Discocyclina speighti*. As Finlay (1946, p. 240) stated, the most reasonable assumption is that the six other species which Chapman recognized at this locality are also *Asterocyclina speighti*. Certainly, the illustrations and descriptions given by Chapman could be reasonably interpreted as representing only one species.

The original description and illustrations given by Chapman of *Asterocyclina speighti* were incomplete. Therefore, a new description and and illustrations based on the specimens from locality 1 have been prepared as this species is seemingly valid.

Asterocyclina speighti (Chapman) Pl. 67, figs. 1-10; Pl. 68, figs. 1-7

1932. *Discocyclina speighti* Chapman, Rec. Canterbury Mus., vol. 3, p. 485, pl. 61, figs. 1*c*, 4*b*; pl. 62, fig. 6*b*.

1932. *Assilina leymeriei* Chapman, *not* d'Archiac and Haime, *idem*, p. 484, pl. 61, fig. 5; pl. 62, fig. 9.

1932. *Heterostegina reticulata* Chapman, *not* Rutimeyer, *idem*, p. 485.

1932. *Discocyclina novaezelandiae* Chapman, *idem*, p. 485, pl. 62, figs. 7, 10.

1932. *Discocyclina dispansa* Chapman, *not* Sowerby, *idem*, p. 485, pl. 61, figs. 1*a*, 2, 4*c*; pl. 62, fig. 6*a*.

1932. *Discocyclina archiaci* Chapman, *not* Schlumberger, *idem*, p. 486, pl. 61, fig. 3.

1932. *Asterocyclina stellata* Chapman, *not* d'Archiac, *idem*, p. 486, pl. 61, fig. 4*a*; pl. 62, fig. 8.

Test of moderate size with diameters from 2.8 to 3.7 mm. The thickness through the center is 0.9 to 1.2 mm. The majority of the specimens possess distinct rays which radiate from the central umbonal area (Pl. 67, figs. 4,5), but some specimens have a distinct umbonal area which is surrounded by a narrow flange (Pl. 68, fig. 6) on which rays are barely discernible. The umbonal area, and to a lesser extent, the rays and interray areas, are covered by small, but prominent, raised papillae. Measurements and comments on the uncut specimens which are illustrated are given in Table 1.

Table 1.—Measurements and surface features of *Asterocyclina speighti*

Specimen		Pl. 67, fig. 5	Pl. 68, fig. 4	Pl. 68, fig. 6
Maximum diameter	mm.	3.3	3.55	2.8
Diameter of umbo	mm.	1.8	1.8	1.7
Diameter of umbonal pillars	μ	100-140	50-100	50-90
Number of rays		6	4	5
Prominence of rays		Pronounced	Pronounced	Indistinct

The initial embryonic chamber is subcircular and partly embraced by the larger second embryonic chamber. The embryonic chambers are enclosed by two rings of periembryonic chambers except at the base of the initial chamber at which place the initial chamber is in contact with a single chamber of the first complete annular ring of equatorial chambers. Measurements of equatorial sections are given in Table 2.

Table 2.—Measurements of equatorial sections of *Asterocyclina speighti*

Specimen		Pl. 67, fig. 10	Pl. 68, fig. 2	Pl. 68, fig. 3	Pl. 67, fig. 8, 9
Diameter	mm.	2.9	2.8	3.65	3.0
Embryonic chambers:					
Diameters of initial chamber	μ	110 x 120	120 x 130	110 x 120	120 x 140
Diameters of second chamber	μ	100 x 160	80 x 210	80 x 200	110 x 220
Distance across both chambers	μ	220	200	190	230
Thickness of outer wall	μ	5	10	8	5
Equatorial chambers:					
Radial diameter	μ	40-65	30-60	30-50	40-80
Tangential diameter	μ	30-40	30-50	30-40	30-40

The lateral chambers are arranged in regular tiers with moderate size pillars irregularly scattered throughout the vertical sections. The floors and roofs of the lateral chambers are straight and have a thickness equal to that of the lateral chamber cavity. Measurements of vertical sections are given in Table 3.

Table 3.—Measurements of vertical sections of *Asterocyclina speighti*

Specimen		Pl. 67, fig. 1, 2	Pl. 67, fig. 3	Pl. 67, fig. 7
Diameter	mm.	3.+	3.4	3.65
Thickness	mm.	1.03	1.1	0.95
Diameter of umbo	mm.	1.5	2.0	1.5
Embryonic chambers:				
Length	μ	200	250	200
Height	μ	130	120	130
Equatorial layer*:				
Height at center	μ	40	30	50
Height at periphery	μ	50	90	100
Lateral chambers:				
Number		16	17	16
Length	μ	50	60-80	50
Height	μ	10	10	10
Thickness of floors and roofs	μ	10	10	10
Surface diameter of pillars	μ	50-110	60-140	50-70

*Includes thickness of floor and roof.

Comparisons.—The arrangement of embryonic apparatus (embryonic and periembryonic chambers) of *A. speighti* is similar to that of certain specimens of *A. stellaris* (Brunner) (see: Brönnimann, 1945, pl. 21, fig. 7), a European species which ranges from the lower Lutetian into the upper Eocene. However, the dimensions of the embryonic chambers are different, and the initial embryonic chamber of *A. speighti* is embraced by the second chamber more completely. *A. speighti* has more numerous and less open lateral chambers than does *A. stellaris.*

Externally, some specimens of *A. speighti* resemble *Asterocyclina penuria* Cole (1957*a*, p. 350), a species found in the upper Eocene of Saipan Island, the Eniwetok Atoll drill holes, and on a seamount near the Tuamotu Archipelago, French Oceania (Cole, 1959, p. 12). The internal structures are different, however, particularly the embryonic apparatus and the lateral chambers.

Type of the species.—Chapman (1932, p. 485) did not designate a type specimen. Although the thin sections which he studied may still be in existence, neither the New Zealand Geological Survey nor the Bureau of Mineral Resources, Canberra, Australia, possesses them (Hornibrook, personal communication July 20, 1962). The best illustration presented by Chapman (1932, pl. fig. 2) which is without question *A. speighti* was identified by him as *Discocyclina dispansa.*

As it is probable that the specimens studied by Chapman will not be found, the uncut specimen (Pl. 67, fig. 5) should be designated as the neotype of *Asterocyclina speighti* (Chapman) (New Zealand Geological Survey catalogue No. TF 1461/1), if the original specimens are not found.

Geologic horizon.—Hornibrook (letter dated 29 June 1962) wrote in part concerning the correlation of the *Asterocyclina* zone at the Eyre River "The only stratigraphic control is that the orbitoid bed is post-Cretaceous and pre-Oligocene. So far as I know there is no other means of dating the middle part of the Eyre Sand Group other than the microfauna of the *Asterocyclina* bed. The upper part of the sands is unfossiliferous. We have several small foraminiferal faunas from this bed, and although they are a facies unique in New Zealand in the Lower Eocene, we correlate the fauna with the middle part of the Dannevirke Series. Finlay assigned the Eyre bed to the Mangaorapan stage, but the presence of a species of *Pseudohastigerina* rather suggests Heretaungan stage."

The presence of *Asterocyclina* in these beds only confirms a post-Cretaceous-pre-Oligocene age for the beds, but it does not give any additional information. However, the species *A. speighti* does afford additional clues to the probable age.

Limestones (loc. 3, 5, 6) from the Chatham Islands which contain this species have been dated as "mid to upper Eocene" by Hornibrook (letter dated 2 February 1962) on the presence of *Globigerapsis index.*

Moreover, *A. speighti* most nearly resembles *A. stellaris,* a European species which ranges from the lower Lutetian into the upper Eocene.

Therefore, there is a distinct possibility that *Asterocyclina speighti* in the vicinity of the Eyre River occurs in middle rather than lower Eocene beds. However, additional evidence must be found before a final decision can be made.

Fortification Hill Locality

The collection from Fortification Hill (loc. 2) consisted of a small number of uncut specimens and three thin sections of the equatorial plane. There were two species of *Asterocyclina* in this collection, one a small, compressed, lenticular species with small papillae (Pl. 68, fig. 8), whereas the other had a group of about eight, large, raised umbonal papillae (Pl. 68, fig. 9).

Although the specimens did not appear to be unusually weathered, they were difficult to section. Moreover, there was only one specimen with large, raised papillae. This specimen was ground to the equatorial plane to determine the arrangement of the equatorial chambers, and, then, completed as a vertical section (Pl. 68, fig. 9). A brief description of this specimen follows:

The diameter of the test is 1.82 mm. and the thickness at the center is 0.82 mm. Rays were not apparent in external view, but a group of large, umbonal papillae were prominent. The equatorial section had the equatorial chambers arranged so that four rays could be seen clearly.

The vertical section has large pillars irregularly scattered throughout. The umbonal pillars have a surface diameter of about 280 μ. There are about 12 lateral chambers to a tier at the center of the test. These chambers have a length of about 100 μ, a height of 10 μ, and a thickness of the roofs and floors of about 10 μ.

Although the identification of a species based upon a single specimen must in most cases be questionable, this specimen is so similar to specimens from the Eniwetok Atoll drill holes which were named *Asterocyclina praecipua* Cole (1957*b*, p. 780) that it is referred to this species.

The other specimens (Pl. 68, fig. 8) associated with this specimen were numerous but even more difficult to section. The details which could be observed follow:

The test is small with diameters from 0.9 to 1.9 mm. There are 4 to 6 rays which are distinct in some specimens and indistinct in others. These rays are more prominent in the peripheral zone and fade into the central area. Many specimens have a slightly projecting central papilla with a diameter of about 100 μ. Smaller, less distinct, papillae occur on the other parts of the test. The thickness of the test at the center is from 0.5 to 0.6 mm.

The embryonic chambers are large, the initial chamber has diameters of 110 by 130 μ, and the second chamber has diameters of 30 by 170 μ. The distance across both chambers is about 160 μ. The embryonic chambers are surrounded by a single ring of periembryonic chambers.

The equatorial chambers are small with radial diameters of about 30 μ and tangential diameters of about 20 μ.

The lateral chambers are arranged in regular tiers with about 8 chambers at the center on each side of the equatorial layer. These chambers have a length of 40 to 80 μ, a height of 10 μ, and the roofs and floors have a thickness of 10 μ. Some sections have a strong central pillar with a surface diameter of about 100 μ. Much smaller pillars occur irregularly in the rest of the vertical sections.

These specimens most nearly resemble those described from Saipan Island under the name *Asterocyclina matanzensis* Cole (1957*a*, p. 350) and later found in the Eniwetok drill holes (Cole, 1957*b*, p. 777). Until more specimens can be studied, they are assigned to this species.

However, there are differences between the types of *A. matanzensis* and the New Zealand specimens. The types have double the number of lateral chambers to a tier, and some of the measurements are at variance with those of the New Zealand specimens. But, the resemblance in the shape and configuration of the New Zealand specimens is nearest that of specimens assigned to *A. matanzensis* than to any other species.

Chatham Islands Localities

The specimens from localities 3, 5, 6 are embedded in limestone and could be studied only in random thin sections. Although several sections were prepared, the only Foraminifera present were *Asterocyclina*. Several of these are illustrated as figure 7, Plate 67 and figures 4, 5, 7, Plate 68.

All the specimens seemingly represent only one species, and this species so far as could be determined is *Asterocyclina speighti*.

These limestones have been dated by Hornibrook (letter dated 2 February 1962) as "mid to upper Eocene" on the presence of *Globigerapsis index* (Finlay).

Another limestone (loc. 4) from the Chatham Islands contained a few specimens of *Asterocyclina* of which two entire specimens and two thin sections were sent to me. Hornibrook (letter dated 2 February 1962) placed this limestone in the Paleocene on the presence of certain species of smaller Foraminifera as he found *Globorotalia compressa*, *Globigerina pseudoiota* and *G. triloculinoides* at this locality.

These *Asterocyclina* (loc. 4) have a diameter from 1.2 to 1.5 mm. and a thickness of about 0.5 mm. The embryonic chambers have a distance across both chambers of 150 to 200 μ. The one vertical section available has about 8 lateral chambers to a tier on each side of the embryonic chambers. Relatively prominent pillars with a surface diameter of 70 μ are scattered irregularly through the vertical section.

It is impossible with so few and poorly preserved specimens to make a satisfactory specific identification. From the details that could be observed, these specimens (loc. 4) resemble superficially small specimens of *Asterocyclina speighti*, but whether they actually are that species can not be determined at this time.

CONCLUSIONS

Three species of *Asterocyclina* occur in the collections from New Zealand and the Chatham Islands representing two distinct stratigraphic horizons. *Asterocyclina speighti* (Chapman) from sediments in the vicinity of the Eyre River, New Zealand, which have been assigned to Mangaorapan stage of the Dannevirke series occurs also in limestones which have been dated as mid to upper Eocene in the Chatham Island. In addition a few specimens questionably referred to *A. speighti* occur at another locality in the Chatham Islands which has been dated by smaller Foraminifera as Paleocene.

These occurrences suggest that *A. speighti* either has a long stratigraphic range from lower into middle Eocene, or the dating of the Eyre River locality is incorrect. Although correlations based on a single species are questionable, the writer suggests that the available evidence indicates that the Eyre River localities are middle Eocene rather than lower Eocene.

If this conclusion is the correct one, the Eyre River localities correlate with those in the Chatham Islands. Thus, the first invasion of *Asterocyclina* in this area would have been in middle Eocene, unless the one possible Paleocene occurrence is verified.

The two species of *Asterocyclina* from the Totara limestone at Fortification Hill, Oamaru, tentatively identified as *A. matanzensis* Cole and *A. praecipua* Cole, are known elsewhere in the upper Eocene. Therefore, the stratigraphic position assigned to this limestone on its fauna of smaller Foraminifera is in agreement with the known ranges of these two species of *Asterocyclina.*

The evidence to date indicates that the only genus of larger Foraminifera to invade the New Zealand area in the Eocene was *Asterocyclina.* This may be an example of selective rafting as postulated by Cole (1960, p. 15) to explain the discontinuous distribution of the larger Foraminifera.

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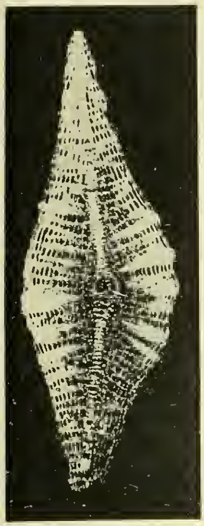
PLATES

EXPLANATION OF PLATE 67

Figure		Page
1-10.	**Asterocyclina speighti** (Chapman)	346
1, 2.	The same vertical section, X 20, to illustrate the lateral chambers and the pillars; 1, by reflected light; 2, by transmitted light.	
3.	Vertical section, X 20.	
4.	External view, X 10, of specimen with four rays.	
5.	External view, X 10; a six-rayed specimen (New Zealand Geological Survey catalogue No. TF 1461/1).	
6.	Part of the vertical section, X 40, of the specimen illustrated as figures 1, 2.	
7.	Vertical section, X20.	
8.	Central part, X 40, of the specimen illustrated as figure 9 to show the details of the embryonic chambers; note particularly the two incomplete rings of periembryonic chambers.	
9, 10.	Equatorial sections, X 20, to show the rayed arrangement of the equatorial chambers.	

1-6, 8-10. Loc. 1—see text for locality descriptions.

7. Loc. 3.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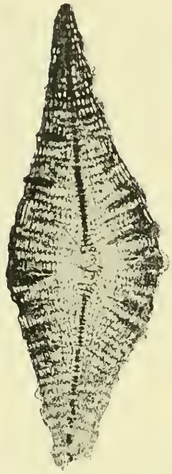
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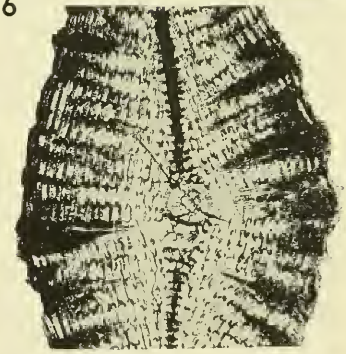
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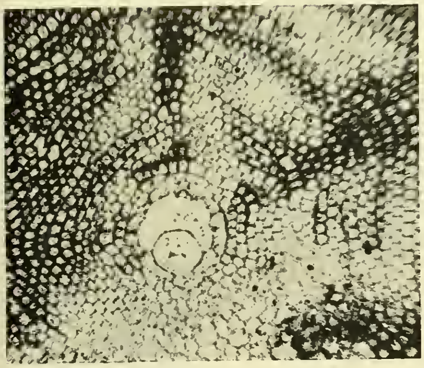
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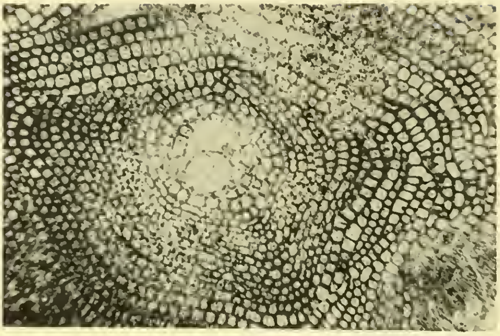
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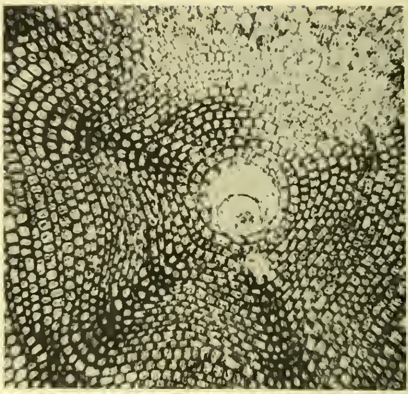
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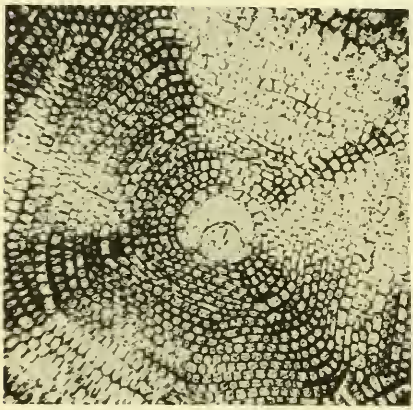
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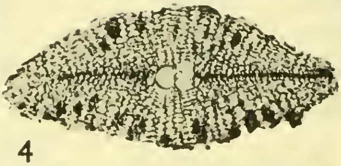
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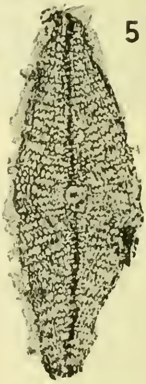
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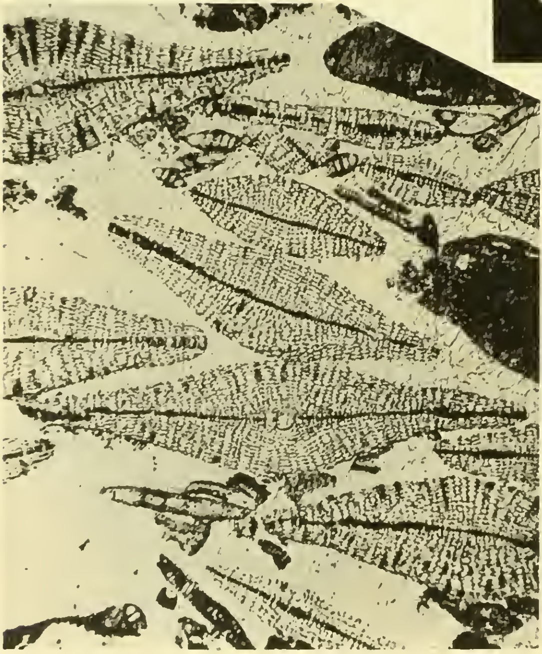
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EXPLANATION OF PLATE 68

Figure Page

1-7. **Asterocyclina speighti** (Chapman) 346

1-3. Parts of equatorial sections, X 40, to show the embryonic, periembryonic, and equatorial chambers; 1, the same specimen illustrated as figure 10, Plate 67.

4, 5. Vertical sections, X 20, from a random section from limestone.

6. External view, X 10, of an umbonate specimen with a flange on which the rays are indistinct.

7. Several vertical sections, X 20, from a random section from limestone.

8. **Asterocyclina matanzensis** Cole 351

Vertical section, X 40.

9. **Asterocyclina praecipua** Cole 350

Vertical section, X 40, by transmitted light to show the strong pillars and the arrangement of the lateral chambers.

1-3, 6. Loc. 1—see text for locality descriptions.
4. Loc. 6
5. Loc. 5.
7. Loc. 3.
8, 9. Loc. 2.

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